HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA

Part I. Introduction, Data Base Management System and Data Processing

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PART 1

INTRODUCTION, DATA BASE MANAGEMENT SYSTEM, AND DATA PROCESSING

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EXECUTIVE SUMMARY

The Cold Lake Study Area is defined as Tp 55-69, R 1-17, W 4 Mer, and covers approximately 23 800 km2 in east-central Alberta. The Cold Lake oil sands deposit occupies a significant portion of the eastern half of the study area. The objective of the study was to determine the baseline hydrogeological situation prior to development of commercial in-situ recovery operations in the oil sands deposit because of the possible impact these might have on the natural flow system, specifically on the nearsurface potable groundwater resources.

When Alberta Environment approached the Alberta Research Council in early 1981 it was agreed to fund this study equally. Because of the vast amount of data available, much of it not in machine-readable form, the Alberta Research Council took the position that its most valuable contribution would be in developing the software necessary to input, sort, interpret and synthesize large hydrogeological data bases. Such software would be of use throughout the province, and for a variety of studies including baseline hydrogeological evaluation. Once the specific data for the Cold Lake Study Area was entered into the data base, the baseline hydrogeological situation could be determined. Accordingly, the results of this study comprise equal emphasis on software development and determination of the baseline hydrogeological situation in the Cold Lake Study Area.

The project results are presented in three distinct formats, each with a specific style and purpose. The first format is a six-part Report, which is effectively a narrative of the work accomplished and the conclusions drawn. The second format is a reference Atlas of maps and cross-sections at a scale of 1:500 000. The third format is a hard copy Data Base of new and interpreted information on the hydrogeology, which can also be supplied in machine-readable format.

Part 1 of the Report outlines the concept of indexed records used for the Ground Water Data Base (GWDB), and the records and elements of eighteen record types. These include location, stratigraphic, drillstem test, core and formation water chemistry information integrated in such a way that cross-linking is easily accomplished. It is written in FORTRAN 77 as implemented on VAX/VMS. Much of the stratigraphic information was derived from the Energy Resources Conservation Board (ERCB) Well Data System computer file. The drillstem test and formation water chemistry software handles the entry, sorting and interpretation of standard hard copy information using interactive direct screen control. The core interpretation software utilizes the ERCB core computer file as input. In addition, software to utilize Quaternary hydrogeological and surface hydrological information was developed.

Data processing software was also developed which takes the point information at any given X-Y-Z coordinate and synthesizes it as maps, statistical characteristics and/or mathematical relationships. Different processing paths were designed for stratigraphic and flow data. Cartographic software was written to represent standard DLS coordinates and linked with surface representation software (SURFACE II and related utilities, Kansas Geological Survey). Because SURFACE II creates a regular grid of values, it is amenable to various grid manipulation techniques and these were developed to allow such features as blanking out regions where information on a particular stratigraphic unit is absent. The flow data were processed somewhat differently and special sorting and interpretive software was developed. Additional software located the flow data in the stratigraphic or hydrostratigraphic sequence for further processing. As a result, the hydrogeological information in GWDB can be synthesized in a variety of forms, including formatting as input to a numerical simulation of the flow regime.

Part 2 of the Report is concerned with the regional geology of the study area, and is organized into two sections; Phanerozoic and Quaternary. The Phanerozoic history is synthesized from the literature and supplemented by a series of surface contour and isopach maps at 1:1 000 000 taken from the Atlas. Although detailed lithological studies were not carried out, the information is presented in terms of which stratigraphic units may act as aquifers, aquitards or aquicludes. Of particular concern were the effects of missing stratigraphic units (due to erosion or non-deposition) and of salt solution, inasmuch as missing aquitards or aquicludes allow juxtaposition of aquifers. As a result of this evaluation of the regional Phanerozoic history, it was decided to limit the hydrogeological study to strata younger than the Middle Devonian Prairie Formation halite. Even this restriction meant that significant contact of aquifers of widely different ages occurred in some parts of the study area. However, the data processing software can handle this complex hydrostratigraphic geometry once the individual hydrostratigraphic units have been identified.

Quaternary history of the study area has been presented in considerable detail because, at this time, it can be found only in an unpublished M.Sc. thesis which covered NTS map sheet 73L (Sand River) which includes the majority of the study area with the exception of a narrow perimeter on the western and southern boundaries. Reconnaissance work in these perimeter areas was completed for this study and the Atlas maps, therefore, cover the entire Cold Lake Study Area. Four glacial episodes have been recognized, with intervening glaciofluvial and glaciolacustrine deposits. They are each described in terms of their distribution and lithology, with their aquifer potential identified on this basis.

Part 3 of the Report deals with the chemistry of formation waters, including shallow potable groundwater. Hydrochemical maps can assist in interpreting potentiometric surfaces by identifying regional hydrochemical trends. The main source of information for the Phanerozoic formation waters was the hard copy files of the ERCB. Special software allowed sorting and culling for such effects as contamination by drilling mud and acid washes; as a result of the culling filters only 23 percent of the nearly 2400 analyses entered

were accepted for study. Using salinity as an example, five distinct hydrochemical trends were identified: (1) Cooking Lake-Beaverhill Lake-Watt Mountain aquifer with smooth regional trends and salinity decreasing to the northeast; (2) Camrose Tongue, Grosmont Formation, and Wabamun-Winterburn aquifers along the western third of the study area, with east-west trending salinity gradients and decreasing salinity to the north; (3) "Lower Mannville" Group aquifer, with steep east-west trending salinity gradients along the southern part of the study area, strong evidence of "drainage" in the Grosmont Formation subcrop region, and northeast-trending salinity gradients in the northeast part of the study area; (4) "Upper Mannville" Group aquifer which was effectively a subdued replica of the "Lower Mannville" Group aquifer; and (5) "Viking sandstone" aquifer which was similar to that in the "Upper Mannville" Group aquifer, but with reduced salinities and shallower salinity gradients. These various hydrochemical trends suggest that the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer is in the northeast-oriented regional flow regime and that the overlying Ireton Formation aquitard isolates it from the northward-oriented flow regime in the Camrose Tongue, Grosmont Formation and Wabamun-Winterburn aquifers which appear, from their hydrochemistry, to be part of the same system. The three Cretaceous aquifers studied exhibit similar hydrochemical patterns with apparently more subdued effects of the Grosmont Formation "drainage" system in the upper aquifers due to the intervening Clearwater Formation and Joli Fou Formation aquitards.

Quaternary formation waters originated from the Central Data File of Alberta Environment and are displayed in a format consistent with those of conventional groundwater studies in Alberta. The regional hydrochemical patterns relate both to proximity to bedrock and to their position in relation to recharge (high topography) and discharge (low topography) areas. Total dissolved solids are generally within Alberta Health Standards of 1000 mg/L, as is fluoride, but the iron content commonly exceeds the limit of

0.3 mg/L, sometimes by more than one order of magnitude. Formation waters in the Quaternary sediments show a salinity pattern unlike any in the Phanerozoic.

Part 4 of the Report describes the techniques used to evaluate the flow regime. Special software was written to enter, sort and interpret drillstem tests and aquifer tests, as well as treat ERCB core data. In addition to determining 1185 hydraulic heads, 665 permeabilities and 639 hydraulic conductivities were calculated from drillstem tests. This information, as well as that from cores, was evaluated using log-normal cumulative frequency plots in order to characterize and identify individual aquifers. On the basis of this evaluation, potentiometric surface maps, and pressure head-versus-depth plots, the following flow features were identified: (1) Cooking Lake-Beaverhill Lake-Watt Mountain aquifer is part of the regional flow regime with flow towards the northeast, and hydraulic continuity between this and the overlying "Lower Mannville" Group aquifer where the Ireton Formation aquitard is absent; (2) Winterburn-Grosmont-Camrose aquifers are in hydraulic continuity along the western third of the study area, and there is also hydraulic continuity with the "Lower Mannville" Group aquifer above the Pre-Cretaceous unconformity; (3) "Lower Mannville" Group-Grosmont Formation aquifers exhibit "drainage" effects due to drawdown by the Grosmont Formation aquifer, as well as potential downward circulation above the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer in the northeastern part of the study area where the Ireton Formation aquitard is absent. In the southwestern corner of the study area, where the Clearwater Formation aquitard is absent, there is downward flow from the overlying "Upper Mannville" Group aquifer; (4) "Upper Mannville" Group aquifer is the most heterogeneous with generally very flat hydraulic gradients, perhaps characteristic of dominantly downward flow; and (5) "Viking sandstone" aquifer, which seems to represent a local "topographically controlled" flow regime, but which may be influenced by an osmotic flow effect from deep in the Alberta Basin which, therefore, renders such a characterization as equivocal. Study of the flow across the aquitards can be analyzed using pressure head-versus-depth plots and this suggests that flow is potentially upwards across the Ireton Formation aquitard and downwards across the Clearwater Formation, Joli Fou Formation and Colorado aquitards.

Part 5 of the Report is concerned with the hydrometeorology of the lower portion of the Beaver River basin, an area of 4220 km^2 in the east-central part of the study area. This specific region was chosen because it coincides, approximately, with the area selected for the steady state numerical simulation, which itself was determined on the basis of hydrogeological considerations. The work was a necessary input to obtain the upper boundary conditions for the numerical simulation, but is also of considerable general use for any hydrometeorological studies of the Cold Lake oil sands development area.

Stream flow data from various hydrometric stations in the study area and vicinity were analyzed and precipitation data evaluated. Lake evaporation was estimated on the basis of class A pan evaporation data, as well as by several other techniques; predicted potential evapotranspiration was estimated from climatic normals. On the basis of frozen-ground methodology, the basin average annual runoff is 30 mm, and the potential for groundwater recharge is small, in the order of 10^1 mm per year.

Part 6 of the Report describes a numerical simulation of the steady state natural flow regime in a region of 4815 km^2 in the east-central part of the study area which encompasses the majority of in-situ pilot plants. The model area was chosen on the basis of a suite of criteria including the limits of solution of the basal aquitard (Upper Devonian Prairie Formation halite) and structure contours on both the Pre-Cretaceous unconformity and the bedrock. It was limited to the Phanerozoic sequence on the basis of the effectively negligible input from the Quaternary. The model used was FE3DGW obtained from Battelle Memorial Institute, Ohio. Because the hydrogeological system was not closed it was necessary to compute a mass balance for the model area, and this defined the hydrostratigraphy as the Prairie Formation aquiclude, the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, the Ireton Formation aquitard (not present throughout the model area), the "Lower Mannville" Group aquifer, which is separated from the "Upper Mannville" Group aquifer by the Clearwater Formation aquitard, and the Colorado Supergroup aquitard (the top of which is the bedrock surface); note that the mass balance indicated that the "Viking sandstone" aquifer can be neglected in this simulation. The flow analysis suggests that the Quaternary flow regime can be "decoupled" from the Phanerozoic flow regime in the numerical simulation. The mass balance computations also helped to define values for the hydraulic parameters for the aquitards, where no field data were available.

The model was calibrated against observed hydraulic heads for the selected aquifers, for two different grid sizes, and three methods of simulating the upper boundary conditions; with respect to the latter, the best approximation was obtained using hydraulic heads in the aquifers immediately above the top of the bedrock rather than the water-table. Maximum error for the final model conditions ranged between 2 and 12 percent for comparison between observed hydraulic heads and computed values at the same locations, with an average error of less than 2.4 percent for the three aquifers studied. The numerical simulation of the three-dimensional steady state natural flow in the model area of the Cold Lake Study Area represents a validation of the synthesized results and a calibration of the numerical model. This calibration now allows for predictive fluid flow modelling of the effects of in-situ oil recovery activities in the model area on the flow of formation waters in the Phanerozoic hydrostratigraphic sequence above the Upper Devonian Prairie Formation aquiclude.

The Atlas comprises nearly 220 maps and cross-sections at a scale of 1:500 000, organized by hydrostratigraphic units. It is essentially a reference document and includes many maps and cross-sections which are not referred to in the written Report.

The Data Base is organized in three sections. The first two are effectively a hard copy form of new and selected interpreted information present in GWDB for the Phanerozoic and Quaternary, respectively. Included are new stratigraphic picks by Alberta Research Council staff, logs of shallow boreholes, the chemical composition and physical properties of formation waters, and interpreted hydraulic parameters of drillstem tests and cores, and well tests and aquifer tests, most organized by hydrostratigraphic units. The third section is an annotated catalogue of manufacturers and the types of equipment they provide for hydrogeological investigations plus a reference list of papers on methods of measuring and using some relevant hydrogeological parameters.

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ACKNOWLEDGEMENTS

Before concluding this Executive Summary I would like to place on record my indebtedness to the very dedicated team of Alberta Research Council staff who made this project possible. All worked hard in their various capacities under my demanding requirements for excellence. Major scientific input fell to the Basin Analysis Group of the Alberta Geological Survey. I particularly wish to acknowledge the work of Mr. Andre T. Lytviak and Dr. Stefan Bachu, with the technical assistance of Mr. Michel Brulotte, who provided all the software necessary to carry out this project. In addition, Dr. Bachu was responsible for the numerical simulation which was the final test of the team's efforts. Development and interpretation of all hydrodynamics were the responsibility of Mr. Claude M. Sauveplane who worked closely with me in linking the hydrochemical and hydraulic data. Responsibility for all aspects of the Quaternary fell to Mr. Laurence D. Andriashek and Dr. Dominique M. Borneuf of the Terrain Sciences Department, and for the hydrometeorology to Dr. Henry Hudson of the Civil Engineering Department, whose efforts are greatly appreciated. Drafting and secretarial work for this project were extensive, and were carried out most efficiently under the direction of Mr. W. Hutniak and Mrs. S.M. Binda, respectively. Finally, the format and presentation of this project were the responsibility of my technical supervisor Mrs. Mika Madunicky whose dedication is most gratefully appreciated and acknowledged.

Brian Hitchon

Brian Hitchon
Project Manager
1985-01-31

INTRODUCTION

BACKGROUND TO STUDY

Initial discussions concerning a study of the hydrogeology of the Cold Lake region took place between the Alberta Research Council (ARC) and Alberta Environment (AE) in early 1981. The primary concern of both parties was the then imminent development of commercial in-situ recovery operations in the Cold Lake oil sands deposit, and the possible impact these operations might have on the natural flow systems, specifically on the nearsurface potable groundwater resources. There was mutual agreement between ARC and AE that whatever study eventually evolved, the experience gained should be applicable to other oil sands deposits in Alberta. Because of the vast amount of data available, and required, for such a hydrogeological study (much of which was not in machine-readable form) one of the primary objectives had to be the entry and processing of information; this aspect of the study was to be transferable to other oil sands deposits and required the development of a series of integrated software packages. Based on these software packages and the specific data entered for the Cold Lake Study Area, a comprehensive report on the hydrogeology of that region could then be carried out. Because the primary concerns and approach to the problem were the same for both ARC and AE it was agreed to fund the study equally.

The study began on 1982-04-01 and was completed 1985-01-31, for a total cost of $958,000. Project guidance was provided by a technical committee comprising staff of ARC and AE, under the chairmanship of Dr. Brian R. Hammond (AE). Project management was the responsibility of Mr. Gordon Gabert until 1983-05-31, and from 1983-06-01 to completion of Dr. Brian Hitchon.

ACKNOWLEDGMENTS

A study of the magnitude and complexity of the present one can only be carried out with the close cooperation of the funding parties and the concerted effort of a dedicated research team. I would like to acknowledge particularly the guidance and understanding of Dr. Brian Hammond, Senior Research Manager, Research Management Division, Alberta Environment who allowed the research team the necessary flexibility to undertake this study in an optimum manner. Mr. Gordon Gabert, formerly Head, Groundwater Department, Alberta Research Council was Project Manager from the commencement until 1983-05-31, and was responsible for internal administration and liaison with Alberta Environment. Throughout the study, his able assistance in relieving me of much day-to-day internal administration is gratefully acknowledged.

The final report is the cooperative effort of many professional, technical and clerical staff of ARC. Professional responsibility for the various sections fell to L.D. Andriashek, S. Bachu, D.M. Borneuf, H.R. Hudson, A.T. Lytviak and C.M. Sauveplane; they comprise an excellent dedicated research team and their assistance and advice throughout this study was much appreciated. Special thanks are due to M. Brulotte, who wrote many of the computer programs, and particularly M.M. Madunicky who was technical assistant to both Project Managers and who was responsible for compiling and assembling the Report, Atlas and Data Base.

Brian Hitchon
1985-01-31

APPROACH TO HYDROGEOLOGICAL RESEARCH

Review of Previous Work

Hydrogeology, by definition and implication, is that branch of geology which is concerned with the flow of formation waters in natural porous media. A fundamental feature in hydrogeology is the existence of an aqueous continuum throughout all sedimentary basins. With the possible exception of thick evaporite beds, which may act as aquicludes, all sedimentary rocks are either aquifers or aquitards. Most sedimentary rocks therefore function in bulk as either water-conducting or water-retarding complexes relative to adjacent strata. The basic hydrogeologic unit may be either a single stratum or a combination of strata that hydraulically function as an aquifer or aquitard relative to the adjacent hydrogeologic units. Thus adjacent strata of vastly different ages may act as a single hydraulic unit, for example, across an unconformity or fault zone. Therefore, to understand, thoroughly, the hydrostratigraphy of an area it is essential to be cognizant of the stratigraphy. This is particularly pertinent to an area such as Alberta with a long and complex geological history.

Gravity-induced cross-formational flow is the mechanism which controls the flow of formation fluids in sedimentary basins, such as Alberta, in which subaerial topographic relief has been developed. The theory on which this concept rests has been well developed over the past half century and is reviewed by Toth (1980); it will not be elaborated further in this report. Hitchon (1969a, b) has outlined the basin-wide flow system in the Western Canada Sedimentary Basin and indicated that the main variables affecting the hydraulic-head distribution are topography and geology. This has been stated more generally by Toth (1980):

> Geologically mature basins are hydraulically continuous environments in which the relief of the water table, commonly a subdued replica of the land surface,

generates interdependent systems of groundwater flow with patterns modified by permeability differences.

In western Canada the dominant fluid potential in any part of the basin corresponds closely to the fluid potential at the topographic surface in that part of the basin (Hitchon, 1969a). Major recharge areas correspond to major upland areas, and major lowland regions are major discharge regions. A specific feature of the Alberta Basin is the development of a low fluid-potential drain in the medium-depth portion of the basin, resulting from the presence of highly permeable Upper Devonian and Carboniferous carbonate rocks, which channels flow northeastward and has modified the theoretical relations between local and regional flow systems. There are different fluid potential subsystems within the low fluid-potential drain (Hitchon, 1969b, 1984), specifically in the Upper Devonian carbonate reef complexes of the Woodbend Group and the Beaverhill Lake Formation. In some areas of central Alberta drawdown along these highly permeable units is reflected through up to 750 m of strata and across the PreCretaceous unconformity.

As a broad generalization, the ultimate destiny of formation waters in the regional flow system of the Alberta Basin is discharge in the major lowland region of northeastern Alberta and extreme northwestern Saskatchewan (see Hitchon, 1984, figure 12 for schematic basin-wide flow directions); this comprises the physiographic areas of the Clearwater Lowland, the Athabasca Delta Plain, the eastern part of the Fort Vermillion Lowland and the Wood Buffalo Plain. The region contains extensive outcrops of Middle and Upper Devonian rocks, as well as saline springs. Hitchon et al. (1969) have shown, by means of hydraulic-head cross-sections and chemical and isotopic analysis of the saline springs, that there is extensive solution of Middle Devonian halite and gypsum by meteoric water and movement of the resulting brines to discharge areas at the principal Devonian outcrop near the Slave River. There is thus no <u>direct</u> evidence of the discharge of deep formation waters although the regional hydrodynamics (Hitchon, 1969a, b) and geothermal gradient pattern (Hitchon, 1984) means that this must occur.

Prior to starting the present study the only published source of the regional hydrogeology of the Cold Lake Study Area was a generalized hydraulic-head cross-section (Hitchon et al., 1969) which showed the relation between the near-surface flow regime and solution of the Middle Devonian Prairie Formation halite; this cross-section is reproduced from the original source in figure 1-1.

Clearly, the theory behind steady state gravity-induced three-dimensional flow in sedimentary basins is well established, although none of the reports cited above had used numerical simulation to represent flow phenomena. In addition, all were, in essence, reconnaissance level studies designed for the specific purpose of determining the broad constraints which affect flow patterns in Alberta. At the time they were carried out ARC did not have the capability of handling vast amounts of data, nor was a computer model for steady state numerical simulation available. A new approach was required which would allow the hydrogeology of the Cold Lake Study Area to be evaluated thoroughly, using effectively all available information.

Present Approach

The steady state model for numerical simulation acquired by ARC requires the following basic information within the model area:

1. Geometry of the hydrostratigraphic units;
2. Hydraulic parameters of the solid matrix;
3. Hydraulic parameters of the fluids.

Before any of this information can be entered into the model, however, there are many steps in assembling data, including:

1. Development of a Data Base Management System;
2. Development of cartographic and surface-representation software;

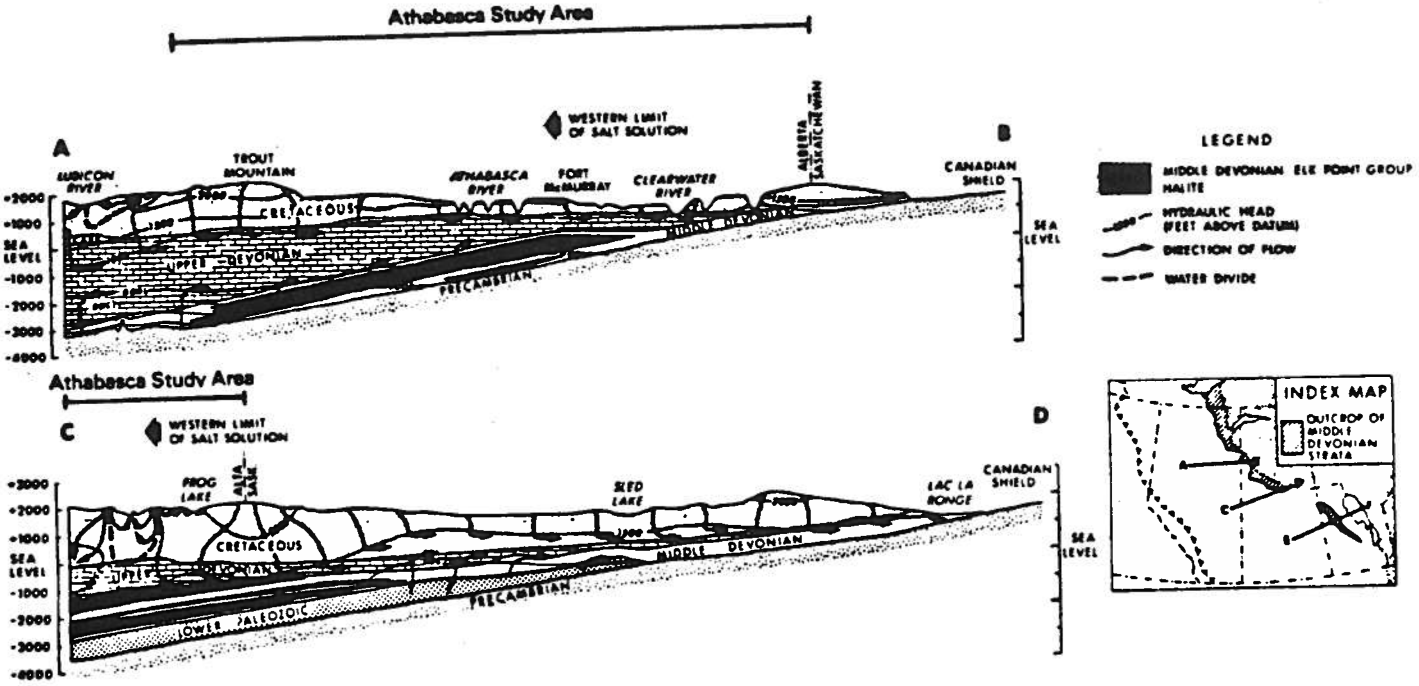

Figure 1-1 Hydraulic-head cross-section showing distribution of fluid flow in relation to solution of Middle Devonian Prairie Formation halite (Hitchon et al., 1969, Fig. 3)

3. Development of software for the entry, sorting and interpretation of geological, core, drillstem test and formation water data;
4. Development of techniques for combining information from stratigraphic units into those of hydrostratigraphic units suitable for the model.

Clearly, this was not a trivial task, and probably half the effort was devoted to development work. Data entry posed a major problem, because the only information in machine-readable form was that acquired from the Energy Resources Conservation Board (ERCB). Much of the information in the ERCB well data file originated from individual petroleum exploration companies, and this fact, together with the size of the data base for the Cold Lake Study Area, meant that considerable sorting and re-interpretation was required. All information on drillstem tests and formation waters had to be entered into the Data Base Management System before sorting and interpretation could begin.

In summary, the present approach has been to use all available information and to treat this vast amount of data through specially developed software, which itself was part of an integrated Data Base Management System. The steady state numerical simulation therefore represents the synthesis of the present flow regime in terms of smoothed trends for all the parameters entered.

FORMAT OF STUDY REPORT

"Hydrogeology of the Cold Lake Study Area, Alberta, Canada" is presented in three distinct formats, each with a specific style and purpose.

The first format is that of a Report, complete with illustrations and tables, which is effectively a narrative of the work accomplished and the conclusions drawn. It is complete, per se, in the conventionally accepted term of a "final report". It comprises six parts, as follows:

Part 1. Introduction, Data Base Management System, and Data Processing (together with an Executive Summary);
Part 2. Regional Geology;
Part 3. Hydrochemistry;
Part 4. Hydrodynamics;
Part 5. Hydrometeorology;
Part 6. Numerical Simulation of fluid flow.

The second format is an Atlas of maps at a scale of 1:500 000 covering the geology, hydrochemistry and hydrodynamics of the region, together with some general maps and cross-sections. In general, it is presented in terms of the hydrostratigraphic units identified. When pertinent, selected maps and cross-sections have been reproduced in the written report, though the majority are not referred to in the final report. It is essentially a reference atlas.

The third format is a hard copy Data Base of information which supplements the ERCB well data file. As such it includes stratigraphic picks made by ARC staff for the specific purpose of this study, together with the culled and interpreted data on the formation waters and drillstem tests used in this study. Similar tables summarize the information used for characterizing the hydrogeology of the Quaternary sediments. Other information in the Data Base includes a catalogue of suppliers for deep well instrumentation. Most information in the Data Base can be supplied also in machine-readable form if required.

DATA BASE MANAGEMENT SYSTEM

INTRODUCTION

With the increased availability of powerful computer systems the modern earth scientist can attempt the analysis of very large data sets. As these may be complex by virtue of their sheer size, he/she must, typically, forgo considering each data element on an individual basis, or refining each interrelationship between elements in pursuit of exact solutions, in favour of identifying generally simpler but broader classes of data elements and achieving approximate solutions.

In the present study extensive use has been made of electronic data processing. This was necessitated by the massive quantity of data to be considered and the large size of the project area. In addition, the data which were available in large volumes had to be generalized and integrated with other types of data which were sparse, unevenly distributed or of local nature only.

Though the existing cartographic (ALBPLOT,GEOPLTR) and surface representation software (SURFACE II and related utilities) were utilized to represent data, much new software had to be written and some of the existing software needed to be extended or otherwise enhanced to facilitate the iterative approach taken to data reduction and interpretation. The single largest software development effort was, therefore, the design and construction of a computer data base.

The system Data Base Management System (DBMS) on the Alberta Research Council central computing facility (CMPARC) was judged to be poorly suited to the needs of the project. The decision was made to construct custom software for data base management. Though this decision required a large outlay of manpower, it did allow us to tailor the resulting DBMS to the strengths and weaknesses of CMPARC and to existing programs for representation of data and results.

The resulting data base, GWDB, was constructed over the past two years. It has been written in FORTRAN 77 as implemented on VAX/VMS (tm DEC). The software was written in such a manner as to be easily maintainable rather than to make it maximally efficient. Though quite specialized when compared to a general system, GWDB proved to be sufficiently general to support a number of projects in addition to the present study.

In order to make it possible to re-implement GWDB on other machinery than the VAX, an effort was made to minimize the utilization of VMS-specific capabilities. The main VMS feature which was utilized extensively is the indexed record structure. Direct access to records may be provided differently on other operating systems.

Because disk storage is a scarce resource on CMPARC, GWDB is typically partitioned into disk and tape resident components. Thus, at any one time, the data base consists of an on-line and an off-line component. As the on-line component is stored as indexed files, it is amenable to random access. The off-line component is stored on magnetic tape and can only be accessed sequentially. With the exception of an inventory program and the program which partitions the data base between on-line and off-line components, all software for data base manipulation deals with the on-disk resident component of the data base. Ease of transfering data holdings to other facilities is a direct consequence of the ability to reduce the data base to sequential form.

GENERAL FORM OF GROUND WATER DATA BASE (GWDB)

Currently, 18 different record types have been defined in GWDB. Provisions have been made to accomodate up to fifty. Not all the defined types have been implemented nor do all data base functions apply to all types. As the study progressed, some record types were found to be of lesser importance to the final aims than others. Similarily, some types of access and report production had to be improved and enhanced; others were found to be of little use and were left in an embryonic form.

All the records are of indexed type. There are two types of keys for this indexing; character and integer.

The character index (Location/id) is always sixteen bytes in length and is composed of the following components:

bytes	1:1	MR	DLS Meridian	4 - 6
	2:4	TP	DLS Township	1 - 126
	5:6	RG	DLS Range	1 - 31
	7:8	SC	DLS Section	1 - 36

9:10	LS	DLS L.S.D.	1 - 16
11:16	IXI	Uniqueness value	

In the case of data originating from the ERCB Well Data System (WDS) IXI can be further divided into the following components:

11:12	Location exception
13:14	Event sequence
15:16	Two byte space (ASCII 32)

Thus, explicit within this key is the Dominion Land Survey (DLS) coordinate of the data point or phenomenon. In the case of the ERCB WDS data, well versions are also indicated. That is, in the case where a major change occurred in the well completion, a new record at the old location is created by incrementing the event sequence value. As these keys are, for the most part, a function or description of an actual location they do not change.

The integer index (Record ID) is always four bytes in length. It is used to link the records located by Location/id to record types which may occur an arbitrary number of times in one well or at one site. This key is also used to link different record types at one site. As these keys are arbitrary, they can change each time the data base in which they reside is rebuilt.

The 18 record types currently defined for GWDB are:

0		Data Base Master record
1	00000	Site Master record
2	00001	Location record
3	10103	ERCB Well Data System (WDS) header record
4	10101	Stratigraphic pick record
5	10107	DST header record
6	DSTA1	DST initial data record
7	10106	Core header record
8	CORE1	Core initial data record
9	101CH	Deep well chemistry header record
10	101CM	Deep well chemistry initial data record
11	DSTB1	DST interpreted data record
12	BCHEM	Deep well chemistry culled data record
13	10200	Shallow well header record
14	10201	Surface feature header record
15	CHEMH	Shallow and surface chemistry header record
16	CHEMD	Shallow and surface chemistry data record
17	LITHO	Abbreviated lithology record

RECORDS AND ELEMENTS OF GWDB

This section lists the data elements in each of the 18 record types. In the case of some elements an encoding of their value was used. If the code is simple it is given in the record description. If it is long it is given after all the records have been described. In the case of codes which were adopted from the ERCB Well Data System (WDS) and not modified for GWDB purposes the reader is referred to the data dictionary available from the ERCB.

In order to clarify the relationship between the records and the elements, the "file open" and "record read" statements are given. These statements show the nature of the nesting of data elements in record structures and the method used to implement variable length and occurence structures.

0) - Data Base Master Record

The primary function of the Data Base Master record is to provide a list of the names and locations of the files which comprise the data base. A secondary function is to provide a short description of the contained files and a count of how many of each type exists on disk.

NRECS	Number of record types in the data base
FILENM	Name of file containing current record type
RECDES	Alphabetic description of records in current file
NTTREC	Total number of records of current type

```
   character*32    FILENM(50), RECDES(50)
   integer         NTTREC(50), NRECS

 1   format(i4)
 2   format(2a,i8)

     open(unit=LUN, file=IFLNM, status='old', readonly,
    * iostat=IOS, err=nm)

     read(LUN,1,end=nm,err=nm) NRECS
     do 25 i=1,NRECS
25   read(LUN,2,end=nm,err=nm,iostat=IOS)
    * FILENM(i),RECDES(i),NTTREC(i)
```

1) Type 00000 - Site Master Record

The primary function of the type 00000 record is to locate the data point on the Earth's surface and to maintain an inventory of up to fifty other record types referring to this point. The 00000 record contains the following elements:

R01ID	Location/id
GRD	Reference datum elevation (metres)
GAC	Accuracy of GRD power of 10 (m)
SRC	Source of initial record 00 (ARC CDF) 03 (ERCB REC03)
DTP	Data type Interpretation of STA could differ for different values of this parameter
AAA	Unassigned
STA	Record status 50 1 byte flags 00 Nothing known about the record type 01 Record known to exist in electronic form 02 Record loaded into data base. This value is incremented by one each time the record is modified

```
   byte              STA(50)
   character*4       AAA
   character*16      R01ID
   integer*2         GAC, SRC, DTP
   real*4            GRD
   common /B00000/   STA, AAA, R01ID, GAC, SRC, DTP, GRD

   open(access='keyed', form='unformatted',
*  file=FILENM(1), iostat=IOS, key=(1:16:character),
*  organization='indexed', recl=20, recordtype='fixed',
*  status='old', unit=LUN, readonly, err=nm)

   read(LUN, key=R01ID, err=nm, iostat=IOS) FCID,
*  GRD, GAC, SRC, DTP, AAA, STA
```

2) Type 00001 - Location Record

The function of the type 00001 record is to improve the accuracy of the data point location. This record need not occur, but even if it does, it may contain only null values. The 00001 record contains the following elements:

R02ID	Location/id
SRC1	Source of NS,MT1,EW,MT2 coordinate
NS	Direction from datum " " if N/A

	"N" if North "S" if South
MT1	Distance in NS direction (m)
EW	Direction from datum " " if N/A "E" if East "W" if West
MT2	Distance in EW direction (m)
SRC2	Source of ALT,ALN coordinate
ALT	Measured latitude
ALN	Measured longitude
SRC3	Source of TLN,TLT coordinate
TLT	Theoretical latitude
TLN	Theoretical longitude
SRC4	Source of UTMZ,UTME,UTMN coordinate
UTMZ	UTM (Universal Transverse Mercator) zone
UTME	UTM easting
UTMN	UTM northing
BBB	Unassigned

```
      character*1     NS, EW
      character*11    BBB
      character*16    R02ID
      integer*2       SRC1, SRC2, SRC3, SRC4, UTMZ
      real*4          MT1, MT2, ALT, ALN, TLT, TLN
      real*8          UTME, UTMN
      common /B00001/ NS, EW, BBB, R02ID, SRC1, SRC2, SRC3, SRC4,
     *                UTMZ, MT1, MT2, ALT, ALN, TLT, TLN, UTME, UTMN

      open(access='keyed', form='unformatted',
     * file=FILENM(2), iostat=IOS, key=(1:16:character),
     * organization='indexed', recl=20, recordtype='fixed',
     * status='old', unit=LUN, readonly, err=nm)

      read(LUN, key=R02ID, err=nm, iostat=IOS) FCID,
     * SRC1, NS, MT1, EW, MT2, SRC2, ALT, ALN, SRC3, TLT,
     * TLN, SRC4, UTMZ, UTME, UTMN, BBB
```

3) Type 10103 - ERCB Well Data System (WDS) Header Record

The type 10103 record contains primarily those elements of the ERCB administrative description of a well which were considered to be of interest to this and similar projects. This record will not occur in the case of data points referring to shallow wells or surface features. The 10103 record contains the following elements:

R03ID	Location/id
CCC	Unassigned
WLN	Well name

KBS	Kelly Bushing elevation (m)
FCD	Field code
PCD	Pool code
OPD	On production date YYMMDD
TDP	Final total depth (m)
PBD	Plug back depth (m)
CDD	Date at which the current value of STT valid
STT	Status code (ERCB WDS)
DDD	Unassigned

```
   character*4     CCC
   character*5     DDD
   character*16    R03ID
   character*47    WLNM
   integer*2       FCD
   integer*4       OPD, CDD, PCD
   real*4          KBS, TDP, PBD
   common /B10103/ CCC, DDD, R03ID, WLNM, FCD, OPD, CDD, PCD,
*                  KBS, TDP, PBD

   open(access='keyed', form='unformatted',
*  file=FILENM(3), iostat=IOS, key=(1:16:character),
*  organization='indexed', recl=25, recordtype='fixed',
*  status='old', unit=LUN, readonly, err=nm)

   read(LUN, key=R03ID, err=nm, iostat=IOS) FCID,
*  CCC, WLNM, KBS, FCD, PCD, OPD, TDP, PBD, CDD, DDD
```

4) Type 10101 - Stratigraphic Pick Record

The type 10101 record contains stratigraphic picks. These are primarily derived from the ERCB WDS computer files; however, the ERCB picks may have been modified or supplemented. In the case of non-ERCB records, all picks were entered by ARC staff members. The 10101 record contains the following elements:

R04ID	Location/id
NFMS	Number of picks in record
	--NFMS times---
FMC	Pick code
FDP	Depth below datum (usually KB) (m)

```
   character*16    R04ID
   integer*2       NFMS, FMC(56)
   real*4          FDP(56)
   common /B10101/ R04ID, NFMS, FMC, FDP

   open(access='keyed', form='unformatted',
```

```
*  file=FILENM(4), iostat=IOS, key=(1:16:character),
*  organization='indexed', recl=90, recordtype='variable',
*  status='old', unit=LUN, readonly, err=nm)

   read(LUN, key=R04ID, err=nm, iostat=IOS) FCID,
*  NFMS, (FMC(i),FDP(i),i=1,NFMS)
```

5) Type 10107 - DST Header Record

The type 10107 record contains a list of pointers to drillstem test (DST) records pertinent to a well. These records are derived from the ERCB WDS computer files. The 10107 record contains the following elements:

R05ID	Location/id
NDSTS	Number of DSTs in record
	--NDSTS times---
DST	Identifier corresponds to R06ID of type DSTA1
	Top of tested interval (m)
	Bottom of tested interval (m)

```
   character*16    R05ID
   integer*2       NDSTS
   real*4          DSTV(48,3)
   common /B10107/ R05ID, NDSTS, DSTV

   open(unit=LUN, file=FILENM(5), status='old',
*  organization='indexed', access='keyed',
*  recordtype='variable', form='unformatted', recl=150,
*  key=(1:16:character), iostat=IOS, err=nm, readonly)

   read(LUN, key=R05ID, err=nm, iostat=IOS) FCID,
*  NDSTS, ((DSTV(i,j),j=1,3),i=1,NDSTS)
```

6) Type DSTA1 - DST Initial Data Record

The type DSTA1 record contains the data relevant to a single drillstem test. These records are derived partially from the ERCB WDS computer files. However, as the drillstem test computer files are primarily of administrative nature, DSTA1 records had to be supplemented by manual entry of data from other sources. One such source was the ERCB microfilm files of drillstem test reports. The DSTA1 record contains the following elements:

R06ID	Record ID
DTD	Total depth (final) of well (m)
ISTTS	Status of data input to this test

IDSTL	Global ID number for this particular DST
QLTY	Quality code 0 1 A B C D E F G where 0,1 are misrun codes from ERCB and the rest are McAllister's codes
TSTTP	Test type 0 - conventional 1 - straddle 2 - hookwall 3 - reverse circulation 4 - wireline 5 - CR sampler 6 - limited recovery 7 - air drill flow test
DINTA	Tested interval top (m) Tested interval bottom (m)
RECDPT	Recorder depth (m)
DTDC	Current (as of this test) total depth (m)
FORME	ERCB stratigraphic "pick" a 2 byte integer code
FORMO	Stratigraphic pick given on hard copy report
PAYTHG	Pay thickness on hard copy report
RDWELL	Diameter of inner well bore (m)
DCLN	Drill collar length (m)
DCID	Drill collar inner diameter (m)
DPID	Drill pipe inner diameter (m)
TEMPB	Temperature at bottom of hole (deg C)
POROG	Given porosity for DST interval
SPORO	Source of POROG value
CTIG	Given total compressibility
SCTG	Source of CTIG value
TRNMG	Given transmissivity value (Md/Cp)
PERMG	Given permeability (m^2)
PTSFG	Given potential surface (m)
RDSING	Given radius of influence (m)
NCMT	Number of lines of comments (max 6)
	--- NCMT times ---
CMTS	Comments

NPHS	Number of phases
NFLD	Number of alpha fluid descriptions (max 6)
	--- NFLD times ---
FLDD	Alpha fluid recovered descriptions

```
MUDAMT   Amount of drilling fluid recovered (m)
MUDWGT   Mud density,weight (kg/m^3)
MUDVSC   Mud viscosity (sec/liter)
MUDFLL   Fluid loss for mud (cc)
BRNAMT   Amount of formation water recovered (m)
BRNTDS   Total dissolved solids of formation water (mg/L)
BRNHLT   Salt content of formation water (mg/L)
BRNRES   Formation water resistivity (ohm cm)
BRNWGT   Formation water density, weight (kg/L)
OILAMT   Amount of oil recovered (m)
OILWGT   API gravity of oil (kg/L)
OILVSC   Viscosity of oil (Cp, centipoises)
GASZFC   Supercompressibility factor of gas (dimensionless)
GASVSC   Viscosity of gas (Cp)
GASSPG   Specific gravity ratio of gas
IPHS     Current phase (1-4)
         -------- NPHS times----------------------------------
BTSTD    Duration of flow phase (minutes and fractions)
NBLDS    Number of lines of alpha blow description (max 6)
         --- NBLDS times ---
BLDSC    Blow description
         ------------------
NBLM     Number of readings in BLMSR (max 24)
         --- NBLM times ---
BLMSR    Time (minutes)
         Rate (m^3/d).
         -----------------
NFDIGT   Number of readings in digitized flow (max 24)
         --- NFDIGT times ---
FDIGT    Time (minutes)
         Pressure (kPa)
         --------------------
RTSTD    Duration of recovery phase (minutes and fractions)
NSDIGT   Number of digitized recovery readings (max 24)
         --- NSDIGT times ---
SDIGT    Time (minutes)
         Pressure (kPa)
         --------------------
HRNRSG   Given Horner slope
HRNRSU   HRNRSG units
             0   case of liquid  kPa/cycle
             1   case of gas (kPa^2/log cycle)x10^-6
HRNRPG   Given extrapolated Horner pressure (kPa)
         -------------------------------------------------------

    character*1       QLTY
    character*16      FORMO, SPORO, SCTG
    character*80      BLDSC(4,6), FLDD(6), CMTS(6)
    integer*2         TSTTP, FORME, NPHS, NFLD, NCMT,
 *                    IPHS, NBLDS(4), NBLM(4), NFDIGT(4),
```

```
     *                 NSDIGT(4), HRNRSU(4), ISTTS
      integer*4        R06ID
      real*4           DINTA(2), RECDPT, DTD, PAYTHG, RDWELL, DCLN,
     *                 DCID, DTDC, DPID, TRNMG, PERMG, PTSFG, TEMPB,
     *                 POROG, CTIG, MUDAMT, MUDWGT, MUDVSC, MUDFLL,
     *                 BRNAMT, BRNTDS, BRNHLT, BRNRES, BRNWGT,
     *                 OILAMT, OILWGT, OILVSC, GASZFC, GASVSC,
     *                 GASSPG, BTSTD(4), BLMSR(4,24,2),
     *                 FDIGT(4,24,2), RDSING, RTSTD(4),
     *                 SDIGT(4,24,2), HRNRSG(4), HRNRPG(4)
      common /BDSTA1/  R06ID, ISTTS, QLTY, TSTTP, DINTA, RECDPT,
     *                 FORME, FORMO, PAYTHG, NPHS, RDWELL, DCLN,
     *                 DCID, DTDC, DPID, TEMPB, POROG, SPORO, CTIG,
     *                 SCTG, TRNMG, PERMG, PTSFG, RDSING, NCMT, CMTS,
     *                 NFLD, FLDD, MUDAMT, MUDWGT, MUDVSC, MUDFLL,
     *                 BRNAMT, BRNTDS, BRNHLT, BRNRES, BRNWGT,
     *                 OILAMT, OILWGT, OILVSC, GASZFC, GASVSC,
     *                 GASSPG, BTSTD, NBLDS, BLDSC, NBLM, BLMSR,
     *                 NFDIGT, FDIGT, RTSTD, NSDIGT, SDIGT, HRNRSG,
     *                 HRNRSU, HRNRPG

      open(unit=LUN, file=FILENM(6), status='old',
     * organization='indexed', access='keyed',
     * recordtype='variable', form='unformatted', recl=1390,
     * key=(1:4:integer), iostat=IOS, err=nm, readonly)

      read(LUN, key=R06ID, err=nm, iostat=IOS) IFCID,
     * ISTTS, QLTY, TSTTP,
     * (DINTA(j),j=1,2), RECDPT, FORME, FORMO, PAYTHG, RDWELL,
     * DCLN, DCID, DTDC, DPID, TEMPB, POROG, SPORO, CTIG,
     * SCTG, TRNMG, PERMG, PTSFG, RDSING, NCMT, (CMTS(j),j=1,NCMT),
     * NPHS, NFLD, (FLDD(j),j=1,NFLD), MUDAMT, MUDWGT, MUDVSC,
     * MUDFLL, BRNAMT, BRNTDS, BRNHLT, BRNRES, BRNWGT, OILAMT,
     * OILWGT, OILVSC, GASZFC, GASVSC, GASSPG, (BTSTD(i), NBLDS(i),
     * (BLDSC(i,j),j=1,NBLDS(i)), NBLM(i), ((BLMSR(i,j,k),k=1,2),
     * j=1,NBLM(i)), NFDIGT(i), ((FDIGT(i,j,k),k=1,2),J=1,NFDIGT(i)),
     * RTSTD(i), NSDIGT(i), ((SDIGT(i,j,k),k=1,2),j=1,NSDIGT(i)),
     * HRNRSG(i), HRNRSU(i), HRNRPG(i),i=1,NPHS)
```

7) Type 10106 - Core Header Record

The type 10106 record contains a list of pointers to core analysis records pertinent to a well. These records are derived from the ERCB computer files. The 10106 record contains the following elements:

R07ID	Location/id
NCRS	Number of cores (max 96)
	--NCRS times---
CORE	Identifier corresponding to R08ID of CORE1
	Top of cored interval (m)
	Bottom of cored interval (m)

```
   character*16    R07ID
   integer*2       NCRS
   real*4          CORE(96,3)
   common /B10106/ R07ID, NCRS, CORE

   open(access='keyed', form='unformatted',
*  file=FILENM(7), iostat=IOS, key=(1:16:character),
*  organization='indexed', recl=294, recordtype='variable',
*  status='old', unit=LUN, err=nm, readonly)

   read(LUN, key=R07ID, err=nm, iostat=IOS) FCID,
*  NCRS, ((CORE(i,j),j=1,3),i=1,NCRS)
```

8) Type CORE1 - Core Initial Data Record

The type CORE1 record contains the data relevant to a single analyzed interval. These records are derived from the ERCB core data file. They generally are small sub-intervals of a cored interval. Some core intervals may have been analyzed more than once, possibly by a different laboratory, thus there may exist a number of CORE1 records for each reference in the 10106 record. The CORE1 record contains the following elements:

R08ID	Record ID
LABC	ERCB code for laboratory doing the analysis
DATE	Date of core analysis
CFLCD	Coring fluid code
CTECD	Coring technique code
CHNCD	Core handling code
ANAT	Analysis type
NSPC	Number of special procedures codes (max 6)
	--NSPC-- times ---
SPC	Special procedure code
NLIN	Number of lines of core analysis (max 390)

```
        --NLIN-- times ---
SPLC    Special line code
DEPT    Top of section analyzed
CLEN    Length of cored section
PREMM   Maximum permeability
PERMN   Permeability at 90° to maximum permeability
PERMV   Vertical permeability
PORO    Porosity
DENS    Grain density
OILS    Oil saturation
H2OS    Water saturation
LITHNA  Lithology/ not analyzed code
            this is an 8 digit code described as
            follows, for example, code 12345678
            RCKT(1) rock type code
            CTXC(2) cementing and texture code
            CGSC(3) crystal or grain size code
            PTSC(4) porosity type and size code
            FRCC(5) fracturing code
            MACC(6) major component
            SECC(7) secondary component
            MICC(8) minor component
             if the left most 7 digits are 0 then
             NACC(8) not analysed code
NXICRN  Index of next core analysis for this interval--
        this variable will provide a form of a link list
        A value of 0 is considered to mark end of list.

   byte             CFLCD, CTECD, CHNCD, ANAT, NSPC,
*                   SPC(6), SPLC(390)
   character*3      LABC
   integer*4        ICRN, DATE, LITHNA(390), NXICRN, RO8ID, NLIN
   real*4           DEPT(390), CLEN(390), PERMM(390), PERMN(390),
*                   PERMV(390), PORO(390), DENS(390), OILS(390),
*                   H2OS(390)
   common /BCORE1/  RO8ID, CFLCD, CTECD, CHNCD, ANAT, NSPC, SPC,
*                   SPLC, LITHNA, ICRN, DATE, DEPT, CLEN, PERMM,
*                   PERMN, PERMV, PORO, DENS, OILS, H2OS, NLIN,
*                   LABC, NXICRN

   open(unit=LUN, file=FILENM(8), status='old',
*  organization='indexed', access='keyed',
*  recordtype='variable', form='unformatted', recl=4090,
*  key=(1:4:integer), iostat=IOS, err=nm, readonly)

   read(LUN, key=RO8ID, err=nm, iostat=IOS) IFCID,
*  LABC, DATE, CFLCD, CTECD, CHNCD, ANAT, NSPC,
*  (SPC(i),i=1,NSPC), NLIN, (SPLC(i), DEPT(i), CLEN(i),
*  PERMM(i), PERMN(i), PERMV(i), PORO(i), DENS(i), OILS(i),
*  H2OS(i), LITHNA(i),i=1,NLIN), NXICRN
```

9) Type 101CH - Deep Well Chemistry Header

The type 101CH record contains a list of pointers to chemical analysis records of formation waters pertinent to a deep well. The 101CH record contains the following elements:

R09ID	Location/id
NCHEM	Number of analyses
	--NCHEM times---
CHEM	Identifier corresponds to R10ID of 101CM
	Top of sampled interval (m)
	Bottom of sampled interval (m)

```
      character*16    R09ID
      integer*2       NCHEM
      real*4          CHEM(96,3)
      common /B101CH/ R09ID, NCHEM,CHEM

      open(access='keyed', form='unformatted',
     * file=FILENM(9), iostat=IOS, key=(1:16:character),
     * organization='indexed', recl=294, recordtype='variable',
     * status='old', unit=LUN, err=nm, readonly)

      read(LUN, key=R09ID, err=nm, iostat=IOS) FCID,
     * NCHEM, ((CHEM(i,j),j=1,3),i=1,NCHEM)
```

10) Type 101CM - Deep Well Chemistry Initial Data Record

The type 101CM record contains the data relevant to a single analyzed sample. These records are the result of manual entry of data from the ERCB formation fluid files. As the fluid may represent more than one well, more than one interval, or may have been produced during a drillstem test which is already on file in GWDR this record type may contain a number of pointers to both record type 00000 and type DSTA1. The 101CM record contains the following elements:

R10ID	Record ID
CSTAT	Chemistry status
METH	A 16 character code indicating method of production, where the first character, a numeric, indicates:

1 DST
2 FWT
3 CRT
4 PUMPED
5 BAILED
6 OTHER

	and characters 2 to 16 are a cross-reference which will depend on the method of production:
	If from DST, encode of DSTID
	If from OTHER, explanation of the method of production
WHPRO	Where was fluid produced
OWNER	Owner's name
OWNSID	Owner's sample id
SDATE	Date sampled (year*1000+month*100+day)
LABN	Name of laboratory that did the analysis
LABSID	Laboratory sample id
RDATE	Date sample received by laboratory
ADATE	Date sample was analyzed
DENSY	Density
DENST	Temperature at which density was determined
PH	pH
PHT	Temperature at which pH was determined
RES	Resistivity (ohm m)
REST	Temperature at which resistivity was determined
RI	Refractive index
RIT	Temperature at which refractive index was determined
H2S	H2S description
ORGD	Organics description
ETDS	Total dissolved solids by evaporation (110 deg C) (mg/L)
ITDS	Total dissolved solids remaining after ignition (mg/L)
NSAP	Number of sample description lines (max 6)
	--NSAP times ---
SAP	Sample appearance

NTDS	Number of total dissolved solids determinations
	---NTDS times---
TDS	Total dissolved solids value
	Temperature at which total dissolved solids measured

NREM	Number of remarks (max 6)
	---NREM times---
REMK	Remarks

NPAR	Number of parameters determined (max 73)
	---NPAR times ---
PAR	Chemical parameter
UNIT	Unit of measure of PAR
VAL	Value of PAR

NWELLS	Number of wells this chemistry represents (max 30)
	---NEWLLS times---
WELLID	Well id
NINT	Number of intervals for this well (max 10)
	--NINT times---

```
DINTB   Interval top
        Interval bottom
        ---------------
        ------------------
```

```
      character*1     UNIT(73), TDSU
      character*16    METH, OWNSID, LABSID, WHPRO, WELLID(30)
      character*32    LABN, OWNER, H2S, ORGD
      character*80    SAP(6), REMK(6)
      integer*2       CSTAT, NSAP, NTDS, NREM, NPAR, PAR(73),
     *                NWELLS,NINT(30)
      integer*4       SDATE, RDATE, ADATE,R10ID
      real*4          DENSY, DENST, PH, PHT, RES, REST, RI, RIT,
     *                ITDS, TDS(3,2), VAL(73), DINTB(30,10,2)
c
      common /B101CM/ R10ID, CSTAT, METH, WHPRO, OWNER, OWNSID,
     *                SDATE, LABN, LABSID, RDATE, ADATE, DENSY,
     *                DENST, PH, PHT, RES, REST, RI, RIT, H2S,
     *                ORGD, ITDS, TDSU, NSAP, SAP, NTDS, TDS,
     *                NREM, REMK, NPAR, PAR, UNIT, VAL, NWELLS,
     *                NINT, DINTB, WELLID

      open(access='keyed', form='unformatted',
     * file=FILENM(10), iostat=IOS, key=(1:4:integer),
     * organization='indexed', recl=1250, recordtype='variable',
     * status='old', unit=LUN, err=nm, readonly)

      read(LUN, key=R10ID, err=nm, iostat=IOS) IFCID,
     * CSTAT, METH, WHPRO, OWNER, OWNSID, SDATE, LABN,
     * LABSID, RDATE, ADATE, DENSY, DENST, PH, PHT, RES, REST,
     * RI, RIT, H2S, ORGD, ITDS, TDSU, NSAP, (SAP(i),i=1,NSAP),
     * NTDS, ((TDS(i,j),j=1,2),i=1,NTDS), NREM, (REMK(i),i=1,NREM),
     * NPAR, (PAR(i), UNIT(i), VAL(i),i=1,npar), NWELLS,
     * (WELLID(i), NINT(i), ((DINTB(i,j,k),k=1,2),j=1,NINT(i)),
     * i=1,NWELLS)
```

11) Type DSTB1 - DST Interpreted Data Record

The type DSTB1 record contains the results of interpretation of data contained in the DSTA1 record. Some of the contained elements are simply a transfer from DSTA1 to DSTB1, others are the result of choosing among several values in DSTA1. DSTB1 also contains new elements which arise from the interpretation. The DSTB1 record contains the following elements:

R11ID	Record ID identical to R06ID of DSTA1 for current drillstem test
BSTTS	Status of current DSTB1 record
DINTC	Tested interval

POROGB	Given porosity
CTIGB	Given total compressibility
IQLTY	Quality of test where IQLTY is the number of parameters, estimated during permeability calculations, plus the graph quality flag
FORMOB	Stratigraphic pick given on hard copy report
FORMF	Formation flag
TEMP	Temperature used for drillstem test calculation
TEMPF	Temperature flag
RDSINGB	Radius of investigation from flow phase Radius of investigation from shut-in phase
FLVISCB	Fluid viscosity
FLVISF	Viscosity flag
FLDENS	Fluid density
FLDENF	Fluid density flag
GASZFCB	Supercompressibility factor of gas (dimensionless) used in parameter value determination
GASZFF	Gas Z factor flag
TRANSV	Transmissivity from flow phase Transmissivity from shut-in phase
HYDCON	Hydraulic conductivity from flow phase Hydraulic conductivity from shut-in phase
STORAT	Storativity from flow phase Storativity from shut-in phase
PERMEA	Permeability from flow phase Permeability from shut-in phase
RECELE	Recorder elevation (m)
COMPOR	(Porosity . compressibility) product
HNRSLP	Horner slope
HNRPRS	Extrapolated pressures
GRFLAG	Flag for which type of graph was used for interpretation 1 Liquid 2 Constant rate gas 3 Variable rate gas
GROLTY	Quality of graph

```
   character*16    FORMOB
   integer*2       GRFLAG, BSTTS, IQLTY, FORMF, TEMPF, FLVISF,
*                  FLDENF, GASZFF, GRQLTY
   integer*4       R11ID
   real*4          DINTC(2), POROGB, CTIGB, GASZFCB, HNRSLP,
*                  HNRPRS, TEMP, RDSINGB(2), FLVISCB, FLDENS,
*                  TRANSV(2), HYDCON(2), STORAT(2), PERMEA(2),
*                  RECELE, COMPOR
   common /BDSTB1/ FORMOB, GRFLAG, BSTTS, IQLTY, FORMF, TEMPF,
*                  FLVISF, FLDENF, GASZFF, GROLTY, R11ID, DINTC,
*                  POROGB, CTIGB, GASZFCB, HNRSLP, HNRPRS, TEMP,
*                  RDSINGB, FLVISCR, FLDENS, TRANSV, HYDCON,
*                  STORAT, PERMEA, RECELE, COMPOR
```

```
     open(unit=LUN, file=FILENM(11), status='old',
   * organization='indexed', access='keyed',
   * recordtype='fixed', form='unformatted', recl=40,
   * key=(1:4:integer), iostat=IOS, err=nm, readonly)

     read(LUN, key=R11ID, err=nm, iostat=IOS) IFCID,
   * BSTTS, (DINTC(j),j=1,2), POROGB, CTIGB, IQLTY, FORMOB, FORMF,
   * TEMP, TEMPF, (RDSINGB(j),j=1,2), FLVISCB, FLVISF, FLDENS,
   * FLDENF, GASZFCB, GASZFF, (TRANSV(j), HYDCON(j), STORAT(j),
   * PERMEA(j),j=1,2), RECELE, COMPOR, HNRSLP, HNRPRS, GRFLAG,
   * GRQLTY
```

12) Type BCHEM - Deep Well Chemistry Culled Data Record

The type BCHEM record contains the results of culling of data contained in the 101CM record. The purpose of the cull is to discard those analyses which do not contain the elements required or show obvious signs of error. The BCHEM record contains the following elements:

R12ID	Record ID identical to R10ID of 101CM for current analysis
BSTAT	Chemistry status
METHB	A 16 character code indicating method of production where the first character, a numeric, indicates 1 DST 2 FWT 3 CRT 4 PUMPED 5 BAILED 6 OTHER and characters 2 to 16 are a cross-reference which will depend on the method of production if from drillstem test encode of DSTID if from OTHER, explanation of the method of production
WHPROB	Where was fluid produced
SOD	Sodium (calculated) (mg/L)
CAL	Calcium (mg/L)
MAG	Magnesium (mg/L)
CLR	Chloride (mg/L)
BROM	Bromide (mg/L)
IODN	Iodide (mg/L)
HCO3	Bicarbonate (mg/L)
CO3	Carbonate (mg/L)
SO4	Sulphate (mg/L)
CATDS	Calculated Total Dissolved Solids (mg/L)
EVTDS	Evaporated(110 C) Total Dissolved Solids (mg/L)
ITDSB	Total Dissolved Solids after iginition (mg/L)

DENSB	Density
PHB	pH
RESB	Resistivity (ohm m)
RIB	Refractive index

```
   character*16    METHB, WHPROB
   integer*2       BSTAT
   integer*4       R12ID
   real*4          DENSB, PHB, RESB, RIB, ITDSB, SOD, CAL, MAG,
*                  CLR, BROM, IODN, HCO3, CO3, SO4, CATDS, EVTDS
   common /BBCHEM/ METHB, WHPROB, BSTAT, R12ID, DENSB, PHB, RESB,
*                  RIB, ITDSB, SOD, CAL, MAG, CLR, BROM, IODN,
*                  HCO3, CO3, SO4, CATDS, EVTDS

   open(access='keyed', form='unformatted',
*  file=FILENM(12), iostat=IOS, key=(1:4:integer),
*  organization='indexed', recl=30, recordtype='fixed',
*  status='old', unit=LUN, err=nm, readonly)

   read(LUN, key=R12ID, err=nm, iostat=IOS) IFCID,
*  BSTAT, METHB, WHPROB, SOD, CAL, MAG, CLR, BROM, IODN, HCO3,
*  CO3, SO4, CATDS, EVTDS, ITDSB, DENSB, PHB, RESB, RIB
```

13) Type 10200 - Shallow Well Header Record

The type 10200 record contains primarily those elements of the CDF well description which were considered to be of interest to this study and similiar projects. This record will not occur in the case of data points referring to wells whose description was extracted from the ERCB Well Date File or data points refering to surface features. The 10200 record contains the following elements:

RWWID	Location/id
WELLT	Well type (Dug, bored, drilled, etc)
ACMPNO	NTS mapsheet number
ACNAME	Owners name
ADATED	Date drilled (YYMMDD)
ACDRLR	Drillers name
ATD	Total depth of well (m)
ASL	Static level (m)
NOPNT	Number of open intervals
	--- NOPNT times ---
AOPNIT	Open interval type (completion types: screen,slots etc,)
AOPITP	Open interval top (m)
AOPIBT	Open interval bottom (m)

III	unassigned

14) Type 10201 - Surface Feature Header Record

The type 10201 record contains primarily those elements of the CDF spring, lake, river, etc., the descriptions of which were considered to be of interest to this study and similiar projects. This record will not occur in the case of data points to deep wells. Record 10201 contains the following elements:

RSWID	Location/id
PTYPE	Feature type (spring,seep,river, etc)
BCMPNO	NTS mapsheet number
BCNAME	Owners name
ADISCR	Description
JJJ	Unassigned

15) Type CHEMH - Shallow and Surface Chemistry Header Record

The type CHEMH record contains a list of pointers to chemical analysis records pertinent to water from shallow wells or surface features. The CHEMH record contains the following elements:

RCAID	Location/id
NANAL	Number of analyses (max 32)
	------ NANAL times ----
SMPID	RECID for analysis
TPS	Top of sampled interval (m)
BTS	Bottom of sampled interval (m)
	------------------------

16) Type CHEMD - Shallow and Surface Chemistry Data Record

The type CHEMD record contains the data relevant to a single analyzed sample. These records are the result of manual entry of data from the CDF water analysis files. As the software used for entry does validity checking, the data in these records are relatively clean. The CHEMD record contains the following elements:

CANID	Record ID
ACIND	Sampler's ID for sample
ACSMPLR	Name of sampler
ATOPI	Top of sampled interval (m)
ABOTI	Bottom of sampled interval (m)
ACLABID	Laboratory ID for sample
ADATES	Date sampled Date submitted Date major components completed Date minor components completed
ATMP	Field temperature of sample (°C)

APHF	Field pH of sample
ACSFCND	Char associated with ACONDF
ACONDF	Field conductivity
ATDS	Total dissolved solids
APHL	Laboratory pH
ACSLCND	Char assoc with ACONDL
ACONDL	Laboratory conductivity
AISCNT	Number of ions stored (13-74)
	--- AISCNT times ---
CMPAR	Parameter measured (index to list)
CHPAR	Associated character (<,>)
UNPAR	Units used (m=mg/L, p=ppm, ' ')
VLPAR	Value of parameter
	-------------------

17) Type LITHO - Abbreviated Lithology Record

The type LITHO record contains a short lithological description of strata penetrated by a well. These records are the result of manual entry of data from the CDF central data file. The LITHO record contains the following elements:

LITHID	Record ID
NHORZ	Number of strata (max 56)
	--- NHORZ times ---
FTPI	Top of interval
FBTI	Bottom of interval
LLTC	Lithology code
LFMC	Formation code (0001 if n/a)

Shallow Well Completion types

SC	Screen
OH	Open hole
SL	Slotted casing

Lithology Codes

SD	sand
GR	gravel
SG	sand and gravel
TL	till
TSD	till and sand
CL	clay
SH	shale
SS	sandstone
SIS	siltstone
SSH	sandstone and shale
CO	coal

Formation Codes

0000	TOP OF HOLE (KB)
0001	NONE IDENTIFIED
0005	RECENT
0010	BASE OF DRIFT
0011	BEDROCK
0020	QUATERNARY
0100	EMPRESS FORMATION
0101	EMPRESS 1 FM
0102	EMPRESS 2 FM
0103	EMPRESS 3 FM
0110	BRONSON LAKE FM
0120	MURIEL LAKE FM
0130	BONNYVILLE FM
0140	ETHEL LAKE FM
0150	MARIE LAKE FM
0160	SAND RIVER FM
0170	GRAND CENTER FM
0500	TERTIARY
0520	HAND HILLS CGL
0540	WINTERING HILLS CGL
0560	CRAWFORD PLATEAU CGL
0580	CYPRESS HILLS FM
0600	SWIFT CURRENT CK BEDS
0620	PORCUPINE HILLS FM
0640	PASKAPOO FM
0660	RAVENSCRAG FM
0680	WILLOW CREEK FM
0990	MESOZOIC SYSTEM
1000	CRETACEOUS
1020	UPPER CRETACEOUS
1040	FRENCHMAN FM
1050	SCOLLARD FM
1060	EDMONTON FM
1080	EDMONTON COAL MKR
1100	ST. MARY RIVER FM
1120	WAPITI GRP
1180	KNEEHILLS TUFF
1185	BATTLE FM
1190	WHITEMUD FM
1195	EASTEND FM
1200	HORSESHOE CANYON FM
1220	BLOOD RESERVE MBR
1240	BEARPAW FM
1260	BELLY RIVER GRP
1261	BELLY RIVER - CARDIUM
1262	BELLY RIVER & MILK RIVER
1263	BELLY RIVER GRP
1280	BRAZEAU FM

1300	OLDMAN FM
1305	OLDMAN TONGUE
1320	FOREMOST FM
1325	RIBSTONE CREEK TONGUE
1340	BASAL BELLY RIVER
1360	VICTORIA TONGUE
1361	VICTORIA SS
1370	BROSSEAU TONGUE
1380	SOLOMON MBR
1390	VERDIGRIS SS
1400	LEA PARK FM
1420	PAKOWKI FM
1440	ALBERTA GRP
1460	SMOKY RIVER GRP
1480	WAPIABI FM
1500	LABICHE FM
1520	PUSKWASKAU FM
1540	CHINOOK MBR
1550	CHUNGO
1560	HIGHWOOD SS
1580	MILK RIVER FM
1581	MILK RIVER & MED HAT
1585	UPPER MILK RIVER
1590	LOWER MILK RIVER
1600	COLORADO GRP
1601	UPPER COLORADO
1620	FIRST WHITE SPECKLED SH
1640	MEDICINE HAT SD
1641	UPPER MEDICINE HAT
1642	MED HAT SUB ZONE
1660	BADHEART FM
1680	MUSKIKI FM
1700	CARDIUM FM
1720	UPPER CARDIUM
1740	CARDIUM CGL
1750	MAIN CARDIUM SAND
1751	A CARDIUM SAND
1753	C CARDIUM SAND
1760	CARDIUM SD
1761	CARDIUM & VIKING
1780	LOWER CARDIUM
1800	BLACKSTONE FM
1820	KASKAPAU FM
1840	JUMPING POUND MBR SS
1860	SECOND WHITE SPECKLED SH
1861	2WS POOL NO. 1
1880	POUCE COUPE MBR
1900	DOE CREEK MBR
1920	DUNVEGAN FM
1940	FORT ST JOHN CRP

1960	SHAFTESBURY FM
1980	CROWSNEST VOL
2000	FISH SCALE ZONE
2020	FISH SCALE SD
2040	BARONS SD
2060	BASE FISH SCALES ZONE
2080	GRIT BEDS
2100	LOWER CRETACEOUS
2110	LOWER COLORADO SAND
2120	BOW ISLAND FM
2121	BOW ISLAND-COLORADO SH
2130	BOW ISLAND SD
2131	FIRST BOW ISLAND SS
2132	SECOND BOW ISLAND SS
2133	BOW ISLAND POOL NO. 1
2140	VIKING FM
2141	VIKING & COLONY
2150	VIKING SS (ARC)
2160	UPPER VIKING
2161	UPPER & LOWER VIKING
2180	VIKING SANDSTONE
2181	VIKING & LOWER MANNVILLE
2182	VIKING & UPPER MANNVILLE
2183	VIKING & BASAL COLORADO
2184	VIKING & MANNVILLE
2185	VIKING & BASAL MANNVILLE
2186	UPPER + MIDDLE VIKING
2187	U+M+L VIK (VIK POOL 1)
2188	VIKING SS-DETRITAL
2189	U VIK, M VIK + U MANN
2190	U VIK, M VIK + V MANN
2191	U+M+L VIK (VIK POOL 2)
2192	VIKING POOL NO. 3
2193	VIKING POOL NO. 4
2194	VIKING POOL NO. 5
2195	VIKING - JOLI FOU
2196	VIKING POOL NO. 6
2197	VIKING POOL NO. 7
2198	VIKING POOL NO. 8
2199	VIKING POOL NO. 9
2200	PROVOST MBR
2201	VIKING POOL NO. 10
2202	VIKING POOL NO. 11
2203	VIKING POOL NO. 12
2210	MIDDLE VIKING
2220	HAMILTON LAKE MBR
2240	LOWER VIKING
2260	MOUNTAIN PARK FM
2280	PEACE RIVER FM
2281	PEACE RIV + NOT + GETH

2300	PADDY MBR
2301	PADDY+CADOTTE
2320	CADOTTE MBR
2340	PELICAN FM
2359	BELOW BS VIK TO BS MANN
2360	JOLI FOU FM
2365	JOLI FOU (ARC)
2380	HARMON
2400	CESSFORD SS
2420	BASAL COLORADO
2421	BASAL COLO + MANNVILLE
2422	BSL COLORADO + BLAIRMORE
2440	BLAIRMORE GRP
2460	UPPER BLAIRMORE
2478	MANNVILLE(ARC)
2480	MANNVILLE GRP
2481	MANNVILLE
2500	UPPER MANNVILLE FM
2501	U MANN + BSL MANN
2502	UPPER MANNVILLE & SPARKY
2503	U MANN & L MANN
2504	UPPER MANN & ELLERSLIE
2505	U MANN, SPARKY & COLONY
2506	UPPER MANN & BLAIRMORE
2520	O SULLIVAN MBF
2540	ST. EDOUARD MBR
2541	ST. EDOUARD POOL NO. 1
2542	ST. EDOUARD POOL NO. 2
2543	ST. EDOUARD POOL NO. 3
2560	COLONY
2561	COLONY POOL NO. 1
2580	UPPER COLONY
2581	SUB U COLONY CRETACEOUS
2600	LOWER COLONY
2601	SUB-COLONY GRAND RAPIDS
2602	LOWER COLONY-DINA
2603	L COLONY TO MCMURRAY
2604	SUB COLONY CRETACEOUS
2605	BASE U CLY TO MCMURRAY
2606	L COLONY TO B OF MANN
2607	BASE OF L COLONY TO MCM
2620	GRAND RAPIDS FM
2621	UPPER GRAND RAPIDS
2622	GRAND RAPIDS-CLEARWATER
2630	FORT AUGUSTUS
2640	SPIRIT RIVER FM
2660	NOTIKEWIN MBR
2661	NOTIKEWIN-GETHING
2680	MCLAREN MBR
2700	WASECA MBR

2720	FALHER A SAND
2721	FALHER B SAND
2722	FALHER C SAND
2723	FALHER D SAND
2728	FALHER TIGHT SANDSTONE
2740	BORRADAILE MBR
2750	LOWER GRAND RAPIDS
2751	L GRD RAP+CLWTR+MCM
2760	SPARKY SD
2761	SPARKY-GEN PETE
2762	SPARKY SD
2780	WAINWRIGHT SD
2781	WAINWRIGHT & SPARKY
2791	MIDDLE MANNVILLE
2796	CLEARWATER (ARC)
2798	BASE CLEARWATER (ARC)
2800	CLEARWATER FM
2801	CLEARWATER-MCMURRAY
2810	CLEARWATER SD
2820	TOVEL MBR
2840	VERMILION SD
2860	GENERAL PETROLEUM SD
2880	REX SD
2900	WILRICH MBR
2920	ISLAY MBR
2940	LLOYDMINSTER SD
2950	CLEARWATER (COLD LAKE)
2960	LUSCAR FM
2980	HOME SD
3000	GLAUCONITIC SS
3001	GLAUCONITIC-MCMURRAY
3002	GLAUCONITIC & ELLERSLIE
3003	GLAUC & SHUNDA
3004	GLAUCONITIC&LOWER MANN
3005	GLAUC & OSTRACOD
3006	GLAUCONITIC POOL NO. 1
3007	GLAUCONITIC POOL NO. 2
3008	GLAUCONITIC POOL NO. 3
3009	GLAUCONITIC SS
3010	GLAUCONITIC POOL NO. 4
3011	GLAUCONITIC POOL NO. 5
3012	GLAUCONITIC & BSL QUARTZ
3020	CUMMINGS MBR
3021	CUMMINGS MBR
3022	CUMMINGS MBR
3040	BLUESKY FM
3041	BLUESKY POOL NO. 1
3049	BLUESKY-SHUND
3050	BLUESKY-GETHING
3051	BLUESKY-GETHING+BANFF

3052	BLUESKY + BULLHEAD
3053	BLUESKY-BULLHEAD-BELLOY
3054	BLUESKY-LOWER MANNVILLE
3055	BLUESKY-DETRITAL
3056	BLUESKY-BULLHEAD-SHUNDA
3057	BLUESKY-GETHING-BELLOY
3058	BLSKY-BLHD-BELLOY-DBLT
3059	BLUESKY-GETHING-WABAMUN
3060	WABISKAW MBR
3061	WABISKAW+WABAMUN
3062	WABISKAW-MCMURRAY
3080	LOWER BLAIRMORE
3081	L SANDSTONE OF L BLAIR
3100	LOWER MANNVILLE FM
3105	LOWER MANNVILLE & ELKTON
3106	LOWER MANNVILLE & JURASSIC
3107	L MANNVILLE & ROCK CREEK
3110	LOWER MANN-PEKISKO
3111	LOWER MANN & CAMROSE
3120	OSTRACOD ZONE
3140	CALCAREOUS MBR
3160	OSTRACOD SS
3170	BANTRY SHALE
3180	BASAL BLAIRMORE
3190	BASAL CRETACEOUS
3200	BASAL MANNVILLE
3201	BASAL MANN-JUR
3202	BASAL MANN-OST
3203	B MANN, JUR-RUN + U MANN
3204	B OF MANN TO B OF WOODS
3205	BASE OF MANNVILLE
3220	DINA MBR
3240	BULLHEAD GRP
3260	GETHING FM
3261	GETHING + CADOMIN
3270	BASAL GETHING
3279	TO TOP OF MCMURRAY
3280	MCMURRAY FM
3281	MCMURRAY & OSTRACOD
3282	MCMURRAY-GROSMONT
3283	MCMURRAY & WABAMUN
3284	MCMURRAY POOL NO. 1
3300	MOULTON SD
3320	SUNBURST SD
3330	SUNBURST-SWIFT
3340	BASAL QUARTZ
3341	QUARTZ SANDSTONE
3342	BASAL QUARTZ SS-DETRITAL
3350	LOWER MANNVILLE SD
3360	ELLERSLIE MBR

3380	CAMERON SS
3400	POPLAR SD
3420	DALHOUSIE CGL
3440	CUTBANK SS
3441	CUTBANK-RUNDLE
3460	TABER
3480	CADOMIN CGL
3481	CADOMIN & JURASSIC
3482	CADOMIN POOL NO. 1
3500	DETRITAL =CRET=
3501	DETRITAL-WABAMUN
3502	DETRITAL-MISSISSIPPIAN
4000	JURASSIC
4010	JURASSIC-TRIASSIC
4020	KOOTENAY FM
4040	MUTZ MBR
4060	HILLCREST MBR
4080	NIKANASSIN FM
4100	ADANAC MBR
4120	MOOSE MOUNTAIN MBR
4140	FERNIE GRP
4160	PASSAGE BEDS
4180	ELLIS GRP
4200	SWIFT FM
4210	UPPER VANGUARD
4220	GREEN BEDS
4240	RIERDON FM
4250	LOWER VANGUARD
4260	GREY BEDS
4280	SAWTOOTH FM
4300	CONRAD MBR FM
4320	ROCK CREEK MBR
4340	SHAUNAVON FM
4350	GRAVELBOURG FM
4360	BELEMNITE ZONE
4380	BROWN SD
4400	POKER CHIP SH
4420	JURASSIC SH
4440	NORDEGG FM
4441	NORDEGG+PEKISKO
4442	NORDEGG DETRITAL
4460	JURASSIC SS
4461	JURASSIC-RUNDLE
4480	CHANNEL FILL SD
4500	JURASSIC DETRITAL
4600	PALEOZOIC(ARC)
5000	TRIASSIC
5001	TRIASSIC-SCHOOLER CREEK
5002	TRIASSIC-RUNDLE
5020	SCHOOLER CREEK GRP

5040	PARDONET FM
5060	BALDONNEL FM
5080	CHARLIE LAKE FM
5100	BOUNDARY MBR
5120	SPRAY RIVER FM
5140	WHITEHORSE MBR
5160	HALFWAY FM
5180	DAIBER GRP
5200	DOIG FM
5220	TOAD FM
5230	TOAD-GRAYLING
5240	MONTNEY FM
5260	SULFUR MTN MBR
5280	GRAYLING FM
5500	PERMIAN
5520	ROCKY MTN GRP
5540	ISHBELL GRP
5560	BELLOY FM
5600	PERMO-PENN
5700	PENNSYLVANIAN
5720	KANNANASKIS FM
5760	STORM CREEK FM
5780	NORQUAY FM
5800	TUNNEL MTN FM
6000	MISSISSIPPIAN
6001	MISSISSIPPIAN LEACHED
6002	MISSISSIPPIAN CHERT
6020	ETHERINGTON MBR
6040	STODDART FM
6050	TAYLOR FLAT
6060	KISKATINAW FM
6061	KISKATINAW-GOLATA
6080	GOLATA FM
6081	GOLATA + KISKATINAW
6100	RUNDLE GRP
6110	RUNDLE-WABAMUN
6111	RUNDLE + PALLISER
6120	DEBOLT FM
6140	MOUNT HEAD FM
6160	CARNARVON MBR
6200	LOOMIS MBR
6220	SALTER MBR
6240	BARIL MBR
6260	WILEMAN FM
6280	LIVINGSTONE FM
6299	SURF TO TUNER VALLEY TOP
6300	TURNER VALLEY FM
6305	TURNER VALLEY-SHUNDA
6320	UPPER POROUS
6340	MIDDLE DENSE

6360	LOWER POROUS
6380	ELKTON MBR
6390	ELKTON-SHUNDA
6400	SHUNDA FM
6401	SHUNDA-PEKISKO
6420	PEKISKO FM
6421	PEKISKO + BANFF
6422	PEKISKO + U BANFF
6423	UPPER PEKISKO
6440	BANFF FM
6441	BANFF POOL NO. 1
6460	BAKKEN FM
6480	EXSHAW FM
6481	EXSHAW + WABAMUN
6499	REWORKED DEVONIAN
6500	DEVONIAN
6520	UPPER DEVONIAN
6540	PALLISER FM
6560	COSTIGAN MBR
6580	WABAMUN GRP
6585	WABAMUN-WINTERBURN
6590	WABAMUN-GRAMINIA
6600	BIG VALLEY FM
6620	THREE FORKS FM
6640	MORRO MBR
6660	STETTLER FM
6680	CROSSFIELD MBR
6700	WINTERBURN GRP
6720	ALEXO FM
6730	SASSENACH MBR
6740	TROUT RIVER FM
6760	CROWFOOT FM
6780	GRAMINIA FM
6800	BLUERIDGE MBR
6820	KAKISA FM
6840	RED KNIFE FM
6860	CALMAR FM
6880	FAIRHOLM GRP
6900	SOUTHESK FM
6920	JEFFERSON FM
6940	ARCS MBR
6950	ARCS-GROTTO
6960	NISKU FM
6961	NISKU & UPPER MANVILLE
6962	NISKU-LEDUC
6963	NISKU-MCMURRAY
6964	NISKU-U IRETON-GROSMONT
6965	NISKU-IRETON-LEDUC
6966	NISKU-CAMROSE
6967	NISKU-UPPER IRETON

6980	MOUNT HAWK FM
7000	UTANH FM
7020	JEAN MARIE FM
7040	WOODBEND GRP
7060	GROTTO MBR
7080	CAMROSE TONGUE =DOL=
7081	CAMROSE
7100	IRETON FM
7101	U IRE-GROSMONT-L IRETON
7102	IRETON-GROSMONT-L IRETON
7103	UPPER IRETON
7110	TOP IRETON(ARC)
7120	FORT SIMPSON FM
7125	IRETON SHALE
7130	TATHLINA FM
7140	HONDO FM
7160	GROSMONT FM
7161	GROSMONT-IRETON
7165	TWIN FALLS FM
7170	LOWER IRETON
7180	PEECHEE MBR
7200	LEDUC FM
7201	LEDUC-COOKING LAKE
7202	WOODBEND REEF-GRANITE WASH
7220	HAY RIVER FM
7240	HAY RIVER LS
7260	CAIRN FM
7261	UPPER CAIRN
7280	DUVERNAY FM
7300	BASAL REEF
7320	COOKING LAKE FM
7321	COOKING LK + BEAVERHILL LK
7325	COOKING LAKE (ARC)
7330	LOWER CAIRN
7340	PERDRIX FM
7360	FRAGMENTAL LS
7380	FLUME FM
7400	MAJEAU LAKE FM
7420	BASAL COOKING LAKE FM
7430	MUSKWA FM
7440	BEAVERHILL LAKE FM
7445	BEAVERHILL LAKE (ARC)
7450	WATERWAYS FM
7460	MILDRED MBR
7480	MOBERLY MBR
7500	CHRISTINA MBR
7520	CALUMET MBR
7540	FIREBAG MBR
7560	SWAN HILLS MBR
7580	SLAVE POINT FM

7581	SLAVE PT & GRANITE WASH
7582	SLAVE PT & SULP PT
7600	LIVOCK FM
7620	FORT VERMILION
7640	GHOST RIVER FM
7660	BASAL DEVONIAN UNIT
7680	MIDDLE DEVONIAN UNIT
7690	YAHATINDA
7700	ELK POINT GRP
7705	ELK PT & WTMT (ARC)
7710	FIRST RED BEDS
7720	WATT MTN FM
7730	DAWSON BAY
7780	GILWOOD MBR
7800	MANNING SD
7810	SULPHUR POINT
7811	SULPH PT, MUSK & KEG RIVERS
7813	SULP PT & KEG RIVER
7815	PRESQUILE FM
7820	MUSKEG FM
7821	MUSKEG & KEG RIVER
7825	HORN RIVER FM
7830	PINE POINT FM
7850	ZAMA MEMBER
7860	PRARIE EVAPORITES
7870	FIRST SALT
7875	FIRST SALT (ARC)
7880	KEG RIVER FM
7881	KEG RIVER FM
7882	KEG RIVER FM
7883	KEG RIVER FM
7885	RAINBOW MBR
7890	KEG RIVER SS
7900	METHY FM
7920	WINNEPEGOSIS FM
7930	LOWER KEG RIVER
7940	CHINCHAGA FM
7960	CONTACT RAPIDS FM
7970	ASSINEAU SAND
7980	RED BEDS
8000	COLD LAKE FM
8010	SECOND SALT
8020	ERNISTINA LAKE FM
8040	LOTSBERG FM
8045	THIRD SALT
8055	FOURTH SALT
8060	BASAL RED BEDS
8200	SILURIAN
8500	ORDOVICIAN
8520	UPPER ORDOVICIAN

8600	MIDDLE ORDOVICIAN
8610	RED RIVER FM
8700	LOWER ORDOVICIAN
9000	CAMBRIAN
9020	UPPER CAMBRIAN
9030	LYNX GROUP
9040	FINNEGAN FM
9100	MONS FM
9140	SULLIVAN FM
9150	WATERFOWL FM
9160	DEADWOOD FM
9180	ACTOMYS FM
9200	MIDDLE CAMBRIAN
9205	EARLIE FM
9210	PIKA FM
9220	ELDON FM
9260	ELDON SHALE
9280	ELDON CARBONATE
9300	STEPHEN FM
9400	CATHEDRAL FM
9420	CATHEDRAL CARBONATE
9440	ALBERTELLA ZONE
9460	MOUNT WHYTE FM
9480	BASAL SANDSTONE UNIT
9500	LOWER CAMBRIAN
9550	GOG GROUP
9760	GRANITE WASH
9800	PRECAMBRIAN
9805	FRESH WATER WELL
9990	FAULT
9998	UNDEFINED
9999	TOTAL DEPTH

Water Well Driller Abbreviations

ACW	A & C W Drilling
ARC	Alberta Research Council
ENV	Alberta Environment
ALR	Al Rite
ART	Artesia
BWS	Banks Drilling
WBE	Bennent W. Drilling
BID	Big Iron Drilling
BQU	Big Quill
RBD	Brosseau Ray Drilling
CBY	Cabay Drilling
CAR	Caribou Drilling
LLC	Chorney Drilling
CME	Clark Measures

COR	Coralta
EPT	Elk Point
ERD	E & R D Drilling
FRE	Frederickson Drilling
GLD	Globe Drilling
GCW	Green Acres Drilling
HIR	Hi-Rate Drilling
IND	Independent Drilling
KCD	K. C. Drilling
KEL	Kellington Drilling
LLD	Lakeland Drilling
LBC	Lubcap Industries
MAN	Mannville Drilling
MAR	Mars Wayne Drilling
MCA	McAllister Drilling
MCI	McIsaac Drilling
MAD	McAuley Drilling
MEL	Mels Drilling
MOR	Morton Drilling
PKE	Parkey's Enterprises
LB	Paws and Byrt Drilling
PET	Peters WW Drilling
PTS	Peterson Drilling
QLT	Quality WW Drilling
RBD	Rainbow Drilling
ROB	Robert D. Drilling
SAT	Satellite Drilling
SBS	Stan Byrt and Sons
SHK	Shank Drilling
STP	St Paul Drilling
STH	Steenhowser Enterprises
TEK	Tee Kay Drilling
TIZ	Tizzard Boring
UHR	Uhryn Boring
UNK	Unknown

List of recognized chemical, physical and isotopic components:

1 CA - calcium
2 CAM - calcium and magnesium determined as calcium
3 CAA - calcium acidified sample
4 MG - magnesium
5 MGA - magnesium acidified sample
6 NA - sodium
7 K - potassium
8 NAK - sodium and potassium determined as sodium
9 CCL - carbonate
10 BCL - bicarbonate
11 SO - sulphate

12 CL - chloride
13 NO - nitrate
14 SI - silica
15 FL - fluoride
16 H1 - hardness
17 A1 - alkalinity
18 N1 - nitrite nitrogen
19 N2 - nitrate nitrogen
20 N3 - nitrite+nitrate nitrogen
21 AL - aluminum
22 AS - arsenic
23 BA - barium
24 BE - beryllium
25 B - boron
26 BR - bromine
27 CD - cadmium
28 CE - cerium
29 CS - cesium
30 CR - chromium
31 CO - cobalt
32 CU - copper
33 GA - gallium
34 GE - germanium
35 AU - gold
36 IN - indium
37 OH - hydroxide
38 I - iodine
39 FE - iron
40 LA - lanthanum
41 PB - lead
42 LI - lithium
43 MN - manganese
44 HG - mercury
45 MO - molybdenum
46 NI - nickel
47 P - phosphorus
48 RA - radium
49 RN - radon
50 RU - rubidium
51 SC - scandium
52 SE - selenium
53 AG - silver
54 TH - thorium
55 SN - tin
56 TI - titanium
57 U - uranium
58 V - vanadium
59 Y - yttrium
60 ZN - zinc
61 ZR - zirconium

62 FA - field alkalinity
63 BCF - field bicarbonate
64 CCF - field carbonate
65 HY - field hydroxide
66 DO - field dissolved oxygen
67 EH - field oxydation potential
68 PC - field P CO2
69 S - field sulphide
70 IC - carbon-14
71 ID - deuterium
72 IO - oxygen-18
73 IT - tritium
74 SR - strontium

CONSTRUCTION OF GWDB

Data Base Master Record

Because the entire data base is a collection of files, the first file constructed was the Data Base Master. This file simply contains a list of the names of files containing the data itself. For some record types these names may be followed by a count of the number of records contained in the data file. This count is not critical to any application but can be used to accelerate the process of index creation for the record types where the index is an arbitrary integer-sequencing value as in the cases of the drillstem test, core, and chemistry data records.

The Data Base Master file was constructed using a text editor to enter file names. Multiple files of this type can be constructed each containing references to any combination of files of the appropriate record types. This is useful when it is desirable to subset a larger data base or to construct a modified version without changing the original records. The routine PICKDERV is an example where a new set of stratigraphic picks is generated on the basis of an existing set. This new set is then referenced as the type 10107 record for a subset data base. The Data Base Master in such a case would otherwise be identical to the original with the exception of the difference in location of the type 10107 record.

Site Master Record (type 00000)

All records pertaining to individual data locations are ultimately related back to the Site Master Record, type 00000, therefore this record type was constructed before any other type with the exception of the Data Base Master.

Ad hoc programs were used to read this record type from the previous storage scheme, to construct a unique identifier, and to write the records into indexed form. As the previous storage scheme for this data varies from site to site, and from time to time, and because it is sometimes advantageous to change the logic used to read the data, several such programs were constructed.

Type 00000 records were derived primarily from data stored in the administrative records of ERCB WDS.

Location Record (type 00001)

Ad hoc programs were used to read data necessary for the type 00001 Location Record from the previous storage scheme, to construct a unique identifier, and to confirm and update the relevant type 00000 record and write the records into indexed form.

In the case of ERCB data, location information was stored in the administrative records, therefore type 00001 records were constructed by the same routines that constructed type 00000 records.

ERCB WDS Header Record (type 10103)

Ad hoc programs were used to read data necessary for the type 10103 Header Record from the previous storage scheme, to construct a unique identifier, to confirm and update the relevant type 00000 record, and to write the records into indexed form.

In the case of ERCB data, this information was stored in the administrative records, therefore type 10103 records were constructed by the same routines that constructed type 00000 and type 00001 records.

Stratigraphic Pick Record (type 10101)

Ad hoc programs were used to read data necessary for the type 10101 Header Record from the previous storage scheme, to construct a unique identifier, to confirm and update the relevant type 00000 record, and to write the records into indexed form.

This type of record contains pointers to a dictionary of stratigraphic names. The only verification performed on these pointers was a range check to confirm that the pointer values were in the range of 0-9999. Several routines were written to manipulate record type 10101:

PICKDERV	allows the construction of a new stratigraphic pick file from an existing one on the basis of culling criterion specified by the user. It allows mapping of multiple pick codes to single ones. It also allows the implementation of a new dictionary to be applied to such mapping.
PICKEDT	allows the user to interactively edit records by adding, deleting, or changing pick depths and codes. Use of this program on the primary data base is not encouraged. This routine also supports changing the value of the elevation datum.
PICKEXM	allows the user to interactively examine stratigraphic pick records on a record-by-record basis.
PICKZAP	allows the user to remove a list of pick records from the data base.
PICKPRP1	allows the user to access the culling procedure used in PICKDERV to produce a file of derivative picks in the format used by GEOPLTR and thus into the format used by SURFACE II.

DST Header Record (type 10107)

Ad hoc programs were used to read data necessary for the type 10107 Header Record from the previous storage scheme, to construct a unique identifier, to confirm and update the relevant type 00000 record, and to write the records into indexed form.

DST Initial Data Record (type DSTA1)

Because only a subset of the required data for the DSTA1 record was available in machine-readable form, these records were constructed in two primary steps.

As a first step, ad hoc programs were used to read data available in electronic form from the previous storage scheme, to construct a unique identifier, to confirm and update the relevant type 10107 record, and to write the records into indexed form. These programs also produced an initial or default value for all fields not present in the previous storage scheme.

The second step consisted of editing and supplementing the data entered in the first step with manual entry of data available only in hard copy form. The routine DSTNTR was constructed for that purpose. DSTNTR takes advantage of the indexed structure of GWDB and direct screen control to allow quick interactive access to, and editing of, the drillstem test records. Further, it includes a large number of validity checking procedures to reduce errors during manual data entry.

Core Header Record (type 10106)

Ad hoc programs were used to read data necessary for the type 10106 Header Record from the previous storage scheme, to construct a unique identifier, to confirm and update the relevant type 00000 record, and to write the records into indexed form.

Core Initial Data Record (type CORE1)

Ad hoc programs were used to read data available from the previous storage scheme, to construct a unique identifier, to confirm and update the relevant type 10106 record, and to write the records into indexed form. These programs also construct the linked structure used to store this data. As the source records for type 10106 and CORE1 records are in different machine-readable data bases, these programs also rationalize discrepancies and forge links between the two record types.

Deep Well Chemistry Header Record (type 101CH)

Because this data was available only in hard copy form these records were constructed as part of a manual entry procedure. The routine CHMNTR, as part of its function, creates a type 101CH record after confirming and updating the relevent type 00000 record. This occurs only if no previous type 101CH record has been created.

Deep Well Chemistry Initial Data Record (type 101CM)

The routine CHMNTR was constructed for the purpose of creating type 101CM records as well as entering and editing the chemistry data values. It takes advantage of the indexed structure of GWDB and direct screen control to allow quick interactive access to, and editing of, the chemistry records. Further, it includes some validity checking procedures to reduce errors during manual data entry. This routine also constructs the pointers to DSTA1 records if the chemistry is related to a specific drillstem test and pointers to 00000 type records if this chemistry is related to a number of different wells.

DST Interpreted Data Record (type DSTB1)

The routine DSTATOB was constructed for the purpose of creating type DSTB1 records on the basis of interactive interpretation of DSTA1 type records. This routine takes advantage of the indexed structure of GWDB and direct screen control to allow quick interactive access to, and calculations upon, DSTB1 records. DSTATOB utilizes a custom graphics package, GSP, to perform part of the interpretation in an interactive graphics mode. Two subroutines, DSTPLOT and DSTSHEET, were written to allow this interpretation to be performed using the more common CALCOMP support library for non-interactive graphics.

Deep Well Chemistry Culled Data Record (type BCHEM)

The routine NCHMCULL was written to create BCHEM records on the basis of culling performed on type 101CM records. This routine also updates the type 00000 record.

DATA PROCESSING

INTRODUCTION

The basic information pertinent to the hydrogeology of the Cold Lake Study Area is contained within the data base management system presented previously. This information is organized in two levels, depending on the amount of processing involved in obtaining it. The first level (A) contains only raw data, as obtained from various sources (for example, ERCB well data files; field or laboratory measurements). The second level (B) contains data which required a certain amount of processing, either automatic or manual, or both (for example, hydraulic heads and permeabilities from drillstem test reports). In both cases, the main characteristic of all the data in the data base is the fact that they represent point information, that is, any value of any parameter is associated with the corresponding coordinates which define the position of the measuring point in space. The system of coordinates used is the Dominion Land Survey (DLS) coordinates for the horizontal directions, and the ground elevation and depth for the vertical direction.

In order to present a conceptual or descriptive model of the hydrogeology of the study area it is necessary to synthesize the information at an even higher level, usually as maps, statistical characteristics and/or mathematical relationships. The synthesizing of the point data in more generalized form follows different processing paths for stratigraphic and flow data.

PROCESSING OF STRATIGRAPHIC DATA

The stratigraphic point data information was obtained from ERCB well data files and selected picks by ARC staff. In the data base this information is stored only in the first level. The stratigraphy is best represented in synthesized form by maps and cross-sections. This form of visual representation can be easily obtained from magnetic storage devices using computer graphics packages. The flowchart in figure 1-2 shows the manual and automatic processing of the stratigraphic information from point data to synthesized data stored on a magnetic device.

In the study area 3100 well records were entered in the ERCB well data file by the middle of 1983, and these were transferred to the first level of GWDB. The first step in the data processing is to select and sort the data by stratigraphic units, and to convert the depth at each location into elevation relative to the sea level datum.

The program PICKEDT (PICKs EDiT) produces a printout of the stratigraphic tops of all the wells in a rectangular area defined at input by its township and range limits.

The program TOPO (ground TOPOgraphy) lists in the magnetic file TOPS the location and the ground elevation of all the wells in a particular area defined at input. This information can be used later to produce a regular grid to describe the ground topography.

The program PICKPRP (PICKs PRePare) extracts from the data base information about point data defining stratigraphic tops. The criteria used for data extraction are the location of the well and the formation code. The well location is checked as to whether it is in the rectangular area defined at input. A logical filter retains only information about the desired formation(s). The output of this program is represented by records stored in the file PICKS on a magnetic device. Each record contains information about a single point in space, characterized by its DLS coordinates, its elevation in m (relative to mean sea level) and the ERCB code of the formation.

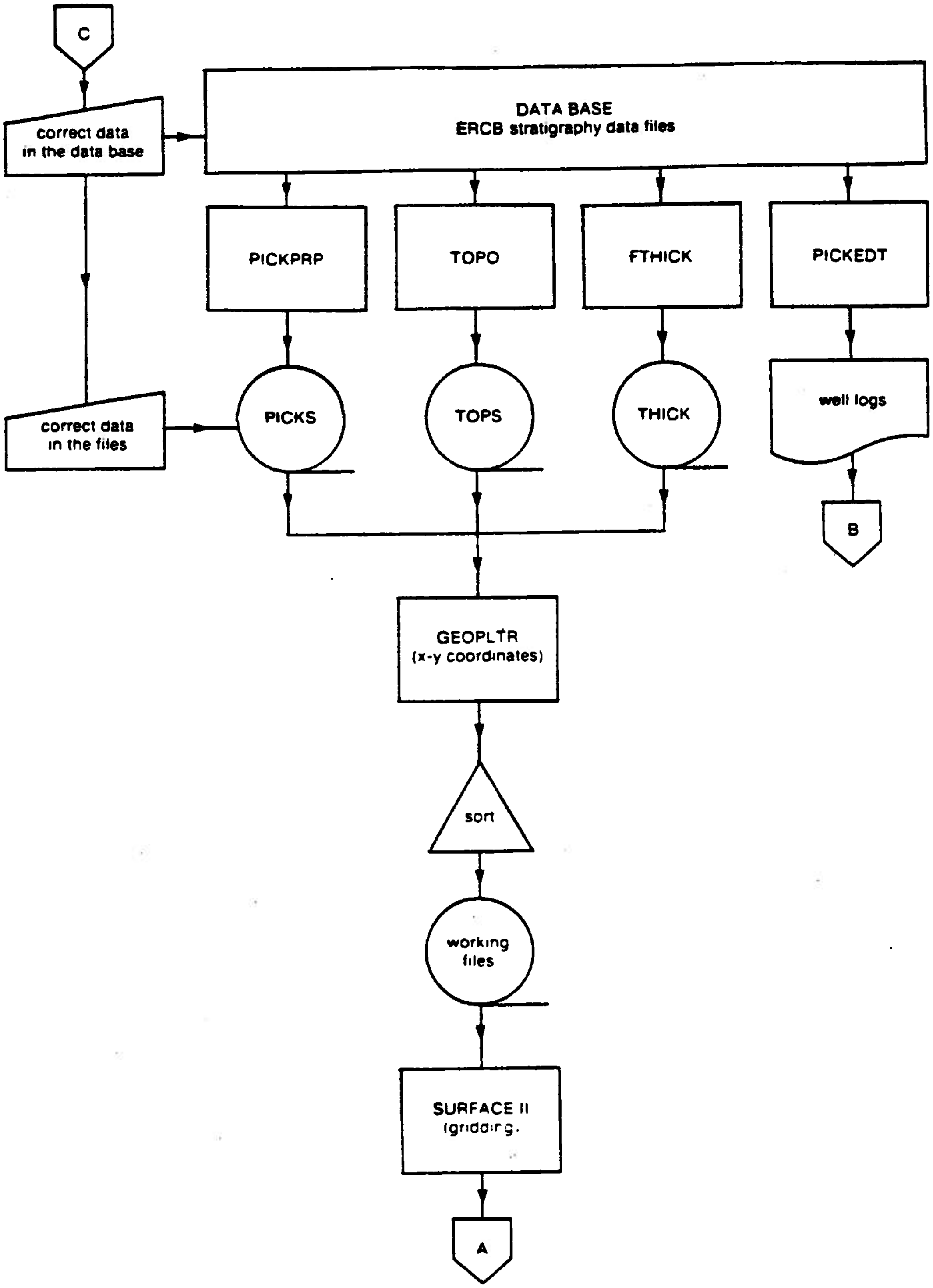

Figure 1-2 Flow chart for the processing of stratigraphic data from point data to synthesized information

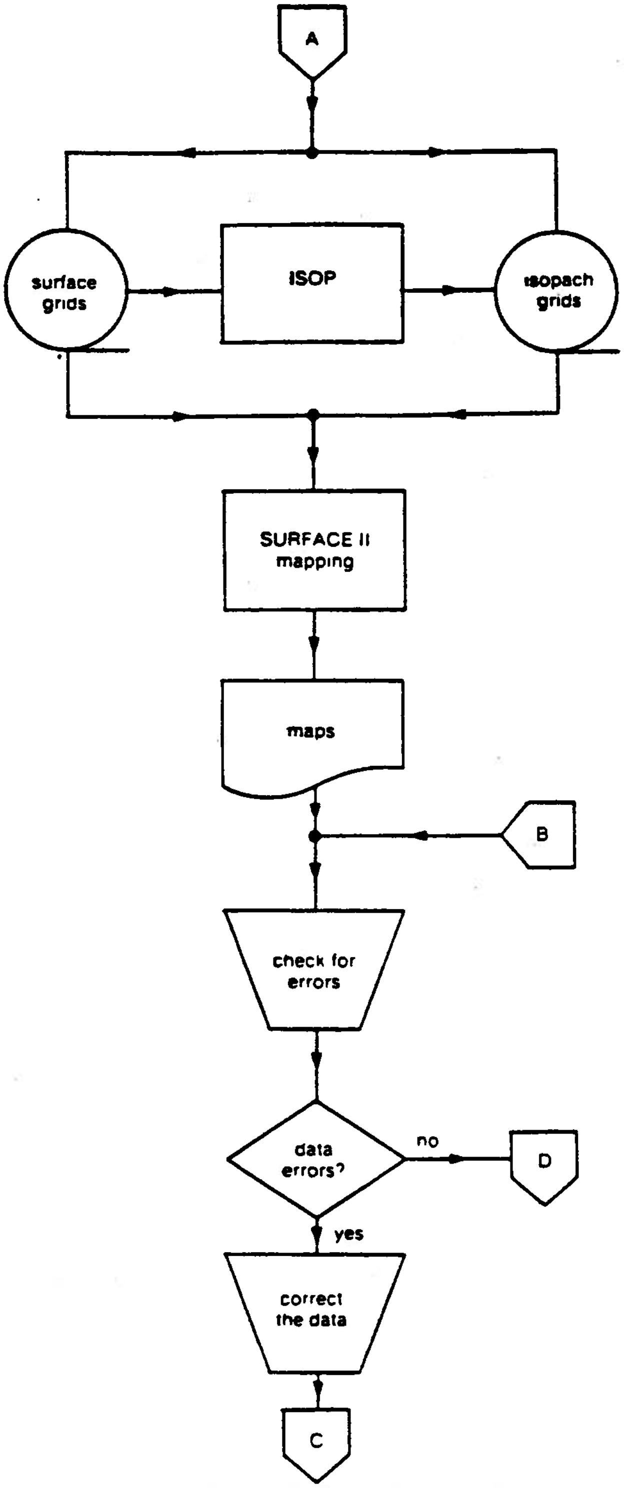

Figure 1-2 continued

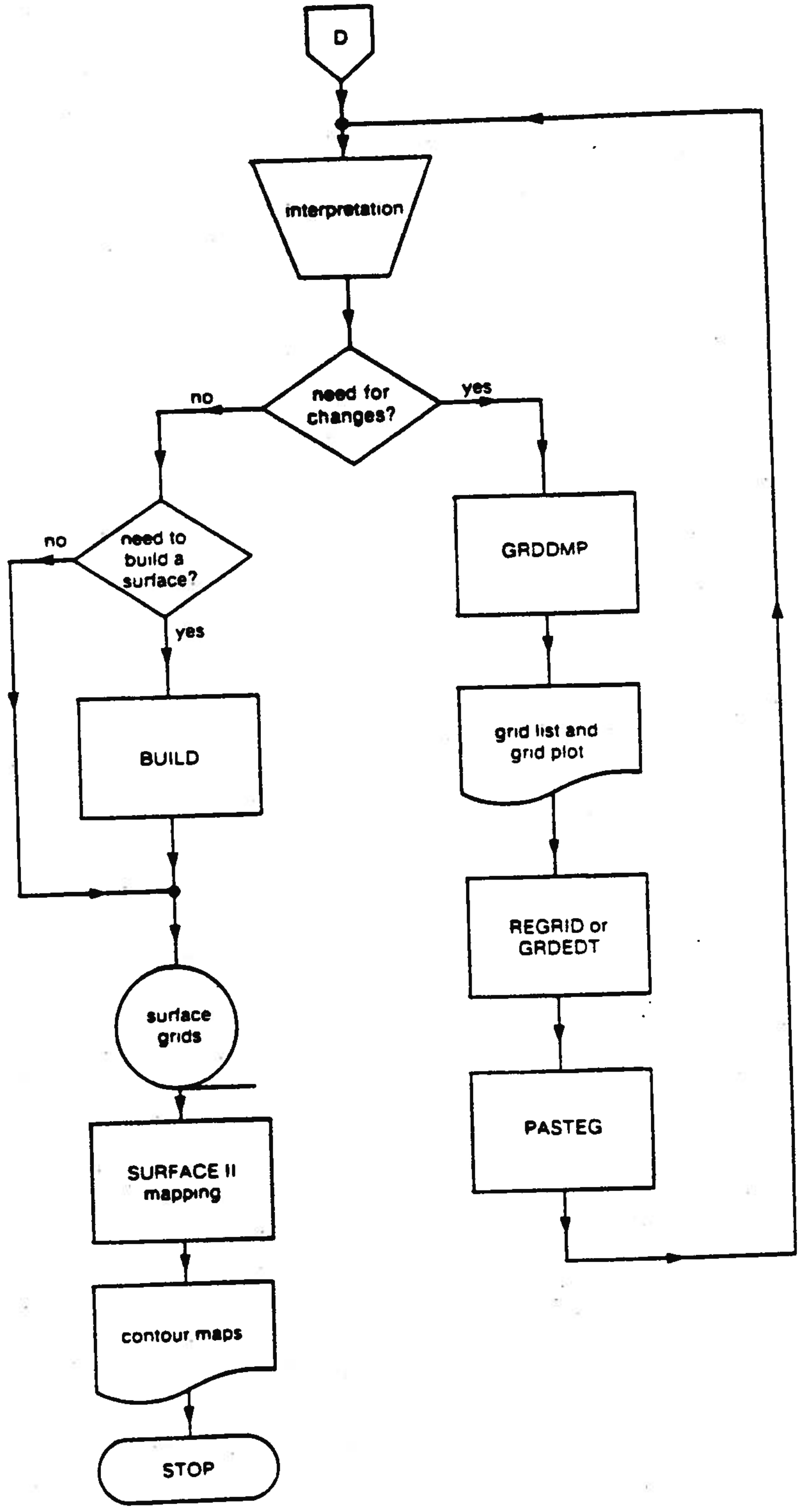

Figure 1-2 continued

The program FTHICK (Formation THICKness) performs basically the same function as PICKPRP, but retains only the wells where two required formations are both identified. The formations are indicated at input by their formation codes, and the thickness of the layer between the two tops, instead of elevations, is listed in the output magnetic file THICK.

Using the system utility software for sorting by locations, formations, or both, the files PICKS and THICK can be separated into derivative files. These derivative files contain the distributions of point data identifying or characterizing a particular stratigraphic unit.

The program GEOPLTR (GEOgraphic PLoTteR) is a complex piece of software for cartographic representation. One of the tasks performed by this program is to transform the DLS coordinates into cartesian paper coordinates at a scale defined at input. Running this task for the files TOPS, PICKS and THICK produces on output the same information per record as at input, plus the x-y coordinates of the point.

The irregular distribution of points which defines each top or thickness of a formation is transformed into a regular grid of values using the SURFACE II software package (Kansas Geological Survey). For this study a grid of 56 rows and 65 columns was used to cover the study area mapped at the 1:500 000 scale, with an average of four grid nodes per township.

Isopach grids are obtained directly from the thickness data in the file THICK, or by using the program ISOP (ISOPach) to subtract two stratigraphic surfaces expressed as grids.

The regular grid distribution of values for stratigraphic tops or isopachs is graphically represented as maps using a computer graphics software package, in this case SURFACE II. Having produced a set of contour maps, manual examination of these allows the detection of possible anomalies and errors in the original data. These possibly anomalous data can be checked by examination of the well logs and corrected in the data base and the files PICKS and THICK. The most common errors detected this way are data entry errors and mis-identified formations. Usually, there is need for a few passes through all this processing loop before the grids and maps represent the required degree of confidence.

The grids for stratigraphic surfaces and isopachs are produced automatically by the computer using interpolation and extrapolation techniques, and are based solely on the data distribution. As a result, a formation could be represented in areas where it is absent just by extrapolating the existing data, or would not appear in areas where it is present because there are no data available (as is commonly the case with the northeast corner of the Cold Lake Study Area). Therefore, following the first processing loop of the stratigraphic data, the grids have to be re-processed using different grid manipulation techniques, based on physical interpretation and knowledge of the geology and stratigraphy of the area.

For the Cold Lake Study Area the data distribution varies significantly between the different stratigraphic units. Out of 3100 wells drilled in the area, only 27 penetrate the top of the Middle Devonian Prairie Formation, which was chosen as the impervious base of the multi-layered hydrogeological system, and only eighteen reach the Precambrian basement. On the other hand, not all the stratigraphic units penetrated by a well are identified in the ERCB well data file. For example, there are 2200 wells reaching the PreCretaceous unconformity, but only seven hundred of them record the Clearwater Formation.

The strategy used to process such an unevenly distributed information base is similar to that described by Jones and Johnson (1983). Several stratigraphic units with a large number of data points were selected as control surfaces. These were the Base of Fish Scales Zone, effectively a time horizon with 2800 points; the top of the Lower Cretaceous Mannville Group with 1700 points, and the top of the Paleozoic, with 2200 points. With respect to the study area, the top of the Middle Devonian Prairie Formation was also used as a control surface, even though it is defined by only 27 points. Special attention had to be given to define the PreCretaceous unconformity, with its erosional and onlap-offlap features. First, the approximate boundaries of the different subcrop regions at the unconformity were defined by examining the well logs and records. For each subcrop region defined by these boundaries, the tops of the respective stratigraphic units were selected, resulting in a fairly homogeneous distribution of points.

Isopachs obtained by subtracting two top surface grids were used to define more precisely subcrop boundaries and onlap-offlap features. Areas of "negative" thickness indicate the absence of a stratigraphic unit and the zero contour line approximately represents the boundary. The boundaries of the subcrop edges of the Cooking Lake and Beaverhill Lake formations were defined this way, as well as the areas where the McMurray Formation is absent on the top of Paleozoic highs. The same isopachs were used to define the top of a formation in the truncation region itself. For example, the PreCretaceous unconformity is a much better defined surface (based on 2200 points) than the primary Beaverhill Lake Formation surface (based only on 270 points). This is due to the fact that the polynomials used to fit the surfaces are dependent on the density distribution of the data points. The primary surface of the top of the Beaverhill Lake Formation was subtracted from the surface of the PreCretaceous unconformity. If the negative values in the resulting isopach are blanked out, the new isopach will be blank where the unit is truncated. By adding this new isopach to the control surface (PreCretaceous unconformity in this case) the entire surface of the top of the truncated unit is rebuilt. The same procedure was used to define the tops of the Grosmont Formation and the Winterburn Group. A different procedure was used to define the boundaries and tops of thin depositional units with relatively few points (of the order of ten to one hundred) such as the Cretaceous Viking sandstone and

Clearwater Formation, and the Devonian Camrose Tongue dolomite. Isopach point data from the file THICK were extracted, and the data distribution was then transformed into a regular grid isopach. The depositional limit of each unit was defined by the zero contour line on the isopach map, the rest of the grid was blanked out, and the next surface in sequence was then built by adding the isopach to the control surface.

Finally, in the case of surfaces with very few control points, but whose boundaries were known, the surface grid was altered interactively to represent the missing feature. This was the case for the Prairie Formation, which is absent in the northeast corner due to salt dissolution. Knowing the position of the salt edge (Hamilton, 1971), the surface grid was blanked out accordingly. The same interactive procedure was used to correct the computer produced top surface of the Watt Mountain Formation on top of the Prairie Formation in the region of salt dissolution and collapse, where only one control point was available.

By using all these various procedures the consistency of the stratigraphic structure is ensured. As a matter of fact, the ground surface was processed the same way based on the ground elevations recorded at the well locations. Also, a grid surface of the top of the bedrock was produced, based on the Sand River map area (Gold et al., 1983), in order to check the accuracy of the procedure and to complete the sequence of stratigraphic representation in magnetic form for computer processing.

All the procedures described previously for modifying the "blind" stratigraphy resulted from the first loop of data processing are actually a hybrid human-computer second loop in the flow of stratigraphic information. The automatic and interactive processing is performed with the help of a few programs which constitute a grid manipulation package.

The program GRDDMP (GRiD DuMP) optionally prints and/or plots a single grid. The printout lists the values at grid nodes in a matrix by rows and columns, while the plot has the location of the nodes at the proper scale, with or without the grid value.

The programs REGRID and GRDEDT (GRiD EDiT) basically perform the same task of allowing interactive access for inspection and/or modification of single or whole blocks of values in a single grid on a magnetic device.

The program PASTEG (PASTE a Grid) performs the creation of a new grid out of two old ones. The new grid is built according to different criteria which, therefore, have to be changed in the program. For example, it can process a particular region of a grid, perform substitutions from one grid into another based on different logical criteria.

The program BUILDG (BUILD a Grid) creates a new surface grid out of a control surface and an isopach, having different options to deal with undefined areas.

All the programs GRDDMP, REGRID, GRDEDT, PASTEG and BUILDG are tailored to fit the grid description and storage resulting from the use of the SURFACE II software package to transform an irregular data distribution into values in a rectangular regular grid. Should another package be used, these programs would have to be modified accordingly.

The boundaries of different formations were also described in terms of a string of points (DLS coordinates) and put into a computer compatible file. The program GEOPLTR assembles the vectors (strings) and plots the respective lines at the proper scale.

The program CRX (Kansas Geological Survey) is complementary to the SURFACE II package. It produces cross-sections at any desired scale described by a succession of surfaces stored as regular grids on a magnetic device.

The stratigraphic maps presented in the Atlas were produced by overlaying the plotted data files from the SURFACE II (contour lines) and GEOPLTR (boundaries, posting, legend) software packages.

The final result of this data processing procedure is a set of stratigraphic surfaces stored on a magnetic device as values in a regular grid , and represented graphically as contour maps of the tops, isopachs, and cross-sections.

PROCESSING OF FLOW DATA

Information on the hydraulic parameters and chemistry of the hydrogeological system is contained in the second level (B) of the data base, following some primary processing and interpretation. Again, the data are associated with a particular location expressed in DLS coordinates and elevation of the recorder or sample. Figure 1-3 presents the processing path from the point data in the data base to synthesized information.

The program RPRTDSTB (RePoRT DST data from B level) extracts information about the hydraulic parameters in a particular area indicated at input. It has the option to report all the data entered in the data base report, or all the data previously reported, or all the data not previously reported. It produces, on output, two sequential files on a magnetic device, HYHEADS (HYdraulic HEADS) and HYPARAM (HYdraulic PARAMeters). A record in the file HYHEADS contains information about the location (DLS coordinates) and elevation of the test recorder, the formation pressure and the computed hydraulic head. Besides the location and elevation, the data in the file HYPARAM are: the permeability, the hydraulic conductivity, the transmissivity, the storativity (all in decimal logarithmic form) and the porosity of the porous medium at the point of measurement.

The program RPRTCHMB (RePoRT CHeMistry data from B level) performs a similar task as RPRTDSTB, but for chemical data. It reports, on the file CHPARAM (CHemistry PARAMeters), up to four of sixteen different chemical parameters. The parameters reported are: Na (calculated), Ca, Mg, Cl, Br, I, HCO_3, CO_3, SO_4, total dissolved solids (calculated), pH, density, refractive index, resistivity, evaporated total dissolved solids (at 110 °C) and total dissolved

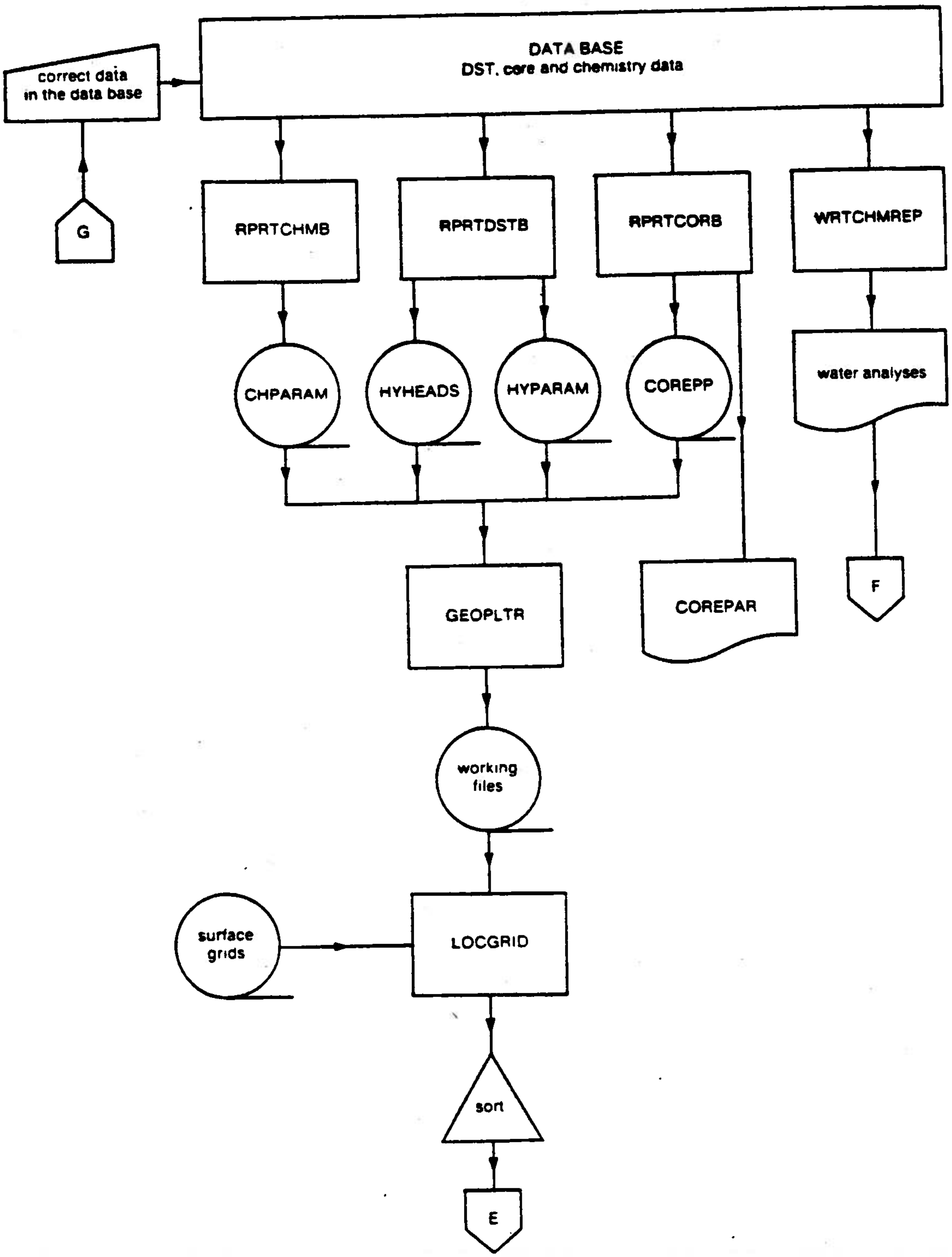

Figure 1-3 Flow chart for the automatic processing of hydraulic and chemical data from point data to synthesized information

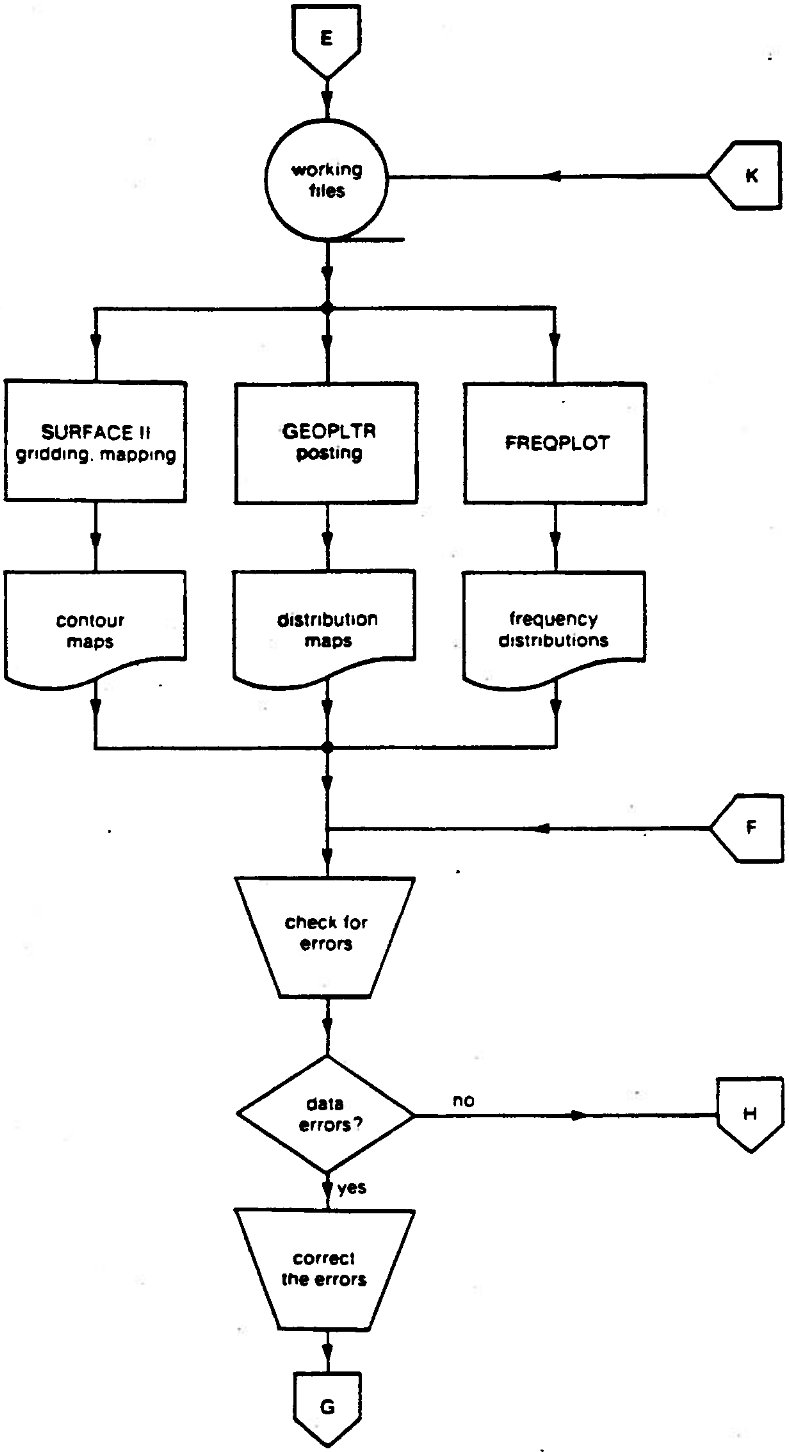

Figure 1-3 continued

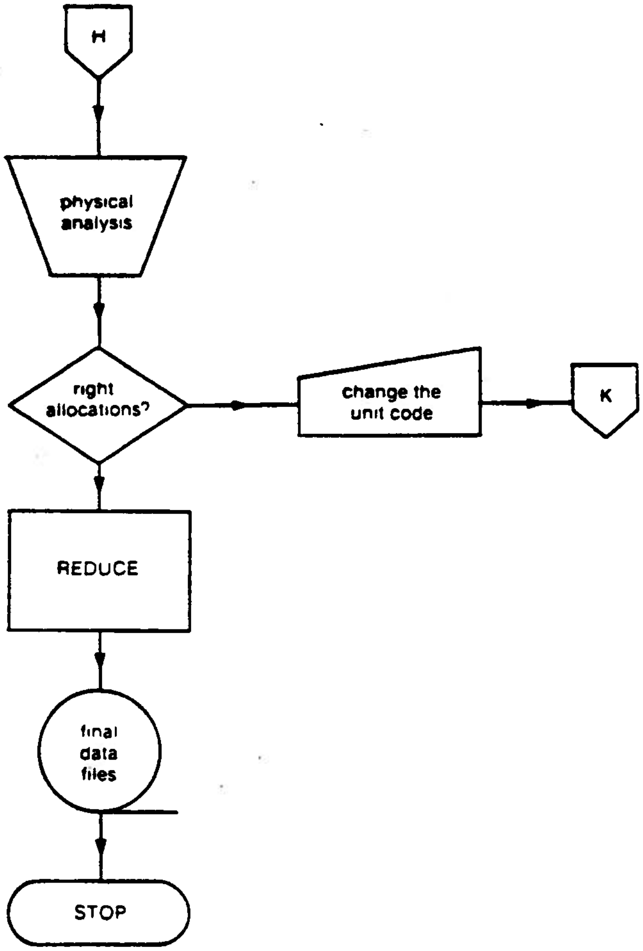

Figure 1.3 continued

solids after ignition. The main difference between RPRTCHMB and RPRTDSTB is in the input and output formats.

The program RPRTCORA (RePoRT CORe data from A level) reports from the first level (A) of the data base information on core analyses. The first report file from RPRTCORA, COREPP (CORE Permeability and Porosity), lists in a magnetic file the location (DLS), the middle and the top elevations of the interval tested, the horizontal and vertical components of permeability (in decimal logarithmic form), and the porosity for every analysis. The second file, COREPAR (CORE PARameters) lists on paper all other standard information in a core analysis but which is not listed in COREPP.

The program GEOPLTR is then run using these files and adding to the data in each record the x-y coordinates of the well location, at the required scale.

The program LOCGRID (LOCate in the GRID) then interpolates each measurement point (x-y-z coordinates) in a three-dimensional stratigraphic structure in order to allocate the data by formations. The stratigraphic structure is defined by a succession of grids of elevation values describing the tops of the formations in the sequence. These grids are actually the end result of the stratigraphic data processing presented previously. The names of the files containing the grids are indicated at input, together with the ERCB formation code and an internal code for the hydrostratigraphic unit. The program reads in all the grids, then reads sequentially one of the files HYHEADS, HYPARAM, COREPP or CHPARAM, and for each record, the x-y-z coordinates are interpolated in three-dimensions. The output file is identical to the input one, with the added information of the interpolated formation (corresponding ERCB code), hydrostratigraphic unit (internal code) and the elevations of the top and the bottom of the specific formation at that point.

The files HYHEADS, HYPARAM, COREPP and CHPARAM are separated in derivative files by hydrostratigraphic units using the system utility software. These derivative files each contain the distributions of a particular parameter in the respective unit.

Based on the derivative files, the GEOPLTR and SURFACE II software packages then produce maps with postings of locations and values, and contour maps if required, for each parameter and unit. If needed, the contour maps can be stored as grids of values on a magnetic device.

The program FREQPLOT (FREQuency distribution PLOT) plots the log-normal distribution of any input variable. Using this program, frequency distributions were plotted for parameters with a geostatistical distribution, such as permeability, and the chloride content of the formation waters.

Reports of particular or whole sets of chemical analyses can be printed using the program WRTCHMREP (WRiTe CHeMistry REPort).

All the produced graphic material was used to detect anomalies in the data distributions (statistical or in space) and errors, usually of a data entry kind. Using the original reports for drillstem tests or printouts for the chemical data, all the doubtful data were checked and corrected as necessary. Also, after examination, some data were rejected from the samples, as in the case of water samples contaminated with mud filtrate. In some cases, the allocation of data to one particular unit was changed after examination of the original data and of the areal and/or frequency distributions. This was the case for measurements close to the boundary between two stratigraphic units, where there was a degree of uncertainty due to the extrapolation/interpolation procedures. The corrections in this case were done interactively in the derivative files.

The processing of hydraulic and chemical data are similar yet independent up to a certain degree. The hydraulic heads and hydraulic conductivities were computed using a standard water density of 1000 kg/m^3. However, it is also possible to take into account the actual water density; therefore, the chemical data processing must be finished first. After the density distributions for each unit are determined and retained as values at nodes in a regular grid, the program RECALHYD (RECALculate HYDraulics) can recalculate the true value of the hydraulic head and of the hydraulic conductivity by reading, at input, the respective derivative file and the appropriate density grid.

The process of data allocation and checking is iterative by nature and necessitates several passes through the loops. After this process is completed, the program REDUCE eliminates from the records in the files HYHEADS, HYPARAM COREPP and CHPARAM the now obsolete information on the top and bottom elevations of the unit.

The final derivative files can then be used for further statistical analysis, or physical interpretation.

In summary, it must be stressed that all the derivative files for stratigraphy, hydraulic parameters and formation water chemistry are not part of the data base, but they do contain information that, basically, is present in the data base. These derivative files, together with the set of programs for their preparation and processing, are only a step in the process of synthesizing the information from irregular point data distributions to regular grids. The computer software developed for the processing of this data actually automates and thereby speeds up a process previously done manually, and allows the processing of huge amounts of data, a task otherwise practically impossible.

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HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA

Part II. Regional Geology

Open File Report 1996 - 1b

Prepared by
Basin Analysis Group
Alberta Geological Survey
Alberta Research Council
(Project Manager: Dr. Brian Hitchon)

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ALBERTA RESEARCH COUNCIL

PART 2

REGIONAL GEOLOGY

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SECTION 1: PHANEROZOIC

INTRODUCTION

The main source of information used in compiling this report on the regional geology of the Cold Lake Study Area was the ERCB Well Data File. This was supplemented by examination of well logs for specific stratigraphic intervals. Generalized information on lithological variations was obtained from the literature; because the objective in studying the regional geology was to determine the geometry of the main rock units, prior to assigning them to hydrostratigraphic units, it is not necessary to carry out studies of detailed variations of lithology. Data processing techniques used to produce the various data distribution, structure contour, and isopach maps in the Atlas are described in Part 1. Tables 2-1 and 2-2 contain general statistics (based on computer grids) of the average elevations and range in thickness, respectively, for selected stratigraphic and hydrostratigraphic intervals shown in the Atlas.

BASINAL SETTING

The Western Canada Sedimentary Basin is basically a simple northeasterly tapering wedge of sedimentary rocks, more than 6 km thick, that extends southwest from the Canadian Shield into the Cordilleran foreland thrust belt (Fig. 2-1). This simple statement (from Porter et al., 1982) belies the complex internal structure that has developed through superposition of contrasting patterns of differential subsidence and uplift throughout the Phanerozoic. The following brief review of the geological history of the Phanerozoic in the Cold Lake Study Area is primarily based on the publications of McCrossan and Glaister (1964), McCrossan (1973) and Porter et al. (1982).

Table 2-1
Average elevation (m relative to sea level datum) of selected surfaces, Cold Lake Study Area

Surface	Atlas map	Average elevation (m)
Ground	-	616
Bedrock	0-g-9	541
Upper Cretaceous		
Second White Speckled shale	0-g-7	343
Lower Cretaceous		
Base of Fish Scale Zone	0-g-5	298
"Viking sandstone"	N-g-4	244
Joli Fou Formation	M-g-3	235
Mannville Group	L-g-6	217
Clearwater Formation (top)	K-g-3	132
Clearwater Formation (base)	K-g-4	128
McMurray/Dina/Ellerslie Formations	J-g-5	84
Pre-Cretaceous unconformity	J-g-7	43
Upper Devonian, Woodbend Group		
Grosmont Formation	H-g-3	64
Ireton Formation	F-g-6	13
Camrose Tongue Dolomite	G-g-3	- 74
"Lower" Ireton (below Grosmont Formation)	-	- 5
"Lower" Ireton (below Camrose Tongue)	-	- 83
Cooking Lake Formation	E-g-9	- 96
Upper Devonian, Beaverhill Lake Formation	E-g-7	- 81
Middle Devonian, Elk Point Group	E-g-5	-296
Prairie Formation	D-g-3	-318
Cambrian	-	-807
Precambrian	B-g-1	-945

Table 2-2

Range in thickness (m) of selected stratigraphic and hydrostratigraphic units, Cold Lake Study Area

Stratigraphic/ hydrostratigraphic unit	Atlas map	Range in thickness(m)
Upper Cretaceous	A-g-1	36-453
Combined Colorado Group/Post-Colorado supergroup aquitard (including thin "Viking sandstone" aquifer)	O-g-8	120-535
Lower Cretaceous	A-g-2	181-376
Mannville Group	L-g-7	93-275
"Upper Mannville" Group aquifer (above Clearwater Formation)	L-g-8	47-139
"Lower Mannville" Group aquifer (below Clearwater Formation)	J-g-10	5-180
Upper Devonian	A-g-3	36-633
Grosmont Formation	H-g-6	0-150
Ireton Formation aquitard (including Camrose Tongue)	F-g-8	0-305
Cooking Lake Formation	-	0- 96
Beaverhill Lake Formation	E-g-10	36-280
Cooking Lake-Beaverhill Lake-Watt Mountain aquifer	E-g-11	50-352
Middle Devonian	A-g-4	282-576
Post-Prairie Formation	-	6- 33
Prairie Formation aquiclude	D-g-4	0-200
Cambrian	A-g-5	23-300

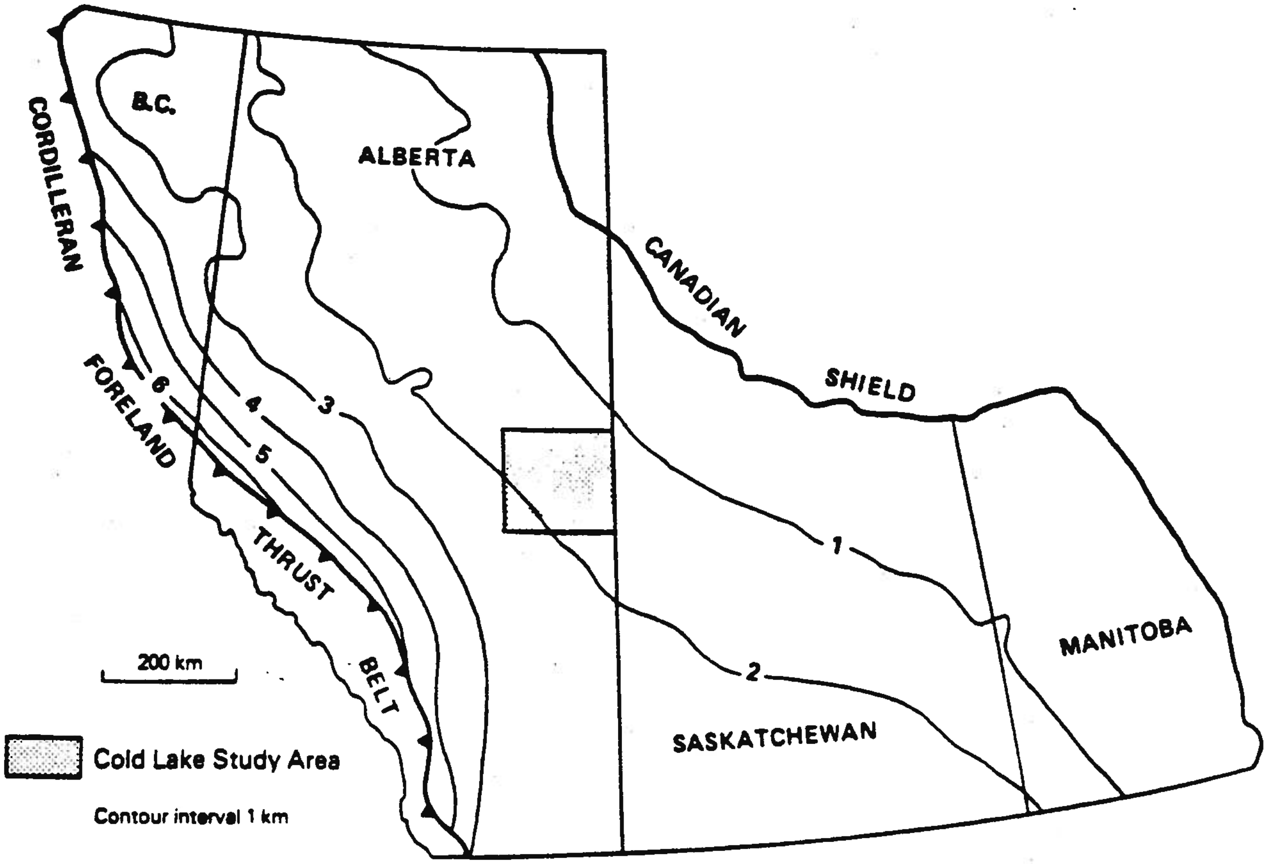


Figure 2-1 Total preserved thickness of Phanerozoic rocks east of the Cordilleran foreland thrust belt (simplified from Porter et al., 1982)

The eastern part of the Cordillera is the deformed counterpart of the sediments that fill the undeformed basin shown in figure 2-1. Palinspastic reconstruction (Price, 1981, Fig. 2) shows that until the initial uplift of the Cordillera, in Middle Jurassic time, the sediments in the present eastern part of the Cordillera formed a continental terrace wedge along the ancient rifted western margin of the North America Precambrian craton, some 200 km west of the present axis of the Alberta syncline. During the Phanerozoic there was effectively continuous deposition in the continental terrace wedge from Early Cambrian to Middle Jurassic time. Coincidentally, there was transgressive onlap of the Precambrian crystalline basement and the development of a series of epeirogenic arches and basins on the cratonic platform. The result was intermittent transgression-regression and erosion to give the present distribution and thickness of the pre-Cordilleran rocks in the undeformed basin. Therefore, depending on which area of the undeformed Western Canada Sedimentary Basin is being considered, different sequences of strata may be absent due to non-deposition or erosion. This has a profound effect on the hydrostratigraphy, and in the Cold Lake Study Area has resulted in the juxtaposition of Cambrian and Middle Devonian rocks, and Upper Devonian and Lower Cretaceous rocks.

During the Late Jurassic to Paleocene interval the continental terrace wedge was compressed, detached from its basement, and thrust over the flank of the craton to form the present eastern part of the Cordillera. In the undeformed basin this resulted, during this time interval, in the continuous deposition of cratonward (eastward) prograding clastic detritus shed by the evolving Cordillera. The initial, generally coarse, clastic detritus forms the reservoirs for the major oil sands and heavy oil occurrences, such as those in the Cold Lake Study Area, in addition to some occurrences (for example, Grosmont) in strata immediately beneath the Pre-Cretaceous unconformity. In the Cold Lake Study Area, however, bitumen is not present in the Grosmont Formation. Erosion from the Late Paleocene

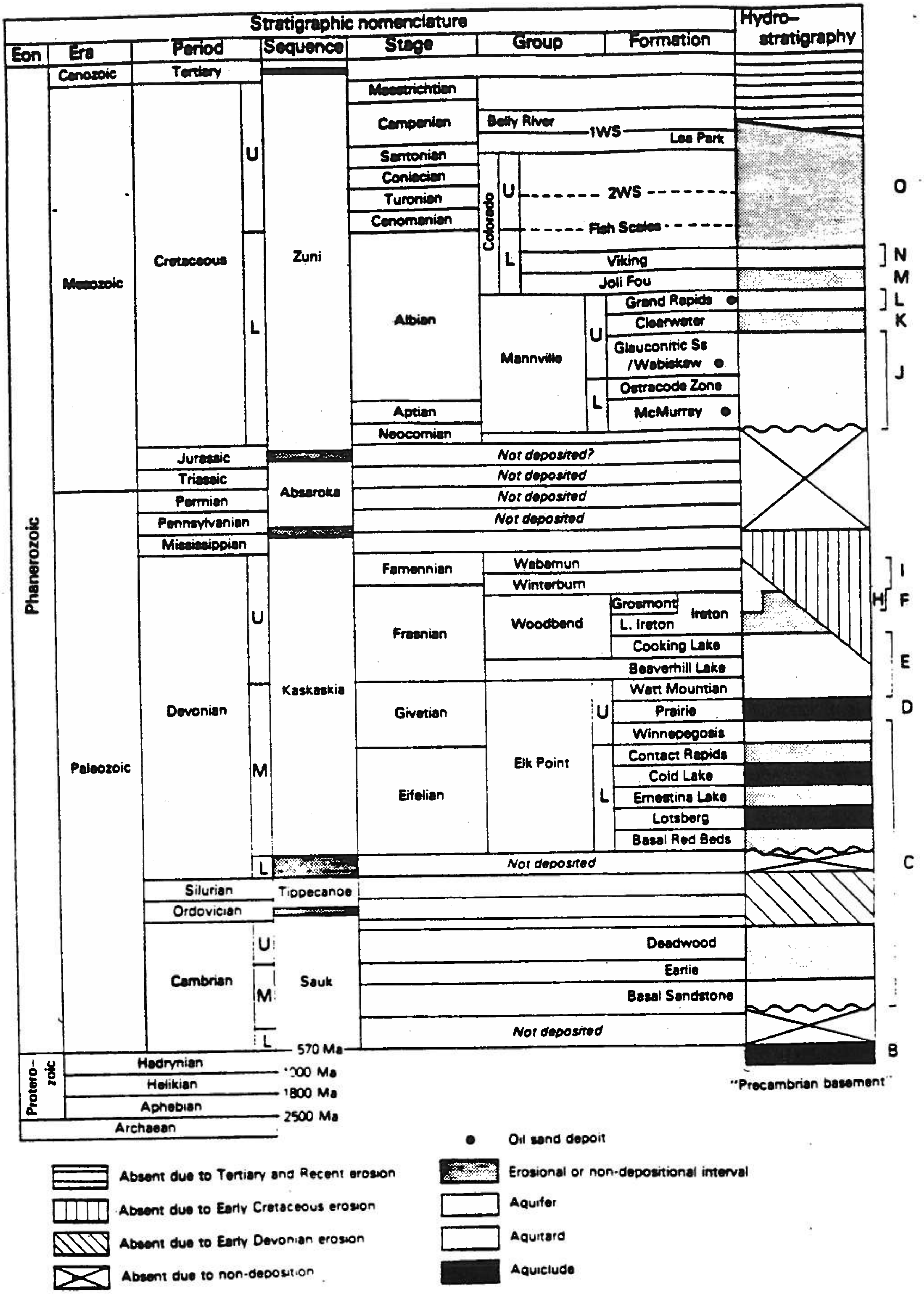


Figure 2-2 · Generalized stratigraphic nomenclature and hydrostratigraphy, Cold Lake Study Area to the present has removed up to 3 km of Tertiary sediments from the basin (Hitchon, 1984, Fig. 23) and exposed rocks as old as Middle Devonian.

The generalized stratigraphic nomenclature and hydrostratigraphy in the Cold Lake Study Area is shown in figure 2-2. The effect of the basin-wide events outlined in the previous paragraphs has been to produce three continuous stratigraphic intervals separated by two major unconformities. The stratigraphic sequences are Middle and Upper Cambrian, Middle and Upper Devonian, and Lower and Upper Cretaceous. Lower Cambrian, Lower Devonian, Upper Carboniferous, Permian, Triassic and Jurassic strata are absent due to non-deposition. Ordovician and Silurian strata are absent due to Early Devonian erosion, and much of the uppermost Upper Devonian and the entire Lower Carboniferous sequence has been removed due to erosion in the Late Paleozoic, Early Mesozoic and Early Cretaceous. Probably at least 1 km of post-Campanian and Tertiary rocks have been removed due to Tertiary and Recent erosion (see Hitchon, 1984, Fig. 23). The Phanerozoic section that remains ranges in total thickness from just over 1 km in the northeast to about 2.3 km in the southwest (Fig. 2-1). The average elevations and range in thickness of some of the remaining individual stratigraphic intervals are shown in tables 2-1 and 2-2, respectively.

PRECAMBRIAN BASEMENT

The Precambrian continental craton, which forms the basement of the Western Canada Sedimentary Basin, consists mainly of Archean crystalline rocks and Aphebian (2500-1750 Ma) supracrustal rocks that were modified by deformation, metamorphism and magmatism during the Early Proterozoic (1750 Ma) Hudsonian orogeny, and are exposed in the Churchill Province of the Canadian Shield. The Cold Lake Study Area lies on the southeast side of the Hudsonian mobile zone. Cores have been obtained from only a few wells which penetrated the Precambrian in east-central Alberta. The rocks are mainly plagioclase-rich gneisses, although granites and acid volcanic rocks have been recorded. Few show no post-crystalline deformation. Further details may be found in Burwash et al. (1964) and Burwash and Krupicka (1969, 1970). In the Cold Lake Study Area the Precambrian basement dips gently towards the southwest (see Atlas map B-g-1). Although the Precambrian basement is commonly regarded as the deepest aquiclude in the Western Canada Sedimentary Basin, recent studies on the exposed Canadian Shield have shown that very saline formation waters occur at depths of greater than 1 km. A variety of possible origins for these deep saline formation waters have been postulated, but most models for saline formation water origins found in the literature are unsatisfactory to explain the origin and genesis of these deep Canadian Shield formation waters. Nothing is known about the presence of comparable saline formation waters in the Precambrian basement where it is covered by Phanerozoic rocks; until such information becomes available, we must assume that the Precambrian basement is the deepest aquiclude in the Western Canada Sedimentary Basin.

CAMBRIAN

The Sauk sequence, which comprises Cambrian and Early Ordovician strata, marks the beginning of the Phanerozoic record of deposition on the cratonic platform. Unlike later Phanerozoic strata the Sauk sequence shows no signs of the influence of the cratonic arches and basins that dominated patterns of erosion and deposition during the subsequent evolution of the Western Canada Sedimentary Basin. The sequence begins with a basal diachronous quartz sandstone that transgresses the entire western flank of the craton, and ranges in age from Early Cambrian in the continental terrace wedge, to late Early Ordovician in the eastern part of the cratonic platform, where it overlies the deformed Aphebian (Early Proterozoic) and Archean rocks of the crystalline basement complex. In the continental terrace wedge this Early Cambrian sandstone succession is more than 2 km thick, but thins to the range 25 to 100 m in the Cold Lake Study Area. The basal Cambrian sandstone sequence was succeeded by a series of Middle and Late Cambrian, and Early Ordovician sedimentary cycles, each of which begins with shales and grades upward into carbonate rocks. The complete sequence of sedimentary cycles is present in the continental terrace wedge, but in the Cold Lake Study Area is represented only by a series of glauconitic siltstones with minor intercalated dolomites and shales of the Earlie Formation. Some of the dolomites may represent the attenuated equivalents of the carbonates of the continental terrace wedge. Pugh (1971, 1973) provides additional information on the stratigraphy and lithology of the individual Cambrian stratigraphic units throughout Alberta. Figure 2-3A shows the distribution of Middle and Upper Cambrian strata in the Cold Lake Study Area and surrounding region. An isopach of Cambrian strata in the Cold Lake Study Area (Fig. 2-4; Atlas map A-g-6) shows the effect of the severe Early Devonian erosion. The zero edge of Cambrian strata differs slightly from that in figure 2-3A due to computer extrapolation.

ORDOVICIAN AND SILURIAN

The pattern of variation of thickness of the Sauk sequence is the result of two episodes of erosional beveling, the earlier of which took place in pre-Middle Ordovician time and affected the sequence over the entire Western Canada Sedimentary Basin. The second episode, in Early Devonian time, was more pronounced but affected only those parts of the Sauk sequence not covered by resistant Middle Ordovician rocks. Ordovician deposition began with a transgressive basal sandstone that overlapped much of the cratonic platform, following the pre-Middle Ordovician episode of erosional beveling. A succeeding shallow-water carbonate shelf environment

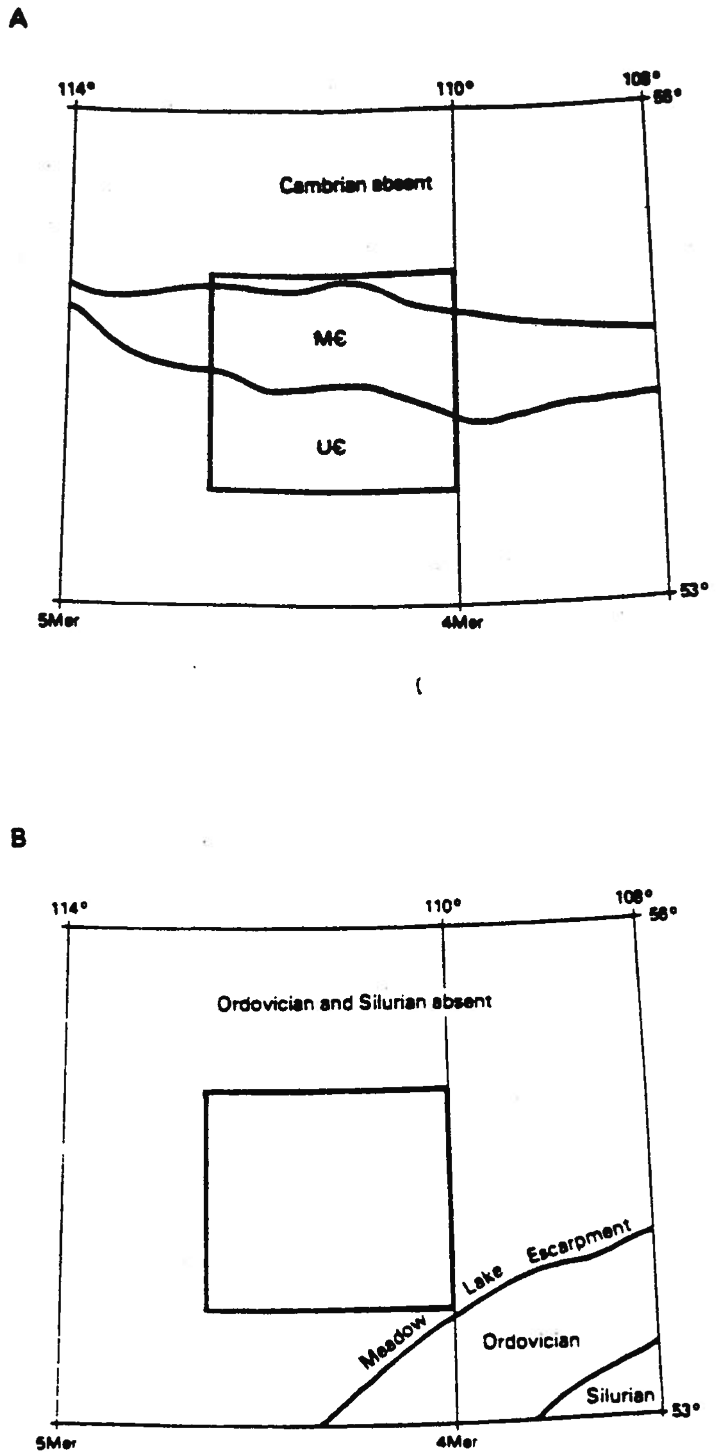


Figure 2-3 A. Distribution of Middle and Upper Cambrian strata in Cold Lake region (after Pugh, 1971, 1973); B. Distribution of Ordovician and Silurian strata in Cold Lake region (after Porter et al., 1964)

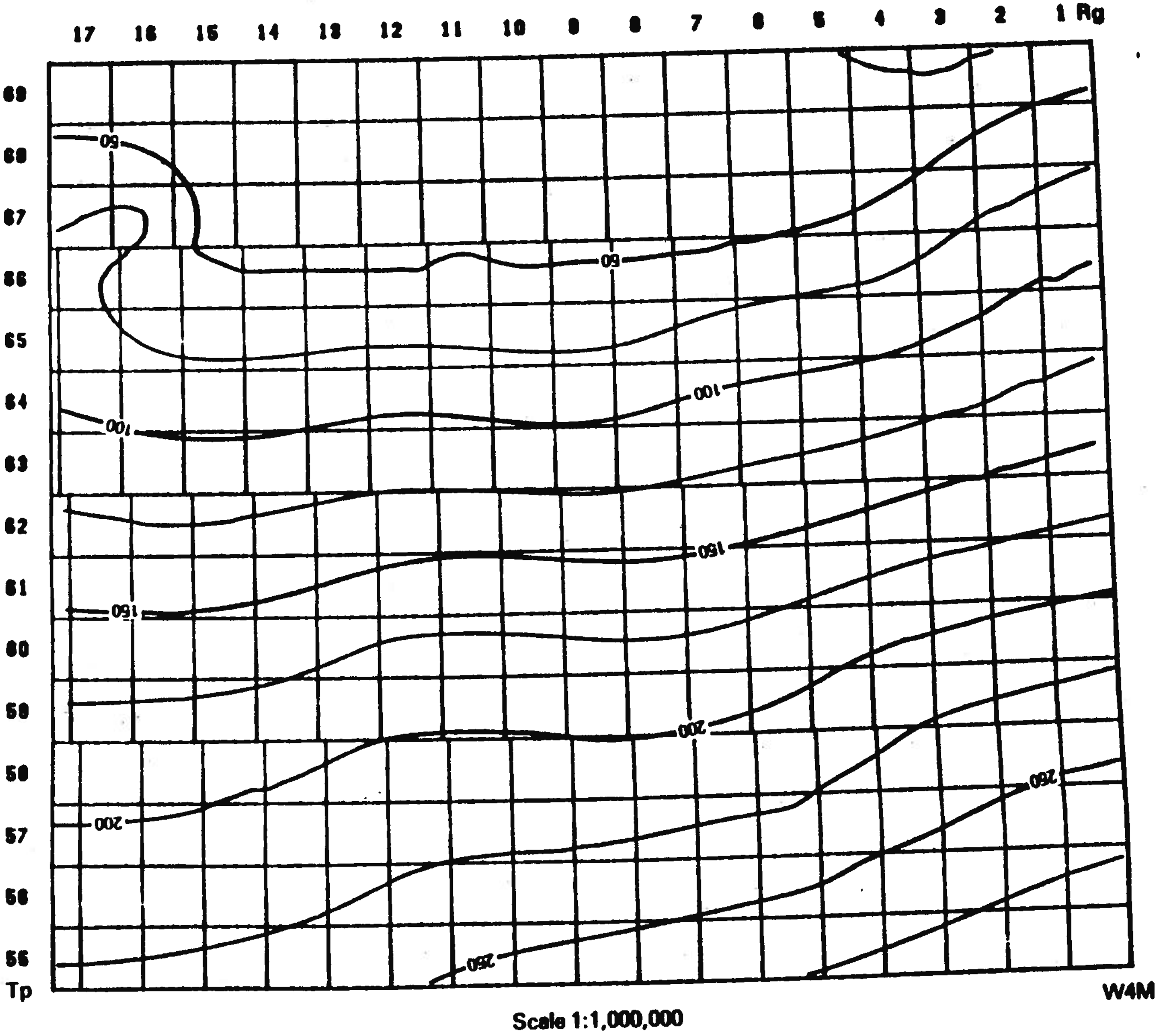


Figure 2-4 Isopach of Cambrian strata, Cold Lake Study Area (Atlas map A-g-6)

persisted until Late Silurian time. This carbonate platform sequence is the most widespread and of the longest duration of any of the Phanerozoic sequences. The maximum transgression probably occurred during Late Ordovician time when most of the North American craton was inundated. In the Cold Lake region (Fig. 2-3B) Early Devonian erosion has removed Ordovician and Silurian rocks except in the southeast corner of the region; rocks from both of these periods are absent in the Cold Lake Study Area.

MIDDLE DEVONIAN

The most profound episode of epeirogenic deformation in the history of the Western Canada Sedimentary Basin took place during Early Devonian time. The surface relief produced by the uplift and ensuing erosion controlled the distribution, thickness and character of the initial deposits of the Middle Devonian. This surface relief forced epeiric seas to transgress from northwest to southeast instead of from the previous westerly direction. In central Alberta and Saskatchewan, where the protective cover of resistant Ordovician carbonate rocks was breached, deep erosion of the less resistant clastic rocks of the underlying Sauk sequence created the northward-facing Meadow Lake Escarpment (see Fig. 2-3B) which was about 250 m high. The initial Middle Devonian deposits consisted of massive halite beds, associated red mudstones and a basal sandstone, which completely filled the topographic depressions that were enclosed on the west by a combination of cratonic arches (Western Alberta, Peace River and Tathlina), on the north by a southward-facing Cambro-Ordovician escarpment in the southern part of the Northwest Territories, and on the south by the northwest-facing Meadow Lake Escarpment. Figure 2-5 shows the distribution of the three main salt beds deposited during this period in the Cold Lake region; note that their western margins, and their southeastern margins against the Meadow Lake Escarpment are both depositional boundaries, whereas the northeastern boundary is due to salt solution effects.

Conformably overlying this early evaporite sequence of the Lower Elk Point Group, is the widespread basal carbonate unit of the Upper Elk Point Group. This is named the Keg River Formation in northern Alberta, the Methy dolomite in east-central Alberta, and the Winnipegosis Formation in Saskatchewan and Manitoba. The Winnipegosis-Keg River carbonate sequence rests conformably on the Lower Elk Point Group, but transgresses unconformably onto the Lower Paleozoic erosional surface southeast of the Meadow Lake Escarpment, and onto the Precambrian surface to the northwest. It comprises reef and non-reef carbonates ranging from less than 10 m thick in the inter-reef areas to more than 200 m in the thickest reef sections. It is commonly highly dolomitized although varying thicknesses of original limestone are preserved in some areas. In the Cold Lake Study Area the Winnipegosis-Keg River Formation ranges from 4 to 71 m in thickness.

The carbonates of the Winnipegosis-Keg River Formation initiated a changing pattern of distribution of successively younger Devonian salt deposits. There was a progressive southward shift of unrestricted marine facies into the central part of the Williston Basin, which was part of a regional pattern involving the southward transgression of barrier reefs behind which evaporite basins developed. The most extensive of these is the Prairie Formation of Givetian age. The Givetian evaporite basin developed southeast of a massive reef complex that lay across the south flank of the Tathlina Arch in northern Alberta and the southern part of the Northwest Territories. On the west, the basin is bounded by the Western Alberta Arch which was emergent and supplied clastic materials to the western margin of the evaporite basin; these are represented by a shaly facies of the Prairie Formation in the western part of the Cold Lake region (Fig. 2-6). Elsewhere in the Cold Lake region the Prairie Formation is dominantly salt, and ranges from 100 to 175 m in thickness, except along the eastern margin where extensive salt

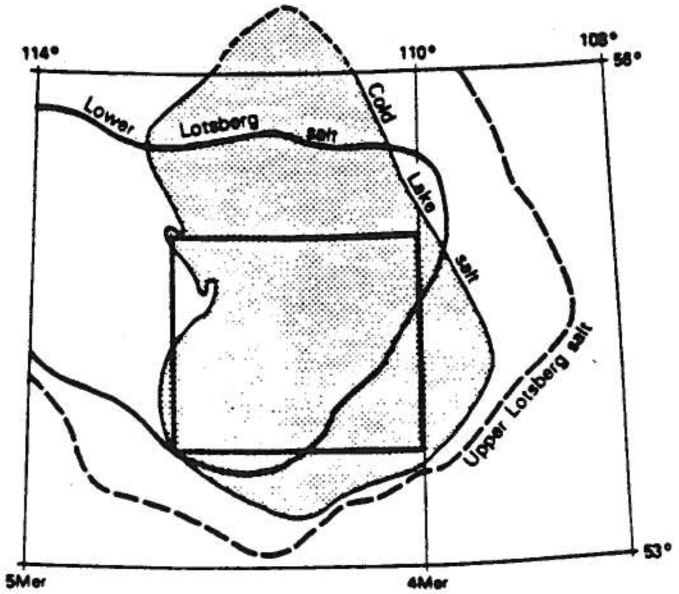


Figure 2-5 Distribution of Middle Devonian Lower Elk Point Group salts in Cold Lake region (from Hamilton, 1971)

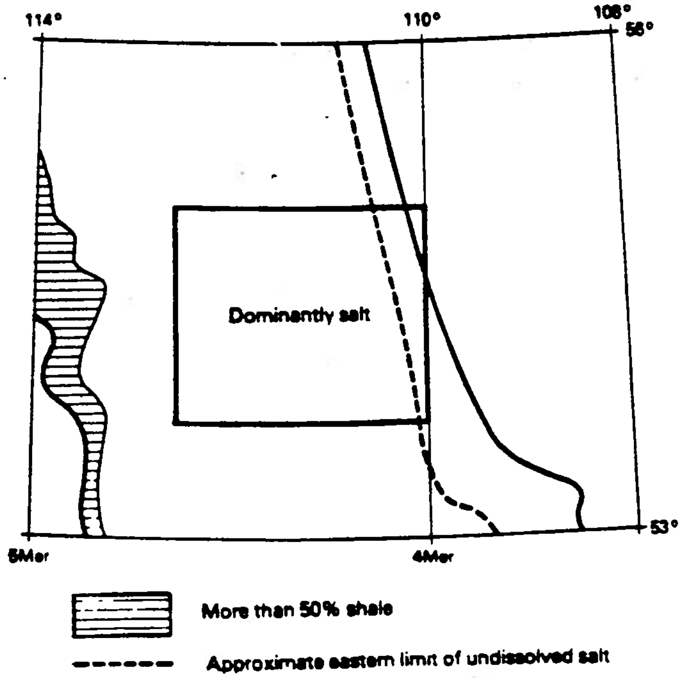


Figure 2-6 Distribution and lithology of Middle Devonian Upper Elk Point Group, Prairie Formation in Cold Lake region (from Hamilton, 1971)

solution has taken place (Fig. 2-7; Atlas map D-g-4). The effects of salt solution and the subsequent collapse of overlying strata is well illustrated by a structure contour map on top of the Prairie Formation (Fig. 2-8; Atlas map D-g-3). In the Cold Lake Study Area the Prairie Formation salt is overlain by a thin (6-33 m) sequence of anhydritic and dolomitic shales. The total thickness of Middle Devonian rocks in the Cold Lake Study Area ranges from 282-576 m, and an isopach map (Fig. 2-9; Atlas map A-g-5) shows both the effect of the limited distribution of the Lower Elk Point Group and salt solution along the eastern margin.

UPPER DEVONIAN

The Upper Devonian (Frasnian and Fammennian) of the Western Canada Sedimentary Basin is characterized by the development of successively younger barrier reefs enclosing progressively smaller salt basins. Frasnian deposits transgressed the Western Alberta Arch and reestablished the marine connection between the cratonic platform and the adjacent continental shelf. Fammennian deposits transgressed the last inliers of the Precambrian basement complex on the crest of the Peace River Arch. The position of the Cold Lake Study Area within the Frasnian and Fammennian basins means that the geometry of the stratigraphic units would be relatively simple were it not for the extensive Early Cretaceous erosion, which has resulted in thicknesses ranging from 36 m at the eastern margin to 633 m in the southwest corner (Fig. 2-10; Atlas map A-g-4).

Beaverhill Lake Formation rocks lie conformably over the Middle Devonian Elk Point Group throughout the Western Canada Sedimentary Basin. In the Cold Lake region they consist mainly of interbedded shales and limestones, although the amount of limestone (in places dolomitized) increases towards the south (Fig. 2-11). In the Cold Lake Study Area limestones predominate only along the southern margin. Thicknesses are uniform, around 250 m, except in the subcrop

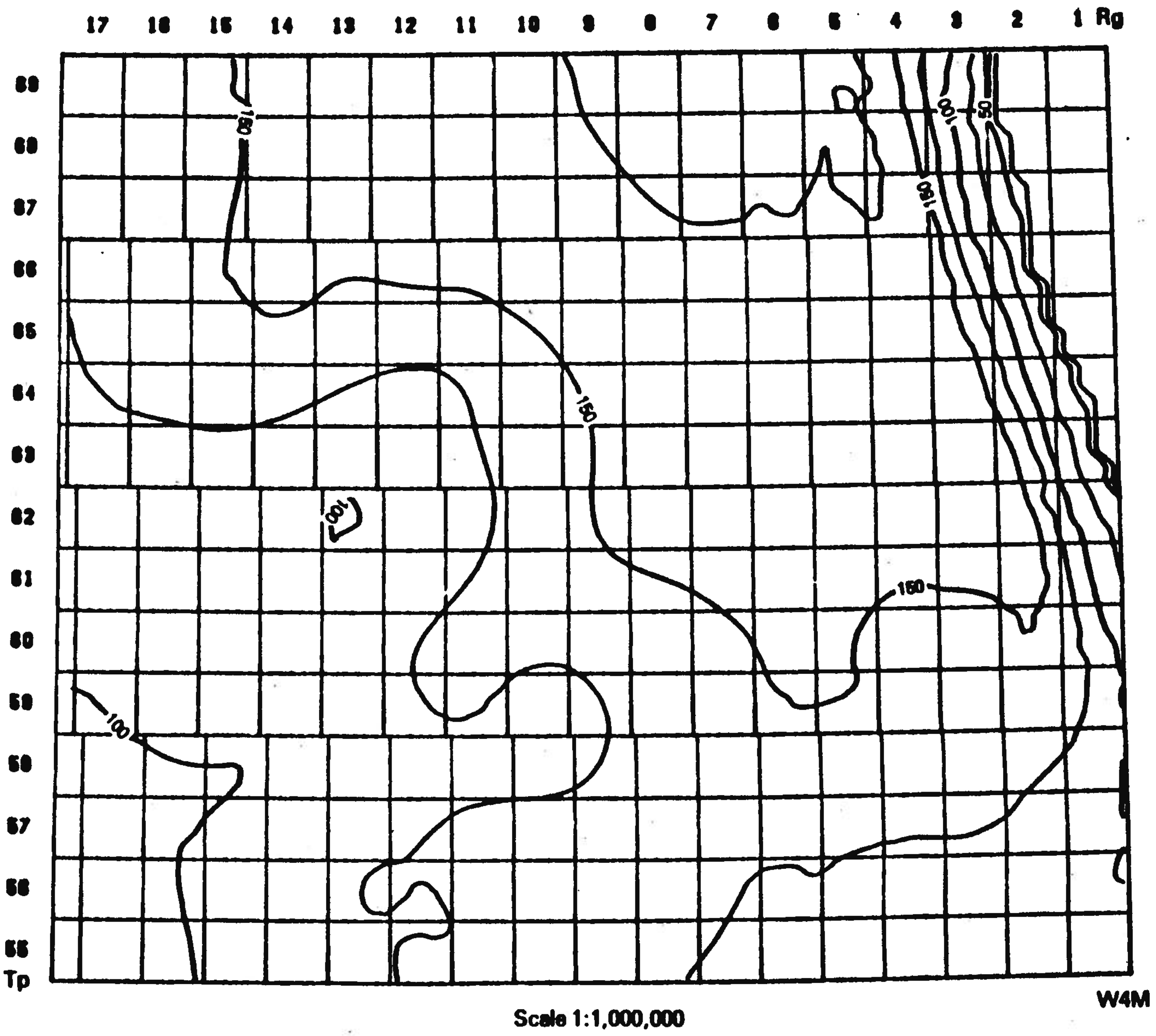


Figure 2-7 Isopach of Prairie Formation aquiclude, Cold Lake Study Area (Atlas map D-g-4)

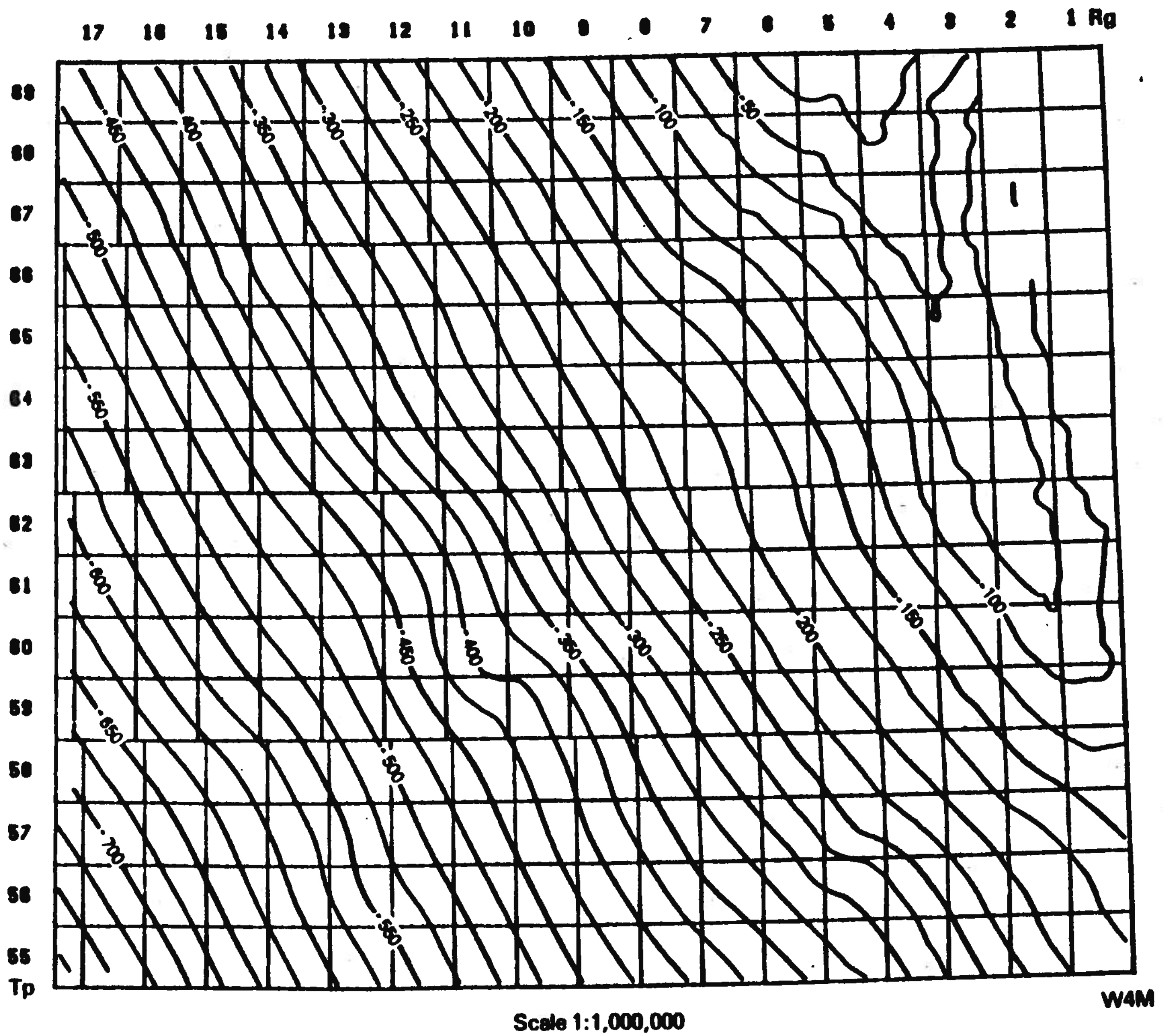


Figure 2-8 Structure contours on top of Prairie Formation, Cold Lake Study Area (Atlas map D-g-3)

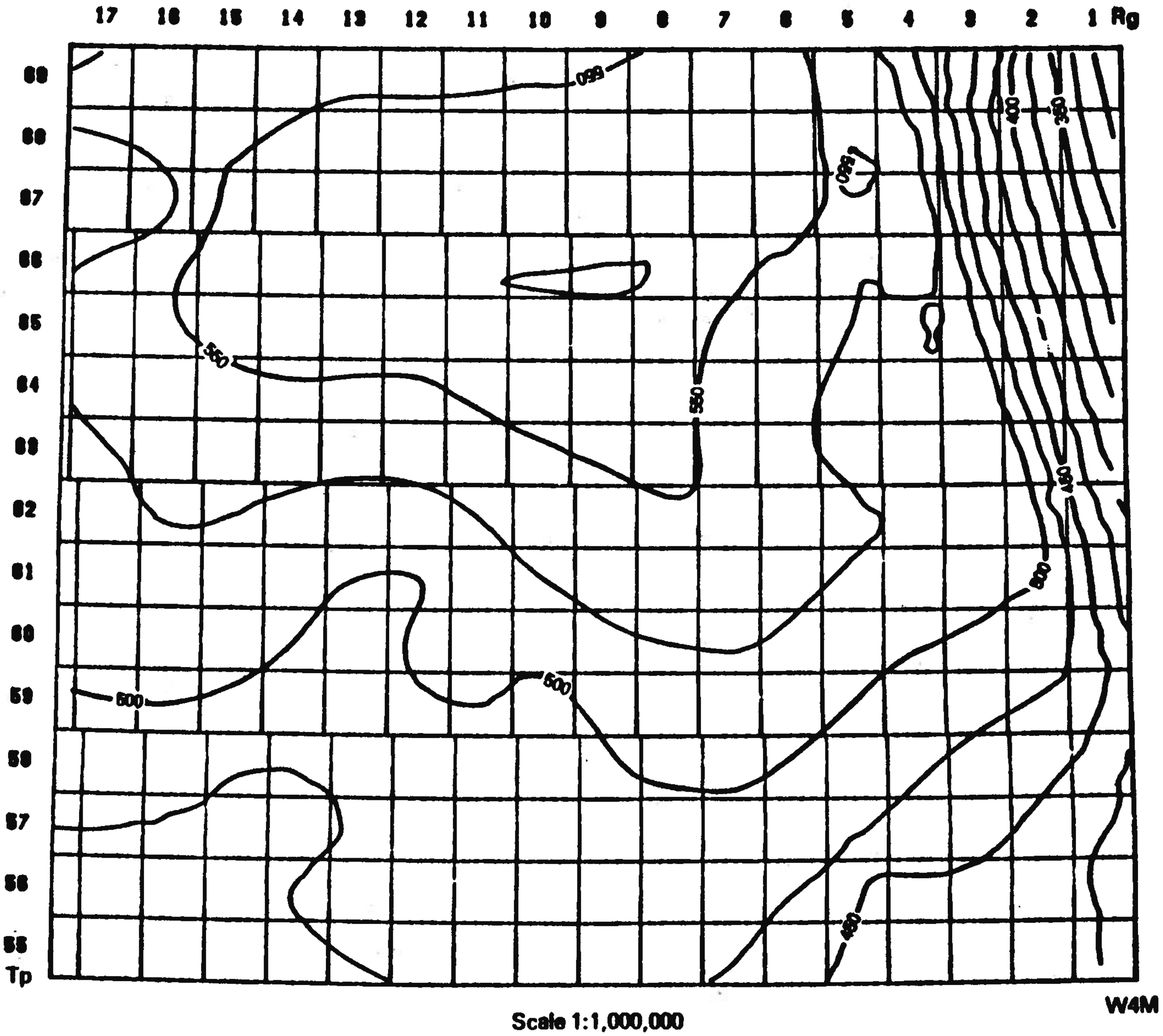


Figure 2-9 Isopach of Middle Devonian strata, Cold Lake Study Area (Atlas map A-g-5)

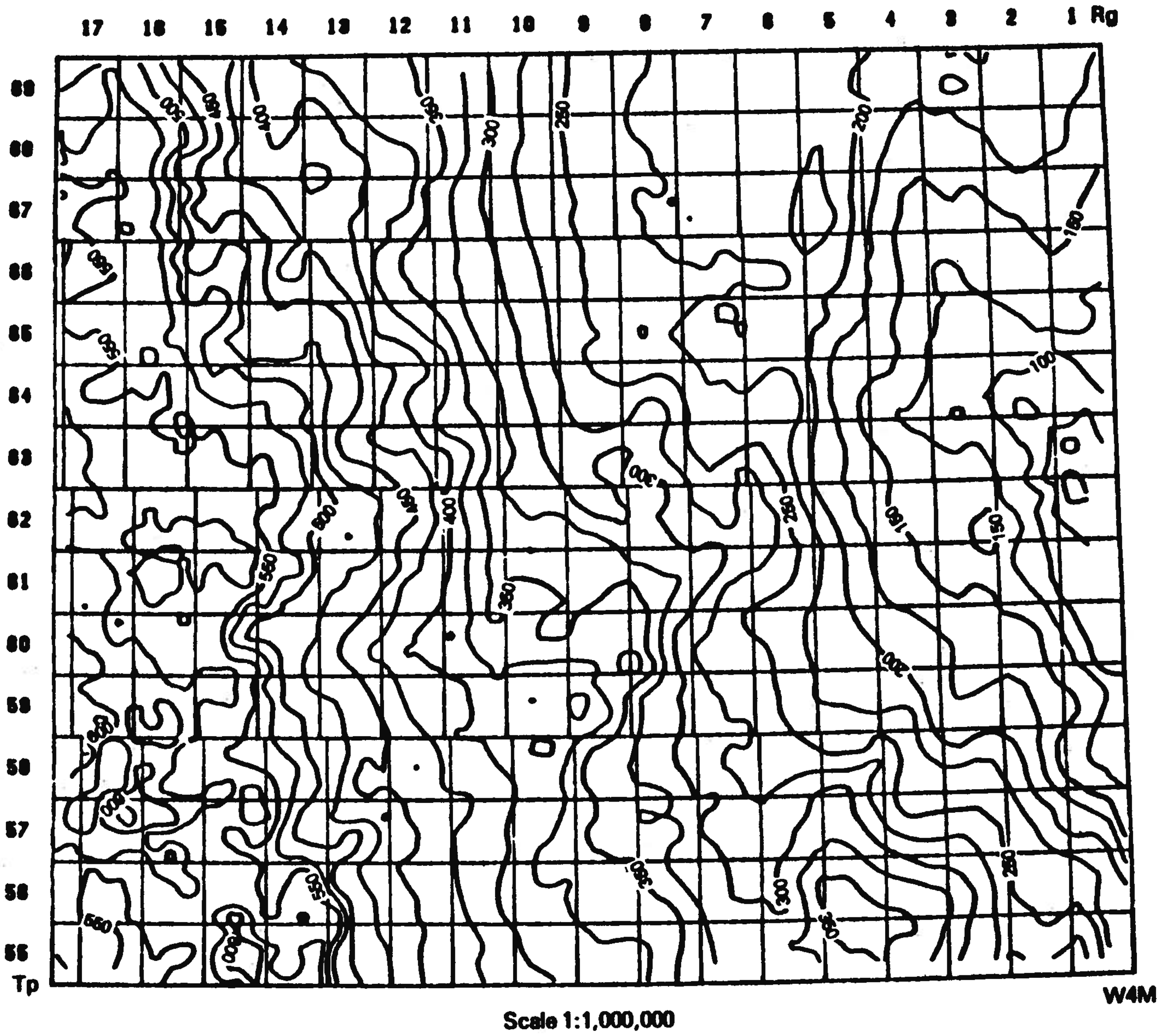


Figure 2-10 Isopach of Upper Devonian strata, Cold Lake Study Area (Atlas map A-g-4)

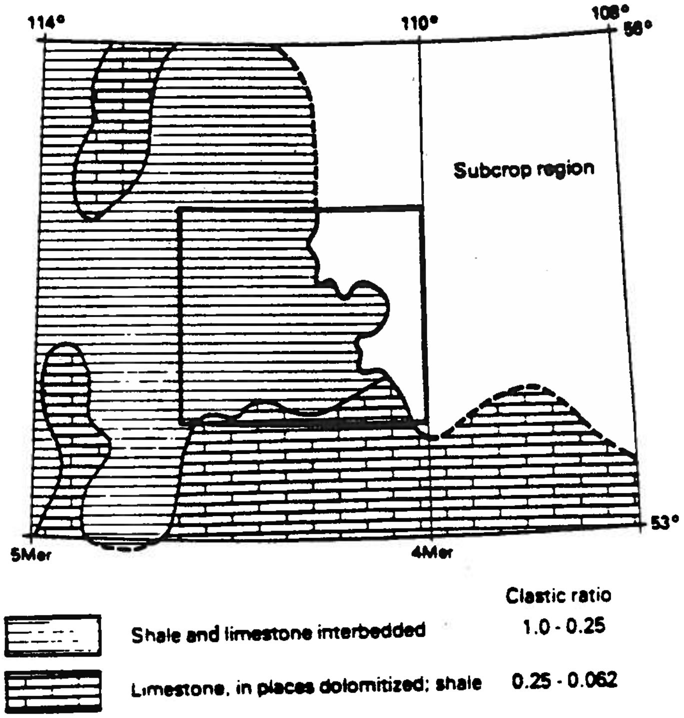


Figure 2-11 Distribution and lithology of Upper Devonian Beaverhill Lake Formation in Cold Lake region (modified from McCrossan and Glaister, 1964)

region where as little as 36 m remain along the eastern margin (Fig. 2-12; Atlas map E-g-10). The Beaverhill Lake Formation dips uniformly and gently to the southwest except in the subcrop region where synclinal structure has developed due to collapse following solution of the Prairie Formation salt (see Atlas map E-g-7).

Platformal limestones of the Cooking Lake Formation conformably overlie the Beaverhill Lake Formation throughout the Cold Lake region. In the Cold Lake Study Area they range in thickness up to 96 m. These limestones formed the base on which reefal carbonate complexes of the overlying Leduc Formation developed at Willingdon (in the Cold Lake Study Area), Redwater, along the Rimbey-Meadowbrook reef chain, and in the Southern Alberta Shelf complex (Fig. 2-13). The Grosmont Formation in the Grosmont carbonate complex is separated from the Cooking Lake platformal carbonates by green shales of the Lower Ireton Formation. Beneath the Grosmont complex, along a line extending north of the Rimbey-Meadowbrook reef chain, there may be a direct connection between the limestones of the Cooking Lake Formation and the carbonate complex of the Grosmont Formation where the Lower Ireton Formation is absent. Although this connection is outside the Cold Lake Study Area its influence is felt in the study area because the lowest hydraulic heads have been found in the Grosmont Formation.

Shales of the Ireton Formation overlie the Cooking Lake Formation throughout the Cold Lake region except where carbonate reef complexes of the Leduc Formation have been developed (Willingdon, Redwater, the Rimbey-Meadowbrook reef chain and the Southern Alberta Shelf complex). Sometime in the middle of the Frasnian, deposition of muds in the northwest part of the Cold Lake region gave way to a carbonate complex with minor evaporites (Grosmont and Hondo formations, respectively). Deposition of muds continued in the inter-reef region between the Grosmont and Southern Alberta Shelf complexes, until even the Willingdon, Redwater and Rimbey-Meadowbrook complexes were buried. An isopach map of the Ireton Formation (Fig.

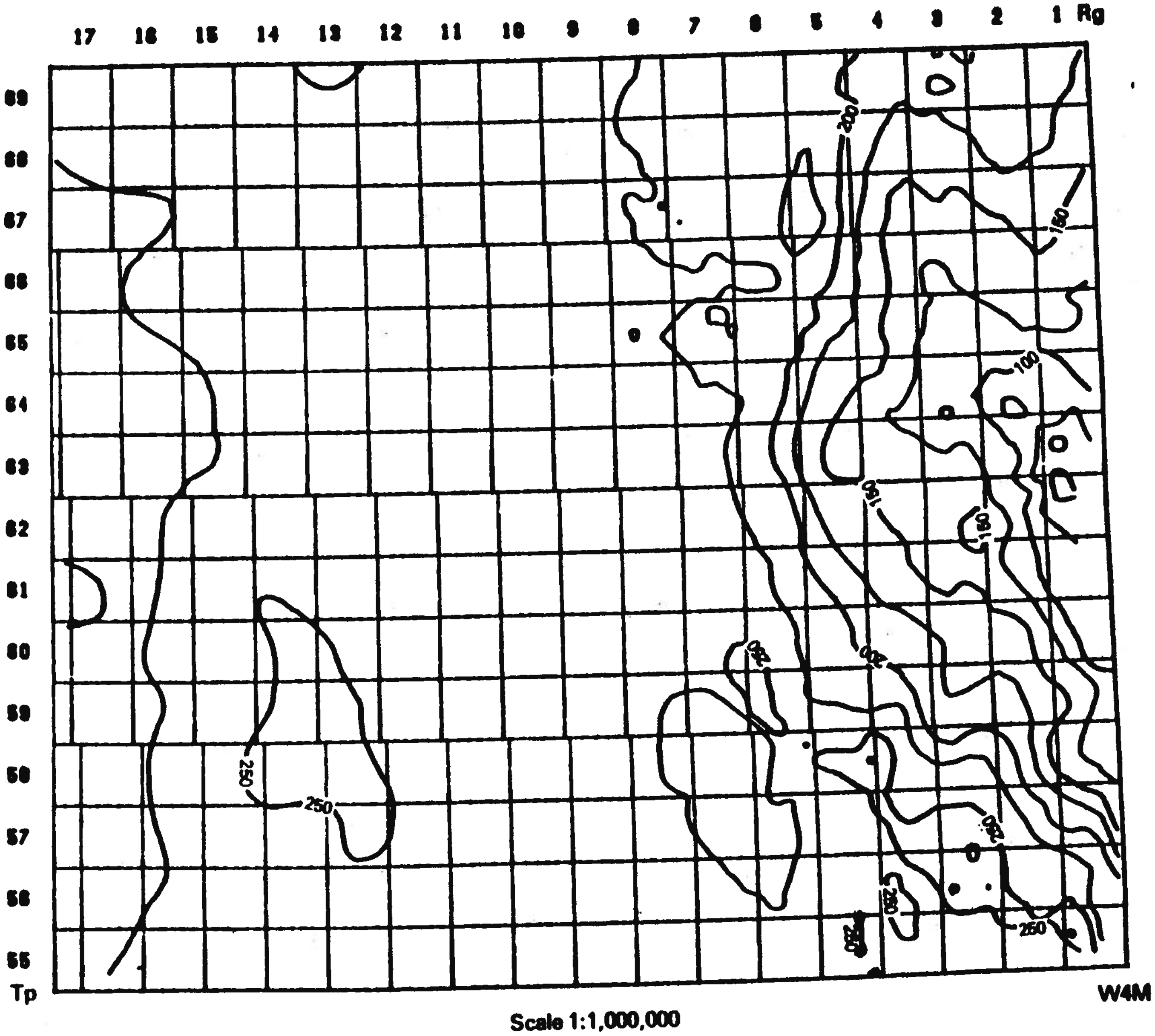


Figure 2-12 Isopach of Upper Devonian Beaverhill Lake Formation strata, Cold Lake Study Area (Atlas map E-g-10)

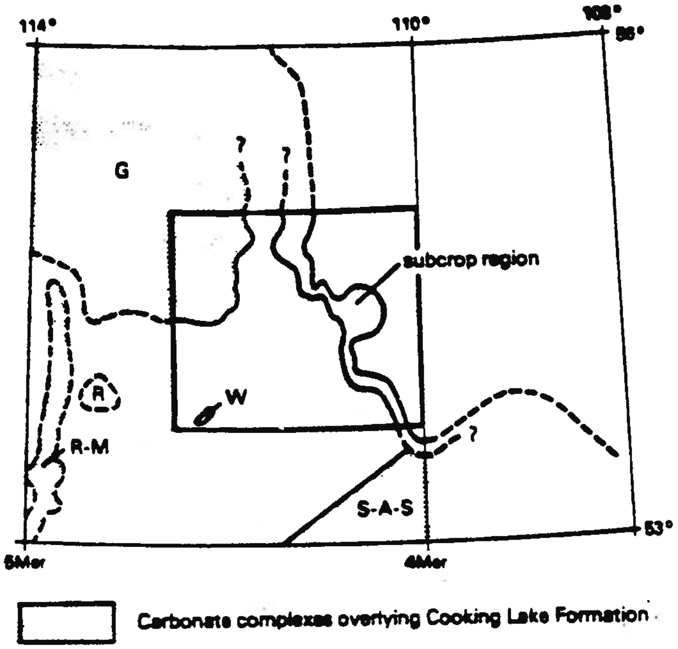


Figure 2-13 Distribution of carbonate reef complexes overlying the Cooking Lake Formation, Cold Lake region (Belyea, 1964)

2-14; Atlas map F-g-8) shows the difference in thickness of this unit where only the lower part is developed below the Grosmont complex (about 150 m) and where a full sequence is developed in the shale basin (up to 300 m). This difference can only be seen along the western margin of the study area where the complete Ireton Formation section has been preserved from Early Cretaceous erosion beneath the overlying Winterburn Group.

In the Southern Alberta Shelf complex, near the top of the sequence, is the Grotto Member which is a slightly argillaceous dolomite that contains an abundant coral and stromatoporoid fauna. Locally, it contains beds of white, coarse-crystalline dolomite, with the same coral and stromatoporoid fauna, which projects from the reef complex into the Upper Ireton Formation. This has been designated as the Camrose Tongue, and it is present in the southwest corner of the Cold Lake Study Area (see Atlas map G-g-5) where it is about 10 m thick.

The Grosmont Formation is a widespread dolomitized platform carbonate, which crops out along the Peace River in northern Alberta, and extends 500 km to its southeastern margin in the Cold Lake Study Area. A recent study (Cutler, 1983) has shown that it may be divided into a series of cycles which represent alternate episodes of sea-level rises and standstill conditions. Evaporitic conditions prevailed in the platform interior during deposition of the uppermost cycle, which is mappable as the Hondo Formation, an anhydritic carbonate unit which is not present in the Cold Lake Study Area. About 150 m of Grosmont Formation dolomites have been preserved from Early Cretaceous erosion beneath the overlying Winterburn Group (see Atlas map H-g-6).

During Late Frasnian time the Cold Lake Study Area was the site of a barrier reef, south of which salt beds developed in south-central Alberta and southern Saskatchewan. During the Fammennian the reef barrier had moved towards the northwest and anhydritic dolomites were deposited over the study area. Due to severe Early Cretaceous

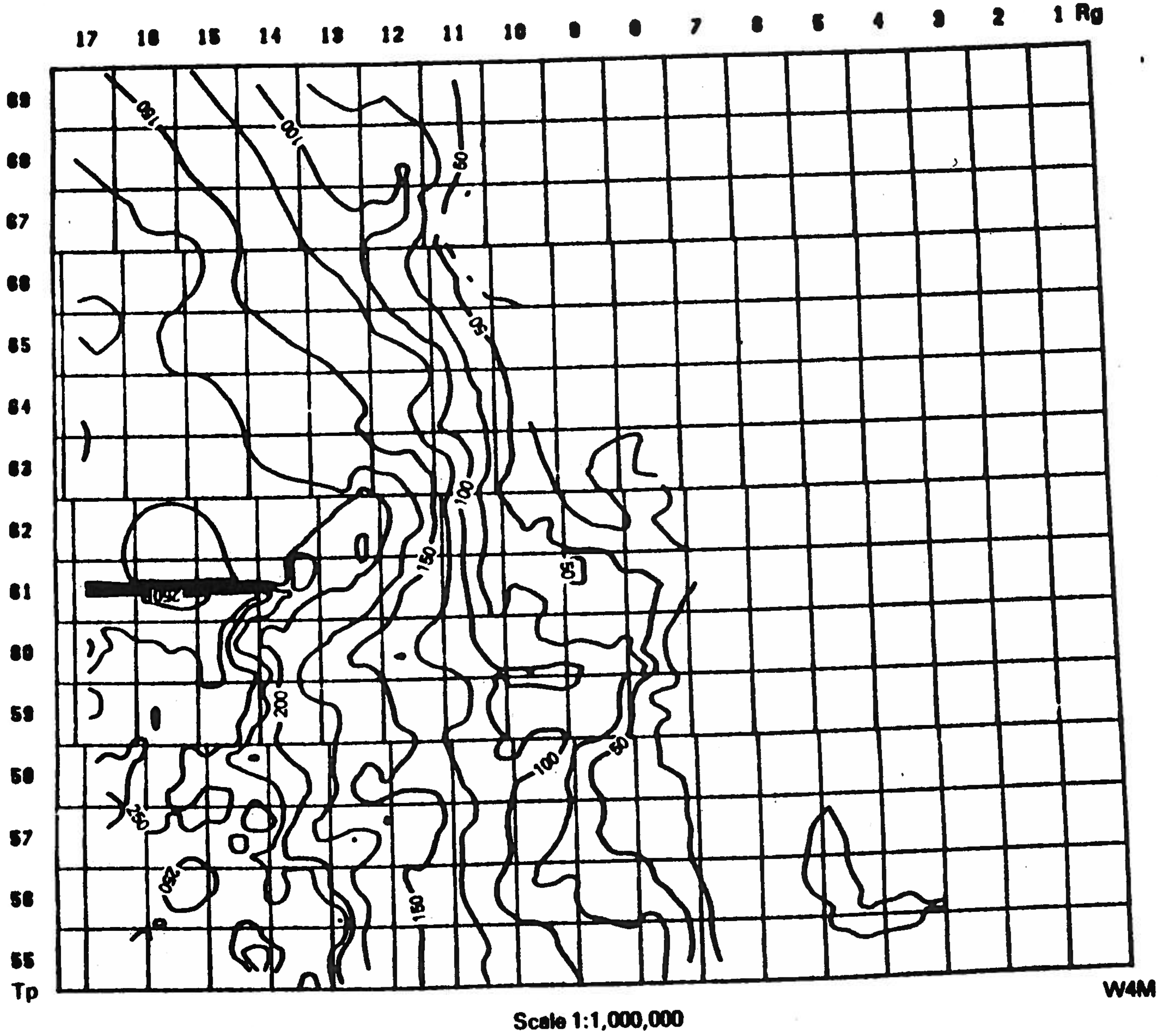


Figure 2-14 Isopach of Upper Devonian Ireton Formation aquitard (including Camrose Tongue), Cold Lake Study Area (Atlas map F-g-8)

erosion only remnants of these dolomites and anhydritic dolomites are preserved along the western margin of the Cold Lake Study Area as the Winterburn and Wabamun groups, respectively.

PRE-CRETACEOUS UNCONFORMITY

Rocks ranging in age from Late Fammennian (Late Devonian) to Early Neocomian (Early Cretaceous) are absent in the Cold Lake Study Area. During this interval of about 200 million years major events occurred in the Western Canada Sedimentary Basin. Porter et al. (1982) have presented a series of maps showing the restored depositional limits for the missing systems. Following deposition of the Upper Devonian, deposition during the Mississippian (approximately Lower Carboniferous) of the Kaskasia sequence was continuous across the Western Canada Sedimentary Basin. Following emergence and westward tilting of the craton there was a characteristic conspicuous westward shift in the limits of sediment accumulation during the Absaroka sequence, with the result that the restored depositional limits of the Pennsylvanian (approximately Upper Carboniferous), Permian and Triassic systems lie west of the Cold Lake Study Area. The network of epeirogenic arches and basins was present during deposition of the Absaroka sequence, as it had been for the previous Kaskasia and Tippecanoe sequences.

During Middle Jurassic time a major transformation took place in the Western Canada Sedimentary Basin as a result of the emerging Cordillera. There was a reversal in the direction of sediment transport so that the non-marine latest Jurassic and earliest Cretaceous sediments now found in the mountains and foothills belt were sourced from the west. In the Cold Lake Study Area Late Paleozoic, Early Mesozoic and Early Cretaceous erosion produced the surface on which Lower Cretaceous strata were deposited (Fig. 2-15; Atlas map J-g-9). In the western two thirds of this map the structure reflects that of the underlying Paleozoic units, whereas in

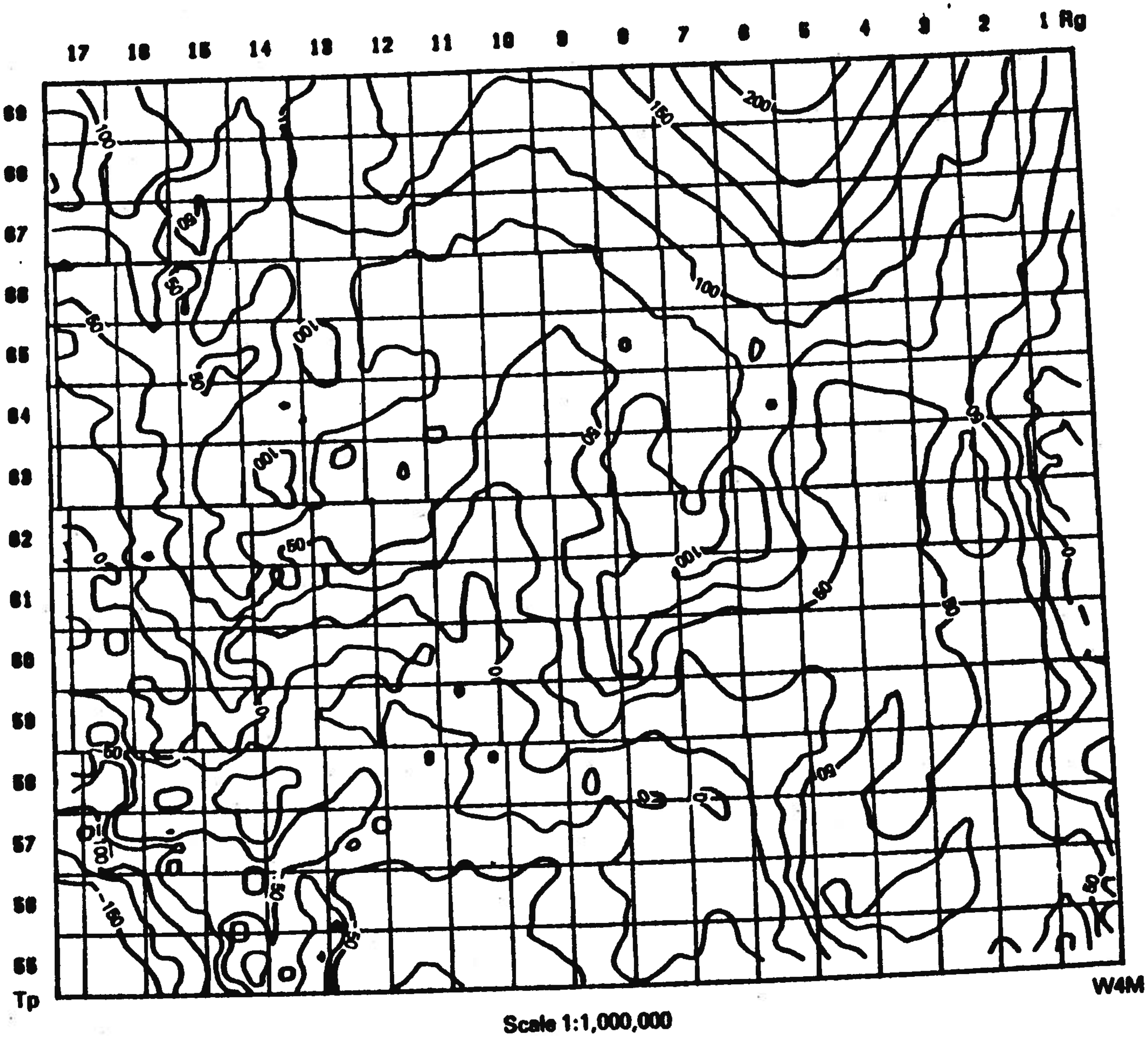


Figure 2-15 Structure contours on top of Pre-Cretaceous unconformity, Cold Lake Study Area (Atlas map J-g-9)

the eastern third the synclinal structure is related to solution of the underlying Middle Devonian Prairie Formation salt and subsequent collapse.

LOWER CRETACEOUS

The earliest Cretaceous synorogenic clastic wedge shed from the emerging Cordillera comprises the non-marine Blairmore Group in the mountains and foothills, and its marine equivalent (Mannville Group) in the Alberta Plains. At the base of the Mannville Group, the dominantly arenaceous McMurray Formation (and the equivalent Dina and Ellerslie formations) filled the hollows on the Pre-Cretaceous erosion surface but left some ridges uncovered, including a few in the Cold Lake Study Area (see Atlas map J-g-7). An extensive marine transgression, which had been encroaching during the earlier Cretaceous from both the Arctic Ocean and the Gulf of Mexico, covered most of the Western Canada Sedimentary Basin by Albian time, and according to Porter et al. (1982) appears to cooincide with a lull in the development of the Cordilleran orogenic belt. In the Cold Lake Study Area the first representatives of this marine transgression are the calcareous-arenaceous Ostracode Zone, and overlying Glauconitic sandstone and Wabasca sandstone. Throughout all except the southeast corner of the Cold Lake Study Area these arenaceous units are overlain by the thin (generally less than 10 m) Clearwater Formation shale (see Atlas map K-g-5). Mannville Group sedimentation is completed by a series of intercalated sandstones, siltstones and shales, variously called Grand Rapids Formation or Upper Mannville. Because of the extensive occurrence of natural gas, heavy oil and crude bitumen in the Mannville Group in the Cold Lake Study Area, many of the individual sandstones have been named and mapped. Distribution maps for some of these individual sandstones can be found in the Atlas, based on the ERCB Well Data File. An isopach of the Mannville Group (Fig. 2-16; Atlas map L-g-7) shows thinning over

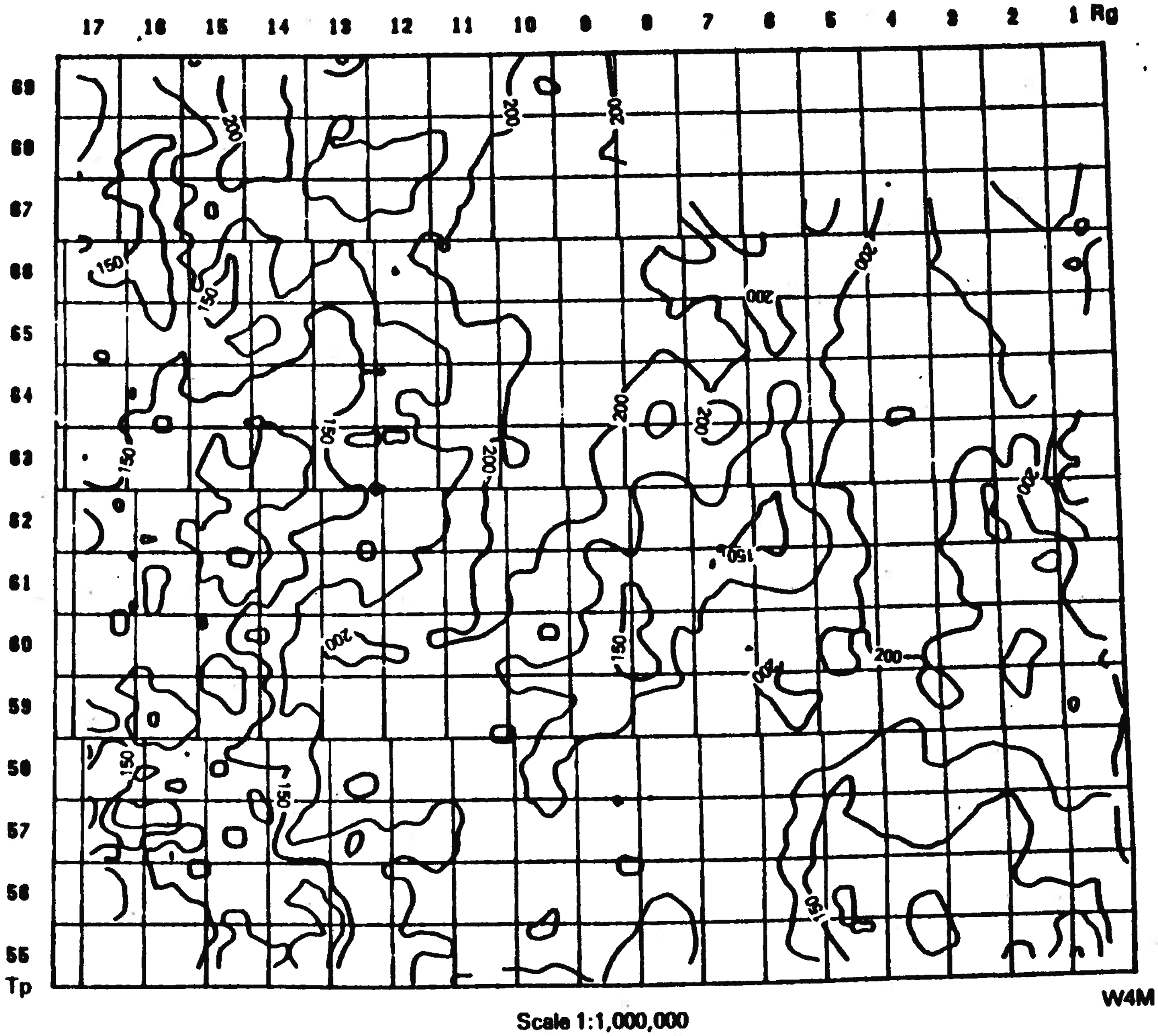


Figure 2-16 Isopach of Lower Cretaceous Mannville Group, Cold Lake Study Area (Atlas map L-g-7)

the Paleozoic highs and thickening in the inter-ridge regions.

Before completing this section on the Mannville Group, it is important to distinguish some stratigraphic terms used here, from hydrostratigraphic terms used elsewhere in this report. By common convention (Rudkin, 1964) the Mannville Group is divided into the Lower Mannville Group below the top of the Ostracode Zone, and the Upper Mannville Group from the top of the Ostracode Zone to the base of the overlying Colorado Group. Hydrostratigraphically, the Mannville Group comprises three units, the middle one being the argillaceous Clearwater Formation. Because the Clearwater Formation lies within the Upper Mannville Group (sensu stricto) we have termed the arenaceous units below the base of the Clearwater Formation as the "Lower Mannville" Group aquifer, and the arenaceous units above the top of the Clearwater Formation as the "Upper Mannville" Group aquifer.

The dominantly argillaceous, marine Colorado Group overlies the Mannville Group throughout the Western Canada Sedimentary Basin. In the Cold Lake Study Area the first unit of the Colorado Group is the Joli Fou Formation, which is a thin shale present throughout the area. It is overlain by the Viking Formation which comprises a few thin sandstones and intervening shales. The sandstones are absent in the northeast part of the study area and in a small region along the southern boundary (see Atlas map N-g-5). Because the Joli Fou Formation cannot be separated from the shales overlying the Viking Formation in the absence of arenaceous units within the Viking Formation, it is shown as absent (for example, see Atlas map M-g-3), although in fact it is present throughout the study area. The Viking Formation is overlain by a continuous sequence of shales stretching up into the Upper Cretaceous; the top of the Lower Cretaceous is defined as the base of the Fish Scale Zone, and figure 2-17 (Atlas map A-g-3) is an isopach of the Lower Cretaceous (from the base of the Fish Scale Zone to the Pre-Cretaceous unconformity). Structure contours at the base of the Fish Scale Zone show gentle dips to the

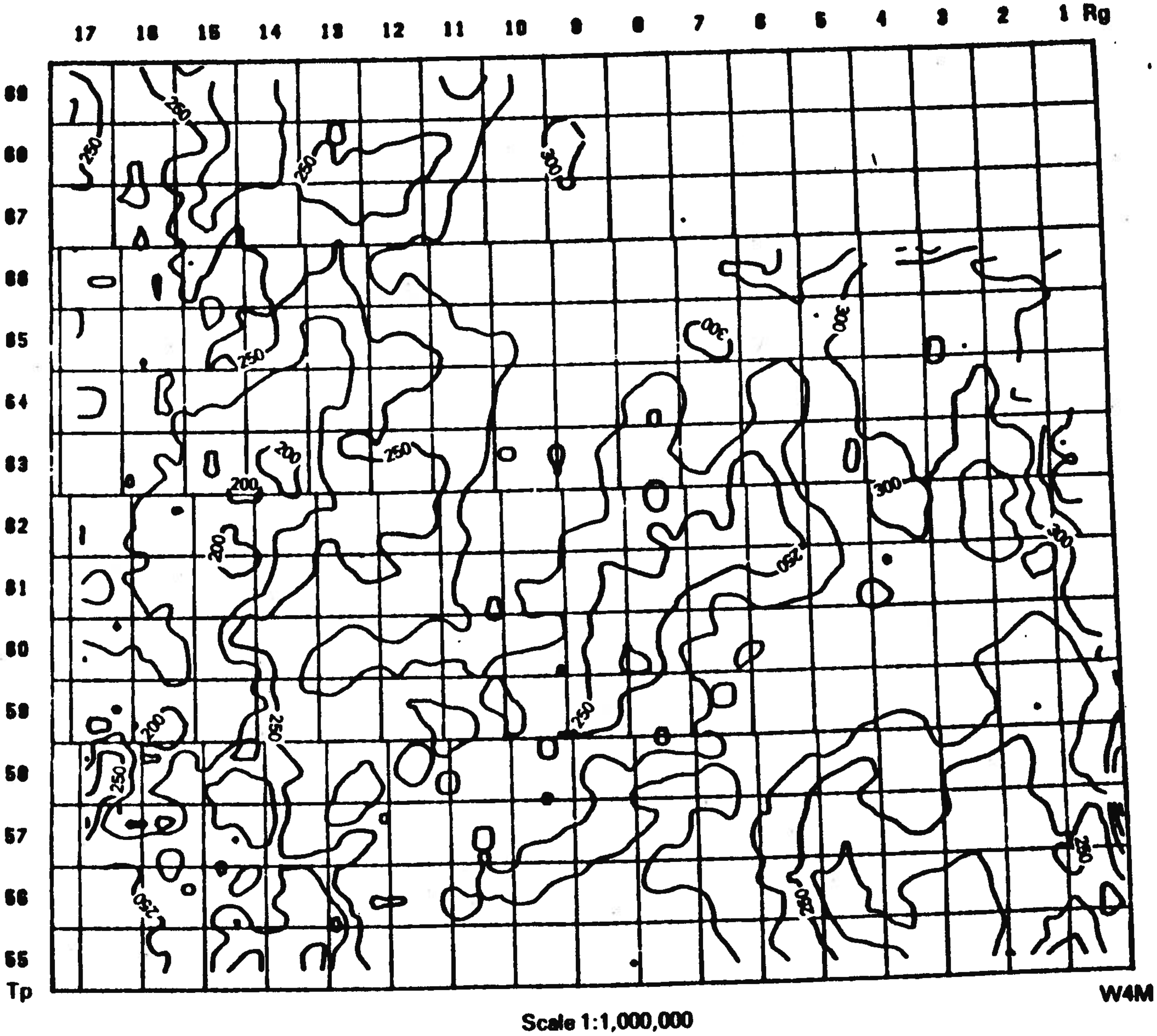


Figure 2-17 Isopach of Lower Cretaceous strata, Cold Lake Study Area (Atlas map A-q-3)

southwest except where synclinal structure is developed overlying the region of salt solution (see Atlas map 0-g-5).

UPPER CRETACEOUS

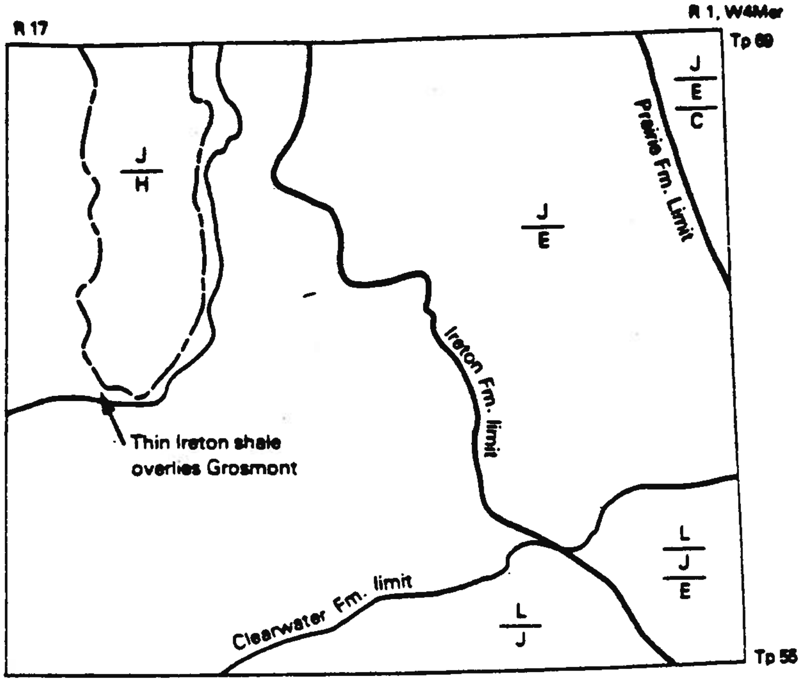
In the Cold Lake Study Area Upper Cretaceous strata consist of a rather monotonous sequence of shales from 36 to 453 m thick, which comprise the upper portion of the Colorado Group and the overlying Lea Park Formation and Belly River Group. Because of Tertiary and Recent erosion an isopach map of this stratigraphic unit (see Atlas map A-g-2) strongly reflects the bedrock topography map (see Atlas map 0-g-9). Structure contours on the top of the Second White Speckled shale, a marker zone within the Colorado Group, show a broad synclinal feature overlying the zone of salt solution (see Atlas map 0-g-7). The Lea Park Formation crops out in the northeast half of the study area and the Belly River Group in the southeast half (see Atlas map 0-g-4 for position of the boundary between these two units).

The remainder of Phanerozoic history in the Cold Lake Study Area is speculative. Certainly, Upper Cretaceous strata younger than the Belly River Group were once present across the area but have been subsequently removed by Tertiary and Recent erosion. As noted previously, probably at least 1 km of rocks have been removed due to this erosion (Hitchon, 1984) but how much of this thickness comprised Tertiary strata is unknown.

AQUICLUDE AND AQUITARD GEOMETRY

The following discussion is limited to those hydrostratigraphic units which are considered in detail elsewhere in this report; there will therefore be no discussion of hydrostratigraphic units below the base of the Middle Devonian Prairie Formation.

In hydrogeological studies it is important to determine the geometry of the aquitards and aquicludes, because the absence of these water-retarding hydrostratigraphic units allows juxtaposition of the aquifers. In the Cold Lake Study Area the Middle Devonian Prairie Formation halite is designated the basal aquiclude for the purposes of this study. Shale sequences which may act as aquitards include the Upper Devonian Ireton Formation and the Cretaceous Clearwater and Joli Fou formations and the Colorado Group. With the exception of the Colorado Group, which extends across the entire study area, the three aquitards and the basal aquiclude are discontinuous. Figure 2-18 shows the various regions of the Cold Lake Study Area where the absence of these aquitards and the basal aquiclude allows juxtaposition of aquifers. The most significant effects result from solution of the Prairie Formation halite and the presence of the Pre-Cretaceous unconformity. These effects act in combination in the northeastern corner of the study area where Lower Mannville Group arenaceous rocks rest unconformably on carbonates of the Beaverhill Lake Formation, which in turn rests on the Watt Mountain Formation; in the absence of the Prairie Formation, this latter unit then rests directly on Keg River Formation carbonates. Downdip from this northwest corner of the study area, absence of the Ireton Formation allows juxtaposition of the Lower Mannville Group and the Cooking Lake and Beaverhill Lake formations. In the southeast corner of the study area, however, where both the Clearwater Formation and the Ireton Formation are absent, "Upper Mannville" and "Lower Mannville" Group rocks are in contact with Beaverhill Lake Formation carbonates beneath the Pre-Cretaceous unconformity. Another region in which strata of vastly different ages come in contact is in the northwest part of the study area where the arenaceous Lower Mannville Group is in direct contact with the porous dolomites of the Grosmont Formation; this contact is broken in a U-shaped region around the Grosmont subcrop, where a thin sequence of Ireton shale overlies the Grosmont Formation.



Diagrammatic cross-section

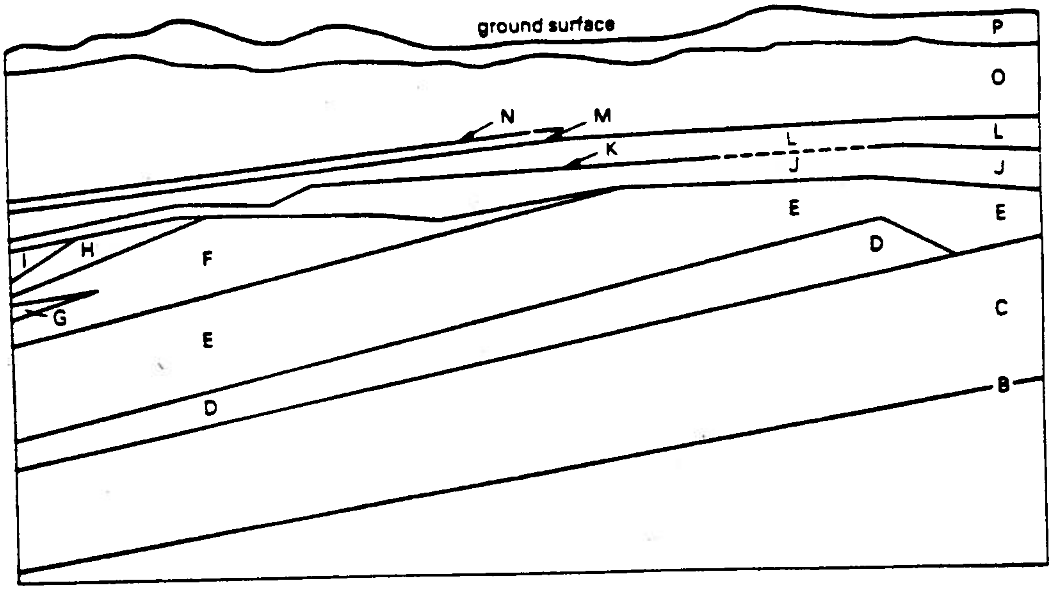


Figure 2-18 Map and diagrammatic cross-section of the Cold Lake Study Area showing regions where the absence of major aquitards and aquicludes allows juxtaposition of aquifers. Letters refer to standard hydrostratigraphic units in the Atlas

This review of the regional geology of the Phanerozoic section in the Cold Lake Study Area has addressed only the very broad geometric and lithological variations of the major stratigraphic units. Although detailed studies were not carried out, the information provided is sufficient background material for the following hydrostratigraphic evaluation. For reasons which will become apparent later in this Report, the Quaternary strata have been considered separately from the Phanerozoic.

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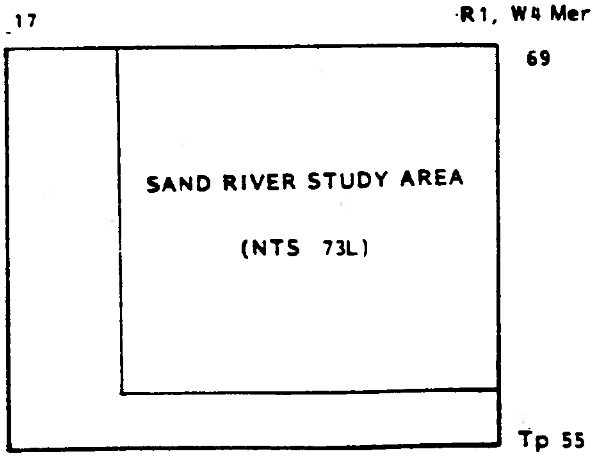
PREAMBLE

For a variety of reasons the regional geology of the Quaternary in the Cold Lake Study Area has been treated differently from the Phanerozoic. First, the Quaternary in that portion of the Cold Lake Study Area comprising topographic map NTS 73L (Sand River) map area is the subject of an unpublished M.Sc. thesis in the Department of Geology, University of Alberta, submitted by L.D. Andriashek; subsequently, it will be published as an ARC Report. Second, because of the length and detailed nature of the unpublished research undertaken by Mr. Andriashek it was decided to provide a fairly comprehensive review in Section 2 of this Report, in contrast to the broader overview of published information given for the Phanerozoic. Third, while the descriptions of Quaternary stratigraphy in the Sand River map area apply strictly to that NTS map sheet, the Atlas maps accompanying this Report show the extension of this stratigraphic information into the entire Cold Lake Study Area, based on work by Mr. Andriashek. Fourth, as will be evident in Parts 4, 5 and 6 of this Report, there are valid reasons for "uncoupling" flow in the Quaternary from flow in the Phanerozoic, and therefore a different treatment of the regional geology is justified. Finally, as a result of this "uncoupling" and the fact that potable groundwater in the Cold Lake Study Area is confined to Quaternary aquifers, a more detailed evaluation of the (unpublished) regional geology is justified. The figure below shows the relation of the Sand River map area to the Cold Lake Study Area.



COLD LAKE STUDY AREA

SECTION 2: QUATERNARY

PHYSIOGRAPHY OF THE SAND RIVER MAP AREA

Physiographically, the Sand River map area lies within the Eastern Alberta Plains and the Mostoos Hills Upland (Atlas of Alberta, 1969). The Mostoos Hills Upland lies in the northeast part of the map area at an elevation above 600 m. The Eastern Alberta Plains lies in the western and southern parts of the map area at an elevations below 600 m. The subdivision of these major physiographic units is shown in figure 2-19. Most of the map area is characterized by glacial terrain with flat to hummocky topography (Fenton and Andriashek, 1983). Outwash plains form a relatively small component of the physiography and are found mainly along the major meltwater channels. Extensive lacustrine plains are absent in the map area.

The map area includes numerous lakes that are connected by a poorly integrated drainage system. The largest of these include Cold Lake in the east, Muriel Lake in the south, Pinehurst, Seibert, Wolf, Touchwood and Spencer lakes in the central part, and Lac la Biche and Beaver Lake in the northwest (Fig. 2-19). Many of the lakes have clear water and sandy beaches, which make the area a favoured recreation site in the province.

Drainage is confined essentially to the Beaver River and the Sand River. The Beaver River, the larger of the two, drains eastward from Beaver Lake and forms part of the Churchill River drainage system. The Sand River drains south from its headwaters north of the map area and joins the Beaver River in the central portion of the map area.

For the convenience of geologic discussions, the two large physiographic units of the map area have been subdivided on the basis of relief, elevation and morphology (Fig. 2-19). The lowest of these physiographic units, the Beaver River Lowland Plain, is situated in

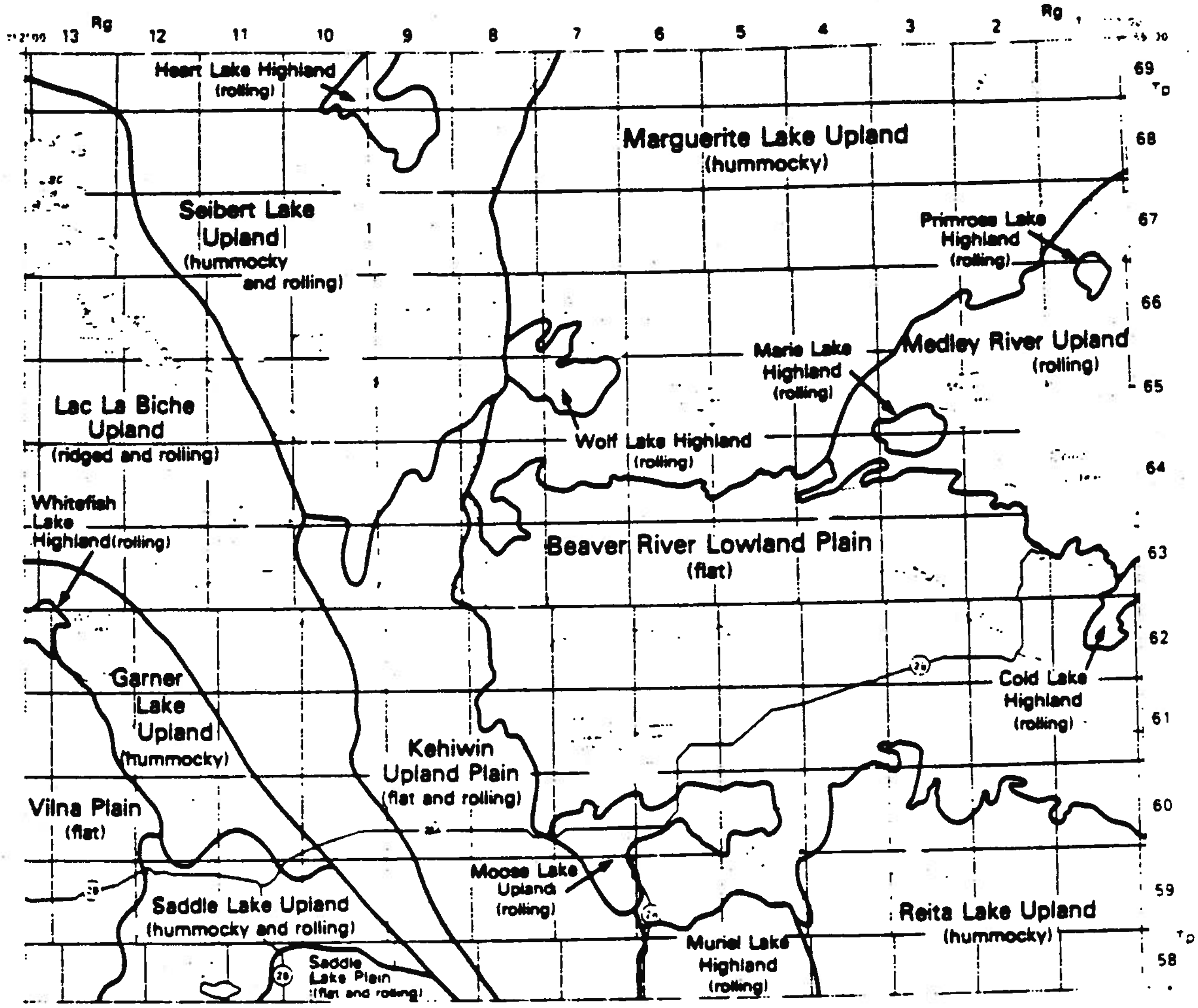


Figure 2-19 Physiography of the Sand River map area

the eastern part of the map area at an elevation generally less than 580 m. This unit is characterized by a flat to gently rolling till plain. The Beaver River drains eastward through the unit and locally fluvial or lacustrine plains are found adjacent to the river.

South of Cold Lake, along the northeastern margin of the Beaver River Lowland Plain, lies the Cold Lake Highland. This unit ranges in elevation from 580 m to about 670 m. The highland is characterized by high relief, rolling terrain, and forms an abrupt scarp along its southern edge.

The Medley River and Marguerite Lake Uplands form the northern margin of the Beaver River Lowland Plain. The Medley River Upland lies at an elevation between 580 m and 610 m and is characterized by gentle to high relief rolling terrain. The Medley River drains southward through this unit.

Lying within the Medley River Upland are two small but conspicuous physiographic units; the Marie Lake and the Primrose Lake Highlands. The Marie Lake Highland ranges in elevation from 610 m to about 650 m, and is characterized by high relief, rolling to hummocky terrain. The Primrose Lake Highland lies at an elevation ranging from 610 m to about 680 m and is characterized by terrain that forms a pronounced knob in the local topography.

The Marguerite Lake Upland ranges in elevation between 580 m to as high as 730 m in the north part of the map area. The unit is bounded in the west by the Sand River and in the east by the Medley River Upland. It is characterized by hummocky terrain with numerous wetlands. Within the Marguerite Lake Upland lies a smaller unit, the Wolf Lake Highland, which ranges in elevation between 640 m to about 730 m. It is characterized by ridged terrain in the northwestern part of the unit and by rolling terrain in the central and eastern part. The Wolf Lake Highland is very conspicuous as one approaches from the south.

The Reita Lake Upland forms the southeastern margin of the Beaver River Lowland Plain. The unit ranges in elevation from 580 m to about 700 m, and is characterized by moderate to high relief, with hummocky to rolling terrain. The unit is bounded in the west by a misfit channel, herein called the Muriel Lake Channel, that once drained southeast of Muriel Lake.

The Muriel Lake Highland lies west of the Reita Lake Upland. It ranges in elevation from 580 m to 800 m, and is characterized by rolling terrain. The unit is bounded by two misfit channels; the Kehiwin Channel in the west, and the Muriel Lake Channel in the east. The Moose Lake Upland lies northwest of the Muriel Lake Highland and forms the extreme southwestern boundary of the Beaver River Lowland Plain. This upland lies between an elevation of about 580 m and 610 m, and is characterized by rolling terrain.

The western boundary of the Beaver River Lowland Plain is defined by the Kehiwin Upland Plain. The unit lies at an elevation between 580 m and 640 m, and is characterized by flat to rolling, glacially streamlined terrain. The Beaver River drains eastward through the north part of this unit.

The Lac la Biche Upland lies west and north of the Kehiwin Upland Plain and ranges in elevation between 640 m and about 670 m, and is characterized by ridged to rolling, glacially streamlined terrain which is oriented in a northwest-southeast direction.

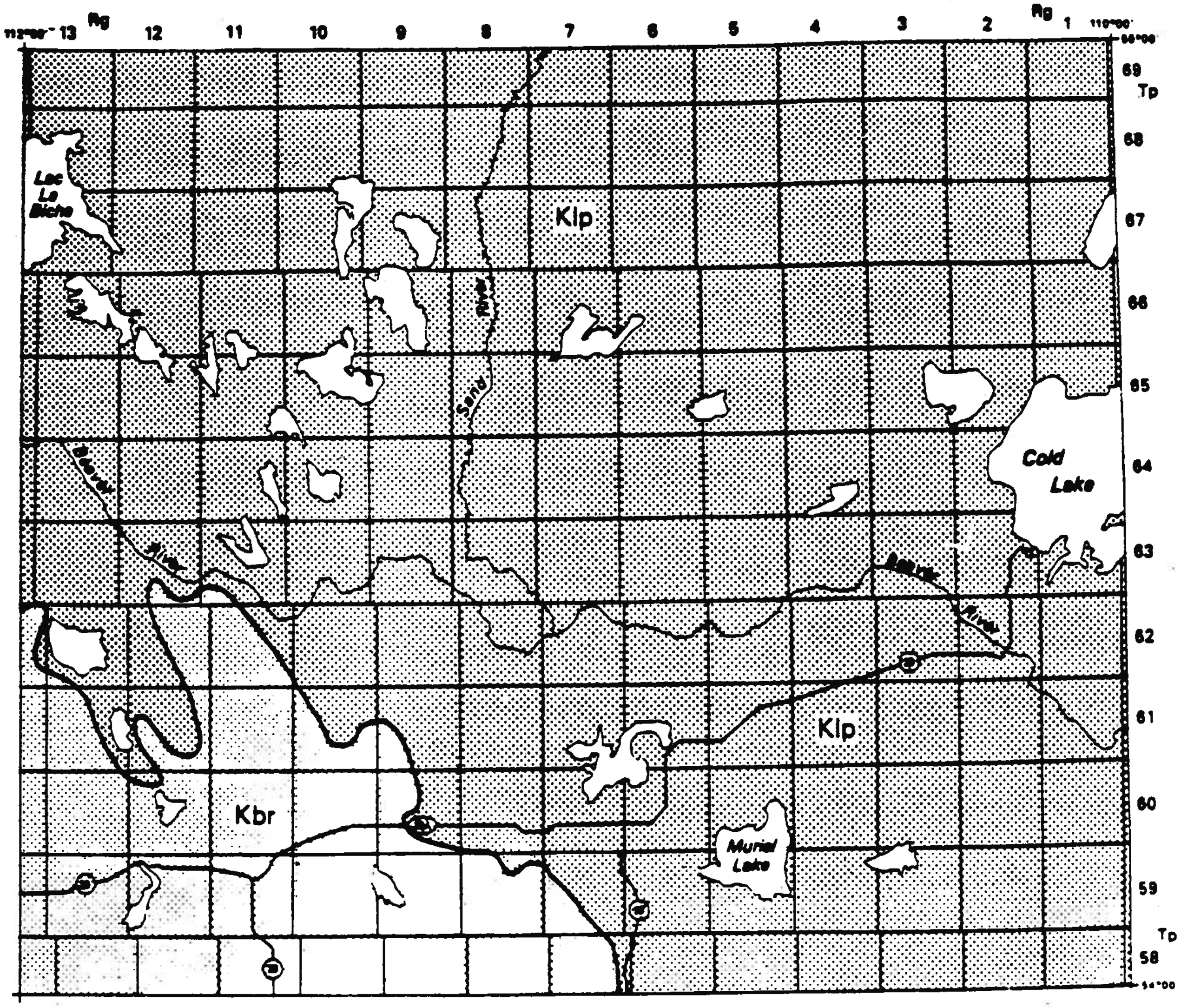
The Lac la Biche Upland is bounded along its southwestern margin by the Garner Lake Upland, and along its northeastern margin by the Seibert Lake Upland. The Garner Lake Upland lies at an elevation ranging between 610 m and 640 m and is characterized by high relief hummocky terrain, with the size of the individual hummocks decreasing southeastward from about 1 km^2 and 30 m high, to about 0.1 km^2 and 3 m high. Adjacent to the northwest part of the Garner Lake Upland lies the Whitefish Lake Highland, a unit characterized by high relief and ridged to rolling terrain. The unit ranges in elevation between 610 m and 670 m.

The Sand River forms the eastern boundary of the Seibert Lake Upland. The upland ranges in elevation from 610 m along its southern margin to as high as 760 m near Heart Lake, though generally it lies below 670 m. The upland is characterized by large-scale, high-relief features which form a hummocky to rolling terrain. In some places adjacent to the Sand River, the landforms have a glacially streamlined north-south orientation. The Heart Lake Highland is located within the north end of the Seibert Lake Upland. The unit ranges in elevation between 760 m and 850 m and is characterized by high relief rolling terain.

The southwestern corner of the map area is characterised by lower relief landforms with differences in morphology. These differences define two plains, the Vilna and the Saddle Lake plains, which are separated by a hummocky to ridged upland, the Saddle Lake Upland. The Vilna Plain lies southwest of the Garner Lake Upland and extends west of the map area. The unit lies at an elevation between 640 m and 670 m, and is characterized by flat to rolling, low relief terrain. It is bounded along its eastern margin by a scarp of the Saddle Lake Upland. The Saddle Lake Plain has a transitional boundary with the southeastern edge of the Saddle Lake Upland. The plain is characterized by flat to rolling, low relief terrain with a series of isolated ridged hummocks which have an east-west orientation.

BEDROCK GEOLOGY

Bedrock in the Sand River map area consists of two Upper Cretaceous stratigraphic units: the Lea Park Formation (originally described by Allan, 1918) which covers most of the map area, and the Belly River Group (originally described by Dawson, 1885) which overlies the Lea Park Formation in the southwest corner (Fig. 2-20).



from geological Map of Alberta, R. Green 1972

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Kbr	**BELLY RIVER FORMATION** grey to greenish grey, thick-bedded feldspathic sandstone; grey clayey siltstone, grey and green mudstone; concretionary ironstone beds; nonmarine
Klp	**LEA PARK FORMATION** dark grey shale, pale grey, glauconitic, silty shale with ironstone concretions; marine

Figure 2-20 Bedrock geology of the Sand River map area

Over most of east-central Alberta the upper portion of the Lea Park Formation consists predominantly of grey, marine shale which contains varying amounts of siltstones and sandstones, ironstone concretions, and bentonite layers (Hume and Hage, 1941; Shaw and Harding, 1949). The thickness of the formation ranges between 135 m and 245 m and thickens to the northeast "as a result of successive lensing-out of several deltaic sand members of the Belly River Formation" (Shaw and Harding, 1949, p. 488). In places, the upper portion has a yellow-brown color (Allan, 1918), but where it was recognized in the testholes in the Sand River map area, it is unoxidized and dark grey (5Y 3/1 Munsell color scale). The formation is believed to crop out along portions of the Kehiwin and Beaver River valleys, but in this study was recognized mainly from rotary and auger testhole samples, and electric log responses. Dry auger flite samples of the shale have a waxy appearance when cut with a knife, and commonly contain inclusions of lighter, buff-colored, non-calcareous clay. The formation is generally soft and poorly lithified, and has a brittle-to-crumbly structure on the auger flites. The upper part of the formation is relatively easy to penetrate with an auger drill. This is one reason why the formation is difficult to differentiate from unlithified Pleistocene deposits of fine-grained lacustrine or fluvial sediment.

The top of the Lea Park Formation is gradational and conformable with the overlying Belly River Group. The marine shale of the Lea Park Formation interfingers with the deltaic sandstones of the Belly River Group and the contact is described as "stair-stepped" (Shaw and Harding, 1949 p.488). In the east-central part of Alberta the Belly River Group consists of an interfingering succession of marine shales and deltaic sandstones that are differentiatied into a number of members (Shaw and Harding, 1949). As an undivided unit, the Belly River Group consists of " a series of gray, to brownish gray, to greenish gray, argillaceous, bentonitic sandstones closely interbedded with brownish gray to gray, carbonaceous shales and silts. Thin carbonaceous layers are characteristic of the normal facies. Thin coal seams characterize the continental-to-marine transition facies." (Shaw and Harding, 1949, p. 491). The unit is about 210 m thick near Edmonton but pinches out to the northeast in an interfingering, conformable contact with the underlying Lea Park Formation.

In this study, sandstones of the Belly River Group were not recognized in outcrop nor within any of the auger testholes. The difficulty in recognizing the Belly River Group in the west is attributed firstly, to its gradational contact with the Lea Park Formation, and secondly, to the similarilty of the petrologic composition of the sandstones compared with the sandstone composition of the overlying unit 1 of the Empress Formation. As well, glacial thrusting has displaced large masses of sandstone, shale, and coal of the Belly River Group in the southwest corner of the map area, and it is difficult to be certain if the unit is in-situ when encountered within a testhole, or, if it is an erratic. This is particularily a problem in the Kikino and Beverly valleys where as much as 60 m of the Belly River Group are known to have been glacialy displaced and deposited within the valleys.

Because of the difficulty in establishing the contact between the Lea Park Formation and the Belly River Group in the Sand River map area, the contact that is shown in figure 2-20 is based on the boundary on the Geology Map of Alberta (Green, 1972). This contact is believed to dip to the southwest with a slope of about of about 4 m/km.

BEDROCK TOPOGRAPHY AND BURIED VALLEYS

INTRODUCTION

During the Laramide orogeny in western Alberta uplift produced a regional slope which drains northeast through the plains of central Alberta. The drainage and erosion which followed from the Eocene through to the Pliocene, removed a significant amount of Upper Cretaceous rocks, forming deep, broad valleys with intervening bedrock uplands. In places, particularily in the western and northern parts of the province, these uplands were mantled by thick fluvial gravel. The extent of this gravel-cap was minor to non-existant in the east-central part of the province, and the erosion produced large scale landforms of exposed soft Cretaceous bedrock. Within the map area, the tops of these bedrock landforms are mapped at an elevation as high as 650 m in the north-central part (see Atlas map P-g-2). Drainage from these uplands was channeled into two major bedrock valleys, the Beverly and Helina valleys. The bedrock surface lies at its lowest elevation within the Helina Valley, about 425 m along the eastern edge of the map area. During Pleistocene time, meltwater from a number of glacial advances eroded additional valleys into the bedrock surface. Glacial and stratified sediment now masks most of this underlying bedrock topography.

BURIED PREGLACIAL VALLEYS

The major preglacial valleys in the map area were formed by rivers which flowed east and northeast from the Rocky Mountains. These valleys are generally very broad, with low gradients and low walls, suggesting a lengthy period during which time downcutting and meandering occurred. Sediment on the floors of these valleys consists of sand or gravelly sand which is composed predominantly of quartzite and chert clasts derived from both the Cordillera and local bedrock. Granitic clasts from the Canadian Shield are absent. Two major buried preglacial valleys and their associated tributaries are present within the map area: the Helina and the Beverly valleys.

Helina Valley and Tributaries

The Helina Valley (Yoon and Vander Pluym, 1974) is the largest buried valley in the map area (see Atlas map P-g-2). It enters the northwestern corner of the map area west of Lac la Biche, trends essentially southeast to Tp 63, R 8, and then swings northeast to Tp 65, R 4, to exit beneath Cold Lake and join the Hatfield Valley in Saskatchewan (Whitaker and Pearson, 1972). The contour lines show that the central and east segment of the valley slope northeast, whereas the northwest segment slopes northwest (see Atlas map P-g-2). The valley is relatively wide, ranging from about 8 km to as much as 12 km. The depth ranges from about 35 m to 65 m but averages about 50 m. Locally, both depth and width are difficult to determine, primarily because the valley walls are poorly defined and the slopes are shallow. The northeast sloping portion of the valley floor falls 40 m in elevation, over about 150 km, yielding a relatively shallow gradient of about 0.25 m/km. Three tributaries of the Helina Valley are recognized in the map area; the Imperial Mills, the Sinclair, and the Vermilion valleys (see Atlas map P-g-2). The Imperial Mills Valley enters the north part of the map area in Tp 69, R 12, and trends south for a distance of 40 km to join the Helina Valley in Tp 65, R 11. The north end of the valley extends into the Winnefred Lake map area where it is believed to join the buried Wiau Valley (Gold, pers. comm.). The width of the valley is estimated to range between 4.5 and 6.5 km but there are insufficient data along the east flank to derive an accurate figure. The depth of the valley could not be determined. A broad depression in the present land surface near the settlement of Imperial Mills is the only topographic expression of the valley.

The Sinclair Valley is located east of Wolf Lake in the northeastern corner of the map area. The valley enters the northern part of the map area in Tp 69, R 6, and slopes southeast for a distance of about 45 km to join the Helina Valley in Tp 65, R 4. The width of the valley ranges between 8 and 10 km, and the depth between 40 and 70 m. The gradient at the southern end of the valley is calculated to be about 1 m/km.

The Vermilion Valley (Carlson and Currie, 1975), is considered to be a tributary of the Helina-Hatfield Valley system in the map area, although the junction of these two valleys has not been mapped. The valley enters in the southeast corner and slopes northward to Tp 61, R 1, where it exits the map area. The valley is believed ultimately to join the buried Hatfield Valley in Saskatchewan. The width of the Vermilion Valley is estimated to range between 3 and 5 km, and the depth is at least 35 m. Yoon and Vander Pluym (1974) calculated a gradient of 1.7 m/km at the head of the valley in the plains region southwest of the map area (Carlson and Currie, 1975).

Beverly Valley and Tributaries

The Beverly Valley is the second largest buried valley in the map area (see Atlas map P-g-2). The valley enters from the west (Carlson, 1967) and slopes essentially northeast to Moose Lake. From there, the valley trends north to Borque Lake in Tp 65, R 5, where it merges with the Helina Valley. The width of the valley ranges between 5 and 8 km, and the depth between 45 and 60 m. The valley is generally narrower and has steeper walls than the Helina Valley. The elevation of the floor of the valley decreases about 60 m from west to east, with a gradient of about 0.5 m/km.

Three preglacial tributaries of the Beverly Valley have been recognized in the map area: the Vegreville, the Kikino, and the St. Paul valleys (see Atlas map P-g-2). The Vegreville Valley enters from the southwest and extends northward to join with the Beverly Valley in Tp 58, R 11. In this segment, the Vegreville Valley begins to merge with the Beverly Valley and thus is wide and poorly defined. In the southern part of the map area Farvolden (1963) describes the valley as having narrow, steep banks and a gradient of 1.3 m/km. Yoon and Vander Pluym (1974) later calculated the width to range between 2.5 and 6 km. Within the map area drill records indicate a valley depth of about 30 m.

The Kikino Valley joins with the Helina Valley in the northwest, and extends southeast to join with the Beverly Valley in Tp 59, R 13. The Kikino Valley is narrower than the Beverly Valley and, except for the area north of Bonnie Lake where the width ranges between 6 and 8 km, the average width is between 3 and 5 km. The depth of the valley averages about 30 m (Yoon and Vander Pluym, 1974) but deepens to about 45 m near the confluence with the Beverly Valley, and to about 90 m near Whitefish Lake. In the northwest, the valley slopes gently to the northwest with a gradient of about 0.5 to 1 m/km (Yoon and Vander Pluym, 1974; Carlson, 1977). The southeast segment appears to slope southeast towards the Beverly Valley.

The St. Paul Valley consists of two branches which merge to join with the Beverly Valley at Tp 59, R 9 (see Atlas map P-g-2). Both branches are relatively narrow and shallow, ranging in width between 1 and 1.5 km, and in depth about 25 m. The west branch has a relatively steep gradient estimated to be about 3 m/km.

BURIED GLACIAL VALLEYS

Although segments of the large preglacial valleys probably functioned as drainage systems for glacial meltwater, there are a number of buried valleys in the map area that are believed to have been formed by rivers in contact with, or near to, a glacier margin. These valleys are recognized by the following features: (1) most, though not all, are oriented in a direction that is semi-perpendicular to the regional drainage (that is, they are oriented in a southeast or east direction, rather than towards the northeast); (2) the valleys are generally narrow and have steep walls, indicating that they served as a drainage system for a short period of time; and (3) stratified sediment on the floor of the valleys contains abundant clasts derived from the Canadian Shield, which indicates a Laurentide glacial source.

At least four major buried glacial valleys have been recognized, all within the eastern part of the map area. These are: the Moore Lake Valley which lies west of Cold Lake in Tp 64, R 3 to 4, the Big Meadow Valley, the Holyoke Valley, and the Bronson Lake Valley.

The Moore Lake Valley extends from Tp 63, R 5, where it joins the Beverly Valley, northeast about 30 km to Tp 65, R 5, where it joins the Helina Valley. The north end of the valley is relatively narrow, about 2 to 3 km wide, but it broadens in the west. Most of the valley lies at a higher elevation than the Beverly Valley and averages about 35 m in depth. The western end however is very deep, at least 60 m, and lies at a lower elevation than the nearby preglacial Beverly Valley.

The Big Meadow Valley lies within the eastern portion of the Beaver River Lowland Plain and joins with the Beverly Valley in Tp 62, R 5, at essentially the same junction as the Bronson Lake Valley. From here the Big Meadow Valley slopes essentially east to Tp 62, R 2, at which point it divides; one branch swings northeast to join the Helina Valley beneath Cold Lake, and the other branch continues east, probably joining the Vermilion Valley in Saskatchewan. The valley is relatively narrow, with an average width ranging between 1 and 1.5 km at the west end, but it widens to about 3 km near the junction with the Helina Valley. The depth ranges between 15 and 25 m. The data are inconclusive to determine the gradient and paleo-flow direction. The Bronson Lake Valley extends about 55 km southeast from its junction with the Beverly Valley in Tp 62, R 5. It appears to intersect the Vermilion Valley, and then continues east into Saskatchewan (Whitaker and Pearson, 1972; Christansen and Whitaker, 1974). The width of the valley narrows from about 3 km in the central segment to about 1.5 km near the junction with the Beverly Valley. The depth of the valley ranges between 30 and 43 m, and within the map area the estimated gradient is about 1.3 m/km to the northwest, that is, towards the Beverly Valley.

The Holyoke Valley is believed to originate beneath Muriel Lake in Tp 59, R 5, and extends southeast approximately 38 km to Tp 58, R 3, where it exits the map area. It is believed that it merges with the preglacial Vermilion Valley beneath Frog Lake in Tp 57, R 2. The width is estimated to range between 1 and 2 km, and the depth between 15 and 20 m. There is a paucity of data for the valley, and the gradient could not be determined.

QUATERNARY STRATIGRAPHY

INTRODUCTION

The Quaternary stratigraphy of the map area was completed in two stages. Stage 1 was initiated by the Alberta Geological Survey in 1976 and focused on the 1:250,000 Sand River map area (NTS 73L). The study of this map area utilized numerous sources of data, including analytical results of samples collected by the Alberta Geological Survey. Consequently, the interpretations of stratigraphic units carry a fairly high degree of confidence. The final drafting of the structure maps were also initiated during stage one. Stage 2 was initiated during 1983-84 and focussed on roughly a four-township perimeter around the Sand River map area. This includes parts of the Tawatinaw, Edmonton, and Vermilion 1:250,000 map areas. In effect, Stage 2 was carried out to allow completion of the regional geology of the Cold Lake Study Area. The stratigraphic data for interpretations of this perimeter consisted almost entirely of borehole data (E-logs and lithologs) from groundwater wells. Analytical data was not available. Thus, the interpretations of the stratigraphy of the perimeter carry a much lower degree of confidence. Special mention will be made of those areas where the units in the Sand River map area have been reinterpreted, because of new information from the perimeter study.

In this report the lithostratigraphy of the Quaternary deposits in the Cold Lake Study Area is defined on the basis of that in the Sand River map area, and the stratigraphic units are shown in Table 2-3. The map area is an easily accessible area in Alberta where the Quaternary sequence is diverse and well preserved. The sequence is very thick (>50 m), but only the upper 10 m or so is exposed. Consequently, much of the stratigraphy defined here relies on subsurface data. The primary source of data consists of lithologs and

Table 2-3 Quaternary stratigraphy of the Sand River map area

Formation	Description	Range in surface elevation (m)	Average and (maximum) thickness (m)	Distribution in map area
Post Glacial and Recent Deposits	Stratified clay, silt, sand, gravel of undifferentiated fluvial, lacustrine or eolian origin		< 5	Discontinuous surface veneer
Grand Centre Formation	Glacial sediment, very coarse sand fraction rich in igneous and metamorphic rock fragments; poor in quartz and carbonate fragments	850-530	<30 - (65)	Extensive throughout
Vilna Member	Clayey glacial sediment (till), commonly with incorporated masses of glacially displaced sediment	700-550	<20 - (40)	Confined to the west
Kehiwin Lake Member	Sandy glacial sediment (till), overlain by stratified sand and gravel in places	850-590	30 - (55)	Extensive in the centre and southwest
Reita Lake Member	Clayey sand glacial sediment (till)	790-550	<10 - (65)	Extensive in the east
Hilda Lake Member	Clayey glacial sediment (till), commonly with incorporated masses of glacially displaced sediment	630-530	<10 - (40)	Discontinuous in the east
Sand River Formation	Stratified sand and gravelly sand, minor silt and clay; undetermined glaciolacustrine or glaciofluvial origin	660-530	<10 - (25)	Extensive in the centre
Marie Creek Formation	Glacial sediment (till); very coarse sand fraction rich in carbonate rock fragments			
Unit 2	Sandy glacial sediment (till)	675-510	<20 - (45)	Absent in northwest and southwest
Unit 2	Clayey glacial sediment (till)	620-500	< 5 - (25)	Confined to the east-centre
Ethel Lake Formation	Stratified silt and clay, minor sand and gravel; glaciolacustrine origin	640-510	<10 - (25)	Discontinuous in the east-centre
Bonnyville Formation	Glacial sediment (till); very coarse sand fraction rich in quartz fragments and poor in igneous and carbonate fragments			
Unit 2	Glacial sediment (till); very sand in eastern two thirds of Sand River map area, less sandy in west	650-490	20 - (35)	Extensive throughout
Unit 1	Clayey glacial sediment (till), overlain by stratified sediment in some places	650-515	20 - (65)	Continuous in segments of buried valleys
Muriel Lake Formation	Stratified sand and gravel of glaciofluvial origin	595-490	10 - (55)	Extensive in the east-centre
Bronson Lake Formation	Clayey glacial sediment (till) mixed with clay of undetermined origin	550-490	10 - (30)	In segments of buried valleys
Empress Formation	Stratified sediment overlying bedrock and underlying lowermost glacial sediment (till)			
Unit 3	Stratified sand and gravel, contains clasts derived from Canadian Shield; glaciofluvial origin	600-480	<10 - (70)	In segments of buried valleys
Unit 2	Stratified silt and clay; undifferentiated fluvial or lacustrine origin	580-470	<10 - (45)	In segments of buried valleys
Unit 1	Stratified sand and gravel, composed primarily of chert and quartzite derived from the Cordillera; preglacial fluvial origin	590-455	10 - (40)	On preglacial valley floors

analyses of about 2500 samples collected from 110 testholes drilled by the Alberta Geological Survey (Alberta Research Council) in 1976 and 1977 (see Atlas map P-g-1). The samples were collected at one-metre intervals from a continuous-flite dry auger, which was capable of penetrating to a depth of 60 m. A secondary source of stratigraphic data was provided by Alberta Environment from their groundwater and buried channel investigations in the Sand River map area. These data consist of excellent quality electric logs, lithologs, and samples collected from drill cuttings and sidewall sampling. Many of these sidewall samples were analysed by Gold (1978) during his study of the Quaternary stratigraphy in the buried channels in the Sand River map area, and much of this analytical data was used during this present study. Testhole data from water-well drillers also proved to be useful in correlating the stratigraphic units. These data consist of drillers' lithologs and, in some places, electric logs. Electric logs supplied by Chorney Drilling and Elk Point Drilling are the highest quality and most useful. Oil company geophysical logs provided the least useful source of stratigraphic data, and generally are only suitable for determining the bedrock contact. In some of the structure testholes, however, the logs are of sufficient sensitivity, and extend far enough above the bedrock contact, that within the Quaternary succession stratigraphic units could be identified and correlated. The following sections of this report deal with the detailed stratigraphy, lithology, distribution and thickness of the individual stratigraphic units shown in table 2-3, as well as methods of differentiation from other Quaternary stratigraphic units, the nature of their contacts and their origin. Structure contour and isopach maps for each formation and some individual units can be found in the Atlas.

EMPRESS FORMATION

The Empress Formation is recognized within most of the major buried valleys in the Sand River study area. The name of the unit was originally proposed as the Empress Group by Whitaker and Christiansen (1972, p. 353) to include the "stratified gravel, sand, silt, and clay of fluvial, lacustrine, and colluvial origin that overlies marine Cretaceous and nonmarine Tertiary bedrock and underlies glacial till of Quaternary age in southern Saskatchewan and adjoining areas of Alberta". The name is derived from the town of Empress, Alberta and the reference section for the Group is along the east bank of the South Saskatchewan River Valley (LSD 13, Sec 9, Tp 22, R 29, W 3 Mer). The name has been changed to the Empress Formation for reasons of consistency in naming of geologic units (Andriashek, 1985). There are no outcrops of the Empress Formation in the map area, but drill records indicate three lithologically distinct units that can be mapped within the formation: unit 1, a basal sand and gravel deposit containing clasts derived only from the Cordillera and local bedrock; unit 2, a middle clay deposit with minor sand and gravel beds, and unit 3, an upper sand and gravel deposit called glacial sand and gravel with clasts derived from the Canadian Shield.

Unit 1: Preglacial Sand and Gravel

Description of Unit

Sand and gravel of unit 1 of the Empress Formation are found primarily on the floors of the buried Helina and Beverly valleys and, within some of their tributaries (see Atlas map P-g-4). This unit consists of clasts derived from either the Cordillera, or from the local bedrock sandstone, and which were deposited by rivers flowing from the west. The unit generally consists of a relatively thin basal gravel overlain by sand, or gravelly sand of varied thickness. The gravel consists primarily of well-rounded light colored quartzite and dark colored chert clasts. Granitic and metamorphic clasts from the Canadian Shield are absent. The sand is characterized by a salt-and-pepper appearance due to the abundance of light colored quartzose and dark colored chert grains; it is generaly medium-grained and the deposits are moderately well sorted and compact. Commonly, the sand has an unoxidized grey color (5Y 5/2); in a few places where it is oxidized, it has a pale olive color (5Y 6/4).

Distribution, Extent and Thickness

Unit 1 lies extensively within the buried Helina, Beverly and Kikino valleys (see Atlas map P-g-2). Note that the initial interpretation shows a wide distribution of unit 1 along the western segment of the Helina Valley, whereas the data along the perimeter area shows that unit 1 is confined to a narrow width along the western segment. The only large area where unit 1 is considered to be absent in the preglacial valley system is within the Beverly Valley in Tp 59, R 14 to 15 (see Atlas map P-g-3). Here, unit 1 is believed to have been eroded by glacial thrusting. Drill records from the Imperial Mills , Sinclair, and Vermilion valleys are sparse, but do indicate that stratified sediment also lies on the valley floors. This sediment is interpreted to consist primarily of unit 1 sand, with little or no gravel. In that portion of the buried Kikino Valley near Bonnie Lake in Tp 60, R 13, the lower stratigraphic sequence consists of a thin basal gravel, overlain by a thin clay unit containing coal layers which, in turn, is overlain by a thick (>50 m), dense sand unit. This thick sequence of sand and clay was initially interpreted to be unit 1. However, palynological evidence indicates that this sequence likely represents a displaced block of the Belly River Group which was probably glacially thrust over the top of unit 1 gravel. The top of unit 1 ranges in elevation from as high as 590 m along the southern flank of the Beverly Valley in the west, to as low as 455 m along the eastern segment of the Helina Valley. The thickness of unit 1 is varied (see Atlas map P-g-4). In places, where the unit is especially thick (>15 m), it generally consists of medium-grained sand that overlies a relatively thin basal gravel.

Differentiation from other Units

Sand and gravel of unit 1 are easily differentiated from the underlying shale of the Lea Park Formation. In the southwest corner of the study area where unit 1 overlies sandstone and shale of the Belly River Group, the gravel can be easily differentiated from both the sandstone and shale beds. However, where unit 1 is composed mainly of sand, the deposits may be similar to the sandstone beds of the Belly River Group and detailed petrologic or palynologic studies are necessary to differentiate these two stratigraphic units. Where unit 1 is overlain by sand and gravel of unit 3, the two are differentiated by their composition; unit 1 is composed mainly of quartzite and chert clasts, whereas unit 3 is composed of granitic clasts derived from the Canadian Shield.

Nature of Contacts

Unit 1 deposits lies unconformably on the surface of the Lea Park Formation and Belly River Group. This contact is easily recognized on electric logs (Fig. 2-21, testhole E1720). The contact is more difficult to recognize in those places where unit 1 sand overlies sandstone of the Belly River Group. The upper contact of unit 1 with the overlying units is variable. In places along the major buried valleys the top of unit 1 is conformably overlain by clay of unit 2 of the Empress Formation. Where unit 2 clay is absent, and where unit 3 sand and gravel of the Empress Formation directly overlies unit 1, the contact is generally poorly defined. Where both units 2 and 3 are absent, unit 1 is commonly disconformably overlain by till, and the contact is generally sharp.

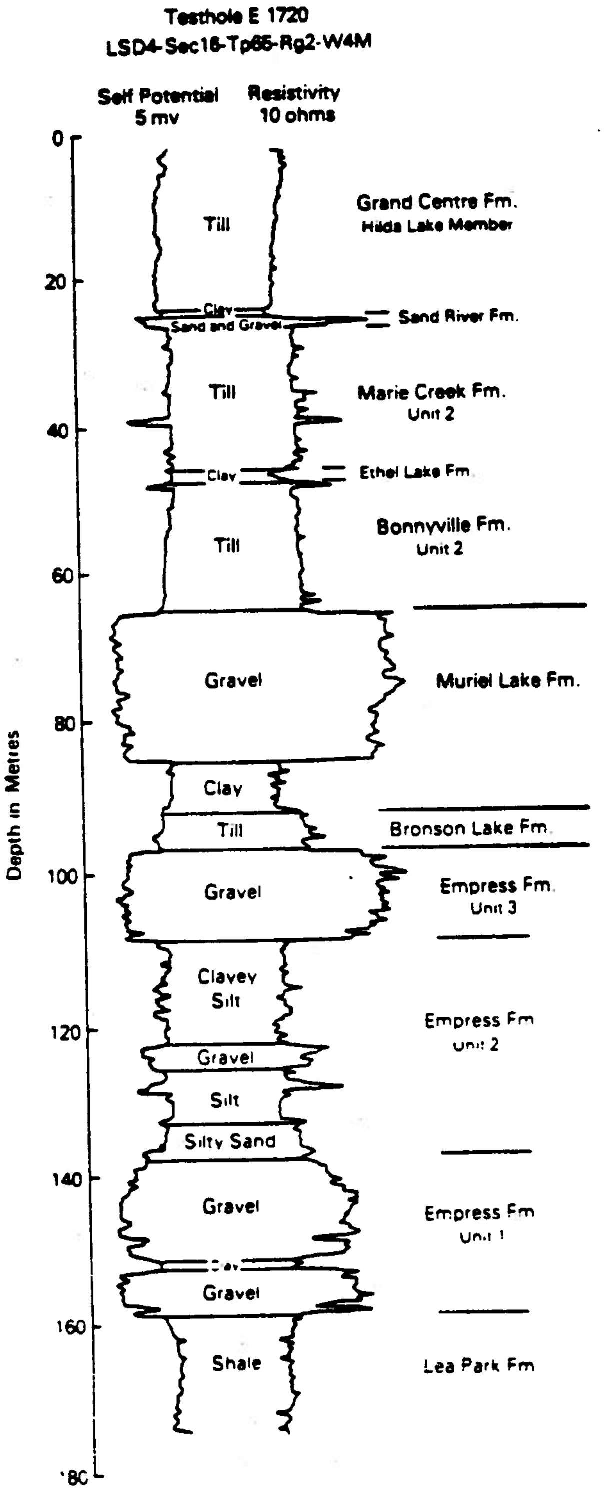


Figure 2-21 Typical electric log response of the Empress Formation. Alberta Environment testhole E 1720 (LSD 1, Sec 6, Tp 65, R 2, W 4 Mer)

Unit 2: Silt and Clay, Minor Sand and Gravel

Description of Unit

Unit 2 of the Empress Formation consists of unoxidized, dark grey silt and silty clay which lies primarily within segments of the major buried valleys. Drill records describe the unit as laminated or finely bedded. In the northeast part of the study area between Tp 64 and 66, R 2 and 5, (see Atlas map Q-g-7, cross-section E1-E1'), glacial sand and gravel are commonly interbedded with the clay.

Distribution, Extent and Thickness

Unit 2 is mapped within only segments of the buried Helina and Beverly valleys, but is believed to be extensive within the Imperial Mills Valley (see Atlas map P-g-5). For the most part the unit is contained almost entirely by the valley walls. The top of the unit ranges in elevation from as high as 580 m in a small deposit in the southwest portion of the Beverly Valley, to as low as 470 m in the western end of the Helina Valley. Unit 2 deposits exhibit a wide range in thickness, varying from less than 5 m to as much as 45 m (see Atlas map O-g-7, cross-section E2-E2', testhole E831).

Differentiation from other Units

Clay of unit 2 is easily differentiated from sand and gravel of either units 1 or 3 of the Empress Formation (Fig. 2-21). In those places where unit 2 lies directly on soft bedrock shale the differentiation is more difficult. Unit 2 clay is differentiated from other silt and clay deposits, such as those of the Muriel Lake, Ethel Lake and Sand River formations, on the basis of stratigraphic position. Clay of unit 2 may, however, be difficult to differentiate from clay of the Bronson Lake Formation, which directly overlies unit

2 in places.

Nature of Contacts

In most places unit 2 lies conformably on the surface of unit 1 of the Empress Formation. This contact is generally sharp and easily recognized from the electric logs (Fig. 2-21). In those segments of the buried valleys where unit 2 is overlain by sand and gravel of unit 3 of the Empress Formation, the contact is generally sharp (see Atlas map Q-g-7, cross-section E1-E1', testhole E765). Where unit 2 is overlain by till the contact may be poorly defined, as shown on the electric logs of testhole E457 (see Atlas map Q-g-7, cross-section E2-E2'). This contact may be relatively easy to define from the descriptions of drill cuttings however.

Unit 3: Glacial Sand and Gravel

Description of Unit

Unit 3 of the Empress Formation consists of sand and gravel which contains abundant igneous and metamorphic clasts derived from the Canadian Shield. The unit does not crop out in the map area but is recognized from electric logs and is described as "glacial" gravel in the drillers' records, indicating that granitic clasts are present. The presence of these igneous and metamorphic clasts indicates either a glaciofluvial or interglacial fluvial origin. Hence, the term "glacial" is applied, to differentiate this gravel from unit 1 of the Empress Formation.

In general, unit 3 glacial sand is characterized by a typical pinkish-brown color where oxidized, and by a pinkish-grey color where unoxidized. The pink tinge is due to abundant grains of potassium feldspar that are derived from eroded granitic and metamorphic rocks from the Canadian Shield. The texture of the sand of unit 3 is described in drillers' records as ranging from fine- to coarse-grained and the deposits are generally soft and loose. Glacial gravel is typically composed of rocks transported into the area by glaciers flowing from the northeast. These include igneous and metamorphic rocks derived from the Canadian Shield, quartzose sandstone from Precambrian Athabasca Sandstone, carbonate rocks from the Devonian outcrops in Alberta and Saskatchewan, and a minor amount of quartzite, chert and locally derived Cretaceous sedimentary rocks. The deposits are generally coarser and less sorted than the gravel of unit 1. Locally, minor amounts of silt and clay are also present within sand and gravel of unit 3. Drill records in the western segments of both the Bronson Lake and Big Meadow valleys describe unit 3 as containing abundant chert and quartzite clasts. It is believed that these represent sand and gravel of unit 1 of the Empress Formation which have been eroded from the base of the Beverly Valley, reworked, and redeposited along the floors of the valleys.

Distribution, Extent and Thickness

Unit 3 is mapped in three geologic settings: overlying portions of silt and clay of unit 2 of the Empress Formation, at the base of a number of major buried glacial valleys, and resting on the level bedrock surface adjacent to these buried valleys (see Atlas map P-g-7). The deposits are extensive in the Helina Valley east of the confluence with the Beverly Valley, and along the western segment of the valley. A reinterpretation of the basal stratified deposits within the Imperial Mills Valley suggests that they may not be unit 3 of the Empress Formation, but rather deposits of the stratigraphically higher Muriel Lake Formation. This reinterpretation is based of the elevation of the stratified deposits. That is, unit 3 in the Imperial Mills Valley lies at an elevation more similar to that of the Muriel Lake Formation to the southeast in the Helina Valley, than to the elevation of unit 3 in the western segment of the Helina

Valley (see Atlas map P-g-7). If so, then unit 3 possibly does not lie in the Imperial Mills Valley. The top of unit 3 ranges in elevation from as high as 600 m on the interfluve between the Beverly and St. Paul valleys, to as low as 480 m southeast of the Moore Lake Valley. The thickness of unit 3 is highly varied, ranging from only a few metres to more than 40 m near the confluence with the Helina Valley (see Atlas map Q-g-7, cross-section E2-E2' testhole E803, and Atlas map P-g-8).

Differentiation from other Units

Unit 3 is most easily differentiated in those areas where it overlies clay of unit 2 and in turn, is overlain by till. This stratigraphic sequence is found primarily within segments of the Beverly, Helina, and Imperial Mills valleys (see Atlas maps P-g-5 and P-g-7). Unit 3 can be difficult to differentiate from stratified deposits of the Muriel Lake Formation. For example, it is uncertain if the deposits east of Tp 62, R 1-4 along the Big Meadow Valley are unit 3 or, if they are deposits of the stratigraphically younger Muriel Lake Formation. Normally, till of the Bronson Lake Formation would separate the two, but in this area the Bronson Lake till is absent, probably having been eroded by the meltwater which deposited the Muriel Lake Formation. Hence, the valley floor sediments in the central and eastern portion of the Big Meadow Valley are classified as the Muriel Lake Formation, even though unit 3 of the Empress Formation may lie at the very bottom. This stratigraphic "stacking" of a younger sand and gravel unit on top of an older one may account for the anamolously thick deposits (29 m) which are mapped as unit 3 in the southwest corner of Tp 62, R 5 (see Atlas map P-g-8) and along the eastern segments of the Bronson Lake Valley (see Atlas map Q-g-7, cross-section E1-E1').

Nature of Contacts

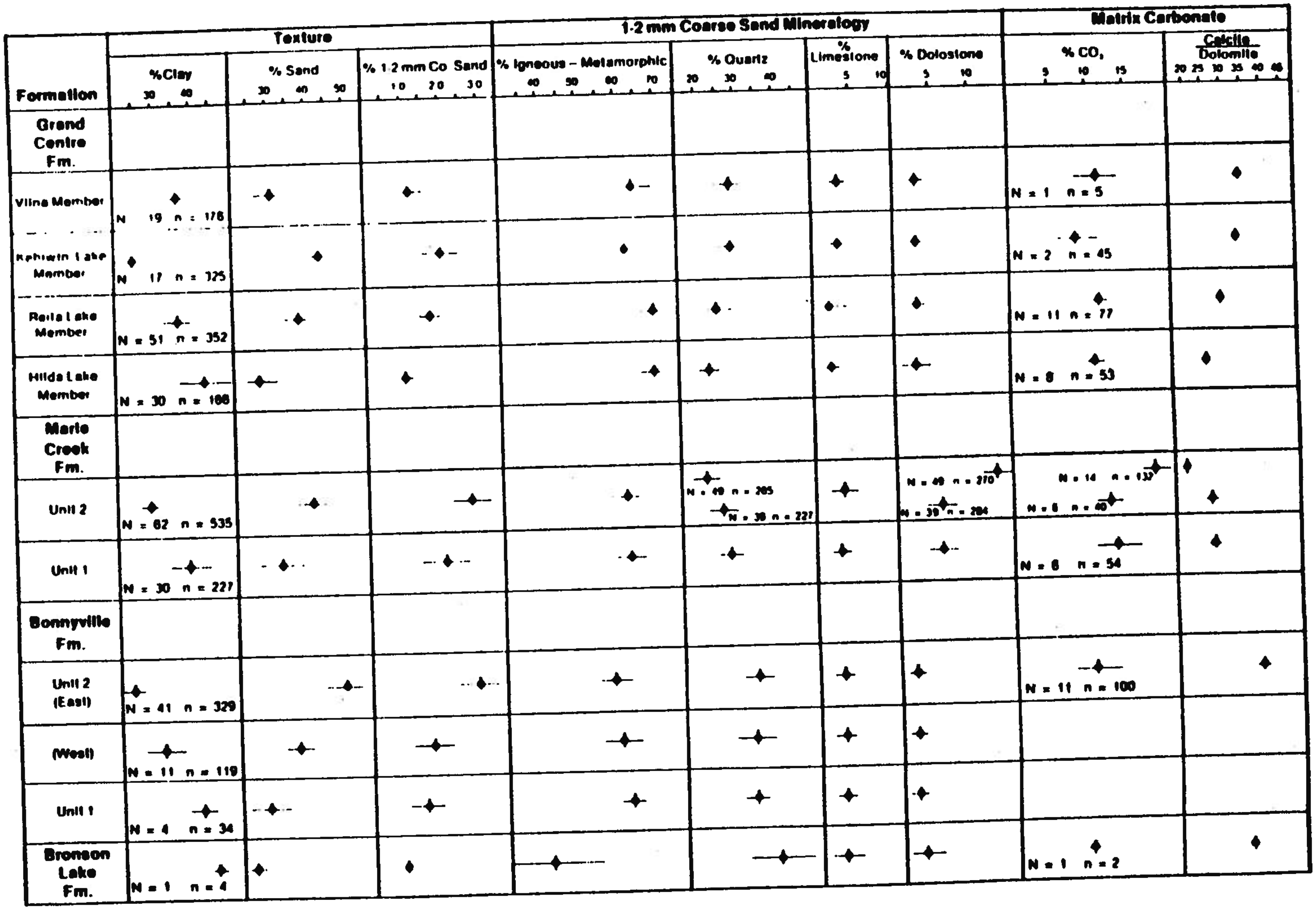
Unit 3 lies unconformably on the bedrock surface of the buried glacial valleys and conformably on unit 2 clay. Generally, this contact is easily recognized on the electric logs (Fig. 2-21). The contact between unit 3 and unit 1 cannot be easily determined without a petrologic examination. In those places where unit 3 is overlain by till, the upper contact is easily recognized on the electric logs (see Atlas map Q-g-7, cross-section E2-E2', testhole E1712). Where glacial sand and gravel of stratigraphically younger units overlie sand and gravel of unit 3, the contact is difficult to determine because of similar compositional and electric log properties.

BRONSON LAKE FORMATION

Description of Formation

The Bronson Lake Formation does not crop out within the map area but is recognized from auger and rotary drill cuttings, electric logs, drillers records, and stratigraphic position. The formation consists of a relatively clast-free, clayey diamicton which, in some places, contains, or is interbedded with, well-sorted sediment, predominantly clay of undetermined origin. In most places, the formation has a very low resistivity response, presumably due to its high clay content. The formation is especially distinct on the electric logs in those places where it is both overlain and underlain by coarse stratified sediment (see Atlas map Q-g-7, cross-section E2-E2', testholes E1708 and E1712). The formation was recognized in only one auger testhole, T-32 (Fig. 2-24). At this location it is oxidized dark grey-brown (2.5Y 4/2), though generally it is unoxidized dark grey elsewhere. In this testhole the unit comprises about 24 percent sand, 33 percent silt, and 44 percent clay (Table 2-4). The 1-2mm sand fraction contains about 35 percent igneous and

Table 2-4 Properties which characterize the glacial formations (tills) in the Sand River map area



N = Number of testholes in which unit is recognized
n = Number of samples analysed from testholes
♦ Mean value of the means from all testholes
· Standard deviation

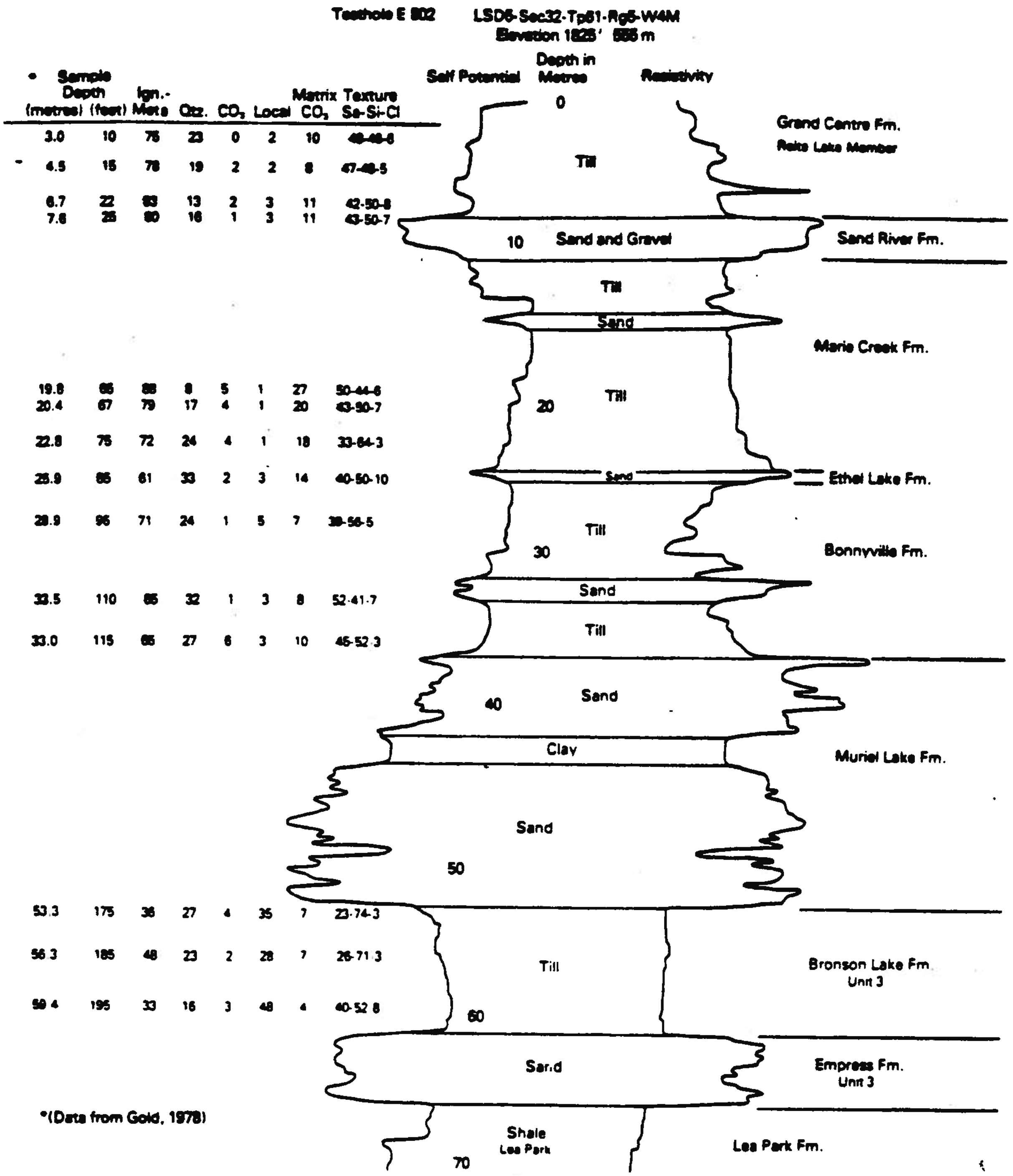
metamorphic rock fragments, 42 percent quartz fragments, 3 percent limestone fragments, 3 percent dolostone fragments, and 14 percent locally- derived bedrock fragments consisting mainly of shale. The silt-clay fraction contains about 9 percent calcareous material, with dolomite more abundant than calcite (calcite/dolomite ratio, 0.34).

Distribution, Thickness and Subcrop Topography

The Bronson Lake Formation is found primarily within or along segments of the major buried valleys. It has not been identified in the interfluves between the valleys, except for that portion between the Bronson Lake and Holyoke valleys in the southeast, and between the Beverly and St. Paul valleys in the southwest (see Atlas map P-g-9). It is uncertain if the formation extends throughout the entire Helina Valley, but it is continuous in the central portion, extending from Tp 64, R 6 in the east, to Tp 65, R 11 in the west. Lithologs from a number of testholes in this area describe the formation as consisting of either "clay" or "till", indicating that the lithologic properties of the formation in this segment of the valley are varied. Similarly, the formation lies extensively within the western segment of the Bronson Lake Valley between Tp 61, R 3 and Tp 62, R 5, and on the relatively flat-lying bedrock interfluve between the Holyoke Valley to the south. Within the map area the top of the formation ranges in elevation from as high as 550 m along the southwest portion of the Beverly Valley, to as low as 490 m in the Beverly and Bronson Lake valleys. The formation is generally thickest (>20 m) within the central segment of the Helina Valley in Tp 62-63, R 7 to 10 (see Atlas map P-g-10). Relatively thick deposits are also found within the Bronson Lake Valley near the junction with the Beverly Valley in the southwest corner of Tp 62, R 5.

Differentiation from other Formations

The Bronson Lake Formation is differentiated from other formations by its stratigraphic position, clayey texture, very low



• Sample Depth (metres)	(feet)	Ign.-Mets	Qtz.	CO_3	Local	Matrix CO_3	Texture Sa-Si-Cl
3.0	10	75	23	0	2	10	48-46-6
4.5	15	78	19	2	2	8	47-48-5
6.7	22	83	13	2	3	11	42-50-8
7.6	25	80	16	1	3	11	43-50-7
19.8	65	88	8	5	1	27	50-44-6
20.4	67	79	17	4	1	20	43-50-7
22.8	75	72	24	4	1	18	33-64-3
25.9	85	61	33	2	3	14	40-50-10
28.9	95	71	24	1	5	7	39-56-5
33.5	110	65	32	1	3	8	52-41-7
33.0	115	65	27	6	3	10	45-52-3
53.3	175	36	27	4	35	7	23-74-3
56.3	185	48	23	2	28	7	26-71-3
59.4	195	33	16	3	48	4	40-52-8

*(Data from Gold, 1978)

Figure 2-22 Electric log response at the type section of the Bronson Lake Formation and the Muriel Lake Formation. Alberta Environment testhole E 802 (LSD 5, Sec 32, Tp 61, R 5, W 4 Mer) resistivity response, abundance of locally-derived rocks in the 1-2 mm sand fraction, relatively high aluminum content of the matrix, and moderate content of carbonate rock fragments in the 1-2 mm sand fraction (Table 2-4). The formation is stratigraphically the lowest diamicton in the map area and its very clayey texture allows it to be easily recognized on the resistivity log responses (Fig. 2-22 and see Atlas map Q-g-7, cross-section E2-E2', testholes E1708 and E1712). The Bronson Lake Formation can be difficult to differentiate from clay of unit 2 of the Empress Formation because in many areas the diamicton of the Bronson Lake Formation is either interbedded with silt and clay, or contains discrete masses of clay. Differentiation between the two units is particularily difficult in the area west of Cold Lake and Marie Lake (Tp 65, R 2) where clay deposits lie both above and below diamicton of the Bronson Lake Formation (see Atlas map Q-g-7, cross-section E1-E1'). In the eastern two-thirds of the map area, the Bronson Lake Formation is easily differentiated from diamicton of unit 2 of the Bonnyville Formation, because it is more clayey and contains more locally derived bedrock and carbonate rock fragments in the 1-2 mm sand fraction. Unit 1 of the Bonnyville Formation may be as clayey as the the Bronson Lake Formation, but the two are commonly separated by stratified sediment of the Muriel Lake Formation. In the west, the differentiation between the Bonnyville Formation and the Bronson Lake Formation is more difficult because both units 1 and 2 of the Bonnyville Formation are also clayey. Here, the differentiation is made on the basis of the relative abundance of locally derived bedrock fragments in the 1-2 mm sand fraction of the Bronson Lake Formation.

Nature of Contacts

The Bronson Lake Formation overlies shale of the Lea Park Formation in a few places within the uplands that flank the buried valleys. This lower contact is disconformable and generally sharp, even though both formations contain an abundance of clay. Gradational contacts are suggested in some testholes which describe blocks of "ice-rafted" shale within diamicton of the Bronson Lake Formation. This indicates that a significant amount of the underlying bedrock has been eroded in places, and incorporated into the formation. In most places the Bronson Lake Formation overlies stratified deposits of the underlying Empress Formation. Where these stratified deposits are coarse (for example, units 1 and 3), the contact is generally sharp and distinct. The Bronson Lake Formation directly overlies clay of unit 2 of the Empress Formation in only a few areas. In the northeastern part of the map area this contact is difficult to establish because both units contain considerable amounts of clay. The upper surface of the Bronson Lake Formation is, in most places, conformably overlain by stratified deposits of the Muriel Lake Formation. This contact is distinct and well defined on the electric logs.

Origin

The Bronson Lake Formation represents glacial sediment deposited by the first glaciation in the area, named the Cherry Grove Glaciation (Andriashek, 1985). Much of the formation is composed of diamicton that is interpreted to be till deposited directly by the glacier. However, because the formation is found primarily at or near the base of the major buried valleys, some of this diamicton may also include slump sediment mixed with glacial sediment (till) from higher up along the valley walls. Within the buried valleys, especially the Helina Valley, the diamicton of the Bronson Lake Formation is not only very clayey but also contains discrete masses, or beds, of silt and clay. The source of this silt and clay is uncertain. The very coarse sand lithology (Gold, 1978) shows that, in places, the diamicton contains abundant locally derived bedrock fragments consisting mainly of shale. This agrees with the data from testhole T-32 (Fig. 2-24). The relatively high shale content in the sand fraction of the Bronson Lake Formation, compared to the amount in any of the other formations, suggests that significant amounts of the underlying shale were eroded by the glacier and incorporated into the Bronson Lake Formation. Christiansen (1968) also noted an abundance of matrix clay and shale fragments in the clast fraction of the lowermost till in a number of map areas in Saskatchewan. He also attributed this clay enrichment to erosion and incorporation, over vast areas of exposed bedrock, by the first glaciation in that province. At a number of locations fluvial or lacustrine silt and clay, which has either been deposited penecontemporaneously with the diamicton, or glacially eroded and incorporated into the matrix as discrete "clasts", appears to account for the very clayey nature of the formation. The source of the incorporated silt and clay may be the underlying unit 2 of the Empress Formation.

MURIEL LAKE FORMATION

Description of Formation

The Muriel Lake Formation does not crop out within the map area but is described from dry auger samples and drillers' records, and is recognized in the subsurface from geophysical logs. The formation generally consists of stratified sand, and sand and gravel with minor silt and clay beds. In some areas along the Helina Valley west of Cold Lake, the formation contains significant amounts of clay interbedded with the sand and gravel (see Atlas map O-g-7, cross-section E1-E1', testhole E767). Locally, the entire formation is composed of silt and clay. Driller's records describe granitic and carbonate clasts in the gravel of the formation, indicating a glaciofluvial or glaciolacustrine origin. Generally, these clasts are fine- to medium- sized. Cobbles or boulders are uncommon. The sand is generally medium-grained and well-sorted, although in some testholes coarse sand was mapped. The deposits of the Muriel Lake Formation are described as unoxidized and have a light to medium gray color.

Distribution, Thickness, and Subcrop Topography

The Muriel Lake Formation lies both within segments of the buried valleys, on top of either the Bronson Lake Formation or the Empress Formation, or on the bedrock surface in the interfluves which separate the valleys (see Atlas map P-g-11). It is believed to be absent in the highlands that lie north and south of the central part of the map area. The distribution of the Muriel Lake Formation can be defined by two trends that intersect near Moose Lake in Tp 61, R 7. The first trend originates within the Beverly Valley in the southwestern corner of the map area and extends northeast, following the Helina Valley towards Cold Lake. The second trend originates along the northwestern end of the Helina Valley and extends southeast, following the orientation of the Bronson Lake and Big Meadow valleys. Data are lacking for the northwest portion of this second trend, but it is possible that the formation extends into the Imperial Mills Valley, as mentioned in the discussion of unit 3 of the Empress Formation. The top of the formation ranges in elevation from as high as 595 m on the eastern flank of the Vegreville Valley in the southwest, to as low as 490 m in the Beverly Valley in Tp 62, R 5. The formation is generally thick over much of its extent (see Atlas map P-g-12). The thickest deposits are found along the Helina Valley where, in Tp 65, R 2, as much as 58 m of clay, sand, and gravel can be mapped. The formation thins to about 5 m along the flanks of the buried valleys.

Differentiation from other Formations

The Muriel Lake Formation has abundant clasts derived from the Canadian Shield and this serves to differentiate it from unit 1 of the Empress Formation. On the basis of petrology alone, however, the Muriel Lake Formation cannot be differentiated easily from the other stratified units of Quaternary age. Thus stratigraphic position becomes the most reliable means of differentiation. As an example, the Muriel Lake Formation and unit 3 of the Empress Formation have a similar composition, and can be differentiated with ease only where they are separated by the Bronson Lake Formation (see Atlas map 0-g-7, cross-section E2-E2', testhole E1712). If the Bronson Lake Formation is absent, then the deposits of sand and gravel likely would be interpreted as part of the Empress Formation. It is for this reason that the glacial sand and gravel deposits which overlie unit 2 clay in the Imperial Mills Valley were originally interpreted to be unit 3 of the Empress Formation. On re-examination, however, the elevation of those deposits matches very closely with the elevation of the Muriel Lake Formation in the Helina Valley to the southeast. As a result, the Muriel Lake Formation can be considered to be continuous almost throughout the entire Helina and Imperial Mills valleys.

Nature of Contacts

In those places where coarse deposits of the Muriel Lake Formation overlie diamicton of the Bronson Lake Formation, the contact is sharp and distinct (see Atlas map 0-g-7, cross-section E2-E2', testholes E1708 and E1712). Conversely, where the base of the Muriel Lake Formation is composed of clay and silt, the contact with the Bronson Lake Formation can be difficult to establish (Fig. 2-21). Generally, the upper portions of the Muriel Lake Formation are composed of sand, or sand and gravel, and the contact with diamicton of the overlying Bonnyville Formation is sharp and distinct.

Origin

It is believed that deposits of the Muriel Lake Formation have different origins and that all were not deposited contemporaneously. The thick clay deposits which lie at or near the base of the formation in a number of locations within the Helina Valley are believed to have a glaciolacustrine origin. These fine sediments were deposited on top of the Bronson Lake Formation by a proglacial lake that followed the retreat of the Cherry Grove Glacier. Although direct evidence is lacking, it is believed that much of the coarser sediments were deposited by glacial meltwater during the retreat of the Cherry Grove Glacier. This served to armour and protect the underlying Bronson Lake Formation in the valleys from future erosion. It is likely, also, that some of the formation, especially in the northeast, was deposited by glacial meltwater during the advance of the next glaciation, the Fort Kent Glacier (Andriashek, 1985). Evidence for this is derived from the fact that the top of the formation lies at a significantly higher elevation in the northeast segment of the Helina Valley than it does in the central and western portions, even though the regional slope is to the northeast. One explanation is that the thick sequences of clay, sand, and gravel were deposited by glacial meltwater in contact with the advancing margin of the Fort Kent Glacier. Interestingly, this thick sequence of sand and gravel forms the core of the Medley River Upland physiographic unit in the northeast part of the map area (see Atlas map Q-g-7, cross-sections E1-E1' and E2-E2').

BONNYVILLE FORMATION

Description of Formation

The Bonnyville Formation is extensive throughout the map area. It has not been observed in outcrop, but has been mapped from dry-auger flite samples, rotary drill cuttings, sidewall samples, and electric logs. The formation consists primarily of diamicton which is characterized by a relative abundance of quartz in the very-coarse sand fraction, and by a relatively minor amount of calcareous material, particularly dolostone and dolomite, in the very-coarse sand and silt-clay fractions. On the basis of differences in matrix texture and electric log responses, the Bonnyville Formation is divided into two units: unit 1, a clayey, low resistive diamicton, and unit 2, an upper sandy, highly resistive diamicton. In places,

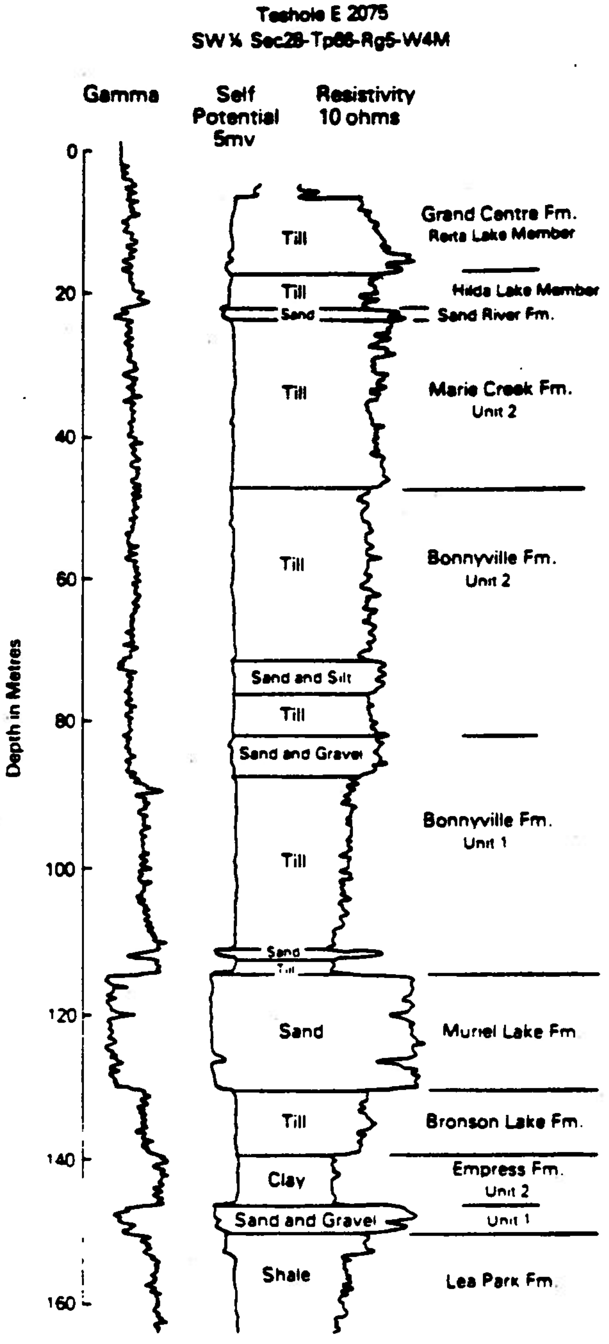


Figure 2-23 Electric and gamma ray log responses of units 1 and 2 of the Bonnyville Formation. Alberta Environment testhole E 2075 (LSD 4, Sec 28, Tp 66, R 5, W 4 Mer)

stratified sediment consisting of clay, sand and gravel, lies between diamicton of units 1 and 2. This sediment is included as part of unit 1. Figure 2-23 shows the electric and gamma ray log characteristics of this stratified sediment as well as the diamicton of both units 1 and 2. The two units of the Bonnyville Formation are described separately below.

Unit 1

Description of Unit

Unit 1 of the Bonnyville Formation is recognized primarily from the electric logs, though some samples of the diamicton of unit 2 have been analysed by Gold and the present author. The unit has also been mapped in a few Alberta Geological Survey auger testholes (see Data Base, testholes T-23, T-38, and T-73). In these testholes unit 1 consists of a clayey, dark grey diamicton which has an average matrix texture of about 28 percent sand, 30 percent silt, and 42 percent clay (Table 2-4). The composition of the very coarse sand fraction consists of about 61 percent igneous and metamorphic rock types, 33 percent quartz fragments, 3 percent limestone, 2 percent dolostone, and about 1 percent local rock types (Table 2-4). Calcareous material makes up 3 percent of the silt-clay fraction (Gold, 1978, testhole E798).

Distribution, Thickness and Subcrop Topography

Unit 1 of the Bonnyville Formation is not extensive within the map area, but lies only within segments of the Beverly, Vegreville, Helina, Sinclair, Holyoke and Kikino valleys (see Atlas map P-g-13). The most extensive deposit of unit 1 is in the southwest corner of the map area, overlying a segment of the Beverly, Kikino and Vegreville valleys in the area defined by Tp 57 to 62, R 8 to 14.

Within much of this area unit 1 is overlain by unit 2 except for the extreme western portion in which unit 2 is believed to have been eroded. Here, unit 1 forms the top of the formation. Along the eastern segment of this deposit, sand and gravel overlies a clayey diamicton. Extensive stratified deposits also overlie diamicton of unit 1 in the area defined by Tp 64 to 65, R 3 to 5 along the Helina Valley. The top of the unit ranges in elevation from as much as 650 m in the southwest in Tp 59, R 14, to as low as 515 m near Trueman in Tp 63, R 8. The thickest deposits of unit 1 are found in the western segment of the map area. Near Spedden, in Tp 59, R 13, as much as 68 m of clayey diamicton have been mapped (see Atlas map P-g-14).

Differentiation from other Formations

Unit 1 of the Bonnyville Formation is differentiated from the underlying Bronson Lake Formation primarily on the basis of stratigraphic position. If the two units are not separated by stratified deposits of the Muriel Lake Formation, then their differentiation is difficult because both have a similar texture and electric log response. This distinction is particularly difficult in the southwestern corner of the map area where the distribution and western extent of the Bronson Lake Formation is poorly known. Generally, the differences in the resistivity responses prove to be the most useful criteria for differentiating unit 1 from the overlying unit 2 of the Bonnyville Formation. Diamicton of unit 1 has a much lower resistivity response than unit 2, presumably because it is more clayey (Fig. 2-23).

Nature of Contacts

In many places unit 1 disconformably overlies shale and siltstone of the Belly River Group and Lea Park Formation. This contact is commonly gradational and difficult to recognize, especially around Spedden in Tp 59, R 13 (see Atlas map Q-g-8, cross-section N2-N2', Chorney waterwell drill log, LSD 9, Sec 28, Tp 59, R 12). Where unit 1 overlies stratified deposits of the Muriel Lake and Empress formations, the contact is sharp and well defined on the electric logs (Fig. 2-23). The upper contact of unit 1 with the base of unit 2 is considered to be conformable and can be gradational, or sharp. In a number of locations above segments of the buried Beverly and Helina valleys, the contact is well defined by stratified sediment which separates the diamictons of the two units (see Atlas map Q-g-7, cross-section E2-E2', testholes E831, E2075). In the southwestern corner of the map area unit 1 is overlain by both stratified sediment of the Sand River Formation, and diamicton of the Grand Centre Formation. In both cases the contact is sharp and well defined on the electric logs.

Unit 2

Description of Unit

Unit 2 consists of a diamicton which, in most places, is unoxidized and very dark grey (5Y 3/1). In a number of places in the west the top of the unit is oxidized olive brown (2.5Y 4/3). Unit 2 is very sandy in the east, with an average matrix texture of about 48 percent sand, 28 percent silt, and 24 percent clay (Table 2-4). The matrix is relatively rich in granules and very coarse sand (about 3 percent), and pebbles and cobbles are abundant. In the east the unit is relatively easy to penetrate with a dry auger, and samples are generally loose, and crumbly on the dry-auger flites. Unit 2 is less sandy in the western part of the map area and contains more clay. The average matrix texture in the west consists of about 36 percent sand, 33 percent silt, and 31 percent clay (Table 2-4). The unit also tends to be stiffer and more difficult to penetrate with a dry-auger in the west. The composition of the 1-2 mm sand fraction of unit 2 is much the same throughout the map area. The average values, shown in table 2-4, consist of about 58 percent igneous and metamorphic fragments, 34 percent quartz fragments, 3 percent limestone, 2 percent dolostone, less than 1 percent quartzite, and between 1 and 2 percent locally derived rock fragments. Calcareous material makes up 5 percent to 12 percent of the silt-clay fraction, with dolomite more abundant than calcite (calcite/dolomite ratio, 0.37). The clay mineralogy of a few representative samples of the sandy facies of unit 2 consists of about 40 to 50 percent illite, 25 to 40 percent kaolinite, 17 to 25 percent montmorillonite, and 5 to 10 percent chlorite.

Distribution, Thickness and Subcrop Topography

Unit 2 of the Bonnyville Formation extends throughout most of the study area and forms the bulk of the entire formation (see Atlas map P-g-15). It appears to be absent along the extreme southern and western portions of the study area, and within a topographic low in Tp 59, R 11 to 14; Here, unit 1 subcrops to form the surface of the formation. The top of unit 2 ranges in elevation from as high as 650 m in a series of discontinous ridges along the southwestern margin, to as low as 490 m within a segment of the Big Meadow Valley south of Cold Lake. The thickest deposits of unit 2 are found in the uplands flanking the Beaver River Lowland Plains; in this area unit 2 commonly exceeds 30 m in thickness. The thickest deposits of both units 1 and 2, combined, are mapped above segments of the buried valleys (see Atlas map P-g-16). For example, in the southwest more than 70 m of the formation lies within segments of the Beverly and Kikino valleys.

Differentiation from other Formations

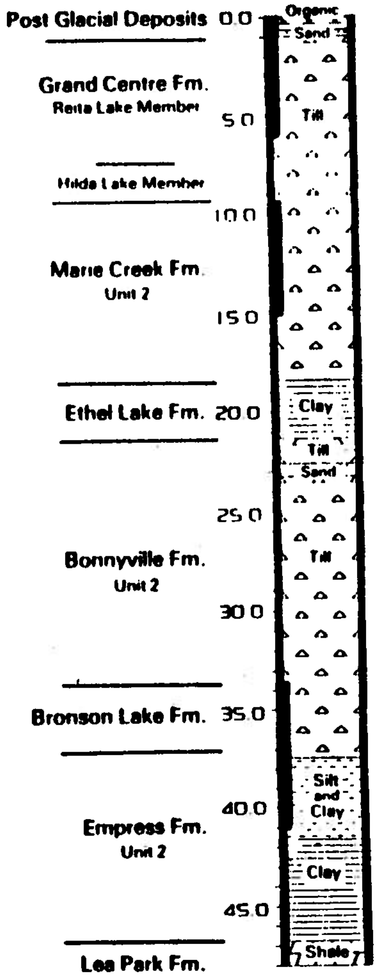
Unit 2 of the Bonnyville Formation is one of the sandiest diamictons in the map area, particularly with respect to the amount of very coarse sand (Table 2-4), and locally it can be differentiated by texture alone. In the eastern part of the map area unit 2 of the Bonnyville Formation is differentiated from unit 2 of the overlying Marie Creek Formation by the difference in carbonate and quartz content in the very coarse sand fraction: unit 2 of the Bonnyville Formation contains much less calcareous material and much more quartz than does the Marie Creek Formation (Data Base, testholes T-6, T-16). In the central part of the map area unit 2 of the Bonnyville Formation is differentiated from the Kehiwin Lake Member of the Grand Centre Formation on the basis of the greater amount of very coarse sand in the matrix, and greater amount of quartz in the very coarse sand fraction of unit 2 (Table 2-4). In the west, where unit 2 is more clayey, it is differentiated from other clayey diamictons, such as the Vilna Member of the Grand Centre Formation, by the relative abundance of quartz, compared to igneous and metamorphic rocks, in the very coarse sand fraction (Table 2-4). Electric log responses for the Bonnyville Formation are useful for differentiating diamicton of the Bonnyville Formation from diamictons of other units. The logs generally show a distinct break in the signatures at the contact of the Bonnyville Formation with the other units. Over most of the eastern half of the map area units 1 and 2 of the Bonnyville Formation are generally less resistive than the upper portions of the overlying Marie Creek Formation and commonly more resistive than the base of the Marie Creek Formation.

Nature of Contacts

Generally, unit 2 overlies shale of the Lea Park Formation over most of the bedrock uplands. This contact is sharp, even though locally unit 2 becomes increasingly more clayey towards the base. The contact between unit 2 and diamicton of the Bronson Lake Formation is recognized in only one auger testhole (Fig. 2-24). Here, the contact

T32

Alberta Geological Survey Testhole T 32
Location SW of LSD 12 Sec 1 Twp 64 Rng 3 W of 4 Mer . NTS 73L
Elevation 1800 Ft 549 M Source 1 50.000 NTS 73L/9
Date drilled 197608 06 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	37 0	26 0	37 0	40 0	29 0	31 0	1 86	13 3	21 4	8 9	0 24	69 6	24 4	1 2	2 3	3 8	0 0	0 0	266
2 00	36 0	25 0	38 0	40 0	28 0	33 0	1 83	15 4	29 1	12 2	0 37	65 5	26 5	0 8	2 4	2 8	0 4	0 0	249
3 00	36 0	25 0	39 0	40 0	28 0	32 0	2 00	15 6	26 2	10 9	0 24	65 6	27 8	0 7	2 6	2 2	0 4	0 0	270
4 00	37 0	26 0	37 0	41 0	28 0	31 0	1 68	14 6	25 8	10 8	0 30	64 0	27 2	2 9	1 3	4 2	1 2	0 0	239
5 00	34 0	26 0	41 0	37 0	28 0	35 0	2 99	14 5	27 6	11 6	0 28	63 9	27 0	1 3	3 5	4 4	0 4	0 0	230
6 00	32 0	26 0	42 0	35 0	29 0	35 0	1 85	14 2	26 3	11 0	0 21	64 4	26 6	2 2	2 6	4 3	0 0	0 0	233
7 00	33 0	28 0	39 0	36 0	31 0	33 0	1 65	12 3				69 1	19 1	2 7	3 1	5 3	0 8	0.0	225
8 00	26 0	28 0	46 0	30 0	31 0	39 0	1 14	14 1	25 3	10 6	0 24	69 4	22 0	0 0	4 1	4 6	0 0	0 0	173
9 00	20 0	31 0	49 0	24 0	36 0	41 0	0 72	14 1	28 2	11 8	0 25	58 8	29 8	0 0	2 6	8 8	0 9	0 0	114
10 00	38 0	30 0	31 0	42 0	32 0	26 0	2 17	8 1	43 6	18 2	0 21	67 1	16 4	0 3	3 4	10 6	1 6	0 0	161
11 00	40 0	30 0	31 0	43 0	31 0	26 0	2 54		41 3	17 2	0 19	66 3	15 6	0 6	2 8	13 4	1 2	0 0	320
12 00	40 0	28 0	31 0	45 0	29 0	26 0	2 15	10 0	41 7	18 2	0 16	65 9	19 6	0 3	2 4	10 1	2 0	0 0	296
13 00	41 0	28 0	32 0	44 0	31 0	25 0	2 43	8 2	38 6	16 1	0 15	63 1	19 6	2 0	5 1	8 7	1 9	0 0	312
14 00	46 0	27 0	27 0	50 0	29 0	22 0	2 48	8 7				61 4	23 5	1 2	4 0	7 1	2 4	0 0	324
15 00	51 0	27 0	21 0	56 0	27 0	17 0	3 64	7 1	29 3	12 2	0 25	58 7	30 4	1 1	3 4	5 0	1 0	0 0	477
16 00	55 0	23 0	22 0	59 0	24 0	18 0	3 06	6 6	30 1	12 6	0 28	56 7	32 0	0 2	4 6	4 8	1 6	0 0	413
17 00	56 0	23 0	22 0	60 0	23 0	18 0	2 76	7 2	30 7	12 8	0 23	55 5	34 7	0 5	3 7	3 7	2 1	0 0	404
18 00	46 0	27 0	28 0	49 0	30 0	21 0	2 56	7 8	29 1	12 2	0 26	59 2	30 9	0 3	2 1	4 5	3 0	0 0	333
19 00								19 6											
20 00								18 6											
21 00	31 0	25 0	44 0	34 0	34 0	32 0	1 18	15 6	15 5	6 5	0 42	49 0	45 0	3 3	0 7	1 3	0 7	0 0	151
22 00	40 0	25 0	35 0	42 0	35 0	23 0	2 71	11 5				54 4	39 7	2 0	2 6	0 0	1 4	0 0	388
23 00	52 0	30 0	18 0	56 0	33 0	11 0	3 16	8 7	20 5	8 6	0 35	59 1	34 5	1 8	3 0	0 5	1 4	0 0	438
24 00	53 0	28 0	19 0	56 0	30 0	14 0	3 44	8 9				53 4	40 5	1 0	1 9	1 5	1 6	0 0	474
25 00	52 0	29 0	19 0	56 0	31 0	14 0	3 37	8 7	20 7	8 7	0 30	58 4	35 8	0 9	1 3	0 9	2 6	0 0	450
26 00	53 0	29 0	18 0	57 0	30 0	14 0	3 16	8 5				60 7	33 5	1 2	2 1	0 7	1 9	0 0	427
27 00	51 0	28 0	19 0	57 0	30 0	14 0	3 29	8 0	20 5	8 6	0 33	60 1	34 6	0 2	3 0	1 6	0 4	0 0	436
28 00	54 0	26 0	20 0	58 0	28 0	14 0	3 16	8 3				58 7	34 3	1 6	2 0	2 0	1 1	0 0	443
29 00	53 0	26 0	21 0	57 0	27 0	16 0	3 41	8 1	20 0	8 4	0 25	56 0	38 0	0 4	1 9	1 0	2 5	0 0	484
30 00	51 0	26 0	22 0	56 0	28 0	16 0	1 61	9 1				60 5	33 5	1 4	1 9	1 7	1 0	0 0	483
31 00	54 0	25 0	21 0	58 0	27 0	15 0	4 64	10 3	19 0	7 9	0 27	56 2	35 5	1 2	2 1	1 5	2 8	0 0	508
32 00	53 0	25 0	22 0	56 0	27 0	17 0	3 75	7 8				54 1	38 4	1 4	3 2	1 6	1 4	0 0	497
33 50	23 0	34 0	43 0	28 0	35 0	38 0	0 74	12 1	20 4	8 6	0 36	38 3	45 2	2 6	4 4	1 7	7 8	0 0	115
34 00	24 0	34 0	43 0	28 0	35 0	37 0	0 80	13 3				57 5	28 3	0 0	5 0	3 3	5 8	0 0	120
35 00	23 0	34 0	43 0	28 0	35 0	37 0	0 80	13 7	21 4	9 0	0 31	57 5	28 3	0 0	5 0	3 3	5 8	0 0	120
36 50	24 0	31 0	45 0	28 0	33 0	39 0	0 76	12 0				34 3	44 4	0 0	3 7	5 6	12 1	0.0	108
37 00	6 0	41 0	53 0	8 0	48 0	44 0	0 14	16 6				21 4	17 9	0 0	0 0	3 6	57 1	0.0	28
38 00								18 7											
39 50								16 0											
40 00								18 4											
41 00								14 9											
42 50								16 3											
43 00								17 5											
44 00								15 7											
45 00								18 2											
46 00								20.4											
47 00								19 5											

NOTE:
Heavy Bar Denotes Oxidized Profile

Figure 2-24 Type section of the Ethel Lake Formation. Alberta Geological Survey testhole T 32 (LSD 12, Sec 1, Tp 64, R 3, W 4 Mer) is well defined by the textural and mineralogic differences (Table 2-4). The buried oxidized horizon on the surface of the Bronson Lake Formation at this location also suggests that the contact is disconformable. Where unit 2 overlies stratified sediment of the Muriel Lake Formation, the contact can be sharp or gradational. Resistivity logs show that, in places, the base of unit 2 contains numerous beds of sand and gravel which appear to grade into the coarse deposits of the underlying Muriel Lake Formation. It is uncertain if these basal beds of sand and gravel were deposited contemporaneously with the diamicton, or, if they represent incorporated lenses of the underlying Muriel Lake Formation. Unit 2 of the Bonnyville Formation is overlain by either stratified sediment of the Ethel Lake and Sand River formations (see Atlas map Q-g-8, cross-section N1-N1') or by diamictons of the Marie Creek and Grand Centre formations (see Atlas map Q-g-7, cross-sections E1-E1', E3-E3'). Where unit 2 is overlain by stratified sediment the contact is sharp. The contact with either of the overlying Marie Creek or Grand Centre formations is considered to be disconformable on the basis of the weathered profile on the surface of unit 2. In the western part of the map area this oxidized profile on the surface of unit 2 is more extensive and the contact is easily recognized from drill samples. Unconformable contacts are indicated at a number of locations where the base of the overlying Marie Creek Formation is gradational with unit 2. It is believed that at these sites the top of unit 2 has been eroded and incorporated into the base of the overlying diamicton. This gradation is expressed in both the texture and mineralogy, particularly carbonate content, of the two formations, as shown in testholes T-25, T-32, and 77SR-3 (see Data Base).

Origin

Diamicton of the Bonnyville Formation represents glacial sediment (till) that was deposited by the second major glaciation in the map area, herein called the Fort Kent Glaciation. On the basis of the sand petrology, it is believed that the Fort Kent Glacier flowed more from the northeast than from the north. The evidence for this is twofold. First, the relatively minor amounts of carbonates in both the clast and matrix fractions suggest that the Fort Kent Glacier incorporated only a small amount of the Devonian carbonates which crop out along most of the southwestern margin of the Canadian Shield in Saskatchewan and Alberta. Possibly, the Bonnyville till is derived from that part of the Fort Kent Glacier which traversed the portion of the Devonian carbonates buried by Cretaceous rocks northeast of the Sand River map area (Whitaker and Pearson, 1972). Secondly, the relative abundance of quartz in the 1-2 mm sand fraction and the very sandy texture of unit 2 suggests that the Fort Kent Glacier incorporated a considerable amount of quartz sand. Two possible sources of this sand are offered: a distant source derived from quartz sandstone of the Athabasca Formation, which crops out along the southern edge of the Canadian Shield in northwestern Saskatchewan and northeastern Alberta, or a local source derived from the extensive sand and gravel deposits of the underlying Muriel Lake Formation. The similarity throughout the map area in the composition of the 1-2 mm sand fraction of both units 1 and 2 suggests that the sand, and in particular the quartz component, was not derived from a local source, but rather, from a more distant source, possibly the Athabasca Formation. The clayey till of unit 1 probably results from the erosion and incorporation of shale and siltstone as the Fort Kent Glacier advanced over the exposed bedrock uplands in the map area. Water well drillers' records in the area south of Spedden (Tp 59, R 13) describe the unit as consisting of clay with very few pebbles, and in places resembling shale. In fact, in the segment of the Kikino Valley within Tp 59 to 60, R 13, and within the Beverly Valley in Tp 59, R 14 to 15, till of unit 1 is absent. Instead, a very thick sequence of Belly River Group shale, siltstone, sandstone, and coal has been displaced and incorporated as an ice-thrust glacial erratic, to form the base of the Bonnyville Formation (see Atlas map , cross-section E4-E4', testhole R81 SR-1; and Gold, 1978). It is believed that near Spedden the process of glacial comminution reworked this displaced bedrock sufficiently to produce the very clayey till of unit 1.

ETHEL LAKE FORMATION

Description of Formation

The Ethel Lake Formation consists of stratified sediment composed mainly of silt and clay, with lesser amounts of sand and gravelly sand. The formation is recognized with certainty only in those places where it overlies the Bonnyville Formation and in turn is overlain by the Marie Creek Formation. The formation does not crop out in the map area, but is recognized from dry-auger flite samples, rotary drill cuttings and geophysical logs, but primarily from electric logs. Silt and clay deposits of the formation are typically unoxidized grey (5Y 4/1). Oxidized horizons are not recognized within, or at the surface of, the formation at any of the testhole locations. Distorted partings and laminations of silt and clay layers in the dry-auger samples indicate bedding within the unit. The silt partings react mildly to the application of 10 percent HCl in field tests. The silt and clay deposits have a moisture content which ranges between 14 percent and 20 percent, and typically are soft and easy to penetrate with a dry-auger. Coarser sand and gravel deposits comprise a minor amount of the Ethel Lake Formation although their extent is widespread. The sand varies from fine- to coarse- grained and is generally well sorted. The petrologic composition of the clasts was not examined in detail but have been described in the field as typical glacial sand and gravel, with clasts derived from the Canadian Shield as well as the local bedrock. In much of the southwestern portion of the map area the sand and gravel is interbedded with finer silt and clay deposits.

Distribution, Thickness, and Subcrop Topography

The Ethel Lake Formation is widespread, but not continuous, throughout most of central and southeastern part of the map area (see Atlas map P-g-17). It is not recognized in the uplands to the north or southwest. Silt and clay deposits of the Ethel Lake Formation are both extensive and thick (see Atlas maps P-g-17 and P-g-18). These fine deposits form a broad arc which extends from the area near Lac la Biche (Tp 69, R 17) southeastward to the Reita Lake area in Tp 59, R 3. Along the western portion of the formation these silt and clay deposits are either overlain by sand and gravel or are interbedded with sand and gravel. This interbedded sequence of clay, silt, sand and gravel forms a series of relatively thick deposits which extend from Tp 59, R 7 in the Kehiwin Uplands northwestward into Tp 67, R 16, in the Lac la Biche Uplands (see Atlas Map P-g-18). Above segments of the buried Helina and Beverly valleys, in the central part of the map area, the Ethel Lake Formation is characterized by a thin veneer of sand and gravel. Although this coarse veneer is believed to be widespread, the data are insufficient to be certain that the distribution is as continuous as shown in Atlas map P-g-17. The elevation of the top of the formation ranges from as high as 640 m in the southeastern edge of the map area, to as low as 510 m along the Beaver River in the east. The thickest deposits are mapped within or near segments of the buried valleys; for example, between 20 and 30 m of clay are mapped above the buried Helina and Bronson Lake valleys.

Differentiation from other Formations

The Ethel Lake Formation is differentiated from all other stratified units primarily on the basis of stratigraphic position. It is recognized with certainty only in those areas where it overlies glacial sediment (till) of the Bonnyville Formation and where it, in turn, is overlain by glacial sediment (till) of the Marie Creek Formation. Therefore, in the southwestern corner of the map area, where the overlying Marie Creek Formation is absent, the Ethel Lake Formation is difficult to differentiate from the Sand River Formation (see Atlas map Q-g-8, cross-sections E4-E4' and N1-N1'). In this corner of the map area any stratified deposit that lies on the surface of the Bonnyville Formation, and which is overlain by the Grand Centre Formation, is assumed to be as young as possible and is therefore included within the Sand River Formation.

Nature of Contacts

Locally, within the uplands in the southeast, silt and clay of the Ethel Lake Formation rest on an oxidized surface of the Bonnyville Formation, indicating a disconformable contact (see Atlas map Q-g-7, cross-section E1-E1', testhole T-41). For the most part this contact is generally sharp. In the central part of the map area, within the Kehiwin Upland Plain and the Beaver River Lowland Plain, sand and gravel deposits of the Ethel Lake Formation conformably overlie unoxidized till of the Bonnyville Formation. The upper surface of the Ethel Lake Formation is considered to be conformable with the base of the Marie Creek Formation. This contact is commonly gradational, especially where the Ethel Lake Formation is composed of stratified silt and clay. The gradational contact probably reflects glacial erosion and incorporation of the top of the Ethel Lake Formation into the base of the Marie Creek Formation. Where the Ethel Lake Formation is composed of coarser sand and gravel, the contact with the Marie Creek Formation is generally much sharper.

Origin

The fine-grained deposits of the Ethel Lake Formation are considered to have a glaciolacustrine origin and were deposited from proglacial lakes which formed during the advance of the third major glaciation in the map area, herein named the Ardmore Glaciation (Andriashek, 1985). It is believed that most of the sediment deposited within these proglacial lakes was derived from both meltwater flowing off the Ardmore Glacier, and from natural drainage ponded against the glacier margin. The curvilinear configuration of the distribution of the thick deposits of the Ethel Lake Formation in the south and southwest probably reflects the control that the glacial margin had on the distribution of these proglacial lakes (see Atlas map P-g-17). The presence of sand and gravel interbedded with, or overlying, the silt and clay (see Atlas map Q-g-8, cross-section N1-N1', testholes E966 and E1723), indicates that glaciofluvial sediment is also present, suggesting a source nearer to the glacier margin. These sediments were possibly deposited in an ice-contact delta along the northeast margin of the ice-ponded proglacial lakes. The veneer of sand and gravel of the Ethel Lake Formation in the north end of the Kehiwin Upland Plain and the Beaver River Lowland Plain, is believed to have a glaciofluvial origin, and was possibly deposited during the retreat of the Fort Kent Glacier, rather than the advance of the Ardmore Glacier.

MARIE CREEK FORMATION

Description of Formation

The Marie Creek Formation consists of diamicton which is characterized by: a high amount of calcareous material, particularly dolomite and dolostone, in both the very coarse sand and silt-clay fractions; a high amount of very coarse sand in the matrix; and a high resistivity response on the electric logs. Commonly, the upper part of the formation is highly oxidized, both in outcrop and subsurface. The formation is extensive, but does not cover all of the study area. Only the upper portions of the formation crop out, mainly along stream cuts and shallow man-made exposures such as road cuts. However, the entire formation has been mapped in the subsurface from dry-auger flite samples, rotary drill cuttings, sidewall samples, and geophysical logs. On the basis of matrix texture, the Marie Creek Formation is divided into two units: unit 1, a clayey diamicton, which is overlain by unit 2, a sandy diamicton.

Unit 1

Description of Unit

Unit 1 consists of unoxidized, dark grey (5Y 4/1) sandy-clay diamicton. The average matrix texture of the unit consists of about 32 percent sand, 30 percent silt, 38 percent clay, with about 2 percent of very coarse sand (Table 2-4). In numerous dry-auger flite samples, discrete lenses or attenuated "clasts" of silt and clay are found as thin layers or streaks within the diamicton. Commonly, these streaks of silt and clay are imbedded in a more sandy matrix, similar to that of the overlying unit 2 of the Marie Creek Formation. The composition of the 1-2 mm sand fraction averages about 62 percent igneous and metamorphic fragments, 27 percent quartz fragments, 3 percent limestone, 6 percent dolostone, less than 1 percent quartzite and quartz sandstone fragments, and less than 2 percent local rock fragments (Table 2-4). Calcareous material makes up 12 to 17 percent of the silt-clay fraction, with dolomite more abundant than calcite (calcite/dolomite ratio, 0 .25). The clay mineralogy of a few representative samples consists of about 45 to 55 percent illite, 25 percent kaolinite, 13 to 24 percent montmorillonite, and 7 percent chlorite.

Distribution, Thickness and Subcrop Topography

Unit 1 of the Marie Creek Formation is confined primarily to the Beaver River Lowland Plain and the Rieta Lake Upland. The unit extends in a lobate form southwest as far as Tp 59, R 10, following a shallow depression on the surface of the underlying Ethel Lake Formation. The unit ranges in elevation from as high as 620 m within the Reita Lake Uplands in the southeast, and the Lac la Biche Uplands in the southwest, to as low as 500 m within a small valley south of Cold Lake. Unit 1 is generally thin within the map area, particularly within the Beaver River Lowland Plain and Reita Lake Upland where it is commonly less than 5 m thick. The unit is thickest within the Kehiwin Upland in the southwest, where as much as 25 m are mapped within a northeast-southwest oriented deposit.

Differentiation from other Units

Unit 1 is differentiated from unit 2 of the Marie Creek Formation primarily on the basis of matrix texture. Unit 1 is more clayey and commonly contains discrete lenses and partings of silt and clay in the form of clasts. Both units have a similar 1-2 mm sand composition, except that unit 1 does not contain the very high dolostone and dolomite facies which lies at the top of unit 2 (Table 2-4). Unit 1 is differentiated from the till of the underlying Bonnyville Formation primarily on the basis of the 1-2 mm sand composition: unit 1 contains considerably more calcareous material, and considerably less quartz than the Bonnyville Formation (Table 2-4).

Nature of Contacts

Unit 1 generally has a gradational contact with the underlying Ethel Lake Formation, and commonly shows incorporation of the underlying silt and clay. The contact is considered to be conformable. In fact, in the Beaver River Lowland Plain large areas of the underlying Ethel Lake Formation have been completely eroded and incorporated into unit 1. In these areas unit 1 overlies the sandy till of the Bonnyville Formation, and the contact is generally sharp and well defined on the basis of textural properties. Unit 1 also has a gradational contact with the base of the overlying unit 2 diamicton, though locally the contact is sharp and abrupt. The contact is commonly recognized in dry-auger samples as the first occurrence of thin silt and clay layers within the diamicton. Resistivity responses are not very useful for establishing the contact.

Unit 2

Description of Unit

Unit 2 of the Marie Creek Formation is widespread over much of the Sand River map area. It is characterized by a sandy diamicton, the top of which, in many places, is weathered and highly oxidized olive (5Y 4/4) to olive brown (2.5Y 4/4). Below the oxidized horizon the diamicton is unoxidized dark grey (5Y 4/1). The upper portion of the oxidized horizon is commonly highly fractured, forming angular shards or blocks about 6 cm in length, 3 cm in width, and 2 cm in thickness. Iron or manganese staining can be found along the joint surfaces and fracture planes. The degree of fracturing diminishes such that only large-scale joints, spaced a few meters apart, are present at depth. The fractured structure, combined with the sandy texture of the unit, results in the upper part being easy to excavate with a pick or backhoe, even though the formation as a whole is very dense and consolidated. A concentration of boulders is found at the contact of unit 2 with the overlying Grand Centre Formation in some places. The average matrix texture of unit 2 consists of about 41 percent sand, 30 percent silt, and 29 percent clay (Table 2-4). Characteristically, the diamicton contains abundant pebbles and clasts, and is relatively rich in the very-coarse sand fraction (2.7 percent). The composition of the 1-2 mm sand fraction averages about 61 percent igneous and metamorphic rocks, 21 percent quartz fragments, 4 percent limestone, 13 percent dolostone, less than 1 percent quartzite and quartz sandstone, and 1 to 2 percent local rocks (Table 2-4). Calcareous material makes up as much as one fifth of the silt-clay fraction with dolomite much more abundant than calcite (calcite/dolomite ratio, 0.17). On the basis of carbonate content, unit 2 can be divided into two facies (Table 2-4). The upper facies is particularily rich in dolostone and relatively low in quartz in the 1-2 mm sand fraction, and rich in dolomite in the silt-clay fraction. The lower facies contains less calcareous material, but even so, the values are still relatively higher than those of the other formations (Table 2-4). The clay mineralogy of a few representative samples consists of about 53 to 61 percent illite, 18 to 26 percent kaolinite, 13 to 20 percent montmorillonite, and 5 to 8 percent chlorite. Resistivity responses show that the top of unit 2 has a distinctly higher resistivity compared to the overlying Grand Centre Formation (Figure 2-21).

Distribution, Thickness, and Subcrop Topography

Unit 2 is extensive in the eastern half and central parts of the study area, but lies primarily along the buried Helina Valley, and segments of the Kikino Valley in the northwest (see Atlas map P-g-19). Though unit 2 was probably once present in the southwest, it is now absent and is considered to have been eroded prior to the last glaciation in the area. The southwestern limit of unit 2 is defined by a northwest-southeast trending margin than extends from Tp 69, R 17 to Tp 58, R 7. Along this margin, unit 2 terminates against the northeast flank of the underlying upland. Two small lobe-forms extend southwest of the upland. One lobe lies along a shallow depression above the buried Beverly Valley in Tp 58 to 59, R 9 to 11. The other lobe extends south and east along the northern segment of the buried Kikino Valley (see Atlas map P-g-19). The northern extent is uncertain because data are lacking. The top of unit 2 lies at an elevation as high as 675 m along the uplands flanking the southwestern margin of the Kikino Valley (in Tp 62, R 16), and as low as 510 m along the Beaver River Lowland Plain (in Tp 63, R 3 to 4). Unit 2 is at least 10 m, and commonly 20 m, thick over much of its extent. The thickest deposits of unit 2 are found primarily in the Reita Lake and Marguerite Lake uplands where as much as 47 m have been mapped (see Atlas map O-g-7, cross-section E2-E2'). Other areas of thick deposits are found along the southwestern margin of the unit in Tp 61, R 10, and above segments of the buried Beverly, Helina, and Big Meadow valleys where the unit infills topographic lows on the surface of the underlying Bonnyville Formation. Because unit 1 of the Marie Creek Formation is thin in most places the total thickness of the formation does not differ much from that of unit 2 (see Atlas map P-g-20).

Differentiation from other Formations

Unit 2 is differentiated from all other units primarily on the basis of its high carbonate content, particularily dolostone and dolomite, and relatively higher resistivity values. This is specially true in the east, where unit 2 of the Marie Creek Formation and unit 2 of the Bonnyville Formation are both very sandy. Unit 2 of the Marie Creek Formation is differentiated from the various members of the overlying Grand Centre Formation by the folowing: (1) with the exception of the Kehiwin Lake Member, unit 2 of the Marie Creek Formation is more highly oxidized and has an olive-brown color which contrasts to the dark grey-brown color of the Grand Centre Formation; (2) the top of unit 2 is commonly highly fractured and well-jointed, which differentiates it from the massive, structureless outcrop appearance of the clayey members of the Grand Centre Formation; (3) unit 2 of the Marie Creek formation is texturally more sandy than most of the members of the Grand Centre Formation, particularily in the amount of very coarse sand (Table 2-4); (4) unit 2 is generally more difficult to penetrate with a dry auger compared to the Grand Centre Formation, presumably because it is more sandy and drier; (5) unit 2 contains significantly more calcareous material, particularly dolostone and dolomite, in both the very-coarse sand and silt-clay fractions, compared to the Grand Centre Formation (Table 2-4). Unit 2 also contains less igneous and metamorhpic rock fragments in the very-coarse sand fraction as well (Table 2-4); (6) in almost all places the top of unit 2 has a higher resistivity than the base of the overlying Grand Centre Formation (Fig. 2-21). In the western part of the map area the differentiation between unit 2 of the Marie Creek Formation and the Grand Centre Formation is difficult. This is because the distinctive sandy texture and upper high-dolostone facies of unit 2 are absent, probably because of glacial erosion. Evidence for glacial erosion comes from displaced slabs of the high-dolostone facies of unit 2 of the Marie Creek Formation that are found as incorporated blocks within the Grand Centre Formation (see Atlas map Q-g-8, cross-section N1-N1', testhole 77SR-12).

Nature of Contacts

In those areas where unit 2 of the Marie Creek Formation directly overlies the Bonnyville Formation, the contact is varied. In some places it is sharp and can be recognized easily from the resistivity logs. In other places the contact is gradational, especially with respect to the texture and 1-2 mm sand composition. As an example, in some testholes unit 2 becomes increasingly more sandy and quartz-rich with depth, and acquires the same textural and compositional properties as the top of the underlying Bonnyville Formation. On the basis of the oxidized profile on the surface of the Bonnyville Formation the contact of unit 2 with the Bonnyville Formation is considered to be disconformable. Unit 2 has a sharp and well-defined contact with the base of the overlying stratifed deposits of the Sand River Formation. In most places the top of unit 2 is oxidized, indicating a disconformable contact with the Sand River Formation. The contact is generally sharp between unit 2 of the Marie Creek Formation and the overlying Grand Centre Formation. Commonly, in the east, the contact is defined by a boulder concentration though it is uncertain to which unit the boulders belong. The contact in the western portion of the study area may be more difficult to define because the sandy, high-dolostone facies of unit 2 is absent, due to glacial erosion.

Origin and Variations in the Properties

Diamicton of both units of the Marie Creek Formation represent glacial sediment (till) that was deposited during the third major glacial advance in the map area, the Ardmore Glaciation. The abundance of carbonates, particularily dolostone, in the till indicates that a considerable amount of the Devonian carbonates were eroded compared to the other rock fragments. This suggests that the Ardmore Glacier flowed along the narrow outcrop belt of carbonate implying a flow direction from the north, instead of northeast. This is also supported by a preferred north-south pebble orientation of the upper part of the Marie Creek Formation, measured at one outcrop section. Regional compositional variations of the Marie Creek Formation show that the high-dolostone facies of unit 2 can be traced into the southwestern part of the map area, but is absent in the west and northwest. It is probable that the high-dolostone facies was present at one time, but was subsequently glacially eroded. The evidence for this consists of thick, displaced masses of the high-dolostone facies of the Marie Creek Formation contained within the Vilna Member of the overlying Grand Centre Formation.

SAND RIVER FORMATION

Description of Formation

The Sand River Formation consists of stratified sand and silt with lesser amounts of clay and gravel. The formation is recognized in outcrops and testholes primarily in the central and southwestern parts of the study area. Dry-auger samples indicate that in the subsurface the top of the formation is oxidized olive brown (2.5Y 4/4), but becomes unoxidized dark grey (5Y 4/1) with depth. In places both the top and bottom of the formation is oxidized but the middle is unoxidized. Sand and silt deposits are commonly oxidized in outcrops. The sand is generally fine- to medium-grained, well-sorted, and commonly clast-free. Field observations describe the composition of the sand as primarily quartz with lesser amounts of igneous, metamorphic and locally derived rock fragments. Commonly, the sand is stratified, with cross-bedding visible in outcrop. Locally the sand is interbedded with silt and lenses of massive diamicton. All deposits of the Sand River Formation are generally poorly consolidated, soft, moist and easy to penetrate with a dry auger.

Distribution, Thickness, and Subcrop Topography

The Sand River Formation lies mainly in the central and southwest parts of the study area (see Atlas map P-g-21). It is either absent or thin and discontinuous within most of the uplands. It overlies the Marie Creek Formation extensively in the east-central part of the area, but overlies the Bonnyville Formation in the southwest, above segments of the buried Vegreville, Beverly, and Kikino valleys (see Atlas map Q-g-8, cross-section E4-E4'). In the northwest, in Tp 67 to 69, R 11 to 13, the Sand River Formation consists mainly of thin silt and clay deposits, which drape the gently west-sloping Bonnyville Formation above the buried Imperial Mills Valley. Small, discontinuous deposits of the formation are also recognized above the buried Helina Valley, and above the buried Vermilion Valley in the southeast. The top of the formation ranges in elevation from as high as 660 m on top of a ridge in Tp 59, R 14 to 15, to as low as 530 m in Tp 62, R 1 within the Beaver River Lowland Plain. The Sand River Formation is generally thin over most of the central part of the map area, averaging less than 10 m thick (see Atlas map P-g-22)). Thicker deposits (> 20 m) are mapped within linear trends above the buried Beverly and Vegreville valleys in the southwest.

Differentiation from other Formations

The Sand River Formation is differentiated from other stratified deposits primarily on the basis of stratigraphic position. The Sand River Formation can be differentiated, with certainty, from the underlying Ethel Lake Formation only in those areas where till of the Marie Creek Formation separates the two. Consequently, the two formations cannot be differentiated in the southwestern parts of the study area where the Marie Creek Formation is absent. For the purpose of mapping, however, all stratified deposits which overlie the Bonnyville Formation are considered to be as young as possible and are therefore included within the Sand River Formation.

Nature of Contacts

In most places the Sand River Formation has a sharp contact with the top of the underlying Marie Creek or Bonnyville formations. The contact is considered to be conformable in those places where oxidized deposits of the Sand River Formation overlie oxidized till of the Marie Creek Formation. Conversely, the contact is considered to be disconformable in those areas where unoxidized deposits of the Sand River Formation overlie oxidized till of either the Marie Creek Formation or the Bonnyville Formation. In some places the oxidized, high-dolostone facies of the upper part of the Marie Creek Formation has been eroded prior to burial by the Sand River Formation, indicating an unconformable contact. The contact of the Sand River Formation with the base of the overlying Grand Centre Formation is sharp in some places, gradational in others. Sharp, disconformable contacts are indicated in those places where unoxidized deposits of the Grand Centre Formation overlie oxidized sand deposits of the Sand River Formation. Gradational, conformable contacts are suggested in those places where the upper part of the Sand River Formation consists of interbedded sand and diamicton that is lithologically similar to the base of the overlying Grand Centre Formation.

Origin

The stratified deposits of the Sand River Formation are believed to have different origins, and likely were deposited at different times. Some of the silt and clay deposits are considered to have a glaciolacustrine origin, deposited from ice-marginal lakes which formed during the retreat of the Ardmore Glacier. These glaciolacustrine deposits were subsequently exposed and weathered, with the oxidation penetrating down to the surface of the underlying Marie Creek Formation in places. The coarser-grained silt and sand deposits, which form a widespread veneer throughout the central part of the map area, may have either a glaciofluvial or glaciolacustrine origin. On the one hand, the widespread abundance of fine-grained sand and silt, interbedded in places with thin diamicton layers, suggests a glaciolacustrine origin. On the other hand, the presence, in places, of gravel beds and large-scale cross-bedding suggests a possible glaciofluvial origin.

GRAND CENTRE FORMATION

Description of Formation

The Grand Centre Formation is the uppermost formation in the Quaternary stratigraphic sequence in the Sand River map area. It is widespread, and lies at the surface in most places, except where it is buried by postglacial stratified deposits (see Fig. 2-25, and Fenton and Andriashek, 1983). The formation is composed primarily of diamicton which generally is characterized by a sandy-clay matrix texture, a relative abundance of igneous and metamorphic rock fragments in the 1-2 mm sand fraction, a soft unconsolidated nature, and a dark grey-brown color. The top of the Grand Centre Formation ranges in elevation from as high as 850 m in the Heart Lake and Muriel Lake highlands, to about 530 m in the Beaver River Lowland Plain (see Atlas map P-g-23). It forms one of the thickest stratigraphic units in the map area, ranging between 10 m and 30 m over most of its extent (see Atlas map P-g-24). Large areas of thick deposits of the Grand Centre Formation are mapped within the Kehiwin Upland Plains, and within the Vilna Plains and Saddle Lake Uplands. In places within these uplands the formation is as much as 60 m thick. Small areas of exceedingly thick deposits of the formation are mapped within the isolated highlands that lie south of the larger lakes in the map area (Cold Lake, Marie Lake, Primrose Lake, Wolf Lake, Muriel Lake). In most of these highlands the Grand Centre Formation consists of ice-thrust, glacially-displaced masses of older sediment, including diamicton that is not characteristic of this formation. For example, within the Wolf Lake and Primrose Lake highlands, the Grand Centre Formation consists of more than 60 m of ice-thrust Marie Creek Formation till. On the basis of differences in matrix texture, color, orientation of glacial ice-flow indicators, and stratigraphic position, the Grand Centre Formation is divided into four members within the Sand River map area (Fig. 2-25). The formation has not been subdivided in the perimeter areas within the Tawatinaw, Edmonton or Vermilion map areas. From oldest to youngest, the four members are: the Hilda Lake Member, the Reita Lake Member, the Kehiwin Lake Member, and the Vilna Member. The following is a summary description of those members.

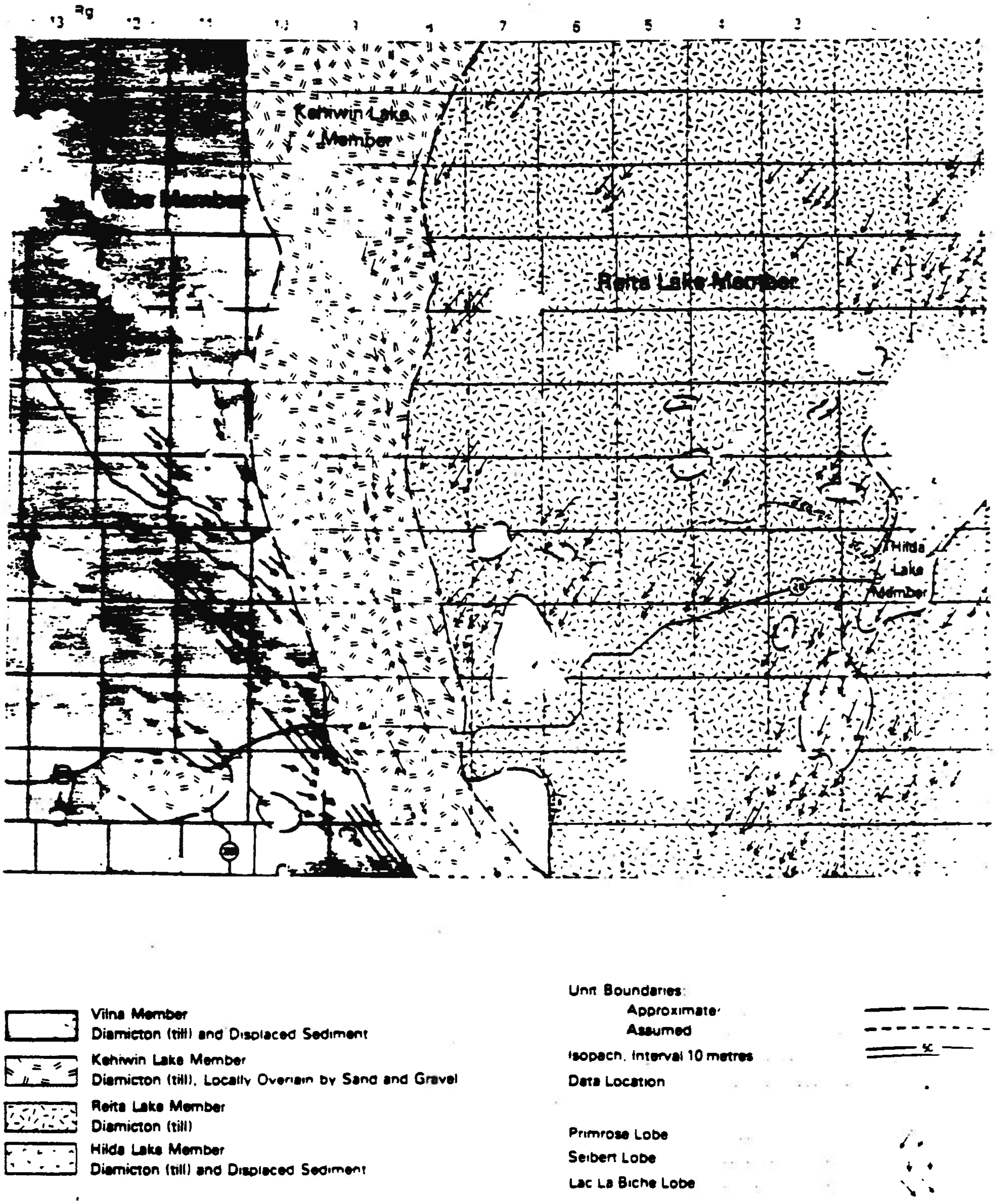


Figure 2-25 Outcrop map of the Hilda Lake, Reita Lake, Kehiwin Lake and Vilna members of the Grand Centre Formation. The figure also depicts the glacial flow directions of the Primrose, Seibert and Lac la Biche lobes of the Cold Lake Glacier

Hilda Lake Member

Description of Member

The Hilda Lake Member consists of a very dark, grey-brown, clayey diamicton, which locally contains incorporated masses of glacially- displaced bedrock including shale and ironstone. The top of the member is poorly oxidized, very dark grey-brown (2.5Y 3/2), and becomes unoxidized, very dark-grey (5Y 3/1) with depth. In outcrop, the diamicton is massive to slightly fissile, though locally larger, slightly iron-stained fractures or joints are present. Directly south of Cold Lake the member consists of significant amounts of glacially transported blocks of shale, sand and silt, and older diamicton which were deposited within a glacially streamlined ridge. The average matrix texture of the diamicton consists of about 27 percent sand, 30 percent silt, and 43 percent clay, with very coarse sand making up less than 1 percent of the matrix (Table 2-4). The member characteristically contains few pebbles or granules, and is soft and easy to penetrate with a dry auger. Commonly, a boulder concentration can be found at the base of the unit. The average composition of the 1-2 mm sand fraction consists of about 69 percent igneous and metamorphic fragments, 23 percent quartz, 2 percent limestone, 3 percent dolostone, 1 to 2 percent local rock fragments, and 1 percent quartzite and quartz sandstone fragments (Table 2-4). Calcareous material makes up about 11 percent of the silt-clay fraction with dolomite more abundant than calcite (calcite/dolomite ratio, 0.24). The clay mineralogy of a few representative samples consists of about 51 percent illite, 20 percent kaolinite, 24 percent montmorillonite, and 5 percent chlorite.

Distribution, Thickness, and Topograophy

The Hilda Lake Member is confined primarily to the central and eastern part of the Sand River map area (Fig. 2-25). Although in most places the member is overlain by the Reita Lake Member (see Atlas map Q-g-7, cross-section E2-E2'), it does crop out within a pronounced high-relief, hummocky ridge, south Cold Lake in Tp 61 to 63, R 1 to 2, and within glacially streamlined ridges near Angling Lake (Tp 60, R 2 to 3; Fenton and Andriashek, 1983). Glacially displaced and transported blocks of shale, silt and sandstone are exposed in both areas. The top of the member ranges in elevation from as high as 630 m in the north, to as low as 530 m within the Beaver River Lowland Plain. The thickest deposits are found within the hummocky ridge directly south of Cold Lake: here, the member is as thick as 53 m. Thick deposits have also been mapped within a number of discontinuous ridges located along the base of the Medley River and Marguerite Lake Uplands, and west of Cold Lake in Tp 65, R 2. Elsewhere, the Hilda Lake Member is generally thin, commonly less than 10 m thick.

Reita Lake Member

Description of Member

The Reita Lake Member consists of a clayey-sand diamicton. The top of the member is oxidized dark grey-brown (2.5Y 4/2) but becomes unoxidized dark grey (5Y 3/1) with depth. The top of the member is generally soft and fissile, but it becomes more compact and massive with depth. It is moist and relatively easy to penetrate with a dry-auger. There are relatively few pebbles or granules but in places a boulder concentration can be found at the base. The average matrix texture of the diamicton consists of about 38 percent sand, 26 percent silt, and 36 percent clay, with very coarse sand making up about 1.5 to 2 percent of the matrix (Table 2-4). The average composition of the 1-2 mm sand fraction consists of about 69 percent igneous and metamorphic rock fragments, 25 percent quartz, 2 percent limestone, 3 percent dolostone, 1 percent quartzite and quartz sandstone fragments, and about 1 percent local rock fragments (Table 2-4). Calcareous material makes up about 11 percent of the silt-clay fraction with dolomite more abundant than calcite (calcite/dolomite ratio, 0.28). The clay mineralogy of a few representative samples consists of about 56 percent illite, 22 percent kaolinite, 16 percent montmorillonite, and 6 percent chlorite. Glacially streamlined features on the surface of the Reita Lake Member have a characteristically northeast-southwest direction.

Distribution, Thickness and Topography

The Reita Lake Member forms the surface unit over most of the eastern half of the Sand River map area, and is believed to extend south into the Vermilion map area (Fig. 2-25). The western limit is defined essentially by the Sand River in the northern and central parts of the map area, and by Kehiwin Creek and Kehiwin Lake in the south-central part. The top of the member ranges in elevation from as high as 790 m within the Muriel Lake Highlands in the south, to as low as 550 m in the eastern part of the Beaver River Lowland Plain. The Reita Lake Member forms a relatively thin drape, generally less than 10 m thick, over most of the Reita Lake and Marguerite Lake uplands, and within segments of the Beaver River Lowland Plain (see Atlas map 0-g-7, cross-section E1-E1'). Thicker deposits of the member are found within the east-west oriented uplands that flank the northern and southern margins of the Beaver River Lowland Plain, and in isolated areas along the western margin of the Beaver River Lowland Plain. The thickest deposits of the Reita Lake Member (>60 m) are found within the isolated highlands in the eastern part of the map area. Within these highlands the member consists primarily of stratigraphically older till, mainly the Marie Creek till, which has been displaced by glacial ice-thrusting.

Kehiwin Lake Member

Description of Member

The Kehiwin Lake Member consists primarily of sandy diamicton which is locally overlain by stratified sand and gravel in the southwestern corner of the Sand River map area. The top of the member is oxidized olive-brown (2.5Y 4/4) but becomes unoxidized dark olive-grey (5Y 3/2) to very dark-grey (5y 3/1) with depth. Typically, the member is well-jointed and has a blocky structure, with iron and manganese staining along the fracture surfaces. The average matrix texture of the diamicton consists of about 43 percent sand, 32 percent silt, and 25 percent clay, with very coarse sand making up about 2 percent of the matrix (Table 2-4). The average composition of the 1-2 mm sand fraction consists of about 62 percent igneous and metamorphic rock fragments, 29 percent quartz, 3 percent limestone, 3 percent dolostone, 1 percent local rock fragments, and 1 percent quartzite and quartz sandstone fragments (Table 2-4). Calcareous material makes up about 8 percent of the silt-clay fraction with dolomite more abundant than calcite (calcite/dolomite ratio, 0.32). Only one sample of the Kehiwin Lake Member was analysed for clay minerals, and that contained about 58 percent illite, 22 percent kaolinte, 15 percent montmorillonite and 5 percent chlorite. Glacially streamlined landforms on the surface of the Kehiwin Lake Member have a characteristic north-south orientation (Fig. 2-25).

Distribution, Thickness, and Topography

The Kehiwin Lake Member crops out along a strip approximately 20 km wide in the central part of the Sand River map area (Fig. 2-25).

The member is believed to extend southwest of the map area and has been mapped within the subsurface in the Vilna and Saddle Lake plains, and the Saddle Lake Upland (see Atlas map Q-g-8, cross-sections E4-E4' and N1-N1'). The eastern boundary of the member essentially parallels the course of the Sand River in the north, and along Kehiwin Lake in the south. The top member ranges in elevation from as high as 850 m within the Heart Lake Highland to as low as 590 m within the Kehiwin Upland Plain. The Kehiwin Lake Member is one of the thickest stratigraphic units in the map area, averaging more than 30 m over most of its extent (see Atlas map Q-g-8, cross-sections N1-N1' and N2-N2'). The member is believed to thin along both the eastern edge where it overlies the Reita Lake Member, and along the western edge where it is overlain by the Vilna Member. Sand and gravel, which overlies the diamicton in the southwestern corner of the map area, is generally less than 7 m thick and appears to lie within a poorly defined meltwater channel eroded onto the surface of the diamicton of the Kehiwin Lake Member (see Atlas map Q-g-8, cross-section E4-E4').

Vilna Member

Description of Member

The Vilna Member consists of a clayey diamicton, which locally includes blocks of glacially displaced older sediment. The member forms the surface unit in the western part of the map area. The top of the member is oxidized dark grey-brown (2.5 Y 4/2) but becomes unoxidized very dark grey (5Y 3/1) with depth. In outcrop the diamicton is commonly very clayey, and contains few pebbles or granules. The diamicton is generally massive, though in places it has a pseudostratified appearance. These "strata" generally consist of older sediment that has been glacially displaced and attenuated in the form of layers or beds within the diamicton. The average matrix texture of the diamicton consists of about 32 percent sand, 32 percent silt, and 36 percent clay, with very coarse sand making up about 1 percent of the matrix (Table 2-4). The unit is generally unconsolidated, soft, and easy to penetrate with a dry auger. The average composition of the 1-2 mm sand fraction consists of about 64 percent igneous and metamorphic rock fragments, 28 percent quartz, 3 percent limestone, 3 percent dolostone, about 1 percent quartzite and quartz sandstone fragments, and 1 percent locally derived rock fragments (Table 2-4). Calcareous material makes up about 11 percent of the silt-clay fraction, with dolomite more abundant than calcite (calcite/dolomite ratio, 0.33). The clay mineralogy of a few samples from one testhole consists of about 53 percent illite, 21 percent kaolinite, 17 percent montmorillonite, and 9 percent chlorite. Glacially streamlined landforms on the surface of the Vilna Member are very pronounced and have a dominant northwest-southeast orientation (Fig. 2-25).

Distribution, Thickness and Topography

The Vilna Member forms the surface unit over most of the western portion of the Sand River map area (Fig. 2-25). The eastern limit of the member lies essentially along R 10, extending south from Tp 69 to Tp 58. This boundary is not clearly defined, primarily because the eastern edge of the member is gradational with, or interfingers with, the Kehiwin Lake Member. The Vilna Member probably extends west and south beyond the Sand River map area and into the Tawatinaw and Vermilion map areas (see Atlas map Q-g-8, cross-sections E4-E4' and N1-N1'). The top of the Vilna Member ranges in elevation from as high as 700 m within a large glacial ice-thrust moraine in the Garner Lake Upland, to as low as 550 m within the area bordering Lac la Biche. The thickest deposits are found within isolated areas in the southwest, and along the southeastern border of the unit. Within these areas the member is as much as 40 m thick. It is notably thin in the extreme southwestern corner of the Sand River map area (Tp 58 to 61, R 13 to 14), where it forms a thin to discontinuous drape over the Kehiwin Lake Member (see Atlas map Q-g-8, cross-section E4-E4').

Differentiation from other Formations

The Grand Centre Formation is the uppermost diamicton and overlies either stratified sediments of the Sand River Formation, or glacial sediment (till) of the Marie Creek and Bonnyville Formations (see Atlas map Q-g-8, cross-section N1-N1'). Diamictons of the four members of the Grand Centre Formation are differentiated from the underlying till of the Marie Creek and Bonnyville formations by the following criteria: (1) with the exception of the Kehiwin Lake Member, all other members of the Grand Centre Formation have a darker, gray-brown oxidized color than the olive-brown oxidized color of the Marie Creek and Bonnyville formations; (2) the Hilda Lake, Reita Lake, and Vilna members are generally massive to slightly fissile, moist, and soft, compared to the Marie Creek Formation, which is jointed, consolidated and relatively dry. The Kehiwin Lake Member may be as jointed, but is soft and unconsolidated; (3) the Hilda Lake, Reita Lake, and Vilna members are less sandy, particularily with respect to the amount of very coarse sand, and are also more clayey than either the Marie Creek Formation or the Bonnyville Formation in the eastern two-thirds of the map area (Table 2-4). In the western part of the map area the textures of both the Vilna Member and the Bonnyville Formation are generally similar. The Kehiwin Lake Member is texturally similar also to both the Marie Creek and Bonnyville formations but does not contain nearly as much very coarse sand (Table 2-4); (4) all members of the Grand Centre Formation contain more igneous and metamorphic rock fragments in the very coarse sand fraction, than either the Marie Creek or Bonnyville formations. In addition, they contain much less quartz than the Bonnyville Formation, and significantly less carbonate than the upper portion of unit 2 of the Marie Creek Formation (Table 2-4). One exception is the Kehiwin Lake Member; it may also have as much quartz as the Bonnyville Formation. The areas of difficulty in differentiation occurr in the highland physiographic units, where significant amounts of glacially displaced blocks of older sediment, especially glacial sediment, are incorporated into the Grand Centre Formation.

Nature of Contacts

The Grand Centre Formation generally has a sharp and distinct contact with the stratified sediments of the underlying Sand River Formation. For the most part, this contact is considered to be disconformable. A conformable contact is suggested in places where the upper part of the Sand River Formation appears to have been deposited immediately prior to the deposition of the Grand Centre Formation. The Grand Centre Formation has a sharp, disconformable contact with the top of the Marie Creek Formation. In places a boulder concentration lies along this contact. Erosional contacts are evident in some places where the top of the Marie Creek Formation has been incorporated into the base of the Grand Centre Formation by glacial ice-thrusting. The nature of this erosion and incorporation is generally in the form of large, discrete masses. The Grand Centre Formation directly overlies the Bonnyville Formation in the southwestern part of the Sand River map area and in this part the contact is generally sharp and easily recognized on the electric logs (see Atlas map Q-g-8, cross-section E4-E4', testhole E496). The presence of a buried oxidized horizon at the surface of the Bonnyville Formation indicates that this contact is disconformable.

Origin

The diamictons of the four members of the Grand Centre Formation represent glacial sediment (till) which was deposited during the last major glacial event in the map area, the Cold Lake Glaciation. The advance of the glacier occurred in the form of three lobes: the first, the Primrose Lobe, advanced from the northeast; the second, the Seibert Lobe, advanced from the north; and the last, the Lac la Biche Lobe, advanced from the northwest (Fig. 2-25). The Hilda Lake and Reita Lake members were deposited by the Primrose Lobe, the Kehiwin Lake Member by the Seibert Lobe, and the Vilna Member by the Lac la Biche Lobe. A significant amount of glacial thrusting was associatied with all three lobes. In fact, all of the highland physiographic units owe their origin, in part, to glacial thrusting by these lobes. This thrusting and incorporation of large masses of the underlying stratigraphic units accounts for the diverse lithology of both the Hilda Lake and Vilna members. The enrichment of the base of the Primrose Lobe with clay from reworked shale had resulted in a very clayey basal till which was deposited from that lobe. It is believed that this is the origin of the very clayey till of the Hilda Lake Member. It is likely that higher up within the Primrose Lobe, less shale would have been incorporated, and thus, the upper portion of the till would be also be less clayey. It is believed that the till of the Reita Lake Member represents this upper, less clayey facies. Glacial thrusting and incorporation of the underlying stratigraphic units also accounts for the varied lithology of the Vilna Member. During the advance of the Lac laBiche Lobe, much of the underlying shale and siltstone of the Belly River Group was displaced and incorporated into the glacier.

SUMMARY OF QUATERNARY EVENTS AND POTENTIAL HYDROSTRATIGRAPHIC UNITS

The oldest and lowermost unit is the Empress Formation, originally defined as the Empress Group (Whitaker and Christiansen, 1972) in southeast Alberta. The formation consists of three lithologically distinct units. The lowermost, unit 1, consists of preglacial sand and gravel, composed predominantly of quartzite, chert, and sandstone deposited by rivers flowing from the Rocky Mountains. The unit lies extensively on the floors of the major preglacial valleys, and thus is considered to have a good aquifer potential. Unit 1 is overlain by undifferentiated fluvial or lacustrine bedded silt and clay of unit 2 of the Empress Formation. Unit 2 is continuous in segments of the buried preglacial valleys, and in these areas can be considered as an aquitard. Glaciofluvial meltwater, which preceeded the first glaciation in the area, deposited sand and gravel above unit 2 and in newly-eroded bedrock valleys. These deposits form unit 3 of the Empress Formation and are characterized by the presence of granitic clasts from the Canadian Shield. Glacial sediment (till), deposited by the glaciation, forms the Bronson Lake Formation, which is characterized by very clayey till, mixed with clay of undetermined origin. The formation is preserved primarily in segments of the buried bedrock valleys, particularly the Bronson Lake and Helina valleys.

Following the retreat of the first glaciation, and possibly during the advance of the second glaciation, glaciofluvial sand and gravel was deposited extensively above the Bronson Lake till in the buried valleys and on the bedrock surface in the interfluves between the valleys. These generally thick and extensive sand and gravel deposits comprise the Muriel Lake Formation, which is considered to have a high aquifer potential.

The second glaciation deposited the Bonnyville Formation which consists of a thick sequence of till, characterized, and differentiated from other tills, by an abundance of quartz, compared to other rock fragments, in the very coarse sand fraction. On the basis of texture and resistivity response, the Bonnyville Formation is divided into a lower, clayey till, locally mantled by a thick sand and gravel sequence, and an upper very sandy till. In the area west of Cold Lake, the sand and gravel, which lies between the two tills, is considered to have a good aquifer potential, even though it is not continuous.

Extensive areas of glaciolacustrine silt, clay, and minor sand and gravel, were deposited during either the retreat of the second glaciation, or advance of the third glaciation. These deposits comprise the Ethel Lake Formation, which forms a discontinuous drape overlying the Bonnyville till in the central and eastern part of the map area. The formation is considered to have a local potential as an aquifer in those areas where sand and gravel are interbedded with the silt and clay.

The third glaciation deposited till which comprises the Marie Creek Formation. The till is characterized by an abundance of dolostone in the very coarse sand fraction, and dolomite in the silt-clay fraction. On the basis of texture, the formation is divided into a lower clayey till, containing "clasts" of silt and clay eroded from the underlying Ethel Lake Formation, and an upper sandy till that is strongly weathered and oxidized. The Marie Creek Formation is extensive throughout the east and central parts of the map area, but is not recognized in the northwest or southwest corners.

Undifferentiated glaciolacustrine or glaciofluvial sand, silt and minor gravel were deposited above the Marie Creek till during both the retreat of the third glaciation, and advance of the fourth and last glaciation. These stratified deposits comprise the Sand River Formation, which is extensive but thin in the central and southwest parts of the map area. The formation is considered to have a moderate potential as an aquifer for local agricultural and home use.

The last glaciation deposited an extensive cover of both till and glacially thrust and displaced older sediment. This forms the Grand Centre Formation which, on the basis of texture and surface landforms, is divided into four members. The lowermost, the Hilda Lake Member, is found only in the east. It consists of a very clayey till mixed with glacially thrust sediment, including much shale from the Lea Park Formation. Glacial flutes and drumlins are oriented northeast-southwest on the surface of the Hilda Lake Member. The Reita Lake Member is also found in the east overlying most of the

Hilda Lake Member. Although generally consisting of a sandy clay till, in the high relief landforms directly south of the major lakes, glacially displaced masses of the Marie Creek till form most of the member. The Kehiwin Lake Member has a gradational interfingering north-south contact with the Reita Lake till in the centre of the Sand River map area. The Kehiwin Lake till is characterized by a very sandy texture, and glacial flutes that are oriented in a north-south direction. The Vilna Member is the uppermost member of the Grand Centre Formation. It overlies the Kehiwin Lake till in the west and is characterized by a generally clayey till, locally mixed with glacially displaced older till and bedrock. Glacial flutes on the surface of the Vilna Member are oriented in a northwest-southeast direction. All tills of the Grand Centre Formation characteristically have a greater amount of crystalline rock fragments in the very coarse sand fraction, compared to the other tills.

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HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA

Part III. Hydrochemistry

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SECTION 1: PHANEROZOIC

INTRODUCTION

Information on the physical and chemical properties of formation waters is important in hydrogeological studies for several reasons. First, unlike crude oil and natural gas, formation waters comprise the aqueous continuum which exists throughout all sedimentary basins; second, regional patterns of some components of formation waters reflect the flow path of that water and thereby may be used to assist in the interpretation of potentiometric surface patterns; third, unlike crude oil and natural gas, formation waters may take part in water-rock reactions, and knowledge of these reactions can be useful in interpreting the history of the formation waters; and fourth, maps of variation in density of the formation waters are essential for correcting hydraulic heads determined from drillstem tests and the production of accurate potentiometric surface maps.

In the Cold Lake Study Area the main source of information on formation waters is the hard copy file of the Energy Resources Conservation Board (ERCB) which contains approximately 3650 analyses in the study area up to the end of 1983. Most of these analyses were obtained by the producing companies and are highly variable with respect to the techniques used for sample preservation in the field, method of collection, and analytical techniques. Because of these facts, and the very large size of the data base, it was necessary to develop special software to cull, manipulate and otherwise sort this information before plotting on maps. The only published analyses of formation waters in the Cold Lake Study Area which contain data on minor and trace elements, and stable isotopes, are those of Hitchon and Friedman (1969) and Hitchon et al. (1971). Individual analyses of bromide, iodide and boron can be found in Hitchon et al. (1977). Unpublished analyses containing data on minor and trace elements are available in the files of the Project Manager; additional unpublished analyses include several injection waters disposed of to deep formations in the Cold Lake oil sands deposit (these form part of a contract carried out by the Alberta Research Council for Environment Canada). All these detailed analyses of formation waters can be made available whenever studies of contaminant transport are carried out in the Cold Lake Study Area. This report, therefore, is limited to the evaluation of the formation waters in the ERCB data base.

DATA CULLING AND MANIPULATION

The main objective of all culling, graphical and statistical techniques for evaluating formation water analyses is to obtain information which is not readily apparent from the analyses. The specific treatment technique depends, to a great extent, on the nature of the required information and the size of the data base. Culling criteria, several simple graphical procedures, the use of dummy values and data transformation techniques, and four fairly sophisticated statistical techniques for the treatment of standard formation water analyses are presented by Hitchon (1985). The size of the ERCB data base in the Cold Lake Study Area, together with the rather simplistic nature of the chemical and physical data available, mean that sophisticated statistical techniques for data analysis are not justified. Further, as noted by Hitchon (1985), most simple graphical methods have limited utility with large data bases, and this is particularly true when only the major ions have been determined. As a result of these limitations the approach to treating the vast number of data present in the ERCB formation water data file has been to develop culling criteria for removing analyses which are not representative of the formation water in the underground environment, and finding methods of treating the remaining data, which is still rather voluminous, to produce maps with reasonably smooth regional trends.

Most of the formation water samples were collected from drillstem tests, or surface facilities such as well heads, treaters, and separators. Some samples came from holding tanks or were produced by bailing, and are consequently of questionable quality. Formation waters from drillstem tests, or from surface facilities produced early in the history of the well, may be contaminated with drilling fluid or mud filtrate water. A poor (high) recovery position in the drillstem test fluid column is commonly indicative of a diluted formation water. Additional contamination may result from the use of KCl muds, acid washes, or washes from cement jobs. In the case of water samples obtained from producing oilfields, contamination may also be due to water injection into the reservoir; this can probably be evaluated with knowledge of the reservoir history. Although poor collection procedures and inadequate sample preservation are criteria which would normally justify culling, pertinent information is commonly not available. When an equivocal analytical procedure is known this also would justify removal of the sample from the data base. In addition to these limitations, generally only the common ions, calcium, magnesium, chloride, sulphate, bicarbonate, and carbonate are determined, with sodium being calculated stoichiometrically as the difference between the sum of the anions and the sum of the cations. Thus, although incomplete analyses and a poor ionic balance would normally be additional reasons for culling formation water analyses, the latter is not a valid criterion where sodium has been determined by difference. Despite all these variables which may affect the composition of formation waters in the ERCB data base, it has been possible to develop culling criteria and data manipulation techniques which result in reliable maps of the regional chemical and physical properties of the formation waters.

Following manual entry of the formation water analyses and ancillary information from the ERCB data file, the chemical information was examined by the routine NCHMCULL, the objective of which is to remove incomplete and obviously erroneous analyses.

Thus, samples that are clearly contaminated with washes from cement jobs, acid washes, and KCl muds are removed; also excluded are analyses where calcium and magnesium have been determined as equivalent calcium, and those for which any of the following are missing: Ca, Mg, Cl, SO_4, HCO_3 and CO_3 (a zero value for the latter can be accepted). For the few analyses in which sodium and potassium have been determined separately, a check is made on the cation/anion balance. Sodium is them calculated "by difference" on the remaining analyses; even if bromide and iodide are reported, which is but rarely, the Na(diff) value is calculated without the values for bromide and iodide. Total dissolved solids (TDS) are then calculated. The need to recalculate Na(diff) and total dissolved solids (calculated) results from our observation that these numbers are commonly in error in the hard copy files. The resulting file (CHPARAM) contains the following information for further testing:

Na(diff), Ca, Mg
Cl, Br, I, HCO_3, CO_3, SO_4
TDS (calc.), TDS(evap. 110C), TDS(ignition)
Density, resistivity

The underlined values are optional. The file CHPARAM is then separated into derivative files by stratigraphic or hydrostratigraphic units using the procedure described in Part 1. These derivative files now each contain information on the formation waters in the respective unit.

Once the most obviously erroneous analyses have been removed, the remaining analyses may be examined by a variety of techniques. Because many geochemical data approximate a log normal distribution, it is possible to use cumulative frequency plots of the logarithm of selected ions as a culling criterion. The most geochemically conservative ion reported in standard formation water analyses is chloride, and accordingly is the best one for constructing cumulative log frequency plots. A typical example is shown in the upper diagram in figure 3-1. Computer printouts are then obtained of the

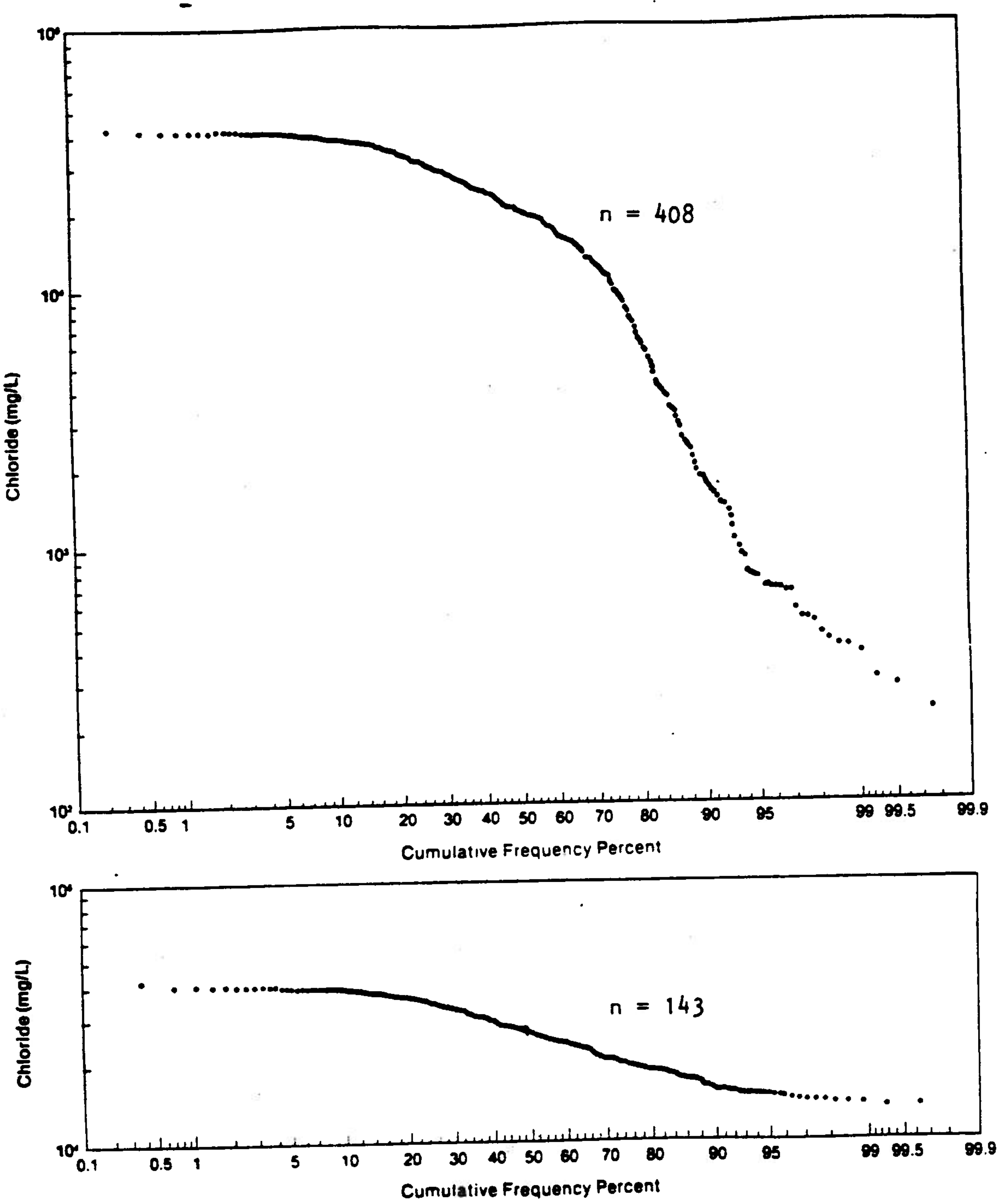


Figure 3-1 Cumulative frequency plots of log Cl in formation waters from the Lower Cretaceous Viking Formation, Cold Lake Study Area. Upper diagram: original data base; Lower Diagram: after removal of the "tails" following manual examination of selected individual analyses

individual analyses at the less-than-10 percent and greater-than-90 percent frequency intervals. Rapid manual examination of these analyses allows removal of all or part of the "tails" and after possibly several iterations, the final satisfactory cumulative frequency profile is obtained (see lower diagram, figure 3-1). Experience shows that the majority of formation water analyses removed by this technique was subject to either evaporation in holding tanks or contamination by drilling mud. Although other ions could be plotted using cumulative log frequency plots, the use of only chloride has proved to be satisfactory.

Contour maps of the regional distribution of selected chemical and physical properties of formation waters from the cleaned-up data base can then be plotted to identify the remaining anomalous samples. The most useful parameters for this purpose are total dissolved solids (calculated), chloride, sulphate, and density. More rigorous culling of the remaining anomalous samples could then be achieved using trend surface maps, although this technique was not used in the present study. Many other culling methods can be devised but it is doubtful if the reliability of the information present in the ERCB data file justifies them at this stage. Sometimes as few as 15 percent of the original data remain after the culling procedures just described although the remaining analyses for the Cold Lake Study Area represent 23 percent of those originally entered. Table 3-1 shows the comparison between the size of the original data base as entered manually from the ERCB data file (see note below table), with the intermediate data base after using the program NCHMCULL, and the final data base following removal of samples using cumulative log frequency plots and contour maps. Although, perhaps, the final data bases could be purged of additional analyses using more rigorous culling techniques, one may have considerable confidence in the general regional trends of the formation water maps shown in the Atlas.

Table 3-1

Comparison of size of intermediate and final formation water data bases following various culling procedures, Cold Lake Study Area

Hydrostratigraphic unit		Intermediate data base (after using NCHMCULL)	Final data base
N	"Viking sandstone" aquifer	408	143
L	"Upper Mannville" Group aquifer	1161	409
J	"Lower Mannville" Group aquifer	597	202
I	Wabamun-Winterburn aquifer	79	37
H	Grosmont Formation aquifer	44	21
G	Camrose Tongue aquifer	29	26
-	Leduc Formation aquifer	6	1
E	Cooking Lake-Beaverhill Lake-Watt Mountain aquifer	42	13
		Total: 2366	Total: 852

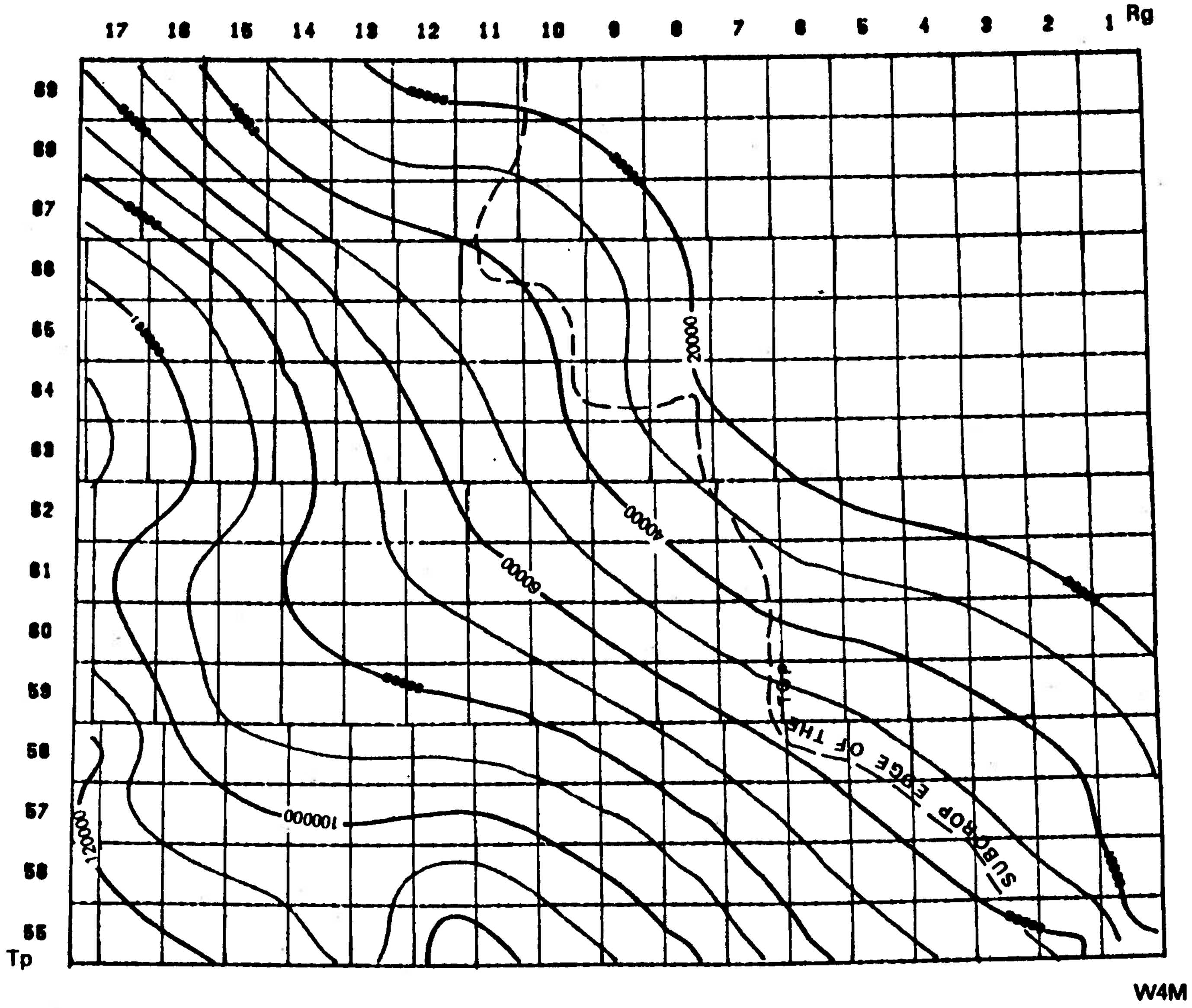
NOTE:

1. Out of more than 3100 wells in the Cold Lake Study Area, formation water analyses were available from only 1894 wells (about 60 percent).
2. Total formation waters entered into data base was 3650, of which 2366 (65 percent) passed NCHMCULL.
3. Final data base (852 analyses) represents 23 percent of the original data base.

COOKING LAKE-BEAVERHILL LAKE-WATT MOUNTAIN AQUIFER

Previous studies of basin-wide flow in the Western Canada Sedimentary Basin (Hitchon, 1969a), including a potentiometric surface map of the Beaverhill Lake Formation aquifer (Hitchon, 1969b, Fig. 1) have shown that this aquifer is in the regional flow regime. The distribution of chloride (Hitchon, 1964, Fig. 15-15) and calcium and magnesium (Hitchon and Holter, 1971, Figs. 14 and 15) are consistent with the regional trends and gradients on the potentiometric surface. Superimposed on the regional trends is an area of formation waters with chloride contents generally greater than 200 000 mg/L, calcium contents greater than 60 000 mg/L and magnesium contents greater than 9000 mg/L, all of which are associated with an evaporite-carbonate sequence in south-central Alberta (McCrossan and Glaister, 1964, Fig. 6-2). As expected from the association with evaporites, these very saline formation waters have high contents of bromide and very low contents of iodide (Hitchon et al., 1977, Fig. 3 and Table 4).

The Cold Lake Study Area lies immediately north and adjacent to the region with the very saline formation waters; that is, it is stratigraphically updip and hydraulically downflow. Accordingly, highest salinities (about 120 000 mg/L) are found in the extreme southwest corner of the study area, and the salinity decreases rather uniformally and gradually towards the northeast where values of about 25 000 mg/L are found in the region where the Beaverhill Lake Formation subcrops beneath the Lower Cretaceous Mannville Group (Fig. 3-2; Atlas map E-c-2). It should be noted that figure 3-2 refers to the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, although all information used to compile this and the other formation water maps from this aquifer in fact came only from the Beaverhill Lake Formation; formation waters from the Cooking Lake and Watt Mountain formations which may have been entered into the original data base were subsequently removed by the culling procedures. Using



Scale 1:1,000,000

Figure 3-2 Total dissolved solids (calculated) in formation waters from Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, Cold Lake Study Area (Atlas map E-c-2) the calcium and magnesium isoconcentration maps found in Hitchon and Holter (1971, Figs. 11 and 12) extrapolation into the Cold Lake Study Area suggests that the composition of formation waters in the Cooking Lake Formation would be similar to those in the underlying Beaverhill Lake Formation; there is no information on which to base a suggestion respecting the composition of formation waters in the Watt Mountain Formation but they are probably at least as saline as those in the Beaverhill Lake Formation, and may be possibly more saline due to their juxtaposition to the Prairie Formation halite. Regional trends and gradients for chloride (Atlas map E-c-3), density (Atlas map E-c-4), calcium (Atlas map E-c-5) and magnesium (Atlas map E-c-6) are comparable to those for salinity. Bicarbonate (Atlas map E-c-7) and sulphate (Atlas map E-c-8) exhibit similar regional compositional trends, which differ from all other trends, for reasons yet unexplained. The general statistics for all of these parameters can be found in Table 3-2.

LEDUC FORMATION AQUIFER

Leduc Formation reefs are developed only at Willingdon, along the southern margin of the Cold Lake Study Area (Fig. 2-13; Atlas map F-g-4). Formation waters were recovered from only one well penetrating this reef complex, the best of which is shown in Table 3-3. Total dissolved solids and chloride are similar to those in the underlying Beaverhill Lake Formation, but the calcium, magnesium, bicarbonate and sulphate contents, and the density are all lower; the lack of comparable formation waters from the Leduc Formation in the study area precludes further comment.

CAMROSE TONGUE AQUIFER

As far as can be ascertained there has been no regional study of the formation waters in the Camrose Tongue and therefore the trends able 3-2

eneral statistics for chemical composition (mg/L) and physical properties of formation waters from aquifers. Cold Lake Study Area

ydrostratigraphic unit	Total dissolved solids (calc.)			Chloride			Density (60°F, 15.56°C)			Calcium			Magnesium			Bicarbonate			Sulphate		
	Min.	Mean*	Max.	Min.	Mean*	Max.	Min.	Mean*	Max.	Min.	Mean*	Max.	Min.	Mean*	Max.	Min.	Mean*	Max.	Min.	Mean*	Max
"Viking sandstone" aquifer	22 555	37 102	68 211	13 650	22 516	41 850	1.016	1.026	1.049	296	856	2114	115	363	1094	100	263	756	2	41	9
"Upper Mannville" Group aquifer	20 236	39 882	43 528	12 100	24 281	48 500	1.003	1.028	1.057	225	965	2571	102	434	1112	102	246	752	1	32	1
"Lower Mannville" Group aquifer	20 183	38 876	81 020	11 758	23 331	49 550	1.010	1.027	1.052	120	828	2703	49	380	1154	124	574	1647	2	36	9
Wabamun-Winterburn aquifer	18 704	39 091	61 702	10 859	23 301	37 600	1.013	1.029	1.044	325	814	1838	135	351	595	158	774	1132	1	33	18
Grosmont Formation aquifer	16 593	26 650	42 869	8 783	15 461	26 000	1.008	1.0175	1.03	140	400	891	64	261	696	397	1004	1542	2	63	26
Camrose Tongue aquifer	37 189	60 039	93 018	22 950	36 562	56 600	1.028	1.043	1.06	953	1662	2979	438	689	1245	150	427	585	4	58	21
Cooking Lake-Beaverhill Lake-Watt Mountain aquifer	25 567	65 705	119 516	15 497	40 667	73 482	1.018	1.048	1.089	435	2223	6915	195	1059	4200	112	201	490	6	1067	255

*Mean is the average of all grid points, rather than the arithmetic average of values in the Data Base. As such it is areally weighted and therefore more closely relates to the volume-weighted mean for the hydrostratigraphic unit in the Cold Lake Study Area.

Table 3-3 -
Chemical composition (mg/L), physical properties and production data for formation water from Leduc Formation, Cold Lake Study Area

Data Base Identification Number	513
Location	2-26-55-15-W4Mer
Depth (m)	662.0-663.5
Source	DST 18(rec. 91 m gassy sw)
Well status	Dual gas well (Viking and Leduc formations)
Na (calc.)	44 102
Ca	560
Mg	261
Cl	69 500
HCO_3	133
SO_4	244
TDS (calc.)	114 800
pH (laboratory)	8.4
Density (60°F, 15.56°C)	1.020

found in the formation waters from this stratigraphic unit in the study area have to be treated in isolation. As a broad generalization, values for salinity, chloride and calcium in formation waters from the Camrose Tongue are about half those of formation waters in the Beaverhill Lake Formation from the same part of the study area; the magnesium content is about twice, the bicarbonate content the same, and the sulphate content about 1/10 the value of those found in formation waters from the Beaverhill Lake Formation in the southwest part of the study area. Bearing in mind that the Camrose Tongue is shallower than the underlying Beaverhill Lake Formation and separated from it by approximately 200 m of Ireton Formation shale, it is speculated that the differences in salinity, chloride and calcium are related to the shallower depth, the increased content of magnesium to more extensive water-rock reaction with the highly dolomitized Camrose Tongue, and the much lower sulphate values to a combination of shallower depth and the absence of evaporites associated with the Camrose Tongue. In one respect, most maps of formation water parameters in the Camrose Tongue differ significantly from those in the underlying Beaverhill Lake Formation and that is in the dominantly northward decrease in concentration gradients (Fig. 3-3; Atlas map G-c-2). The difference in the direction of the regional concentration gradients between the formation waters in the Camrose Tongue and the Beaverhill Lake Formation in this part of the study area may relate to the facts that the formation waters in the Beaverhill Lake Formation in the Cold Lake Study Area are flowing in a widespread stratigraphic unit which extends deep into the Alberta Basin and is part of the regional flow system, whereas the Camrose Tongue is relatively isolated by Ireton Formation shales and its stratigraphic and lithological connection lies with the Southern Alberta Shelf complex to the south.

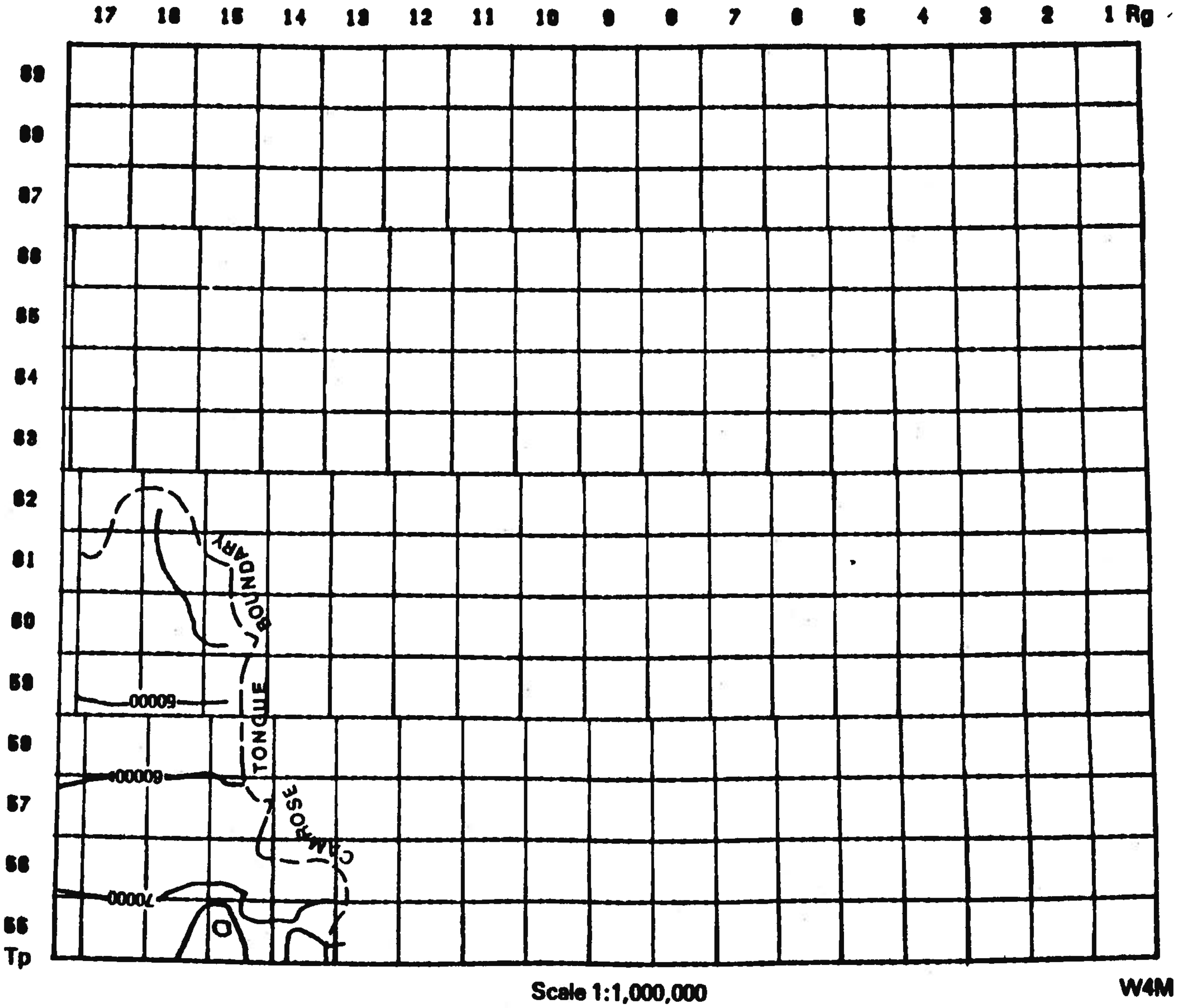


Figure 3-3 Total dissolved solids (calculated) in formation waters from Camrose aquifer, Cold Lake Study Area (Atlas map G-c-2)

GROSMONT FORMATION AQUIFER

Early studies of the potentiometric surface of the Woodbend Group in the Western Canada Sedimentary Basin demonstrate the dominantly regional flow within the carbonate complexes, with the lowest hydraulic heads being found in the Grosmont Formation (Hitchon, 1969b, Fig. 2). Pressure-elevation, temperature-depth, and temperature-elevation profiles confirm the continuous flow system between the Rimbey-Meadowbrook reef chain and the updip Grosmont Formation carbonate complex (Hitchon, 1984, Figs. 15 to 17). These trends are reflected in the distribution of chloride in the formation waters (Hitchon, 1964, Fig. 15-17), and also calcium and magnesium (Hitchon and Holter, 1971, Figs. 8 and 9) and to a lesser extent bromide (Hitchon et al., 1977, Fig. 2).

The general statistics for the chemical composition and physical properties of formation waters from the Grosmont Formation aquifer can be found in Table 3-2. Like the formation waters in the Camrose Tongue aquifer to the south, salinity decreases towards the north (Fig. 3-4; Atlas map H-c-2) as do those for chloride (Atlas map H-c-3), calcium (Atlas map H-c-5), magnesium (Atlas map H-c-6) and, less obviously, density (Atlas map H-c-4). At the southern end of the Grosmont Formation in the study area, the values of all these parameters correspond extremely closely with those at the northern end of the Camrose Tongue. Because the distribution of these two stratigrapic units interfingers in the region of Tp 61 and 62, it is inferred that they form part of a continuous regional hydrochemical trend extending along the western portion of the Cold Lake Study Area. Although the bicarbonate content of formation waters from the Camrose Tongue and Grosmont Formation are similar in the region where the distribution of these two stratigraphic units interfingers, bicarbonate increases towards the north in the Grosmont Formation aquifer. Along the eastern margin of the Grosmont Formation bicarbonate contents exceed 1200 mg/L in places (Atlas map H-c-7) and

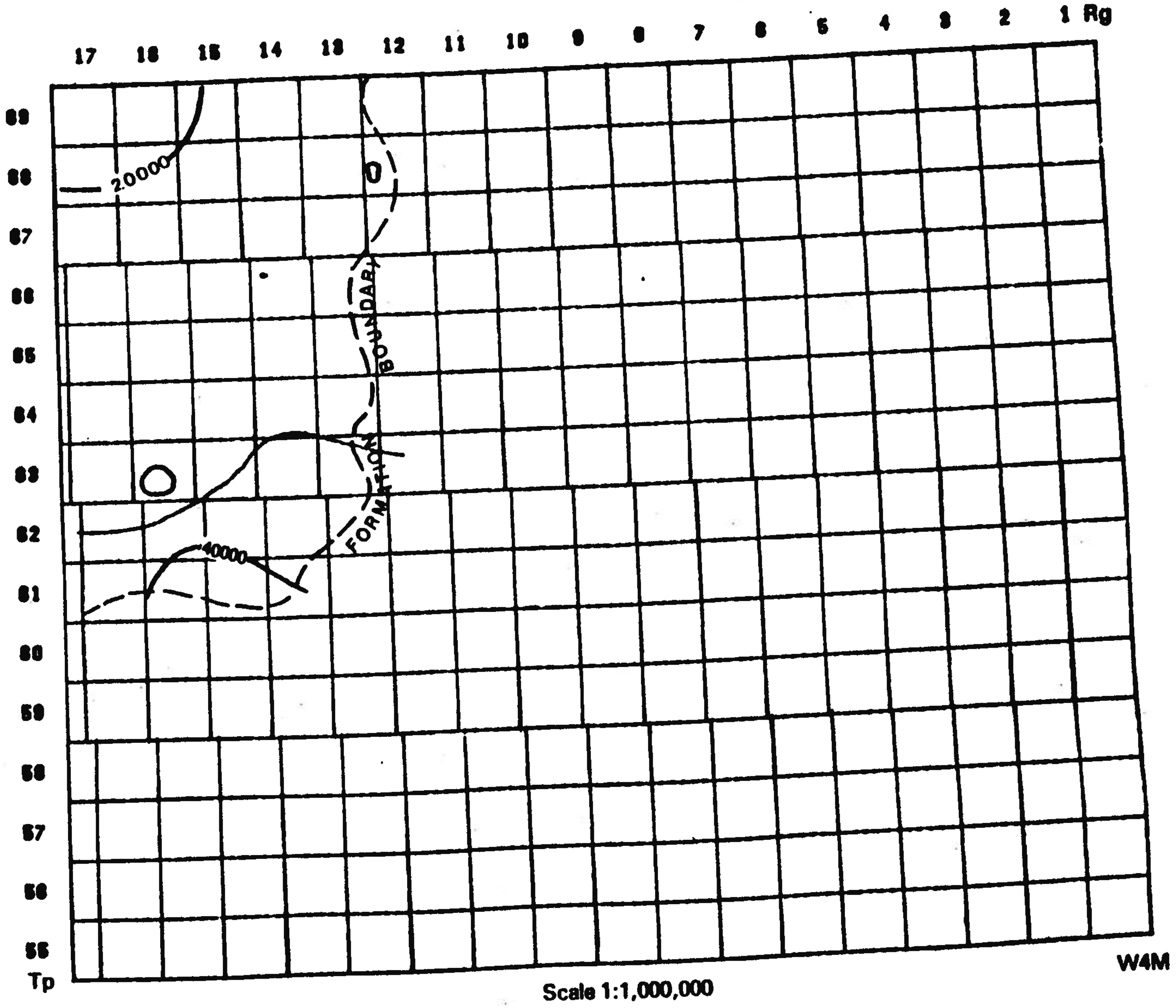


Figure 3-4 Total dissolved solids (calculated) in formation waters from Grosmont Formation aquifer, Cold Lake Study Area (Atlas map H-c-2)

it is in this same region that the Grosmont Formation is separated by only a thin layer of Ireton Formation shale from the overlying Lower Mannville Group (see Fig. 2-18). Where the Grosmont Formation is overlain directly and unconformably by the Lower Mannville Group the patterns of bicarbonate distribution in the formation waters are similar. From all this information it is inferred that the formation waters in the Camrose Tongue and Grosmont Formation are part of a continuous hydrochemical system flowing northward along the western margin of the Cold Lake Study Area, upon which has been imposed a region of mixing where the Grosmont Formation lies directly beneath the Lower Mannville Group or is separated from that group by only a thin sequence of Ireton Formation shales.

WABAMUN-WINTERBURN AQUIFER

Due to severe Early Cretaceous erosion only remnants of the Wabamun and Winterburn groups remain along the extreme western margin of the Cold Lake Study Area. Their boundaries are difficult to determine, complexly contorted with numerous outliers, and hence the Atlas maps show only a generalized boundary for the Winterburn Group in the southern half of their subcrop region in the study area. For this reason some of the formation water data points appear to fall outside the Winterburn Group boundary (see Atlas map I-c-1). Because most of the formation waters recovered from the Wabamun-Winterburn aquifer were from the Nisku Formation in the Winterburn Group the Atlas maps for formation waters from this aquifer are described, for simplicity, as coming from the Winterburn Group.

Computer contouring of data in extremely elongate areas (in this case 3 townships by 15 townships) is difficult but despite this all parameters of formation waters in this aquifer show a distinct decrease in values from south to north. Values for all parameters are less than those in the underlying Camrose Tongue/Grosmont Formation hydrochemical system; for example, salinity ranges from about 60 000 to 20 000 mg/L in the Wabamun-Winterburn aquifer (Fig. 3-5; Atlas map I-c-2) compared with a range of 90 000 to 20 000 mg/L in the underlying Camrose Tongue/Grosmont Formation aquifer. These differences are probably due to the shallower depth of the Wabamun-Winterburn aquifer, although the salinity gradients suggest that formation waters in this aquifer are part of the same general hydrochemical trend as the underlying Camrose Tongue/Grosmont Formation aquifers.

"LOWER MANNVILLE" GROUP AQUIFER

Before commencing discussion of the formation waters in this aquifer the reader is reminded that the term "Lower Mannville" Group refers to that section of the Mannville Group which lies below the argillaceous Clearwater Formation. Most of the formation waters in this aquifer come from the McMurray Formation and equivalent strata, although some were recovered from the Glauconitic sandstone, the Clearwater sandstone, and other variously named sandstones. In any part of the Cold Lake Study Area, a preliminary perusal (without the benefit of rigorous statistical evaluation) showed that the composition of formation waters from different sandstones within this aquifer were similar, and could therefore be treated as one hydrochemical unit.

The regional compositional pattern of formation waters in the "Lower Mannville" Group aquifer shows three distinct trends, which may be illustrated using the map of salinity distribution (Fig. 3-6; Atlas map J-c-2). In the southern third of the study area salinity decreases uniformly northward across the entire region from about 70 000 mg/L to 40 000 mg/L, with the exception of a significant reentrant on the 40 000 mg/L isosalinity contour in the region of Tp 59, R 11. In the northeast corner of the study area salinity continues to decrease updip but with lower isosalinity gradients and a change in direction from north to northeast. The northwest

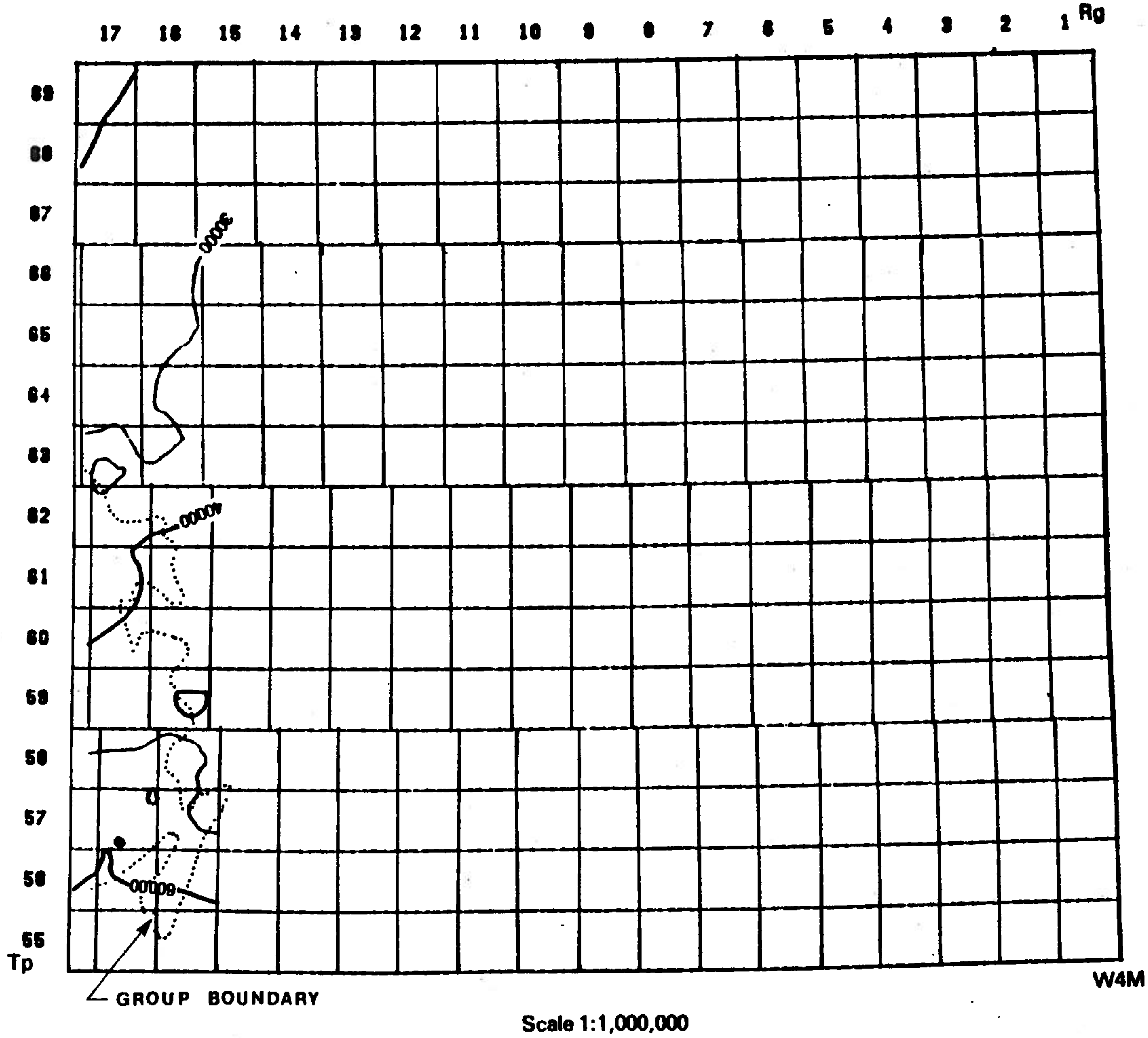


Figure 3-5 Total dissolved solids (calculated) in formation waters from Winterburn Group aquifer, Cold Lake Study Area (Atlas map I-c-2)

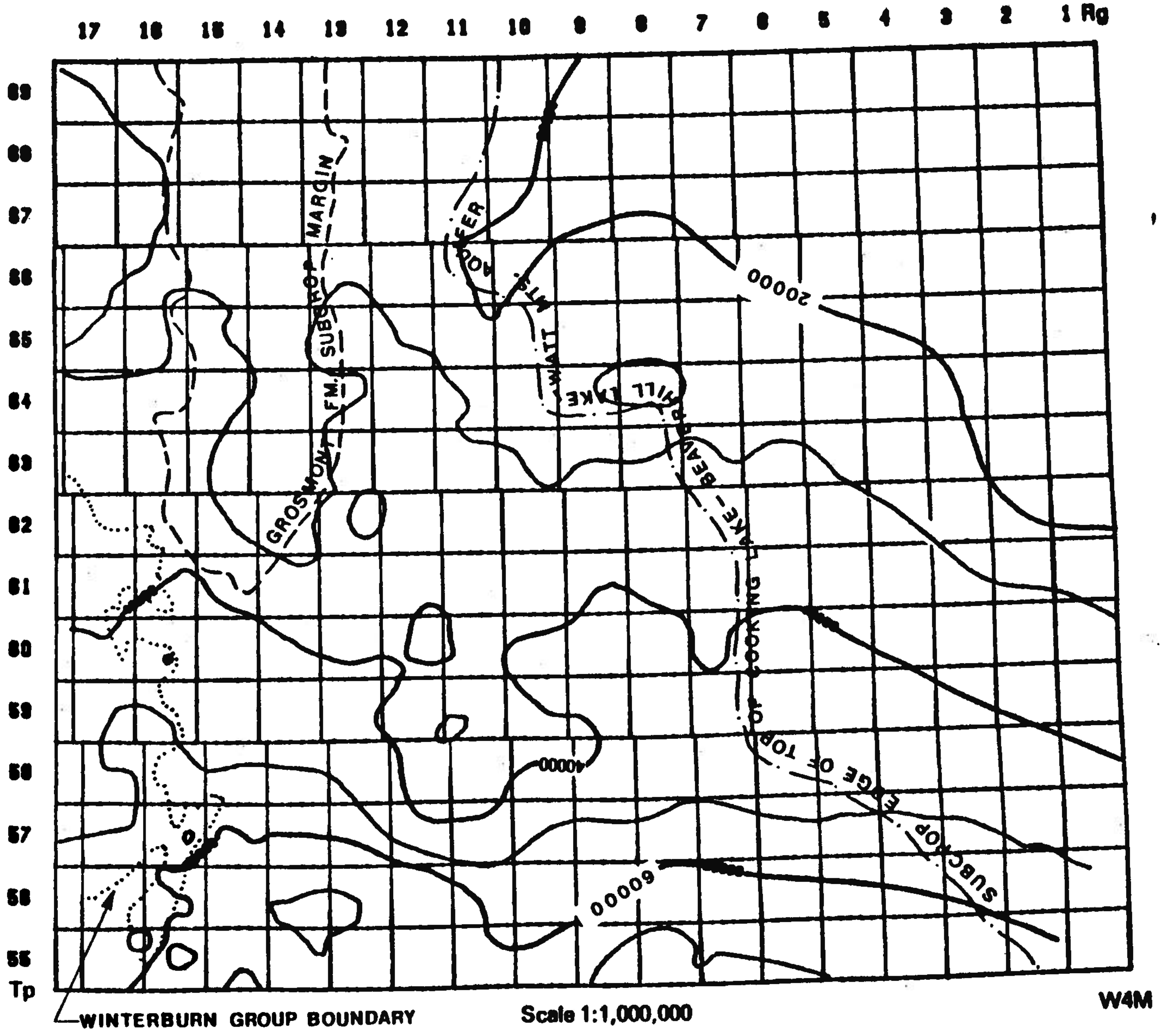


Figure 3-6 Total dissolved solids (calculated) in formation waters from "Lower Mannville" Group aquifer, Cold Lake Study Area (Atlas map J-c-2)

quadrant of the study area exhibits the most interesting isosalinity patterns because there is a clear relation of lower salinities and the area where the "Lower Mannville" Group rests directly on the Grosmont Formation. This is well illustrated by the major reentrant on the 30 000 mg/L isosalinity contour. The reentrants shown by the 30 000 and 40 000 mg/L isosalinity contours form part of a continuous zone of relatively less saline formation waters stretching in a gentle curve from the Grosmont Formation subcrop area to Tp 59 R 11; most other formation water parameters in this aquifer exhibit a similar trend. Comparison of the composition of formation waters in the Grosmont Formation and the "Lower Mannville" Group aquifer in the Grosmont Formation subcrop area, indicates that those in the Grosmont Formation are generally more saline. These various observations suggest that formation waters are moving downward from the "Lower Mannville" Group aquifer into the Grosmont Formation aquifer in the subcrop region, and that this "drainage" has affected formation waters in the "Lower Mannville" Group aquifer as far south as Tp 59, R 11. In the subcrop area of the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer (where the Ireton Formation aquitard is absent) the "Lower Mannville" Group aquifer rests directly on strata of the Cooking Lake and Beaverhill Lake formations (Fig. 2-18). It is in this region that the salinity trends in the upper aquifer change from north to northeast, similar to the regional trends in the lower aquifer. Bearing in mind the sparse data distribution in this area and the effects of computer extrapolation, the similar isosalinity trends and gradients between the formation waters in the upper and lower aquifers suggests that they are in hydraulic continuity, but there is no evidence from the formation waters to suggest the direction of movement.

"UPPER MANNVILLE" GROUP AQUIFER

Again, the reader is reminded that the "Upper Mannville" Group aquifer refers to that part of the Mannville Group younger than the argillaceous Clearwater Formation, and further, that the "Lower Mannville" and "Upper Mannville" group aquifers are in contact in the extreme southeastern part of the Cold Lake Study Area (Fig. 2-18). Regional compositional trends of formation waters in the "Upper Mannville" Group aquifer can be represented by the salinity map in figure 3-7 (Atlas map L-c-2) which may be generally described as a subdued replica of the trends found in the "Lower Mannville" Group aquifer (see Fig. 3-6). In both aquifers the most saline formation waters are found in a broad band along the southern margin of the study area with salinities in the range 70 000 to 50 000 mg/L. North of this region, with its relatively steep salinity gradients, the salinity gradients become less steep and the trend to fresher waters changes from dominantly northerly to northeasterly. There is only the slightest indication on the 40 000 mg/L isosalinity contour of the sharp reentrant that was present on this same contour in the underlying "Lower Mannville" Group aquifer. It may be inferred, therefore, that the "drainage" effects of the Grosmont Formation aquifer have been dampened by the presence of the Clearwater Formation aquitard. Another feature of salinity variations in the "Upper Mannville" Group aquifer, which does not appear in the "Lower Mannville" Group aquifer, is the presence of a series of isolated regions of relatively higher or relatively lower salinity imposed on the broad regional trends in the central part of the study area; this feature may be due to either the hydrologic conditions in the "Upper Mannville" Group aquifer or its more complex lithological variations. Despite the larger size and better distributed data base for the "Upper Mannville" Group aquifer, compared to that for the "Lower

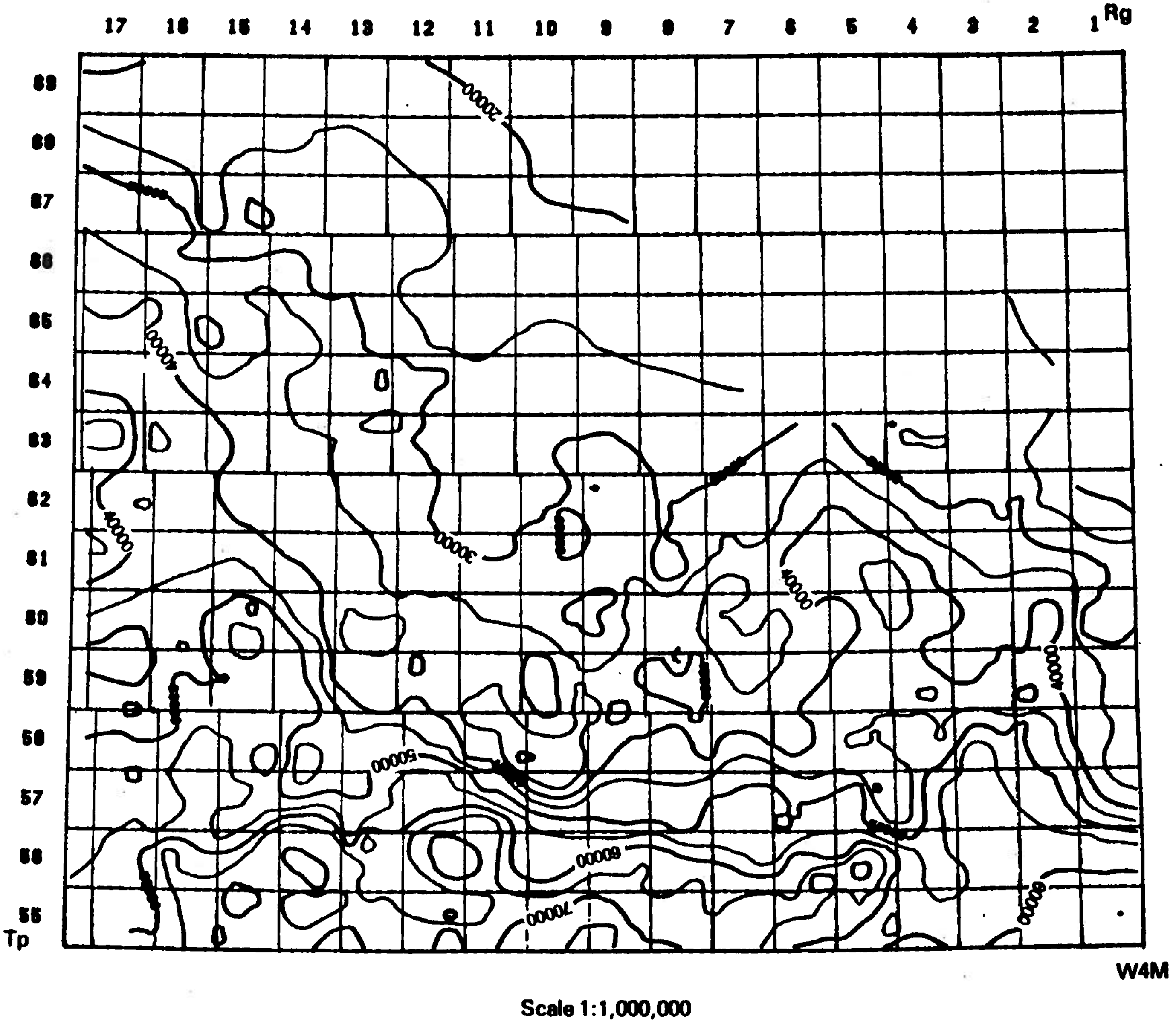


Figure 3-7 Total dissolved solids (calculated) in formation waters from "Upper Mannville" Group aquifer, Cold Lake Study Area (Atlas map L-c-2)

Mannville" Group aquifer, this feature is almost certainly not due to computer effects because the culling techniques and contour intervals for both aquifer maps were similar.

"VIKING SANDSTONE" AQUIFER

For the purposes of this study the "Viking sandstone" aquifer comprises the aggregate of the several thin sandstones which are present in the Viking Formation in the Cold Lake Study Area. Studies of the potentiometric surface of the "Viking sandstone" aquifer in the Western Canada Sedimentary Basin (Hill et al., 1961; Hitchon, 1969b, Fig. 4) indicate the presence, in central Alberta, of a large closed potentiometric surface low, elongated in a general northwest direction, roughly parallel to the axis of the Alberta Basin and centered at Gilby over the southern end of the Rimbey-Meadowbrook carbonate reef chain. It has been speculated (Hitchon, 1969b) that this closed potentiometric surface low is due to osmotic effects across shale membranes, which are imposed on the gravity flow regime. In the Cold Lake Study Area flow directions may therefore represent a complex combination of downdip flow towards the closed potentiometric surface low and regional updip flow.

In the Western Canada Sedimentary Basin the patterns of regional variations in formation water composition appear to relate more to the total thickness of sandstones in the Viking Formation (see Rudkin, 1964) than they do to the basin-wide variations in the potentiometric surface. This can be seen in maps of the regional distribution of chloride (Hitchon, 1964, Fig. 15-36) and iodide (Hitchon et al., 1977, Fig. 5). In the Cold Lake Study Area, in addition to these factors, the "Viking sandstone" aquifer is absent in the northeast part of the study area as well as parts of the eastern and southern boundaries, the individual sandstones are very thin, and the aquifer is as shallow as 300 m in places. Because a detailed investigation of the lithological variations within the

Viking Formation was beyond the limits of the present study, the hydrochemical patterns of formation waters in the "Viking sandstone" aquifer can be interpreted only in general terms.

Figure 3-8 (Atlas map N-c-2) shows the regional variations in salinity of formation waters from the "Viking sandstone" aquifer; similar trends are found for chloride (Atlas map N-c-3), density (Atlas map N-c-4), calcium (Atlas map N-c-5) and magnesium (Atlas map N-c-6). The most saline formation waters are found in the southwest corner of the study area, where total dissolved solids range from about 40 000 mg/L to more than 60 000 mg/L. In this region the salinity gradients are relatively steep, compared to elsewhere in the study area, and trend in a general northwest direction. This hydrochemical pattern suggests that formation waters in this part of the study area may belong to the downdip-flowing system. To the northeast of this region, salinity gradients are shallower and are characterized by a prominent reentrant in the central part of the study area, which is well illustrated by the 30 000 mg/L isoconcentration contour. Between the 40 000 and 30 000 mg/L isoconcentration contour lines there are a number of relatively more saline and relatively less saline isolated regions; as a general rule, similar isolated regions do not occur in formation waters less saline than about 30 000 mg/L. It is speculated that this region of variable formation water salinity, between the 30 000 mg/L and 40 000 mg/L regional contours, is coincident with the hydraulic divide between formation water which flows downdip towards the closed potentiometric surface low in central Alberta and those which flow updip towards the northeast.

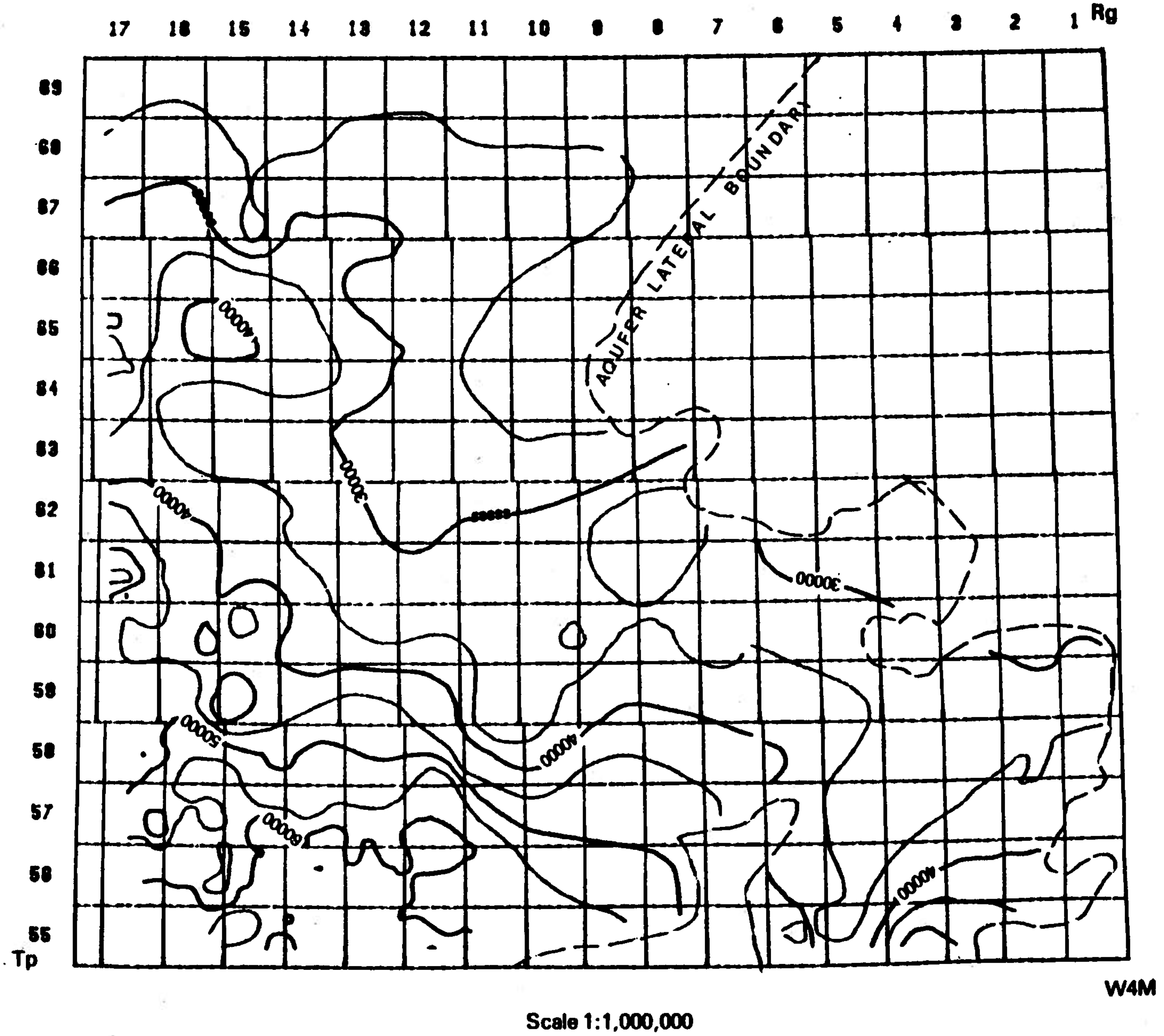


Figure 3-8 Total dissolved solids (calculated) in formation waters from "Viking sandstone" aquifer, Cold Lake Study Area (Atlas map N-c-2)

INTRA-COLORADO AQUIFERS

In the Cold Lake Study Area strata younger than the Viking Formation are dominantly argillaceous and for the purposes of this study have been grouped together as the Colorado aquitard. Formation waters have been recovered on drillstem testing from minor porous zones at the base of the Fish Scales Zone and within the Second White Speckled Zone. Unfortunately, few of these formation waters passed the culling procedures, and of those that did the number was insufficient for computer contouring. As expected, all were less saline than those in the underlying "Viking sandstone" aquifer and approached the composition of the comparatively fresh waters found in the near surface bedrock in some instances.

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SECTION 2: QUATERNARY

INTRODUCTION

Formation waters from the Quaternary surficial sediments have been treated separately from those in the underlying Phanerozoic for a variety of reasons. First, it is desirable to display the data in a format that is consistent with those of conventional groundwater studies in Alberta. Second, additional ions, such as iron and fluoride, are commonly determined because of their value in assessing the potability of the groundwater. Third, sodium and potassium are commonly determined separately, and therefore the waters can be culled on the basis of their true ionic balance, rather than using the sodium-by-difference method, as was used for the Phanerozoic formation waters. Finally, the data originated from a separate source, namely the Central Data File of Alberta Environment.

The Central Data File of Alberta Envrionment was searched for chemical analyses of groundwater found within the Cold Lake Study Area, and if the well completion was unknown, or the chemical analyses incomplete, the analysis report was rejected. Through this process about 375 chemical analyses were entered into the data base and subsequently culled based on their ionic balance; the distribution of the remaining analyses is shown in Atlas map P-c-1. The data distribution is generally good except in the northern part of the study area, and grid manipulation of the contouring software was adjusted to fit the distribution. It should be pointed out that data distribution within the individual Quaternary stratigraphic units was so irregular and sparse that the chemical data for the Quaternary surficial sediments represents the aggregate of all stratigraphic units. Two types of parameters were selected for presentation of the groundwater chemistry data:

1) total dissolved solids, iron and fluoride in mg/L; 2) 60 percent epm (equivalents per million) for calcium-plus-magnesium, sodium-plus-potassium, bicarbonate-plus-carbonate, and sulphate; only one sample exceeded 60 percent epm chloride.

TOTAL DISSOLVED SOLIDS

The distribution of total dissolved solids in groundwaters from the Quaternary in the Cold Lake Study Area is shown in figure 3-9 (Atlas map P-c-2). Values range from close to those in the surface waters to more than 2500 mg/L. As a broad generalization three main zones can be distinguished:

1. In the southwestern third of the Cold Lake Study Area groundwater salinities are generally in the range 500 to 1000 mg/L. Most of the water wells for which chemical data is available were completed either in the bedrock channels (Beverly, Kikino) or in the Sand River and Grand Centre formations. Regions with salinities generally less than 500 mg/L are associated with topographic highs, and the salinity increases to 1000 mg/L or more in topographic lows; for example, towards Lac La Biche in the north, the Beaver River valley in the central part of the study area, and in the direction of the Beverly Channel in the south. In the latter direction, salinities of 2400 mg/L were found in a well completed at the base of the Quaternary section near the top of the Belly River Group.
2. The second zone comprises a rather narrow area across the central portion of the region, oriented in a northwest-southeast direction, in which salinities are generally greater than 1000 mg/L and range up to slightly more than 2500 mg/L. In this zone the groundwater samples came from water wells completed in various Quaternary formations ranging from the shallowest to those found only in the

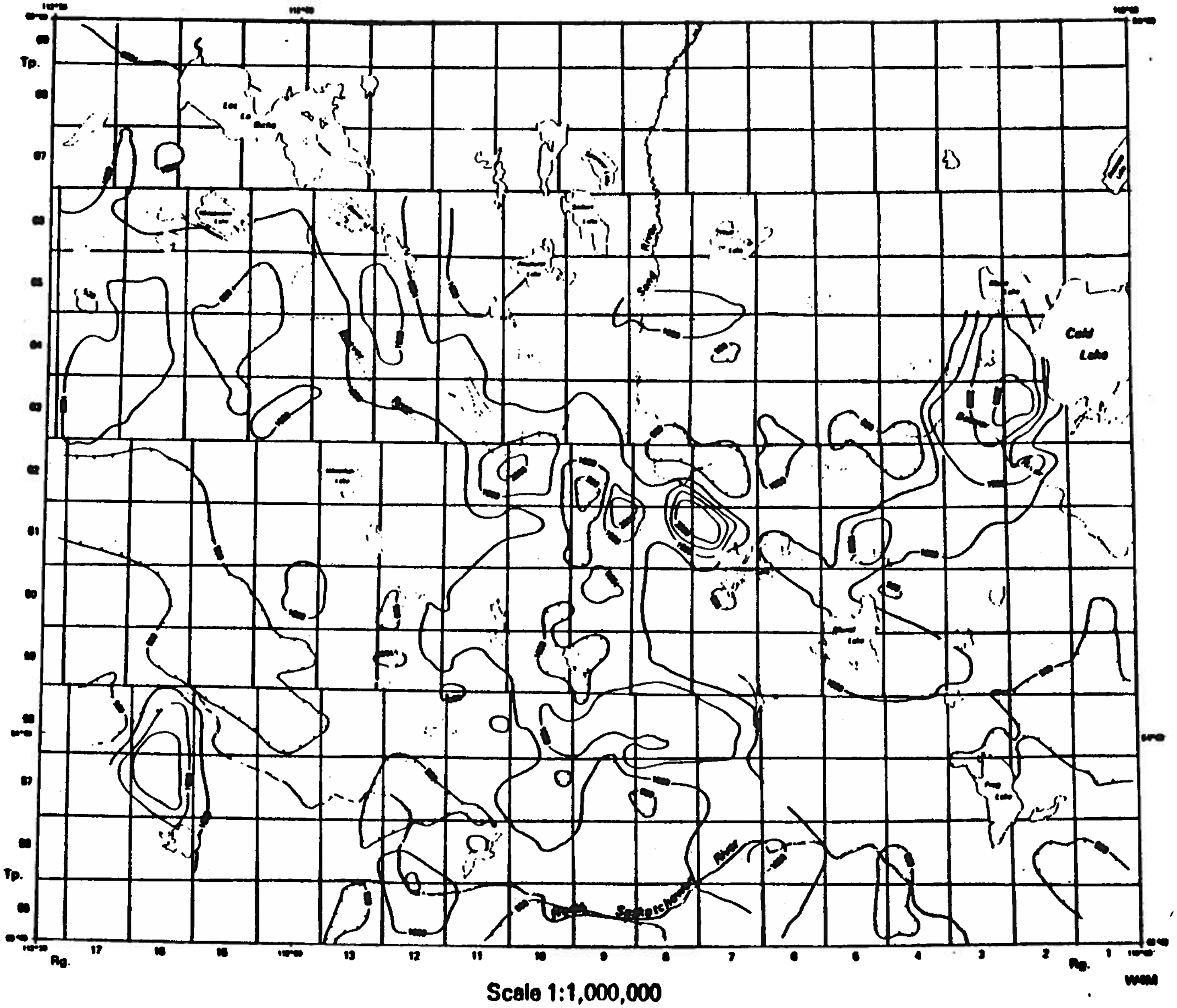

Figure 3-9 Total dissolved solids in groundwaters from Quaternary stratigraphic units, Cold Lake Study Area (Atlas map P-c-2)

deeper bedrock channels; a salinity of 2700 m/L is recorded from one water well completed at the base of the Quaternary section in contact with shales of the Lea Park Formation.

3. The northeastern portion of the study area is characterized by groundwaters with salinities from less than 500 to more than 2500 mg/L. Relatively shallow wells (about 20 m in depth) and wells located on topographic highs have groundwater salinities generally less than 500 mg/L. The highest salinity occurs in a well completed near the base of the Quaternary section close to the contact with shales of the Lea Park Formation, where a salinity of 2700 mg/L is recorded; groundwater salinities rarely reach 1500 mg/L in surrounding wells which do not penetrate so deeply.

In summary, a large portion of the groundwaters in the Cold Lake Study Area are within the Alberta Health Standards limit of 1000 mg/L total dissolved solids. Generally, wells producing in stratigraphic units in proximity to bedrock have increased contents of total dissolved solids, ranging up to 2700 mg/L in two cases where the bedrock comprised shales of the Lea Park Formation.

HYDROCHEMICAL CLASSIFICATION

Quaternary groundwaters in the Cold Lake Study Area have been classified on the basis of the 60 percent epm contours for calcium-plus-magnesium, and sodium-plus-potassium (Atlas map P-c-3) and bicarbonate-plus-carbonate, and sulphate (Atlas map P-c-4); in these Atlas maps isosalinity contours have been superimposed on the distribution of these various hydrochemical zones. The most common chemical type is a calcium-magnesium-bicarbonate groundwater, with less than 1000 mg/L total dissolved solids. Groundwaters with more than 60 percent epm sulphate commonly have salinities greater than 2000 mg/L; in many of these areas sodium-plus-potassium is greater than 60 percent epm, and all these characteristics suggest possible groundwater contribution from the bedrock to the overlying Quaternary strata.

FLUORIDE AND IRON

The distribution of fluoride in Quaternary groundwaters in the Cold Lake Study Area is shown in Atlas map P-c-5. Fluoride contents range from less than 0.2 mg/L to slightly over 0.8 mg/L, with an average value about 0.3 mg/L, and therefore nowhere in the study area does the fluoride content exceed the upper limit of 1.5 mg/L set by the Alberta Health Standards.

The distribution of iron in groundwaters from the Quaternary sediments in the Cold Lake Study Area is shown in Atlas map P-c-6. The Alberta Health Standards have set an upper limit for iron in potable groundwater at 0.3 mg/L. Only a few small regions in the west, southwest and south of the study area fall within these limits. In the remainder of the study area, several isolated regions have iron contents greater than 3 mg/L iron, reaching a maximum of 22 mg/L in one isolated case. In general, therefore, most groundwaters in the Cold Lake Study Area do not meet the Alberta Health Standards for iron.

HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA

Part IV. Hydrodynamics

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ILLUSTRATIONS

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SECTION 1: PHANEROZOIC

INTRODUCTION

This part of the Report describes the specific techniques that have been used to interpret the raw hydraulic data and to obtain point data for the relevant hydraulic parameters. It then examines how the analysis of the flow regime can be deduced from the synthesis of these interpreted point data. By point datum, it is understood here any value associated with a specific location in a three-dimensional structure. For the Phanerozoic sequence, the treatment of the interpreted point data to obtain synthesized data is identical to the processing of stratigraphic and hydrochemical point data and has been discussed in Part 1. The three sources of raw hydraulic data are the results of drillstem tests ("in situ" measurements) and of core analyses (obtained under laboratory conditions) for the Phanerozoic sediments, and of aquifer tests (pumping tests with more than one observation well) for the Quaternary. Each type of data has been interpreted in a particular fashion; the first section describes the main features of the interpretive techniques that have been used and the second focuses on the flow regime analysis in the Phanerozoic sequence. The main features of the flow in the Quaternary are dealt with separately.

The relevant hydraulic parameters for this study are: the rock matrix intrinsic permeability $[L^2]$,the hydraulic conductivity $[LT^{-1}]$ and the hydraulic head [L] of the (rock + fluid) system. The core porosities have also been processed and are reported, although not used directly in this study. For completeness, the methods to obtain specific storage $[L^{-1}]$ are documented but the results for this parameter are not synthesized.

INTERPRETIVE TECHNIQUES

DRILLSTEM TESTS

Introduction

A drillstem test is a temporary completion of a deep well where the tested interval is isolated from the column of drilling mud by means of one or two inflatable packers attached to a string of the drillcollar and/or drillpipe. Drillstem tests are run for three primary reasons: 1) to assess the productivity of the formation; 2) to evaluate the hydraulic characteristics of the tested interval from recorded pressure data; and 3) to obtain a sample of the formation fluid. When correctly performed and interpreted, a drillstem test provides valuable and often unique information about the hydraulic heads and hydraulic parameters of the tested interval. During a typical drillstem test, a valve is opened and formation fluid flows through perforations into the pipe (flow period); the valve is then closed (shut-in period) to allow recovery of pressure in the tested interval. The variations of pressure are recorded with manometers, one of which is located outside the tested interval to test that the packers are adequately sealed. Manometers are now commonly replaced by pressure transducers. The time required for a quasi-complete pressure recovery is inversely proportional to the formation permeability and directly proportional to the volume of produced fluid. Traditionally, a short initial flow period is followed by an initial shut-in period (up to approximately 30 minutes) and together, these constitute the first phase of the test. The second phase consists of a longer flow period and a longer second or final shut-in period (up to approximately 2 hours). The final shut-in pressure is generally of less value than the formation pore pressure because of commonly incomplete recovery and hence the trend of pressure build-up must be extrapolated to obtain the real pore pressure.

The technology of drillstem testing is now well established (Timmerman and van Poollen, 1972). The criteria used to judge whether a test is mechanically successful or not are based on the physical significance of the various components of the recorded pressure charts. When a test is conclusive, the charts are broken down (or "digitized") into time/pressure increments in order to perform a quantitative analysis.

Drillstem test reports generally include the pressure charts, the pressure increments, and additional information about the test that is usually sufficient for a complete quantitative analysis. For the present study, only previously digitized pressure charts were used because of the large numbers of such tests in the majority of the hydrostratigraphic units. However, for stratigraphic units where the data distribution was poor (below the PreCretaceous unconformity), additional pressure charts were digitized whenever possible.

Shut-in analysis

The plot of the pressure, P, versus log (t+t'/t') where t is the flowing time and t' the shut-in time, should be a straight line in the late portion of the plot if the assumptions of the line-source solution are valid. The line-source solution is also known as the "infinite-acting", the exponential integral, or the Theis solution. It assumes a homogeneous and isotropic aquifer of infinite lateral extent produced at a constant rate by a well of infinitely small diameter; moreover, it reflects the hydraulic head variations at a certain radial distance from the producing well which is supposed to penetrate the aquifer completely. It is clear from the knowledge we have of the lithology of, for instance, the Cretaceous sediments, and of the testing procedure, that these conditions are generally not met in the Cold Lake Study Area. Nevertheless, most of the departures from the ideal conditions are either active at early times (partial penetration, finite diameter, variations of the flow rate, natural fracturing, mud invasion) or at late times (finite lateral extent of the aquifer, leakage). Also, the use of more appropriate analytical models requires a degree of information that is not known at the level at which this study was conducted. In spite of these limitations, which are well recognized, it is a fact of experience that the use of the line-source solution to analyze drillstem test data provides, statistically, the best local estimates of the hydraulic characteristics of deep formations. The "straight-line" method (Horner analysis) generally used is analogous to the Jacob's recovery method in groundwater hydraulics (logarithmic approximation of the exponential integral solution). The shape of the semi-logarithmic plot indicates the degree of interpretability and reliability of the deduced hydraulic parameters; for example, a zero slope reflecting pressure stabilization for both initial and final shut-in periods may suggest a high permeability, although its numerical value cannot be obtained. The analysis may also be qualitative because of problems such as severe formation damage (or "skin effect"), an insufficient flow period when heterogeneities are present (Streltsova and McKinley, 1984) or lack of key parameters for the interpretation. A test is suspect when a major difference ("depletion") exists between both shut-in extrapolated pressures at log (t+t'/t') = 1. A reasonable depletion may indicate that the aquifer is laterally bounded.

Three types of semi-logarithmic plots are considered:

a) when the produced fluid is a liquid (formation water and/or crude oil) with minimal content of drilling mud, the conventional Horner plot was used, that is, P versus log (t+t'/t');

b) when the produced fluid is a gas flowing at the surface at a virtually constant rate, qG, the plot is of P^2 versus log (t+t'/t');

c) when the produced fluid is a gas flowing at the surface at a variable rate, the plot is of P versus SUM(j=1,N) q(j)/qN log [tN - t(j-1) + t'/tN - t(j) + t'] where tN is the total flow period and t(j) is the time step of the flow period for which q(j) is assumed to remain constant; qN is the last value of the flow rate measurement.

The intercept of the best fitting line with the pressure axis [at log(t+t'/t')=1, that is, when the shut-in time, t', tends toward infinity], gives the pore pressure, Pf, of the interval tested; this is a general condition for all three types of plots. The slope of the straight line is used to calculate the intrinsic permeability with the following SI equations:

case a) $k = 2.12 \times 10^{-9} q(\mu)/M\ b$ (1)

case b) $k = 1.49 \times 10^{-9}\ qG(\mu g)zT/M'b$ (2)

case c) $k = 7.44 \times 10^{-9} qN(\mu g)zT/M''Pfb$ (3)

where k is in m^2; q, qG and qN are the respective flow rates in m^3/D; (μ) and (μg) are the fluid dynamic viscosities in Pa.s; z is the gas supercompressibility factor (dimensionless); T is the temperature at recorder depth (in degrees Kelvin); b is the interval thickness in m; M is the Horner slope for liquid (in kPa/log cycle); M' is the Horner slope for constant rate gas (in kPa^2/log cycle) and M" is the Horner slope for variable rate gas(in kPa/log cycle). A typical example of a shut-in analyses for the liquid case is shown in figure 4-1.

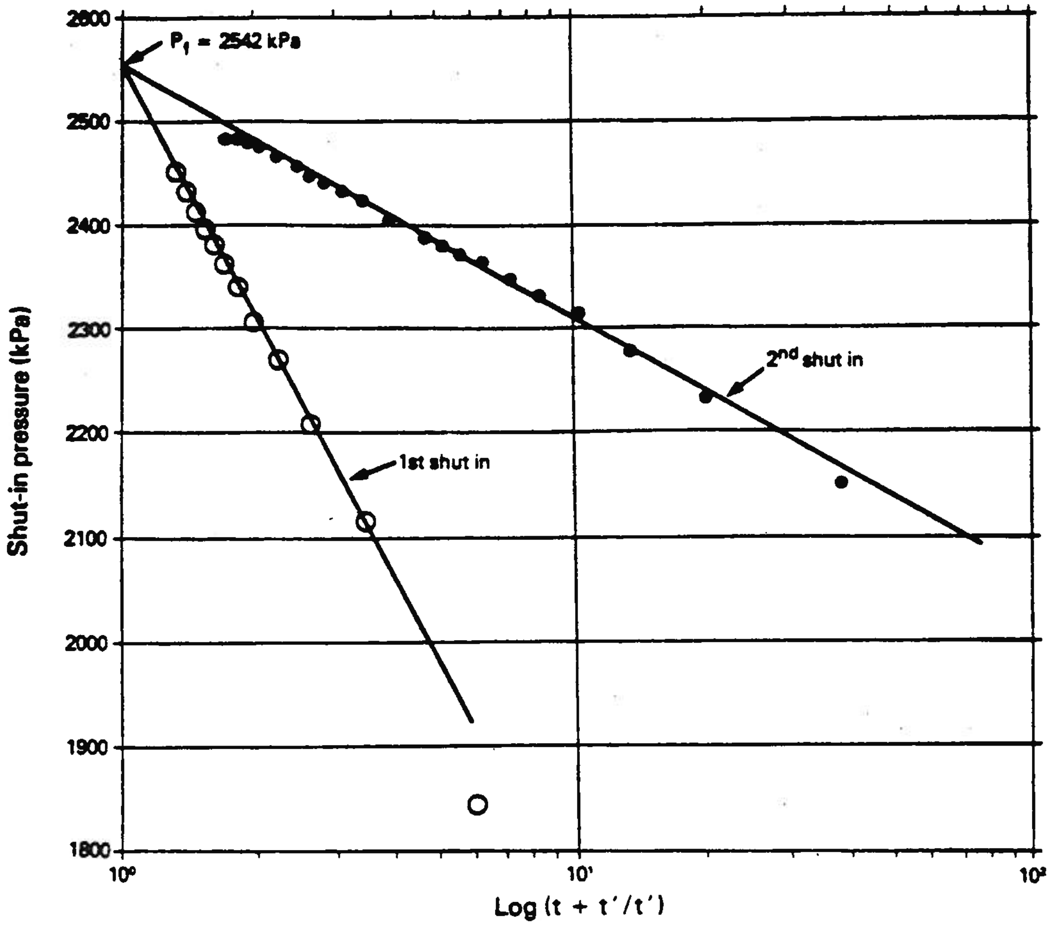
Once the formation pore pressure, Pf, and the intrinsic permeability, k, have been determined, the hydraulic head, H, and the hydraulic conductivity, K, are computed according to their respective definitions:

$H = Z + Pf/(\rho)g$ (4)

$K = k(\rho)g/(\mu)$ or $K=k(\rho)\ /(\mu g)$ (5)

where Z is the elevation of the drillstem test recorder (relative to mean sea level); (ρ) is the density of the produced fluid and g is the acceleration due to gravity.

In practice, not all of the parameters needed in equations (1) to (5) are given in the drillstem test report. We will now examine how the lack of specific data for interpretation can be overcome.



Interval: 345 - 349 m (z = + 233.1 m)
Formation = Colony sandstone
Slope 2^{nd} shut-in: m = 234.9/log cycle
Extrapolated formation pressure = P_f = 2542 kPa
Recovery = 175 m of salt water; Q = 113.5 m^3/day
Estimated ϱ = 1000 kg/m^3, μ = 10^{-3} Pa.sec.

k = 2.6 x 10^{-13} m^2 (eq. (1))
K = 2.5 x 10^{-6} m/s (eq. (5))
T = 1 x 10^{-6} m^2/s
H = 492.3 m (eq. (4))

Porosity and total compressibility are not given and the specific storage cannot be obtained.

Figure 4-1 Example of a shut-in Horner plot for a drillstem test with only liquid recovered.

Flow rate estimation

In the case of produced gas the flow rates qG,q(j) and qN are given in the drillstem test reports; in the case of liquid production, an average value of q is obtained by calculating the produced volume from the height of the recovered column in the drillpipe and drillcollar and dividing this volume by the total flow time.

Estimation for missing data

The fluid temperature is estimated at the recorder depth from the mean geothermal gradient (25°C/km) of the study area:

$$T = 0.025D + 8 \tag{6}$$

where D is the depth in m and T is the temperature in degrees Celsius. This equation is based on a linear regression fit to 1650 bottomhole temperature data, 20 of them at the Precambrian basement.

The formation water density (ρ) is obtained from temperature-dependent curves of NaCl solutions when some indication of the salinity (total dissolved solids, chloride, or resistivity) is given in the drillstem test report, otherwise a standard value of 1000 kg/m^3 has been used. The gas specific gravity (density relative to air) varies between 0.568 and 0.654 for 175 natural gases in the study area, and a standard value of 0.58 was used whenever this information was missing in the drillstem test report (air density = 1.2256kg/m^3). The gas density is only used in the computation of the hydraulic conductivity (equation 5) when gas is the only fluid produced; in this case, the hydraulic head is computed with the standard density of 1000 kg/m^3 in order to obtain an equivalent value comparable to the surrounding "liquid" values of this parameter.

The formation water dynamic viscosity (μ), when not given, has been estimated from its dependence on temperature (as derived from equation 6) and on salinity (when given in the drillstem test report); its variation with pressure has been neglected. In the very few cases when only crude oil was produced, both density and dynamic viscosity were given in the drillstem test report. The dynamic viscosity for gas varies between 1 x 10^{-5} and 1.5 x 10^{-5} Pa.s in a sample of 193 data from the study area, so that an average value of 1.25 x 10^{-5} Pa.s was used. The coefficient (z) varies between 0.81 and 0.98 and a standard value of 0.921 has been adopted when the value for (z) is missing.

The specific storage, Ss, may be computed in a very limited number of cases when both the porosity, n, and the total compressibility, (cT), of (rock + fluid) are given in the drillstem test report with:

$$Ss = (\rho)gn(cT) \qquad (7)$$

Automatic interpretation of shut-in period

Given the large number of drillstem test records reported for the study area (approximately 7000), an interactive software package (automatic plots and spreadsheet calculator) was developed to interpret the digitized shut-in data. This program, called DSTATOB, performs on a terminal screen an automatic Horner plot of the time-pressure data entered in the first level (A) of the drillstem test data base, together with the best fitted line through these data points. Often, because of early-time effects of various origins, this fitted line is not the most appropriate to retain, so the user has the option to modify it as desired. There is also the option to choose between the first and second shut-in periods as to which slope and pressure intercept is to be used for the calculations. Then, both slope and intercept are passed to the spreadsheet calculator that computes the hydraulic characteristics making use of the appropriate equations (1) to (7).

Limitations of the method

The experience gained from the interpretation of some 4000 drillstem tests in the Cold Lake Study Area suggests more specific comments than the ones previously given about the degree of confidence that one can have in the results obtained from shut-in analysis. Insufficient shut-in time for low permeability intervals and "supercharging" are the most probable sources of error in the estimations. In the first case, the straight line can only be defined by a small (less than 5) number of points and both under- and over-estimations may result. For "supercharging", or invasion of the formation around the wellbore by drilling mud, both higher pore pressure and lower permeability than the true values may result if the flowing period is not long enough to overcome this early effect. In both instances, however, the errors can be detected because they are likely to generate anomalies on the contour map of hydraulic heads or on the log-normal cumulative frequency plot of permeability. The option is then to try to reinterpret the given drillstem test and check if, after a new straight line has been used, the abnormal point remains, or to simply reject that point if this trial-and-error procedure is not successful (persistence of the anomaly) or if the original straight line that was used is the only possible one.

Data-entry errors can usually be detected on the semi-logarithmic plot for the pressures; these often have their origin in a transcription error during the digitization of the chart or in the entry itself in the drillstem test data base. The latter type of error can easily be corrected; in the former case, the abnormal point has to be removed from the interpretation. Other data-entry problems are more difficult to detect (for example, errors in recorder depth or flow rate estimations), but they may be identified in the regional trend analysis. Again, when the error cannot be corrected, the point-datum was rejected.

A more problematic source of error comes from the composition of the produced fluid because the relative proportions of a composite liquid are not often reported. Also, when gas is flowing at the surface, it commonly happens that a liquid (mud, or water, or both) is reported as being produced during the test. Our best judgment has been used to decide whether the drillstem test can be treated as a single-liquid case in the first example, or as a gas or liquid test in the second instance. In the case of production of a composite liquid where data are available on the respective proportions of each liquid, composite values of density and dynamic viscosity are used in the calculations (Earlougher, 1977, p. 18). These composite values are only a way of approximating an otherwise multi-phase flow problem that should actually be treated using relative permeabilities and saturations with respect to each phase. The composite laws that are used in this case are:

$$V\,(\rho)=\mathrm{sum}(i=1,n)[Vi(\rho)i] \qquad (8)$$

$$V/(\mu)=\mathrm{sum}(i=1,n)[Vi/(\mu)i] \qquad (9)$$

where V is the total volume of liquid recovered, Vi the volume of phase (i) and n the number of recovered phases.

Drillstem tests with non-digitized pressure charts and tests of poor quality, with missing parameters and undetectable sources of error, were not retained; as a result, a total of 1185 point values of hydraulic head are used for the construction of the potentiometric surfaces, and 665 point values for the permeability distribution maps. This means that 44 percent of the drillstem tests that provided a value of hydraulic head did not yield a value of permeability for a variety of reasons (for example, no slope on the semi-logarithmic plot or mud as the main or only produced fluid). The interpreted results for drillstem test shut-in analysis are presented per hydrostratigraphic unit in tables E-h-1, E-h-2, G-h-1, H-h-1, I-h-1, J-h-1, J-h-3, L-h-1, N-h-1, O-h-1, O-h-3, and O-h-4 in the Data Base.

Flow period analysis

A type-curve matching technique may be used to analyze the digitized flow period pressures in the case when the producing rate is not constant. This category of tests is characterized by curved flow pressure charts instead of the usual linear segments. Ramey et al. (1975) have shown that such a drillstem test is equivalent to a "slug" test and that the heat transfer analogue solution for a cylinder with heat resistance (the"skin effect") is applicable, provided that a proper type-curve parameter is used to reflect the wellbore storage and the skin effect. In groundwater hydraulics, the zero-skin solution has been applied by Cooper et al. (1967) to analyze "slug" test data.

First, the ratio (Pf-P/Pf-Po) is computed using Pf of the shut-in interpretation (Po is the pressure at time t=0 of the flow period). This ratio is then plotted versus (log t) and the best fit with a type-curve is sought by lateral translation of the two overlying semi-logarithmic graphs. When a satisfactory match is obtained (both early and long-time data being weighed equally), a matching point is chosen and is defined by three coordinates: the time t* on the data graph, the ratio (tD/cD)* and the quantity [cD (exp2s)]* from the type-curve graph. Usually, one chooses (tD/cD)*=1 or 10, in order to make the subsequent calculations easier. Finally, the hydraulic conductivity is computed using:

$$K = (rp^2/2b)\ (1/t^*)\ [(tD/cD)^*] \qquad (10)$$

where rp is the inside radius of the drillpipe; frequently, when a drillcollar is present above the drillstem tool, rp can be computed ("equivalent" radius) as:

$$rp = [L1\ (rdc)^2 + L2\ (rdp)^2/L]^{0.5} \qquad (11)$$

where L1 and rdc are the height and inside radius of the drillcollar, respectively; L2 is the height of fluid recovered in the drillpipe of radius rdp, and L is the total height of liquid recovered. The two values of K determined by this interpretation and by the shut-in analysis should be of the same order of magnitude for a given drillstem test.

When the skin factor (s) is given, or can be estimated from the shut-in analysis, the dimensionless wellbore storage (cD) can be computed from the value of [cD (exp2s)]* and the specific storage:

$$Ss = (1/2b)1/cD(rp/rw)^2 \qquad (12)$$

where rw is the radius of the wellbore and rp is as defined for equations (10) or (11). The determination of Ss by this technique should provide results in the same order of magnitude as the results obtained by applying equation (7); although of limited accuracy, it somehow reflects more in-situ conditions than with the use of (7), where n and cT have another source (usually core determination).

In the study area, about 30 drillstem test flow periods can be analyzed with the above-described method (out of 256 tests with digitized flow periods). The high rejection rate (88 percent) is essentially due to the lack of enough pressure data to obtain a satisfactory match with the type-curves. The interpreted results for Ss are not reported here given the wealth of information obtained from shut-in interpretations and because the specific storage is not a required parameter for this study. An example of the flow period analysis is illustrated in figure 4-2.

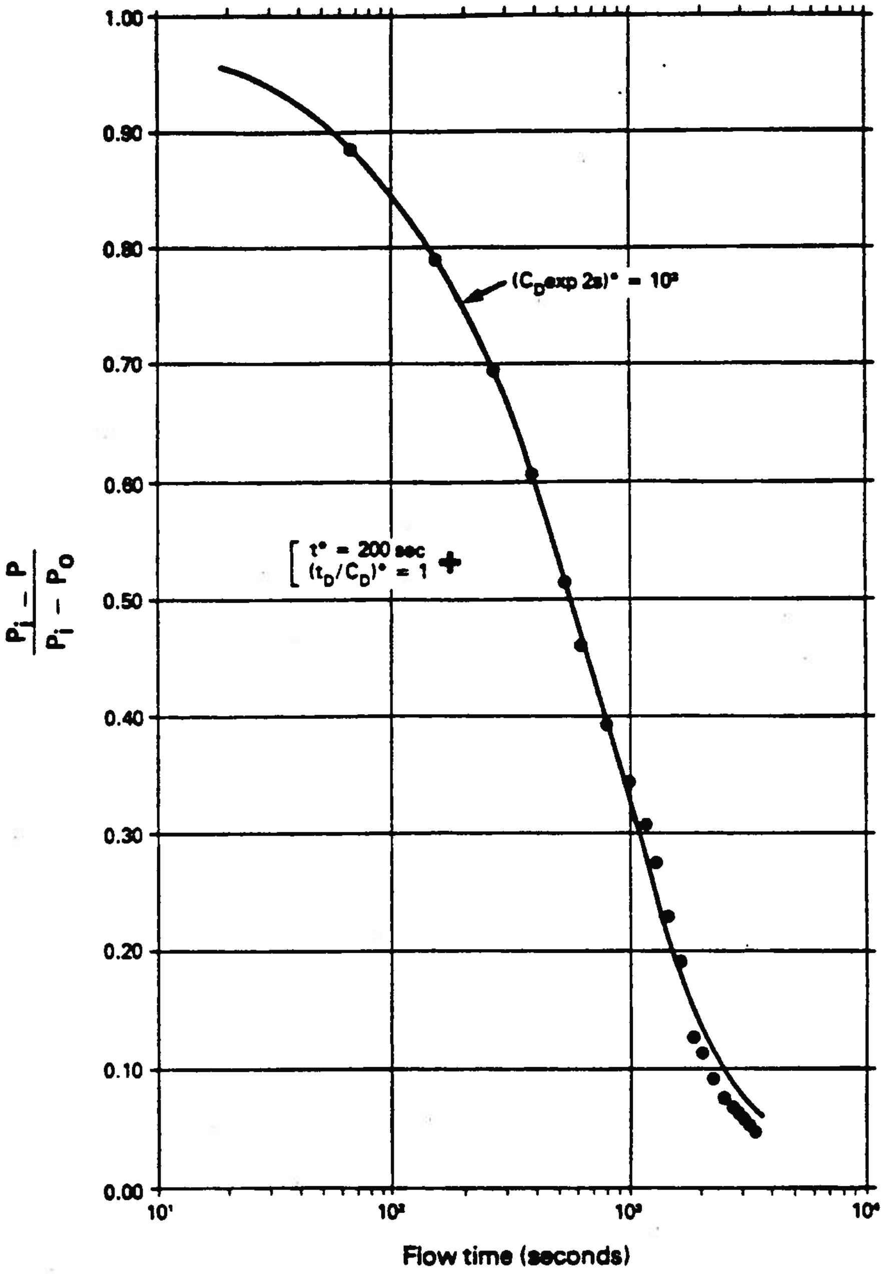
CORE DATA

Introduction

The core data were obtained from the ERCB Well Data File, and no additional information was entered from the hardcopy reports, such as was necessary in the case of the drillstem test data base. The information of interest from the core data base concerns the following parameters: the horizontal maximum permeability, the horizontal permeability at 90° to the preceding one, the vertical permeability, and the porosity.

Permeability

These data are all measured in the laboratory but the methods of measurement are not reported in the core data base and, for instance, there is no specific information on the type of fluid (air or liquid) and on the pressure conditions prevailing during the permeability measurements. Examination of a few original reports issued by the laboratories suggests that there are no "routine" overburden pressure



Interval = 448.0 - 466.3 m
Formation = "Upper Mannville" Group ——— Trace of Ramey *et al.* (1975) p. 97, type-curve
From eq. (11): $r_p^2 = 4.32 \times 10^{-3} m^2$
From eq. (10): $K = 5.9 \times 10^{-7}$ m/s $T = 1.08 \times 10^{-5} m^2/s$
From shut in interpretation s = 2.0 eq. (12) gives: $S_s = 1.5 \times 10^{-4} m^{-1}$ $S = 2.75 \times 10^{-3}$

Figure 4-7 Example of a flow period analysis for a drillstem test.

measurements and no correction for the Klinkenberg effect induced by the general use of air as a measuring fluid. Other factors causing errors are related to the disturbed character of the core sample, for example, stress relief, drying to carry out the test, and potential water-clay reactions. The complexity of these cumulative effects is such that the correction factors that should be applied to core permeabilities are very difficult to evaluate.

The core data base contains the permeability results obtained on plugs of a few centimeters long and representative values for the whole cored interval are weighted as follows:

$$k(\text{weighted}) = \text{sum } (i=1,n)[k(i)\ L(i)]\ /\text{sum } (i=1,n)[L(i)] \qquad (13)$$

where k(i) is the permeability value measured for the plug (i) of length L(i) and n is the number of plugs in the considered interval.

Equation (13) is applied successively to the three types of permeability given in the core data base, designated kmax, k90 and kvert, to obtain (kmax)weighted, (k90)weighted and (kvert)weighted, all in m^2. Calling these weighted values (kmax)w, (k90)w and (kvert)w, the horizontal permeability, kh, for the cored interval is calculated with:

$$kh = \left\{[(kmax)w]^2 + [(k90)w]^2\right\}^{0.5} \qquad (14)$$

and the vertical permeability, kv, of the interval is kept as (kvert)w. A cored interval is thus characterized by values of both kh and kv. Its vertical location is defined by the elevation (m, relative to sea level datum) of the mid-point and by the elevation of the top, so that four parameters fully describe the core permeability.

Porosity

This parameter, n, is weighted by replacing k by n in equation (13) and is reported as such. The core porosity can be considered more reliable than the core permeability insofar as the methods of measurement are concerned, but overestimates are also unavoidable because the rock sample is disturbed.

The derivative files obtained after processing the core data are presented in the Data Base in tables E-h-3, E-h-4, G-h-2, H-h-2, I-h-2, J-h-2, J-h-4, L-h-2, N-h-2, O-h-2, O-h-3, O-h-4 and O-h-5 for each hydrostratigraphic unit.

AQUIFER TESTS

The most reliable aquifer tests in the Cold Lake Study Area are located in the deepest formations of the Quaternary (Muriel Lake and Empress formations). These aquifers are semi-confined by the overlying till and of finite lateral extent. For the Empress Formation, the most commonly tested unit is the buried channel aquifer that runs along the lows of the bedrock topography; the lateral boundaries of the Muriel Lake aquifer are not so regular.

Partial solutions of the flow problem with both leakage and boundary effects as for "leaky-strip" aquifers are given in Bukhari et al. (1969) and Vandenberg (1976); the most general solution is presented in Vandenberg (1976). It uses the theory of images. In close form, the analytical solution can be written as:

$$sD = W(u,r/B) + \mathrm{sum}\ (i=1,\ )[W(ui,ri/B)] \qquad (15)$$

where $sD=4\ Ts/Q$, and $u=Sr^2/4Tt$ are, respectively, the dimensionless drawdown and the dimensionless time; r is the distance to the observation well where the drawdown, s (r,t), is measured at pumping time t; Q is the constant pumping rate; $B=[Tb'/K']^{0.5}$ is the leakage factor where b' and K' are the thickness and the vertical hydraulic conductivity of the overlying aquitard, respectively; ri is the distance from the ith image well to the observation well and $ui=S(ri)^2/4Tt$. The function W is the integral:

$$W(u,r/B)=\int_u^\infty (1/x)\exp[-x-(r/2B)^2/x]dx$$

where x is a dummy variable of integration. The function W is the well function for infinite leaky aquifers.

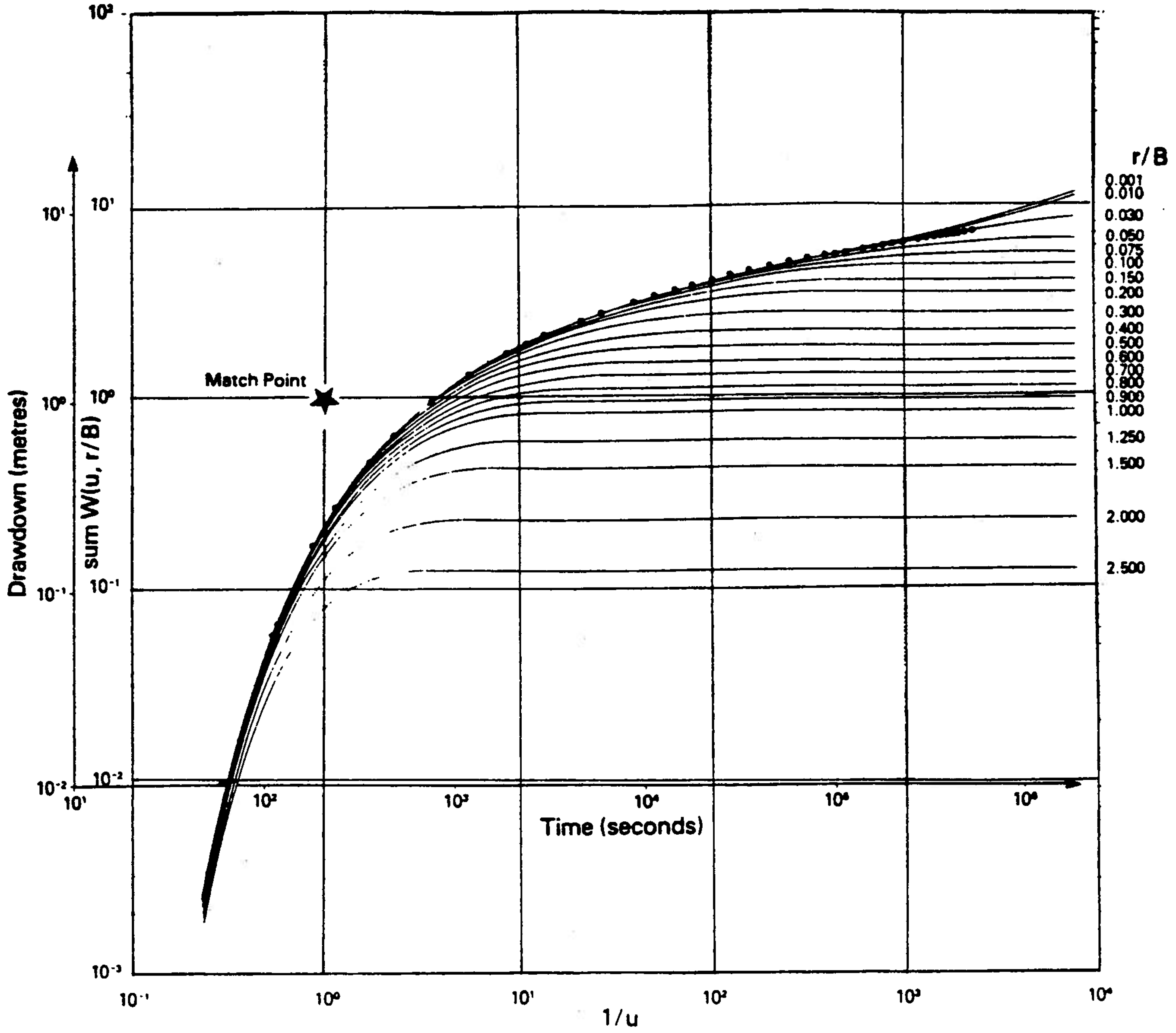
Specially developed software computes the values of sD for a given field situation, that is, the relative location of both producing well and observation well inside a channel of known width and orientation (both measured with respect to the perpendicular from the channel axis at the level of the producing well). Then the time-drawdown plot at the observation well is interpreted with the usual matching technique overlying this log-log plot over the specific set of type-curves; both log-log plots are at the same scale. This interpretation provides the transmissivity and storativity of the produced aquifer, as well as an estimate of the vertical hydraulic conductivity of the overlying leaky bed. The quality of the fit between the measured drawdowns and the analytical model has proved quite satisfactory for the Empress Formation aquifer tests, as illustrated in figure 4-3. The interpreted results are reported in Section 2 on the Quaternary.

HYDROSTRATIGRAPHIC UNITS

DATA MANIPULATION

In this section, the main features of the flow regime as they can be deduced from the results of the data interpretation are discussed. Prior to this, a detailed definition of the hydrostratigraphic units based on the hydraulic parameters is necessary. All the following definitions are based on the interpreted results of drillstem tests for reasons that will be fully discussed later in this report; the core results do not, however, contradict the groups derived from the drillstem tests.

Each test was allocated to a given stratigraphic unit using the automatic interpolation procedure described in Part 1. The next step was to characterize each unit by its permeability (range and median); because this parameter should be log-normally distributed within each unit, log-normal cumulative frequency plots were constructed and used to detect anomalies (which were checked before rejection) and to define the range of variation as well as the median value. Whenever two adjacent aquifers show similar characteristics with respect to the range and the median permeability, they were grouped together and



5-10-66-5-W4M   Q = 60.61 L/sec   r = 125 m

Y_P = 1980.00   D = 5200.00   TST = 0.0060
Y_O = 2061.10 X_O = 96.80

From the match between the measured drawdowns (● ●) and the type-curve, $r/_B$ = 0.03

B = 4167 m   b = 23.2 m
K' = 2.7×10^{-9} m/s   b' = 10.7 m
T = 4.4×10^{-3} m²/s
S = 2.4×10^{-4}

(All symbols are defined in text)

Geometrical parameters:

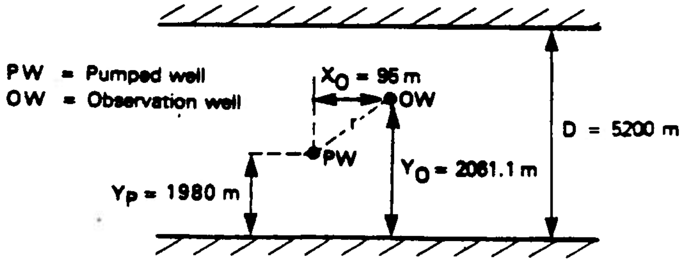


Figure 4-3 Example of an aquifer test interpretation using the "leaky strip" analytical model.

a combined log-normal cummulative frequency plot produced. Because most of the test data are in pervious zones of aquifers, this method is only used to group aquifers of common lithologies (sandstone in the Cretaceous and carbonate in the Paleozoic). On the basis of this technique, seven aquifers were identified. The log-normal cumulative frequency plots of permeability are illustrated in figures 4-4 to 4-10, and the aquifers, together with the data distribution maps in the Atlas are listed below:

Aquifer(s)	Figure(s)	Atlas map(s)
Cooking Lake-Beaverhill Lake-Watt Mountain	4-4	E-h-2
Winterburn-Grosmont-Camrose	4-5	G-h-2, H-h-2 and I-h-2
McMurray Formation	4-6	J-h-2
"Lower Mannville" Group above McMurray Formation	4-7	J-h-3
"Upper Mannville" Group	4-8	L-h-2
"Viking sandstone"	4-9	N-h-2
Intra-Colorado	4-10	O-h-2

There is a marked difference in the pattern of permeability on the log-normal cumulative frequency plots between the sandstones (Wabiskaw, Cummings and Lloydminster) below the base of the Clearwater Formation (above the McMurray Formation) and those in the McMurray Formation. Although the "Lower Mannville" Group above the McMurray Formation and the McMurray Formation data sets show similar permeability means and ranges, the latter appears more homogeneous. At this stage of the study, therefore, we separated the Mannville Group aquifers below the Clearwater Formation aquitard into two hydrostratigraphic units, which were subsequently to be combined into the "Lower Mannville" Group aquifer (see discussion on terminology in Part 2).

The log-normal cumulative frequency plots for the "Upper Mannville" Group aquifer suggests the existence of two populations

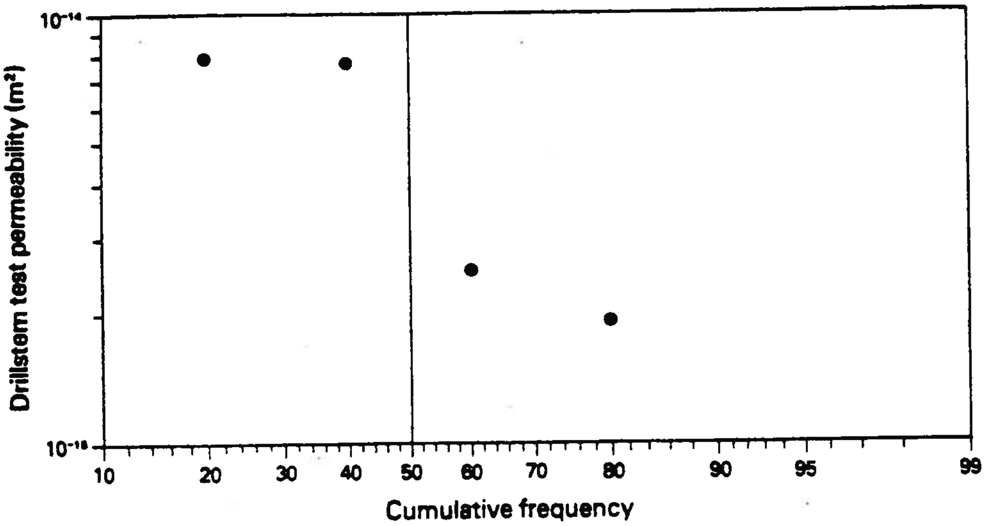


Figure 4-4 Log-normal cumulative frequency plot for permeabilities derived from drillstem tests, Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, Cold Lake Study Area.

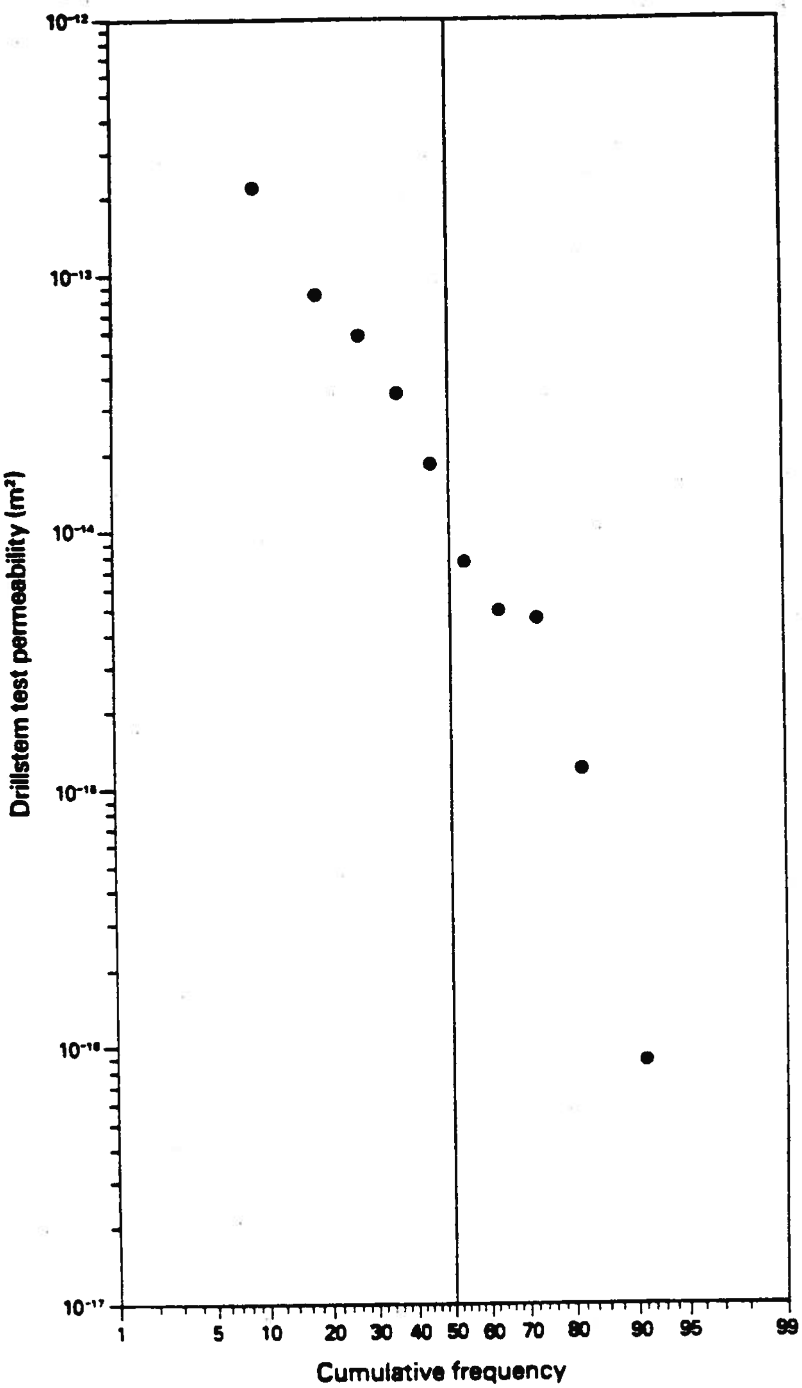


Figure 4-5 Log-normal cumulative frequency plot for permeabilities derived from drillstem tests, Winterburn-Grosmont-Camrose aquifers, Cold Lake Study Area.

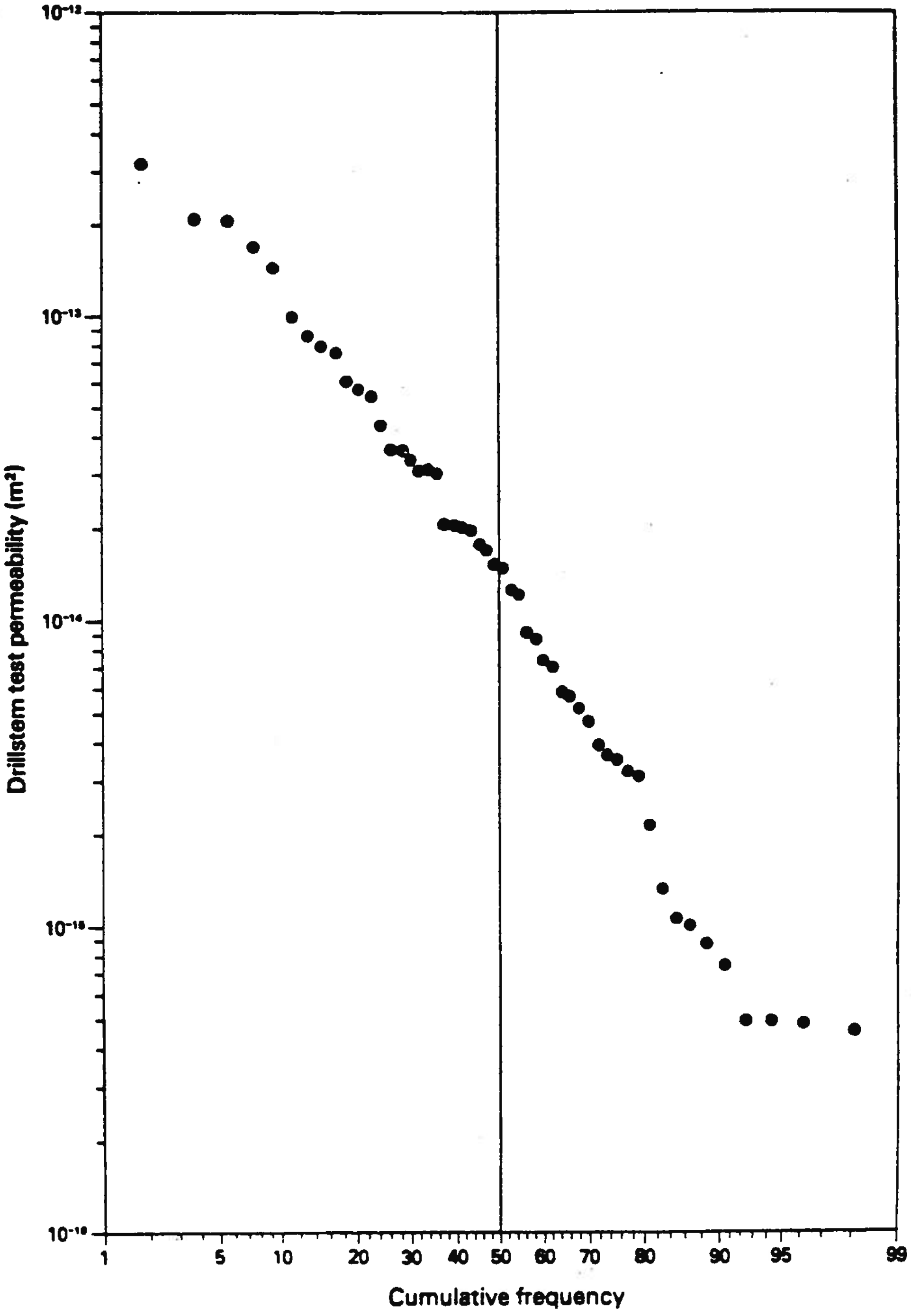


Figure 4-6 Log-normal cumulative frequency plot for permeabilities derived from drillstem tests, McMurray Formation aquifer, Cold Lake Study Area.

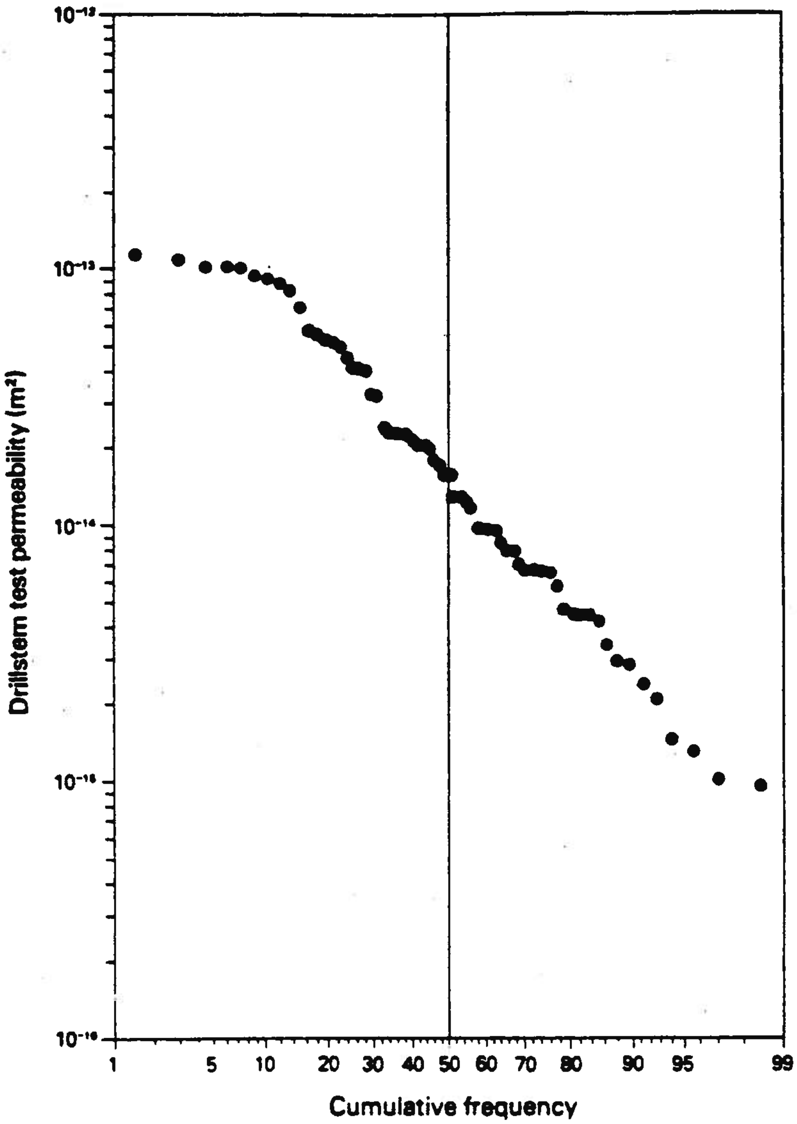


Figure 4-7 Log-normal cumulative frequency plot for permeabilities derived from drillstem tests, "Lower Mannville" Group aquifer above McMurray Formation, Cold Lake Study Area.

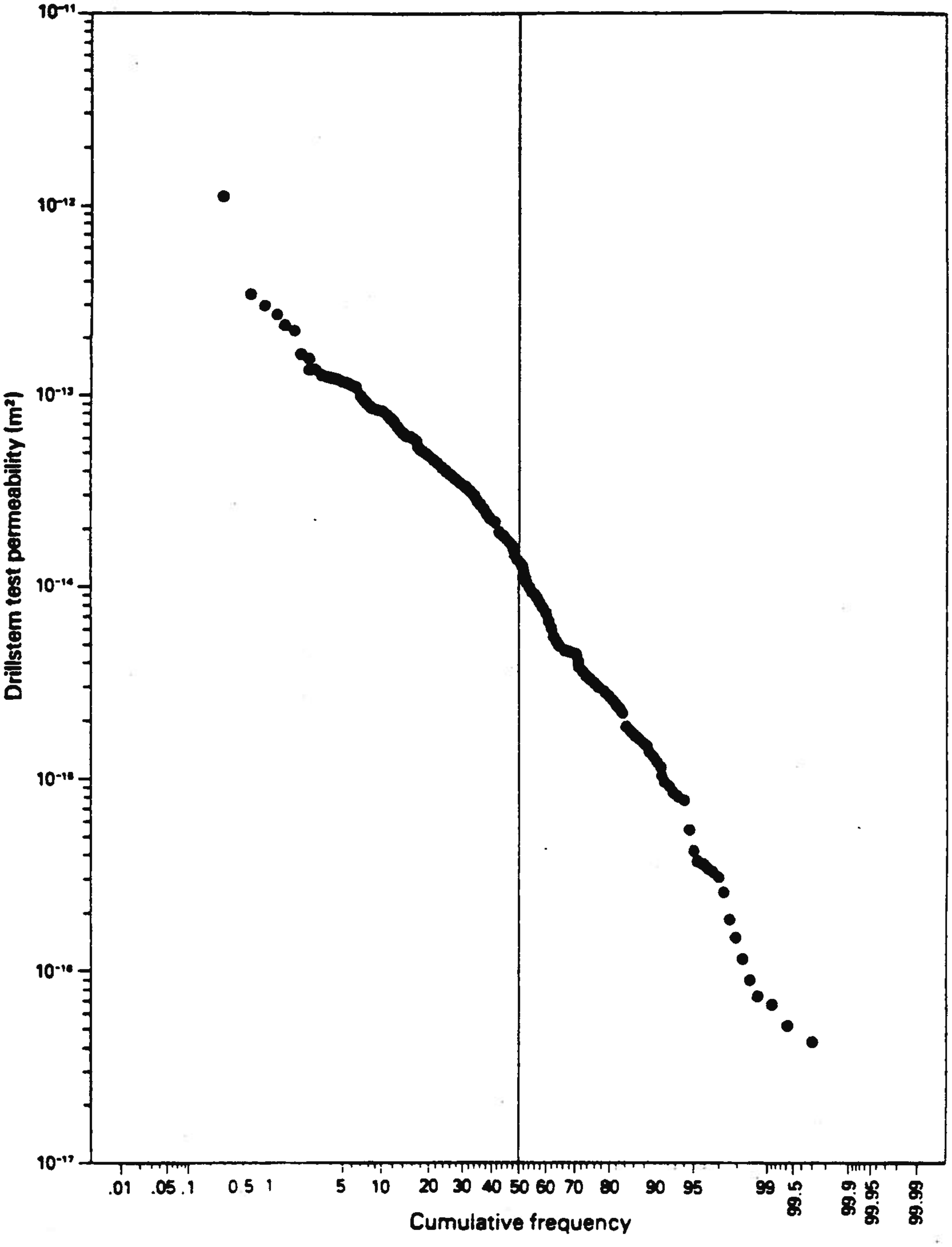


Figure 4-8 Log-normal cumulative frequency plot for permeabilities derived from drillstem tests, "Upper Mannville" Group aquifer, Cold Lake Study Area.

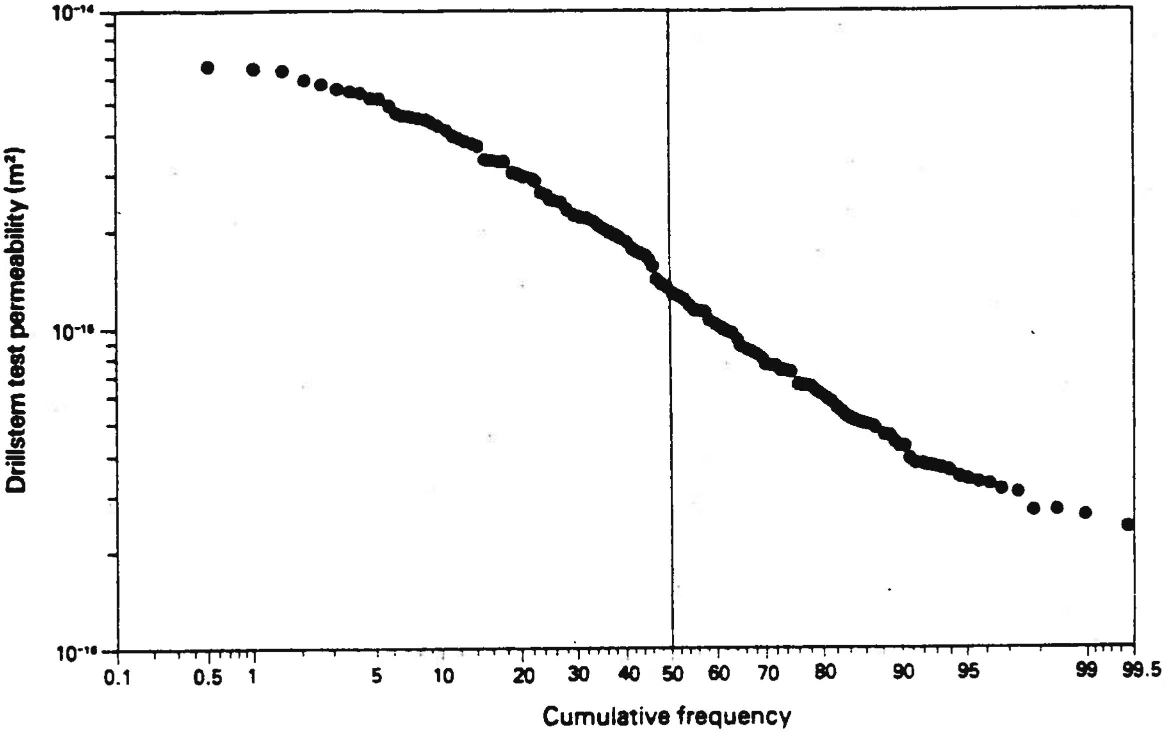


Figure 4-9 Log-normal cumulative frequency plot for permeabilities derived from drillstem tests, "Viking sandstone" aquifer, Cold Lake Study Area.

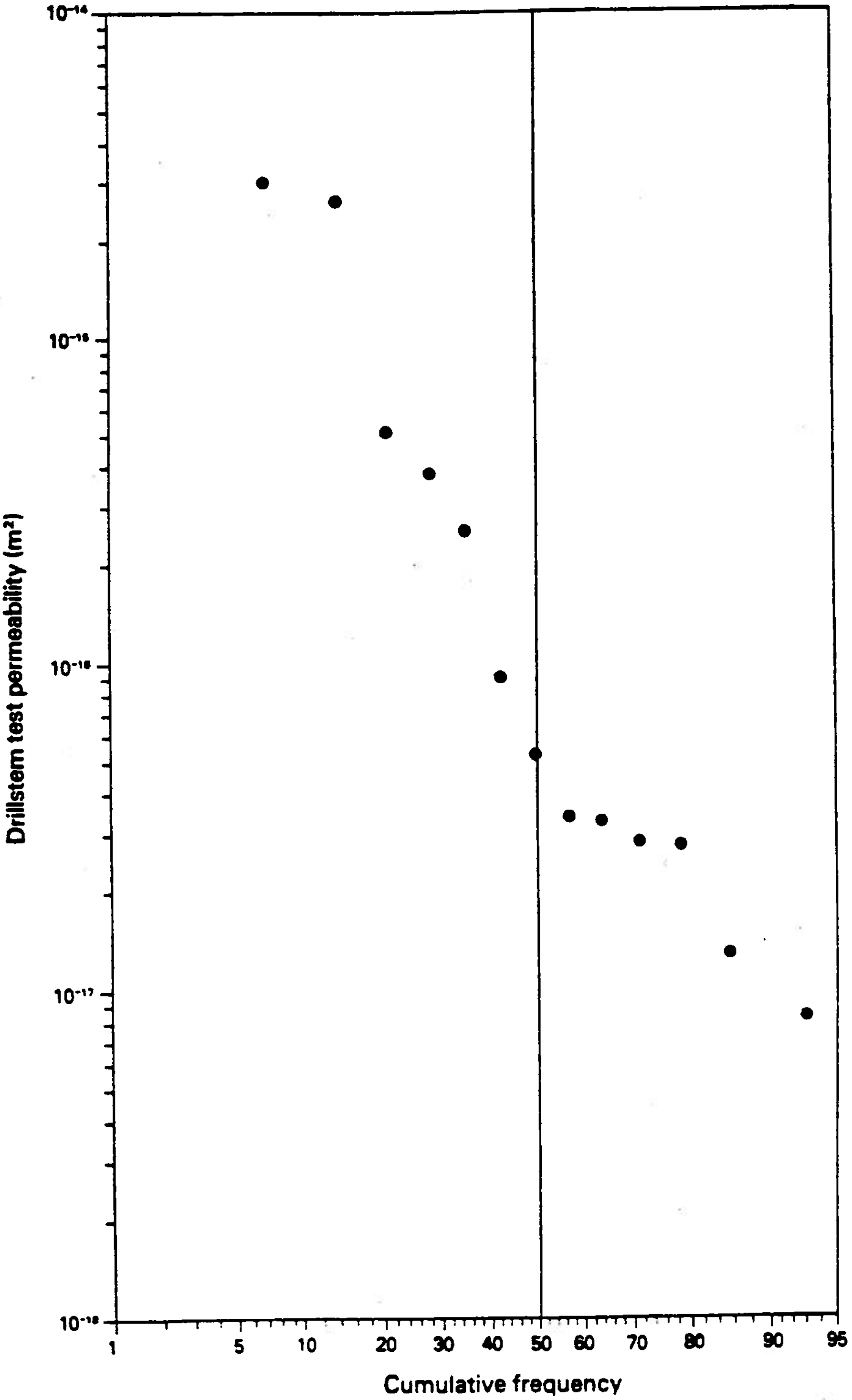


Figure 4-10 Log-normal cumulative frequency plot for permeabilities derived from drillstem tests, Intra-Colorado aquifers, Cold Lake Study Area.

with two lines on the graph intersecting at 1.5×10^{-14} m^2. This reflects its lithological heterogeneity. East of R 10, the permeability is more homogeneous (the range is 9×10^{-17} to 3.4×10^{-13} m^2) with a median of 3×10^{-14} m^2 based on 203 data points. West of R 10, two populations persist with an intersection of the straight lines at 3×10^{-14} m^2 (128 data points) and a range of 4.2×10^{-17} to 1.6×10^{-13} m^2. For the purpose of this study, however, the "Upper Mannville" Group aquifer can be treated as a homogeneous unit characterized by the values given in table 4-1.

Table 4-2 summarizes the aquifer hydraulic conductivities that are derived from the drillstem test data using equation (5). Their log-normal cumulative frequency plots are shown in figures 4-11 to 4-17. The log-normal cumulative frequency plots of hydraulic conductivity exhibit a more homogeneous behaviour than the corresponding ones for permeability, especially for aquifers within the Mannville Group. The combination of the "Lower Mannville" Group above the McMurray Formation, with the McMurray Formation aquifer into a single unit appears fully justified by the log-normal cumulative frequency plots of figures 4-12 to 4-14, as well as by the ranges and medians of hydraulic conductivity shown in table 4-2. This was not so obvious based on the drillstem test permeabilities because of the particular behaviour of this parameter in the Mannville Group below the Clearwater Formation aquitard.

For the hydraulic conductivity of the four aquitards (Colorado, Joli Fou, Clearwater and Ireton shales) there is no data in the drillstem test results (as expected). The accepted permeability range for western Canada for the Joli Fou shale is 1×10^{-25} to 5×10^{-22} m^2, based on core results. The upper bound of this range is adopted here because of the shallow position of this formation in the study area with respect to the rest of the basin. This results in a value of hydraulic conductivity of about 5×10^{-14}m/s and a leakage factor, B, of about 1400 m. The average permeability of the Clearwater Formation shale is 2.9×10^{-21} m^2 at an average depth of

Table 4-1

Permeability (m^2) of hydrostratigraphic units determined from drillstem tests, Cold Lake Study Area

Hydrostratigraphic unit	Number of determinations	Permeability (m^2)		
		k_{min}	k_{median}	k_{max}
Cooking Lake-Beaverhill Lake-Watt Mountain aquifer	4	1.9×10^{-15}	3.5×10^{-15}	7.9×10^{-15}
Winterburn-Grosmont-Camrose aquifer	10	8.9×10^{-17}	9×10^{-15}	2.2×10^{-13}
McMurray Formation aquifer	52	4.5×10^{-16}	1.1×10^{-14}	3.2×10^{-13}
Lower Mannville Group (above McMurray Formation) aquifer	66	9.6×10^{-16}	1×10^{-14}	1.1×10^{-13}
"Upper Mannville" Group aquifer	333	4.2×10^{-17}	1.3×10^{-14}	1.1×10^{-12}
"Viking sandstone" aquifer	187	2.4×10^{-16}	1.3×10^{-15}	6.6×10^{-15}
Intra-Colorado aquifers	13	8.4×10^{-18}	1×10^{-16}	3.1×10^{-15}

Table 4-2

Hydraulic conductivity (m/s) of hydrostratigraphic units determined from drillstem tests, Cold Lake Study Area

Hydrostratigraphic unit	Number of determinations	Hydraulic conductivity (m/s) minimum	median	maximum
Cooking Lake-Beaverhill Lake-Watt Mountain aquifer	3	1×10^{-9}	7×10^{-9}	1×10^{-7}
Winterburn-Grosmont-Camrose aquifer	10	1.1×10^{-9}	3.8×10^{-8}	1.7×10^{-7}
McMurray Formation aquifer	47	2.5×10^{-10}	2.7×10^{-8}	2.1×10^{-6}
"Lower Mannville" Group aquifer (below base of Clearwater Formation aquitard)	110	2.5×10^{-10}	1.2×10^{-8}	2.1×10^{-6}
Lower Mannville Group (above McMurray Formation) aquifer	63	6.4×10^{-10}	8.5×10^{-9}	7.5×10^{-7}
"Upper Mannville" Group aquifer	322	2.4×10^{-11}	1.2×10^{-8}	1×10^{-6}
"Viking sandstone" aquifer	181	1.3×10^{-10}	1×10^{-9}	3.7×10^{-9}
Intra-Colorado aquifers	13	4.7×10^{-12}	5.8×10^{-11}	2.9×10^{-8}

1615 m. This value is probably valid for the study area, given the contradictory influences of shallower depths (higher permeability, theoretically) and overestimations from core analyses. It follows that a hydraulic conductivity of 3×10^{-14} m/s and a leakage factor of 17000 m are reasonable values. No similar indications are available for the Ireton Formation aquitard, but a hydraulic conductivity of 1×10^{-14} m/s appears reasonable, yielding a leakage factor of 7000 m. With these estimations, the Joli Fou Formation aquitard is twelve and five times more resistant to vertical flow than are the Clearwater

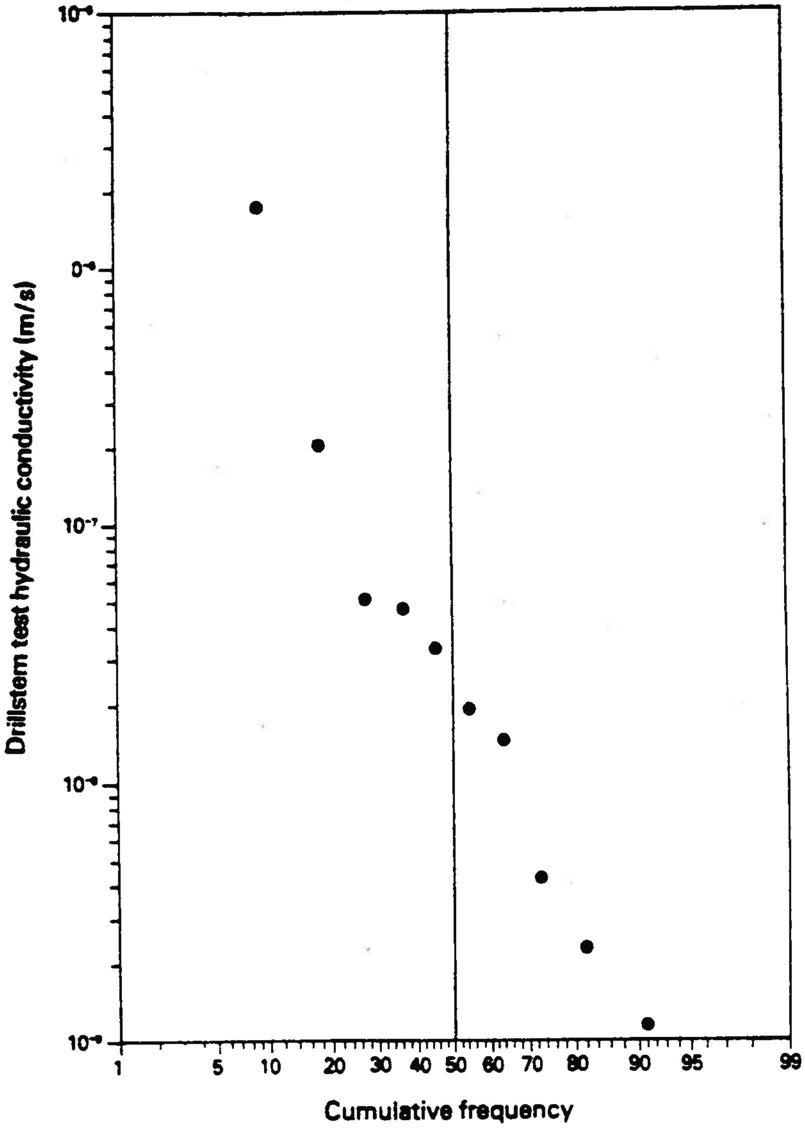


Figure 4-11 Log-normal cumulative frequency plot for hydraulic conductivity derived from drillstem tests, Winterburn-Grosmont-Camrose aquifers, Cold Lake Study Area.

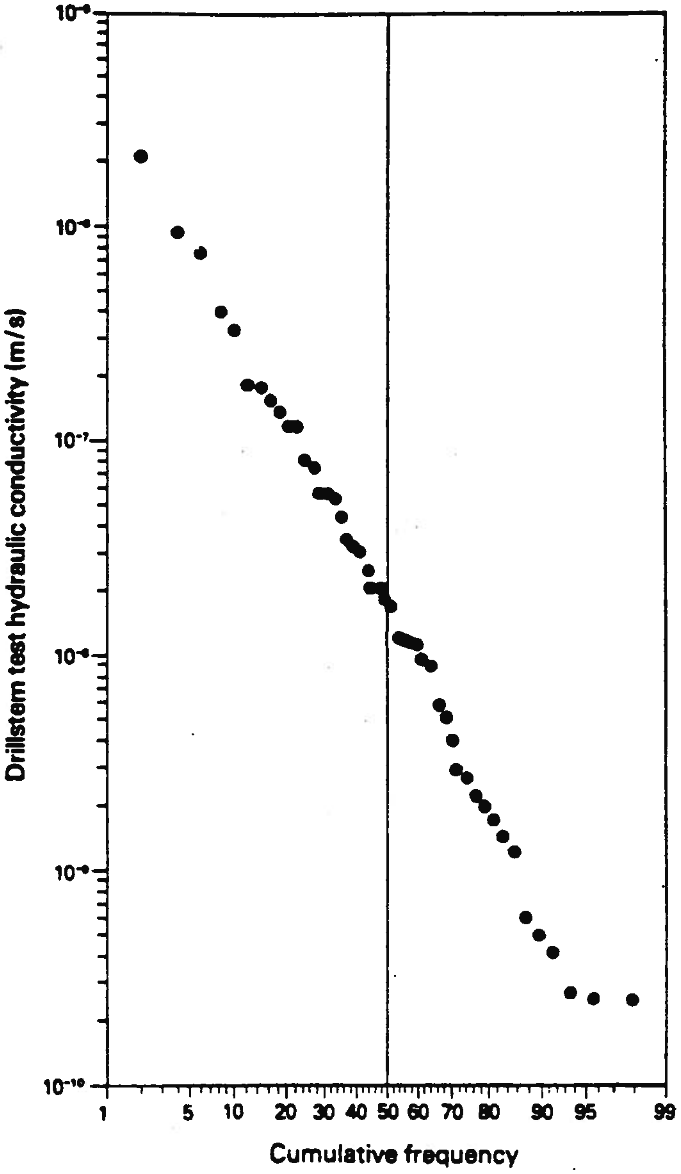


Figure 4-12 Log-normal cumulative frequency plot for hydraulic conductivity derived from drillstem tests, McMurray Formation aquifer, Cold Lake Study Area.

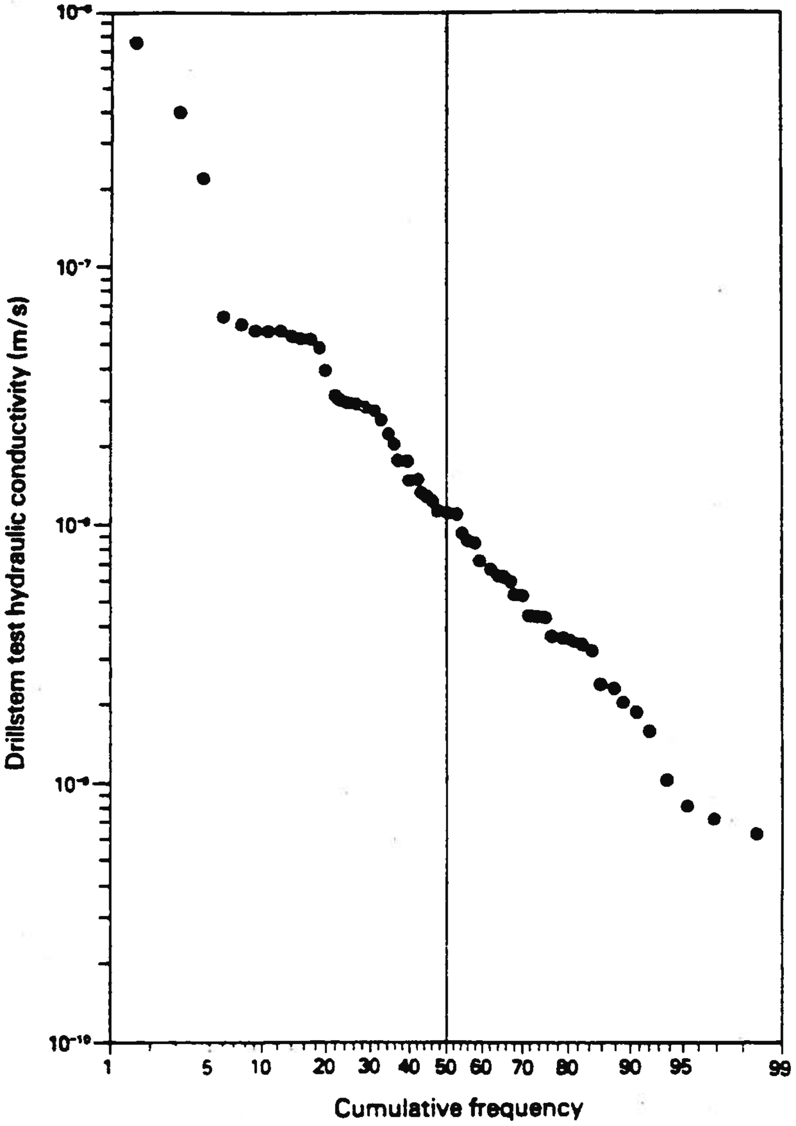


Figure 4-13 Log-normal cumulative frequency plot for hydraulic conductivity derived from drillstem tests, "Lower Mannville" Group aquifer above McMurray Formation, Cold Lake Study Area.

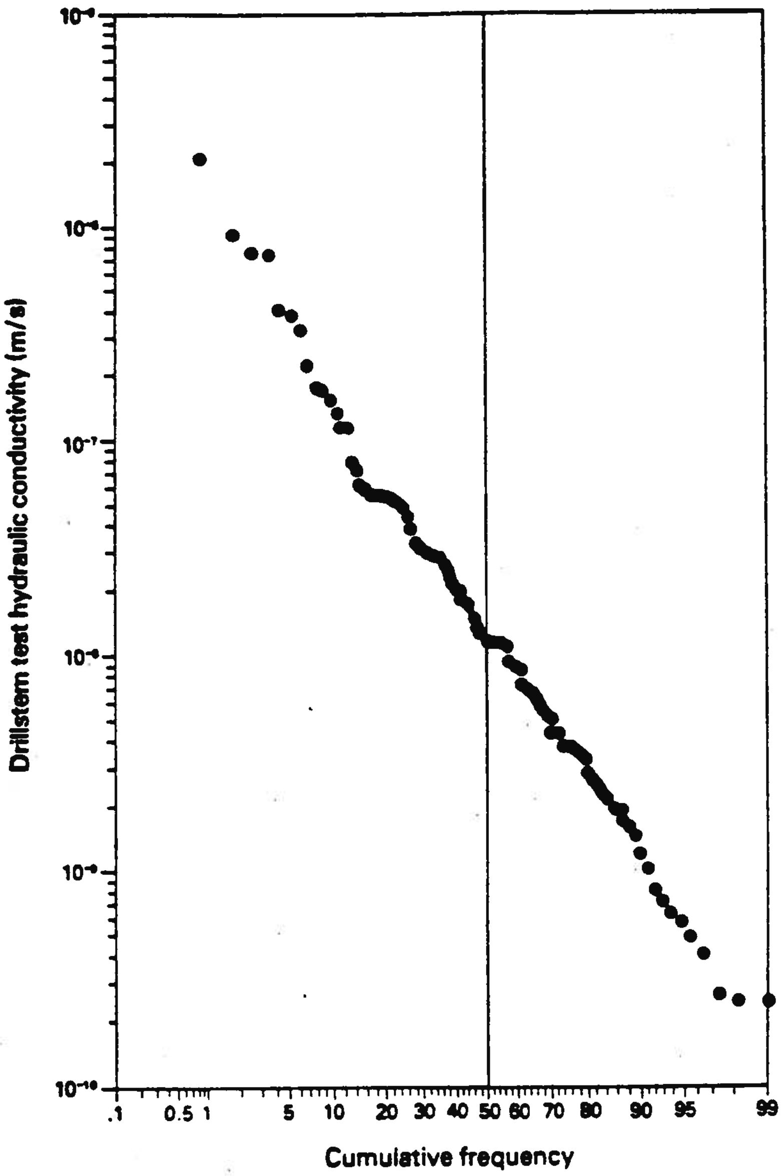


Figure 4-14 Log-normal cumulative frequency plot for hydraulic conductivity derived from drillstem tests, "Lower Mannville" Group aquifer (below base of Clearwater Formation aquitard), Cold Lake Study Area.

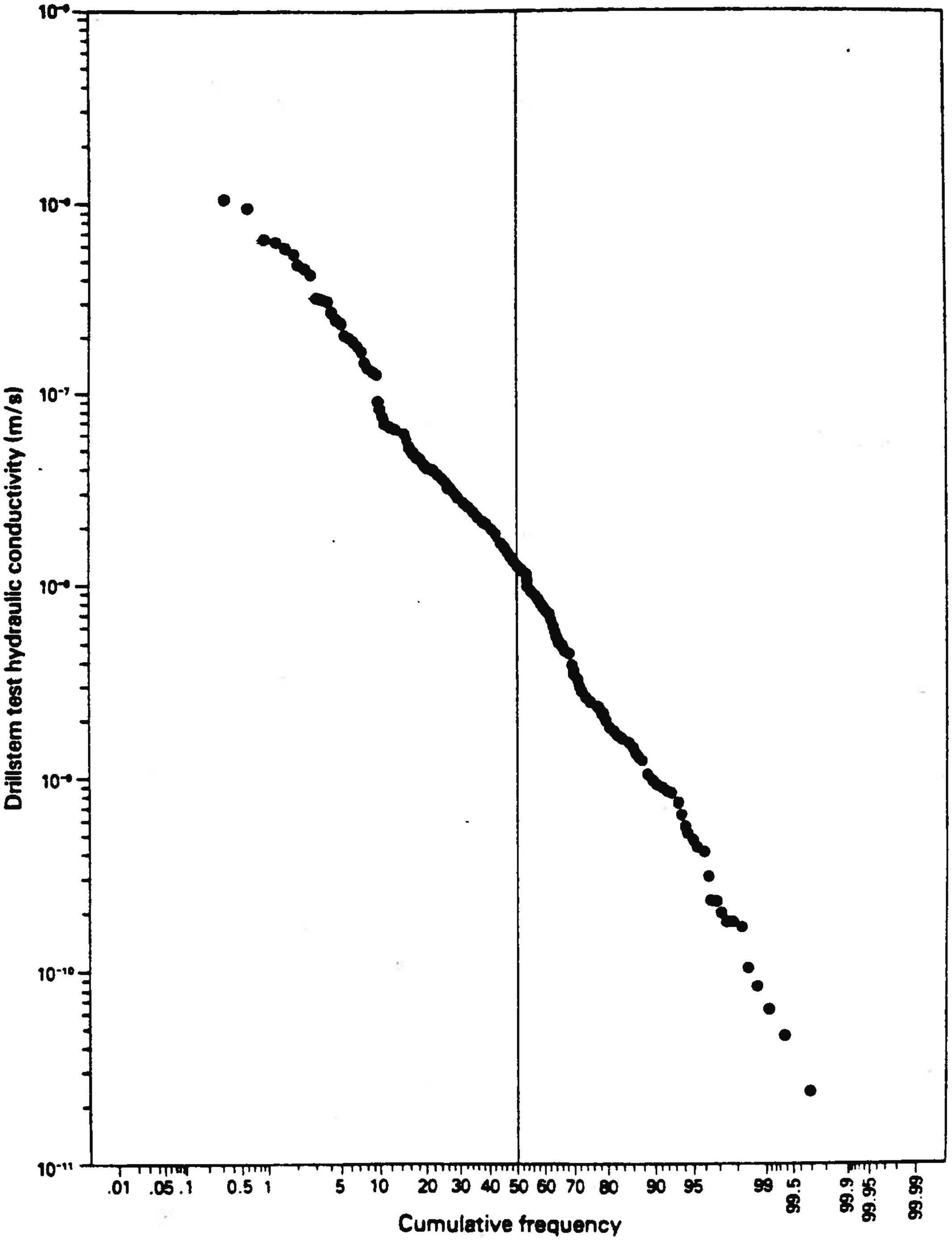


Figure 4-15 Log-normal cumulative frequency plot for hydraulic conductivity derived from drillstem tests, "Upper Mannville" Group aquifer, Cold Lake Study Area.

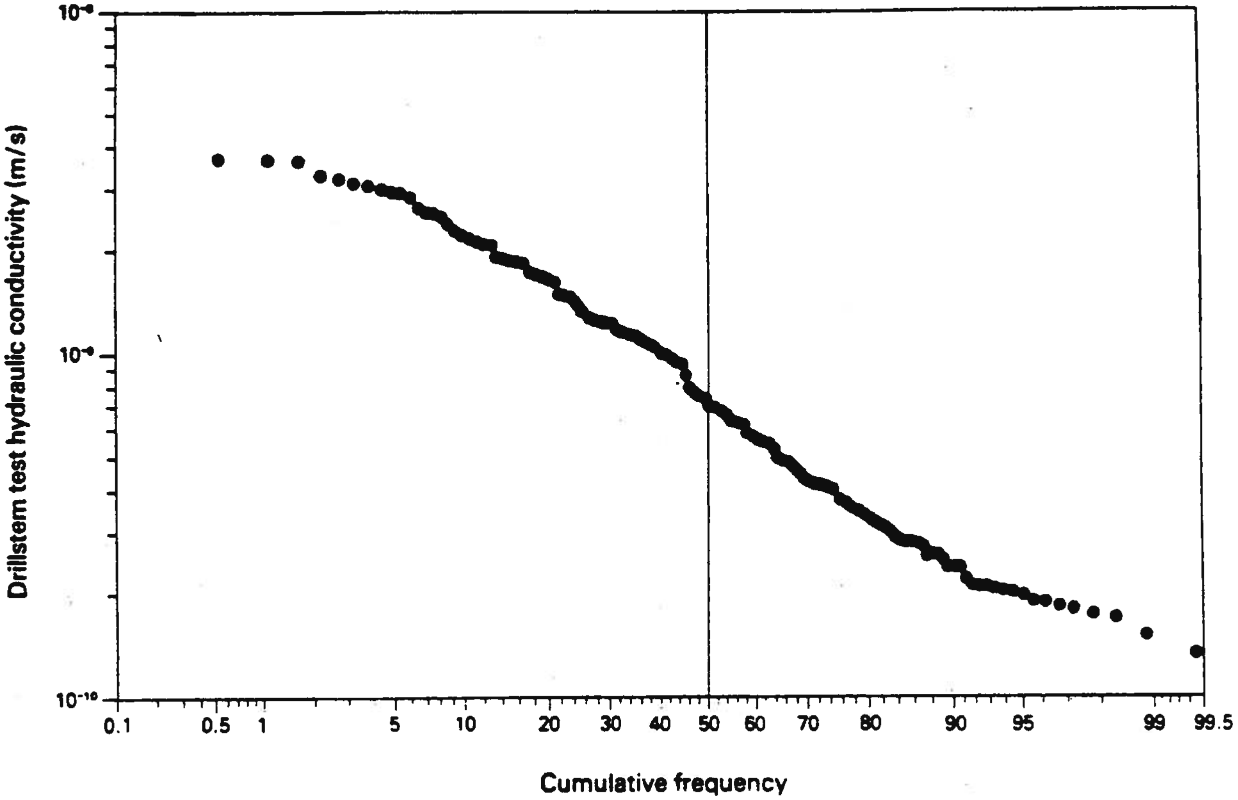


Figure 4-16 Log-normal cumulative frequency plot for hydraulic conductivity derived from drillstem tests, "Viking sandstone" aquifer, Cold Lake Study Area.

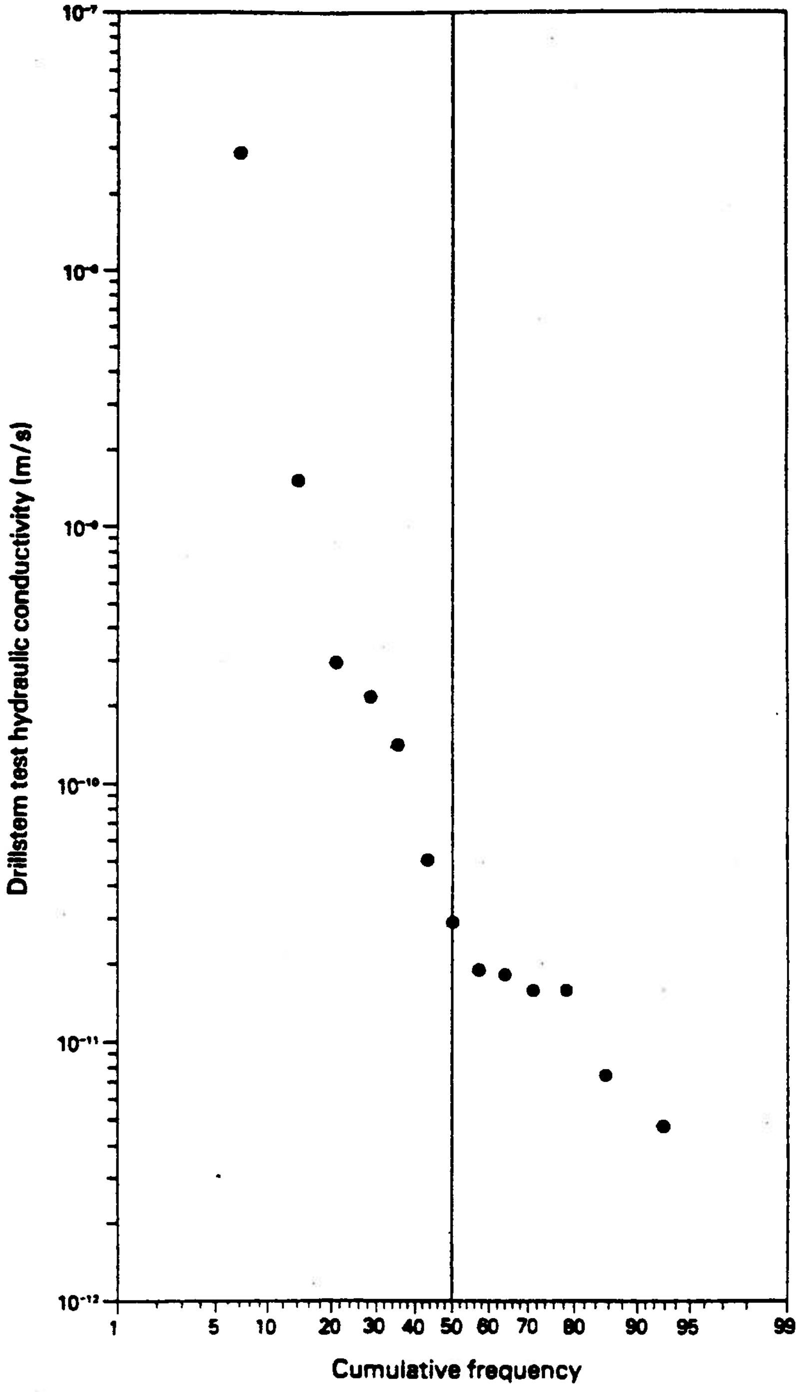


Figure 4-17 Log-normal cumulative frequency plot for hydraulic conductivity derived from drillstem tests, Intra-Colorado aquifers, Cold Lake Study Area.

Formation and Ireton Formation aquitards, respectively. This may be an argument to treat the thin "Viking sandstone" and the Intra-Colorado aquifers as an integral part of the Colorado aquitard that would be essentially an aquitard, but with a higher hydraulic conductivity than the Joli Fou Formation shale itself. The aquitard hydraulic conductivities will be reconsidered in the section dealing with mass balance that precedes the numerical simulation in Part 6.

In summary, on the basis of the geology (Part 2) and of the drillstem test results, the study area can be characterized by the following hydrostratigraphic units within the upper part of the Phanerozoic sequence, listed in descending sequence:

Colorado aquitard
Intra-Colorado aquifers (Second White Speckled shale and Base of Fish Scales Zone)
"Viking sandstone" aquifer
Joli Fou Formation aquitard
"Upper Mannville" Group aquifer
Clearwater Formation aquitard
"Lower Mannville" Group aquifer
Winterburn-Grosmont-Camrose aquifer
Ireton Formation aquitard
Cooking Lake-Beaverhill Lake-Watt Mountain aquifer
Prairie Formation aquiclude

An alternative (simplified) approach is to group the first four units into a "Colorado Supergroup" aquitard with a higher hydraulic conductivity (by at least one order of magnitude) than the value attributed to the Joli Fou Formation aquitard. The most detailed classification, however, is supported by the hydraulic head results and by the hydrochemical synthesis in Part 3.

COMPARISON OF DRILLSTEM TEST AND CORE RESULTS

In the Cold Lake Study Area, a total of 1691 cored intervals have been analyzed in the Phanerozoic sequence, providing an equal amount of porosity values. Only 769 values of horizontal permeability and 84 of vertical permeability were obtained after processing the raw data. The log-normal cumulative frequency plots of horizontal and vertical core permeability are given in figures 4-18 to 4-24, and 4-25 to 4-30, respectively. Table 4-3 shows this information summarized by hydrostratigraphic units.

The core results for the horizontal permeability distributions exhibit parallel patterns for each unit, but displaced upward by more than one order of magnitude for comparable data derived from drillstem tests. Table 4-4 gives the summary of these results; the Intra-Colorado aquifers are not reported because of the non-significance of the sample size (only ten horizontal and one vertical determination). In table 4-4, the results of table 4-3 are put in such a form that a direct comparison with the drillstem test results can be made: the geometrical mean of the median values of horizontal and vertical core permeabilities is computed; this represents the "effective" permeability that is then compared for each unit with the median of drillstem test permeability by calculating their ratios.

The last column of table 4-4 shows that, except for the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, the discrepancy between the core and drillstem test permeabilities is more than one order of magnitude for the median values of each aquifer. The reason for overestimation of permeability by core analysis has been discussed previously. Could the factors evoked then be sufficient to explain the difference observed in the "Upper Mannville" Group aquifer, with a ratio of 52?. One may argue that systematically the "skin annulus" permeability has been measured by the drillstem tests, yielding underestimates of the true permeability. Assuming then that the core permeabilities are more accurate, this would mean that,

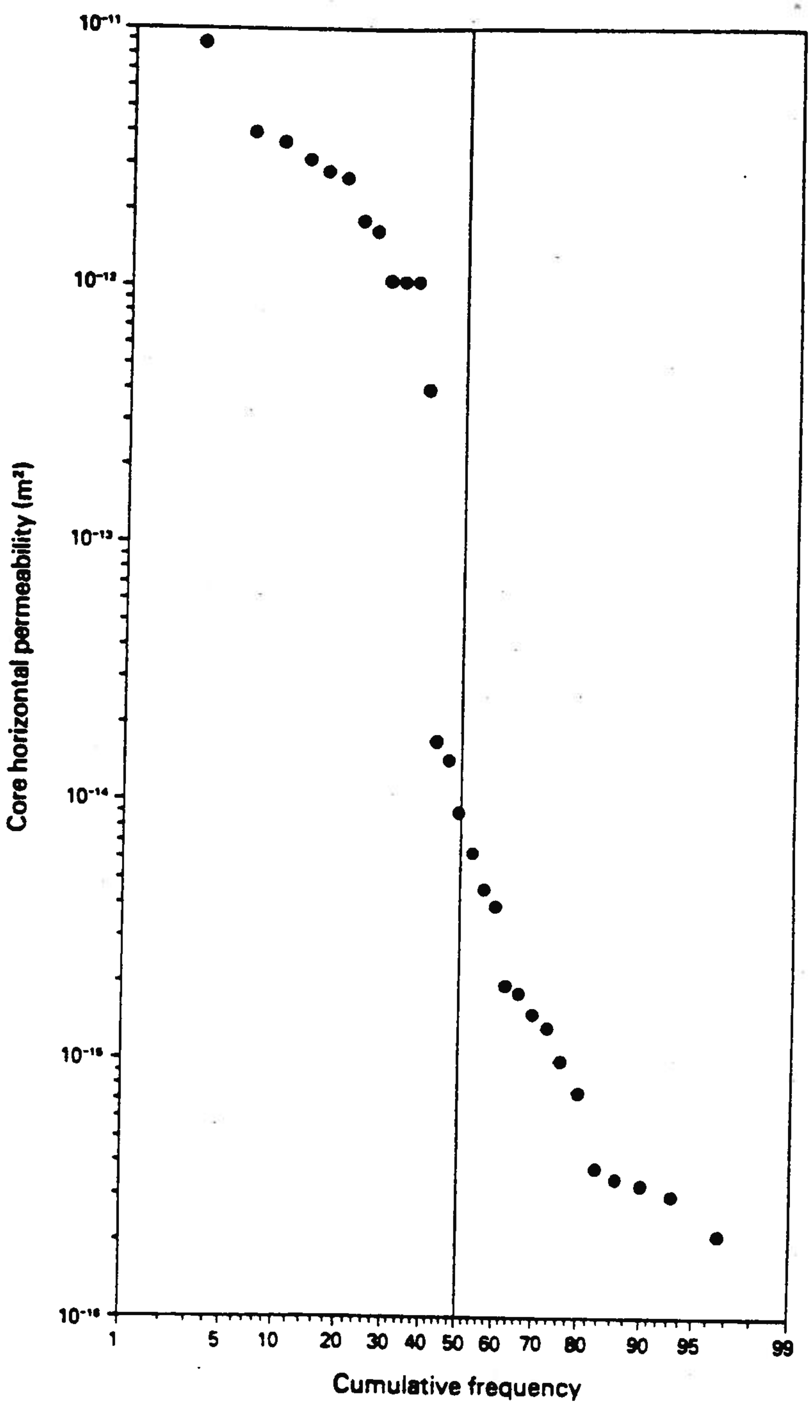


Figure 4-18 Log-normal cumulative frequency plot for horizontal permeability derived from core data, Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, Cold Lake Study Area.

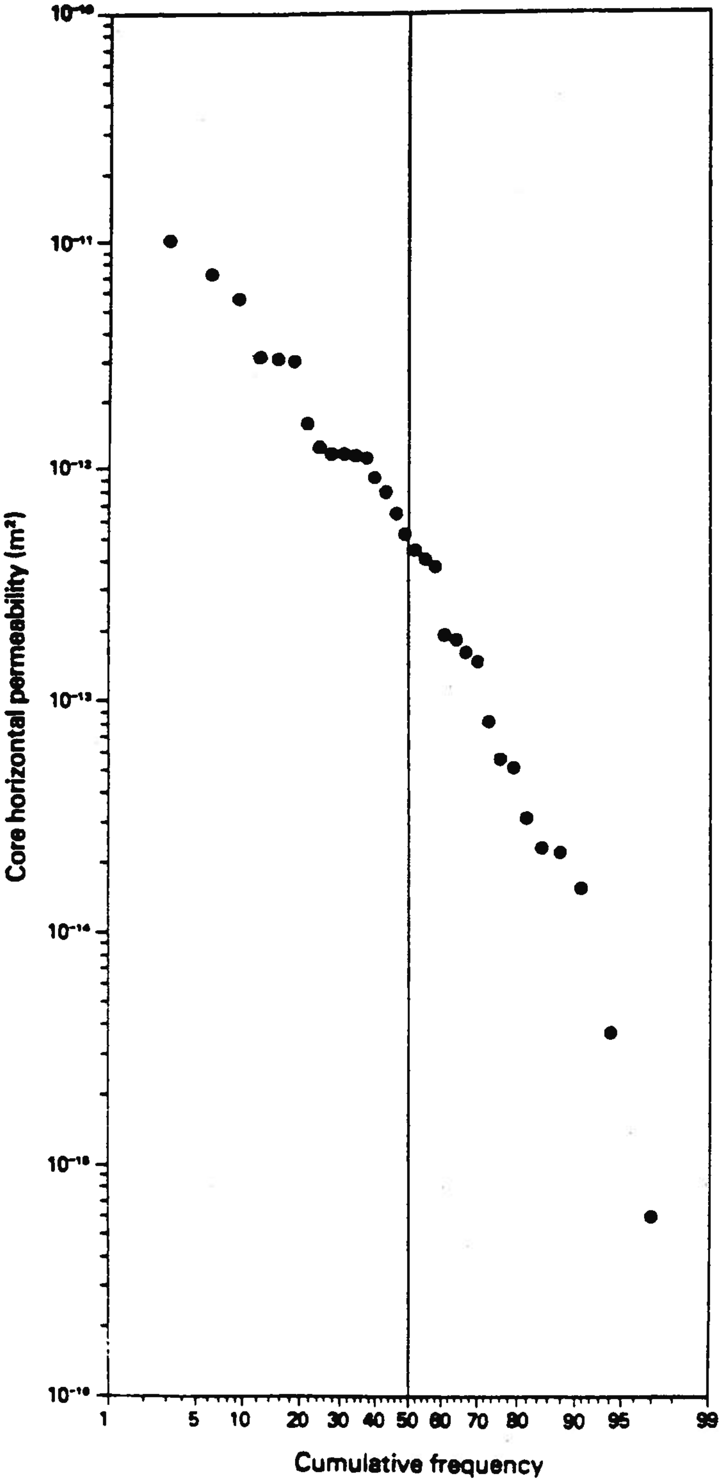


Figure 4-19 Log-normal cumulative frequency plot for horizontal permeability derived from core data, Winterburn-Grosmont-Camrose aquifer, Cold Lake Study Area.

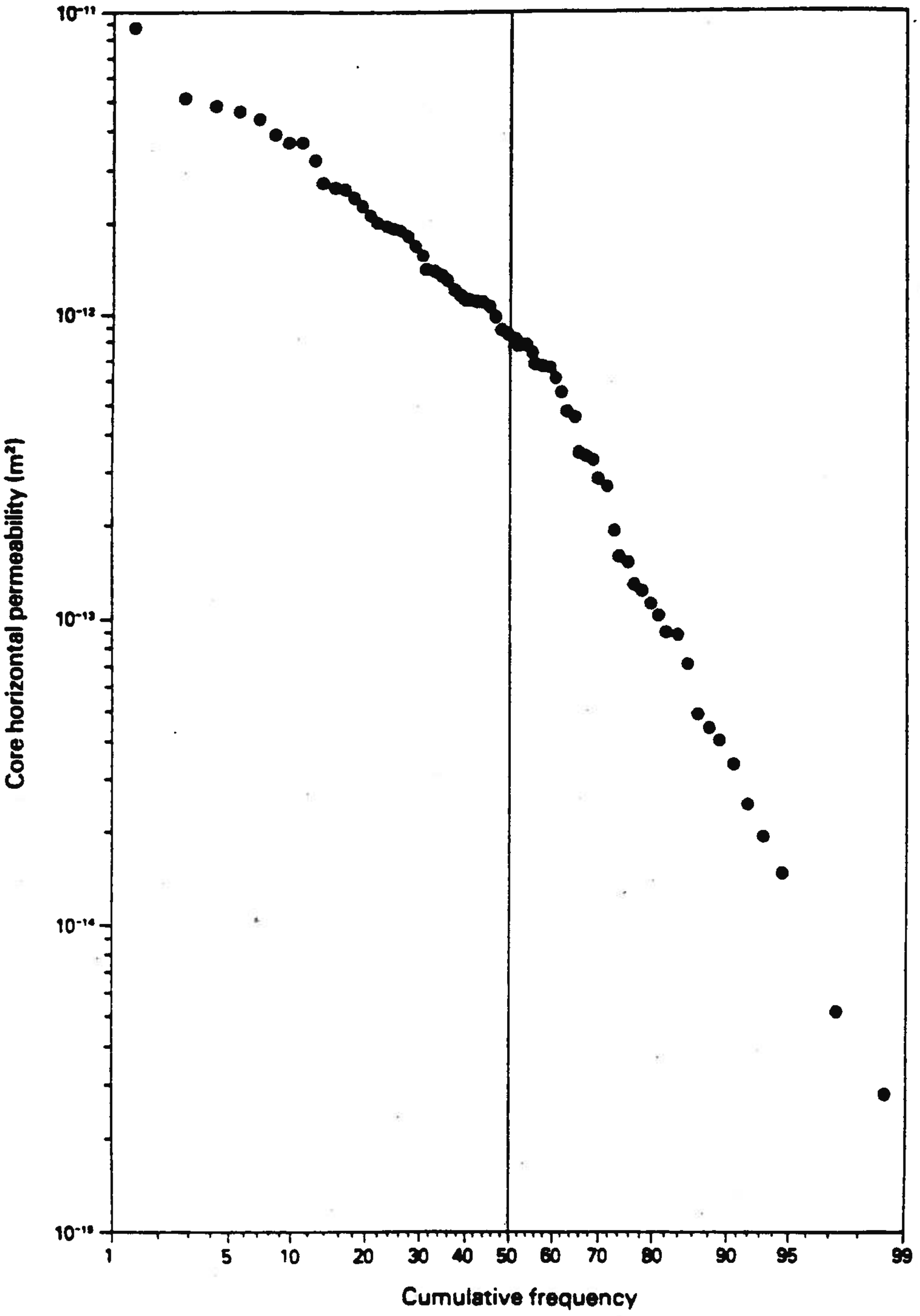


Figure 4-20 Log-normal cumulative frequency plot for horizontal permeability derived from core data, McMurray Formation aquifer, Cold Lake Study Area.

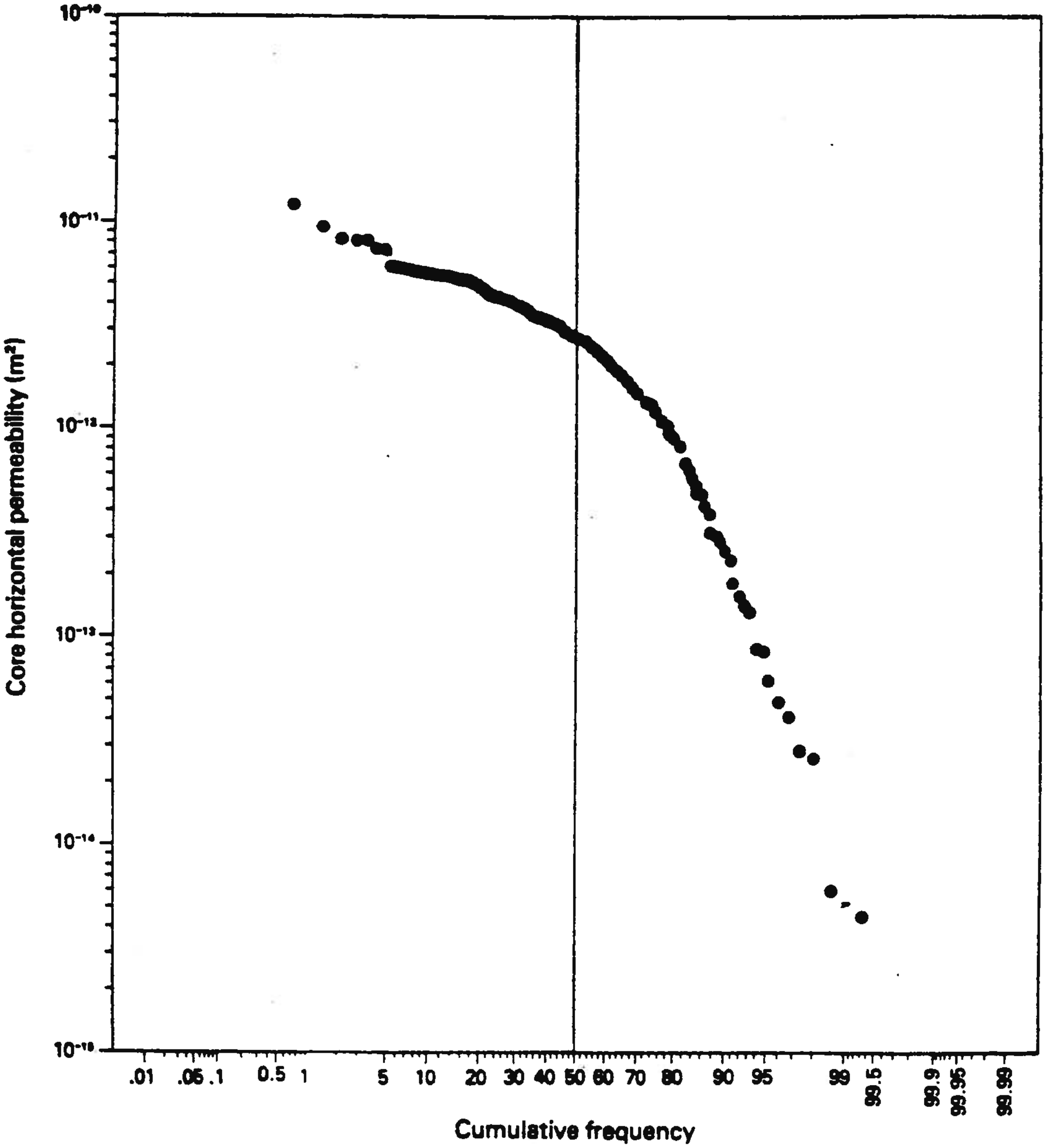


Figure 4-21 Log-normal cumulative frequency plot for horizontal permeability derived from core data, "Lower Mannville" Group aquifer above McMurray Formation, Cold Lake Study Area.

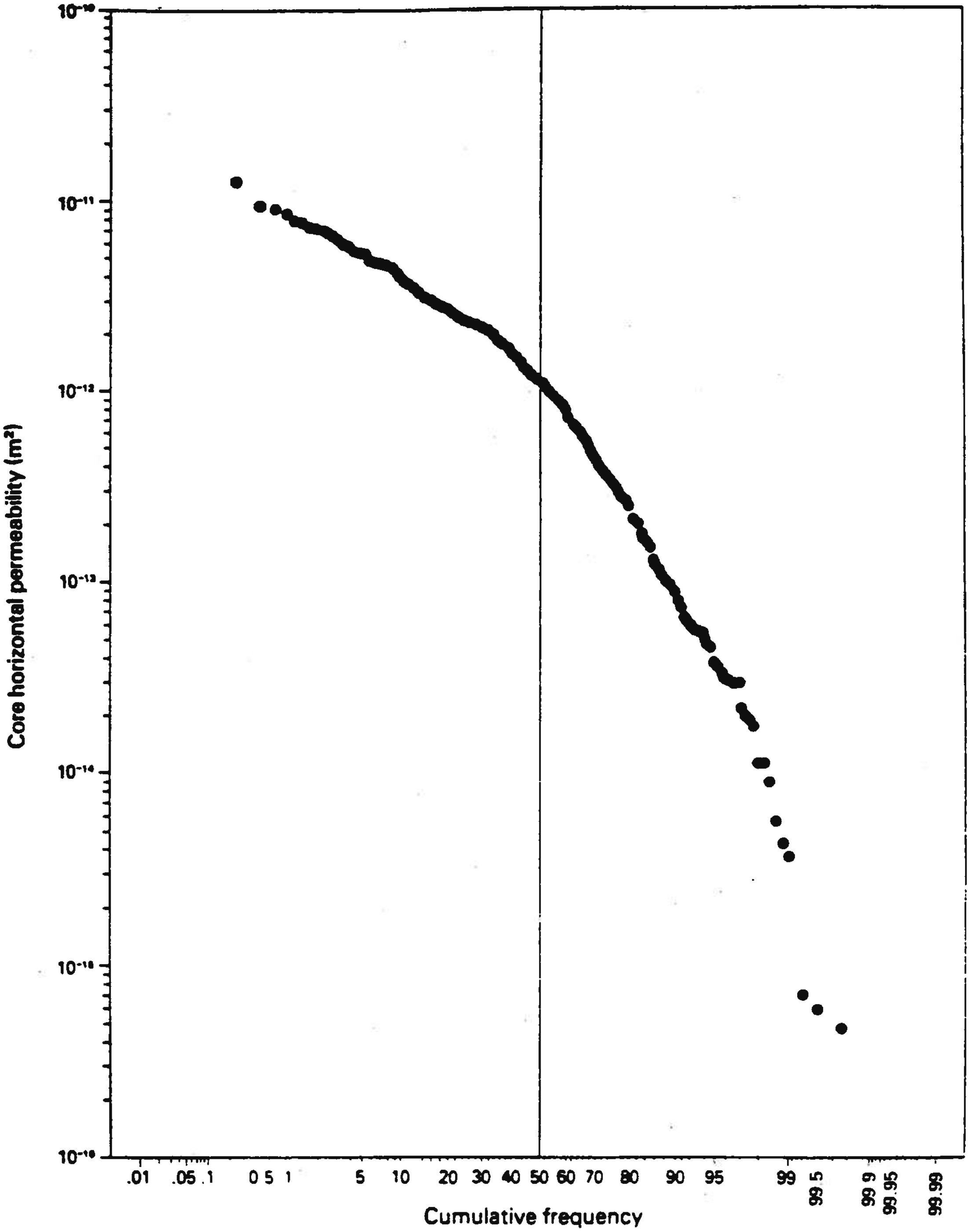


Figure 4-22 Log-normal cumulative frequency plot for horizontal permeability derived from core data, "Upper Mannville" Group aquifer, Cold Lake Study Area.

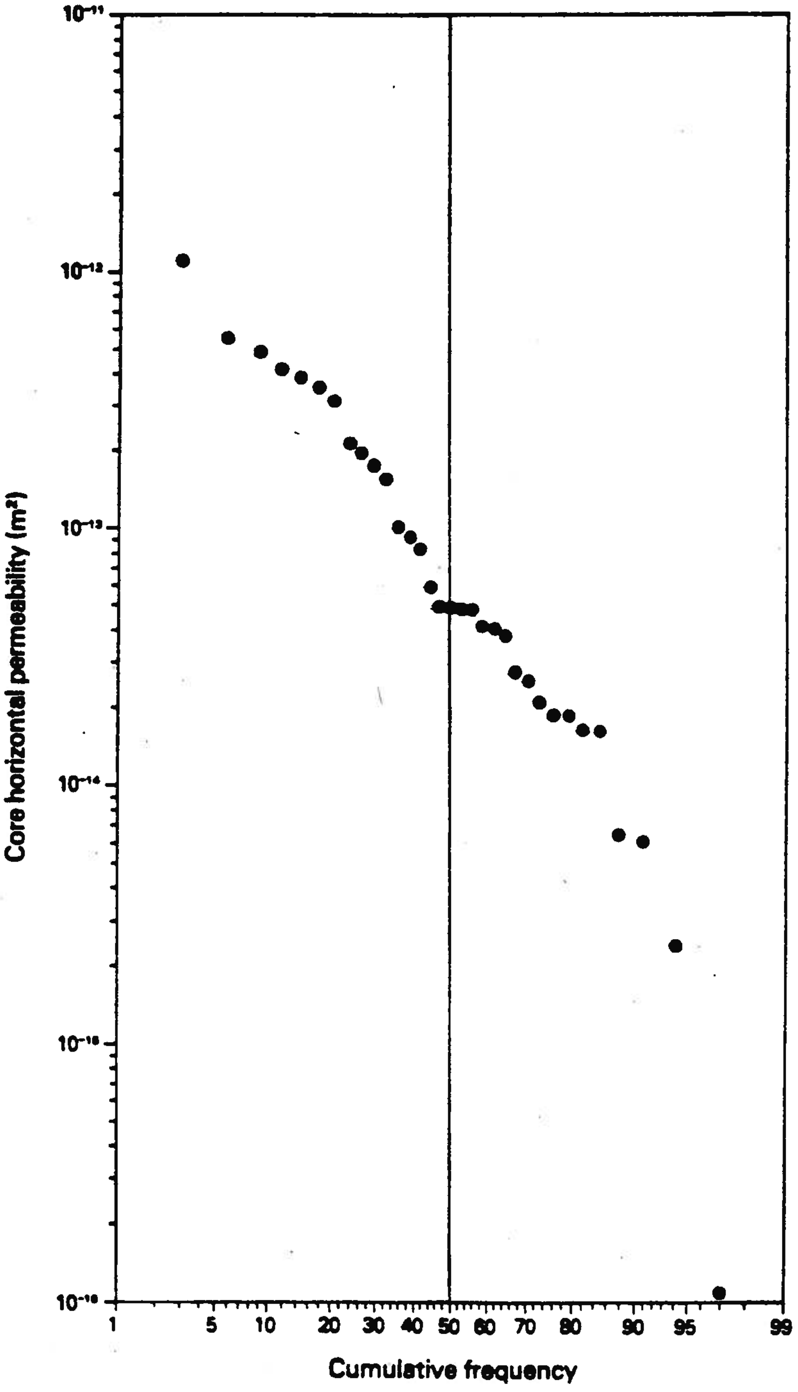


Figure 4-23 Log-normal cumulative frequency plot for horizontal permeability derived from core data, "Viking sandstone" aquifer, Cold Lake Study Area.

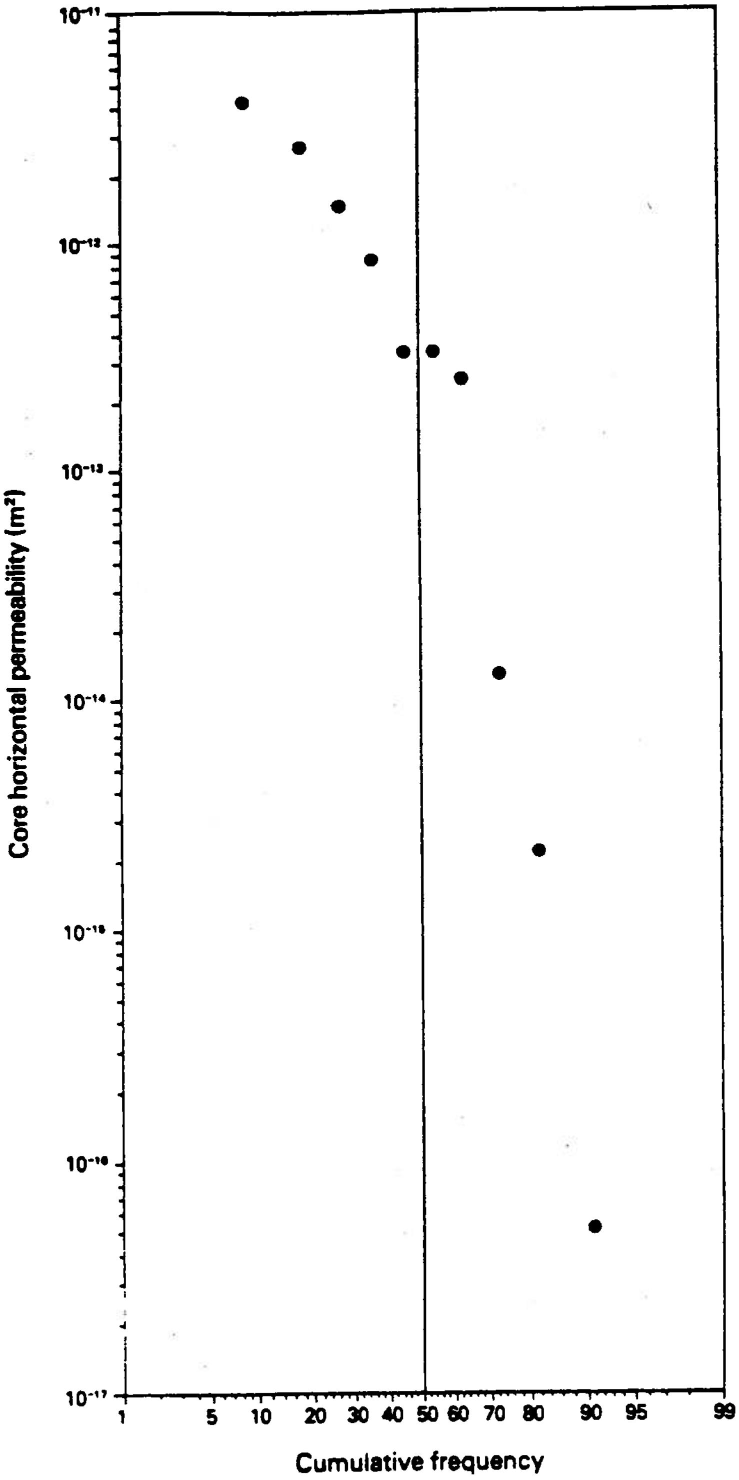


Figure 4-24 Log-normal cumulative frequency plot for horizontal permeability derived from core data, Intra-Colorado aquifers, Cold Lake Study Area.

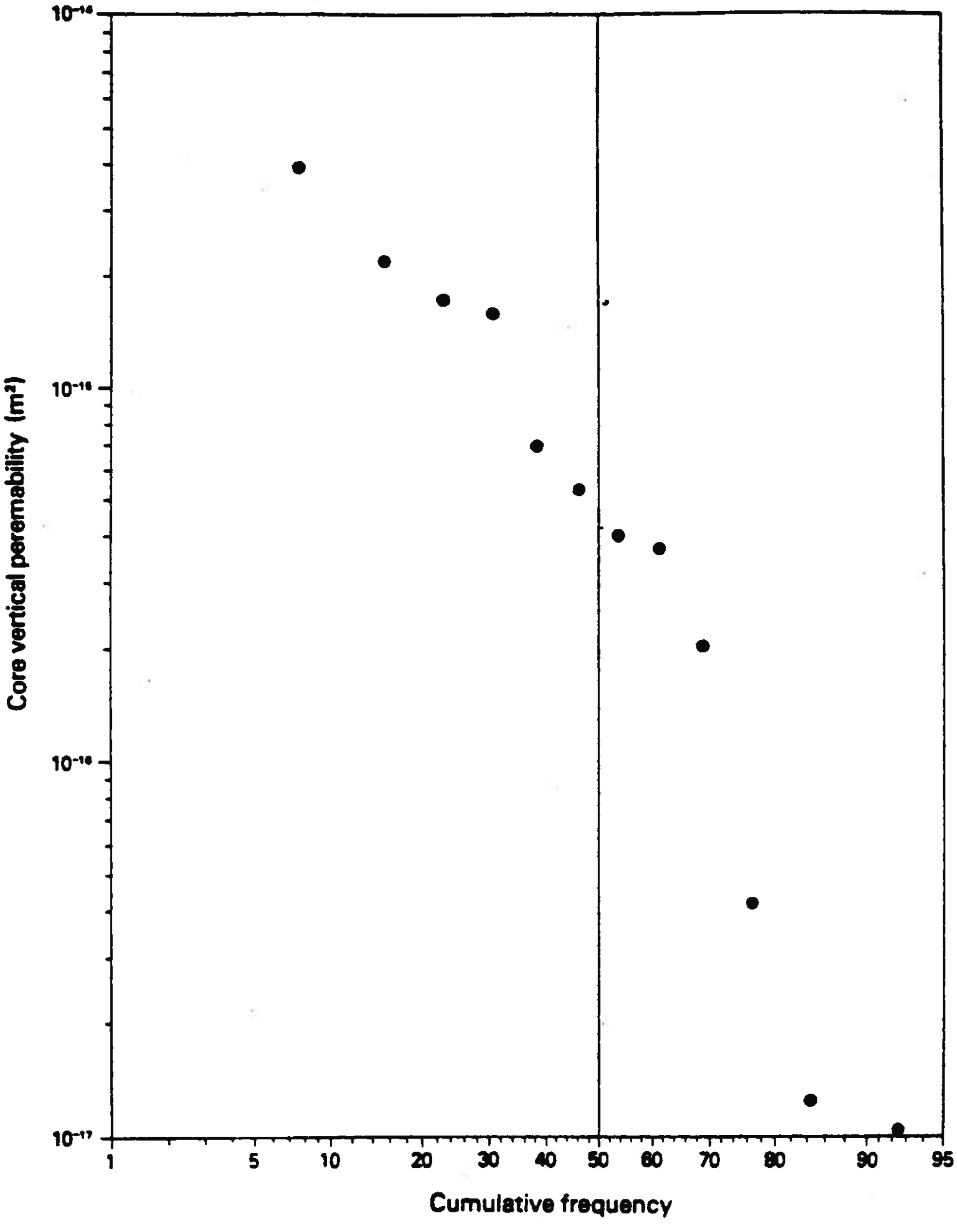


Figure 4-25 Log-normal cumulative frequency plot for vertical permeability derived from core data, Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, Cold Lake Study Area.

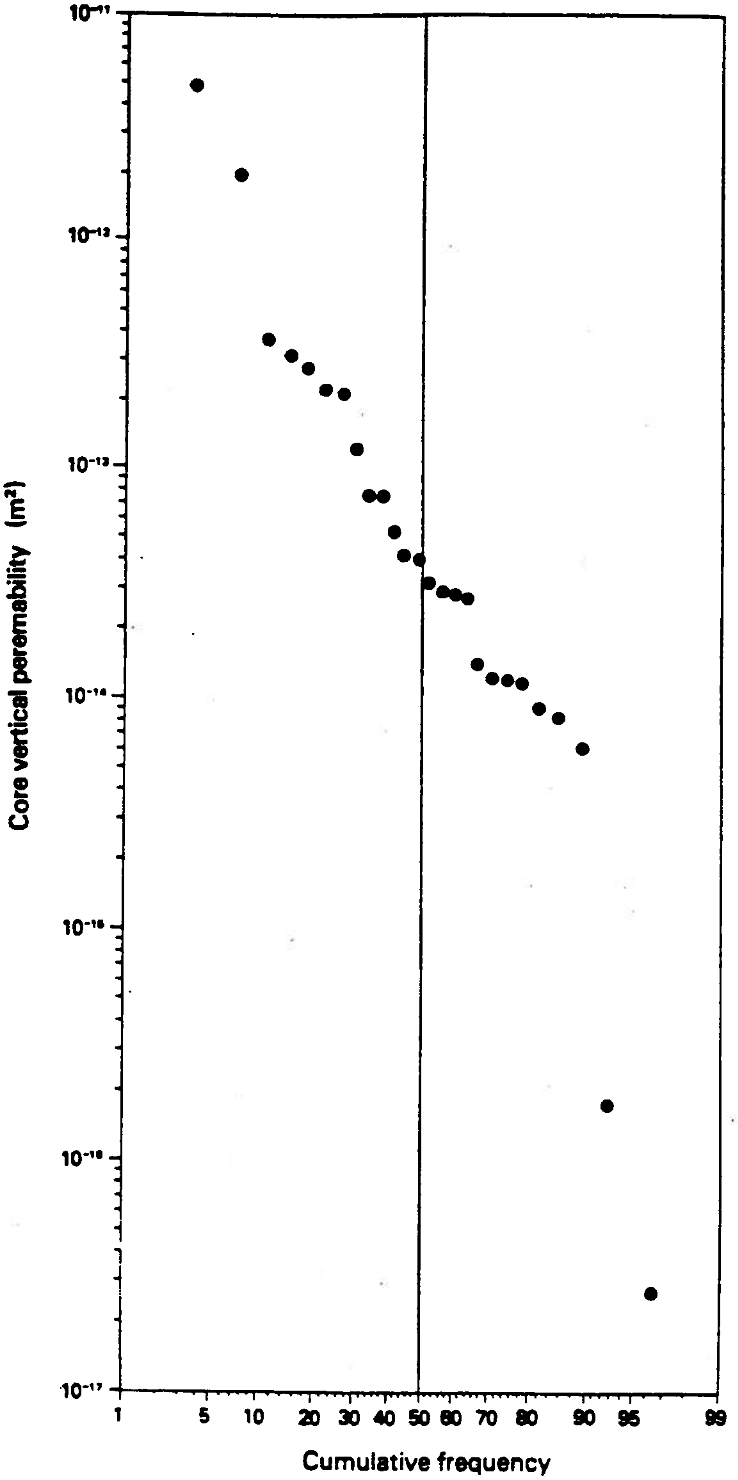


Figure 4-26 Log-normal cumulative frequency plot for vertical permeability derived from core data, Winterburn-Grosmont-Camrose aquifers, Cold Lake Study Area.

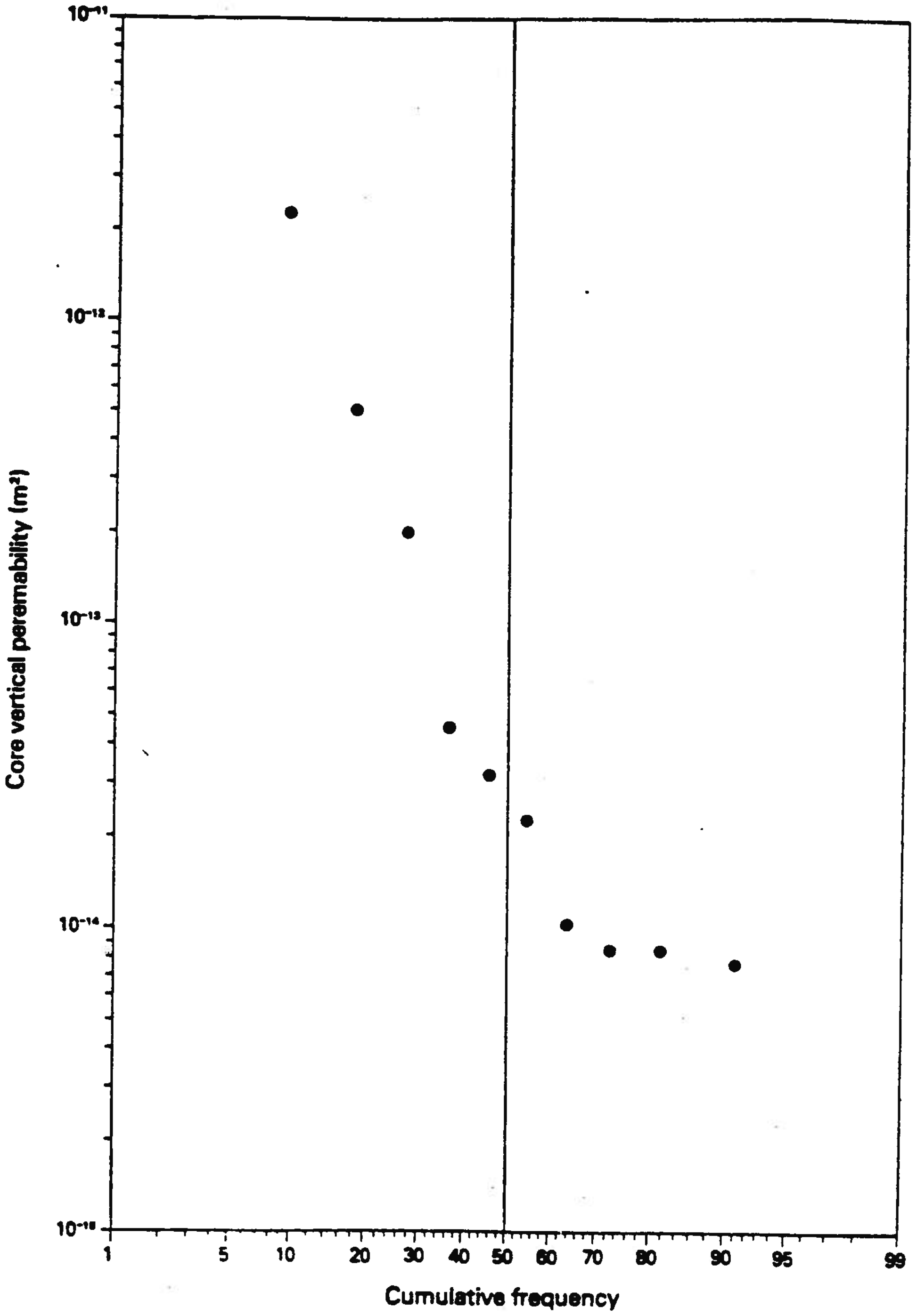


Figure 4-27 Log-normal cumulative frequency plot for vertical permeability derived from core data, McMurray Formation aquifer, Cold Lake Study Area.

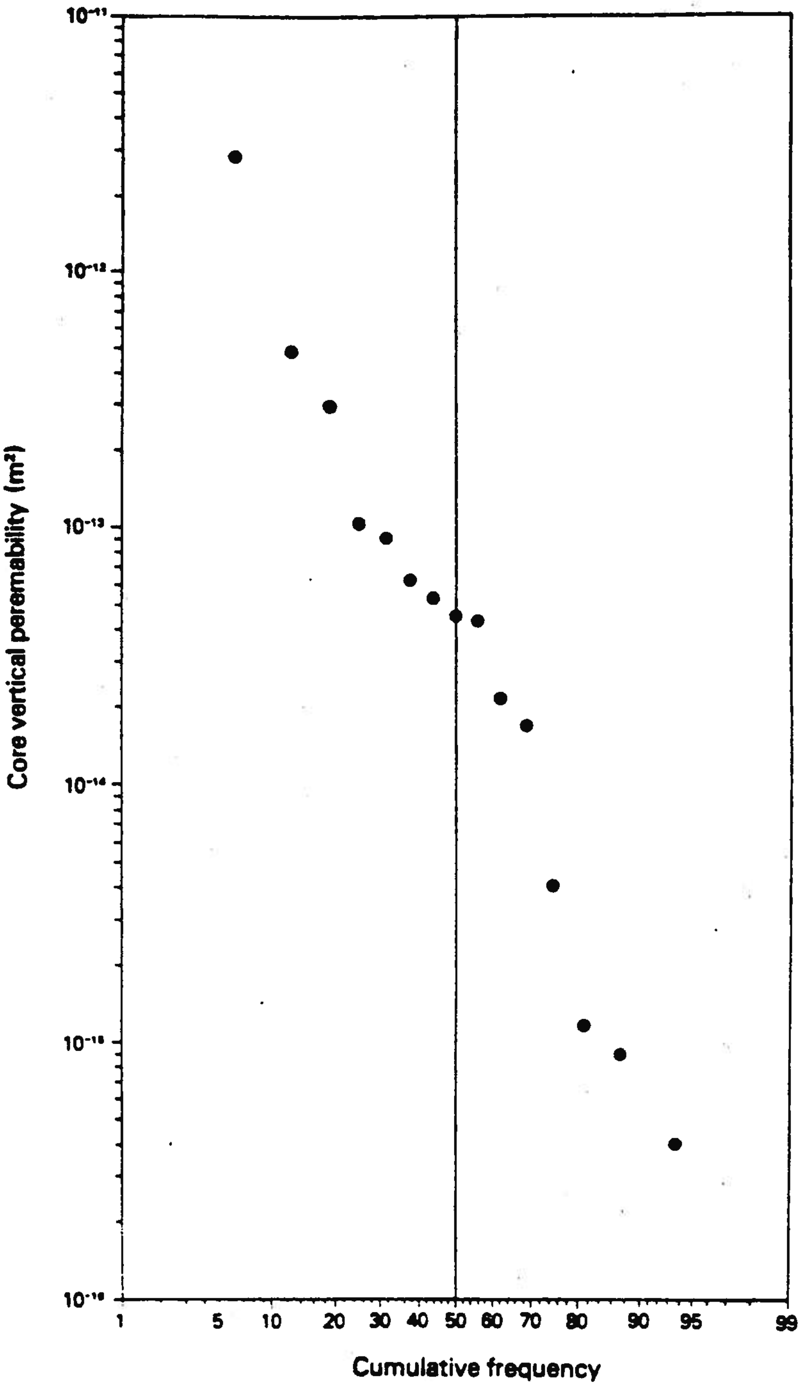


Figure 4-28 Log-normal cumulative frequency plot for vertical permeability derived from core data,"Lower Mannville" Group aquifer above McMurray Formation, Cold Lake Study Area.

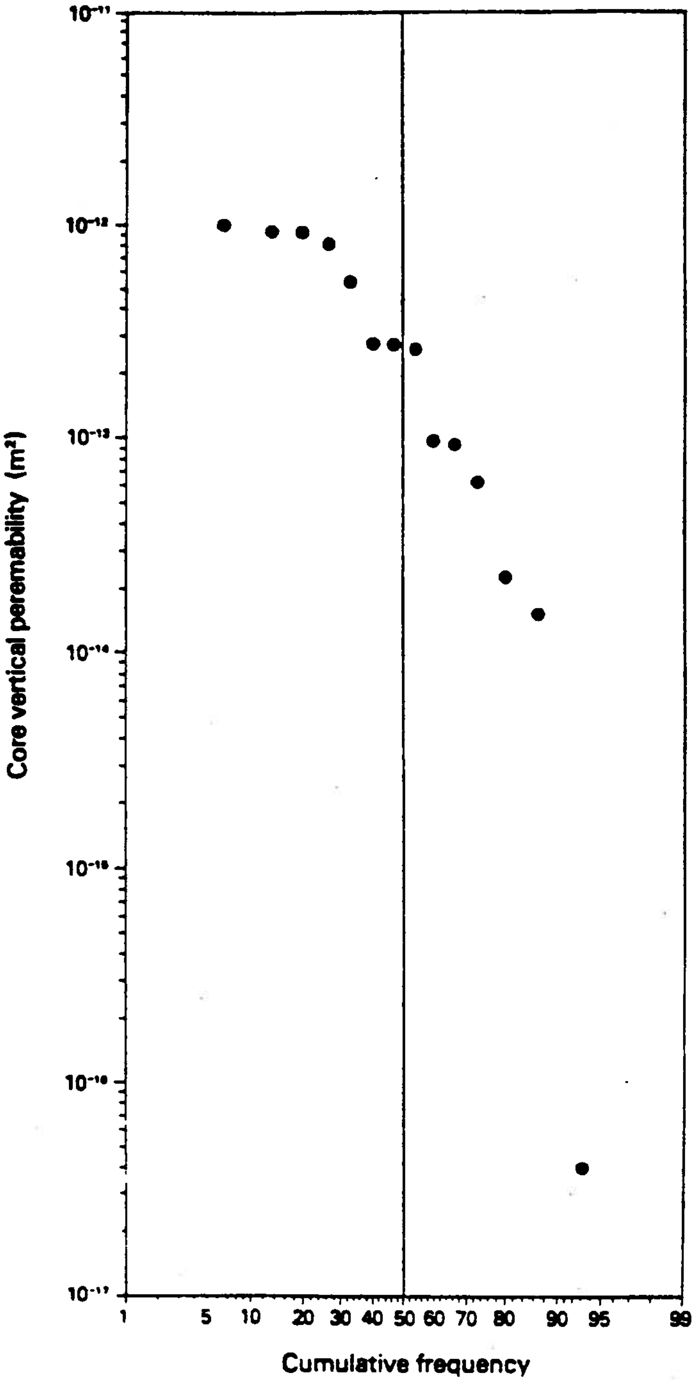


Figure 4-29 Log-normal cumulative frequency plot for vertical permeability derived from core data, "Upper Mannville" Group aquifer, Cold Lake Study Area.

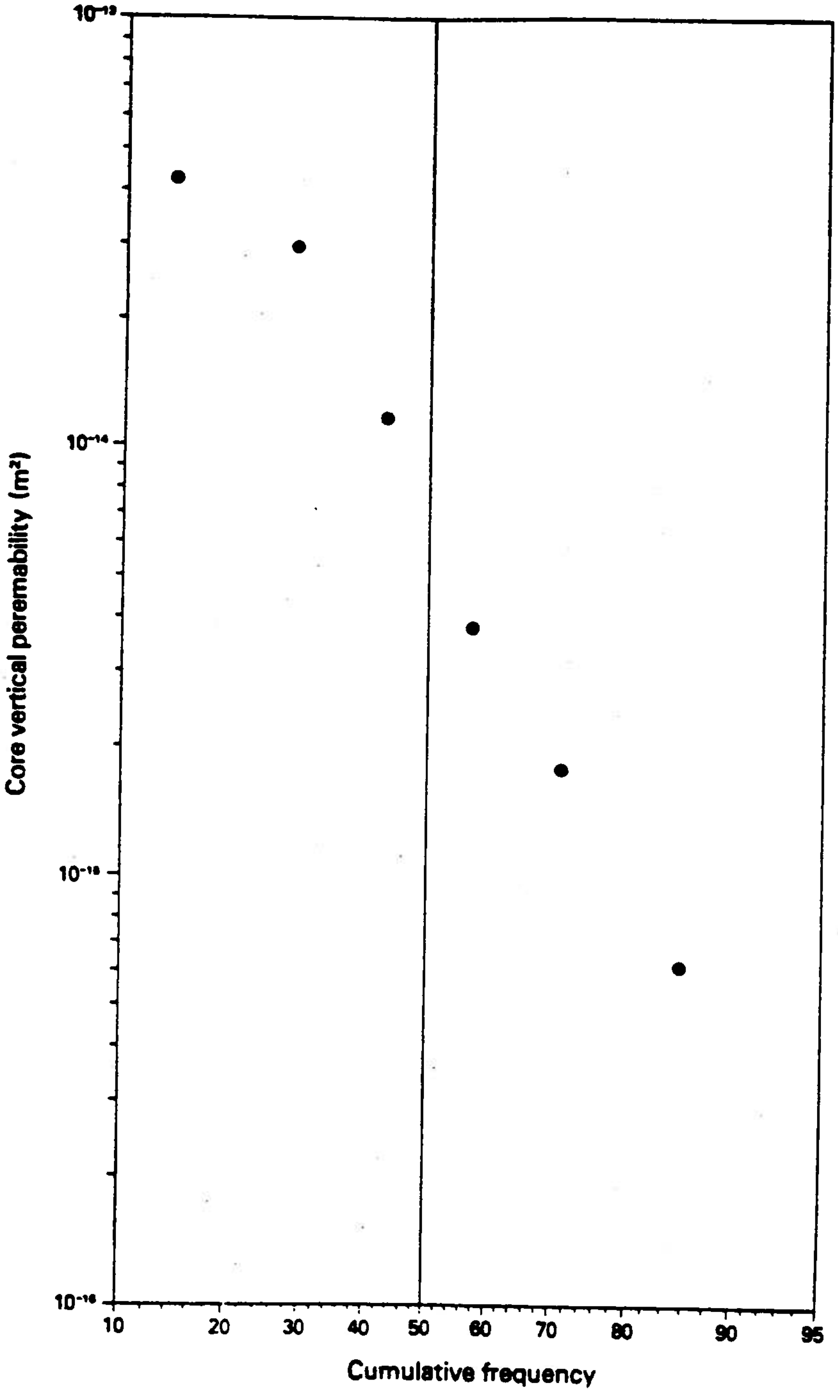


Figure 4-30 Log-normal cumulative frequency plot for vertical permeability derived from core data, "Viking sandstone" aquifer, Cold Lake Study Area.

Table 4-3.

Permeability (m^2) of hydrostratigraphic units determined from cores, Cold Lake Study Area

Hydrostratigraphic unit	Horizontal permeability k (m^2)				Vertical permeability k (m^2)			
	No. of determinations	min.	median	max.	No. of determinations	min.	median	max.
Cooking Lake-Beaverhill Lake-Watt Mountain aquifer	29	2.1×10^{-16}	8.4×10^{-14}	8.9×10^{-12}	12	1×10^{-17}	4.5×10^{-16}	3.9×10^{-15}
Winterburn-Grosmont-Camrose aquifer	32	6×10^{-16}	4×10^{-13}	1×10^{-11}	26	2.7×10^{-17}	2.9×10^{-14}	4.8×10^{-12}
McMurray Formation aquifer	72	2.8×10^{-15}	6.5×10^{-13}	8.8×10^{-12}	10	7.7×10^{-15}	4.6×10^{-14}	2.3×10^{-12}
Lower Mannville Group (above McMurray Formation) aquifer	146	9.6×10^{-16}	1×10^{-14}	1.1×10^{-13}	15	4.1×10^{-16}	2.7×10^{-14}	2.8×10^{-12}
"Upper Mannville" Group aquifer	333	4.2×10^{-17}	1.3×10^{-14}	1.1×10^{-12}	14	$3/9 \times 10^{-17}$	2.3×10^{-13}	1×10^{-12}
"Viking sandstone" aquifer	187	2.4×10^{-16}	1.3×10^{-15}	6.6×10^{-15}	6	6.1×10^{-15}	3.8×10^{-15}	4.2×10^{-14}

Table 4-4.

Comparison of permeability (m^2) determined by drillstem tests and cores for hydrostratigrahic units, Cold Lake Study Area

Hydrostratigraphic unit	Anisotropy (from core data)	Effective permeability (from core data) (m^2)	Ratio of median core and drillstem test permeabilities
Cooking Lake-Beaverhill Lake-Watt Mountain aquifer	13.7	6.2×10^{-15}	1.8
Winterburn-Grosmont-Camrose aquifer	3.7	1.1×10^{-13}	12.0
McMurray Formation aquifer	3.8	1.7×10^{-13}	15.7
Lower Mannville Group (above McMurray Formation) aquifer	6.1	1.6×10^{-13}	16.4
"Upper Mannville" Group aquifer	3.0	6.8×10^{-13}	52.2
"Viking sandstone" aquifer	4.2	1.6×10^{-14}	12.1

systematically, a minimum "skin factor" of 20 affects all the drillstem test intervals. This is not in agreement with the few values of "skin factor" found in the original drillstem test reports, which is commonly less than 10. To elucidate further this problem, figure 4-31 is a cross-plot of the core horizontal permeability versus the drillstem test permeability for wells having the same interval tested by both techniques. Only five exact matches are found, which is quite surprising, and only the core horizontal permeability was determined for these five points; it would have been more meaningful to be able to cross-plot the core "effective" permeability against that for the drillstem test.

This raises three questions:

1. Given the complex lithology of the Cretaceous strata, is it meaningful to operate a direct comparison between core and drillstem test permeabilities without a clear understanding of the vertical distribution of the tested intervals inside each hydrostratigraphic unit? A proper answer requires a detailed study of the geometry of the sand bodies within each hydrostratigraphic unit (and especially for the "Upper Mannville" Group aquifer) so that the data are first allocated to the subunits and then compared.
2. Is there any relation between the mineralogy, the degree of consolidation, and the presence of oil sand deposits? This might explain some systematic change of permeability in some subunits as a function of geographical location; but how does this relation affect the core and drillstem test results?
3. What is the relative importance of analytical and "geological" bias in the observed discrepancies between core and drillstem test permeabilities?

It is obvious that a study aimed at answering these questions is beyond the scope of the present effort. Recognizing this, it was decided to use only the drillstem test data for permeability and

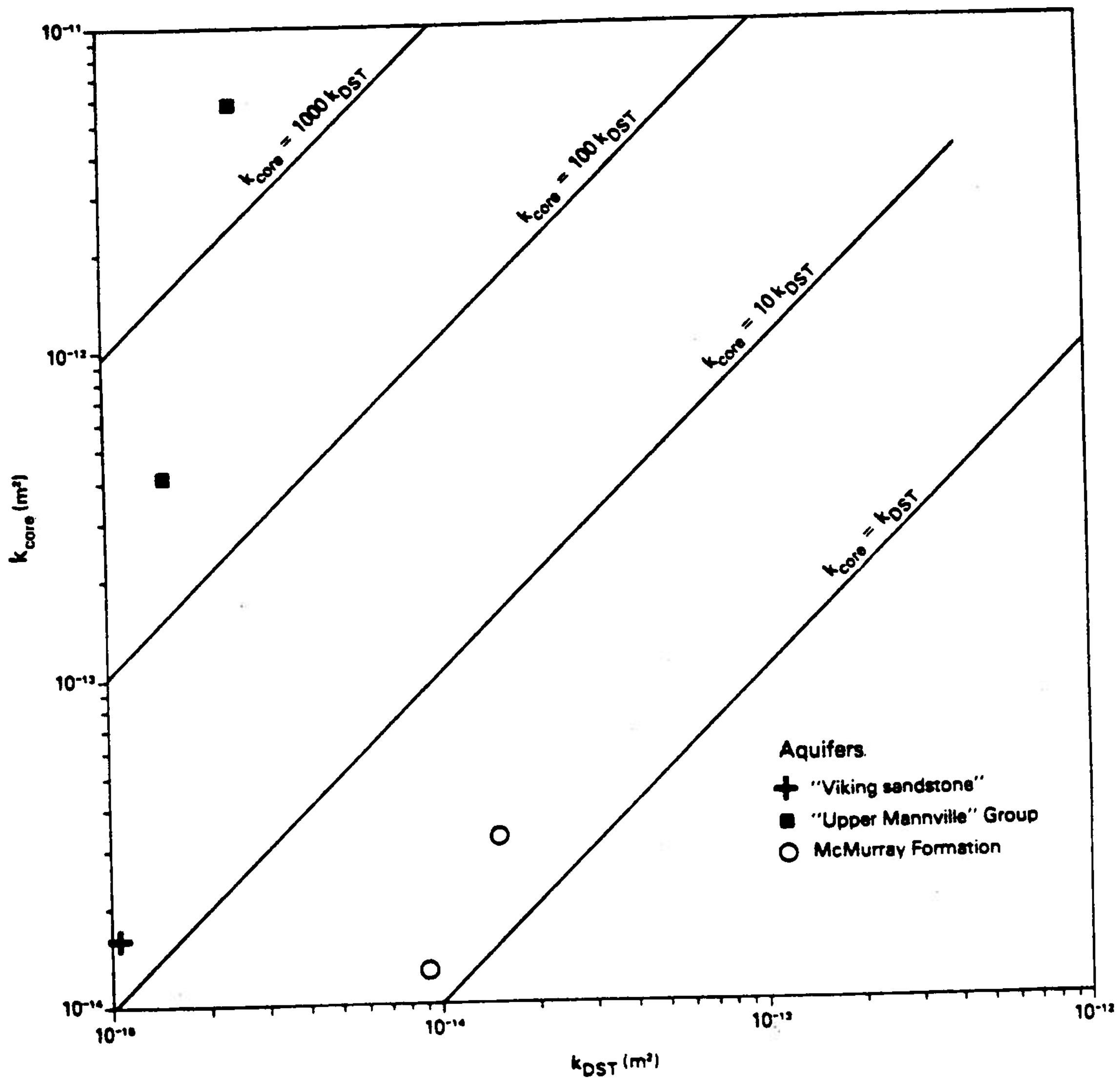


Figure 4-31 Comparison between drillstem test and core permeabilities for the same tested interval.

hydraulic conductivity because they represent a closer insight into the flow processes and are consistent with the results for formation pressures and hydraulic heads that have been used.

Although not of direct use in this project, the core porosities have been processed and the average results are as follow:

Intra-Colorado aquifers	(N=45):	20%
"Viking sandstone" aquifer	(N=80):	23%
"Upper Mannville" Group aquifer	(N=920):	33%
"Lower Mannville" Group aquifer	(N=645):	34%
Winterburn-Grosmont-Camrose aquifer	(N=35):	12%
Cooking Lake-Beaverhill Lake-Watt Mountain aquifer	(N=18):	13%

FLOW ANALYSIS

INTRODUCTION

This section treats, successively, the lateral flow in the aquifers and the cross-formational (vertical) flow through the aquitards. The positions of the hydraulic head cross-sections can be found on the topographic map in figure 4-32.

Before commencing the detailed evaluation of the flow patterns, it is important to note that pressure head versus depth plots will be used in this analysis rather than the more conventional "pressure-depth" plots. The pressure head is defined as the difference, H-Z, in equation (4), that is, the ratio $P_f/(\rho)g$ with dimension [L]. A plot of the pressure head versus depth means the following: when the slope of the point data measured in the same well is unity, the conditions are hydrostatic, which should be the general case along a same vertical in an aquifer where the flow is only lateral; if the slope is less than unity, flow is potentially downward; for a slope greater than unity, the flow is potentially upward. Also, when points are plotted along the same line, they belong to the same hydrostratigraphic unit. This type of plot is preferred to the

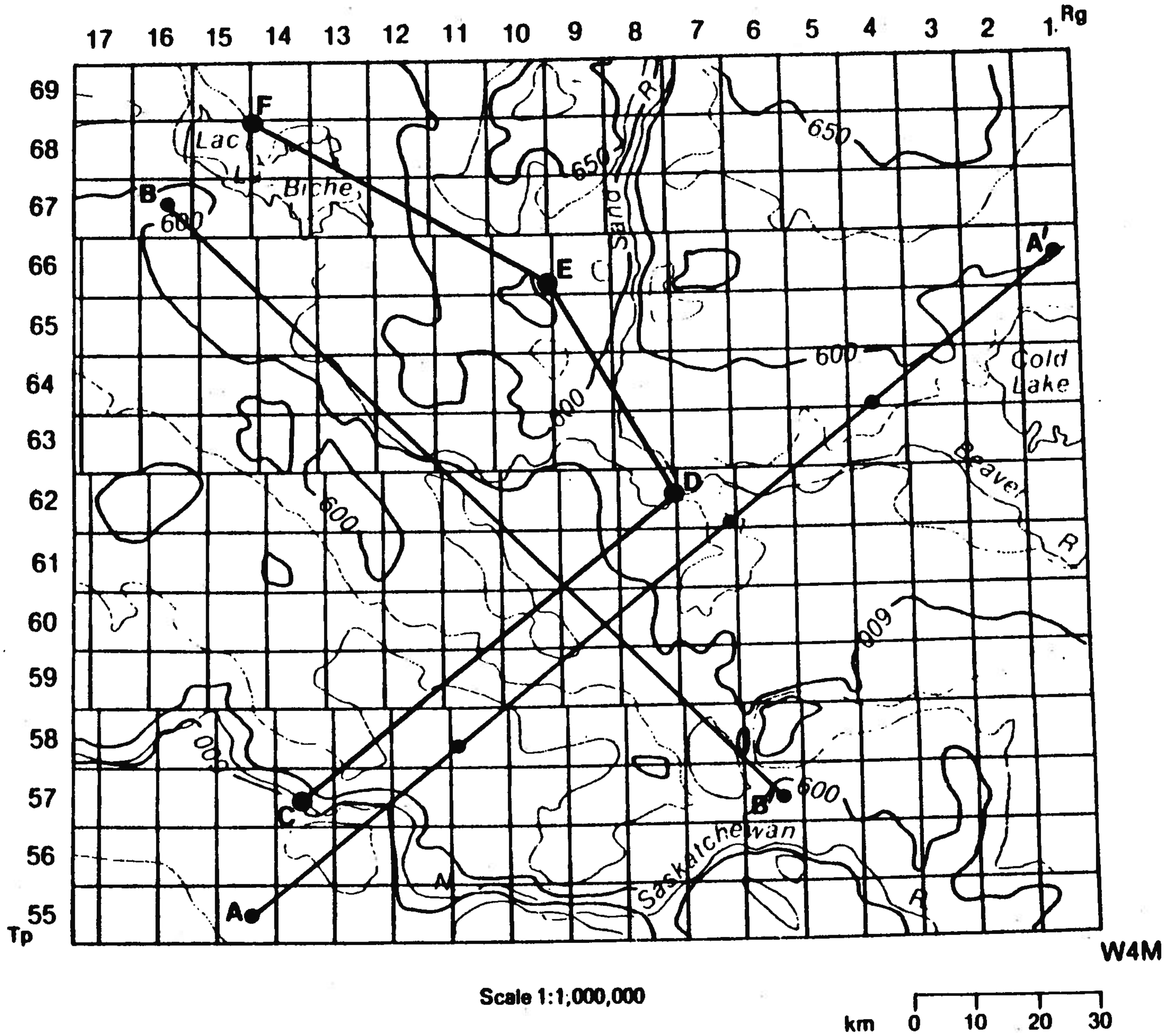


Figure 4-32 Topographic map of the Cold Lake Study Area showing the location of the hydraulic head cross-sections in figures 4-35 (A-A'), 4-38 (B-B') and 4-44 (C-D-E-F).

traditional "pressure-depth" plot where the dependence on the fluid density may mask the dominant flow features.

COOKING LAKE-BEAVERHILL LAKE-WATT MOUNTAIN AQUIFER

Flow in this aquifer is regional, and towards the northeast of the study area, as illustrated in figure 4-33 (Atlas map E-h-3). The hydraulic gradient is in the range 6.5×10^{-4} to 3.9×10^{-3} with an average value of 1.3×10^{-3}. According to Darcy's law, the average velocity is about 0.3 mm/year. The hydraulic head ranges from 559 to 469 m and the pore pressure from 7555 to 3575 kPa, based on only 15 data points. The elevation range for the point data is -213 to +88 m. East of the boundary of the Ireton Formation aquitard, this aquifer is in direct contact with the "Lower Mannville" Group aquifer. In this area, unfortunately, no drillstem tests were completed in the same well for both aquifers. The pressure head versus depth plot in figure 4-34 attempts to show the hydraulic continuity between the two adjacent aquifers based on neighbouring wells only, and shows a potential for downward flow in the "Lower Mannville" Group aquifer (slope 0.8) and a potential for upward flow in the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer with a slope of 1.5.

East of the subcrop limit of the Ireton Formation aquitard the potentiometric map in figure 4-33 was built using the hydraulic head values of the "Lower Mannville" Group aquifer. The 29 values used range between 492 and 409 m, and in this region two data points in the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer are also included (452 and 463 m). The hydraulic head cross section A-A (figure 4-35) illustrates the continuity of the two aquifers east of the Ireton Formation boundary where both profiles are coincident. East of the Prairie Formation salt solution edge, hydraulic continuity should exist between the Keg River Formation aquifer and the two overlying ones but, unfortunately, there is no data to substantiate this suggestion.

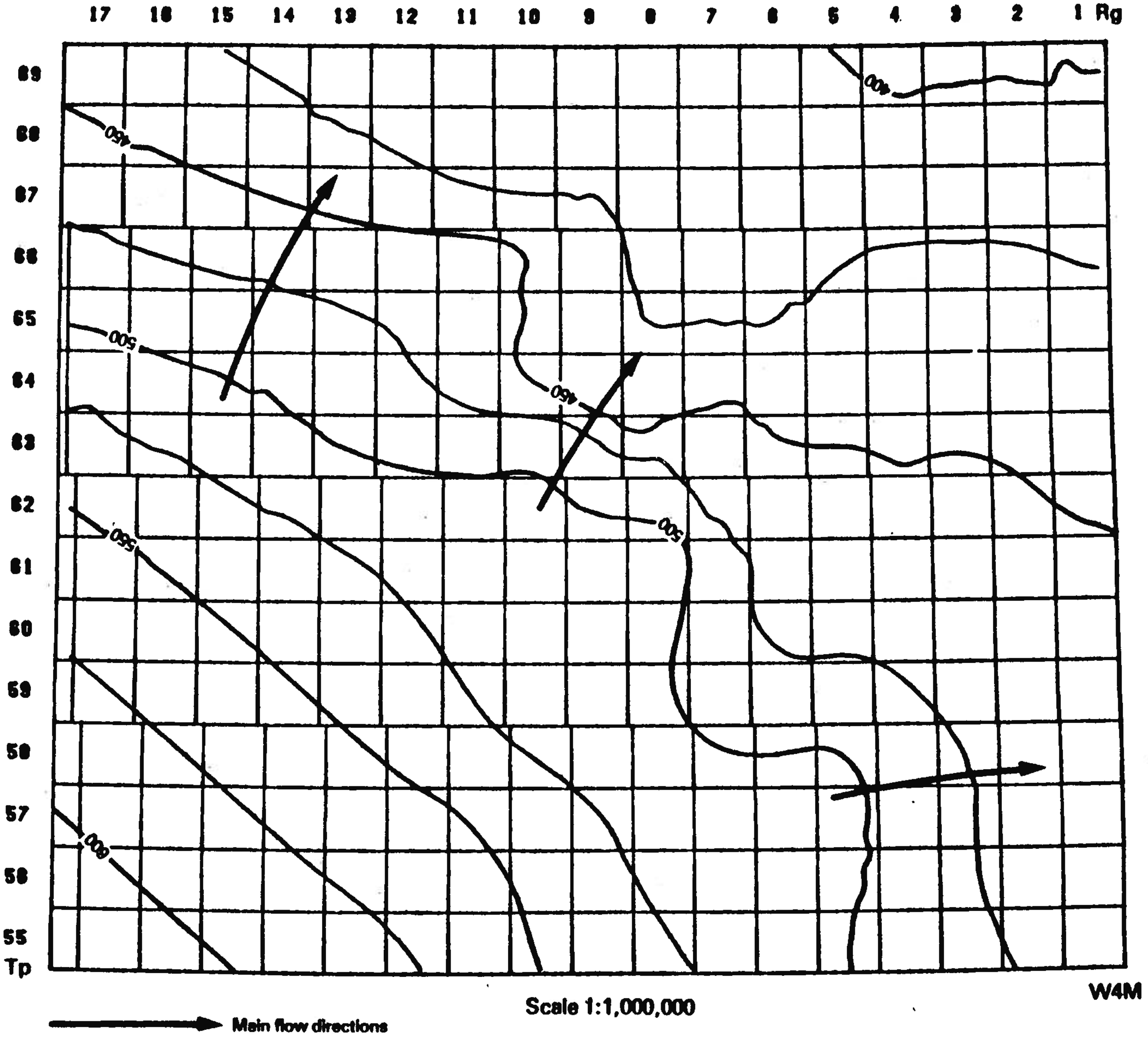


Figure 4-33 Potentiometric surface of Cooking Lake-Beaverhill Lake-Watt Mountain aquifer (Atlas map E-h-3), Cold Lake Study Area.

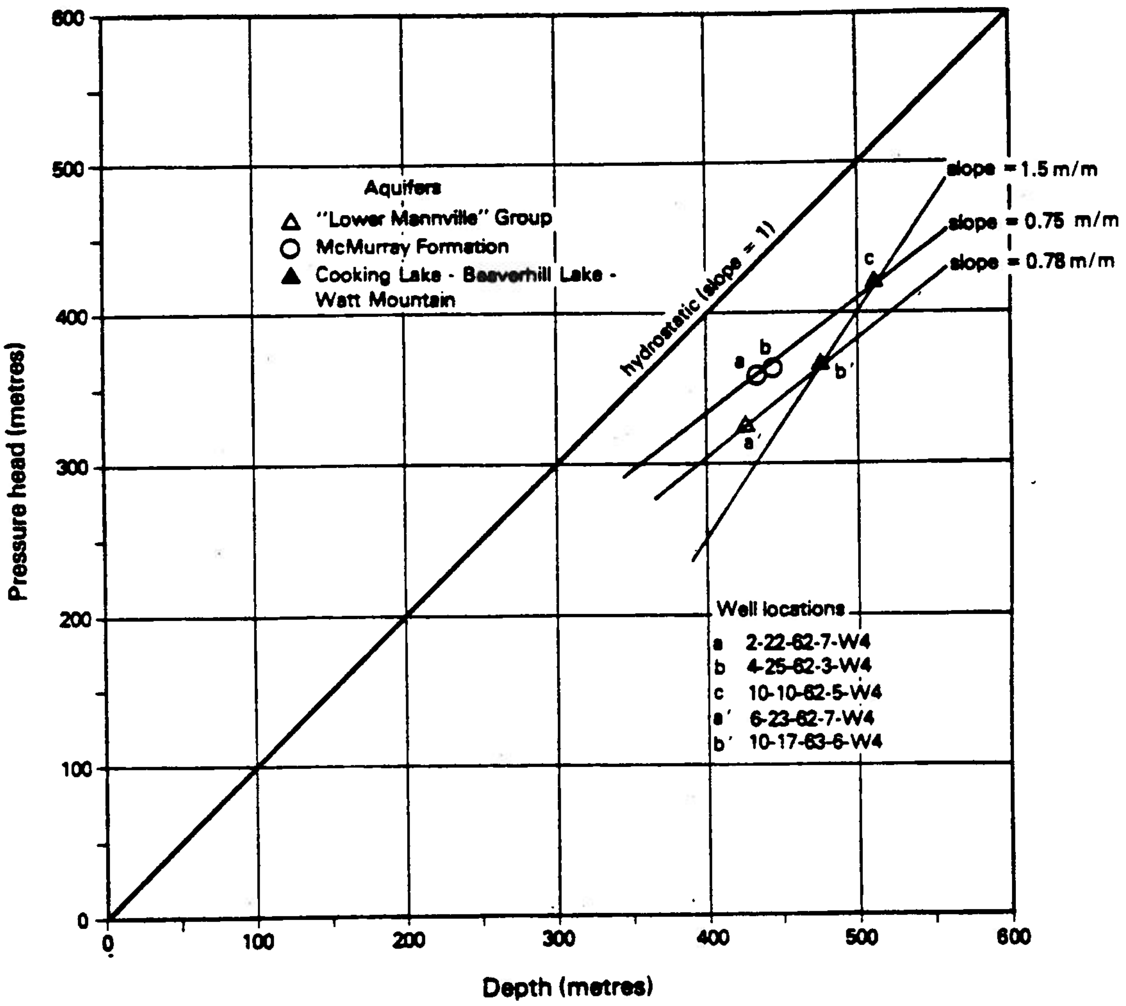


Figure 4-34 Pressure head versus depth plot showing hydraulic continuity between the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer and the "Lower Mannville" Group aquifer where the Prairie Formation aquiclude is absent, Cold Lake Study Area.

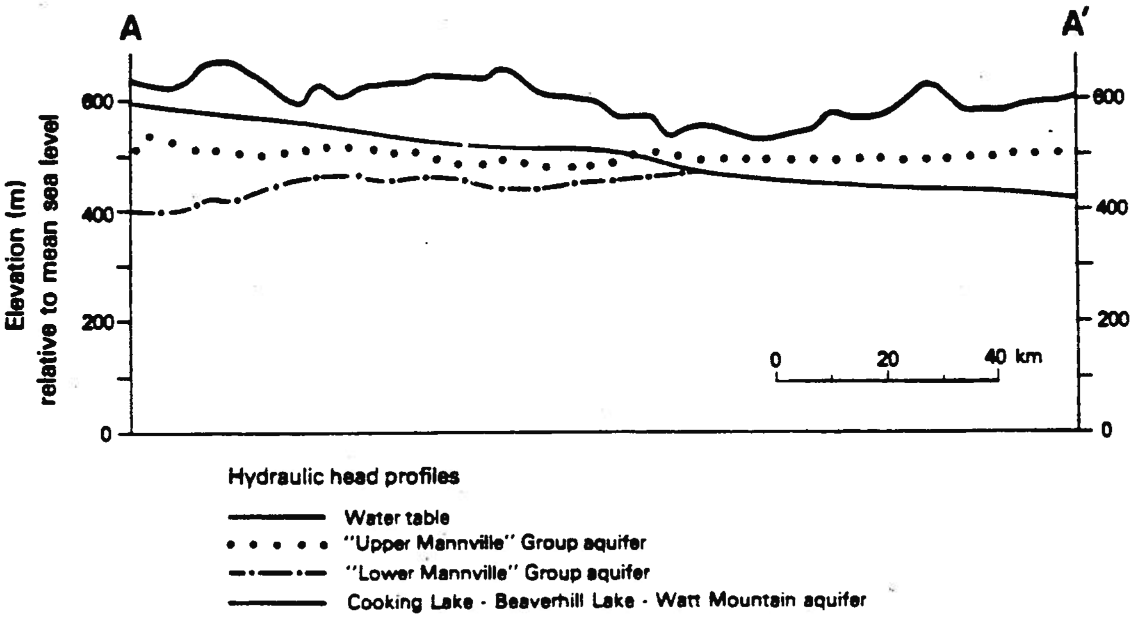


Figure 4-35 Hydraulic head cross-section A-A' (see figure 4-32 for location), Cold Lake Study Area.

WINTERBURN-GROSMONT-CAMROSE AQUIFERS

This hydrostratigraphic unit is only present to the west of R 12. The Winterburn and Grosmont aquifers are in hydraulic continuity through the "Lower Mannville" Group aquifer above the PreCretaceous unconformity. The hydraulic head range is, respectively, 352 to 393 m, and 339 to 391 m. For the Camrose Tongue aquifer, the hydraulic head range is 366 to 420 m and the question of its hydraulic continuity with the Grosmont Formation aquifer in the area of possible contact is difficult to answer with the available hydraulic head data. In Tp 61, R 14 the pressure head in the Grosmont Formation aquifer is 348 m, compared to that at Tp 61, R 15 where the pressure head in the Camrose Tongue aquifer is 346 m. There is thus a possible connection, although the argument is not fully conclusive. In the area of contact between the "Lower Mannville" Group aquifer and the Winterburn-Grosmont aquifer, the range of hydraulic head in the latter aquifer is 321 to 456 m. As shown in figure 4-36, there is a strong tendency for downward flow in the southern part of the common area (slope 0.4), while to the northwest, this tendency is apparently reversed (slope 1.5). It is likely that the true contrast between the hydraulic conductivities in "Lower Mannville" Group and the Winterburn-Grosmont aquifers is not properly reflected by the median drillstem test values shown in table 4-2. The factor of 3.2 in favor of the Winterburn-Grosmont aquifer is too low to explain its role as a "drain" as suggested by the pressure heads with respect to the "Lower Mannville" Group aquifer. The Grosmont Formation aquifer (at least) might be fractured or karstified although this is not apparent with the available drillstem test intervals. In any case, the grouping of both aquifers into the "Lower Mannville"-Grosmont aquifer does not create anomalies in the combined potentiometric surface map (see figure 4-37 and Atlas map J-h-4). The feature of strong westward flow is present in the potentiometric surface map of the "Lower Mannville" Group aquifer when considered separately, and this flow direction is not

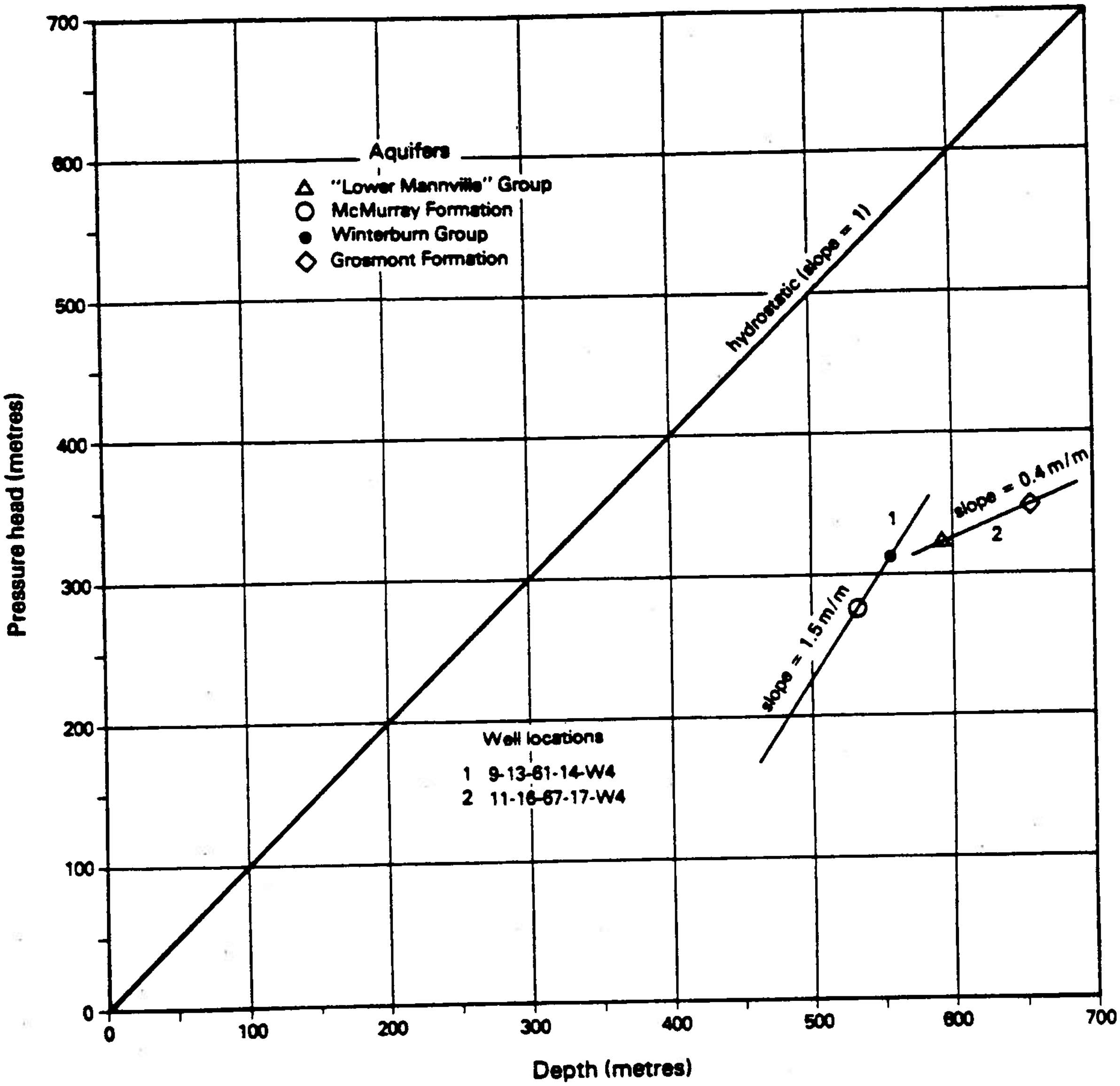


Figure 4-36 Pressure head versus depth plot showing hydraulic continuity between the Winterburn-Grosmont and "Lower Mannville" Group aquifers, Cold Lake Study Area.

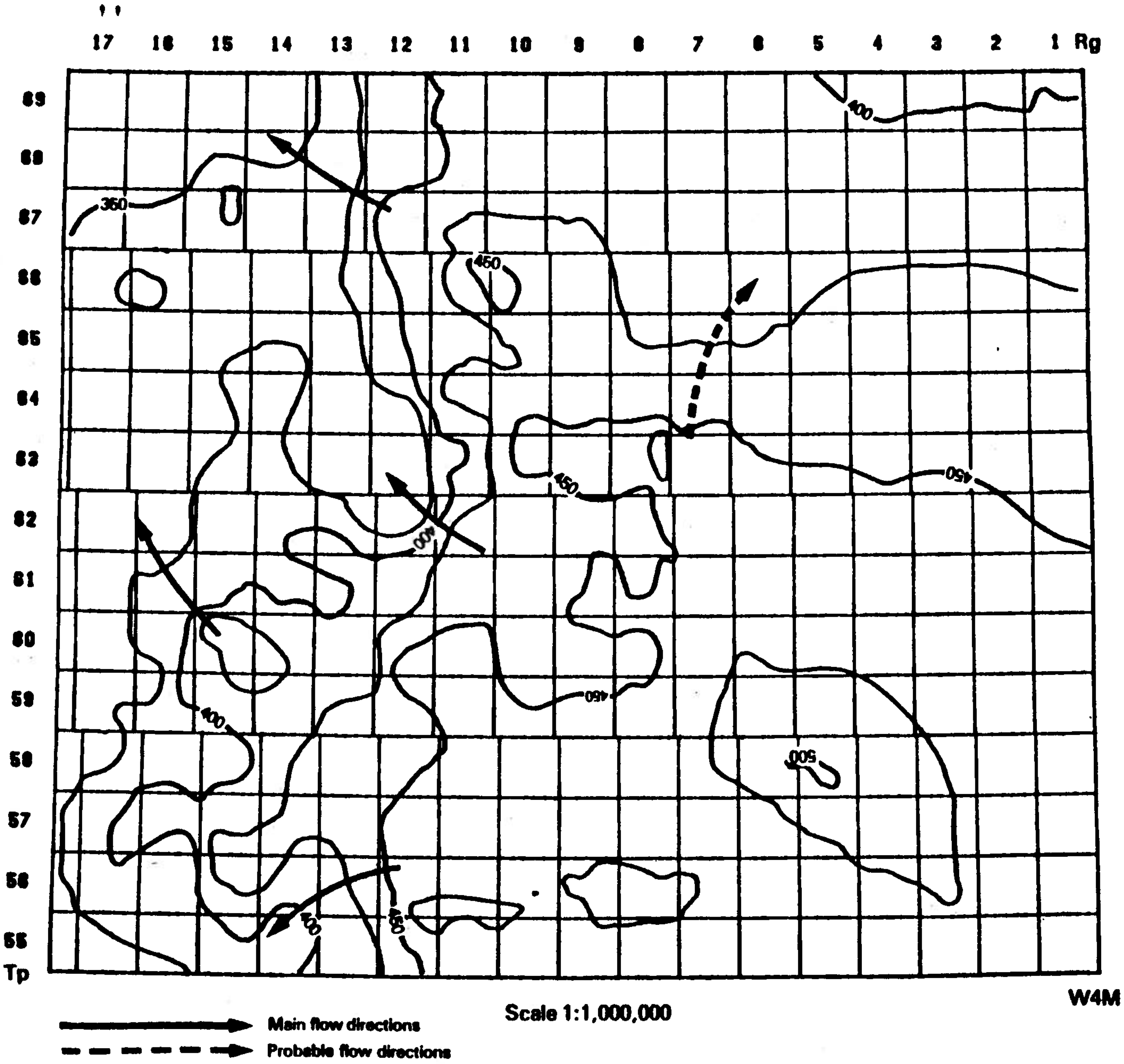


Figure 4-37 Potentiometric surface of "Lower Mannville"-Grosmont aquifer (Atlas map J-h-4), Cold Lake Study Area.

substantially modified by the introduction of the Winterburn-Grosmont hydraulic head data.

"LOWER MANNVILLE" GROUP-GROSMONT FORMATION AQUIFERS

Flow in this hydrostratigraphic unit is illustrated by the map in figure 4-37 (Atlas map J-h-4). The main flow direction is to the northwest, with hydraulic gradients between 2.6×10^{-3} and 1.3×10^{-2}, yielding a Darcy average velocity of 5 mm/year. This is well illustrated by the hydraulic head cross-section BB' in figure 4-38. The flow in the eastern part of the study area is to the northeast (similar to the regional flow) with weaker gradients (between 8×10^{-4} and 2×10^{-3}). In this eastern area, as already discussed, there is a potential downward circulation above the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, which could explain the relative flatness of the potentiometric surface in that area. To the southwest, outside the area of "drawdown" by the Grosmont Formation aquifer, the flow is to the southwest with a gradient of 3.5×10^{-3}. The hydraulic head values are consistent with those in the "Upper Mannville" Group aquifer in the southeast corner of the study area, where the Clearwater Formation aquitard is absent. The range of hydraulic heads for the "Upper Mannville" Group aquifer in this area is 450 to 505 m, and in the "Lower Mannville" Group aquifer it is 440 to 475 m. The difference in the ranges supports the concept of downward flow from one aquifer to the other.

"UPPER MANNVILLE" GROUP AQUIFER

As already discussed, this aquifer is probably the most heterogeneous in terms of hydraulic conductivity. It is also the one where the lateral flow component is the least apparent. Based on figure 4-39 (Atlas map L-h-3), it is clear that the potentiometric surface is essentially flat with a range of hydraulic heads between 433 and 540 m (averaging 500 m), for a wide range of elevations (sea level to 312 m). The potentiometric surface map was constructed with

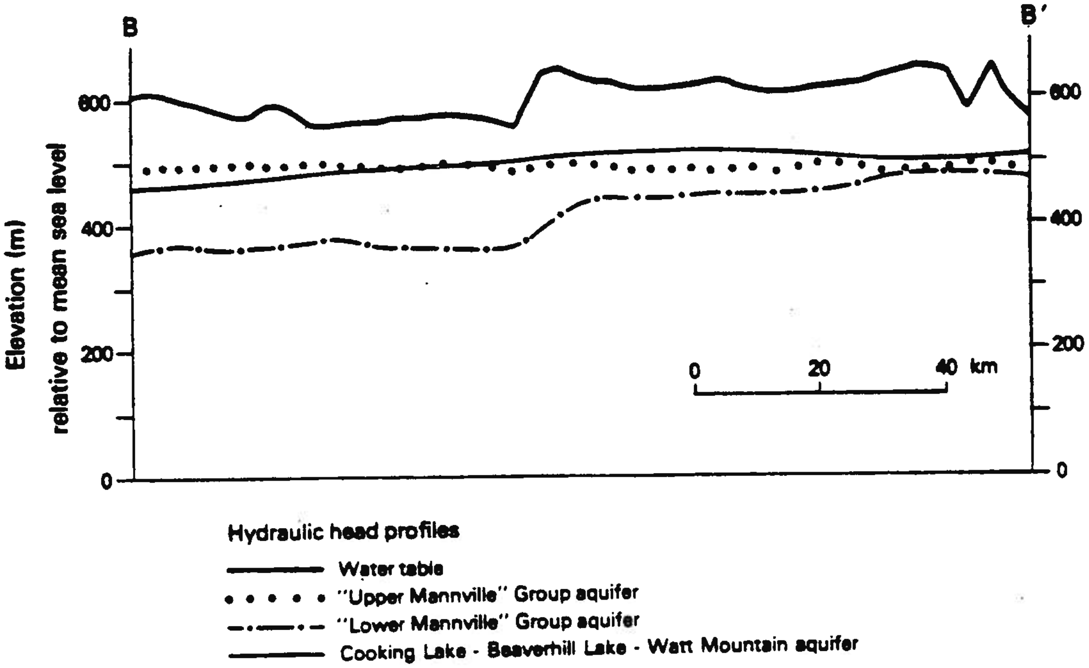


Figure 4-38 Hydraulic head cross-section B-B' (see figure 4-32 for location), Cold Lake Study Area.

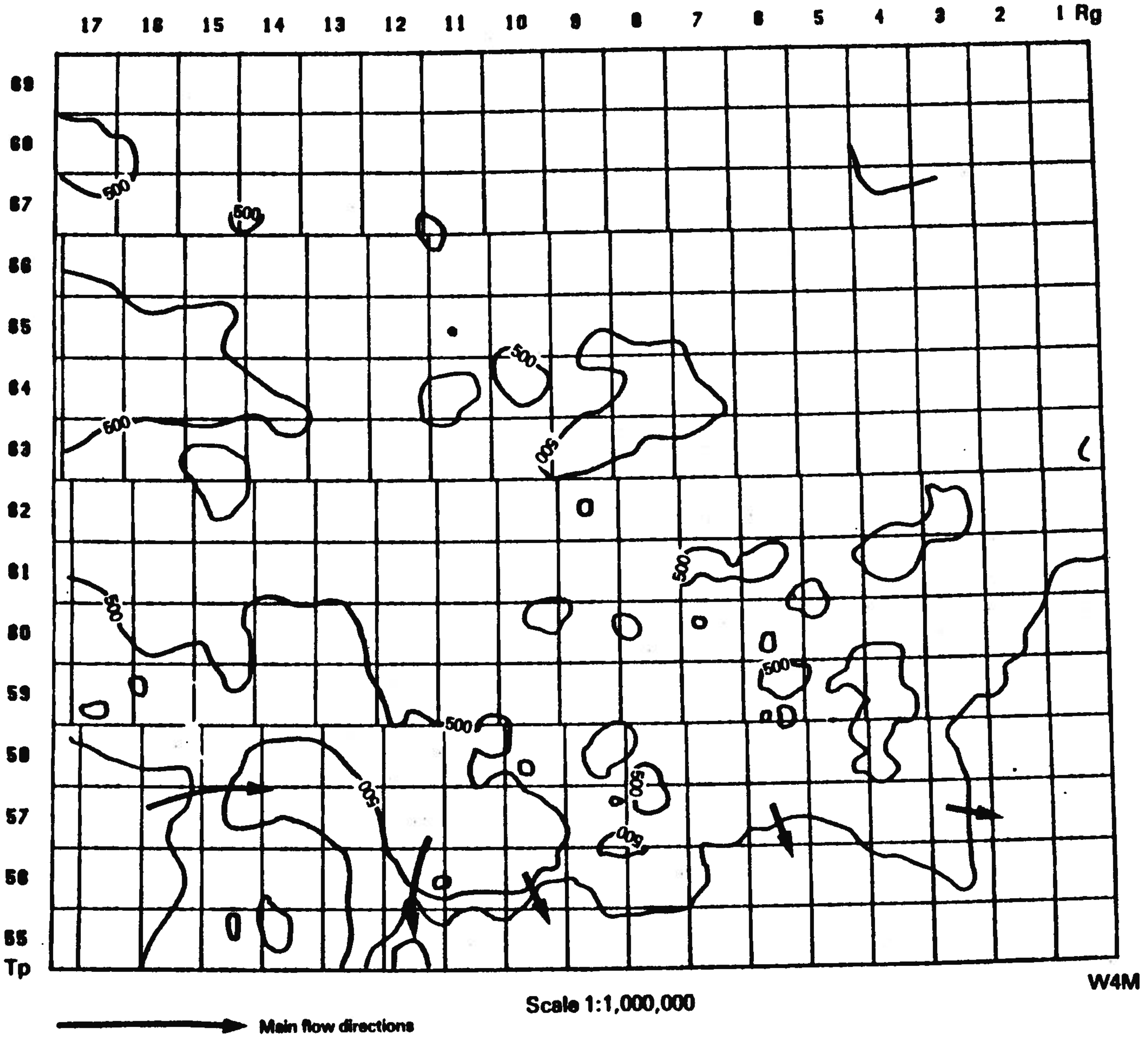


Figure 4-39 Potentiometric surface of "Upper Mannville" Group aquifer (Atlas map L-h-3), Cold Lake Study Area.

523 hydraulic head data points. The pressure head versus depth plots in figures 4-40 to 4-43 indicate slopes varying from 0.6 to 1 m per m of "Upper Mannville" Group aquifer thickness, confirming the regional downward flow component in this unit. Minor lateral flow components are, however, present in Tp 55 and 56 and in the southwest corner of the study area.

"VIKING SANDSTONE" AQUIFER

The range of hydraulic heads in this aquifer is 512 to 666 m for 305 data points with an elevation range of 128 to 349 m. As shown on the cross-section C-D-E-F (figure 4-44), the trace of which follows the maximum relief of the potentiometric surface of figure 4-45, flow in the "Viking sandstone" aquifer is a quasi-exact replicate of the ground surface, which also approximates the water table. For gravity controlled flow, this would be classified as a local flow system, however, osmotic effects (Part 3) could be superimposed on the purely gravity flow, rendering such a characterization equivocal. More specifically, flow in this aquifer is outward from the region with hydraulic heads greater than 600 m, that is, flow is to the northwest, southwest, southeast and northeast; this last direction has the strongest hydraulic gradient (1.3 x 10^{-3}), corresponding to a Darcy velocity of 0.4 mm/year.

INTRA-COLORADO AQUIFERS

There is insufficient information to characterize the flow in the thin aquifers of the Intra-Colorado unit.

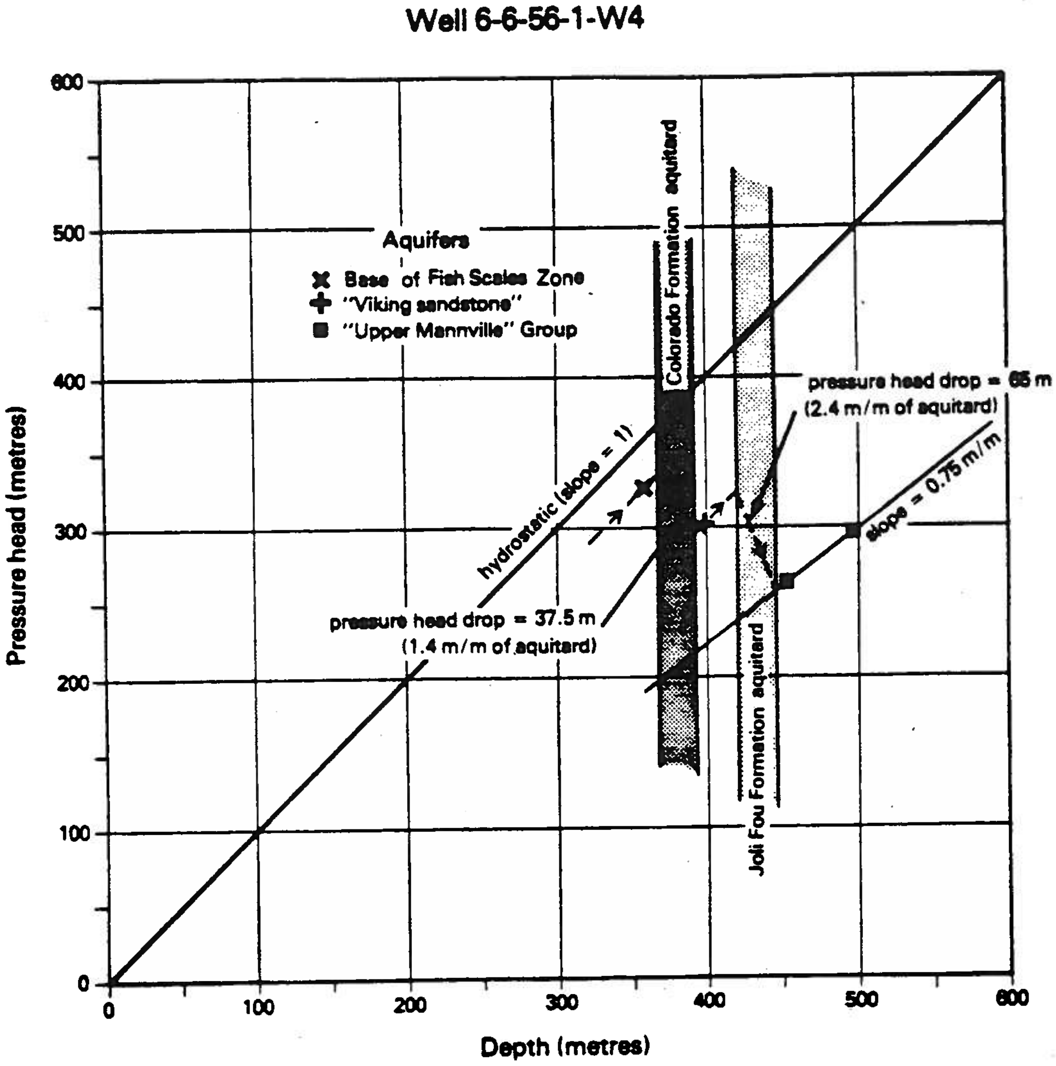


Figure 4-40 Pressure head versus depth plot for the well at 6-6-56-1 W4Mer.

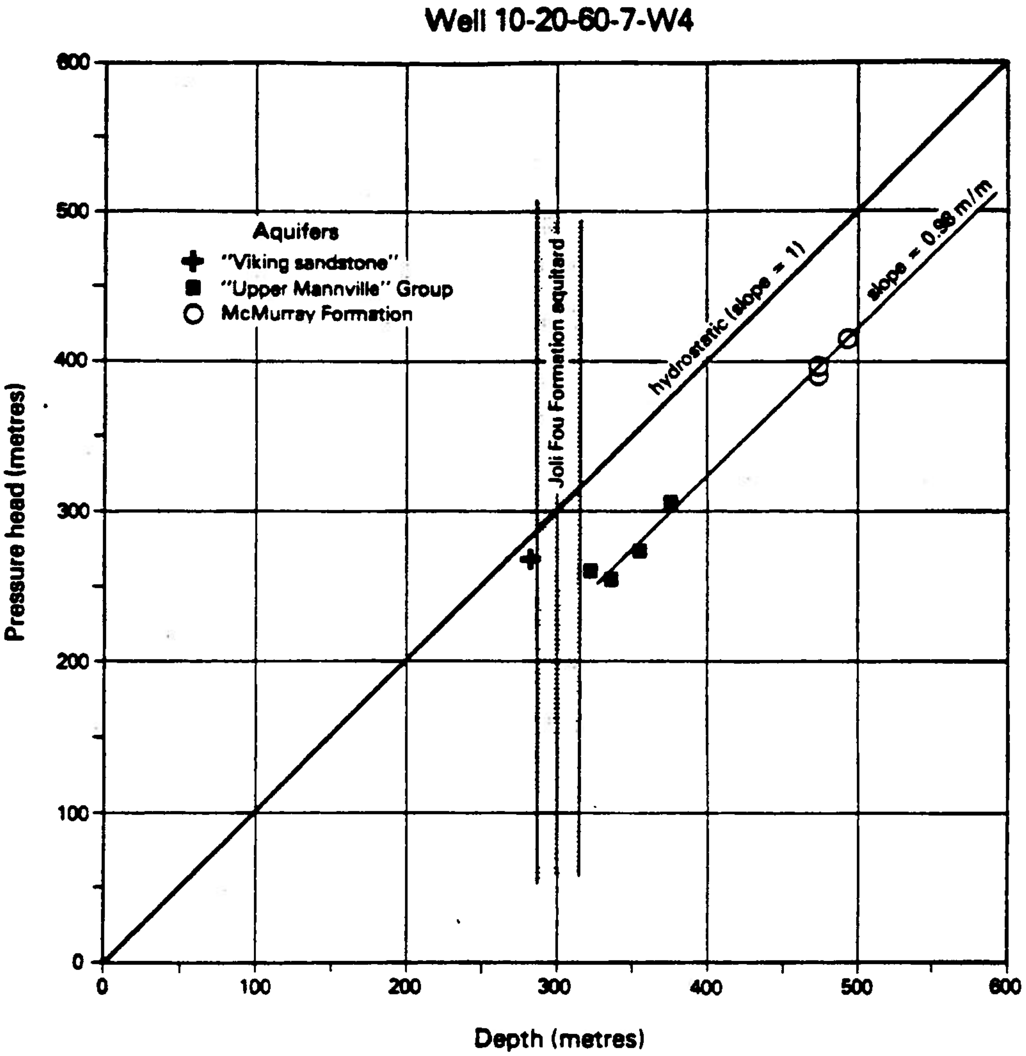


Figure 4-41 Pressure head versus depth plot for the well at 10-20-60-7 W4Mer.

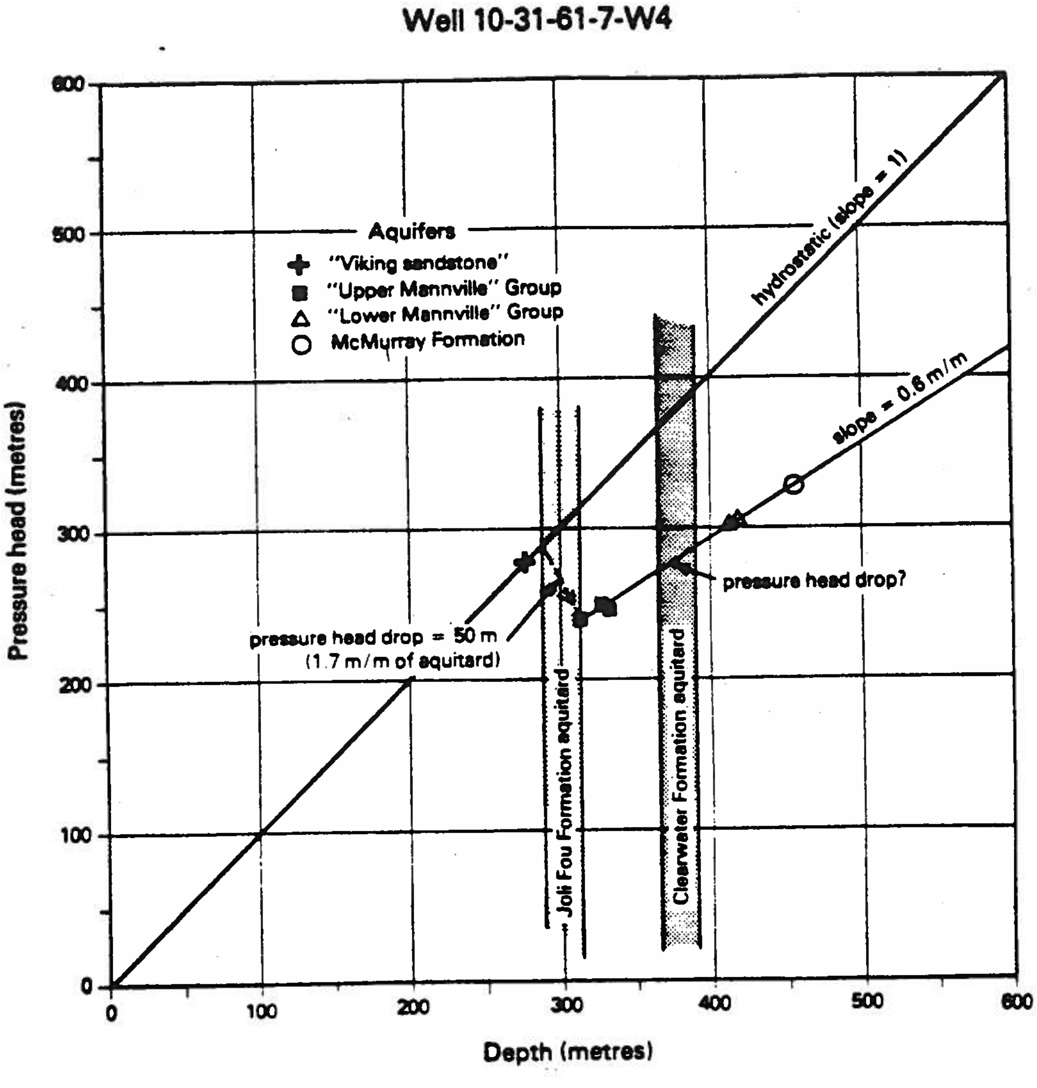


Figure 4-42 Pressure head versus depth plot for the well at 10-31-61-7 W4Mer.

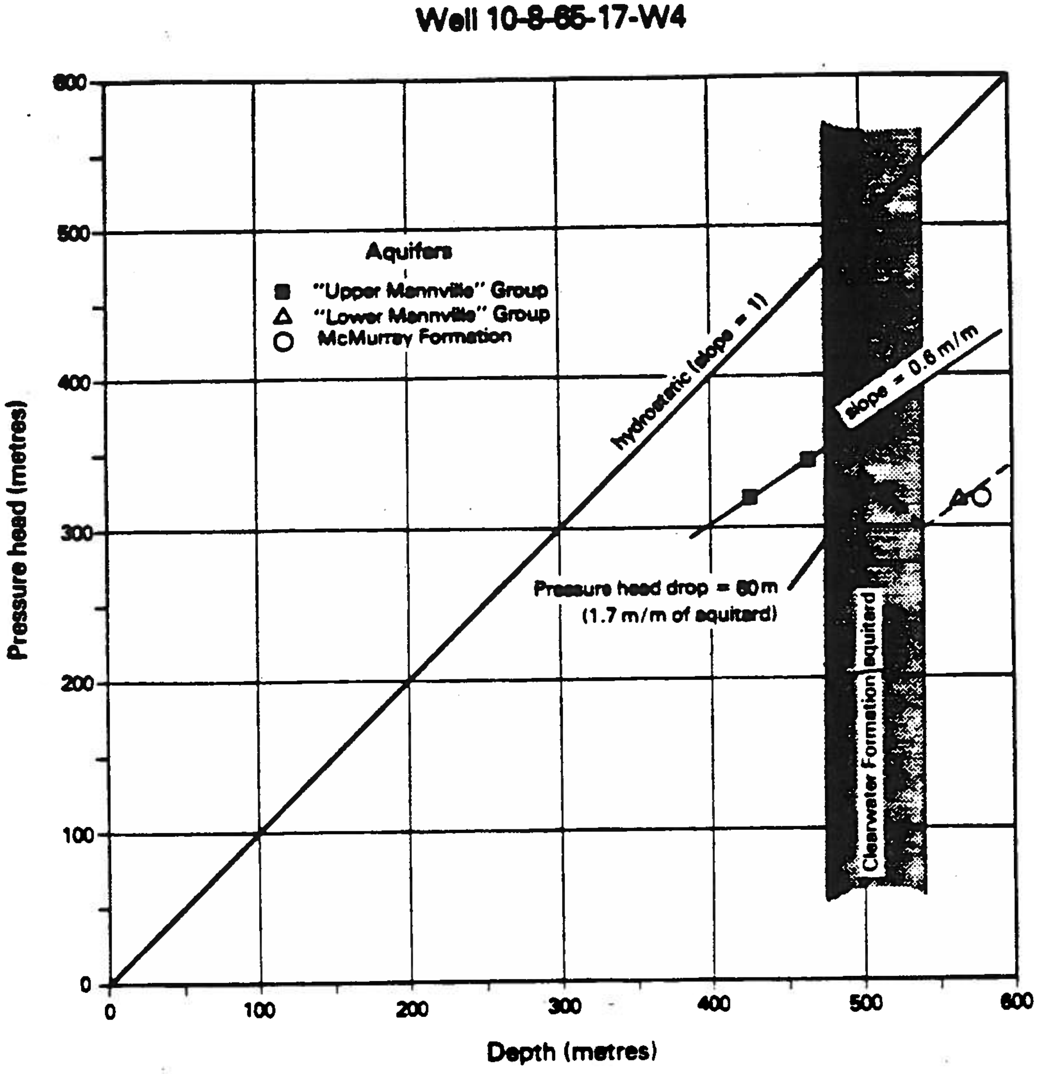


Figure 4-43 Pressure head versus depth plot for the well at 10-8-65-17 W4Mer.

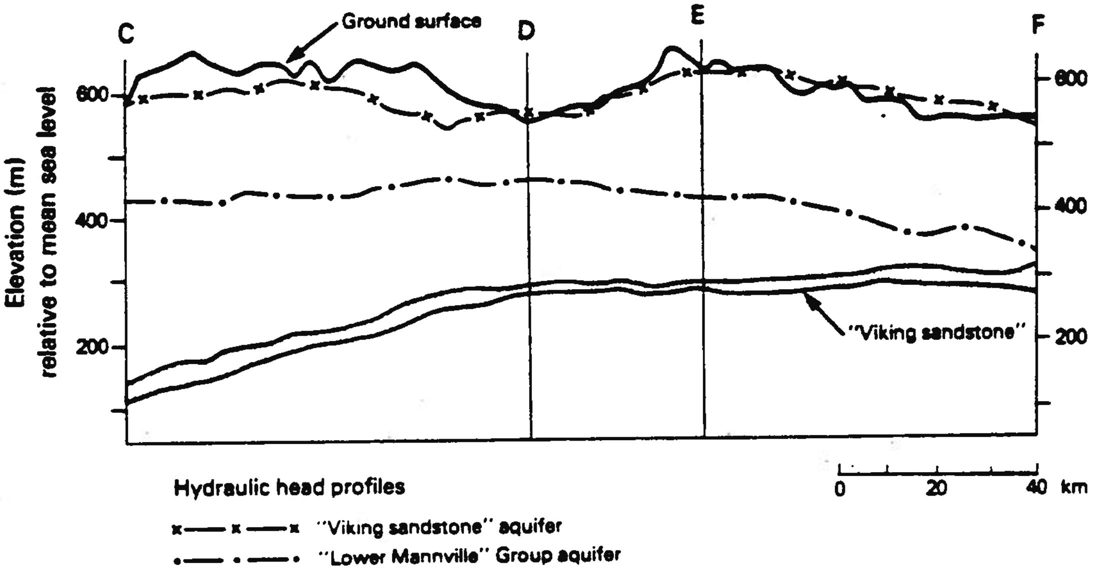


Figure 4-44 Hydraulic head cross-section C-D-E-F (see figure 4-32 for location), Cold Lake Study Area.

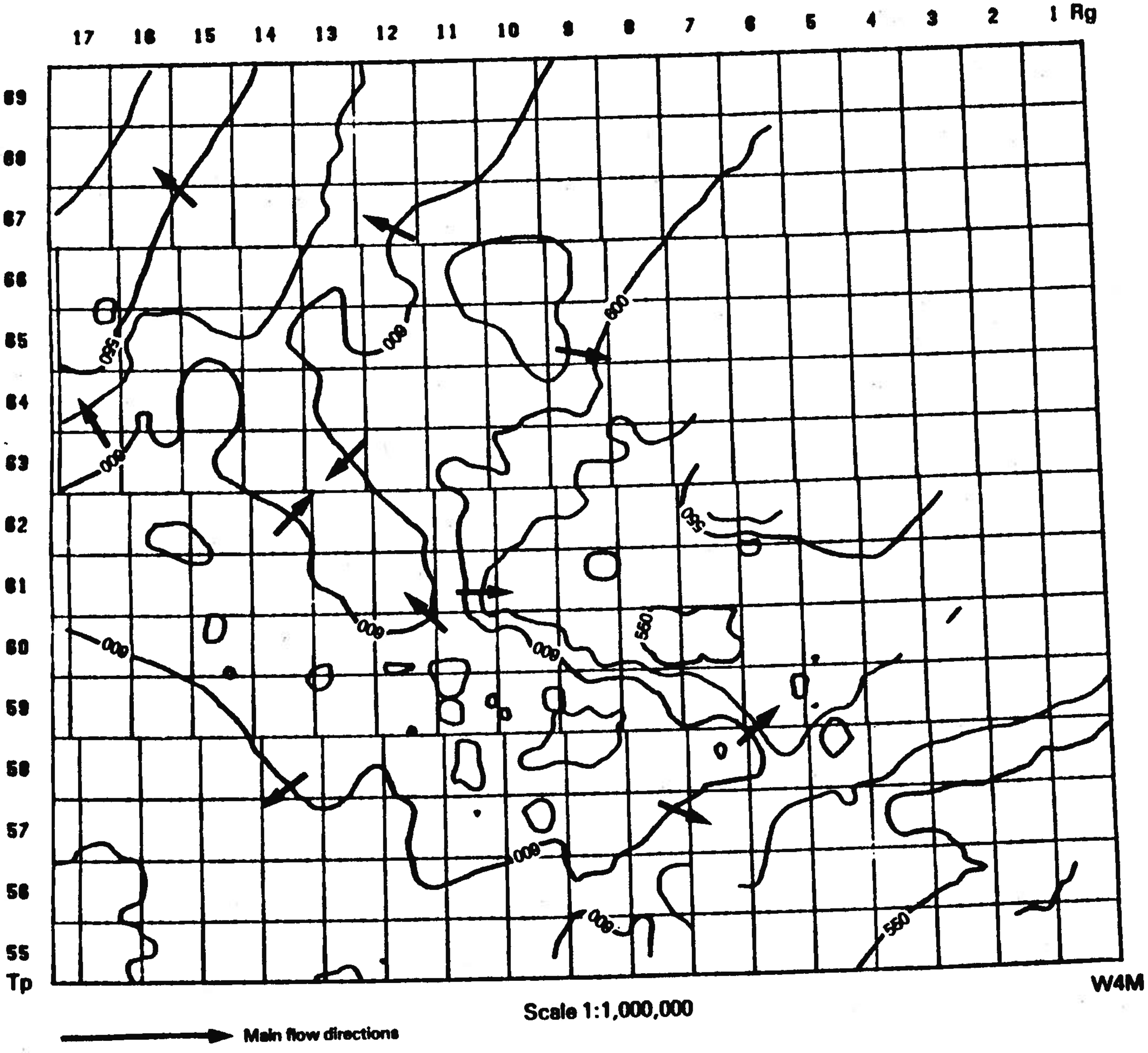


Figure 4-45 Potentiometric surface of "Viking sandstone" aquifer (Atlas map N-h-3), Cold Lake Study Area.

FLOW ACROSS AQUITARDS

Besides having the general characteristic of being dominantly vertical, flow across the aquitards can also be analyzed using pressure head versus depth plots. On the plots in figures 4-40 to 4-43, the top and base of the aquitards are represented in the vertical direction for each well evaluated and hydrostatic conditions are assumed for all the intermediate aquifers except the "Upper Mannville" where the flow is mostly downward.

The pressure head drop in the southeast corner of the study area (figure 4-40) is 1.4 m per m of Colorado shale aquitard and 2.4 m per m of Joli Fou Formation aquitard. In the central part of the study area (figure 4-42), the pressure head drop is only 1.7 m per m of Joli Fou Formation aquitard, although there does not appear to be any pressure head drop at the southern boundary of the Clearwater Formation aquitard. In the northwest of the study area, the pressure head drop through the Clearwater Formation aquitard is 1 m per m; in this area, the Clearwater Formation shale is the thickest (see figure 4-43). Flow is downward through the three above-mentioned aquitards.

Unfortunately, the lack of drillstem test data does not allow a similar analysis for the Ireton Formation aquitard. Remembering the earlier discussion about the vertical hydraulic conductivities and leakage factors of the aquitards, one may anticipate, for this unit, intermediate pressure head drops between the values observed for the Joli Fou Formation and Clearwater Formation aquitards. However, increases instead of decreases for pressure heads across the Ireton Formation aquitard cannot be excluded; this would indicate a potential for upward vertical flow.

SUMMARY

In the Phanerozoic sequence, the flow is regional to the northeast in the Cooking - Beaverhill Lake - Watt Mountain aquifer; it is of intermediate type, mainly towards the northwest, in the "Lower Mannville" - Grosmont aquifer (due to the "drain" effect from the Grosmont aquifer) and downward in the "Upper Mannville" Group aquifer. Two hypothesis are formulated for the flow in the "Viking sandstone" aquifer; according to the first one, the flow in only gravity-controlled and of local type; the second hypothesis involves the influence of the important closed hydraulic head depression located near Gilby in central Alberta that has been explained (see discussion in Part 3) as the result of osmotic effects through shale membranes. Only a more detailed basin-wide study of flow in Cretaceous sediments will clarify this point. Between the Camrose Tongue and the Grosmont Formation aquifers, hydraulic continuity is observed and supported by the hydrochemical regime, although not proven unequivocally. Vertical downward flow is present through the Colorado, Joli Fou and Clearwater aquitards; the flow is potentially upward through the Ireton Formation aquitard, although not demonstrated with the same degree of confidence.

The existance of differences between core and drillstem test permeabilities has not been conclusively elucidated within the limits of this study and it is proposed to use the drillstem test results for the numerical simulation.

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SECTION 2: QUATERNARY

HYDRAULIC PARAMETERS OF THE QUATERNARY SEDIMENTS

In the Quaternary each aquifer is separated by an aquitard comprising glacial till and, therefore, the hydrostratigraphic units are defined strictly according to the stratigraphic nomenclature. After the initial data culling, the hydraulic parameters are derived from the results of 53 well tests and 9 aquifer tests; the well tests are interpreted for transmissivity values using the Jacob's approximation of the Theis solution applied to recovery data; the aquifer tests are interpreted with the "strip"-leaky model in the fashion already described. Leakage factor and vertical hydraulic conductivity of the overlying aquitard are also deduced from aquifer test interpretations.

The overall interpreted results are presented per aquifer in tables P-h-10 to P-h-15 in the Data Base and the well locations for the calculated hydraulic parameters are shown in Atlas map P-h-1. The aquifer hydraulic conductivities are summarized in Table 4-5.

Table 4-5. Hydraulic conductivity in the surficial sediments (m/s)

Aquifer	Number of tests	K_{min}	K_{max}	K_{geom}*	K_{median}**
Empress Formation	9	1.5×10^{-4}	1.4×10^{-3}	2.5×10^{-4}	2.8×10^{-4}
Muriel Lake Formation	16	4.2×10^{-7}	7.3×10^{-3}	6.8×10^{-5}	9×10^{-5}
Bonnyville Formation	11	1×10^{-6}	2.2×10^{-4}	2.6×10^{-5}	2.5×10^{-5}
Ethel Lake Formation	6	1.2×10^{-5}	3.7×10^{-2}	3.6×10^{-4}	3×10^{-4}
Sand River Formation	4	8.4×10^{-5}	5.1×10^{-4}	1.6×10^{-4}	--

*computed as $[\mathrm{Prod.}\ (i=1,n)Ki]^{1/n}$
**obtained from log-normal cumulative frequency plots

Only partial conclusions can be deduced from this table because of the paucity of data; however, it suggests that the most conductive aquifers are the Ethel Lake and Empress formations; also, the widest range of hydraulic conductivity is found in the Muriel Lake Formation.

There are more transmissivity determinations than there are hydraulic conductivity values because the aquifer thickness is unknown or poorly defined in some wells. Aquifer transmissivities range from 4×10^{-6} m^2/s in the Bonnyville Formation to 1.5×10^{-2} m^2/s in the Empress Formation. The location of wells for which transmissivity values have been calculated is shown in Atlas map P-h-1. The storativity values could only be determined from the aquifer test data and averages are 8.9×10^{-4} and 2.2×10^{-4} for the Empress and Muriel Lake formations, respectively.

The twenty-year safe yield follows the trend of the hydraulic conductivities with highest values, in the Ethel Lake and Empress formations, of between 8 and 62 L/s. These aquifers are thus the most productive ones.

The aquitard hydraulic parameters are the vertical hydraulic conductivity and the leakage factor; the interpreted results for the various observation wells of each aquifer test are in tables P-h-16 and P-h-17 in the Data Base. For the Bronson Lake aquitard, the geometric mean of the 10 results for vertical hydraulic conductivity is 2.2×10^{-8} m/s; the arithmetic average of the leakage factor is 1624 m. For the Bonnyville unit 1 aquitard, the corresponding values are 2.3×10^{-8} m/s and 2190 m, based on two determinations.

Table 4-6 summarizes the results of measured hydraulic heads in the Quaternary sediments; details from individual wells can be found per aquifer in tables P-h-1 to P-h-9 in the Data Base.

Table 4-6. Hydraulic heads in the surficial sediments

Unit	Number of determinations	Range of hydraulic head (m) Minimum	Maximum
Empress Formation (unit 1)	62	515	607
Empress Formation (unit 3)	52	509	642
Bronson Lake Formation	49	512	649
Muriel Lake Formation	226	494	653
Bonnyville Formation (units 1 and 2)	232	532	670
Ethel Lake Formation	171	515	653
Marie Creek Formation (Unit 2)	75	505	652
Sand River Formation	160	531	674
Grand Centre Formation	144	494	689
TOTAL	1171	494	689

The number of point data in column 2 corresponds to the data used in the construction of the potentiometric surfaces (Atlas maps P-h-2 to P-h-13). The absolute range (494 to 689 m) compares well with the range of the hydraulic heads in the "Viking sandstone" aquifer (512 to 666 m) and for the top of the Phanerozoic (573 to 664 m). This could be used to support the observation about the local nature of the flow in the "Viking sandstone" aquifer.

FLOW IN UNIT 1 OF THE EMPRESS FORMATION

In the southwestern part of the study area, the flow is potentially upward from the Belly River Group into unit 1 of the Empress Formation; in particular, at Tp 58, R 17, a difference of 10 m exists between the hydraulic head in the Belly River Group (574 m) and the Beverly Valley aquifer (564 m). The buried valley acts as an upward drain for the flow at the top of the Phanerozoic sequence. Following the Beverly Valley to the east from this location and beyond the confluence with the Kikino and Vegreville valleys, flow is from the southwest to the northeast as far as the Moose Lake region, where the potentiometric surface shows a closed depression (Atlas map P-h-4); at this location the lake water level (533 m) is 8 m higher than the hydraulic head in the aquifer, suggesting a downward movement through the thin (60 m) Quaternary sediments. Beyond the Moose Lake closed depression, as far as the confluence between the Beverly and Helina valleys, flow is towards the closed depression from the northeast to the southwest; the hydraulic gradients of both flow paths towards the closed depression are moderate, of the order of 2 per mille. The Moose Lake closed depression is a potential recharge area for the Phanerozoic sequence.

Although hydraulic head data are less abundant, a similar closed depression with converging flow from both sides is observed in the Helina Valley, about 10 km to the west of the confluence between the Sand River and the Beaver River; hydraulic gradients towards the depression are weaker (1.5 per mille). In the Helina Valley, beneath Lac La Biche, hydraulic heads are close to the lake water level (544 m) suggesting a possible connection through the bottom of the lake.

The flow is towards Cold Lake (gradient 3 per mille) beyond the junction of the Beverly and the Heline valleys and slightly upward beneath the lake (lake water level at 535 m). Because the lake bottom is coincident with the top of the Empress Formation, it constitutes a (partial) discharge for that aquifer.

Due to the lack of hydraulic head data, the flow cannot be described in the Kikino, Vegreville and Vermilion buried valleys.

FLOW IN UNIT 3 OF THE EMPRESS FORMATION

This aquifer is typically discontinuous and the potentiometric surface (Atlas map P-h-5) is only defined to the west of Cold Lake and along the Bronson Lake Valley. In the first area, flow is towards Cold Lake with a hydraulic gradient of about 1 per mille; in the aquifer beneath the lake, the hydraulic head has the same value as the lake water level. In the Bronson Lake Valley, the flow is from the southeast and turns to the west towards the Moose Lake closed depression with a hydraulic gradient of 1.8 per mille.

FLOW IN THE MURIEL LAKE FORMATION

The flow converges from two directions towards the region around Moose Lake, from the southeast with a gradient of 8 per mille and from the southwest with a gradient of 3 per mille (Atlas map P-h-7). Northeast of the Moose Lake region, the flow is to the northeast; thus in the Muriel Lake aquifer the depression is "open" to the northeast, beneath Moose Lake. There is a closed depression in the potentiometric surface west of the confluence of the Sand and Beaver Rivers with a hydraulic gradient from the west-southwest direction of about 5 per mille. Southwest of Cold Lake, flow is outward from beneath the lake towards the Beaver River Valley with a 2.6 per mille gradient; in this latter area the Muriel Lake aquifer may represent a hydraulic connection between Cold Lake and the Beaver River (in the valley, the river water level is at 515 m and the sediment thickness is only 40 m). Northwest of Cold Lake, the flow is towards the lake with a hydraulic gradient of 3.4 per mille and the aquifer is in potential hydraulic continuity with the lake.

FLOW IN THE BONNYVILLE FORMATION

Unit 1 of the Bonnyville Formation is essentially an aquitard. The potentiometric surface for unit 1 and 2 was produced after manual correction of the SURFACE II contour map (see Atlas map P-h-8). It is subdivided into three areas labelled area 1 (the largest, with the best defined potentiometric surface) and areas 2 and 3 which are smaller and with less hydraulic head data.

In area 1, three protuberances with hydraulic heads greater than 650 m divide the flow which is to the northeast in the northern part and to the North Saskatchewan River in the southern part. Evidence for hydraulic connection with the North Saskatchewan River is present at Tp 56, R 6 and 7, where the river water level (535 m) is about 50 m below the hydraulic heads in the aquifer. In area 1, the hydraulic gradients range from 1 to 5 per mille. The Beaver River "drains" the flow in area 2 and beneath Cold Lake, the hydraulic heads are slightly above the lake water level. In Tp 64, R 13 and 14 of area 3, the difference between hydraulic heads in the aquifer and the Beaver River ranges from 40 to 50 m; to the north of this high in the potentiometric surface, the flow is towards Lac La Biche with a gradient of 2.2 per mille.

FLOW IN THE ETHEL LAKE FORMATION

The potentiometric surface is poorly defined for this widespread aquifer (see Atlas map P-h-10). In the Moose Lake region, although the aquifer is not present beneath the lake, the flow converges towards the previously mentioned closed depression from the southeast with a 9 per mille gradient and from the southwest (gradient of 2 per mille).

Around Frog Lake, the flow is towards the lake (lake water level is 575 m). In the Lac La Biche region the flow is again towards the lake with steep gradients (10 per mille) from the southeast and a moderate gradient (2 per mille) from the southwest. South of Cold Lake flow is towards the Beaver River with gradients of about 6 per mille.

FLOW IN THE SAND RIVER FORMATION

A continuous flow in the northeast direction is present in this aquifer (see Atlas map P-h-12); the hydraulic gradients are steeper in the narrow "arms" of the formation: 5 per mille at Tp 59, R 14 and 3.3 per mille at Tp 59, R 8 and 9. The flow converges from the north, west and southeast to the Moose Lake closed depression which is open to the northeast. Further to the northeast the flow is "channeled" by the Beaver River and then directed to the southern extremity of Cold Lake. A low in the potentiometric surface (610 m) is present at Tp 58, R 12. The potentiometric surface of the Sand River Formation is, in general, a subdued replica of the ground surface.

FLOW IN THE GRAND CENTRE FORMATION

As illustrated by Atlas map P-h-13, the potentiometric surface of this aquifer is very close to the ground surface. The flow is towards Lac La Biche in the northwestern part of the Cold Lake Study Area, with a gradient of 2.3 per mille. In the southern part of the study area, the flow is "drained" by the North Saskatchewan River. In the eastern half of the study area, a flow divide can be identified at Tp 58, with a flow direction towards the Beaver River (gradient 4 per mille), north of the divide. A difference of about 45 m exists locally around Frog Lake with respect to the lake water level.

FLOW ACROSS THE AQUITARDS

A detailed analysis of the cross-formational flow is complex and should be conducted at a local level rather than at the broad regional level of the present study. As suggested by the ranges of hydraulic heads in table 4-6, the flow is potentially downward through the till aquitards, but in discrete areas, upward flows cannot be excluded. The vertical hydraulic conductivity in the tills is about six orders of magnitude higher than for the Phanerozoic aquitards; these high values are also supported by evidence of fracturing and the amount of cross-formational flow is important whenever permitted by the vertical hydraulic gradient. For instance, in the Moose Lake region the downward leakage is from the lake to the Bonnyville and younger aquifers, creating the possibility for a downward "recharge" of the Phanerozoic section from the buried valley of unit 1 of the Empress Formation; the areal extent of such a zone is limited, however. A similar conclusion can be drawn for the potentiometric surface depression located to the west of the confluence of the Sand River with the Beaver River.

In summary, it has been shown that the lateral flows in the aquifers of the Quaternary sequence permit local hydraulic communications with the major surface water systems (North Saskatchewan River, Beaver River, Cold Lake, Lac La Biche and Moose Lake). Cross-formational flow through the aquitards is possible in areas where the multilayered system is sufficiently complete; such areas have not been studied in detail, given the limits of this regional approach. Downward movement to the Phanerozoic sequence is only identified in a few isolated areas where the two lowest potentiometric surfaces show a closed depression; in addition to the closed depressions which have been defined (beneath Moose Lake, for instance), it is possible that similar closed depressions exist beneath Cold Lake and Lac La Biche. Besides the difficulty of evaluating these downward fluxes, they are not likely to be of significance as recharge to the Phanerozoic strata.

APPENDIX

Water-level fluctuations in observation wells

INTRODUCTION

In the second part of 1982 six observation wells in the Cold Lake Study Area were fitted with Stevens six-month water-level recorders in order to determine water-level fluctuations with time. Water-level data have been processed for the period ending 1983, although manual readings continued to be taken throughout the period of observation until August, 1984. Hence, manual readings appear past the trace of the hydrograph after the end of 1983. Breaks in the hydrographs are due to mechanical failure of the water-level records. Two of the observation wells are completed in unit 1 of the Empress Formation, two in unit 3 of the Empress Formation, and the other two in the Muriel Lake Formation.

As a general observation, most of the water-levels responded quickly to changes in barometric pressure; those measured at the Canadian Forces Base, Cold Lake, were used for comparison in this study.

IRON RIVER SITE (LSD 4, Sec 27, Tp 62, R 7, W4 Mer)

Two observation wells were drilled at this site. The completed intervals are in unit 1 of the Empress Formation and in the Muriel Lake Formation. Unit 1 of the Empress Formation is composed of sand between 92.9 and 101.2 m, and the Muriel Lake Formation consists of very fine sand at depths between 53.6 and 57.9 m. These two test intervals are separated by about 35 m of mostly tills and sands. Detailed lithologs are given in Table A.

Comparison of both hydrographs (Figures A-1 and A-2) indicates, throughout the period of observation, a maximum fluctuation of about 0.7 m in unit 1 of the Empress Formation and about 0.6 m in the Muriel Lake Formation. Daily fluctuations are of the order of a centimeter, rather than a decimeter as is the case for the Marie Lake site, although a 5 to 10 cm recovery is observed in both wells in the middle of November, 1983. In unit 1 of the Empress Formation (Figure A-1) water levels stay fairly stable up to the last few days of November, 1982, when they decline until about mid-June, 1983. The levels then recover until mid-November, 1983. At the last manual reading, in mid-August, 1984, the water level is the lowest recorded. In the Muriel Lake Formation (Figure A-2) water levels appear to behave essentially similar to those in unit 1 of the Empress Formation, although part of the hydrograph is missing due to mechanical failure. Again, the minimum water level (manual reading) occurs in mid-August, 1984.

TABLE A

IRON RIVER SITE (LSD 4, Sec 27, Tp 62, R 7, W4 Mer)

Well completed in unit 1,
Empress Formation
Elevation: 564.351 m (amsl)

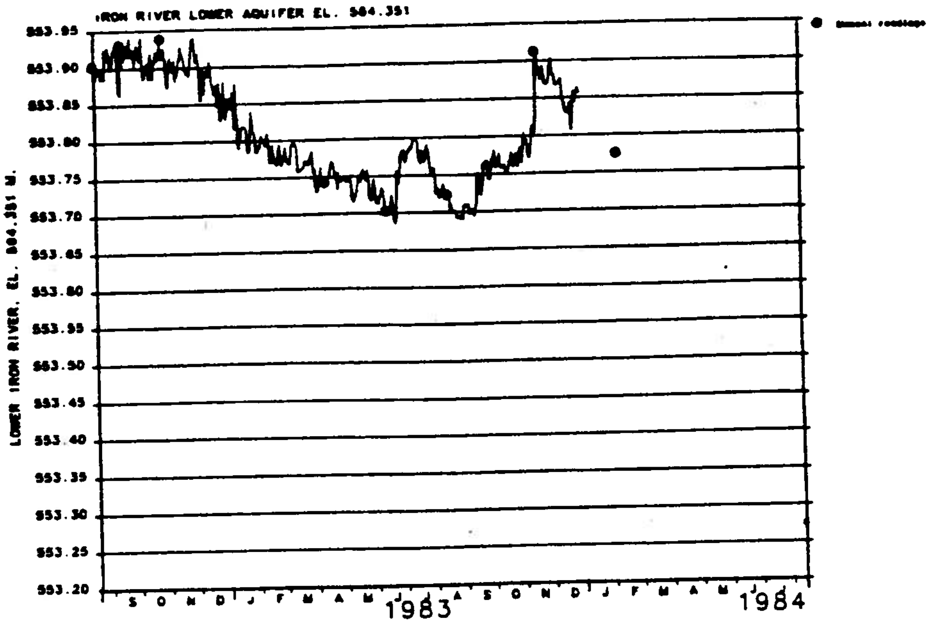
Depth (m)	Lithology
0 - 1.5	Sand
1.5 - 4.6	Clay
4.6 - 6.0	Sand
6.0 - 9.1	Till
9.1 - 11.3	Gravelly Till
11.3 - 15.2	Till
15.2 - 16.4	Sand
16.4 - 25.0	Till
25.0 - 33.5	Gravelly Till
33.5 - 38.1	Sand
38.1 - 39.6	Gravel
39.6 - 42.7	Till
42.7 - 47.2	Sand
47.2 - 53.6	Gravelly Till
53.6 - 54.9	Sand and Gravel
54.9 - 57.9	Very Fine Sand
57.9 - 60.3	Gravel
60.3 - 77.7	Till
77.7 - 83.8	Sand and Clay
83.8 - 92.9	Till
92.9 - 101.2	*Sand

Completion: 7" casing to 92.9 m
Screen: 6" diameter, stainless steel, from 96.3 to 101.2 m
* = tested interval

Well completed in Muriel
Lake Formation
Elevation: 564.474 m (amsl)

Depth (m)	Lithology
0 - 1.5	Sand
1.5 - 4.6	Clay
4.6 - 6.1	Sand
6.1 - 9.1	Sandy Till
9.1 - 9.7	Gravel
9.7 - 11.0	Till
11.0 - 11.3	Gravel
11.3 - 15.2	Clay
15.2 - 16.4	Sand
16.4 - 19.2	Clay
19.2 - 19.8	Gravel
19.8 - 24.4	Sandy Clay
24.4 - 25.0	Sand
25.0 - 33.5	Clay
33.5 - 38.1	Sand
38.1 - 39.6	Gravel
39.6 - 42.7	Clay
42.7 - 47.2	Sand
47.2 - 53.6	Clay
53.6 - 57.9	*Very Find Sand

Completion: 7" casing to 47.5 m
Screen: 6" diameter, stainless steel, from 52.7 to 57.3 m
* = tested interval



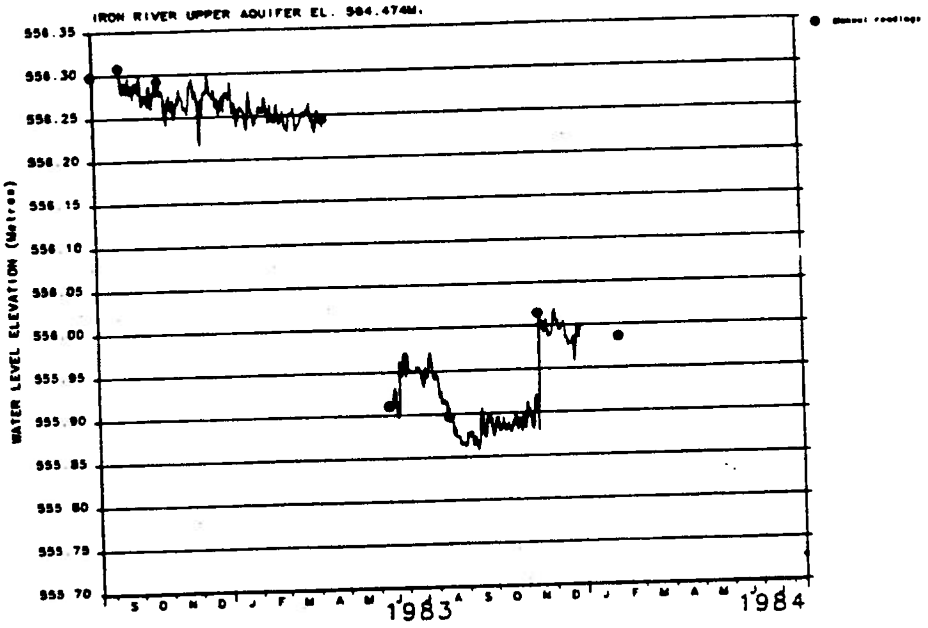


Figure A-1 (upper diagram): Hydrograph for unit 1 of the Empress Formation, Iron River site, Cold Lake Study Area

Figure A-2 (lower diagram): Hydrograph for Muriel Lake Formation, Iron River site, Cold Lake Study Area

MARIE LAKE SITE (LSD 4, Sec 9, Tp 65, R 2, W4 Mer)

Two observation wells were drilled at this site. The two completed intervals were unit 3 of the Empress Formation consisting of sand between 65.2 and 72.5 m, and unit 1 of the Empress Formation, which is composed of gravel interspersed with clay found between 139.3 and 167.7 m. These two permeable zones are separated by about 64.6 m of tills and clays, with minor sand and gravel layers. Detailed lithologs are given in Table B.

Comparison of the hydrographs at this location (Figures B-1 and B-2) indicates a maximum fluctuation of about 0.18 m in unit 1 of the Empress Formation and 0.23 m in unit 3 of the Empress Formation for the period of observation. Maximum daily amplitude is about 0.1 m in unit 1 of the Empress Formation and about 0.12 m for unit 2 of the Empress Formation. These hydrographs display the same type of annual fluctuations although the hydrograph for the lower tested interval is incomplete from mid-April to mid-June, 1983. Water levels gradually decrease starting in August, 1982 until about April, 1983, with only short recovery periods. Essentially, water levels then rise again from April, 1983 to February, 1984, with short periods of decreasing water levels in the period of August to September, 1983 and again in November to December, 1983.

TABLE B

MARIE LAKE SITE (LSD 4, Sec 9, Tp 65, R 2, W4 Mer)

Well completed in unit 1,
Empress Formation
Elevation: 593.263 m (amsl)

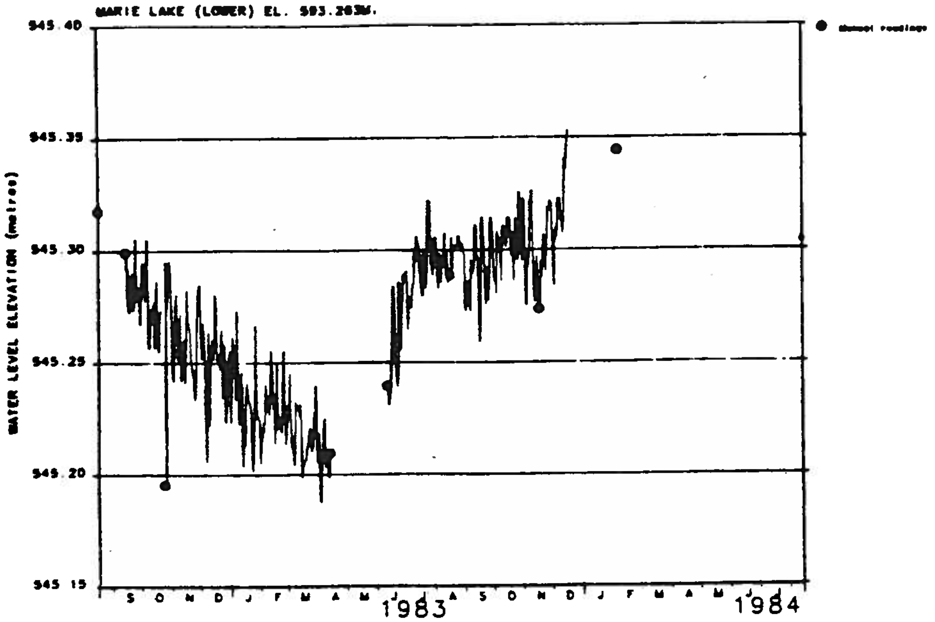
Depth (m)	Lithology
0 - 5.5	Brown sand
5.5 - 24.4	Till
24.4 - 41.1	Till with boulders
41.1 - 65.2	Sandy till
65.2 - 74.7	Sand and gravel
74.7 - 139.3	Till with gravel stringers
139.3 - 146.9	*Sand and gravel

Completion: 7" casing to 136.8 m
Screen: 5" diameter, stainless steel, from 140.2 to 144.8 m
* = tested interval

Well completed in unit 3,
Empress Formation
Elevation: 593.290 m (amsl)

Depth (m)	Lithology
0 - 5.5	Brown sand
5.5 - 24.4	Till
24.4 - 41.1	Till with boulders
41.1 - 65.2	Sandy till
65.2 - 72.5	*Sand and gravel

Completion: 7" casing to 65.2 m
Screen: 5" diameter, stainless steel, from 67.9 to 72.5 m
* = tested interval



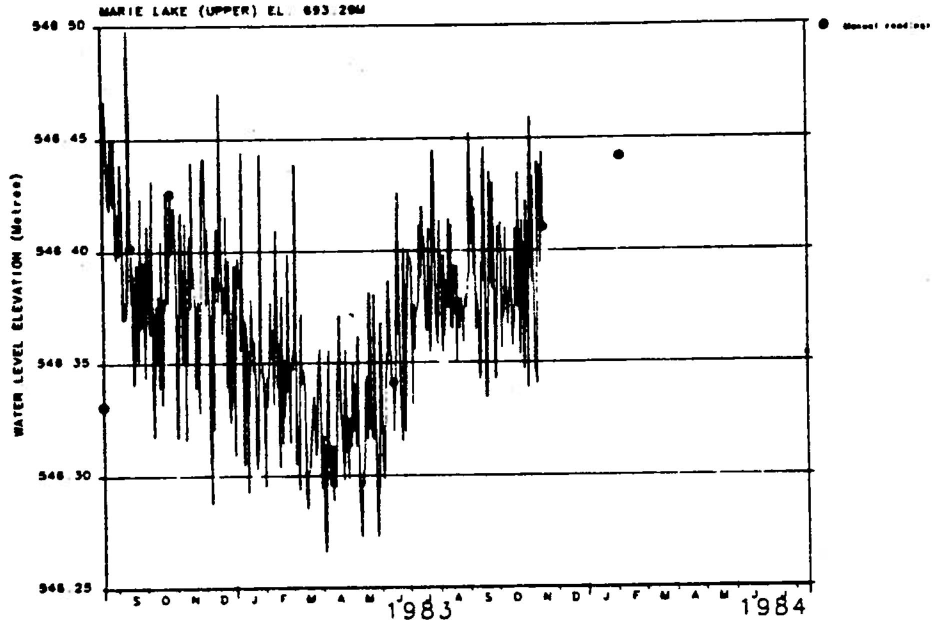


Figure B-1 (upper diagram): Hydrograph for unit 1 of the Empress Formation, Marie Lake site, Cold Lake Study Area

Figure B-2 (lower diagram): Hydrograph for unit 3 of the Empress Formation, Marie Lake site, Cold Lake Study Area

ESSO RESOURCES SITE (LSD 9, Sec 1, Tp 65, R 4, W4 Mer)

Only one interval was completed at this site, in unit 3 of the Empress Formation, which is composed mainly of medium- to fine-grained sand with occasional coarse particles, located at depths between 88.4 to 97.5 m. A detailed lithology is shown in Table C, below.

The hydrograph for this site is shown in figure C-1. The maximum variation of water levels in this well during the period of observation is about 4.5 m. Overall, the water levels decline during the period of observation, apart for short-recovery events near the stable periods from the beginning of January, 1983 to mid-July, 1984. Daily amplitude is in the range of 5 to 10 cm. This hydrograph may indicate pumpage nearby, with recovery when pumping ceases, followed by a decline in water-level when pumping resumes.

TABLE C

Well completed in unit 3, Empress Formation

Elevation: 607 m (amsl)

Depth (m)	Lithology
0 - 3.0	Medium to fine-grained sand
3.0 - 5.2	Light grey sandy till
5.2 - 9.1	Coarse- to fine-grained sand, occasional pebbles
9.1 - 48.8	Grey clay
48.8 - 79.2	Medium- to fine-grained sand
79.2 - 88.4	Clay till
88.4 - 97.5	*Medium- to fine-grained sand, occasional coarse particles
97.5 - 115.8	Sand, as above with abundant shale particles
115.8 - 118.9	Coarse- to fine-grained sand, some gravel
118.9 - 140.2	Grey shale

Completion: 5 1/2" casing to 87.5 m

Screen: 5" diameter, stainless steel, from 87.5 to 92.1 m

* = tested interval

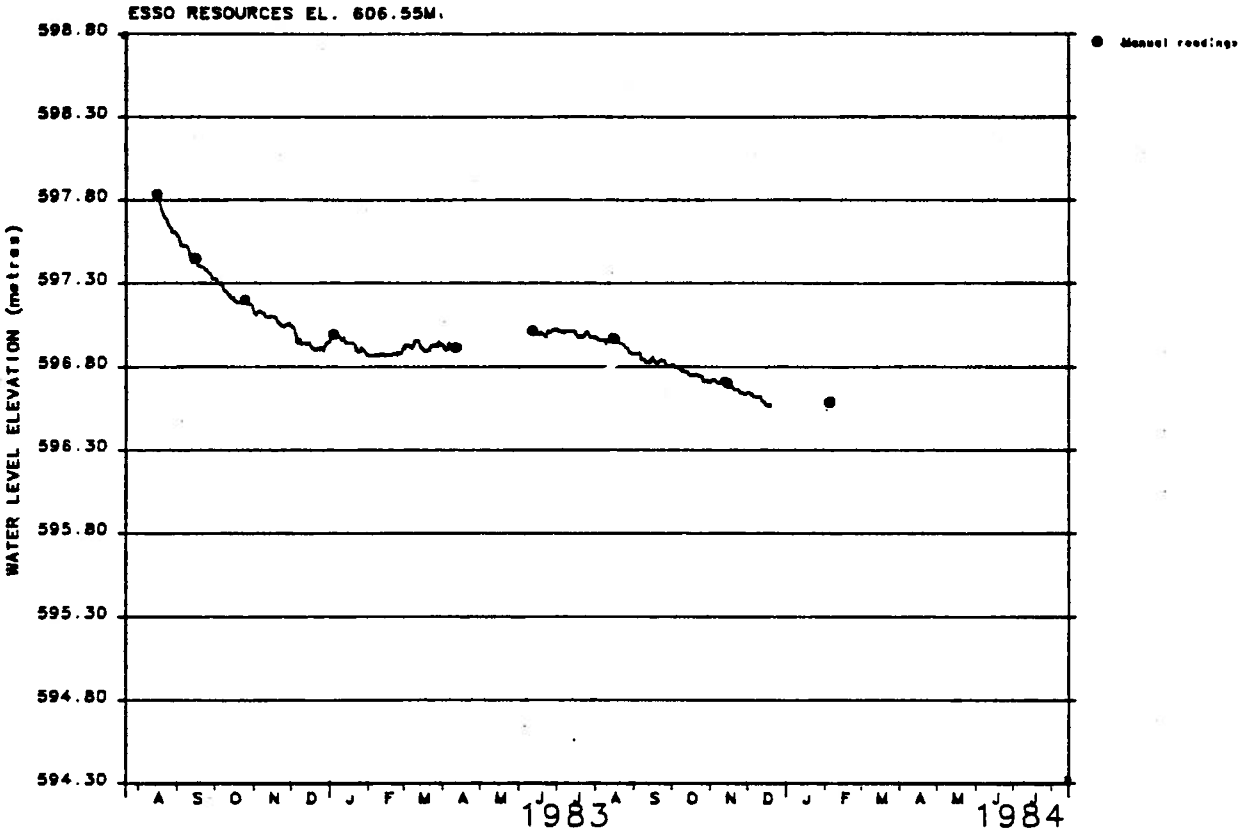


Figure C-1: Hydrograph for unit 3 of the Empress Formation, Esso Resources site, Cold Lake Study Area

BP-TRIAD SITE (LSD 4, Sec 28, Tp 66, R 5, W4 Mer)

This observation well was completed in the Muriel Lake Formation, in an interval comprising sand, located between 114.3 and 130.15 m (the observation well is completed only in the central part of these sands). A detailed lithology is shown in Table D (below).

Maximum variation of the water levels (figure D-1) in this well during the observation period is 0.77 m, with a maximum decrease of 0.5 m taking place over a few days at the end of January, 1983. Although water levels had been dropping gradually until January, 1983 (interspersed with short recovery periods), the levels recovered again in the period January to November, 1983.

TABLE D

Well completed in Muriel Lake Formation
Elevation: 648.0 m (amsl)

Depth (m)	Lithology
0 - 35.0	Till, stony
35.0 - 114.3	Clay and boulders
114.3 - 130.2	*Sand

Completion: 7" casing to 116.4 m
Screen: 5" diameter, stainless steel, from 121.6 to 126.2 m

*=tested interval

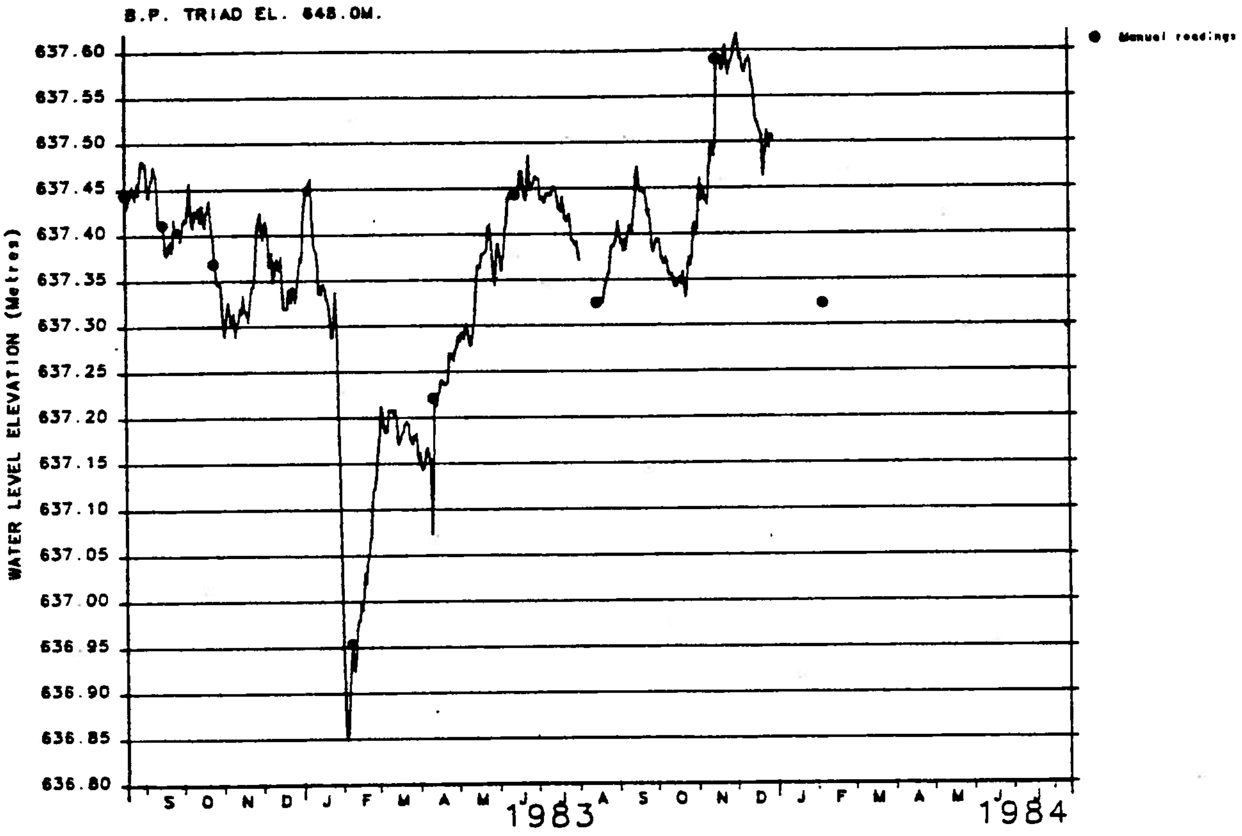


Figure D-1: Hydrograph for Muriel Lake Formation, BP-Triad site, Cold Lake Study Area

HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA
Part V. Hydrometeorology
Open File Report 1996 - 1e

Prepared by
Basin Analysis Group
Alberta Geological Survey
Alberta Research Council
(Project Manager: Dr. Brian Hitchon)

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and Alberta Environment

1985-01-31

ALBERTA
RESEARCH
COUNCIL

PART 5

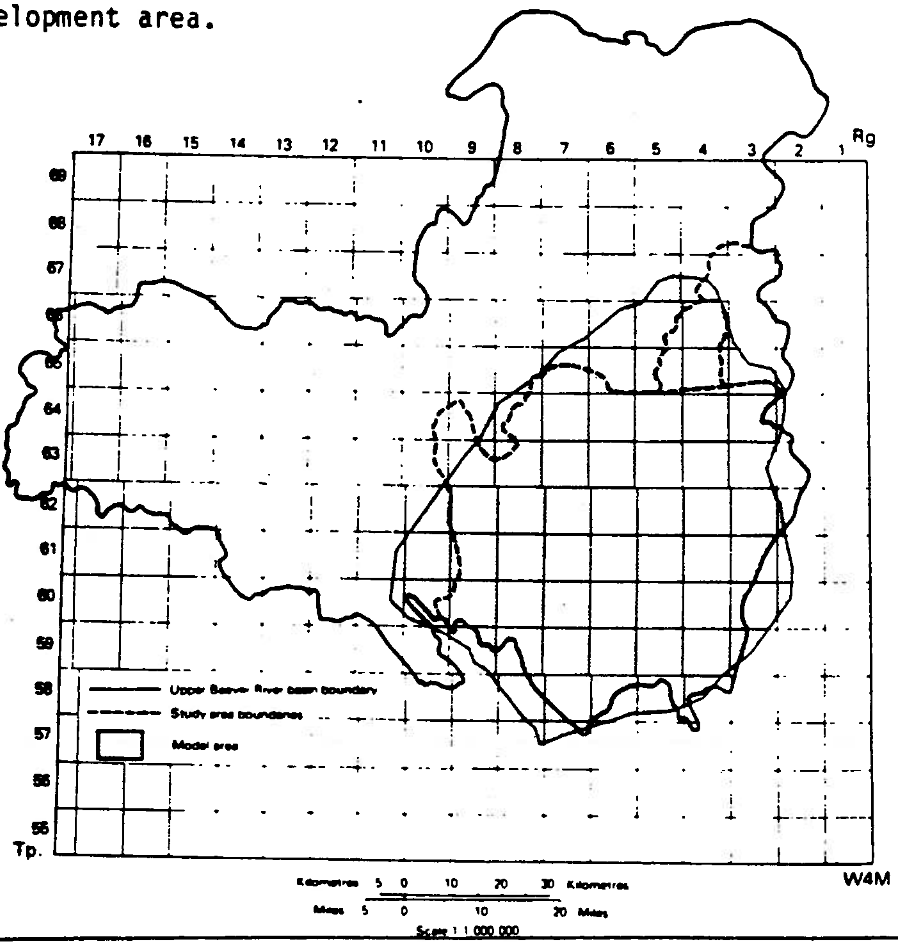
HYDROMETEOROLOGY

Dr. Henry R. Hudson

(Civil Engineering Department)

PREAMBLE

The Cold Lake Study Area (Tp 55-69, R1-17, W4 Mer) covers approximately 23 800 km^2 in east-central Alberta. Most parts of this Report and the accompanying Atlas and Data Base deal with the entire study area. In order to obtain the upper boundary conditions for the numerical simulation of fluid flow in the model area (Part 6), it was necessary to carry out a hydrometeorological study. Rather than attempt an analysis of the entire study area, which comprises several river basins and would be a major undertaking, it was decided to evaluate only the lower portion of the Beaver River basin. Although this lower portion is only 4220 km^2, its situation within the Cold Lake Study Area is such that results of the evaluation are directly applicable to the area covered by the numerical simulation (see map below). The compiled information is also of considerable general use for any hydrometeorological studies in the Cold Lake oil sands development area.



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INTRODUCTION

The objective of this investigation is to provide an overview of the hydrometeorological regime of the lower Beaver River basin (figure 5-1). The relationship between surface water movements and meteorologic conditions are investigated in order to provide the upper boundary hydrologic conditions for the steady-state numerical simulation described in Part 6 of this Report. The primary objectives of the study presented here are:

(1) to delineate the boundaries of the basin and the major hydrologic features, and

(2) to estimate the average annual contribution of precipitation to the groundwater regime using a water-budget approach.

Several intermediate steps are required to achieve these objectives. The location and extent of the basin, the topography, surficial materials, land use, and the hydrologic features have to be described. Then, hydrologically important aspects of the climate must be discussed. This provides the background information for the hydrometeorologic analysis, where components of the water budget are outlined, described and discussed. Simulated runoff is compared with measured runoff to test the accuracy of the water-budget approach. Finally, implications of the analysis are discussed. A description of methods is appended.

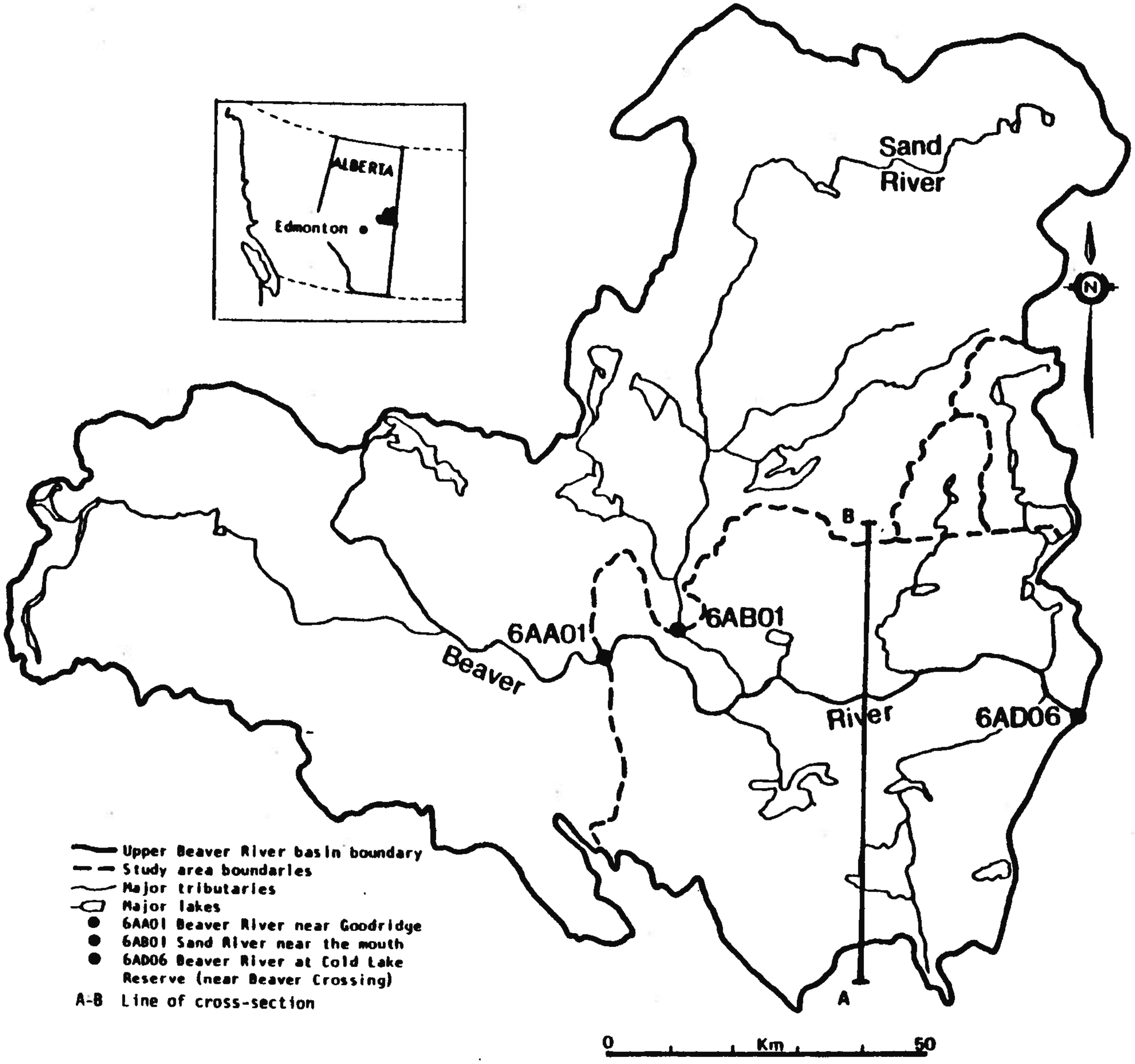

Figure 5-1 Location and boundaries of the Beaver River basin

PHYSICAL FEATURES OF THE STUDY AREA

LOCATION AND EXTENT

The Beaver River basin is located approximately 200 km northeast of Edmonton, near the Saskatchewan border (figure 5-1). The study area encompasses much of the Beaver River basin above Beaver crossing (station 6AD06: figure 5-1). The northeast portion of the Beaver River basin, (upper Jackfish and upper Marie creeks), was arbitrarily excluded for the purposes of the study. The basin, as defined in figure 5-1, has an area of 4220 km^2.

PHYSIOGRAPHY

The major physiographic units of the Sand River 1:250 000 map sheet are shown in figure 5-2. The area consists largely of a flat to gently rolling till plain known as the Beaver River Lowland, which is bounded on three sides by various uplands or highlands. The uplands to the north and south have gentle to high relief, with hummocky or rolling morraines. To the west, the Kehiwin Plain is a flat to rolling morraine (Andriashek and Fenton, in prep.).

From the river basin cross-section (figure 5-3) it is apparent that the lower Beaver River basin has subdued topography. The lower end of the river has an elevation of approximately 490 m (amsl), and at the upstream end it is approximately 526 m. This 36 m difference in elevation occurs over a valley length of about 91 km. The river has an average sinuosity of 1.3. The average elevations along the northern topographic divide are around 640 m. The highest point, the Wolf Lake Highland, is about 730 m (amsl). The heights along the southern divide range from about 640 m to a maximum of about 790 m on the Muriel Lake Highland (figure 5-2). The Kehiwin Plain, to the west, has an elevation which ranges from about 520 to 640 m.

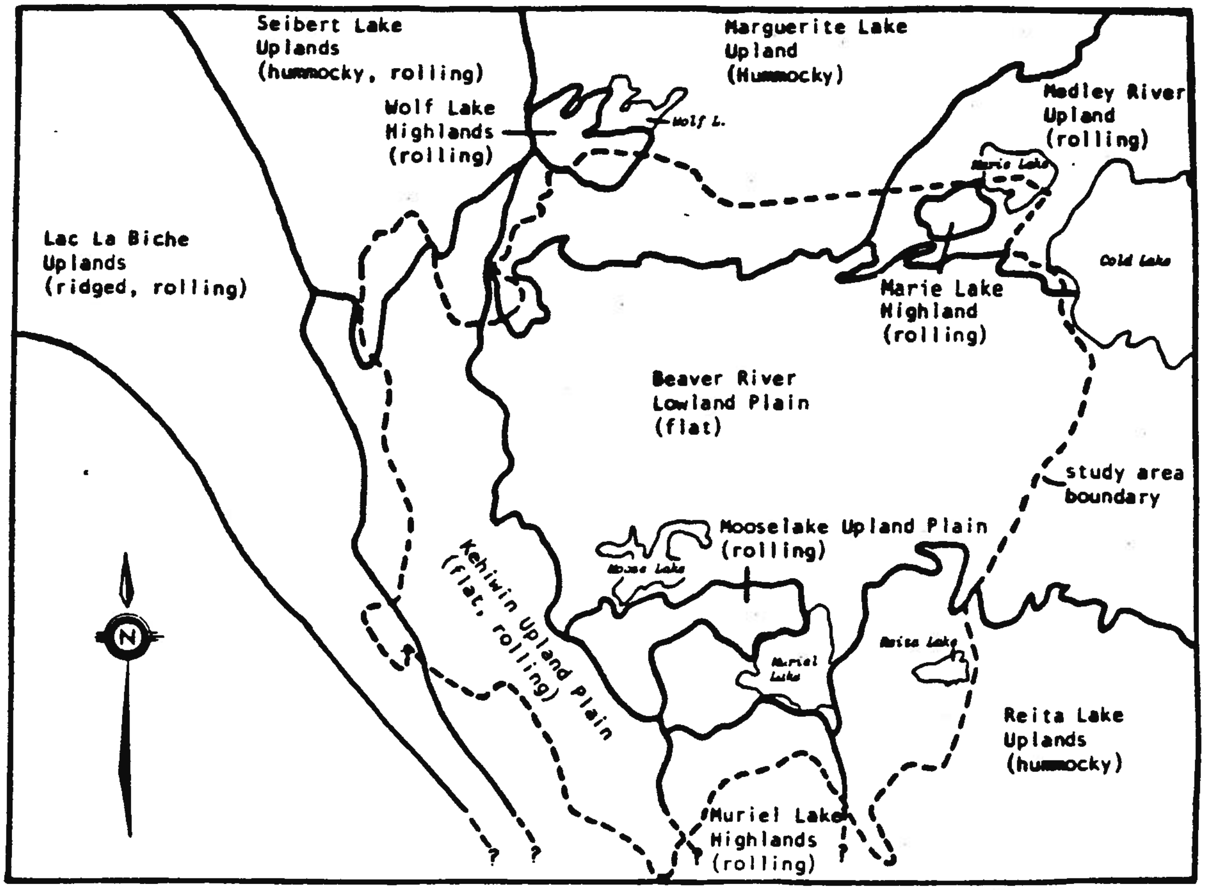

Figure 5-2 Physiography of the Sand River map sheet

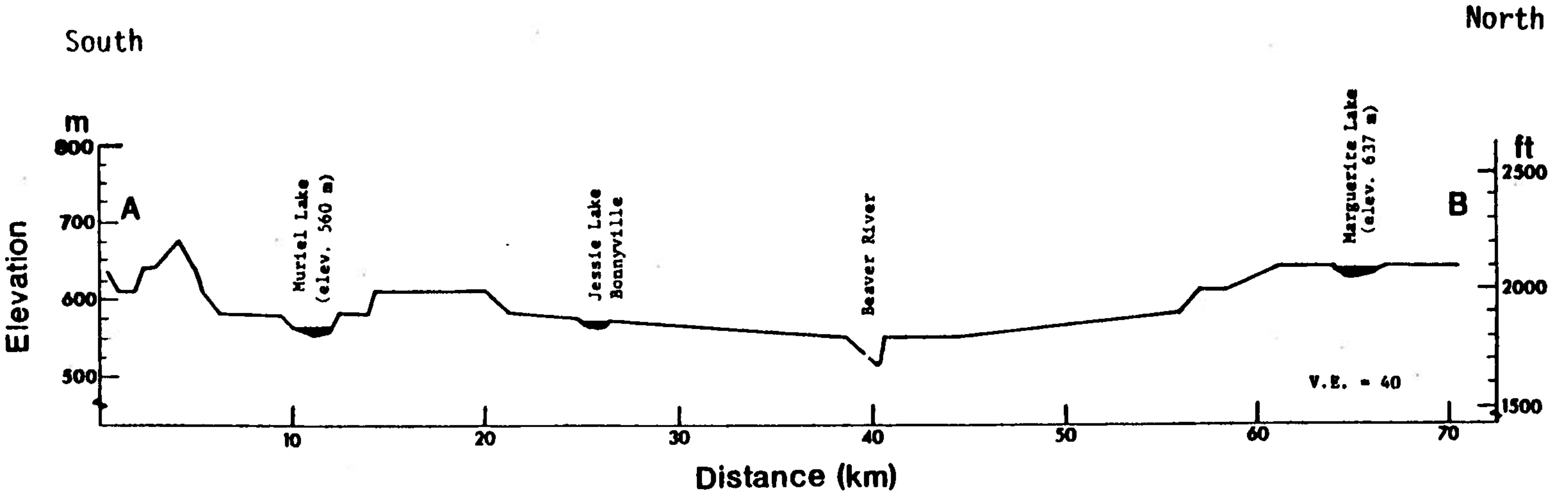

Figure 5-3 North to south cross-section through the Beaver River basin (location of cross-section on figure 5-1)

SURFICIAL MATERIALS

In this investigation we were concerned only with Quaternary sediments exposed at the surface. The distribution and characteristics of the surficial materials of the Sand River map sheet have been described by Andriashek and Fenton (in prep.) (figure 5-4). There are three major surficial material units in the study area - fluvial sediments, and tills from the Grand Centre Formation and the Medley Formation. The fluvial deposits are mainly sand and silt, with minor amounts of clay and gravel. These deposits are confined to the Beaver River valley, some tributaries, and lake margins. They cover about 4.7 percent of the basin. In addition, glacio-fluvial sand and gravel deposits, which are in scattered pockets throughout the area, occupy about 6.7 percent of the basin.

The Grand Centre Formation has four members, two of which, the La Corey and Glendon members, cover 80 percent of the basin (62 percent and 18 percent, respectively). The La Corey Member is a sandy clay-till, with relatively few pebbles or granules and with a massive to slightly fissile structure. Surface samples average 35 percent sand and 38 percent clay. The Glendon Member is also a till, but is sandier (42 percent sand, 34 percent clay) and has a blocky, well-jointed structure. These surficial material units are quite thick, varying from less than 9 m, on segments of the Beaver Lowland, to 60 m on the Kehiwin Plain. In general, the units are 10 to 30 m thick.

The Medley Formation generally underlies the Grand Centre Formation, but erosion of the latter has exposed the upper unit of the Medley Formation in the south-central portion of the basin. About four percent of the surficial material cover is Medley Formation. The exposed unit is a clayey, sandy till with an average composition of 41 percent sand and 29 percent clay. The material is coarser textured in the sand-size range than are the tills of the Grand Centre Formation, and it has abundant pebbles and clasts in the matrix. The formation is highly fractured and forms angular shards.

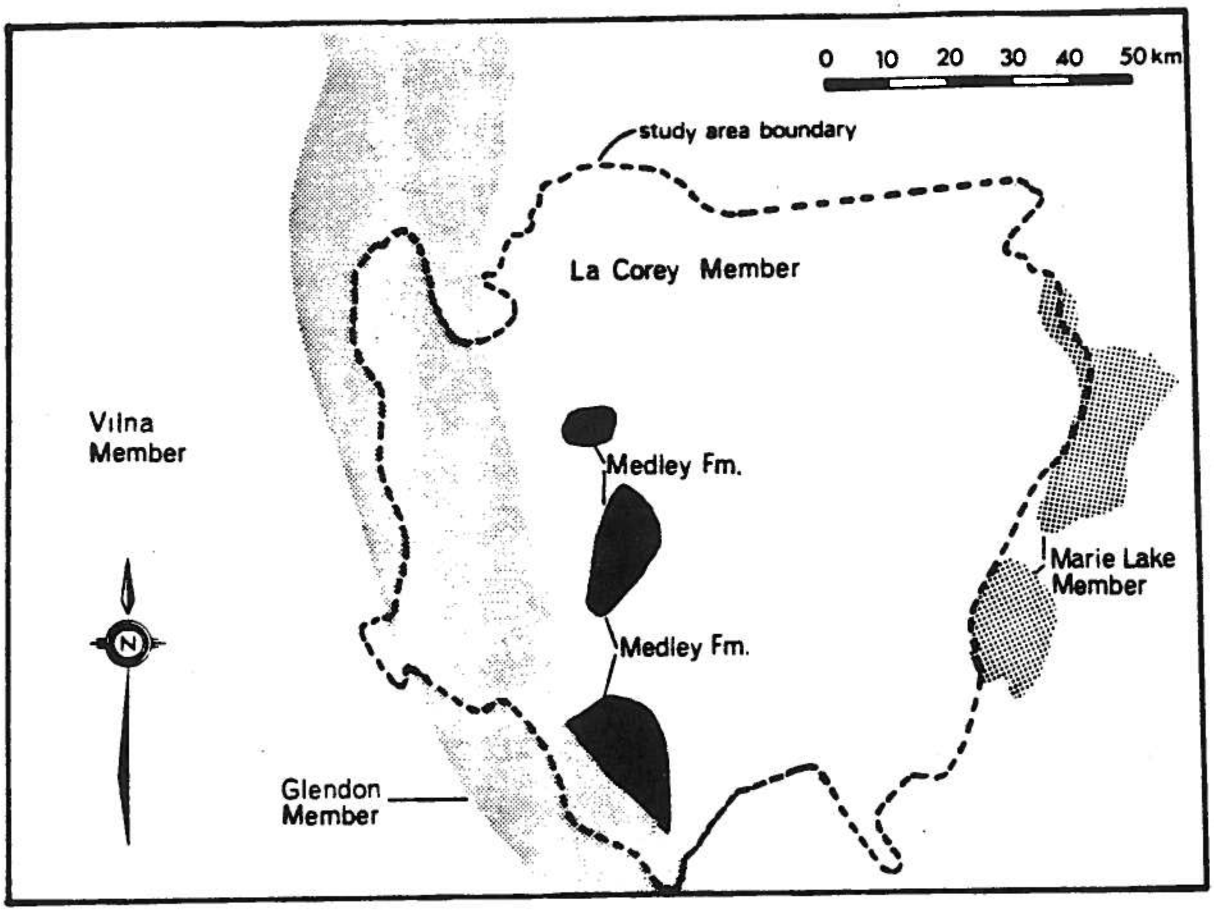

Figure 5-4 Surficial materials, Sand River map sheet

LAND USE

Canada Land Inventory maps at a 1:50 000 scale were used to determine land use (table 5-1, figure 5-5), which is an important index of hydrologic response. The upland areas in the north and south are largely forested. The Kehiwin Upland Plain in the west and the Beaver River Lowland are largely in cropland and pasture. There are several towns and service centres within the area, the main ones being Bonnyville, Grand Centre and Cold Lake. All these communities have water-works based on groundwater supplies.

CLIMATE

The climate of the area is characterized as high latitude and markedly continental, featuring a long cold winter and short cool summer, with maximum precipitation in the summer. Precipitation occurs mainly as snow in the period October to April. Details of temperature and precipitation are presented in table 5-2 for stations within the area (Iron River and Le Corey Ranger Stations) and for stations in the immediate vicinity (Cold Lake, Elk Point, St. Lina and Sand River).

A knowledge of the volume, timing and distribution of precipitation are required in a hydrometeorological study. Standard rain gauges are used to estimate precipitation volumes at the climatic stations in and near the area. It is known that these gauges underestimate precipitation volumes largely as a function of wind (Gray, 1970). The amount of precipitation reported from the gauges is not corrected, hence underestimates of point precipitation volumes are probable. The average wind speed in the area is about 3.75 m/s, thus undercatch of rain may be in the order of 12 percent and the undercatch of snow may be in the order of 30 percent (Gray, 1970). In addition to the problem of measuring precipitation at a point, the representativeness of a point is questionable. Longley (1973), for example, found that gauges in prairie river

Map Sheet	A	B	E	K	L	M	P	T	U	X	Z
73 L 1	1.4			1.4		3.0	0.6	60.0	25.1	8.5	
2	7.3			11.1		1.3	4.9	42.1	24.5	8.1	0.7
3	61.4	0.1		2.1		1.5	1.7	19.8	11.4	1.5	0.4
6	24.7			2.6		0.6	7.1	45.2	18.4	1.3	0.2
7	59.2	0.3		11.4		3.2	3.5	13.6	11.7	4.9	1.0
8	44.3	2.1	0.2			2.3	2.0	16.6	19.5	0.2	1.3
9	0.6					2.0	-	34.7	51.4	10.8	0.5
10	2.4			0.4		3.3	1.9	50.0	39.8	1.9	0.2
11	1.6			1.5		3.7	1.1	44.7	46.3		1.1
Mean %	25.1	0.3		4.4		2.2	3.2	34.3	25.5	4.4	0.6
Storage (mm)	100	13 to 250		150 to 250	13	M	150	250	150		150

Based on Canada Land Inventory 1:50,000 maps, where:

A Croplands
B Urban
E Mines, quarries, gravel pits
K Biologically unproductive land
L Rock or other unvegetated surfaces
M Swamp, marsh and bogs (storage equal to surrounding land use)

P Pasture
T Productive woodland
U Non-productive woodland
X Water surfaces
Z Unimproved pasture and range land

Storages from Laycock (pers. comm.)

Table 5-1 Summary of land use of the lower Beaver River basin

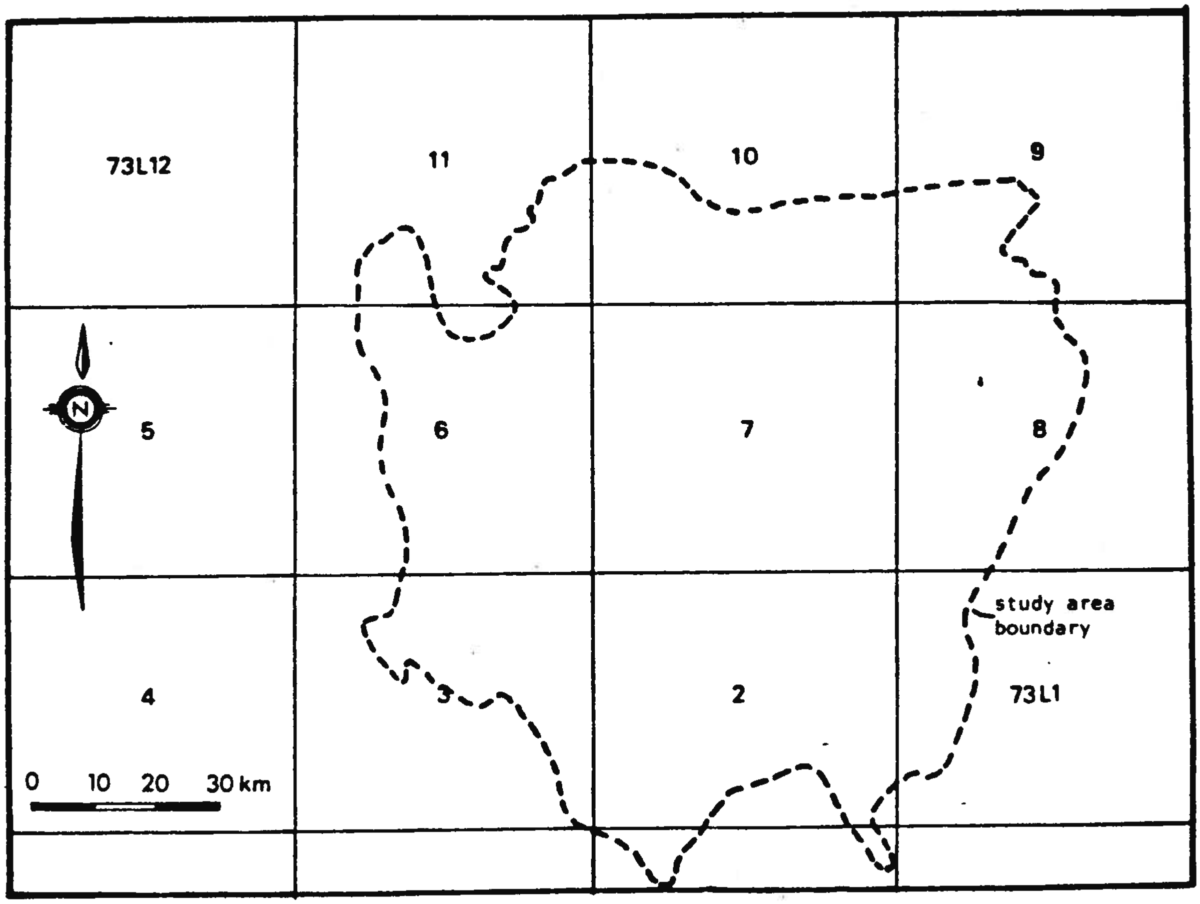

Figure 5-5 Canada Land Inventory map sheets of the lower Beaver River basin

Table 5-2 Climatic normals (1951-1980) Cold Lake region climate stations

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	CODE
COLD LAKE A 54 25′N 110° 17′W 541 m														
Daily Maximum Temperature	-14.0	-7.9	-1.7	8.7	16.9	20.6	22.9	21.3	15.4	9.8	-1.9	-9.6	6.7	2
Daily Minimum Temperature	-23.9	-19.3	-13.5	-2.9	3.8	8.4	10.9	9.6	4.2	-0.9	-10.5	-18.8	-4.4	2
Daily Temperature	-19.0	-13.6	-7.6	2.9	10.4	14.5	16.9	15.5	9.8	4.5	-6.2	-14.2	1.2	2
Standard Deviation, Daily Temperature	4.5	4.1	3.4	2.9	1.4	1.3	1.1	1.6	2.1	1.8	3.6	4.5	0.8	2
Extreme Maximum Temperature	10.6	11.7	16.7	29.4	31.7	35.6	36.1	32.8	32.8	27.4	18.9	10.0	36.1	
Years of Record	28	28	28	28	28	28	28	28	28	28	28	28		
Extreme Minimum Temperature	-48.3	-42.8	-41.1	-34.4	-7.8	-3.3	0.0	-0.5	-9.4	-15.6	-36.7	-42.8	-48.3	
Years of Record	28	28	28	28	28	28	28	28	28	28	28	28		
Rainfall	0.9	0.3	1.5	9.2	36.8	71.9	85.6	76.2	42.4	9.9	1.8	0.9	337.4	2
Snowfall	23.8	18.1	21.0	12.4	3.0	T	0.0	0.0	2.5	7.0	21.2	26.4	135.4	2
Total Precipitation	22.1	15.8	20.1	21.6	39.7	71.9	85.6	76.2	44.9	16.9	20.3	24.8	459.9	2
Standard Deviation, Total Precipitation	9.4	9.2	12.5	14.7	24.0	42.4	32.5	34.2	25.7	15.4	12.8	11.9	65.4	2
Greatest Rainfall in 24 hours	10.4	2.0	7.9	22.6	33.8	93.7	44.2	43.4	46.7	39.9	4.3	5.0	93.7	
Years of Record	27	27	27	27	28	28	28	28	28	28	28	28		
Greatest Snowfall in 24 hours	20.8	13.5	23.9	17.8	26.7	T	0.0	T	11.9	18.8	30.5	15.7	30.5	
Years of Record	27	27	27	27	28	28	28	28	28	28	28	28		
Greatest Precipitation in 24 hours	20.8	9.9	19.6	24.6	33.8	93.7	44.2	43.4	46.7	39.9	30.5	15.2	93.7	
Years of Record	27	27	27	27	28	28	28	28	28	28	28	28		
Days with Rain	*	1	1	3	9	12	14	13	10	5	1	1	70	2
Days with Snow	12	9	9	4	1	0	0	0	1	3	8	11	58	2
Days with Precipitation	12	10	10	7	10	12	14	13	11	7	9	12	127	2
ELK POINT 53′ 53′N 111° 4′W 594 m														
Daily Maximum Temperature	-14.0	-7.5	-1.9	9.2	17.3	20.8	23.1	21.6	15.8	10.0	-1.8	-9.6	6.9	1
Daily Minimum Temperature	-25.0	-20.0	-14.7	-3.6	2.9	7.1	9.7	8.2	3.0	-2.5	-11.7	-19.8	-5.5	1
Daily Temperature	-19.5	-13.8	-8.3	2.8	10.2	14.0	16.4	14.9	9.4	3.8	-6.8	-14.7	0.7	1
Standard Deviation, Daily Temperature	4.4	4.2	3.3	2.7	1.3	1.4	1.0	1.6	2.1	2.0	3.5	4.5	0.9	1
Extreme Maximum Temperature	12.8	12.2	17.2	31.7	33.9	35.6	37.8	33.3	32.8	27.5	18.3	9.4	37.8	
Years of Record	55	51	52	54	53	50	52	55	55	53	54	53		
Extreme Minimum Temperature	-53.3	-49.4	-41.7	-40.0	-14.4	-6.7	-5.0	-6.7	-13.3	-25.0	-37.2	-51.1	-53.3	
Years of Record	55	51	52	54	53	50	52	55	55	53	54	53		
Rainfall	0.6	0.3	0.7	10.5	40.1	70.1	83.0	73.5	43.7	11.3	1.6	0.2	335.6	2
Snowfall	22.3	14.6	19.6	10.3	0.7	0.0	0.0	0.0	2.0	8.3	17.3	23.1	118.2	2
Total Precipitation	22.9	14.9	20.3	20.8	40.7	70.1	83.0	73.5	45.7	19.4	18.9	23.3	453.5	2
Standard Deviation, Total Precipitation	11.5	10.8	12.6	17.1	33.6	37.8	38.4	41.2	27.2	16.9	13.5	15.2	67.4	2
Greatest Rainfall in 24 hours	8.9	8.4	14.0	18.3	41.4	70.4	52.6	71.1	53.1	38.1	22.6	2.5	71.1	
Years of Record	56	54	54	52	52	50	53	56	53	50	53	55		
Greatest Snowfall in 24 hours	27.9	19.1	22.9	24.1	19.1	1.3	0.0	0.5	11.2	20.3	19.0	21.6	27.9	
Years of Record	55	53	53	53	52	51	55	57	53	51	52	54		
Greatest Precipitation in 24 hours	27.9	19.1	22.9	24.1	41.4	70.4	52.6	71.1	53.1	38.1	22.6	21.6	71.1	
Years of Record	55	53	54	52	53	50	53	56	53	51	52	54		
Days with Rain	*	*	*	3	8	11	13	13	9	4	1	*	62	2
Days with Snow	8	6	6	2	*	0	0	0	*	2	5	8	37	2
Days with Precipitation	8	6	6	5	8	11	13	13	9	5	5	8	97	2

Con't

IRON RIVER
54° 25'N 111° 0'W 549 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	
Daily Maximum Temperature	-13.6	-7.1	-1.9	8.7	17.5	20.9	23.2	21.9	15.8	10.4	-1.8	-9.1	7.1	3
Daily Minimum Temperature	-24.8	-20.1	-15.4	-4.1	2.9	7.1	9.9	8.4	3.1	-2.0	-11.1	-19.4	-5.5	3
Daily Temperature	-19.2	-13.7	-8.7	2.3	10.3	14.0	16.6	15.2	9.5	4.2	-6.4	-14.3	0.8	3
Standard Deviation, Daily Temperature	4.6	3.4	3.5	2.5	1.4	1.3	1.0	1.4	2.0	1.9	3.6	5.0	0.8	3
Extreme Maximum Temperature	11.1	14.4	16.1	32.8	34.4	36.1	36.1	33.3	30.6	26.7	19.4	12.2	36.1	
Years of Record	49	49	47	47	45	48	48	48	47	45	46	48		
Extreme Minimum Temperature	-51.1	-50.0	-44.4	-35.0	-12.2	-3.3	-0.6	-6.1	-14.4	-23.3	-40.0	-46.1	-51.1	
Years of Record	50	49	47	47	45	47	48	48	47	45	46	48		
Rainfall	0.1	0.1	0.7	5.4	33.9	69.5	79.0	70.2	38.6	7.7	1.5	0.1	308.8	3
Snowfall	18.7	13.6	17.8	10.8	2.1	0.0	0.0	0.0	2.8	7.9	17.8	18.0	109.5	3
Total Precipitation	18.8	13.7	18.5	17.2	36.1	69.5	79.0	71.7	41.5	15.6	19.3	18.1	419.8	3
Standard Deviation, Total Precipitation	11.2	8.4	12.5	17.1	26.3	47.0	32.8	44.0	27.1	10.7	14.0	9.5	95.7	3
Greatest Rainfall in 24 hours	9.9	2.3	10.9	47.2	58.4	55.9	88.9	55.4	58.7	41.9	16.5	5.1	88.9	
Years of Record	49	48	45	45	45	42	47	47	44	43	42	46		
Greatest Snowfall in 24 hours	20.3	15.2	25.4	23.1	12.7	0.0	0.0	0.0	11.4	18.5	48.3	25.4	48.3	
Years of Record	45	47	45	45	46	47	48	48	46	43	41	43		
Greatest Precipitation in 24 hours	20.3	15.2	25.4	47.2	58.4	55.9	88.9	55.4	58.7	41.9	48.3	25.4	88.9	
Years of Record	45	47	45	46	45	42	47	47	44	43	41	43		
Days with Rain	•	•	•	1	5	8	10	9	7	2	•	•	42	3
Days with Snow	7	6	5	3	•	0	0	0	1	2	5	6	35	3
Days with Precipitation	7	6	6	4	5	8	10	9	7	4	6	6	78	3

LA COREY RS
54° 25'N 110° 46'W 579 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	
Daily Maximum Temperature	-14.7	-8.4	-2.2	8.0	17.1	20.5	22.7	21.2	15.4	9.8	-2.1	-9.5	6.5	8
Daily Minimum Temperature	-27.2	-22.3	-17.2	-4.2	2.4	6.7	9.2	7.8	2.4	-3.0	-12.7	-22.0	-6.7	8
Daily Temperature	-21.0	-15.4	-9.7	1.9	9.8	13.6	16.0	14.5	8.9	3.4	-7.4	-15.8	-0.1	8
Standard Deviation, Daily Temperature	5.0	3.7	4.0	1.4	1.3	1.2	1.1	1.3	2.6	1.9	3.6	5.8	0.7	5
Extreme Maximum Temperature	9.4	9.4	13.3	24.4	31.7	33.3	34.4	32.2	32.2	25.6	13.9	6.1	34.4	
Years of Record	6	6	6	7	15	14	13	14	14	13	8	6		
Extreme Minimum Temperature	-50.0	-42.8	-42.8	-22.2	-10.6	-4.4	-0.6	-3.3	-12.2	-18.9	-35.0	-46.1	-50.0	
Years of Record	6	5	6	6	15	13	14	14	14	13	7	6		
Rainfall	1.1	0.4	3.2	8.8	34.0	69.1	76.9	75.6	38.3	9.1	3.0	1.4	320.9	8
Snowfall	20.7	19.4	18.0	15.7	1.4	0.0	0.0	0.0	2.2	6.7	14.8	18.1	117.0	8
Total Precipitation	20.2	19.1	20.8	25.6	34.9	69.1	76.9	75.6	40.8	15.8	17.9	19.3	436.8	8
Standard Deviation, Total Precipitation	7.3	9.1	15.7	13.7	18.5	53.0	21.4	33.4	26.6	13.0	13.7	9.0	62.0	5
Greatest Rainfall in 24 hours	11.4	1.3	7.1	17.8	29.0	55.9	33.0	53.1	41.1	15.7	5.3	1.5	55.9	
Years of Record	6	6	6	7	15	13	14	14	14	12	8	6		
Greatest Snowfall in 24 hours	11.4	9.7	21.3	16.0	5.6	0.0	0.0	0.0	11.7	14.5	19.8	15.2	21.3	
Years of Record	6	6	6	6	14	14	14	14	14	13	5	6		
Greatest Precipitation in 24 hours	11.4	9.4	33.0	17.8	29.0	55.9	33.0	53.1	41.1	20.1	19.8	15.2	55.9	
Years of Record	6	6	6	6	15	13	14	14	14	12	6	6		
Days with Rain	1	1	1	3	8	12	13	12	9	4	1	1	66	8
Days with Snow	9	7	6	4	1	0	0	0	1	2	6	8	44	8
Days with Precipitation	10	8	6	6	9	12	13	12	10	6	7	9	108	8

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	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	CODE
SAND RIVER LO														
54° 39'N 110° 59'W 732 m														
Daily Maximum Temperature	M	M	M	M	15.1	18.7	20.9	19.2	13.5	8.4	M	M	M	6
Daily Minimum Temperature	M	M	M	M	3.9	8.5	10.7	9.5	4.4	-0.1	M	M	M	6
Daily Temperature	M	M	M	M	9.5	13.6	15.8	14.4	9.0	4.2	M	M	M	6
Standard Deviation, Daily Temperature	M	M	M	M	1.8	1.2	1.3	1.6	2.6	2.5	M	M	M	6
Extreme Maximum Temperature	M	M	M	19.4	28.9	32.8	30.0	28.9	30.0	23.9	7.8	M	32.8	
Years of Record	0	0	0	1	17	18	18	18	17	7	1	0		
Extreme Minimum Temperature	M	M	M	M	-11.7	-1.7	4.0	-3.0	-9.4	-10.0	M	M	M	
Years of Record	0	0	0	0	15	18	18	18	17	5	0	0		
Rainfall	M	M	M	M	40.9	76.4	89.8	80.4	49.2	5.5	M	M	M	6
Snowfall	M	M	M	M	5.4	0.0	0.0	0.0	3.6	5.7	M	M	M	6
Total Precipitation	M	M	M	M	45.8	76.5	89.8	80.4	52.8	20.9	M	M	M	6
Standard Deviation, Total Precipitation	M	M	M	M	27.8	45.6	42.3	47.5	31.5	4.1	M	M	M	5
Greatest Rainfall in 24 hours	M	M	M	6.6	39.0	58.4	72.1	58.7	73.4	7.9	M	M	M	
Years of Record	0	0	0	1	22	24	23	24	23	6	0	0		
Greatest Snowfall in 24 hours	M	M	M	3.6	27.9	0.8	0.0	0.0	15.2	13.5	M	M	M	
Years of Record	0	0	0	2	23	24	23	24	23	7	0	0		
Greatest Precipitation in 24 hours	M	M	M	10.2	39.0	58.4	72.1	58.7	73.4	13.5	M	M	M	
Years of Record	0	0	0	2	22	24	23	24	22	6	0	0		
Days with Rain	M	M	M	M	8	12	15	13	11	3	M	M	M	6
Days with Snow	M	M	M	M	1	0	0	0	1	2	M	M	M	6
Days with Precipitation	M	M	M	M	9	12	15	13	11	7	M	M	M	6

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	CODE
ST LINA														
54° 18'N 111° 27'W 632 m														
Daily Maximum Temperature	-13.0	-6.7	-1.6	9.0	17.0	20.4	22.8	21.1	15.5	9.9	-1.6	-9.0	7.0	6
Daily Minimum Temperature	-23.4	-18.8	-14.2	-3.8	2.2	6.3	9.0	7.7	3.1	-2.0	-11.1	-18.6	-6.3	6
Daily Temperature	-18.2	-12.8	-7.9	2.6	9.6	13.4	15.9	14.4	9.3	4.0	-6.4	-13.8	0.4	6
Standard Deviation, Daily Temperature	3.6	5.5	2.8	3.0	1.4	1.2	1.2	1.7	1.9	1.9	3.6	4.3	0.9	5
Extreme Maximum Temperature	8.9	10.6	11.1	31.1	31.1	35.0	30.6	30.6	27.0	27.0	17.8	11.0	35.0	
Years of Record	10	10	10	10	11	11	11	11	11	11	11	11		
Extreme Minimum Temperature	-48.3	-45.0	-39.4	-27.2	-10.0	-2.2	0.0	-4.4	-10.0	-19.4	-38.1	-46.1	-48.3	
Years of Record	10	10	10	10	10	11	11	11	11	11	11	11		
Rainfall	0.0	0.0	0.2	10.2	47.9	76.1	91.3	77.5	54.2	10.6	1.7	0.5	370.1	6
Snowfall	23.8	15.4	18.9	12.1	0.2	0.0	0.0	0.0	2.8	4.8	15.9	19.6	113.5	6
Total Precipitation	23.4	14.9	19.2	22.8	47.7	76.1	91.3	77.5	57.4	16.0	17.6	20.4	484.3	6
Standard Deviation, Total Precipitation	19.2	18.7	9.9	16.1	35.7	45.2	32.6	38.0	33.5	10.4	13.9	11.1	99.2	5
Greatest Rainfall in 24 hours	T	T	T	15.2	62.0	66.5	34.6	45.7	35.6	8.9	9.1	10.0	66.5	
Years of Record	10	10	10	10	10	11	11	11	11	11	11	11		
Greatest Snowfall in 24 hours	26.7	16.0	18.3	16.8	2.5	0.0	0.0	0.0	10.2	10.2	14.0	16.5	26.7	
Years of Record	10	10	10	10	10	11	11	11	11	11	11	11		
Greatest Precipitation in 24 hours	26.7	16.0	18.3	20.6	62.0	66.5	34.6	45.7	35.6	10.2	14.2	16.5	66.5	
Years of Record	10	10	10	10	10	11	11	11	11	11	11	11		
Days with Rain	0	0	0	2	8	11	13	12	9	4	0	0	59	6
Days with Snow	7	4	5	2	0	0	0	0	0	1	4	5	28	6
Days with Precipitation	7	4	5	4	8	11	13	12	9	4	4	5	86	6

Source: Canadian Climate Normals, Temperature and Precipitation 1951-1980, Prairie Provinces. Environment Canada, Atmospheric Environment Service, 1982.

valleys record 10 to 20 percent less precipitation than gauges on the surrounding terrain. The gauges used in this study are not located in the river valley bottom, thus their records should be reasonably representative of the relatively flat surrounding area.

The density of the gauging network is important for two reasons. First, spatial variability of precipitation within storms may occur and second, the type of precipitation event may be important in the distribution and amount of rain. During spring and early summer, rainstorms are usually cyclonic and produce low intensity rainfall over large areas. By mid-summer, precipitation is largely convectional in origin and is characterized by intense, short duration rainfall over relatively small areas (Longley, 1972). Because of the relatively sparse rain gauge network, it cannot be expected that the amount of rainfall from individual rainstorms is adequately monitored, particularly for convective events. However, the network should provide a reasonable indication of precipitation totals over a period of months or years, given the inherent problems in obtaining representative point data.

The major climate station in the region is at Cold Lake Airport, which has an average annual precipitation of 460 mm. The average precipitation of the lower Beaver River basin is 452 mm, when each station is weighted by the isohyetal method. There is a trend between elevation and precipitation. The greatest amounts of precipitation tend to occur on the highlands and uplands of the region (figure 5-6). The relation between total annual precipitation (P mm) and elevation (E m) is:

$$P = 0.341\ E + 252\ (r^2 = 0.67;\ n = 7) \tag{1}$$

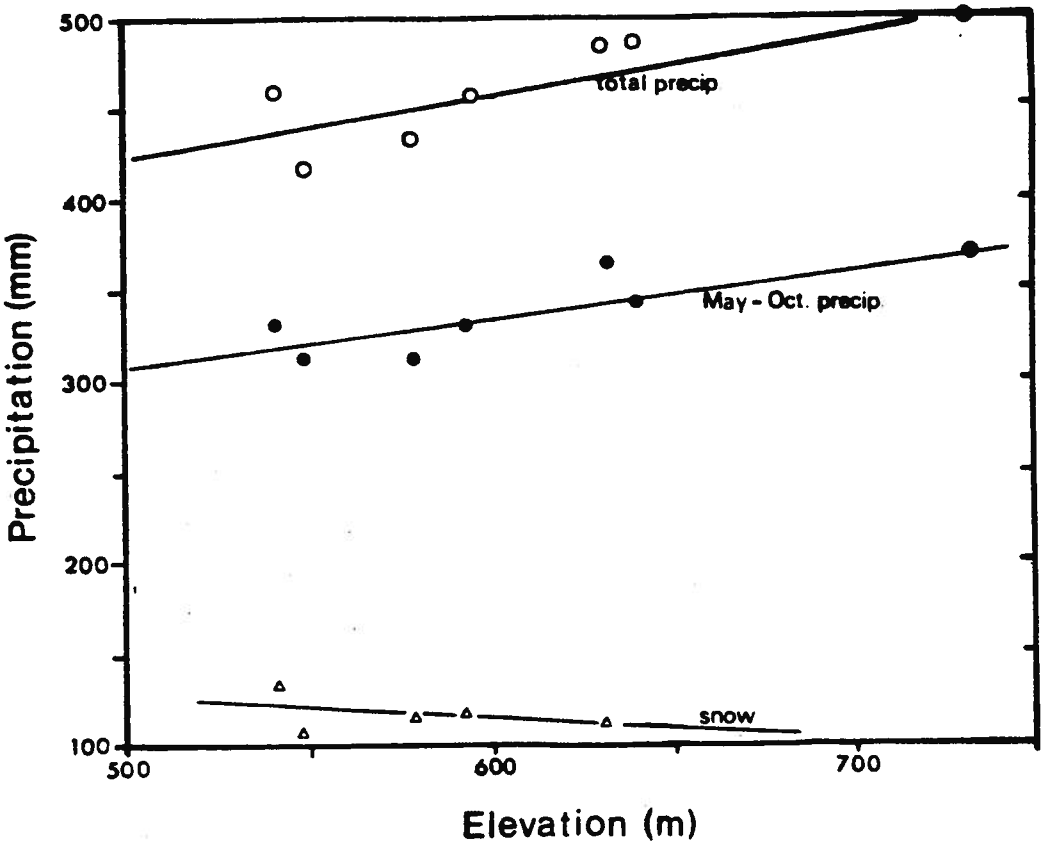


Figure 5-6 Precipitation-elevation relations, Cold Lake region

The relation between May-to-October precipitation and elevation is also strong:

$$P = 0.261\ E + 179\ (r^2 = 0.61;\ n = 7) \qquad (2)$$

The amount of snow tends to decline weakly with elevation (figure 5-6):

$$P = -0.12\ E + 183\ (r^2 = 0.20;\ n = 5) \qquad (3)$$

Although precipitation may occur as snow in nine or ten months of the year (table 5-2), the water equivalent of the total snowfall is approximately one quarter (26.4 percent) of the total annual precipitation. This amount is very significant because snow cover is, on average, "permanent" from mid-November to mid-April (Potter, 1965). Consequently, although the winter precipitation is relatively small, the storage as snow and rapid release as snowmelt in spring effectively redistributes several months of winter precipitation into the short duration snowmelt period.

Values of mean monthly temperatures and extremes of temperature (table 5-2) indicate that the area is markedly continental with dramatic seasonal and monthly temperature variations. For example, the extreme maximum and minimum temperatures in January and July for Cold Lake Airport are +10.6 and -48.3, and +36.1 and 0°C, respectively. Warm periods in winter are relatively rare. Longley (1967) indicates that the Cold Lake area has chinook conditions, (temperatures greater than 3.9°C) on about 4 to 5 days each winter.

The low winter temperatures produce a relatively long period of frozen soil in the area. Data from Vegreville, which is about 130 km southwest of the centre of the study area, but at a similar elevation (636 m amsl), snow that at least part of the soil column is frozen for six months of the year (table 5-3). The upper soil layers freeze in November. The depth of frozen soil increases with time, reaching

Table 5-3 Normals of soil temperatures (°C), Vegreville (1958-1978)

DEPTH/TIME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1CM AM													
1 PM													
5CM AM	-6.2	-4.9	-2.7	0.9	7.3	13.3	15.7	14.5	9.4	3.4	-1.2	-4.2	3.8
5 PM	-6.0	-4.6	-2.5	3.6	12.1	18.3	20.5	18.8	12.8	5.6	-0.8	-4.0	6.2
10CM AM	-5.8	-4.6	-2.7	0.8	7.2	12.9	15.7	15.0	10.2	4.7	-0.3	-4.0	4.1
10 PM	-5.7	-4.6	-2.7	2.0	9.5	15.3	18.1	16.9	11.6	5.6	-0.2	-3.9	5.2
20CM AM	-4.8	-4.2	-2.6	0.8	6.9	12.6	16.1	15.4	11.2	6.0	0.9	-2.8	4.6
20 PM	-4.8	-4.2	-2.6	1.0	7.2	13.0	16.4	15.6	11.3	6.0	0.8	-2.8	4.7
50CM AM	-2.3	-2.5	-1.7	-0.2	4.0	10.1	13.5	14.1	11.1	6.6	2.5	-0.4	4.6
100 AM	0.6	-0.1	-0.3	-0.1	1.1	6.3	9.9	11.6	10.6	7.8	4.6	2.0	4.5
150 AM	2.0	1.1	0.7	0.7	1.2	4.7	8.0	9.9	9.9	8.2	5.9	3.6	4.7
300 AM	4.1	3.2	2.4	2.0	1.9	2.9	4.6	6.7	7.7	7.7	6.9	5.4	4.6

Vegreville:	Latitude 53°29', Longitude 112° 02', elevation 636 m a.s.l., 14 years of record
Source:	Phillips and Aston, 1979, Soil tempertaure averages 1958-1978, Environment Canada Atmospheric Environment Report CLI 3-79, 17pp.

a maximum of about 1.15 m in March. In spring the upper soil layers thaw leaving a frozen layer which extends from about 0.44 to 1.06 m depth at the end of April. From May to October frozen soil conditions are not generally experienced.

HYDROLOGICAL FEATURES

The delineation of the lower Beaver River basin is based on surface water divides, with the exception of the northeast boundary which was arbitarily drawn through the Jackfish Creek and Marie Creek drainage basins (figure 5-1). Ultimately, the Beaver River drains into Hudson Bay via the Churchill River system. Major tributaries within the area include Moose Lake, Jackfish, Muriel, Marie and Columbine creeks. Two major rivers flow into the study area - Sand River (basinal area = 4920 km^2), and the Beaver River near Goodridge, which defines the upstream study area boundary (Station 6AA01, 4710 km^2).

A conspicious feature of the lower Beaver River basin is the extent of depression storage as lakes and sloughs. About 190 km^2 of the area, or 4.5 percent, is in this category. A further 105 km^2 is classified in the Canada Land Inventory (CLI) as swamp, marsh or bog. The areas designated as swamp, marsh or bog on 1:50 000 topographic maps are up to about ten times more extensive than on the Canada Land Inventory maps. The difference occurs because these maps classify areas such as forested swamps as forest land (T or U in table 5-1), whereas the topographic map series has a dual classification of swamp and forest cover. For the purposes of calculating a water budget, storage terms such as swamps are taken to be equivalent to the surrounding land use (Laycock, pers. comm., (table 5-1)).

Within the area defined by the surface water divides (the "gross drainage area"), there are large expanses which would not normally route surface runoff into the main stream. These areas, which were defined using 1:50 000 topographic maps and airphotos, usually consist of lakes, marshes and sloughs, without connecting channels to the main stream. Under extreme flood conditions, runoff could cross the depression divide and escape to the stream network. However, in these circumstances, the depth of the depressions precludes the escape of a few to several meters depth of water. These areas are referred to as internally drained areas. Internally drained areas are common on glaciated prairies (Stichling and Blackwell, 1957). The remainder of the basin might conceivably route surface runoff to the main stream during normal runoff events. Stichling and Blackwell (1957) referred to this area as the "effective area".

Gross, effective and internal drainage areas are presented in figure 5-7 and table 5-4. From a gross drainage area of 4220 km^2, about 17 percent (720 km^2) is internally drained. The lowest proportions of internal drainage (around 5 percent) occur in the west of the study area, on the Kehiwin Upland Plain (figures 5-2 and 5-7). The most extensive areas of internal drainage occur in the Beaver River Plain, which occupies the central portion of the region; more than 25 percent of this region is internally drained. The upland areas of the north and northeast have low to moderate proportions of internal drainage. The Moose Lake Upland in the south, has a high proportion of internal drainage, but the highlands which form the remainder of the southern portion of the basin have a low proportion of internal drainage (figures 5-2 and 5-7, table 5-4).

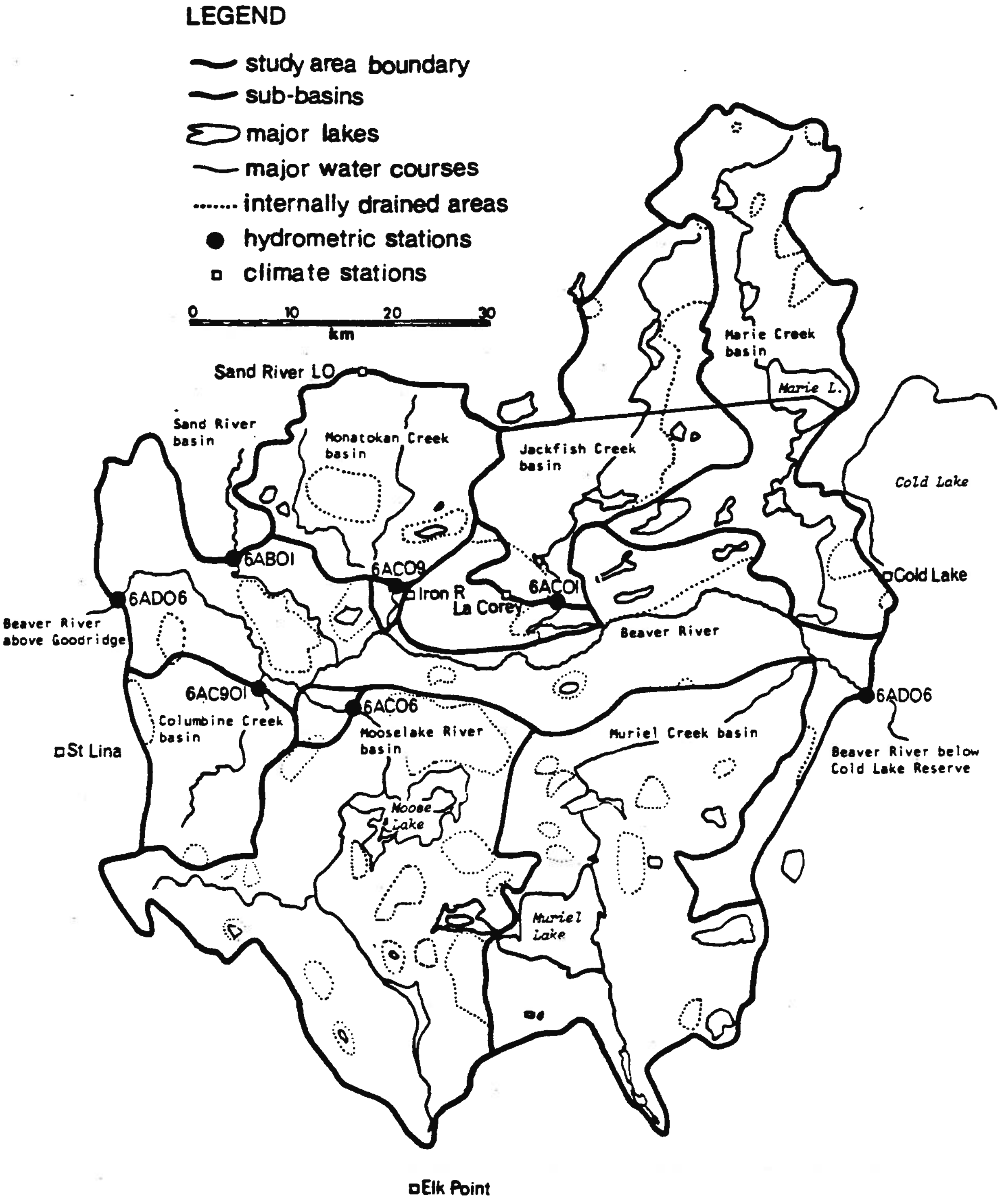


Figure 5-7 Drainage basin boundaries and hydrologic features of the lower Beaver River basin

Table 5-4 Sub-basin drainage areas, lower Beaver River basin

Hydrometric Station	Drainage Areas				
	Gross	Internal		Effective	
	km^2	km^2	%	km^2	%
6AA901 Columbine Ck	243	13	5.3	230	94.7
6AC009 Monotokan Ck	385	46	11.9	339	88.1
6AC006 Mooselake Ck	961	172	17.9	789	82.1
6AC001 Jackfish Ck *	305	79	25.9	226	74.1
Marie Ck *	295	17	5.8	278	94.2
Muriel Ck	942	116	12.3	826	87.7
Residual	1088	278	25.6	810	74.4
TOTAL	4219	721	17.1	3498	82.9

* Drainage areas are within the study area boundary which truncates the upper portion of Jackfish and Marie Creeks. The total gross areas of these basins are 501 and 697 km^2, respectively.

HYDROMETEOROLOGICAL REGIME

CONCEPTUAL FRAMEWORK

The hydrologic cycle can be schematically presented as having four major components: precipitation, atmospheric losses, runoff, and basin storage. There are several sub-divisions of each component (figure 5-8). The components may be evaluated using a simple continuity, or water-budget, approach:

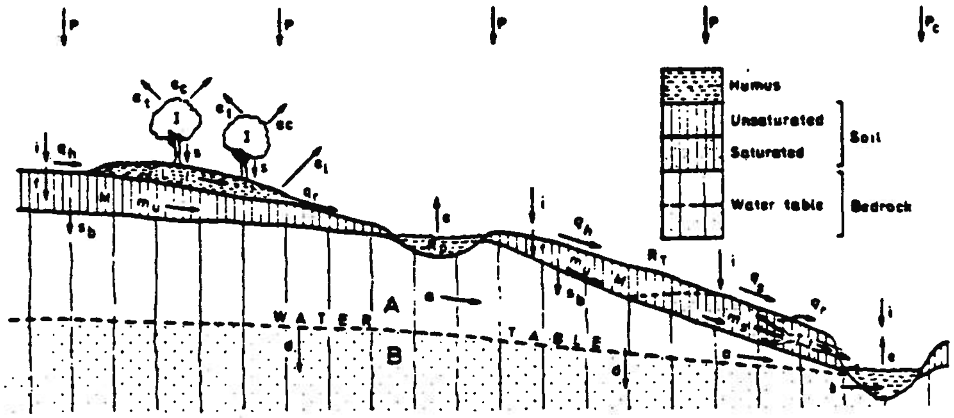
$$Q = P - A \pm Sc \tag{4}$$

Where: Q = runoff
P = precipitation
A = atmospheric loss
Sc = changes in storage

The equation can be rearranged to isolate the storage, or groundwater flux, term:

$$Sc = P - Q - A \tag{5}$$

The major difficultly in such an approach is obtaining measurements, or estimates, of the variables with sufficient accuracy to have confidence in the residual, or storage, term. The average monthly and annual precipitation have been discussed. The surface water runoff can be quantified from hydrometric data from several stations in the area (figure 5-1, table 5-5). Atmospheric losses and changes in storage are very difficult to measure, therefore, estimates have to be made of these components.



Precipitation (gross rainfall)	P	Horton overland flow	q_h
Channel precipitation	P_c	Saturated overland flow	q_s
Precipitation intensity	i	Return flow	q_r
Evapotranspiration	e_t	Pipe flow	t
Canopy interception loss	e_c	Pipe storage	T
Interception and canopy storage	I	Unsaturated throughflow	m_u
Stemflow and drip	s	Saturated throughflow	m_s
Litter flow	l	Soil-moisture storage	M
Litter interception loss	e_l	Seepage into bedrock	s_b
Litter storage	L	Interflow in bedrock	a
Evaporation	e	Aeration zone storage	A
Depression storage	R_p	Deep seepage	d
Detention storage	R_T	Baseflow	b
Infiltration	f	Groundwater storage	B

Figure 5-8 Components of the hydrologic cycle (source: Chorley, 1978)

Table 5-5 Hydrometric stations in the lower Beaver River basin

Station	Area (km^2)	Record
Beaver River at Cold Lake Reserve, 06AD006	14447	1955 - 69 MC 70-81 RC
Beaver River near Goodridge, 06AA001	4710	1967 - 81 RS
Columbine Creek near Glendon, 06AA901	243	1977 - 81 RS
Jackfish Creek near La Corey, 06AC001	501	1971 - M 1972 - 81 RS
Menatokan Creek near Iron River, 06AC009	385	1981 RS
Mooselake Creek near Franchere	961	1980 - 81 RS
Sand River near the mouth, 06AB001	4920	1967 - 81 RS

M Manual guage
R Recording guage

C Continuous operation (12 months)
S Seasonal operation (March to October)

STREAMFLOW

There are several streamflow gauging stations which can be used to describe the runoff regime of the lower Beaver River basin (table 5-5, figure 5-7). These streamflow records are of varying length (1 to 26 years) and for various periods (seasonal and annual). In order to describe the hydrologic response of the study area, it is necessary to estimate the streamflow throughout the year. Further, because the more recent period appears to be wetter than the long term, it is necessary to standardize the period of record. The average annual discharge of the Beaver River at Cold Lake Reserve was 915 550 da m^3 in the period 1970 to 1980, which is 16 percent larger than the average annual discharge of 787 570 da m^3 in the period 1956 to 1969. The Beaver River at Cold Lake Reserve, which had the longest record in the basin, was considered a suitable base period, because the record at this station (1956 to present) almost coincides with the climatic normal period, 1950 to 1980, which was used to describe the climate.

The records of the Sand River, Jackfish Creek, Beaver River and Goodridge hydrometric stations were extended by correlation with the Beaver River at Cold Lake Reserve for each month of coincident record (table 5-6) using monthly averages. The October correlations with Cold Lake Reserve were used to predict the November and December discharges, and the March relations were used to predict the January and February discharges, at each station.

The correlation of discharge at Cold Lake Reserve with individual stations for particular months, range from very weak to very strong (r^2 = 0.08 to 0.97) (table 5-6). To check the resulting discharge estimates (table 5-7), an alternative approach was employed. The average monthly discharge of each of the hydrometric stations was compared with the coincident discharge at Cold Lake Reserve. The ratio of the discharge of each station to that of Cold Lake Reserve was multiplied by the long-term discharge at each

Table 5-6 Runoff relations between the Beaver River at Cold Lake Reserve and other hydrometric stations

Beaver River at Goodridge, 06AA001

Month	Adopted Relation	Correlation Coefficient (r^2)	Years of Record
March	$GR = 0.355\ CLR - 0.425$	0.63	12
April	$= 0.394\ CLR + 0.1380$	0.91	12
May	$= 0.141\ CLR^{1.144}$	0.91	13
June	$= 0.149\ CLR^{1.133}$	0.88	13
July	$= 0.113\ CLR^{1.162}$	0.90	13
August	$= 0.090\ CLR^{1.195}$	0.66	14
September	$= 0.177\ CLR^{1.022}$	0.57	14
October	$= 0.123\ CLR^{1.110}$	0.66	14

Sand River at the mouth, 06AB001

March	$SR = 0.364\ CLR + 0.825$	0.90	12
April	$= 0.382\ CLR - 0.730$	0.94	12
May	$= 0.500\ CLR - 1.795$	0.97	12
June	$= 0.646\ CLR^{0.944}$	0.94	13
July	$= 0.613\ CLR - 0.211$	0.97	13
August	$= 0.737\ CLR^{0.927}$	0.86	13
September	$= 0.577\ CLR^{1.018}$	0.93	13
October	$= 0.624\ CLR - 0.009$	0.87	12

Where: CLR is the mean monthly discharge of the Beaver River at Cold Lake Reserve and GR and SR are the corresponding discharge at Goodridge and Sand River, respectively in m /s.

Con't

Table 5-6 continued

Jackfish Creek near La Corey, 06AC001

Month	Adopted Relation	Correlation Coefficient (r^2)	Years of record
March	JF = 0.0107 CLR +0.075		9
April	= 0.0308 CLR -0.105	0.94	9
May	= 0.0396 CLR -0.450	0.93	9
June	= 0.001 $\mathrm{CLR}^{1.703}$	0.90	9
July	= 0.002 $\mathrm{CLR}^{1.622}$	0.86	9
August	= 0.0175 CLR -0.050	0.49	9
September	= 0.009 $\mathrm{CLR}^{0.932}$	0.46	9
October	= 0.006 CLR + .011	0.31	7

Where: JF is the mean monthly discharge at Jackfish Creek and CLR is the corresponding discharge of the Beaver River at Cold Lake Reserve.

Table 5-7 Discharge estimates, lower Beaver River basin hydrometric stations

STATION/PERIOD		J	F	M	A	M	J	J	A	S	O	N	D	MEAN
Beaver R. Cold Lake Res.														
1956 - 1980		4.76	4.11	4.55	48.9	63.1	51.3	46.1	28.9	26.5	21.5	12.5	6.51	26.7
1968 - 1980		5.35	4.93	5.36	51.8	63.4	40.6	49.3	28.1	26.9	24.1	12.9	7.33	26.8
1969 - 1980		5.68	5.19	5.49	55.1	68.0	43.5	53.1	30.1	28.1	24.1	13.0	7.68	28.4
1972 - 1980		5.61	5.27	5.41	46.1	68.3	46.4	36.0	25.4	26.8	22.1	11.4	6.92	25.6
Beaver R. near Goodridge														
1968 - 1980				1.53	20.8	16.7	11.2	12.3	6.07	6.36	4.88			
ratio G/CLR				0.29	0.40	0.26	0.28	0.25	0.22	0.24	0.20			0.27
1956 - 1980 (1)		1.29	1.11	1.30	19.6	16.6	14.2	11.5	6.24	6.27	4.35	3.38	1.76	7.31
1956 - 1980 (2)		1.26	1.03	1.19	20.7	16.2	12.9	9.7	5.01	5.04	3.71	2.03	0.98	6.65
Sand R. near Mouth														
1969 - 1980				2.82	20.3	32.2	22.7	32.3	17.8	17.9	15.1			
ratio S/CLR				0.51	0.37	0.47	0.52	0.61	0.59	0.64	0.63			0.54
1956 - 1980 (1)		2.57	2.22	2.34	18.0	29.9	26.8	28.0	17.1	16.9	13.5	6.75	3.52	14.0
1956 - 1980 (2)		2.56	2.32	2.48	18.0	30.0	26.6	28.1	16.7	16.2	13.4	7.79	4.05	14.1
Jackfish Ck														
1972 - 1980				0.133	1.32	2.25	0.954	0.790	0.396	0.226	0.228			
ratio J/CLR				0.025	0.029	0.033	0.021	0.022	0.016	0.008	0.010			0.021
1956 - 1980 (1)		0.100	0.086	0.112	1.40	2.08	1.06	1.01	0.45	0.223	0.222	0.263	0.137	0.598
1956 - 1980 (2)		0.13	0.12	0.12	1.40	2.05	0.82	1.00	0.46	0.19	0.14	0.09	0.05	0.550
Lower Jackfish Ck´														
1956 - 1980 (2)		0.08	0.07	0.07	0.85	1.25	0.50	0.61	0.28	0.12	0.09	0.05	0.03	0.33
Lower Marie Ck´														
1956 - 1980 (2)		0.05	0.05	0.05	0.57	0.84	0.34	0.41	0.19	0.08	0.06	0.04	0.02	0.23
Study area net														
1956 - 1980 (2)	m³/s	0.76	0.59	0.71	8.27	14.1	10.7	6.93	6.56	5.0	4.20	2.55	1.41	5.17
	da m³	2039	1433	1910	21436	37705	27659	18570	16567	12963	11251	6616	3778	162921
	mm	0.5	0.3	0.5	5.1	8.9	6.6	4.4	4.2	3.1	2.7	1.6	0.9	38.6

1956 - 1980 (1) Discharge estimates from coincident period ratios with Cold Lake Reserve (CLR).
1956 - 1980 (2) Discharge estimates from regression relationships with CLR (Table 6).
´Lower Jackfish and Marie creek estimates from area weighting.
Units m³/s, unless otherwise specified.

station. The average ratio of the station to Cold Lake Reserve was used to predict the unknown winter discharges (table 5-7).

The boundary of the area investigated truncates the Jackfish Creek and Marie Creek basins. The discharge of the lower portions of these drainage basins were estimated by area weighting (table 5-7). The runoff from the study area itself was estimated as the difference between the outflow at Cold Lake Reserve and the inflows into the study area (Sand River, Beaver River above Goodridge, upper Jackfish and upper Marie creeks).

Runoff is unevenly derived with respect to both space and time. Much of the discharge of the Beaver River at Cold Lake Reserve is derived from outside of the area investigated. The lower Beaver River basin represents 29 percent of the drainage basin above the gauge at Cold Lake Reserve, but contributes 19 percent of the average total annual discharge. Sand River produces a disproportionate amount of the total discharge at Cold Lake Reserve (53 percent of the discharge from 33 percent of the drainage area). The annual yield from Sand River is 90 mm compared with 44.5 mm for the Beaver River above Goodridge, 34.7 mm for Jackfish Creek and 38.6 mm for the lower Beaver River basin as a whole. When "effective" drainage areas are considered (table 5-3) the yield increases to 46.8 mm for Jackfish Creek and 46.6 mm for the lower Beaver River basin.

About 25 percent of the annual runoff in the lower Beaver River basin occurs in May (figure 5-9). Over 55 percent of the total annual discharge from the lower Beaver River basin occurs in the three month period April through June. About 85 percent of the total annual runoff occurs in the six months April through September.

From figure 5-9 it is apparent that precipitation inputs and basin runoff do not appear to be coincident. About 13 percent of the annual precipitation occurs in April and May, whereas over one third of the total annual discharge occurs in this period. There is a simple reason for this temporal inequality in precipitation and runoff. Precipitation occurs mainly as snow in the period October to

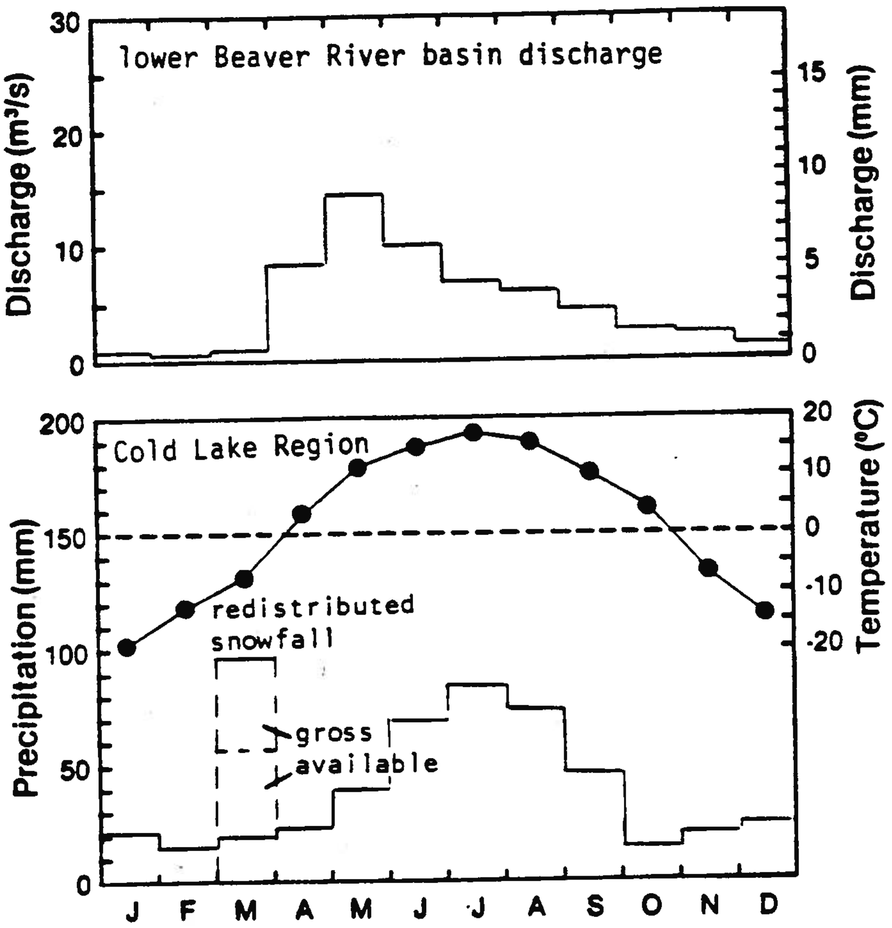


Figure 5-9 Hydrometeorological summary, Cold Lake region

April. On average, the snow cover is "permanent" from mid-November until mid-April (Potter, 1965). Consequently, although the winter precipitation is relatively small, the storage as snow and rapid release as snowmelt in spring effectively redistributes several months of winter precipitation into the short duration periods of snowmelt. However, the total or "gross" snowfall amount cannot be redistributed temporally, even within the "permanent" snowfall period, because the "permanent" snow pack is subject to losses.

Most studies do not consider sublimation losses as a major water loss during the winter when temperatures are below 0°C (for example, Louie, 1977: Steed, 1982). However, snow course data at Cold Lake Airport suggest considerable losses take place. For 12 years of record, in the period 1966 to 1979, the average water equivalence of snow on the ground on April 1 was 55.5 mm, with a standard deviation of 56.4 mm. For this same period there was no snow cover by April 1 for a quarter of the years of record and snow cover was never recorded beyond April 15. Thus, almost half of the winter precipitation (November to March, inclusive) of 103 mm is lost. On average, 55.5 mm of the winter precipitation is actually "available" for snowmelt runoff in April (figure 5-9).

Combinations of snowmelt and rainfall in April have produced the annual peak flow every other year. Rainfall, which occurs during the spring flood recession while flows are still relatively high, produces annual maximum floods in May or June about once every four years. Annual flood peaks from rainfall alone occur during the summer months and are generally smaller than the spring floods (table 5-8).

Mean monthly flows decrease from the spring melt period to reach a minimum in February (table 5-7, figure 5-9). Minimum daily flows occur most frequently in December (table 5-8). Average discharge from the lower Beaver River basin is equivalent to 3.3 mm of runoff from November to March.

Table 5-8 Annual extremes of discharge and total annual discharge for the period of record, lower Beaver River basin hydrometric stations

Beaver River at Cold Lake Reserve - Station No. 06AD006
(Annual Record)

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE (m^3/s)	MAXIMUM DAILY DISCHARGE (m^3/s)	MINIMUM DAILY DISCHARGE (m^3/s)	TOTAL DISCHARGE (dam^3)
1955	---	---	---	---
1956	---	214 ON APR 26	1.98 B ON JAN 1	1 360 000
1957	---	82.4 ON APR 27	2.10 B ON MAR 1	464 000
1958	118 AT 14:00 MST ON APR 11	116 ON APR 11	1.76 B ON DEC 20	555 000
1959	62.9 AT 08:30 MST ON SEP 8	62.6 ON SEP 7	0.963B ON FEB 17	518 000
1960	---	154 ON AUG 3	0.566B ON FEB 17	1 370 000
1961	105 AT 18:00 MST ON APR 28	105 ON APR 28	1.68 B ON DEC 26	675 000
1962	617 AT 03:00 MST ON JUN 13*	612 ON JUN 13*	1.65 B ON JAN 2	1 920 000
1963	---	275 ON APR 19	1.03 B ON DEC 20	884 000
1964	---	41.9 ON MAY 14	0.368B ON FEB 14*	354 000
1965	---	159 ON JUN 7	2.06 B ON MAR 30	989 000
1966	---	73.3 ON APR 10	2.86 B ON FEB 4	596 000
1967	---	101 B ON MAY 1	1.30 ON DEC 31	423 000
1968	---	36.2 ON OCT 1	1.18 B ON JAN 10	241 000
1969	---	162 ON APR 20	1.44 B ON FEB 28	677 000
1970	263 AT 12:38 MST ON JUL 10	261 ON JUL 10	3.00 B ON FEB 17	1 410 000
1971	275 AT 18:00 MST ON APR 20	268 ON APR 25	3.54 B ON DEC 25	1 400 000
1972	110 AT 10:30 MST ON MAY 3	109 ON MAY 3	1.64 B ON DEC 14	489 000
1973	104 AT 06:30 MST ON JUN 23	103 ON JUN 22	1.78 B ON MAR 11	881 000
1974		394 A ON APR 26	6.71 ON DEC 31	1 700 000
1975	159 E AT 23:00 MST ON APR 25	135 ON APR 26	5.55 B ON APR 3	1 050 000
1976	99.7 AT 15:00 MST ON JUL 20	99.1 ON JUL 20	3.40 B ON DEC 15	624 000
1977	70.5 AT 00:00 MST ON APR 17	51.3 ON MAY 31	4.02 B ON JAN 1	479 000
1978	171 AT 04:00 MST ON JUN 6	168 ON JUN 6	4.84 B ON MAR 1	750 000
1979	205 B AT 09:50 MST ON APR 26	181 B ON APR 26	4.05 B ON DEC 30	831 000
1980	160 AT 09:45 MST ON APR 16	106 ON APR 16	2.88 B ON MAR 12	457 000

Beaver River near Goodridge - Station No. 06AA001
(March to October record)

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE (m^3/s)	MAXIMUM DAILY DISCHARGE (m^3/s)	MINIMUM DAILY DISCHARGE $m^3/s)$	TOTAL DISCHARGE (dam^3)
1967	---	---	---	---
1968	---	7.36B ON MAR 27	0.142B ON MAR 1	27 200
1969	---	---	---	---
1970	79.6 AT 12:20 MST ON JUL 6	79.0 ON JUL 6	0.283B ON MAR 1	322 000
1971	127 AT 00:30 MST ON APR 22	126 ON APR 22	1.77 B ON OCT 27	478 000
1972	34.5 AT 02:20 MST ON APR 28	34.3 ON APR 27	0.357B ON MAR 25	142 000
1973	35.7 AT 10:20 MST ON JUN 20	35.4 ON JUN 20	0.113B ON MAR 1*	108 000
1974	148 AT 23:00 MST ON APR 19*	143 ON APR 20*	1.27 B ON APR 6	400 000
1975	56.6 B AT 20:00 MST ON APR 23	42.8 ON APR 24	1.33 ON MAR 24	226 000
1976	---	22.9B ON APR 9	0.575 ON OCT 7	93 600
1977	26.2 AT 19:15 MST ON MAY 20	26.0 ON MAY 20	0.623B ON MAR 22	126 000
1978	94.3 AT 16:15 MST ON JUN 2	92.9 ON JUN 2	0.150B ON MAR 21	296 000
1979	74.6 B AT 19:30 MST ON APR 23	71.2 ON APR 24	1.60 ON OCT 25	303 000
1980	29.0 AT 13:30 MST ON APR 12	28.5 ON APR 13	0.344 ON JUL 22	70 600

Table 8 continued

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE (m³/s)	MAXIMUM DAILY DISCHARGE (m³/s)	MINIMUM DAILY DISCHARGE (m³/s)	TOTAL DISCHARGE (dam³)
1967	---	---	---	---
1968	---	---	---	---
1969	---	67.4 ON APR 22	0.850B ON MAR 1*	322 000
1970	161 AT 17:38 MST ON JUL 7	159 ON JUL 7	2.27 B ON MAR 1	698 000
1971	115 AT 09:00 MST ON APR 27	114 ON APR 26	3.68 B ON MAR 5	595 000
1972	67.7 AT 15:00 MST ON MAY 3	67.4 ON MAY 1	1.78 ON SEP 13	207 000
1973	69.4 AT 22:30 MST ON AUG 30	69.1 ON AUG 31	0.850B ON MAR 1	528 000
1974	191 AT 11:00 MST ON APR 27*	190 ON APR 27*	3.68B ON MAR 1	731 000
1975	84.1 AT 20:00 MST ON JUL 5	83.0 ON JUL 6	3.23B ON MAR 22	519 000
1976	103 AT 13:30 MST ON JUL 18	97.7 ON JUL 18	2.97B ON MAR 14	386 000
1977	---	25.5B ON APR 18	2.28B ON MAR 22	210 000
1978	57.2 AT 17:00 MST ON JUN 2	56.6 ON MAY 31	2.19B ON MAR 1	294 000
1979	57.0 AT 23:20 MST ON JUN 17	57.0 ON JUN 17	2.89B ON MAR 1	348 000
1980	42.9 AT 16:20 MST ON AUG 14	42.8 ON AUG 15	1.97B ON MAR 1	271 000

Jackfish Creek near La Corey - Station No. 06AC001
(March to October record)

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE (m³/s)	MAXIMUM DAILY DISCHARGE (m³/s)	MINIMUM DAILY DISCHARGE (m³/s)	TOTAL DISCHARGE (dam³)
1972	---	3.26B ON APR 24	0.014E ON SEP 3	11 100
1973	2.26B AT 06:30 MST ON APR 14	1.85 ON MAY 11	0.085B ON MAR 1	18 800
1874	13.2 AT 06:00 MST ON MAY 3*	13.1 ON MAY 3*	0.009 ON OCT 22	46 400
1975	---	4.11 ON JUL 7	0.042B ON MAR 1	29 800
1976	2.32 AT 23:00 MST ON JUL 21	2.31 ON JUL 21	0.014B ON OCT 27	10 300
1977	---	0.779BON APR 20	0 B ON MAR 1*	5 740
1978	2.80B AT 09:00 MST ON APR 29	2.80B ON APR 29	0.003 ON SEP 20	13 900
1979	3.47B AT 12:00 MST ON MAY 2	2.47B ON APR 20	0.022B ON MAR 14	9 380
1980	2.85 AT 07:40 MST ON APR 22	1.65 ON APR 22	0.001 ON MAY 27	4 370

B - Ice Conditions
E - Estimated
* - Extreme recorded for the period of record

LAKE EVAPORATION

Atmospheric losses are estimated from evaporation pan measurements and from empirical correlations with climatic data. The methods employed are discussed in the following sections and in more detail in Appendix A.

The nearest climate station that records pan evaporation is Vegreville, which is located about 130 km southwest of the study area at a similar elevation (636 m). For eight years of record, the average annual class A pan evaporation is 831 mm (table 5-9). "Lake evaporation", which is defined as the evaporation from small, natural, open-water bodies with negligible heat storage, can be estimated from the pan data using monthly wind, air and water temperature data (Treidl, 1979). The average annual lake evaporation, thus defined, is 628 mm, with most of the loss occurring in the period May to August (table 5-10).

Several popular formulae were used to estimate lake evaporation using climatic data from Cold Lake Airport and surrounding climatic stations (table 5-11 and 5-12). Bothe (1981) estimated average annual lake evaporation for lakes in Alberta using Morton's (1979) energy balance approach. For the period 1973 to 1978, average annual lake evaporation of 641 mm was predicted. The Christiansen (1968) method, based on radiation, temperature, wind, humidity and elevation, predicted an annual pan evaporation of 985 mm, which corresponds with 745 mm of lake evaporation using Treidl's (1979) relationship between pan and lake evaporation at Cold Lake. The Penman equation, as presented by Nemec (1972), predicts an annual free-surface evaporation loss of 734 mm (table 5-12).

There is a reasonably small variation in the estimates of annual lake evaporation (table 5-12). The mean estimate is 687 mm, with a range from 628 to 745 mm. Anderson and Jobson (1982) found that lake evaporation estimates based on corrected class A pan evaporation (Kohler et al., 1955) were generally more accurate for estimating lake evaporation than the model derived by Morton (1979). Using data

Table 5-9 Class A pan evaporation at Vegreville (mm/month)

YEAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT.	TOTAL
1972			202	146	158			
1973			196	193	146	93		
1974		106	195	184	135	97		
1975		171	169	203	141	97		
1976		198	186	169	179	109		
1977		180	227	175	139	68		
1978		157	199	212	205	70		
1979		162	159	206	152			
MEAN	21E	162	192	186	157	89	24E	831

Table 5-10 Lake evaporation estimates from class A pan measurements at Vegreville (mm/month)

YEAR	APR.	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	TOTAL
1972			155	118	126			
1973			150	149	116	72		
1974		83	144	146	106	75		
1975		134	137	157	109	76		
1976		144	145	132	133	83		
1977		136	170	133	110	54		
1978			141	149	144	49		
1979		114	112	145	107			
MEAN	16E	122	144	141	119	68	18E	628

Data Source: Atmospheric Environment Service unpublished data

E: Estimate based on Slave Lake class A pan data in Treidl (1979)

Table 5-11 Mean monthly values of climatic parameters for Cold Lake Airport

PARAMETER / MONTH	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YEAR
a Precipitation (mm)	22.1	15.8	20.1	21.6	39.7	71.9	85.6	76.2	44.9	16.9	20.3	24.8	459.9
1 Radiation (mm water evaporated/day)	2.60	4.84	8.04	11.95	15.01	16.61	15.92	13.37	9.62	6.04	3.32	2.12	3336.6
a Bright Sunshine, n/ month (hours)	90.8	125.2	171.8	228.2	272.1	282.7	312.6	255.3	175.4	154.8	94.3	76.4	2239.6
a Maximum Sunshine, N/ month (hours)	256.1	274.3	364.0	418.9	488.9	502.8	504.8	457.0	383.4	327.6	263.9	240.1	4481.8
a Bright/Max. Sunshine (%)	35.5	45.6	47.2	54.5	55.7	56.2	61.9	55.9	45.7	47.3	35.7	31.8	50.0
a Air Temperature (^{o}C)	-19.0	-13.6	-7.6	2.9	10.4	14.5	16.9	15.5	9.8	4.5	-6.2	-14.2	1.2
2 Dew Point Temperature (^{o}C)	-20.3	-16.0	-9.7	-4.0	1.5	7.1	10.6	9.8	4.9	-1.2	-9.1	-20.8	-3.9
2 Vapour Pressure (Kpa)	0.16	0.23	0.33	0.49	0.73	1.07	1.31	1.28	0.90	0.59	0.35	0.16	0.63
2 Saturation Vapour Pressure (Kpa)	0.22	0.34	0.54	1.03	1.66	2.11	2.39	2.14	1.47	1.00	0.47	0.21	1.13
2 Relative Humidity (%)	71.8	66.2	62.3	49.4	44.2	49.8	55.1	59.5	62.2	59.4	75.3	79.0	55.7
3a Wind (m/s)	3.31	3.31	3.58	4.11	4.36	4.00	3.75	3.53	3.94	4.03	3.69	3.33	3.75

a Source: Canadian Climatic Normals, Atmospheric Environment Service (AES)

1 Radiation refers to the mean monthly extra-terrestrial radiation on a horizontal plane expressed in mm of water evaporated per day (Source: Gray, 1970)

3 At an elevation of 10m above the ground

2 An average of readings at 11:00 and 17:00 hours (based on 10 years of records), from the Monthly Record, Meteorological Observations in Canada, published by AES.

Table 5-12 Estimates of annual lake evaporation (mm/month) derived by various methods using climatic normals (1951-1980)

Method	APR	MAY	JUN	JUL	AUG	SEP	OCT	YEAR
Class A Pan	16	122	144	141	119	68	18	628
Christiansen (1968)	70	137	155	162	118	68	35	745
Morton (1979)	66	108	131	143	101	50	20	641+
Penman (Nemec, 1972)	80	130	146	152	114	65	47	734
Mean	58	124	144	150	113	63	30	687
Std. deviation	29	12	10	10	8	9	14	61

+ The Morton approach predicts evaporation of 1 mm in February, 19 mm in March and 2 mm in November from 1973 to 1980 inclusive data, whereas the other methods predict no evaporation in months when mean air temperature is $\leq 0^\circ$C.

from 30 lakes in the U.S.A., they found Morton's model over-predicted lake evaporation by 34 percent and Kohler et al. (1959) under-predicted lake evaporation by 9 percent. Thus, the pan estimate is selected to represent lake evaporation for the lower Beaver River basin. On average, an additional 47.5 mm of evaporation from snowpack occurs. Thus, the lakes have a net average annual evaporative loss of 215.5 mm.

EVAPOTRANSPIRATION

Evapotranspiration is the water loss to the atmosphere which takes place by evaporation from the soil and plant surfaces and by transpiration from plants. Potential evapotranspiration (PET) is the amount of water that would be evaporated or transpired from a vegetated surface if there was sufficient water in the soil at all times for the use of vegetation. Actual evapotranspiration is generally less because of the inequality in the amount and timing of precipitation and atmospheric losses.

A large number of evapotranspiration formulae exist. McGuiness and Bordne (1972) evaluated 14 formulae against 15 years of lysimeter-derived PET measurements at Coshocton, Ohio. The formulae may be ranked in terms of the minimum deviation from measured PET: 1. Christiansen (1968); 2. Jensen and Haise (1963): 3. Penman (1948); 4. Blaney and Criddle (1950); 5. Van Bavel (1966): and 6. class A pan evaporation. The Thornthwaite (1948) method, ranked eleventh, was the approach favoured by Laycock (1967) in the prairie provinces and was used by Phillips (1976) for the whole of Canada.

The formulae by Christiansen (1968), Jensen and Haise (1963), Penman (1948), Thornthwaite (1948), and pan evaporation measurements, are used to estimate potential evapotranspiration with climatic normals as the climatic input (table 5-13). Corrections for forest-interception-losses are also included (Calder and Newson, 1979). These were corrected for North American conditions (Appendix A). The Van Bavel (1966) method is similar to Penman's

Table 5-13 Estimates of potential evapotranspiration (mm/month) calculated by various methods using climatic normals (1951 - 1980) for Cold Lake.

	Method	APR	MAY	JUN	JUL	AUG	SEP	OCT	YEAR
a	Clader and Newson (1979)	62	115	130	135	101	51	37	631
b	Christiansen (1968)	47	93	106	110	80	46	24	506
c	Jensen and Haise (1963)	29	86	118	135	96	42	15	520
d	Penman (1948)	56	104	117	122	92	46	33	569
	Thornthwaite (1948)	22	78	111	124	104	60	25	524
e	Meyboom (1967)	12	94	111	108	91	52	14	482
Mean		38	95	116	122	94	50	25	539
Standard Deviation		20	13	8	12	9	6	9	53

a Uses Penman PET estimate for low vegetation and a correction for forest interception loss and rainfall.

b Christiansen's pan evaporation estimate multiplied by a consumptive use coefficient of 0.68 (Sonmor, 1963).

c Using Budyko's cloudless day radiation values.

d Nemec's (1972) nonogram method with Penman's seasonal consumptive use estimates.

e Class A pan evaporation multiplied by a consumptive use coefficient of 0.58 for phreatophyte vegetation in Saskatchewan.

formula, thus it was not used, and the Blaney and Criddle (1950) formula was not used because empirical constants are not available for Cold Lake.

The average annual PET estimates are calculated from climatic normal data, which provides an estimate of PET for long-term average monthly climatic conditions. No indication of variance in PET from year to year is given. In order to evaluate variations in PET annually and for given months, an analysis of monthly climatic data was undertaken using the Thornthwaite method (table 5-14). Two conclusions emerge from this analysis. Climatic normals fairly represent the average PET estimated from each year of data (means of 524 and 528 mm, respectively) and there appears to be a limited variation in the annual PET estimates (a range from 506 to 559 mm). The largest variations in monthly PET estimates tend to occur at the beginning and end of the period with atmospheric losses (table 5-14).

The annual PET estimates average 539 mm, with a range from 482 to 631 mm. The two highest estimates, by the Penman, and Calder and Newson methods, are related. Calder and Newson use Penman's method to predict PET losses from short vegetation and add a correction for interception losses and lack of transpiration during rain periods (see Appendix A). The other PET estimates have a limited range of 482 to 524 mm per year. Two of these methods are also related. In the Christiansen method class A pan evaporation is estimated, converted to lake evaporation, and converted again to PET. The coefficients averaged 0.755 (Treidl, 1979) and 0.68 (Sonmor, 1963) for southern Alberta, respectively, resulting in an estimated annual PET of 506 mm. Meyboom (1967) multiplied pan evaporation by 0.58 to estimate phreatophyte consumption in southern Saskatchewan, which results in a predicted PET of 482 mm.

Because there is quite a large variation in the estimates of PET, a choice has to be made in selecting a representative PET value. In view of the uncertainity of the appropriateness of any one formula, an average of all the formulae is taken to represent PET.

Table 5-14 Variations in potential evapotranspiration estimates by the Thornthwaite method for each month in the period 1963 to 1982.

Year	Apr	May	Jun	Jul	Aug	Sept	Oct	TOTAL
1963	23.6	65.6	111.4	134.3	110.6	74.0	39.7	559
1964	24.3	81.8	114.0	131.4	98.0	49.4	34.6	534
1965	22.5	72.4	107.8	133.6	111.3	31.7	35.6	515
1966	5.7	84.4	101.2	123.8	100.9	72.6	21.2	510
1967	0.0	71.0	98.7	122.9	116.4	81.6	19.6	510
1968	26.0	77.6	110.2	122.8	95.9	62.4	23.0	518
1969	50.5	82.0	108.4	125.8	115.3	63.2	6.7	552
1970	23.0	76.2	123.9	126.8	107.1	56.4	20.0	533
1971	26.5	95.1	107.4	84.9	117.7	54.9	23.7	510
1972	17.9	93.5	118.7	111.0	118.0	36.7	10.3	506
1973	19.4	86.8	108.3	126.5	106.9	59.5	24.9	532
1974	31.6	62.0	115.0	124.3	96.0	52.7	36.5	518
1975	9.8	75.6	105.0	137.2	92.3	64.5	24.7	509
1976	46.3	83.0	101.3	123.2	113.7	71.5	14.3	553
1977	45.9	93.3	114.1	110.9	84.6	57.6	29.8	536
1978	26.8	78.5	113.2	122.0	97.4	58.2	35.6	532
1979	0.0	65.1	104.3	136.2	104.4	67.1	31.9	509
1980	59.5	87.1	108.1	123.8	95.0	52.7	32.7	559
1981	27.9	86.9	99.9	124.5	125.3	67.7	14.8	547
1982	4.1	74.9	115.6	124.9	92.9	65.1	30.4	508
Mean:	24.6	79.6	109.3	123.5	105.0	60.0	25.5	528
std.dev.:	16.5	9.5	6.6	11.4	10.9	12.0	9.4	19

Thus, as a first approximation, the mean PET value of 539 mm per year is used in water balance calculations.

WATER BALANCE ESTIMATES

Introduction

From the schematic view of the hydrologic cycle (figure 5-8) it is apparent that precipitation may take several paths once it strikes the Earth's surface. There are both vertical and horizontal fluxes of water in the land phase. The vertical fluxes may be upward (evaporation and evapotranspiration) or downward (recharge). Horizontal fluxes may occur over, or through, the regolith. The magnitude of the fluxes are determined largely by boundary conditions. Surface horizontal fluxes of water may be ignored when the ground is not frozen. Verma and Toogood (1969) found that soils in the Edmonton area readily absorb rain falling at the maximum one hour intensities which are likely to occur. Hence, there is a very slight chance of infiltration excess overland flow occurring. Further, in-channel precipitation is also insignificant because of the small area involved (0.15 percent of the lower Beaver River basin).

Vertical water fluxes are determined by atmospheric losses and soil moisture retention capacity in the root zone. Laycock (pers. comm.) has assigned soil moisture storage capacity according to land use. The land use pattern, hence moisture storage capacities, is relatively complicated. Although each of the four major soil moisture storage units (100, 150, 200 and 250 mm) occurs in each physiographic zone, there is some generality to the pattern. The plains areas tend to be predominantly cropland or pasture, and the uplands and highlands, which form the northern and southern boundaries of the lower Beaver River basin, are largely forested. Drainage basins within the basin are composed of a combination of small and large land use classes with different storages. To simplify analysis, the average soil moisture storage has been calculated for each of the major physiographic units. The land uses by map-sheet were assigned a storage value (table 5-1) and the area of each storage unit in each physiographic division was determined from figures 5-2 and 5-5. The Beaver River Lowland and Kehiwin Upland Plain have an area-weighted average storage of 143 and 163 mm, respectively, with a range from 100 to 250 mm. The Muriel Lake Highlands in the north, and the southern highlands, have an area-weighted average storage of 199 and 208 mm, respectively. The highland areas are composed almost exclusively of 150 and 250 mm storage units.

Calculation of the Water Balance

The calculation of a water balance for an area requires a detailed record of precipitation (P) and information on potential evapotranspiration (PET) and soil moisture status (Appendix B). Potential evapotranspiration is subtracted from precipitation, which then identifies periods of potential water recharge or plant utilization of moisture from the soil. The deficit is the difference between potential and actual evapotranspiration. Surplus is the excess P-PET, whenever soil moisture storage is at field capacity. Once the water-holding capacity (field capacity) of the upper soil layers is satisfied, the excess runs off. In the water balance computation, it is assumed that 50 percent of the available surplus in any month will run off. The remainder is held over and added to the surplus in the following month and thus made available for runoff in that month (of which only 50 percent will run off) (Appendix B).

A conventional water balance (Mather, 1978) was calculated for a 100 mm soil storage which represents the cropped area of the central part of the lower Beaver River basin. The Iron River climate station (elevation 549 m) was used to represent the lowland precipitation (figure 5-7). The snowfall was adjusted to reflect sublimation losses, using the Cold Lake Airport snow course relation between gross and available snowfall. There is no surplus moisture for runoff in the conventional water balance (table 5-15), although streamflow estimates indicate that the gross drainage area produces 38.6 mm of runoff per year on average (table 5-7). Hence, it is necessary to investigate special environmental conditions which are not generally described in such studies.

There are three major environmental factors which appear to be significant in the water balance: the effect of freezing and thawing of the ground; the mode of snow removal; and the paths of snowmelt runoff. From table 5-3, it is apparent that in the period November to March the soil is frozen from near the surface to progressively greater depths with time. During this period, precipitation occurs primarily as snow that is stored on the ground, which subsequently melts mainly in April (figure 5-9). The snowpack is subject to significant losses, approximately 45 percent, in water equivalence, during this period. The path of this water loss is critical in determining the water balance.

Snowpack water losses are considered to be largely due to sublimation - that is, direct evaporation into the atmosphere, because chinook conditions (mean daily temperatures above 3.9°C) occur an average of 4 to 5 days per winter at Cold Lake (Longley, 1967). Also, measurements by Price et al., (1978) in a high-clay-content soil under boreal forest at Schefferville, Quebec (54° 48'N, 66° 48'W) demonstrated that during active snowmelt, a shallow saturated layer developed at the base of the snowpack. Infiltration and subsurface runoff were negligible. Runoff occurred as Hortonian overland flow, the volume of which corresponded closely to the total amount of snow water equivalence on the 2000 m^2 plots. Thus, the "available precipitation" is taken to be represented by the average water equivalent snow storage on April 1 (figure 5-9).

If it is assumed that the clay loams of the lower Beaver River basin are impermeable when frozen, as at Schefferville, then in terms of a water balance, the soil moisture status would not change

Table 5-15 The water balance for the Beaver River Lowlands, given a 100 mm soil moisture storage, the average potential evapotranspiration of several methods, and estimated available precipitation at Iron River

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR (mm)
Temperature	-19	-14	-8	3	10	15	17	16	10	5	-6	-14	
Precipitation	10	7	10	17	36	70	79	72	42	16	10	10	379
PET	0	0	0	38	95	116	122	94	50	25	0	0	539
P-PET	10	7	10	-21	-59	-46	-43	-22	-8	-9	10	10	-161
Storage	42	49	59	81	44	27	18	14	13	12	22	32	
Storage	10	7	10	22	-37	-17	-9	-4	-1	-1	10	10	
AET	0	0	0	38	73	87	88	76	43	17	0	0	422
Defecit	0	0	0	0	22	19	44	18	7	8	0	0	118
Surplus	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0

appreciably with time from the onset of freezing to thaw, if water movements to the freezing front are ignored. The soil is frozen in March and thawed by May (table 5-3). The average thawed depth in April, based on a correlation of soil temperature and depth, is estimated to be 0.44 m. If the depth of thaw is zero on April 1, and 0.44 m in mid-April, then, as an approximation, the average depths of thaw would be 0.22 m and 0.66 m in the first and second half of April, respectively. Given these approximations, the water balance can be calculated. The computations should be undertaken over a two-year period so that the given starting soil moisture status (81 mm in April; table A6 Mather, 1978; Appendix B) achieves an equilibrium with precipitation and PET.

In year one, the soil moisture storage would not change from the end of October through March because the soil is frozen and impermeable (table 5-16). The moisture content at the end of March would be 12 mm. In the first half of April, the thaw depth is 0.22 m. The non-frozen moisture content is thus 2.6 mm (12 x 0.22). In addition, snow melt occurs and contributes 47 mm of water during the first half of April. The non-frozen soil moisture content would increase by the addition of snowmelt (47 plus 2.6 mm), to a maximum moisture content of 22 mm (100 mm storage x 0.22 m). A surplus of 27.6 mm results (49.6 - 22 mm). In addition, it is assumed that half of the monthly precipitation of 17 mm falls in the first half of April. The total surplus is therefore 36.1 mm (27.6 plus 8.5 mm). In the second half of April, the average thaw depth is 0.66 m and the soil moisture content is 22 mm in the upper 0.22 m and 5.3 mm in the 0.22 to 0.66 m soil zone (0.44 x 12 mm), for a total soil moisture content of 27.3 mm. In addition, 8.5 mm of precipitation occurs which brings the soil moisture content to 35.8 mm. PET (38 mm) can use up this moisture, resulting in a slight moisture deficit. Throughout the rest of spring and summer, PET exceeds the moisture supply, therefore, no further runoff occurs. The total surplus of 36.1 mm occurs in the first half of April in year one.

Table 5-16 The water balance for the Beaver River Lowlands, given a 100 mm soil moisture storage, the average potential evapotranspiration of several methods, the estimated available precipitation at Iron River, and frozen soil conditions.

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR (mm)
Temperature °C	-19	-14	-8	3	10	15	17	16	10	5	-6	-14	
Precipitation	10	7	10	17	36	70	79	72	42	16	10	10	379
PET	0	0	0	38	95	116	122	94	50	25	0	0	539
P-PET	10	7	0	-21	-59	-46	-43	-22	-8	-9	10	10	-161
Storage (yr 1)	12	12	12	12*	44	27	18	14	13	12	12	12	
Storage (yr 2)	0	0	0	*	0	0	0	0	0	0	0	0	
Snow Storage	10	7	10								10	10	47
Surplus				33.5									33.5
Runoff				16.8	8.4	4.2	2.1	1.0	0.5	0.3	0.15		33.5

* See text for explanation.

In the second year there is no soil moisture available following the spring melt. Before runoff can occur, the soil moisture has to be replenished up to field capacity (22 mm). Therefore, the surplus of 33.5 mm results from precipitation (8.5 mm), plus snowmelt (47 mm), minus soil moisture recharge. In the second half of April, the soil moisture is utilized by PET and deficits occur from that period throughout the year.

In conventional water balances 50 percent of the surplus runs off in any given month. A 33.5 mm surplus in early April would therefore result in 16.8 mm runoff in April, 8.4 mm in May, 4.2 mm in June, 2.1 mm in July, 1.0 mm in August, 0.5 mm in September, 0.3 mm in October and 0.1 mm in November. Although such an apportionment of runoff with time may reasonably simulate the quantity and timing of measured runoff, the apportionment procedure in questionable. Even if the surplus could be apportioned differently, however, the procedure would be equally subjective. The important point is that the estimated quantity of runoff is fairly close to the measured runoff. Therefore, the frozen-ground approach is used to predict the water balance for other locations and soil moisture storages within the lower Beaver River basin (tables 5-17 and 5-18).

The precipitation recorded at St. Lina (elevation 632 m) is used to represent the Keniwin Upland in the western part of the lower Beaver River basin (figures 5-2 and 5-7). The St. Lina winter precipitation values are adjusted to reflect sublimation losses using the snow course data for Cold Lake Airport. The area-weighted average soil moisture storage is 163 mm. To estimate the soil moisture status in spring, the 150 mm storage tables are used (Appendix B). In the second year a soil moisture deficit occurs throughout the year, apart from the first half of April. The basin average soil moisture storage of 163 mm in used to indicate field capacity. The relatively high atmospheric losses deplete the moisture supply so that recharge to field capacity only occurs in early April. The resulting surplus is 36.9 mm (table 5-17).

Table 5-17 The water balance for the Kehiwin Uplands, given a 150 mm soil moisture storage, the average potential evapotranspiration of several methods, estimated available precipitation at St. Lina, and frozen soil conditions

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR (mm)
Temperature	-18	-13	-8	3	10	13	10	4	9	4	-6	-14	
Precipitation	13	8	10	23	48	76	91	78	57	16	10	11	441
PET	0	0	0	38	95	116	122	94	50	25	0	0	539
P-PET	13	8	10	-15	-47	-40	-31	-16	7	-9	10	11	-99
Storage (yr 1)	52	52	52	135	98	75	61	54	61	52	52	52	
Storage (yr 2)	0	0	0	*	0	0	0	0	0	0	0	0	
Snow Storage	13	8	10								10	11	52
Surplus	0	0	0	36.9	0	0	0	0	0	0	0	0	36.9
Runoff				18.5	9.2	4.6	2.3	1.2	0.6	0.3	0.1		36.9

* See text for explanation.

Table 5-18 The water balance for the Cold Lake Highlands, given a 200 mm soil moisture storage, the average potential evapotranspiration of several methods, estimated available precipitation at St. Lina, and frozen soil conditions

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR (mm)
Temperature	-18	-13	-8	-3	10	13	16	14	9	4	-6	-14	
Precipitation	13	8	10	23	48	76	91	78	57	16	10	11	441
PET	0	0	0	38	95	116	122	94	50	25	0	0	539
P-PET	13	8	10	-15	-47	-40	-31	-16	7	-9	10	11	-99
Storage (yr 1)	92	92	92	185	146	119	102	94	101	92	92	92	
Storage (yr 2)	0	0	0		0	0	0	0	0	0	0	0	
Snow Storage	13	8	10								10	11	52
Surplus				19.5									19.5
Runoff				9.8	4.9	2.4	1.2	0.6	0.3	0.2	0.1		19.5

The highland areas, which form the northern and southern boundaries of the basin, have an average soil moisture storage capacity of about 200 mm. The average elevations along the northern topographic divide range from 640 to 730 m. The southern divide heights range from about 640 to 790 m. The St. Lina climatic station is used to represent the highland precipitation (figure 5-6; table 5-2). A surplus of 19.5 mm occurs in early April (table 5-18).

Discussion

The annual runoff from the major physiographic units of the lower Beaver River basin has been calculated from estimates of potential evapotranspiration (PET), available precipitation, soil moisture retention and depths of frozen soil. The water balance approach predicts a basin average yield of 30 mm, when frozen ground conditions are considered. The surplus is generated unevenly in time (the first half of April) and space. The annual yield of the Beaver River Lowlands, which occupy about 50 percent of the basin, is 33.5 mm. The Kehiwin Upland Plain, which occupies 20 percent of the study area, has a calculated annual yield of 36.9 mm, and the northern and southern uplands produce 19.5 mm of runoff. The calculated annual runoff of 30 mm from the water balance approach is reasonably close to the estimated long-term runoff of 38.6 mm. However, the yield from the effective drainage area is 46.6 mm. Therefore, the water balance approach predicts 64 percent of the estimated runoff.

SUMMARY AND CONCLUSIONS

A surface water balance study was undertaken to estimate the magnitude of groundwater fluxes in the lower Beaver River basin. The basin is relatively flat, with largely till-derived clay-loam soil, and there are numerous lakes and sloughs. About 17 percent of the 4219 km^2 study area is internally drained. The northern and southern uplands are largely forested whereas the central belt is largely cropland and pasture. The former units have an area-weighted average soil moisture storage of 200 mm and the central lowland has a 150 mm storage.

Streamflow data from various hydrometric stations in the study area and vicinity were analysed and the record of relevant stations were extended to a common long-term base period (1956 to 1980) by correlation with coincident discharges of the Beaver River at Cold Lake Reserve. The average long-term discharge at Cold Lake Reserve is 26.7 m^3/s from a drainage area of 14 447 km^2. Only a small proportion of this discharge is derived from the 4219 km^2 study area. The net yield of the study area is 5.17 m^3/s, which translates into a net yield of 46.6 mm from the "effective" drainage area of 3498 km^2 and 38.6 mm from the gross drainage area. Most of the study area runoff occurs in a short period in spring and early summer. Over 55 percent of the total annual discharge occurs in May, June and July.

Winter precipitation is stored as snow which is "permanent" from mid November until mid April. Substantial sublimation losses occur during this period. On average 55.5 mm of snow water equivalence from a gross snowfall of 103 mm, remains on April 1. The total precipitation available for runoff and further atmospheric losses is on average 452 mm. The net precipitation is about 405 mm after snow sublimation losses. Precipitation tends to increase with elevation. About 80 percent of the available precipitation is lost to lake evaporation, evapotranspiration and perhaps very limited groundwater recharge.

Lake evaporation is estimated at 628 mm per year based on corrected class A pan evaporation data. Other estimates of evaporation range from 641 mm (Morton, 1979) to 745 mm (Christiansen, 1968). The net annual loss from the 190 km^2 area of lakes is about 41 000 da m^3 or 215.5 mm.

Several methods were used to predict potential evapotranspiration (PET) from climatic normals. Annual PET estimates range from 482 to 631 mm. Estimates based on climatic normals are almost identical to mean values from monthly calculations over the period 1963 to 1982. The annual surplus of 46.6 mm cannot be simulated using an annual PET estimate of 539 mm and conventional water budgeting procedures. Runoff can be reasonably simulated if frozen-ground conditions are taken into account. The frozen ground is thought to be impermeable in this area, hence soil moisture does not change from the onset of freezing in November until thaw in April. Snow accumulates and sublimates above the ground and rapidly runs off in spring. Some snowmelt infiltrates into the thin surface thaw layer while the remainder is assumed to run off as Hortonian overland flow, or through flow.

The frozen-ground methodology indicates that the basin average annual runoff is 30 mm. Yields are calculated to be greatest on the Kehiwin Upland (36.9 mm), and least in the highland areas (19.5 mm), which border the basin to the north and south. The calculated yield is 64 percent of the estimated long-term runoff. The underestimate of runoff by the water balance method may be due to several factors: the precipitation may be underestimated; potential evapotranspiration may be overestimated; the near-surface hydrology is poorly understood; and finally, the discharge estimates and record extensions may not be accurate. Given those limitations, the analysis suggests that the potential for groundwater recharge in the lower Beaver River basin is small; in the order of 10^1 mm per year.

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APPENDIX A

APPLICATION OF EVAPORATION AND EVAPOTRANSPIRATION FORMULAE

INTRODUCTION

Methods which were used to predict evaporation and evapotranspiration are outlined using examples from the lower Beaver River basin study. The methods are described in the order in which they are presented in the text. The first group of methods deals with evaporative loss and the second with evapotranspiration. There is some duplication between the groups.

EVAPORATION ESTIMATION TECHNIQUES

Class A Pan

The class A pan is a 1219 mm diameter, 254 mm deep tray set on timber supports 150 mm above the ground. The water level is maintained within 50 to 75 mm of the lip. Evaporation from small, open-water bodies with negligible heat storage (for example, shallow lakes or reservoirs) range from 0.6 to 0.8 of the class A pan evaporation. "Lake evaporation" can be estimated from pan data using a pan coefficient derived from wind-run, air temperature and water temperature (Treidl, 1979).

Pan evaporation was not measured in this study. The nearest climate station that records pan evaporation is Vegreville, which is located about 130 km southwest of the study area. The topography of the Vegreville area and the study area are similar and they are of a similar elevation (Vegreville climate station is 636 m amsl and the study area ranges from 490 to 730 m amsl). The Vegreville station has records in the period May to September, for eight years starting in 1972 (Treidl, 1979). Significant evaporation occurs from April through October in other areas in Alberta. Therefore, the Vegreville record was extended by correlation with records at Slave Lake, which has a similar annual total pan evaporation loss:

Table A-1 Pan evaporation of Slave Lake and Vegreville

Station	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Total	Record
Slave Lake	22.4	130.6	156.2	167.4	115.6	73.2	27.2	692.6	4 years
Vegreville		140.2	190.2	181.6	145.3	83.8		741.1	4 years
Ratio SL/V		0.93	0.82	0.92	0.80	0.87		0.93	

The April pan evaporation at Vegreville was calculated from the ratio of the May evaporation at the two stations (0.93 x 22.4 = 20.8 mm). The October pan evaporation at Vegreville was calculated similarly (0.87 x 27.2 = 23.7 mm). The April and October pan evaporation was converted to lake evaporation using the ratio of pan to lake evaporation reported at Vegreville for the months of May and September (Treidl, 1979).

Christiansen (1968)

$$E_{pan} = 0.473\, R\, C_T\, C_W\, C_H\, C_S\, C_E\, C_M \qquad \text{(A-1)}$$

Solve using Cold Lake Airport climatic normals (tables 5-2 and 5-11 in text); example: July.

R, Radiation Coefficient:

Latitude 54° 25', interpolate from table A-2

R = 19.67 in x 25.4 = 499.6 mm

C_T, Temperature Coefficient:

Mean daily temperature, T = 16.9°C

From table A-3 or equation A-2

Table A2 Solar radiation, R at top of atmosphere in units of equivalent evaporation at 20°C, in inches

Latitude	January	February		March	April	May	June	July	August	September	October	November	December
		28 days	29 days										
(a) North													
60	1.76	3.90	4.03	8.53	13.28	18.05	19.57	19.12	15.39	10.23	5.68	2.27	1.17
50	1.59	6.59	6.97	11.27	15.12	19.01	19.80	19.72	16.91	12.48	8.70	5.15	3.90
45	6.05	7.92	8.20	12.53	15.69	19.34	19.88	19.90	17.52	13.51	10.12	6.60	5.21
40	7.53	9.21	9.54	13.69	16.56	19.57	19.89	20.00	18.02	14.45	11.44	8.03	6.67
35	9.03	10.45	10.82	14.74	17.12	19.69	19.80	20.00	18.41	15.29	12.66	9.15	8.16
30	10.52	11.62	12.03	15.66	17.57	19.70	19.60	19.90	18.68	16.02	13.78	10.80	9.66
25	11.97	12.71	13.16	16.50	17.90	19.59	19.28	19.58	18.82	16.63	14.80	12.10	11.15
20	13.35	13.71	14.20	17.20	18.10	19.35	18.84	19.31	18.63	17.11	15.74	13.34	12.61
15	14.63	14.61	15.13	17.77	18.16	18.94	18.29	18.87	18.70	17.45	16.50	11.50	14.03
10	15.81	15.41	15.95	18.20	18.07	18.48	17.63	18.27	18.44	17.65	17.36	15.57	15.36
5	16.88	16.08	16.65	18.49	17.85	17.86	16.86	17.55	18.05	17.72	17.98	16.53	16.59
(b) Equator													
	17.84	16.63	17.22	18.63	17.50	17.12	15.99	16.71	17.53	17.67	18.42	17.37	17.70
(c) South													
5	18.66	17.06	17.69	18.62	17.03	16.27	15.02	15.77	16.88	17.46	18.69	18.02	18.67
10	19.40	17.42	18.05	18.47	16.43	15.32	13.95	14.73	16.10	17.15	18.80	18.70	19.51
15	20.02	17.56	18.19	18.19	15.71	14.27	12.79	13.60	15.20	16.70	18.80	19.19	20.23
20	20.52	17.68	18.31	17.79	14.87	13.12	11.57	12.39	14.20	16.12	18.70	19.55	20.73
25	20.90	17.68	18.31	17.27	13.92	11.89	10.29	11.11	13.17	15.42	18.50	19.77	21.21
30	21.14	17.54	18.17	16.63	12.86	10.58	8.95	9.77	12.00	14.61	18.19	19.85	21.56
35	21.28	17.25	17.88	15.84	11.70	9.21	7.57	8.38	10.77	12.70	17.72	19.81	21.78
40	21.22	16.85	17.45	14.92	10.45	7.80	6.19	6.95	9.49	12.69	17.11	19.65	21.86
50	20.88	15.62	16.18	12.68	8.00	5.09	3.59	4.16	6.28	10.31	15.44	19.07	21.65

[a] Computed from data by Napier Shaw (19).

Table A3 Mean temperature, T and T_C, coefficient of temperature, C_T, and log C_T

T, in degrees Fahrenheit	T_C, in degrees Celsius	C_T[a]	Log C_T	T, in degrees Fahrenheit	T_C, in degrees Celsius	C_T[a]	Log C_T	T, in degrees Fahrenheit	T_C, in degrees Celsius	C_T[a]	Log C_T
				56	13.33	0.787	-0.1040	81	27.22	1.243	0.0944
32	0.00	0.391	-0.4060	57	13.89	0.804	-0.0946	82	27.78	1.262	0.1010
33	0.56	0.408	-0.3891	58	14.44	0.822	-0.0853	83	28.33	1.281	0.1076
34	1.11	0.424	-0.3727	59	15.00	0.839	-0.0761	84	28.89	1.300	0.1141
35	1.67	0.440	-0.3569	60	15.56	0.857	-0.0671	85	29.44	1.320	0.1205
36	2.22	0.455	-0.3415	61	16.11	0.874	-0.0583	86	30.00	1.339	0.1269
37	2.78	0.471	-0.3267	62	16.67	0.892	-0.0495	87	30.56	1.359	0.1332
38	3.33	0.487	-0.3122	63	17.22	0.910	-0.0410	88	31.11	1.379	0.1394
39	3.89	0.503	-0.2982	64	17.78	0.928	-0.0325	89	31.67	1.398	0.1456
40	4.44	0.519	-0.2845	65	18.33	0.946	-0.0242	90	32.22	1.418	0.1517
41	5.00	0.536	-0.2712	66	18.89	0.964	-0.0160	91	32.78	1.438	0.1577
42	5.56	0.552	-0.2582	67	19.44	0.982	-0.0080	92	33.33	1.458	0.1637
43	6.11	0.568	-0.2455	68	20.00	1.000	0.0000	93	33.89	1.478	0.1696
44	6.67	0.585	-0.2332	69	20.56	1.018	0.0078	94	34.44	1.498	0.1754
45	7.22	0.601	-0.2211	70	21.11	1.037	0.0156	95	35.00	1.518	0.1812
46	7.78	0.618	-0.2093	71	21.67	1.055	0.0232	96	35.56	1.538	0.1870
47	8.33	0.634	-0.1978	72	22.22	1.073	0.0307	97	36.11	1.558	0.1927
48	8.89	0.651	-0.1865	73	22.78	1.092	0.0382	98	36.67	1.579	0.1983
49	9.44	0.668	-0.1755	74	23.33	1.110	0.0455	99	37.22	1.599	0.2039
50	10.00	0.684	-0.1647	75	23.89	1.129	0.0527	100	37.78	1.620	0.2094
51	10.56	0.701	-0.1541	76	24.44	1.148	0.0599	101	38.33	1.640	0.2149
52	11.11	0.718	-0.1437	77	25.00	1.167	0.0670	102	38.89	1.661	0.2203
53	11.67	0.735	-0.1335	78	25.56	1.186	0.0739	103	39.44	1.682	0.2257
54	12.22	0.753	-0.1235	79	26.11	1.205	0.0808	104	40.00	1.702	0.2311
55	12.78	0.770	-0.1137	80	26.67	1.224	0.0876	105	40.56	1.723	0.2364

[a] From Eq. 31 and Eq. 32.

$CT = 0.393 + 0.02796\ T + 0.0001189\ T^2$ (A-2)

$= 0.393 + 0.02796\ (16.9) + 0.0001189\ (16.9^2)$

$= 0.393 + 0.473 + 0.034$

$= 0.900$

C_W, Wind Coefficient:

Wind speed at 10 m is 13.5 km/hr

From table A-4, (equation A-3 is incorrect)

$C_W = 1.137$

$C_W = 0.708 + 0.00546\ W - 0.00001\ W^2$ (A-3)

$= 0.780$

C_W can be calculated using a regression model ($r^2 = 0.98$), based on values in table A-4.

$C_W = 0.700 + 0.030\ W$ (A-4)

$= 1.105$

C_H, Humidity Coefficient:

The noon humidity, or the mean of the 1100 and 1700 hour readings, H = RH%/100 = 0.55

From table A-5, or equation A-5

$C_H = 1.250 - 0.87\ H + 0.75\ H^2 - 0.85H^4$ (A-5)

$= 1.250 - 0.87(0.55) + 0.75(0.55^2) - 0.85(0.55^4)$

$= (1.250 - 0.479) + (0.227 - 0.078)$

$= 0.920$

C_S, Sunshine Coefficient:

Bright/maximum possible sunshine hours S = n/m = 0.62

From table A-6 or equation A-6

$C_S = 0.542 + 0.80\ S - 0.78\ S^2 + 0.62\ s^3$ (A-6)

$= 0.542 + 0.80(0.62) - 0.78(0.62^2) + 0.62(0.62^3)$

$= 0.542 + 0.496 - 0.300 + 0.148$

$= 0.886$

Table A4 Wind velocity, W, coefficient of wind, C_W, and log C_W

Anemometer Height						$C_W{}^a$	Log C_W
2 feet	0.6 meters	6.6 feet	2 meters	20 feet	10 meters		
miles per day	kilometers per hour	miles per day	kilometers per hour	miles per day	kilometers per hour		
0	0.0	0	0.0	0	0.0	0.708	-0.1497
5	0.3	17	1.2	20	1.5	0.735	-0.1334
10	0.7	31	2.1	37	2.7	0.762	-0.1180
15	1.0	44	2.9	51	3.7	0.788	-0.1034
20	1.3	54	3.7	64	4.6	0.814	-0.0896
25	1.7	64	4.3	75	5.4	0.839	-0.0764
30	2.0	74	4.9	86	6.2	0.863	-0.0639
35	2.3	82	5.5	96	6.9	0.887	-0.0520
40	2.7	90	6.1	106	7.6	0.911	-0.0406
45	3.0	98	6.6	115	8.3	0.934	-0.0297
50	3.4	105	7.1	123	8.9	0.956	-0.0194
55	3.7	112	7.5	132	9.5	0.978	-0.0095
60	4.0	119	8.0	140	10.0	1.000	-0.0000
65	4.4	125	8.4	147	10.6	1.021	0.0090
70	4.7	132	8.8	155	11.1	1.042	0.0177
75	5.0	138	9.2	162	11.6	1.062	0.0260
80	5.4	144	9.6	169	12.1	1.081	0.0339
85	5.7	149	10.0	175	12.6	1.100	0.0415
90	6.0	155	10.4	182	13.1	1.119	0.0488
95	6.4	160	10.8	188	13.5	1.137	0.0557
100	6.7	166	11.1	194	14.0	1.154	0.0624
110	7.4	176	11.8	206	14.8	1.188	0.0749
120	8.0	186	12.5	218	15.7	1.220	0.0862
130	8.7	196	13.1	230	16.5	1.249	0.0965
140	9.4	206	13.8	241	17.4	1.277	0.1061
150	10.1	216	14.5	253	18.2	1.302	0.1147
160	10.7	226	15.1	265	19.0	1.326	0.1225
170	11.4	236	15.8	276	19.9	1.348	0.1296
180	12.1	246	16.5	288	20.7	1.367	0.1358
190	12.7	255	17.1	300	21.6	1.385	0.1414
200	13.4	265	17.8	311	22.4	1.400	0.1461
210	14.1	275	18.5	323	23.2	1.414	0.1504
220	14.8	285	19.1	335	24.1	1.426	0.1541
230	15.4	295	19.8	346	24.9	1.435	0.1569
240	16.1	305	20.5	358	25.7	1.443	0.1593
250	16.8	315	21.1	370	26.6	1.448	0.1609

(Source: Christiansen, 1968)

Table A5 Relative humidity, Hn and Hm, coefficients, C_{Hn} and C_{Hm} and logarithms of C_{Hn} and C_{Hm}

Hn, as a percentage	C_{Hn}[a]	Log C_{Hn}	Hm, as a percentage	C_{Hm}[b]	Log C_{Hm}
0.10	1.170	0.0682	0.10	1.213	0.0839
0.15	1.136	0.0554	0.15	1.194	0.0772
0.20	1.105	0.0432	0.20	1.176	0.0703
0.22	1.093	0.0386	0.22	1.168	0.0675
0.24	1.082	0.0341	0.24	1.161	0.0647
0.26	1.071	0.0296	0.26	1.153	0.0619
0.28	1.060	0.0253	0.28	1.145	0.0589
0.30	1.050	0.0210	0.30	1.138	0.0560
0.32	1.039	0.0168	0.32	1.130	0.0529
0.34	1.030	0.0126	0.34	1.121	0.0498
0.36	1.020	0.0085	0.36	1.113	0.0466
0.38	1.010	0.0043	0.38	1.105	0.0432
0.40	1.000	0.0000	0.40	1.096	0.0398
0.42	0.990	-0.0042	0.42	1.087	0.0361
0.44	0.981	-0.0083	0.44	1.077	0.0323
0.46	0.970	-0.0130	0.46	1.067	0.0283
0.48	0.960	-0.0177	0.48	1.057	0.0241
0.50	0.949	-0.0226	0.50	1.046	0.0196
0.52	0.938	-0.0277	0.52	1.035	0.0148
0.54	0.927	-0.0331	0.54	1.023	0.0097
0.56	0.916	-0.0383	0.56	1.010	0.0042
0.58	0.902	-0.0450	0.58	0.996	-0.0017
0.60	0.888	-0.0517	0.60	0.981	-0.0082
0.62	0.873	-0.0588	0.62	0.966	-0.0152
0.64	0.858	-0.0666	0.64	0.949	-0.0228
0.66	0.841	-0.0751	0.66	0.931	-0.0312
0.68	0.823	-0.0844	0.68	0.912	-0.0402
0.70	0.804	-0.0945	0.70	0.890	-0.0505
0.72	0.784	-0.1057	0.72	0.868	-0.0617
0.74	0.762	-0.1180	0.74	0.843	-0.0741
0.76	0.738	-0.1317	0.76	0.817	-0.0880
0.78	0.713	-0.1469	0.78	0.788	-0.1034
0.80	0.686	-0.1636	0.80	0.757	-0.1207
0.82	0.657	-0.1827	0.82	0.724	-0.1402
0.84	0.625	-0.2040	0.84	0.688	-0.1622
0.86	0.592	-0.2280	0.86	0.650	-0.1874
0.88	0.553	-0.2573	0.88	0.608	-0.2163
0.90	0.517	-0.2867	0.90	0.563	-0.2497
0.95	0.408	-0.3893	0.95	0.434	-0.3623
1.00	0.280	-0.5528	1.00	0.280	-0.5528

(Source: Christiansen, 1968)

Table A6 Sunshine percentage; S, coefficient of sunshine, C_S, and log C_S

S, as a percentage	C_S^{a}	Log C_S	S, as a percentage	C_S^{a}	Log C_S	S, as a percentage	C_S^{a}	Log C_S	S, as a percentage	C_S^{a}	Log C_S
0	0.542	-0.2660	26	0.708	-0.1499	51	0.829	-0.0813	76	0.972	-0.0125
2	0.558	-0.2536	27	0.713	-0.1467	52	0.834	-0.0787	77	0.979	-0.0094
3	0.565	-0.2477	28	0.718	-0.1436	53	0.839	-0.0761	78	0.986	-0.0063
4	0.573	-0.2420	29	0.724	-0.1405	54	0.844	-0.0736	79	0.993	-0.0031
5	0.580	-0.2365	30	0.729	-0.1375	55	0.849	-0.0710	80	1.000	0.0001
6	0.587	-0.2311	31	0.734	-0.1346	56	0.854	-0.0684	81	1.008	0.0033
7	0.594	-0.2259	32	0.738	-0.1317	57	0.859	-0.0658	82	1.015	0.0066
8	0.601	-0.2209	33	0.743	-0.1288	58	0.865	-0.0632	83	1.023	0.0099
9	0.608	-0.2160	34	0.748	-0.1260	59	0.870	-0.0606	84	1.031	0.0133
10	0.615	-0.2112	35	0.753	-0.1232	60	0.875	-0.0579	85	1.039	0.0167
11	0.621	-0.2066	36	0.758	-0.1204	61	0.880	-0.0553	86	1.047	0.0201
12	0.628	-0.2021	37	0.763	-0.1177	62	0.886	-0.0526	87	1.056	0.0236
13	0.634	-0.1978	38	0.767	-0.1150	63	0.891	-0.0499	88	1.064	0.0271
14	0.640	-0.1935	39	0.772	-0.1123	64	0.897	-0.0472	89	1.073	0.0307
15	0.647	-0.1894	40	0.777	-0.1096	65	0.903	-0.0444	90	1.082	0.0343
16	0.653	-0.1854	41	0.782	-0.1070	66	0.908	-0.0417	91	1.091	0.0379
17	0.659	-0.1814	42	0.786	-0.1044	67	0.914	-0.0389	92	1.101	0.0416
18	0.664	-0.1776	43	0.791	-0.1018	68	0.920	-0.0361	93	1.110	0.0454
19	0.670	-0.1739	44	0.796	-0.0992	69	0.926	-0.0332	94	1.120	0.0491
20	0.676	-0.1702	45	0.801	-0.0966	70	0.932	-0.0304	95	1.130	0.0529
21	0.681	-0.1666	46	0.805	-0.0940	71	0.939	-0.0275	96	1.140	0.0568
22	0.687	-0.1631	47	0.810	-0.0915	72	0.945	-0.0245	97	1.150	0.0607
23	0.692	-0.1597	48	0.815	-0.0889	73	0.952	-0.0216	98	1.160	0.0646
24	0.698	-0.1564	49	0.820	-0.0864	74	0.958	-0.0186	99	1.171	0.0686
25	0.703	-0.1531	50	0.825	-0.0838	75	0.965	-0.0156	100	1.181	0.0725

(Source: Christiansen, 1968)

C_E, Elevation Coefficient:

Elevation of station expressed in units of 1000 feet

From table A-7 or equation A-7

$$\begin{aligned} C_E &= 0.970 + 0.030\,E \qquad \text{(A-6)} \\ &= 0.970 + 0.030(1.774) \\ &= 0.970 + 0.053 \\ &= 1.023 \end{aligned}$$

C_M, Monthly Coefficient:

For a latitude of 49.8°N, representing Canada, a July value of 1.07 is given table A-8.

The coefficient represents an average correction factor which adjusts predictions to match measured pan losses (Christiansen, 1968:251).

Solving for July climate normals, using equation A-2:

$$\begin{aligned} \text{Epan} &= 0.473\ R\ C_T\ C_W\ C_H\ C_S\ C_E\ C_M \\ &= (0.473)\ (499.6)\ (0.900)\ (1.137)\ (0.920)\ (0.886) \\ &\quad (1.023)\ (1.07) \\ &= 215.76 \text{ mm/month pan evaporation} \end{aligned}$$

The above computations were undertaken for each month (table A-9) where mean monthly temperatures exceed 0°C. The pan evaporation values were converted to lake evaporation values using the constants calculated by Treidl (1979). In table A-9 two monthly values are given: V, which is the parameter value (e.g. April temperature is 2.9°C) and C, which is the coefficient used in the equation.

Table A7 Elevation E, coefficient of elevation, C_E, and log C_E

Elevation *E*, in thousands of feet	Elevation, in meters	C_E[a]	Log C_E	Elevation *E*, in thousands of feet	Elevation, in meters	C_E[a]	Log C_E
0.0	0	0.970	-0.0132				
0.1	30	0.973	-0.0117	3.6	1097	1.078	0.0326
0.2	61	0.976	-0.0106	3.7	1128	1.081	0.0338
0.3	91	0.979	-0.0092	3.8	1158	1.084	0.0350
0.4	122	0.982	-0.0079	3.9	1189	1.087	0.0362
0.5	152	0.985	-0.0066	4.0	1219	1.090	0.0374
0.6	183	0.988	-0.0052	4.1	1250	1.093	0.0386
0.7	213	0.991	-0.0039	4.2	1280	1.096	0.0398
0.8	244	0.994	-0.0026	4.3	1311	1.099	0.0410
0.9	274	0.997	-0.0013	4.4	1341	1.102	0.0422
1.0	305	1.000	0.0000	4.5	1372	1.105	0.0434
1.1	335	1.003	0.0013	4.6	1402	1.108	0.0445
1.2	366	1.006	0.0026	4.7	1433	1.111	0.0457
1.3	396	1.009	0.0039	4.8	1463	1.114	0.0469
1.4	427	1.012	0.0052	4.9	1494	1.117	0.0481
1.5	457	1.015	0.0065	5.0	1524	1.120	0.0492
1.6	488	1.018	0.0077	5.1	1554	1.123	0.0504
1.7	518	1.021	0.0090	5.2	1585	1.126	0.0515
1.8	549	1.024	0.0103	5.3	1615	1.129	0.0527
1.9	579	1.027	0.0116	5.4	1646	1.132	0.0538
2.0	610	1.030	0.0128	5.5	1676	1.135	0.0550
2.1	640	1.033	0.0141	5.6	1707	1.138	0.0561
2.2	671	1.036	0.0154	5.7	1737	1.141	0.0573
2.3	701	1.039	0.0166	5.8	1768	1.144	0.0584
2.4	732	1.042	0.0179	5.9	1798	1.147	0.0596
2.5	762	1.045	0.0191	6.0	1829	1.150	0.0607
2.6	792	1.048	0.0204	6.5	1981	1.165	0.0663
2.7	823	1.051	0.0216	7.0	2134	1.180	0.0719
2.8	853	1.054	0.0228	7.5	2286	1.195	0.0774
2.9	884	1.057	0.0241	8.0	2438	1.210	0.0828
3.0	914	1.060	0.0253	8.5	2591	1.225	0.0881
3.1	945	1.063	0.0265	9.0	2743	1.240	0.0934
3.2	975	1.066	0.0278	9.5	2896	1.255	0.0986
3.3	1006	1.069	0.0290	10.0	3048	1.270	0.1038
3.4	1036	1.072	0.0302	10.5	3200	1.285	0.1089
3.5	1067	1.075	0.0314	11.0	3353	1.300	0.1139

(Source: Christiansen, 1968)

Table A8 Adjusted mean monthly coefficients, C_M, for groups of stations

Group Number	Location	Mean Elevation in feet	Mean Latitude in °N	Months of Record	Adjusted Mean C_M												Weighted Mean C_M	Standard Deviation
					Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
1	Chula Vista, Calif.	10	32.6	120	1.00	1.00	1.00	1.01	1.01	1.00	0.99	0.99	1.01	1.05	1.07	1.05	1.01	0.052
2	N. Central Calif.	60	38.7	419	0.90	0.90	0.95	0.99	0.99	0.97	0.97	1.00	1.03	1.03	1.01	0.95	0.97	0.120
3	Friant & Backus R. Calif	1580	36.0	211	1.12	1.07	1.06	1.07	1.07	1.06	1.10	1.16	1.21	1.27	1.33	1.28	1.15	0.161
4	Arizona	1260	32.9	197	1.01	1.02	1.03	1.02	1.01	0.99	0.98	0.98	0.99	1.01	1.03	1.03	1.00	0.116
5	Ysleta & Spur, Texas	3100	32.1	189	1.21	1.18	1.10	1.02	0.95	0.91	0.95	1.00	1.01	1.07	1.15	1.21	1.05	0.162
6	Central & E. Texas	390	29.4	502	1.14	1.09	1.02	0.91	0.91	0.91	0.92	0.94	1.00	1.07	1.15	1.18	1.02	0.144
7	Seattle & Prosser, Wash.	640	46.9	126	—	—	0.80	0.79	0.79	0.80	0.83	0.85	0.85	0.84	0.85	0.88	0.82	0.077
8	Moses Lake, Wash.	1200	47.1	48	—	—	—	1.23	1.17	1.11	1.09	1.08	1.09	1.10	—	—	1.13	0.104
9	Western Montana	3470	47.5	162	—	—	—	1.04	0.95	0.90	0.91	0.97	0.99	0.95	—	—	0.95	0.124
10	Northern Utah	4570	40.9	322	—	—	0.98	0.90	0.85	0.84	0.83	0.91	0.92	0.97	0.98	—	0.88	0.077
11	Milford, Ut. & G. J., Colo.	4920	38.8	112	—	—	—	1.14	1.07	1.05	1.04	1.11	1.15	1.29	—	—	1.11	0.080
12	Estes Park & Pueblo, Colo.	5880	39.1	123	—	1.07	1.05	0.97	0.88	0.82	0.77	0.77	0.90	1.02	1.08	—	0.88	0.088
13	Western Oregon	880	43.5	209	0.90	0.90	0.98	1.01	1.00	1.01	1.03	1.04	1.01	0.95	0.92	0.91	0.99	0.118
14	Iowa	1030	41.9	62	—	—	—	0.97	0.91	0.87	0.86	0.88	0.94	1.08	—	—	0.92	0.063
15	Indiana	690	39.8	37	—	—	—	0.89	0.88	0.87	0.88	0.91	0.99	1.07	—	—	0.93	0.051
16	Georgia	950	33.3	50	—	—	0.96	0.93	0.93	0.95	0.95	0.94	0.96	0.99	1.03	1.07	0.96	0.074
17	San Juan, Puerto Rico	40	18.5	34	0.93	0.90	0.91	0.91	0.88	0.85	0.84	0.86	0.88	0.87	0.93	0.96	0.89	0.085
18	Panama	170	9.2	68	0.91	0.91	0.90	0.90	0.92	0.94	0.94	0.94	0.95	1.01	1.03	0.98	0.94	0.158
19	Hawaii	50	21.0	106	1.07	1.05	1.01	1.00	1.00	1.00	1.00	1.00	1.01	1.05	1.05	1.04	1.03	0.101
20	Alaska	150	61.6	13	—	—	—	—	1.12	1.01	0.98	1.08	1.14	—	—	—	1.05	0.171
21	Nigeria	1030	8.7	53	—	0.94	—	1.01	—	1.02	1.01	0.99	0.99	1.01	1.02	—	1.00	0.185
22	Huancayo, Peru	10870	12.08	34	1.31	1.35	1.38	1.33	1.27	1.27	1.40	1.38	1.30	1.22	1.17	1.23	1.30	0.089
23	Canada	1360	49.8	27	—	—	—	1.15	1.14	1.10	1.07	1.08	1.15	1.17	—	—	1.11	0.104
24	Northeast Thailand	550	15.9	404	1.12	1.07	1.04	1.04	1.06	1.08	1.08	1.08	1.09	1.12	1.14	1.15	1.09	0.118
	Total and Weighted Mean			3928														0.116

(Source: Christiansen, 1968)

Table A9 Christiansen method, Cold Lake climatic normals, annual pan evaporation estimates

Factor	Table	Equation	Apr V	Apr C	May V	May C	Jun V	Jun C	Jul V	Jul C	Aug V	Aug C	Sep V	Sep C	Oct V	Oct C	Year
Constant				0.473		0.473		0.473		0.473		0.473		0.473		0.473	
R, Radiation 54° 25′	A2		2.9		359		465		498		494		414		289		187
C_T, Temperature	A3	A2		0.475	10.4	0.697	14.5	0.823	16.9	0.899	15.5	0.855	9.8	0.678	4.5	0.521	
C_W, Wind Velocity	A4	A4	14.8	1.188	15.7	1.220	14.4	1.171	13.5	1.137	12.7	1.104	14.2	1.163	14.5	1.175	
C_H, Relative Humidity	A5	A5	.49	0.955	.44	0.981	.50	0.949	.55	.921	.50	0.888	.62	0.873	.59	0.895	
C_S, Sunshine	A6	A6	.55	0.849	.56	0.854	.56	0.854	.62	.886	.56	0.854	.46	0.805	.47	0.810	
C_E, Elevation	A7	A7		1.023		1.023		1.023		1.023		1.023		1.023		1.023	
C_M, Monthly Coefficient	A8	A8		1.15		1.14		1.10		1.07		1.08		1.15		1.17	
[1] Pan Evaporation (mm/mo)				91.4		182.7		207.0		213.3		154.9		89.1		47.0	985.4
[2] Ratio lake to pan evapo.				0.76		0.75		0.75		0.76		0.76		0.76		0.75	0.76
Lake Evaporation (mm/mo)				69.5		137.0		155.3		162.1		117.7		67.7		35.3	744.5
[3] Evapotranspiration (mm/mo)				62		124		141		145		105		61		31	670

[1] March and November evaporation can not be estimated because freezing point is taken as the threshold for evaporation.
[2] From Treidl (1979), for Slave Lake and Vegreville.
[3] Pan evaporation x 0.68 (Sonmor, 1963).

Morton (1979)

Bothe (1981) and Morton (1979) used the Morton method to calculate lake evaporation throughout Alberta:

Table A-10 Monthly estimates of lake evaporation for Cold Lake (mm)

YEAR	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
1973	-	-	-	-	-	-	142	108	52	18	-2	-2	-
1974	-1	-1	4	70	88	133	139	103	45	21	2	-4	599
1975	-1	0	7	56	100	120	152	91	57	18	3	-2	601
1976	-3	2	25	69	116	130	136	113	62	18	7	-2	673
1977	-2	8	27	76	112	147	117	96	-	-	-	-1	-
1978	-1	0	26	53	100	138	150	103	40	25	-1	-3	630
1979	-3	-0	30	46	110	130	155	108	53	18	1	-5	643
1980	-3	-2	12	95	132	119	149	87	40	22	2	-1	652
MEAN	-2	1	19	66	108	131	143	101	50	20	2	-3	641[1]

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[1] negative values (condensation) ignored.

Penman (1948)

A nomogram method of solving Penman's (1948) energy budget formula (figure A-1) was used following Nemec (1972). The nomogram example used to compute free surface evaporation is based on the following data:

average daily temperature T = 18°C
ratio bright to maximum sunshine n/m = 0.4
mean extra terrestrial radiation R = 800 g/cal/cm^2/day
mean daily relative humidity H = 0.6
average daily wind speed of 2 m U_2 = 3.0 m/s

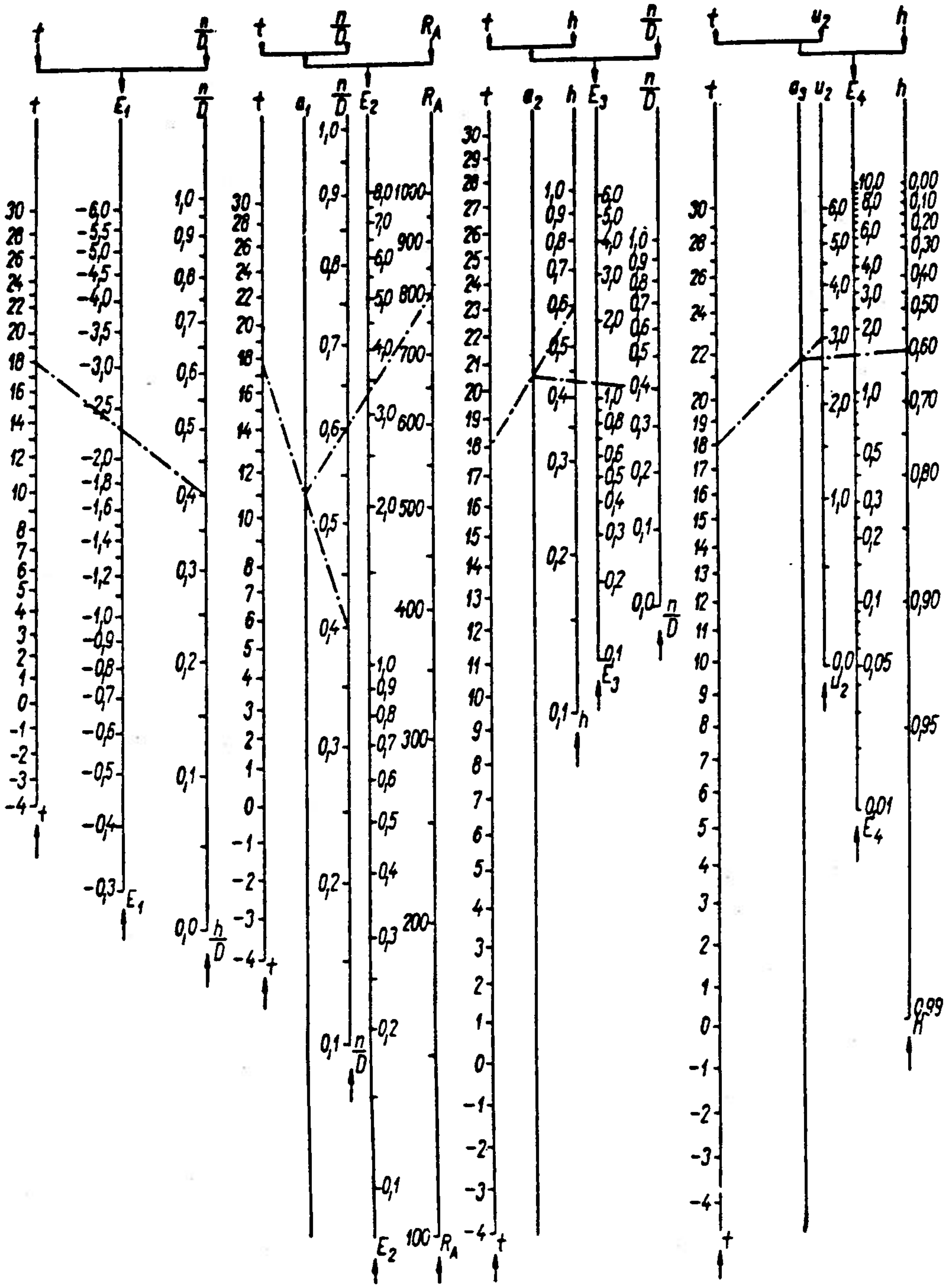

Figure A1 Nomogram for computation of evaporation (E_0) from free water surface according to Penman (source: Nemec, 1972)

The nomogram is solved in four parts which are summed to calculate evaporation from open water surfaces (E_o) in mm/day:

$E_1 = -2.28$, $E_2 = +3.30$, $E_3 = +1.12$, $E_{4f} = 1.52 = 3.66$ mm/day

Temperature, sunshine, relative humidity and wind speed for Cold Lake are obtained from table 5-11 in the text. Radiation values are from table A-11. Evaporation estimates for Cold Lake are presented in table A-12.

Table A11 Solar radiation on a horizontal plane without atmosphere (cal day/cm^2)

Longitude of Sun	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
Date (day/month)	21/3	13/4	6/5	29/5	22/6	15/7	8/8	31/8	23/9	16/10	8/11	30/11	22/12	13/1	4/2	26/2
Latitude																
90 N		436	796	1030	1110	1025	789	431								
80 N	160	436	784	1014	1093	1010	777	431	158	7						7
70 N	316	541	772	968	1043	963	765	535	312	133	25				25	135
60 N	461	655	834	963	1009	957	826	648	456	281	151	74	51	75	151	285
50 N	593	755	894	988	1020	984	886	747	586	427	295	210	181	211	298	432
40 N	707	832	938	1002	1022	997	929	823	698	562	442	359	327	361	447	570
30 N	799	892	958	997	1005	990	949	882	789	684	581	507	480	509	586	691
20 N	867	922	952	964	964	959	944	911	857	784	706	646	624	649	712	793
10 N	909	925	921	908	900	904	913	914	898	861	813	771	756	775	820	871
0	923	900	863	829	814	825	856	890	912	913	897	877	869	881	905	924
10 S	911	849	784	729	708	726	776	839	898	938	956	960	962	965	965	949
20 S	867	773	680	611	585	608	674	764	857	935	989	1019	1030	1024	998	946
30 S	799	674	560	479	449	477	555	666	789	904	994	1052	1073	1057	1003	915
40 S	707	555	426	339	306	338	422	549	698	844	973	1059	1092	1064	982	854
50 S	593	421	285	199	170	198	282	416	586	766	929	1045	1089	1049	937	775
60 S	461	277	144	70	48	70	143	274	456	664	866	1018	1078	1023	873	672
70 S	316	131	24				24	130	312	548	802	1024	1114	1029	809	556
80 S	160	7						7	158	442	814	1073	1167	1078	821	447
90 S										442	826	1089	1185	1095	834	447

(Source: Brutsaert, 1982)

Table A12 Evaporation estimates for Cold Lake using Nemec's (1972) nomogram of the Penman (1948) method

Factor	APR	MAY	JUN	JUL	AUG	SEP	OCT	YEAR
[1]Albedo, r	0.20	0.15	0.18	0.18	0.20	0.20	0.20	
[2]Sunshine, n/m %	54.5	55.7	56.2	61.9	55.9	45.7	47.3	
[3]Radiation, g/cal/cm^2/day	705	920	1015	970	776	521	354	
[2]Temperature	2.9	10.4	14.5	16.9	15.5	9.8	4.5	
[2]Relative humidity, %	49.4	44.2	49.8	55.1	59.5	62.2	59.4	
[2]Mean wind, km/hr	4.11	4.36	4.00	3.75	3.53	3.94	4.03	
[4]E_1	-1.55	-2.2	-2.5	-2.9	-2.6	-1.85	-1.51	
[4]E_2	2.50	3.80	4.75	5.00	3.70	1.85	1.15	
[4]E_3	0.21	0.78	1.0	1.1	0.94	0.77	0.54	
[4]E_4	1.5	1.8	1.6	1.7	1.65	1.4	1.35	
E_o (lake evapo) (mm/day)	2.66	4.18	4.85	4.90	3.69	2.17	1.53	
E_o (mm/day)	79.8	129.6	145.5	151.9	114.4	65.1	47.4	733.7
[5]Ratio E_T/E_o	0.7	0.8	0.8	0.8	0.8	0.7	0.7	
E_T evapotranspiration (mm/mo)	55.9	103.7	116.4	121.5	91.5	45.6	33.2	567.8

[1] From Gray 1970; [2] From Table 11; [3] Brutsaert, 1982; [4] Nemec, 1972; [5] Penman, 1948.

EVAPOTRANSPIRATION ESTIMATION TECHNIQUES

Calder and Newson (1979)

Calder and Newson (1979) recognized that atmospheric losses appear to depend on vegetation type. They suggest that the Penman (1948) evapotranspiration formula provides a reliable estimate of annual atmospheric losses from grass and other short vegetation. However, they cite work where atmospheric losses from forests exceeded losses from grassed areas by a factor of 1.7.

To predict losses from forests a more complex approach was followed. They suggest that, for Wales of least, transpiration losses are broadly in agreement with the long-term Penman potential transpiration (E_T) values, when these values are reduced in proportion to the average fraction of time when the canopy is wet and transpiration will not occur. They suggest that interception losses can be roughly estimated from rainfall data and that the annual atmospheric loss can be estimated from the sum of the proportional losses arising from the forested and non-forested areas:

$$E_A = ((1 - F)\ E_T) + F\ [(1 - W)\ E_T + Pi] \qquad \text{(A-8)}$$

where: E_A is annual atmospheric loss (mm)
F is the fraction of the drainage basin with complete canopy coverage
P is the annual precipitation
i is the interception fraction
w is the fraction of the year when the canopy is wet.
E_T is the evapotranspiration loss from a grassed surface (Penman, 1948).

The first terms in equation (A.8) refer to the fraction of the basin which has grass or short vegetation, and the expected atmospheric loss, E_T. The remainder concerns the fraction of the basin which is forested, the forest transpiration (E_T) and the estimated forest interception loss (i).

The terms in equation (A-8) can be quantified from data in the previous sections describing the environmental setting. The fraction of the drainage basin area with complete canopy coverage can be estimated from Canada Land Inventory land use maps (table 5-1 in text). However, much of this area (25.5 percent) is "non-productive woodland", which is land with sparse or scrub vegetation. Productive woodland (T) is land bearing forest with over 30 percent crown cover and 6 m height, plus restocked and planted areas. Thus, F = 0.34 from table 5-1. The annual precipitation is 460 mm from table 5-2 in the text. However, seasonal precipitation is of interest here. Evaporative losses from the snowpack were treated previously. The April to October inclusive precipitation is 356.8 mm. The fraction of precipitation lost to interception (i) is a function of annual, or in this case seasonal, precipitation, and is given in figure A-2 as 0.48. Wet canopy conditions (w), which is the period with no transpiration during and immediately following rainfall, can be estimated from:

$$w = (\text{rain hours})\,(1.5/\text{total hours}) \qquad \text{(A-9)}$$

where rain hours is the toal duration of rainfall per year or season and total hours is the total number of hour in that year or season.

Equation (A-9) can be solved from Atmospheric Environment Service data on the number of hours with rainfall reported at Cold Lake Airport in the period 1957 to 1966. In the April to October period rainfall occurs on average in 413.6 hourly periods. The total number of hours in this period is 5136, thus, w is roughly 0.12.

The equations proposed by Calder and Newson (1979) were developed for coniferous forest in Britain. Anderson et al, (1976) suggest that transpiration accounts for most of the vaporization from the forest in the United States; perhaps 80 percent in hardwoods and 60 percent in conifers. The remainder is lost from interception by the canopy and litter, and from the soil beneath. Therefore, Calder and Newson's (1979) equation (A-8) should be modified for North American tree types by dividing the predicted interception loss (Pi) by a factor proportional to the lesser loss expected from decidious forests in North Amercia (50 percent, thus a factor of 2):

$$E_A = ((1 - F)\ E_T) + (F\ ((1 - w)\ E_T) + (Pi/2) \qquad \text{(A-10)}$$

where: E_T is estimated from Penman's E_0 (table A-5), thus:

$$\begin{aligned} E_A &= ((1 - 0.34)\ 568) + 0.34\ ((1 - 0.12)\ 568) + (357(0.48)/2) \\ &= 375 + 170 + 85.7 \\ &= 631 \text{ mm/year} \end{aligned}$$

To apply the interception loss correction to monthly data the ratio of E_A from equation (A-10) to the annual E_T from Penman's equation (631/568 = 1.11) is multiplied by the monthly Penman equation E_T values.

Christiansen (1968)

Christiansen's (1968) method estimates pan evaporation. To obtain estimates of evapotranspiration he suggested using conversion formulae. Sonmor (1963) determined the relationship between consumptive use and class A pan evaporation in southern Alberta. The ratio of comsumptive use to pan evaporation ranged from 0.500 for corn to 0.678 for grass and pasture (table A-13). The grass and

Table A13 Average seasonal ratio of consumptive use of maximum yield to evaporation from three different evaporimeters for crops grown in field plots in southern Alberta (Taber and Jauxhall, 1950-1961)

Crop	Buried 4-foot pan			Black Bellani plate atmometer			U.S.W.B. class "A" pan		
	Years	Mean (in./in.)	±S.D.	Years	Mean (in./cc.)	±S.D.	Years	Mean (in./in.)	±S.D.
Perennials (close-seeded)									
Alfalfa	11	0.845	0.078	7	0.00300	0.00021	4	0.659	0.052
Grass, pasture	8	0.828	0.073	5	0.00308	0.00043	2	0.678	0.029
Annuals (close-seeded)									
Soft wheat	9	0.845	0.092	6	0.00302	0.00034	3	0.658	0.112
Hard wheat	8	0.834	0.078	5	0.00293	0.00034			
Oats	8	0.776	0.089	5	0.00276	0.00030	2	0.586	0.117
Barley	9	0.802	0.094	6	0.00281	0.00041	3	0.640	0.151
Flax	5	0.749	0.116	2	0.00256	0.00054	—	—	—
Canning peas	5	0.854	0.055	2	0.00314	0.00012	—	—	—
Annuals (row crops)									
Sugar beets	10	0.684	0.048	7	0.00250	0.00018	4	0.542	0.048
Potatoes	8	0.702	0.055	6	0.00254	0.00025	4	0.556	0.037
Canning corn	7	0.637	0.053	4	0.00223	0.00014	4	0.500	0.033
Field corn	8	0.600	0.070	5	0.00222	0.00021			
Tomatoes	6	0.689	0.096	3	0.00238	0.00048	—	—	—

(Source: Sonmor, 1963)

pasture values were used to represent the relationship between consumptive use and pan evaporation in the lower Beaver River basin study area.

Jensen and Haise (1963)

$$E_{tp} = (0.014\ T_F - 0.37)\ R_S \qquad \text{(A-12)}$$

where E_{tp} represents potential evapotranspiration (in/day)
T_F mean air temperature (°F)
R_S solar radiation received on a horizontal surface expressed in inches evaporation equivalent

$$R_S = R_{SO}\ (0.35 + 0.61\ S) \qquad \text{(A-13)}$$

where R_{SO} is cloudless day radiation
S is fraction of bright (n) to maximum (m) number of sunshine hours (n/m).

Jensen and Haise (1963) used Rudyko's estimates of cloudless sky radiation (table A-14), whereas table 5-11 in the text derives R_{SO} from Criddle's (1958) R_{SO} estimates (table A-15). The resulting E_{tp} estimates are a factor of 1.3 different (699 against 520 mm/year, respectively; tables A-16 and A-17).

Penman (1948)

Penman (1948) studied atmospheric losses from evaporation pans, bare soil and grass soil lysimeters in southern England and concluded that the evaporative loss from continuously wet bare soil (E_B) was 90 percent of the openwater surface loss (E_0) exposed to the same weather conditions in all seasons. Provisional values of the ratio of evapotranspiration (E_T) to open water evaporation (E_0) were given as follows:

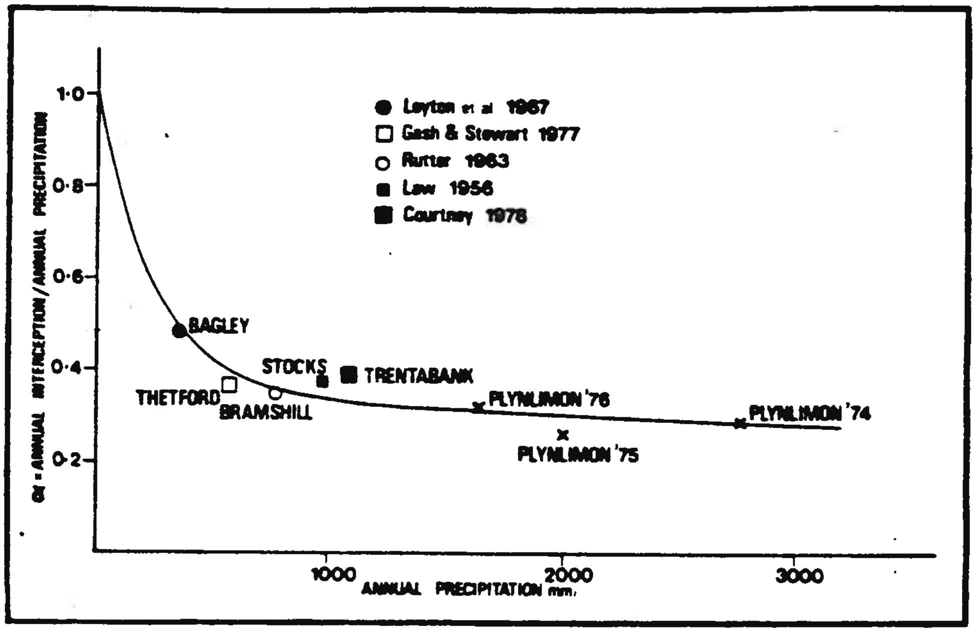

Figure A2 Measurements of annual interception loss, expressed as a fraction of the annual precipitation, plotted against annual precipitation (source: Calder and Newson, 1979)

Table A14 Total solar and sky radiation for cloudless skies calculated by Budyko, expressed in inches evaporation equivalent (source: Jensen and Haise, 1963)

Latitude, °N	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
60	1.1	2.6	6.4	10.3	13.9	14.9	14.4	10.9	7.0	4.1	1.7	0.8
55	2.0	3.7	7.7	11.1	14.3	15.1	14.7	11.8	8.2	5.1	2.7	1.5
50	3.1	5.0	9.0	11.9	14.7	15.3	15.0	12.5	9.5	6.4	3.9	2.5
45	4.4	6.3	10.3	12.7	15.1	15.5	15.3	13.4	10.7	7.7	5.1	3.8
40	5.8	7.7	11.3	13.3	15.3	15.7	15.5	14.1	11.7	8.9	6.5	5.1
35	7.2	9.1	12.3	14.0	15.3	15.7	15.5	14.5	12.5	10.1	7.9	6.4
30	8.5	10.1	13.0	14.4	15.3	15.7	15.5	14.8	13.2	11.0	9.1	7.6
25	9.5	11.0	13.5	14.5	15.3	15.6	15.4	14.9	13.7	11.7	10.0	8.7
20	10.3	11.7	13.9	14.5	15.1	15.3	15.1	14.8	14.0	12.3	10.9	9.7
15	11.1	12.2	14.0	14.4	14.7	14.8	14.7	14.5	14.1	12.8	11.5	10.5
10	11.6	12.7	14.0	14.2	14.1	14.1	14.1	14.1	14.1	13.1	12.0	11.1
5	12.0	13.0	13.9	13.9	13.6	13.2	13.4	13.7	13.9	13.3	12.4	11.5
0	12.3	13.2	13.6	13.5	12.8	12.0	12.5	13.1	13.6	13.3	12.7	12.0

Table A15 Mean-monthly extra-terrestrial radiation on a horizontal plane (mm water/day) (source: Gray, 1970)

North. Lat.	90°	80°	70°	60°	50°	40°	30°	20°	10°	0°
Jan.	-	-	-	1.3	3.6	6.0	8.5	10.8	12.8	14.5
Feb.	-	-	1.1	3.5	5.9	8.3	10.5	12.3	13.9	15.0
Mar.	-	1.8	4.3	6.8	9.1	11.0	12.7	13.9	14.8	15.2
Apr.	7.9	7.8	9.1	11.1	12.7	13.9	14.8	15.2	15.2	14.7
May	14.9	14.6	13.6	14.6	15.4	15.9	16.0	15.7	15.0	13.9
June	18.1	17.8	17.0	16.5	16.7	16.7	16.5	15.8	14.8	13.4
July	16.8	16.5	15.8	15.7	16.1	16.3	16.2	15.7	14.8	13.5
Aug.	11.2	10.6	11.4	12.7	13.9	14.8	15.3	15.3	15.0	14.2
Sept.	2.6	4.0	6.8	8.5	10.5	12.2	13.5	14.4	14.9	14.9
Oct.	-	0.2	2.4	4.7	7.1	9.3	11.3	12.9	14.1	15.0
Nov.	-	-	0.1	1.9	4.3	6.7	9.1	11.2	13.1	14.6
Dec.	-	-	-	0.9	3.0	5.5	7.9	10.3	12.4	14.3

Table A-16 Jensen-Haise Method Potential Evapotranspiration estimate using Criddle's cloudless day radiation values.

Factor	Apr	May	Jun	Jul	Aug	Sep	Oct	Units
R_{SO}	0.47	0.59	0.65	0.63	0.53	0.38	0.24	in/day
S	0.55	0.56	0.56	0.62	0.56	0.46	0.47	hrs/hrs
T_F	37.2	50.7	58.1	62.4	59.9	49.6	40.1	°F
R_S	0.32	0.41	0.45	0.46	0.37	0.24	0.15	in/day
E_{tp}	0.048	0.139	0.200	0.232	0.173	0.078	0.029	in/day
E_{tp}	36.50	109.45	152.40	182.68	136.22	59.44	22.61	mm/mo

Table A-17 Jensen-Haise Method Potential Evapotranspiration Estimates Using Budyko's Cloudless Day Radiation Values.

Factor	Apr	May	Jun	Jul	Aug	Sep	Oct	Units
R_{SO}	0.37	0.46	0.50	0.47	0.38	0.27	0.16	in/day
S	0.55	0.56	0.56	0.62	0.56	0.46	0.47	hrs/hrs
T_F	37.2	50.7	58.1	62.4	59.9	49.6	40.1	°F
R_S	0.25	0.32	0.32	0.34	0.26	0.17	0.10	in/day
E_{tp}	0.038	0.109	0.155	0.171	0.122	0.055	0.019	in/day
E_{tp}	28.7	85.6	118.3	134.8	95.9	42.0	15.1	mm/mo

Table A-18 Thornthwaite method estimates of potential evapotranspiration.

Factor	Apr	May	Jun	Jul	Aug	Sep	Oct	
Temperature	2.9	10.4	14.5	16.9	15.5	9.8	4.5	
Heat Index	0.44	3.03	5.01	6.32	5.55	2.77	0.85	23.97
Unadjusted Eq	1.92	5.94	7.97	9.13	8.45	5.63	2.83	
Sunlight	34.91	40.74	41.90	42.07	38.08	31.95	27.30	
E_T	22.3	78.1	111.3	123.9	103.8	60.0	24.9	524.3

Temperature °C; unadjusted E_T (cm/mo); sunlight duration in units of 12 hours (extrapolated from Table A.19); E_T (mm/mo) = unadjusted E_T x sunlight x 10 ÷ number of days in that month.

Northern Latitudes	J	F	M	A	M	J	J	A	S	O	N	D
0°	31.2	28.2	31.2	30.3	31.2	30.3	31.2	31.2	30.3	31.2	30.3	31.2
1	31.2	28.2	31.2	30.3	31.2	30.3	31.2	31.2	30.3	31.2	30.3	31.2
2	31.2	28.2	31.2	30.3	31.5	30.6	31.2	31.2	30.3	31.2	30.0	30.9
3	30.9	28.2	30.9	30.3	31.5	30.6	31.5	31.2	30.3	31.2	30.0	30.9
4	30.9	27.9	30.9	30.6	31.8	30.9	31.5	31.5	30.3	30.9	30.0	30.6
5	30.6	27.9	30.9	30.6	31.8	30.9	31.8	31.5	30.3	30.9	29.7	30.6
6	30.6	27.9	30.9	30.6	31.8	31.2	31.8	31.5	30.3	30.9	29.7	30.3
7	30.3	27.6	30.9	30.6	32.1	31.2	32.1	31.8	30.3	30.9	29.7	30.3
8	30.3	27.6	30.9	30.9	32.1	31.5	32.1	31.8	30.6	30.6	29.4	30.0
9	30.0	27.6	30.9	30.9	32.4	31.5	32.4	31.8	30.6	30.6	29.4	30.0
10	30.0	27.3	30.9	30.9	32.4	31.8	32.4	32.1	30.6	30.6	29.4	29.7
11	29.7	27.3	30.9	30.9	32.7	31.8	32.7	32.1	30.6	30.6	29.1	29.7
12	29.4	27.3	30.9	31.2	32.7	32.1	33.0	32.1	30.6	30.3	29.1	29.4
13	29.4	27.3	30.9	31.2	33.0	32.1	33.0	32.4	30.6	30.3	28.8	29.4
14	29.4	27.3	30.9	31.2	33.0	32.4	33.3	32.4	30.6	30.3	28.8	29.1
15	29.1	27.3	30.9	31.2	33.3	32.4	33.6	32.4	30.6	30.3	28.5	29.1
16	29.1	27.3	30.9	31.2	33.3	32.7	33.6	32.7	30.6	30.3	28.5	28.8
17	28.8	27.3	30.9	31.5	33.6	32.7	33.9	32.7	30.6	30.0	28.2	28.8
18	28.8	27.0	30.9	31.5	33.6	33.0	33.9	33.0	30.6	30.0	28.2	28.5
19	28.5	27.0	30.9	31.5	33.9	33.0	34.2	33.0	30.6	30.0	27.9	28.5
20	28.5	27.0	30.9	31.5	33.9	33.3	34.2	33.3	30.6	30.0	27.9	28.2
21	28.2	27.0	30.9	31.5	33.9	33.3	34.5	33.3	30.6	30.0	27.6	28.2
22	28.2	26.7	30.9	31.8	34.2	33.6	34.5	33.3	30.6	29.7	27.6	27.9
23	27.9	26.7	30.9	31.8	34.2	33.9	34.8	33.6	30.6	29.7	27.6	27.6
24	27.9	26.7	30.9	31.8	34.5	34.2	34.8	33.6	30.6	29.7	27.3	27.6
25	27.9	26.7	30.9	31.8	34.5	34.2	35.1	33.6	30.6	29.7	27.3	27.3
26	27.6	26.4	30.9	32.1	34.8	34.5	35.1	33.6	30.6	29.7	27.3	27.3
27	27.6	26.4	30.9	32.1	34.8	34.5	35.4	33.9	30.6	29.7	27.0	27.0
28	27.3	26.4	30.9	32.1	35.1	34.8	35.4	33.9	30.9	29.4	27.0	27.0
29	27.3	26.1	30.9	32.1	35.1	34.8	35.7	33.9	30.9	29.4	26.7	26.7
30	27.0	26.1	30.9	32.4	35.4	35.1	36.0	34.2	30.9	29.4	26.7	26.4
31	27.0	26.1	30.9	32.4	35.4	35.1	36.0	34.2	30.9	29.4	26.4	26.4
32	26.7	25.8	30.9	32.4	35.7	35.4	36.3	34.5	30.9	29.4	26.4	26.1
33	26.4	25.8	30.9	32.7	35.7	35.7	36.3	34.5	30.9	29.1	26.1	25.8
34	26.4	25.8	30.9	32.7	36.0	36.0	36.6	34.8	30.9	29.1	26.1	25.8
35	26.1	25.5	30.9	32.7	36.3	36.3	36.9	34.8	30.9	29.1	25.8	25.5
36	26.1	25.5	30.9	33.0	36.3	36.6	37.2	34.8	30.9	29.1	25.8	25.2
37	25.8	25.5	30.9	33.0	36.6	36.9	37.5	35.1	30.9	29.1	25.5	24.9
38	25.5	25.2	30.9	33.0	36.9	37.2	37.5	35.1	31.2	28.8	25.2	24.9
39	25.5	25.2	30.9	33.3	36.9	37.2	37.8	35.4	31.2	28.8	25.2	24.6
40	25.2	24.9	30.9	33.3	37.2	37.5	38.1	35.4	31.2	28.8	24.9	24.3
41	24.9	24.9	30.9	33.3	37.5	37.8	38.1	35.7	31.2	28.8	24.6	24.0
42	24.6	24.6	30.9	33.6	37.8	38.1	38.4	35.7	31.2	28.5	24.6	23.7
43	24.3	24.6	30.6	33.6	37.8	38.4	38.7	36.0	31.2	28.5	24.3	23.1
44	24.3	24.3	30.6	33.6	38.1	38.7	39.0	36.0	31.2	28.5	24.0	22.8
45	24.0	24.3	30.6	33.9	38.4	38.7	39.3	36.3	31.2	28.2	23.7	22.5
46	23.7	24.0	30.6	33.9	38.7	39.0	39.6	36.6	31.2	28.2	23.7	22.2
47	23.1	24.0	30.6	34.2	39.0	39.6	39.9	36.6	31.5	27.9	23.4	21.9
48	22.8	23.7	30.6	34.2	39.3	39.9	40.2	36.9	31.5	27.9	23.1	21.6
49	22.5	23.7	30.6	34.5	39.6	40.2	40.5	37.2	31.5	27.6	22.8	21.3
50	22.2	23.4	30.6	34.5	39.9	40.8	41.1	37.5	31.8	27.6	22.8	21.0

Table A19. Mean Possible Monthly Duration of Sunlight in the Northern Hemisphere.

Mid-winter (November to February)	0.6
Spring and autumn (March to April and September to October)	0.7
Midsummer (May to August)	0.8
Whole year	0.75

These corrections can be applied to the open water evaporation (E_0) estimates which were discussed previously to provide estimates of evapotranspiration (E_T).

Thornthwaite (1948)

Thornthwaite's (1948) estimate of potential evapotranspiration is based on mean daily air temperature:

$$e = 1.62\ (10\ T/I)^a \qquad \text{(A-14)}$$

where e is the unadjusted potential evapotranspiration (cm/mo)
T mean monthly temperature (°C)
I annual heat index
a an exponent

$$i = (Tm/S)^{1.514} \text{ (monthly heat index)} \qquad \text{(A-15)}$$

I = sum of i for each month

$$a = (67.5 \times 10^{-8}\ I^3) - (77.1 \times 10^{-6}\ I^2) + 0.01791\ I + (0.492)$$

The product "e" has to be adjusted for sunlight duration and the number of days in the month.

APPENDIX B

WATER BALANCE CALCULATIONS

WATER BALANCE CALCULATIONS

The calculation of a water balance for an area requires detailed records of monthly precipitation, and information on potential evapotranspiration and changing soil moisture status. Soil moisture defecits and surpluses (runoff and groundwater recharge) are calculated based on the changing soil moisture status. An example is given in table B-1.

Temperature, T, and precipitation, P, may be average values (for example, climatic normals), or given monthly values. Potential evapotranspiration (PET) may be calculated by several methods (Appendix A). The balance of P-PET is obtained by subtraction. Laycock (pers. comm.) has assigned soil moisture storage capacity according to land use (table B-2). To obtain moisture remaining in the soil after plant utilization, tabulated values may be used (tables B-3 to B-6). Start in the first month with a negative value of P-PET (April in table B-1). The soil moisture storage for a P-PET of -21 is 81mm. Add the P-PET values for the month of April and May (-21 + -59 = -80). The corresponding soil moisture is depleted to 44 mm. Continue cumulating the negative values and read off the corresponding soil storage (June -80 + -46 = -126, storage = 27 mm; July -126 + -43 = -169, storage = 18 mm; August -169 + -22 = -191, storage = 14 mm; September -191 + -8 = -199, storage = 13 mm; October -199 + -9 = -208, storage = 12 mm). The positive values of P-PET are added directly to the storage of the previous month. Thus, November 12 + 10 = 22; December 22 + 10 = 32, January 32 + 10 = 42 and so on.

When a water balance is calculated for each month over a period of several years, an alternative soil moisture budgeting procedure is used. Laycock (pers. comm.) suggested starting the period during a low rainfall year where defecits occur. The P-PET values are directly added (positive values) or subtracted (negative values) to soil storage. The minimum value is zero. For example, in table B-1, if the available soil moisture in December of the previous year was 50 mm, then the storage in January of the year in question would be

Table B1 The water balance for the Beaver River Lowlands area given a 100 mm soil moisture storage, the average potential evapotranspiration of several methods and estimated available precipitation at Iron River

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR (mm)
Temperature	-19	-14	-8	3	10	15	17	16	10	5	-6	-14	
Precipitation	10	7	10	17	36	70	79	72	42	16	10	10	379
PET	0	0	0	38	95	116	122	94	50	25	0	0	539
P-PET	10	7	10	-21	-59	-46	-43	-22	-8	-9	10	10	-161
Storage	42	49	59	81	44	27	18	14	13	12	22	32	
Storage	10	7	10	22	-37	-17	-9	-4	-1	-1	10	10	
AET	0	0	0	38	73	87	88	76	43	17	0	0	422
Defecit	0	0	0	0	22	19	44	18	7	8	0	0	118
Surplus	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0

Table B2 Soil moisture retention capacities for Cold Lake study area land use units

Map Sheet	A	B	E	K	L	M	P	T	U	X	Z
73 L 1	1.4			1.4		3.0	0.6	60.0	25.1	8.5	
2	7.3			11.1		1.3	4.9	42.1	24.5	8.1	0.7
3	61.4	0.1		2.1		1.5	1.7	19.8	11.4	1.5	0.4
6	24.7			2.6		0.6	7.1	45.2	18.4	1.3	0.2
7	59.2	0.3		11.4		3.2	3.5	13.6	11.7	4.9	1.0
8	44.3	2.1	0.2			2.3	2.0	16.6	19.5	0.2	1.3
9	0.6					2.0	-	34.7	51.4	10.8	0.5
10	2.4			0.4		3.3	1.9	50.0	39.8	1.9	0.2
11	1.6			1.5		3.7	1.1	44.7	46.3		1.1
Mean %	25.1	0.3		4.4		2.2	3.2	34.3	25.5	4.4	0.6
Storage (mm)	100	13 to 250		150 to 250	13	M	150	250	150		150

Based on Canada Land Inventory 1:50,000 maps, where:

A	Croplands
B	Urban
E	Mines, quarries, gravel pits
K	Biologically unproductive land
L	Rock or other unvegetated surfaces
M	Swamp, marsh and bogs (storage equal to surrounding land use)
P	Pasture
T	Productive woodland
U	Non-productive woodland
X	Water surfaces
Z	Unimproved pasture and range land

Storages from Laycock (pers. comm.)

Table B3 Soil moisture retention table - 100 mm storage unit

WATER RETAINED IN SOIL

PE	0	1	2	3	4	5	6	7	8	9
0	100	99	98	97	96	95	94	93	92	91
10	90	89	88	88	87	86	85	84	83	82
20	81	81	80	79	78	77	77	76	75	74
30	74	73	72	71	70	70	69	68	68	67
40	66	66	65	64	64	63	62	62	61	60
50	60	59	59	58	58	57	56	56	55	54
60	54	53	53	52	52	51	51	50	50	49
70	49	48	48	47	47	46	46	45	45	44
80	44	44	43	43	42	42	41	41	40	40
90	40	39	39	38	38	38	37	37	36	36
100	36	35	35	35	34	34	34	33	33	33
110	32	32	32	31	31	31	30	30	30	30
120	29	29	29	28	28	28	27	27	27	27
130	26	26	26	26	25	25	25	24	24	24
140	24	24	23	23	23	23	22	22	22	22
150	22	21	21	21	21	20	20	20	20	20
160	19	19	19	19	19	18	18	18	18	18
170	18	17	17	17	17	17	16	16	16	16
180	16	16	15	15	15	15	15	15	14	14
190	14	14	14	14	14	14	13	13	13	13
200	13	13	12	12	12	12	12	12	12	12
210	12	11	11	11	11	11	11	11	11	11
220	10	10	10	10	10	10	10	10	10	10
230	9	9	9	9	9	9	9	9	9	9
240	8	8	8	8	8	8	8	8	8	8
250	8	8	8	7	7	7	7	7	7	7
260	7	7	7	7	7	7	6	6	6	6
270	6	6	6	6	6	6	6	6	6	6
280	6	6	6	6	6	5	5	5	5	5
290	5	5	5	5	5	5	5	5	5	5
300	5	5	4	4	4	4	4	4	4	4
310	4	4	4	4	4	4	4	4	4	4
320	4	4	4	4	4	4	4	4	4	4
330	3	3	3	3	3	3	3	3	3	3
340	3	3	3	3	3	3	3	3	3	3
350	3	3	3	3	3	3	3	3	3	2
360	2	2	2	2	2	2	2	2	2	2
370	2	2	2	2	2	2	2	2	2	2
380	2	2	2	2	2	2	2	2	2	2
390	2	2	2	2	2	2	2	2	2	2
400	2	2	2	2	2	2	2	2	2	2
410	2	2	2	2	2	1	1	1	1	1
420	1	1	1	1	1	1	1	1	1	1
430	1	1	1	1	1	1	1	1	1	1
440	1	1	1	1	1	1	1	1	1	1

(Source: Thornthwaite and Mather, 1957)

Table B4 Soil moisture retention table - 150 mm storage unit

PE	0	1	2	3	4	5	6	7	8	9
	Water Retained in Soil									
0	150	149	148	147	146	145	144	143	142	141
10	140	139	138	137	136	135	134	133	132	131
20	131	130	129	128	127	127	126	125	124	123
30	122	122	121	120	119	118	117	116	115	114
40	114	113	113	112	111	111	110	109	108	107
50	107	106	106	105	104	103	103	102	101	100
60	100	99	98	97	97	97	96	95	94	93
70	93	92	92	91	90	90	89	89	88	87
80	87	86	86	85	84	84	84	83	83	82
90	82	81	81	80	79	79	78	77	77	76
100	76	76	75	75	74	74	73	72	72	71
110	71	71	70	70	69	69	68	68	67	67
120	66	66	66	65	65	64	64	63	63	62
130	62	62	61	61	60	60	60	59	59	58
140	58	58	57	57	56	56	55	55	54	54
150	54	53	53	53	52	52	52	52	51	51
160	51	51	50	50	50	49	49	48	48	47
170	47	47	47	46	46	46	45	45	45	44
180	44	44	44	43	43	43	42	42	42	41
190	41	41	41	40	40	40	40	39	39	39
200	39	38	38	38	37	37	37	37	36	36
210	36	36	35	35	35	35	35	34	34	34
220	34	34	33	33	33	33	33	32	32	32
230	32	31	31	31	31	31	30	30	30	30
240	30	29	29	29	29	29	28	28	28	28
250	28	27	27	27	27	27	26	26	26	26
260	26	26	25	25	25	25	25	24	24	24
270	24	24	24	23	23	23	23	23	23	23
280	22	22	22	22	22	22	22	22	21	21
290	21	21	21	20	20	20	20	20	20	20
300	20	19	19	19	19	19	19	19	18	18
310	18	18	18	18	18	18	18	17	17	17
320	17	17	17	17	17	17	17	16	16	16
330	16	16	16	16	16	16	16	15	15	15
340	15	15	15	15	15	15	14	14	14	14
350	14	14	14	14	14	14	14	13	13	13
360	13	13	13	13	13	13	13	12	12	12
370	12	12	12	12	12	12	12	12	11	11
380	11	11	11	11	11	11	11	11	11	11
390	11	11	11	10	10	10	10	10	10	10
400	10	10	10	10	10	10	10	10	9	9
410	9	9	9	9	9	9	9	9	9	9
420	9	9	9	8	8	8	8	8	8	8
430	8	8	8	8	8	8	8	8	8	8
440	8	8	8	7	7	7	7	7	7	7

(Source: Thornthwaite and Mather, 1957)

Table B5 Soil moisture retention table - 200 mm storage unit

WATER RETAINED IN SOIL

PE	0	1	2	3	4	5	6	7	8	9
0	200	199	198	197	196	195	194	193	192	191
10	190	189	188	187	186	185	184	183	182	182
20	181	180	179	178	177	176	175	174	173	173
30	172	171	170	169	168	168	167	166	165	164
40	163	162	162	161	160	159	168	158	157	156
50	155	154	153	153	152	151	151	150	149	148
60	148	147	146	145	145	144	143	142	142	141
70	140	140	139	138	138	137	136	135	135	134
80	133	133	132	131	131	130	129	128	128	127
90	127	126	125	125	124	124	123	122	122	121
100	120	120	119	119	118	118	117	116	116	115
110	115	114	113	113	112	112	111	110	110	109
120	109	108	108	107	107	106	106	105	104	104
130	104	103	102	102	102	101	100	100	99	99
140	98	98	97	97	96	96	96	95	94	94
150	94	93	93	92	92	91	91	90	90	89
160	89	88	88	88	87	87	86	86	85	85
170	85	84	84	83	83	82	82	82	81	81
180	80	80	80	79	79	78	78	78	77	77
190	76	76	76	75	75	74	74	74	73	73
200	73	72	72	71	71	71	70	70	70	69
210	69	69	68	68	68	67	67	66	66	66
220	66	65	65	65	64	64	64	63	63	63
230	62	62	62	61	61	61	60	60	60	60
240	59	59	59	58	58	58	58	57	57	57
250	56	56	56	56	55	55	55	54	54	54
260	54	53	53	53	52	52	52	52	51	51
270	51	51	50	50	50	50	49	49	49	49
280	48	48	48	48	47	47	47	47	46	48
290	46	46	46	45	45	45	45	44	44	44
300	44	44	43	43	43	43	42	42	42	42
310	42	41	41	41	41	41	40	40	40	40
320	40	39	39	39	39	39	38	38	38	38
330	38	37	37	37	37	37	36	36	36	36
340	36	36	35	35	35	35	35	34	34	34
350	34	34	34	33	33	33	33	33	32	32
360	32	32	32	32	32	32	31	31	31	31
370	31	30	30	30	30	30	30	29	29	29
380	29	29	29	29	29	28	28	28	28	28
390	28	28	27	27	27	27	27	27	27	26
400	26	26	26	26	26	26	26	25	25	25
410	25	25	25	25	25	24	24	24	24	24
420	24	24	24	23	23	23	23	23	23	23
430	23	22	22	22	22	22	22	22	22	22
440	22	21	21	21	21	21	21	21	21	21

(Source: Thornthwaite and Mather, 1957)

Table B6 Soil moisture retention table - 250 mm storage unit

WATER RETAINED IN SOIL

PE	0	1	2	3	4	5	6	7	8	9
0	250	249	248	247	246	245	244	243	242	241
10	240	239	238	237	236	235	234	233	232	231
20	231	230	229	228	227	226	225	224	223	222
30	222	221	220	219	218	217	216	215	214	213
40	213	212	211	210	209	208	208	207	206	205
50	204	204	203	202	201	200	199	198	197	196
60	196	195	194	193	192	192	191	190	189	188
70	188	188	187	186	185	185	184	183	182	181
80	181	180	179	178	177	177	176	176	175	174
90	174	173	172	171	171	170	170	169	169	168
100	167	167	166	165	165	164	164	163	162	161
110	160	160	159	159	158	157	157	156	156	155
120	154	154	153	152	152	151	151	150	149	148
130	148	147	146	146	145	145	144	144	143	143
140	142	142	141	140	140	139	139	138	137	137
150	136	136	135	135	134	134	133	132	132	131
160	131	130	130	129	129	128	128	127	127	126
170	126	125	125	124	124	123	123	122	122	121
180	121	120	120	119	119	118	118	117	117	116
190	116	115	115	114	114	114	113	113	112	112
200	111	111	110	110	109	109	108	108	108	107
210	107	107	106	106	105	105	105	104	104	103
220	103	103	102	102	101	101	101	100	100	99
230	99	99	98	98	97	97	97	96	96	95
240	95	95	94	94	93	93	93	92	92	91
250	91	91	90	90	89	89	89	88	88	87
260	87	87	87	86	86	86	86	85	85	84
270	84	84	83	83	82	82	82	82	81	81
280	81	81	80	80	79	79	79	79	78	78
290	78	78	77	77	76	76	76	76	75	75
300	74	74	74	73	73	73	73	72	72	71
310	71	71	71	70	70	70	70	69	69	69
320	69	68	68	68	67	67	67	66	66	66
330	66	66	65	65	65	65	64	64	64	63
340	63	63	63	62	62	62	62	61	61	61
350	61	61	60	60	60	60	59	59	59	58
360	58	58	58	57	57	57	57	56	56	56
370	56	55	55	55	55	55	54	54	54	54
380	54	54	53	53	53	53	53	52	52	52
390	52	52	51	51	51	51	51	50	50	50
400	50	50	49	49	49	49	49	48	48	48
410	48	48	47	47	47	47	47	46	46	46
420	46	46	45	45	45	45	45	44	44	44
430	44	44	43	43	43	43	43	42	42	42
440	42	42	42	42	41	41	41	41	41	41

(Source: Thornthwaite and Mather, 1957)

50 + 10 = 60; February, 60 + 7 = 67; March, 67 + 10 = 77; April, 77 - 21 = 56; and May 56 - 59 = -3. The lower limit for available soil moisture is zero storage. Therefore, the May through October storage is 0.0 mm. In November, P-PET = 10, therefore, storage increases by 10 mm, and so on.

The change in storage (Δ storage) is the difference in storage from one month to the following month. For example, January 42, February 49, change = 7 mm; April 81 mm, May 44 mm, change = 37 mm. The change in storage represents soil-moisture replenishment or depletion and is used to calculate actual evapotranspiration (AET).

AET represents the calculated atmospheric loss from the soil and vegetation. When the soil moisture storage is at capacity, or when P exceeds PET, AET is not limited by moisture supply and will, therefore, be at the potential rate (AET = PET). When PET exceeds P, then AET consists of P plus the removal of moisture from the soil (Δ storage).

Deficits occur when PET exceed AET. P-PET is negative, which indicates the soil is drying out and there is not enough water to satisfy vegetation needs.

The surplus is the excess of water above field capacity which runs off or recharges the groundwater systems. When soil moisture storage is below capacity, excess precipitation (P-PET) recharges the soil. When field capacity is achieved, the remaining excess precipitation runs off or percolates to the water table.

Annual runoff is, by definition, equal to the available annual surplus. The surplus is lagged to produce runoff. A 50 percent lag factor is generally used. Thus, half of the surplus will run off in that month, while the remainder is held over and added to the surplus of the following month, of which half runs off, and so on. Mather (1978) indicates that there may be a hold-over of surplus on December that must be added to the January surplus, in which case it is necessary to continue month-by-month runoff computation using the new values of surplus carryover until the value of monthly runoff does not change from one year to the next.

HYDROGEOLOGY OF THE
COLD LAKE STUDY AREA
ALBERTA, CANADA
Part VI. Numerical Simulation of Fluid Flow
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Alberta Geological Survey
Alberta Research Council
(Project Manager: Dr. Brian Hitchon)

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RESEARCH
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PART 6

Numerical Simulation: Dr. S. Bachu

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INTRODUCTION

The objective of mathematical modelling and numerical simulation of formation water flow in the Cold Lake Study Area is to provide a predictive tool for determining the impact of in-situ oil recovery processes and waste disposal on the natural hydrogeological regime in the region. Any modelling process which seeks to achieve this objective must be carried out in two stages. The first stage is to describe the natural conditions that existed prior to any recovery or disposal. The second stage is to examine how the hydrogeological system reacts to, and is modified by, the in-situ and waste disposal processes. The description of the natural (baseline) situation does not necessarily involve mathematical and/or physical modelling (see parts of this Report), but the predictive stage must be based on analog and/or numerical simulation. In terms of modelling, therefore, the primary purpose of the present investigation was to calibrate a numerical model for simulation of steady state natural flow of formation waters within the complex hydrogeological system in the Cold Lake Study Area.

SELECTION OF THE MODEL AREA

The flow of formation waters in the Cold Lake Study Area is three-dimensional within a complex spatial structure of aquifers, aquitards and aquicludes. For modelling purposes it is necessary to define a bounded three-dimensional region with appropriate boundary conditions for fluid flow. Because the present investigation is directed at the effects of in-situ oil recovery and waste disposal, a further restriction is that the model area should include as many of the existing pilot plants as possible (see Atlas map A-a-2). To the north, the Primrose Air Weapons Range (Tp 67-69, R 1-10) is generally off limits to drilling and therefore stratigraphic and hydraulic data are very scarce in this part of the study area, as they also are in the region close to the Alberta-Saskatchewan border (see Atlas map A-a-3).

In addition to the general restrictions noted in the previous paragraph, some hydrostratigraphic restrictions prevailed which limited the areal boundaries of the model area and the stratigraphic sequence within which the numerical simulation was to be carried out. Because it is desirable to have an impermeable lower boundary it was decided to limit the numerical simulation to hydrostratigraphic units lying above the Prairie Formation halite; stratigraphic and hydraulic data are very limited below this aquitard (see Atlas maps C-g-1, C-h-1, and C-h-2). Because of the facts that (1) the Prairie Formation is absent in the northeast corner of the study area due to solution effects, and (2) limited stratigraphic data in the region between the eastern limit of undissolved salt (see fig. 2-6) and the edge of the Prairie Formation results in only tentative structure contours on this aquitard (see Atlas map D-g-3), therefore, the eastern boundary of the model area was set at the approximate eastern limit of undissolved salt. As a result of this decision, the basal aquitard is a uniformly dipping (see Atlas map D-g-3) salt bed about 150 m thick (see Atlas map D-g-4).

There are no hydraulic boundaries (impervious, imposed hydraulic head or prescribed flux) for hydrostratigraphic units lying above the Prairie Formation that can be used as physical boundaries of the model area. The very complex hydrostratigraphic situation in the western half of the Cold Lake Study Area, due to the Leduc Formation carbonate complex, and the hydraulically-interconnected Camrose Tongue, Grosmont Formation, and Wabamun-Winterburn aquifers meant that the model area should be restricted to the eastern half of the study area (which is also coincident with the distribution of the in-situ pilot plants), otherwise the numerical simulation would become extremely complex due to the drawdown effects in the Grosmont Formation aquifer described in Part 4 of this report.

With respect to the upper boundary of the model area, the rivers and lakes present throughout the study area are boundaries of imposed hydraulic head for the shallow Quaternary aquifers, but their influence does not extend into the Phanerozoic sequence (see Parts 4 and 5 of this Report). In the south of the study area the topographic heights to the north of the North Saskatchewan River are the hydraulic surface water divide between the North Saskatchewan and Beaver rivers. These same topographic heights correspond to high elevations on the bedrock surface (see Atlas map 0-g-9) and also to the boundary of the Clearwater Formation aquitard.

The final boundaries of the model area (4815 km^2) are shown in figure 6-1, together with in-situ pilot plants and the boundaries of selected stratigraphic units. Actual delineation of the boundary was related to the subsurface topography on the Pre-Cretaceous unconformity and the structure contours on bedrock. The eastern boundary follows a topographic high on the Pre-Cretaceous unconformity, which is close to the eastern limit of undissolved salt in the Prairie Formation, and to the east of which synclinal structures due to salt solution can be seen in all stratigraphic units to the top of the Cretaceous. The western boundary is centered along a low on the Pre-Cretaceous unconformity. The northeastern and southwestern boundaries are approximately parallel to structure contours on top of the Pre-Cretaceous unconformity. The extreme northern boundary lies immediately south of the Primrose Air Weapons Range. These boundaries also reflect structure contours on the bedrock which was taken into account in defining the exact boundaries, to insure that these were coincident with highs on the bedrock surface and that the model area boundaries crossed bedrock channels normal to the channel axis.

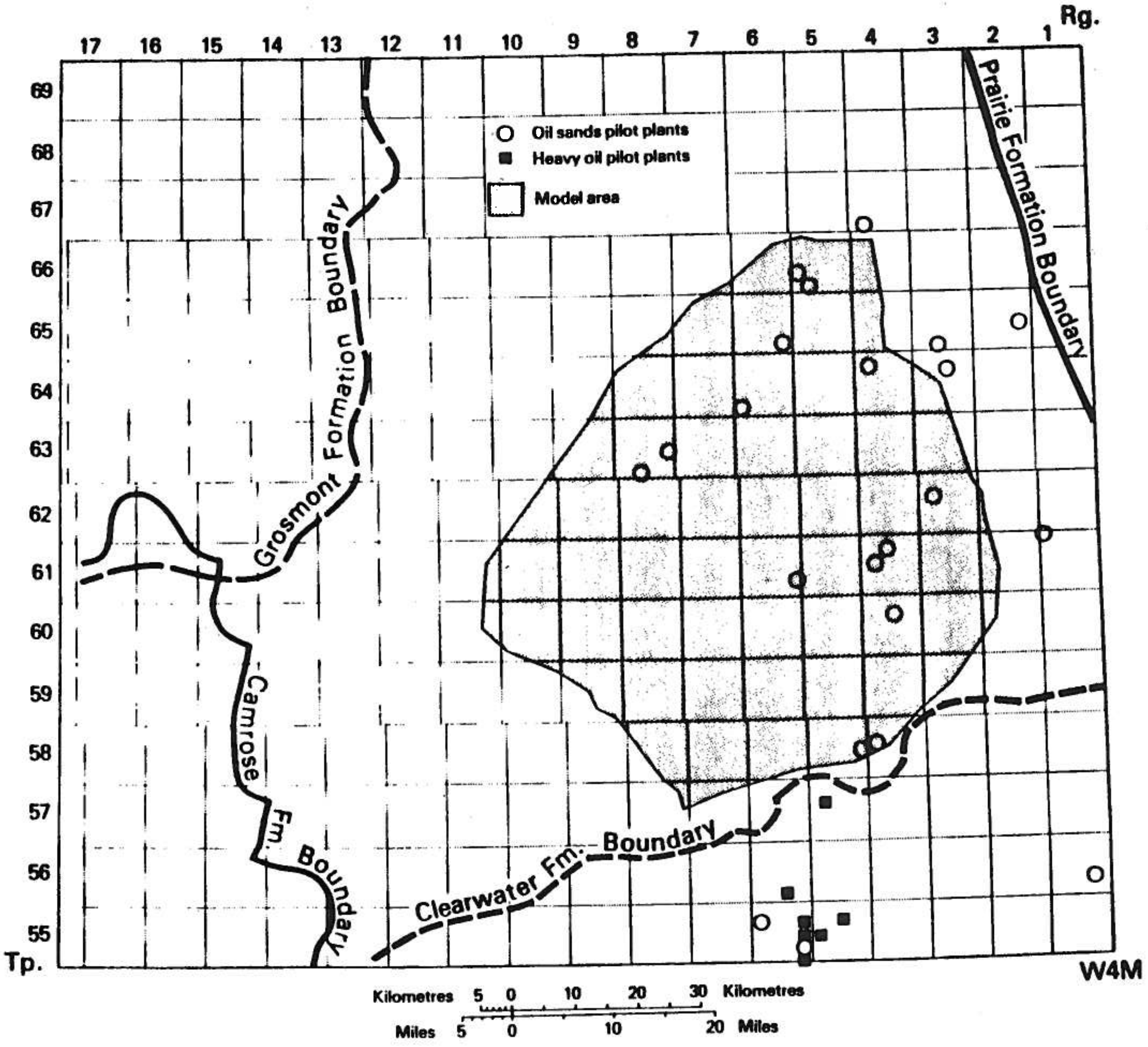

Figure 6-1 In-situ pilot plants and boundaries of selected hydrostratigraphic units in relation to model area, Cold Lake Study Area

MASS BALANCE COMPUTATION

The sedimentary sequence in the model area, down to the Prairie Formation aquiclude, is not a closed hydrogeological system; the only impervious boundary is at the bottom. At the top of the sedimentary sequence there is natural replenishment into the system from the Quaternary. Fluid flow in the aquitards is vertical, so that within them there is no mass exchange along their lateral boundaries between the sedimentary sequence in the model area and the rest of the study area. In contrast, fluid flow in the aquifers has a horizontal component which cannot be neglected. Along the lateral boundaries of the aquifers fluid moves in and out of the system. Considering the case of steady state natural flow, before any injection or pumping activity, there are no fluid sources or sinks in the area. Therefore, the mass balance of the system must close.

The lateral inflow or outflow across the boundary of each aquifer can be computed according to:

$$Q=\Sigma q_i S_i \tag{6.1}$$

where Q is the total flux crossing the lateral boundary, S_i is the area of an element of the lateral surface bounding the aquifer along the boundary of the model area, and q_i is the specific discharge normal to the respective surface element. The specific discharge, q_i, is computed according to Darcy's Law for flow in porous media. The lateral surface elements are defined between the top and bottom of the aquifer and vertically down from nodes along the boundary of the model area. A computer program was written to automatically handle this procedure, starting from synthesized data stored on magnetic devices. The inputs into the program are the regular grids describing the potentiometric surface, the top and bottom of the respective aquifer, the nodes describing the boundary and their coordinates, and the hydraulic conductivity for each element. The program locates the position of the nodes into the grids, computes the area, S_i, of the areal element between the nodes i and i+1, the hydraulic gradient normal to the surface, S_i, and finally, the fluid flux across this element. Actually, a constant value of the hydraulic conductivity was used for each aquifer, which was equal to the median value for that aquifer in the model area. This was dictated, in part, by the fact that the numerical model used subsequently considered each hydrostratigraphic unit as homogeneous. Table 6-1 shows the lateral fluxes across the boundaries of the aquifers in the sedimentary sequence in the model area. It should be noted here that the values of hydraulic conductivity used in the mass balance and numerical simulation refer to the model area only, and not to the entire Cold Lake Study Area.

Table 6-1

Lateral fluxes in Phanerozoic aquifers, model area, Cold Lake Study Area

Aquifer	Hydraulic conductivity (m/s)	Lateral area (km^2)	Inflow (m^3/day)	Outflow (m^3/day)	Net flow (m^3/day)
"Viking sandstone"	$1x10^{-9}$	0.42	0.045	0.031	0.014
"Upper Mannville" Group	$1x10^{-8}$	26.31	5.68	13.05	-7.37
"Lower Mannville" Group	$1.3x10^{-7}$	24.04	93.90	167.00	-73.10
Cooking Lake-Beaverhill Lake-Watt Mountain	$7.8x10^{-8}$	63.20	12.60	13.95	-1.35

For any modelling process it is necessary to know the hydraulic conductivity of the aquitards. A value of $1x10^{-13}$m/s is indicated by Bredehoeft and Hanshaw (1968), but more precise values for the average effective hydraulic conductivity can be obtained by calculating the flow mass balance for the entire hydrostratigraphic sequence in the model area, including the aquitards.

There is a difference of several orders of magnitude between the hydraulic conductivities of aquifers and aquitards. It follows, then, that the drop in hydraulic head between two aquifers separated by an aquitard takes place effectively entirely over the thickness of the aquitard. Given the potentiometric surfaces in each aquifer and the thickness of the aquitard, it is possible to compute the vertical hydraulic gradients in the aquitard. Assuming values for the hydraulic conductivity of the aquitard, the total crossflow between aquifers can then be computed. This procedure was automated using a program which reads at input the grids defining the isopach of the respective aquitard, the potentiometric surfaces for the aquifers above and below it, the contour of a closed area (here the model area), and a value of the average hydraulic conductivity assigned to that aquitard. The closed area has to be divided into elements defined by their nodes (which in any case is a necessary procedure in finite-element modelling). The program locates each element in the grids, computes the hydraulic gradient and specific discharge at the center of each element, and integrates the specific discharge over the entire closed area. The output contains information about the area, specific discharge and flux for each element as well as for the entire model area. The only unknown data for computing the vertical flow through the aquitards are their hydraulic conductivities. These values can be found by a trial-and-error procedure until the flow mass balance of the entire system is closed.

The potentiometric surface in the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer is higher than that in the "Lower Mannville" Group aquifer whenever the Ireton Formation aquitard is present (see figs. 4-33 and 4-37, respectively). Therefore, there is upward flow from the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer into the "Lower Mannville" Group aquifer through the Ireton Formation aquitard. Taking into account the fact that the bottom of the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer is impervious (top of Prairie Formation aquiclude), it follows that there will always be a flow deficit in the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer (see Table 6-1) unless a different hydraulic conductivity is used for the western and eastern parts of the aquifer in the study area, or the potentiometric surface is changed to accommodate more lateral inflow from the west and/or less lateral outflow in the east. Assuming a value of the hydraulic conductivity of $1x10^{-13}$ m/s for the Ireton Formation aquitard, the total flow deficit in the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer is $Q=29.85\ m^3$/day, which is about 2.5 times more than the total inflow. Because there are no grounds, based on the distribution of data points, to change either the potentiometric surface or the hydraulic conductivity in the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, this deficit can only be brought to a more reasonable ratio by changing the value of hydraulic conductivity in the Ireton Formation aquitard. For $K=1x10^{-14}$ m/sec, the flow deficit becomes $Q=4.2\ m^3$/day (about 33 percent of the total inflow), out of which 2.85 m^3/day flow upwards to the "Lower Mannville" Group aquifer.

The "Lower Mannville" Group aquifer has a lateral flow deficit in the model area of $Q=73.10\ m^3$/day. Considering the 2.85 m^3/day coming from the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer through the Ireton Formation aquitard, it follows that the remainder of 70.25 m^3/day has to come from the "Upper Mannville" Group aquifer, downward through the Clearwater Formation aquitard. Based on the difference between the potentiometric surfaces of the "Upper Mannville" Group and "Lower Mannville" Group aquifers, and on the thickness of the Clearwater Formation aquitard, this amount of vertical flow is made possible if the average hydraulic conductivity of the Clearwater Formation aquitard is assumed to be $2x10^{-14}$ m/s.

The "Viking sandstone" aquifer is present only in the southwest half of the model area, and has an average thickness about 2 m. Lateral flow in this aquifer is two to three orders of magnitude less than the lateral flow in any other aquifer in the hydrostratigraphic sequence. This aquifer is separated from the "Upper Mannville" Group aquifer by the Joli Fou Formation aquitard (average thickness, 20 m), and from the top of the bedrock by 200-300 m of shales of the Colorado aquitard, which includes thin layers and lenses of sandstone (Intra-Colorado aquifers). Based on this quantitative analysis, the "Viking sandstone" aquifer can be neglected, and all strata between the top of the "Upper Mannville" Group aquifer and the top of the bedrock can be considered as a single aquitard, here termed the Colorado Supergroup. This approximation has a considerable effect in reducing the computational effort of numerical simulation by substantially decreasing the number of nodes and elements in the finite element grid.

The mass balance of the "Upper Mannville" Group aquifer shows that a discharge of $Q=77.62\ m^3/day$ has to flow downward from the Quaternary strata into this aquifer through the Colorado Supergroup aquitard. In order to be able to evaluate the average hydraulic conductivity of this aquitard, it is necessary to know the potentiometric surface at the top of the bedrock. The Quaternary aquifers have a very high hydraulic conductivity ($K=1x10^{-4}$ m/s), compared to the aquifers and aquitards in the Phanerozoic sequence. As a first approximation, the water table can be considered as the potentiometric surface at the top of the bedrock, resulting in a value of $K=5x10^{-13}$ m/s for the hydraulic conductivity in the Colorado Supergroup aquitard. Taking into account that there is actually a hydraulic head drop between the water table and the top of the bedrock, the hydraulic conductivity of the Colorado Supergroup aquitard must be about $K=1x10^{-12}$ m/s to account for the downward flow of 77.62 m^3/day over the model area.

The variation of hydraulic conductivity between the shales of the Colorado Supergroup aquitard and those of the Ireton Formation aquitard is due to variations in permeability. The general decrease of shale permeability with depth results from compaction processes, but the higher permeability of the Colorado Supergroup aquitard is due, specifically, to the fact that it includes the "Viking Sandstone" aquifer and some thin layers and lenses of sandstone (Intra-Colorado aquifers).

The recharge of 77.62 m^3/day at the top of the bedrock over a surface area of 4815 km^2 (model area) amounts to $5.9x10^{-3}$ mm/yr infiltration. The annual rainfall in the region is 452 mm/yr, the runoff is 38 mm/yr, and the evaporation and sublimation losses are 263 mm/yr (see Part 5). The majority of the remainder of 151 mm is lost back to the atmosphere by evapotranspiration, leaving a small amount for the local recharge of the surficial groundwater system. The amount of this recharge was not determined in this study, but still it seems to be several orders of magnitude higher than the recharge from the Quaternary strata into the Phanerozoic sequence. Taking into account the contrast between the hydraulic conductivities of the Quaternary aquifers and aquitards ($K=1x10^{-4}$ m/s and $K=1x10^{-8}$ m/s, respectively) and of the Colorado Supergroup aquitard ($K=1x10^{-12}$ m/s) at the top of the Phanerozoic sequence, as well as the recharge at the top of the bedrock, it follows that flow in the Quaternary strata is mainly horizontal. The top of the bedrock therefore acts like an impervious bottom boundary for the Quaternary hydrostratigraphic sequence. More than that, there is a difference of scale between the groundwater flow in the Quaternary sequence and the flow of formation waters in the Phanerozoic sequence (for example, thicknesses of the aquifers and aquitards, permeabilities, specific discharge). Therefore, the Quaternary and Phanerozoic sequences have to be disconnected and treated separately. From the point of view of the numerical and computational effort, this conclusion has a marked impact by reducing the computer resources needed for numerical simulation of fluid flow in the Phanerozoic hydrostratigraphic sequence.

As a result of this mass balance analysis, the hydrostratigraphy of the Phanerozoic sequence in the model area (fig. 6-2) is defined in

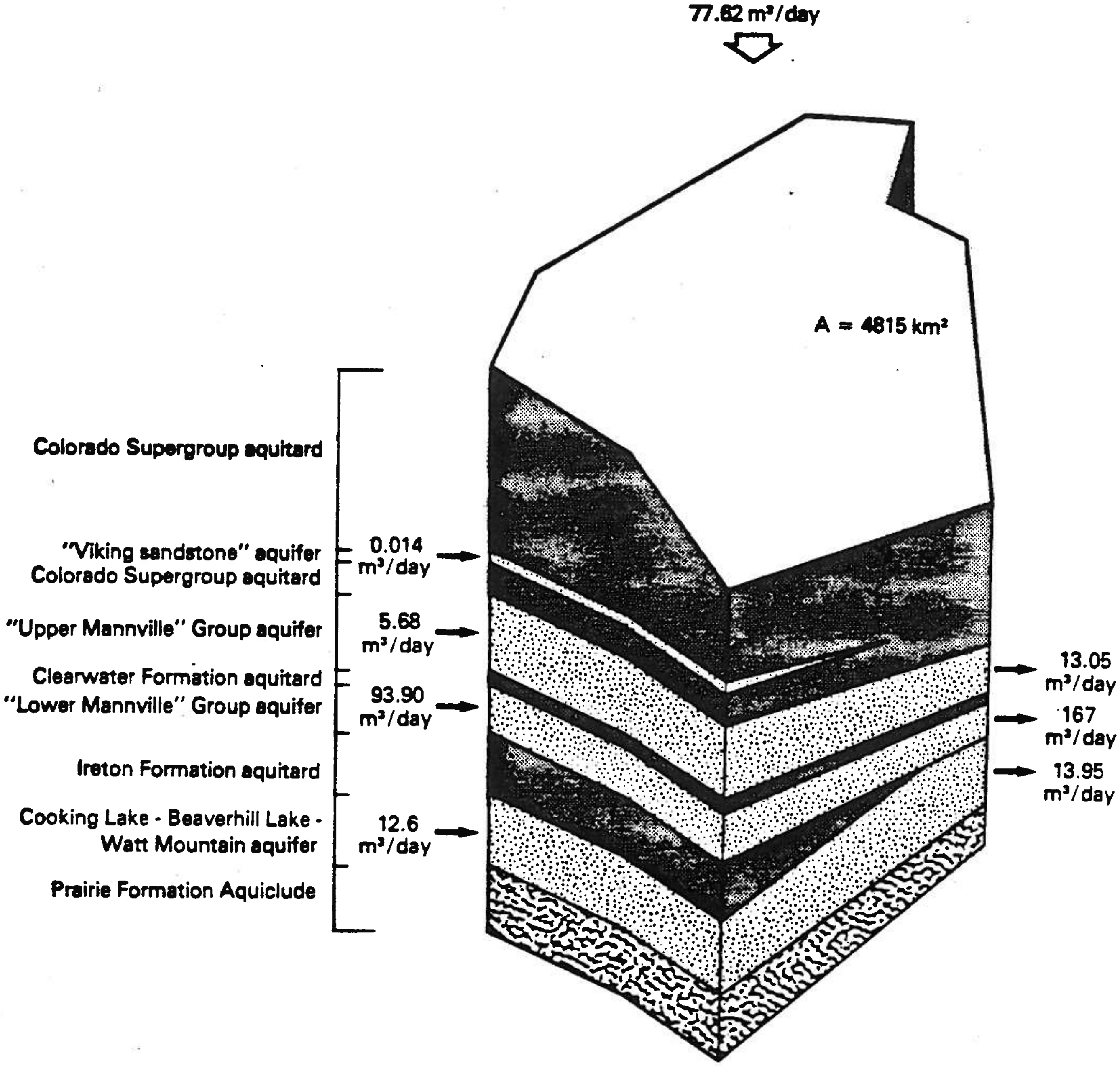

Figure 6-2 Block diagram of the Phanerozoic sequence in the model area, Cold Lake Study Area. The arrows indicate input and output volumes

ascending order by: the Prairie Formation aquiclude, the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, the Ireton Formation aquitard (not present throughout the model area), the "Lower Mannville" Group aquifer, which is separated from the "Upper Mannville" Group aquifer by the Clearwater Formation aquitard, and the Colorado Supergroup aquitard (the top of which is the bedrock surface).

MATHEMATICAL AND NUMERICAL MODEL

The unsteady saturated flow in nonhomogeneous porous media of an incompressible fluid is described by the following continutiy equation (Bear, 1972):

$$\nabla.(\bar{\bar{K}}\nabla H)-Q=S_s\partial H/\partial t \qquad (6.2)$$

where $\bar{\bar{K}}$ [L/T] is the hydraulic conductivity tensor, H[L] is the hydraulic head above a common datum, S_s [1/L] is the specific storage, Q [1/t] is the strength of the sources and/or sinks, and t is time.

Except for a few particular cases, there is no analytical solution to equation 6.2. In the case of the Cold Lake Study Area it is not possible to obtain an analytical solution due to the complexity of the three-dimensional hydrostratigraphic structure, the variability of the parameters, and of the boundary conditions. In order to solve equation 6.2, it is necessary to obtain a numerical solution, provided by a numerical model. For the purpose of this study, the model FE3DGW (Finite Element 3-Dimensional GroundWater) was selected for the numerical simulation of the flow. This model was developed by Pacific Northwest Laboratory (USA), and the complete description of the numerical formulation and of the pertinent software is given in Gupta et al. (1979). This software package was received by the Basin Analysis Group, Alberta Geological Survey, Alberta Research Council, from Battelle Memorial Institute, Ohio, together with a set of data as an example. The package was implemented on the Research Council's computer system (VAX/VMS) and tested with the original set of data. The main advantage of the finite element formulation over the finite difference formulation consists in the elasticity of the former in describing complex geometrical structures.

The FE3DGW software is composed of five main programs which can be run independently, but in a specified order (fig. 6-3).

The main program for data input is PROG1. It reads in from the file MODIN (MODel INput) all the time-independent data which describe the region modelled, accounting for finite element formulation as follows: hydraulic properties of the strata and of the fluid; node definition; surface element definition; and constant boundary conditions (imposed hydraulic heads and/or prescribed fluxes). Based on the surface nodes and elements, the program then builds the three-dimensional elements along the vertical logs down from the surface. The program PROG2 checks the input data from the point of view of finite element formulation and computes the Gauss integration parameters. If an element is not properly described, a message is printed out and further computations are not allowed. The program BAND forms the matrix of unknowns for the numerical solution of equation 6.2. The program PROG3I then allows for changes in the boundary conditions defined at the input of PROG1, as well as for time dependent boundary conditions and/or sources and sinks (injection, pumping). The input data for PROG3I are read from the file CONDIN (CONDitions at INput). The program PROG3 is the one which actually performs all the computations to find the solution for equation 6.2. The output of PROG3 consists of a list of nodes in the system and the corresponding computed hydraulic head. If the problem is a case of unsteady flow, such a list is printed at the end of each time step. For the steady state case, this list is printed at the end of the computations. The intermediary data created by one program of the package and needed by another are transmitted through temporary files.

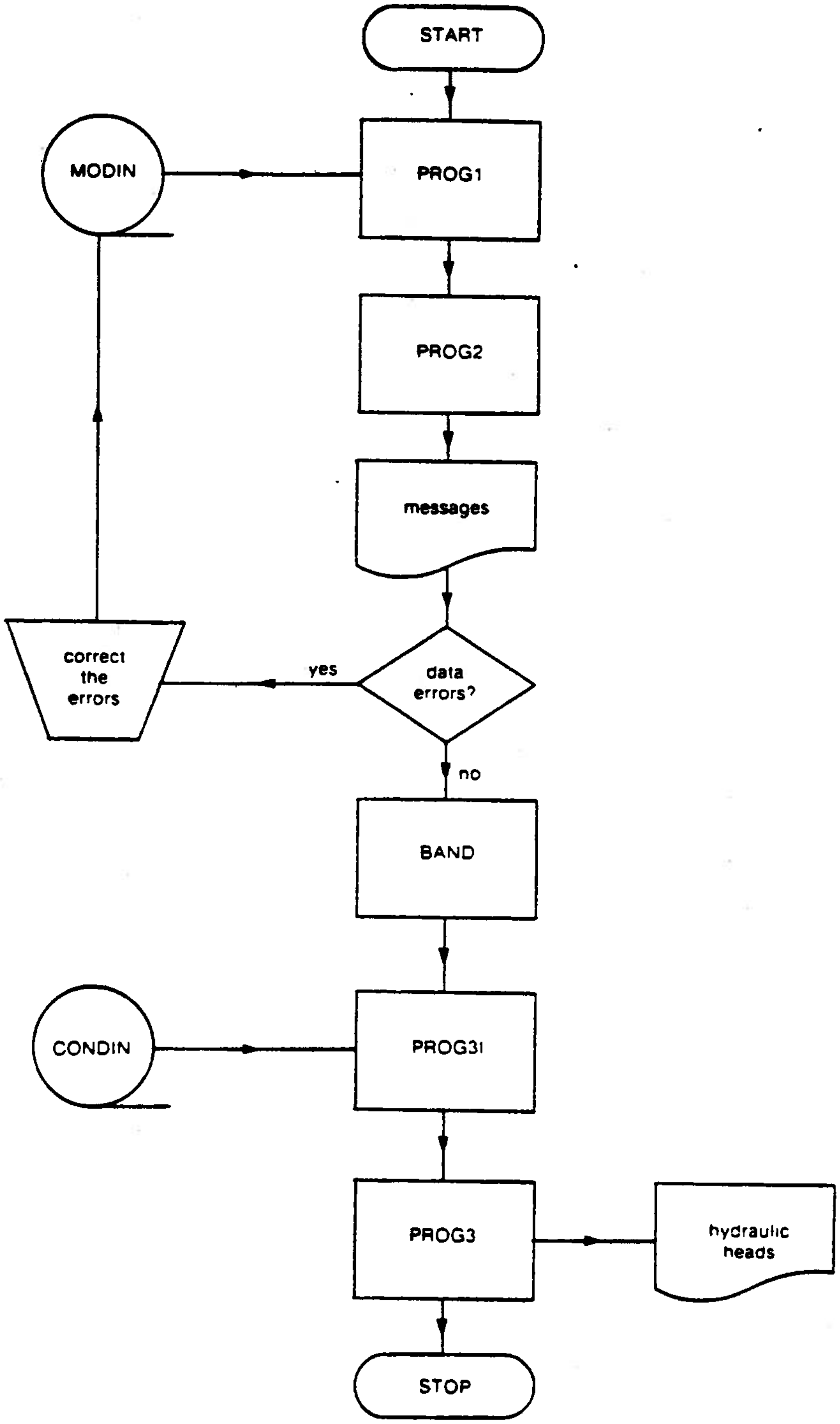

Figure 6-3 Flow chart of modular links in the FE3DGW software

In order to apply the numerical model FE3DGW to the Cold Lake model area, it was necessary to prepare the input data as required by the programs PROG1 and PROG3I. At the same time, the results of the modelling process resulting from PROG3 had to be represented in the same manner as all data from the Cold Lake Study Area. To achieve this, a set of programs was developed to link the representation and storage of synthesized data for the Cold Lake Study Area with the FE3DGW model, such that human interference was minimized.

The files MATSEF (MATerial properites SEquential File), ARNOD (ARea NODes), AREL (ARea ELements), HEADBC (HEAD Boundary Conditions) and FLUXBC (FLUX Boundary Conditions) had to be created by the user (fig. 6-4). The file MATSEF contains information about the material properties of the strata in the model area: name, code, density, compressibility, specific storage, permeability, hydraulic conductivity and porosity. The program WINMAT (Write INdexed MATerials file) creates a sequential indexed file MATINF (MATerial properties INdexed File) out of MATSEF, to be read as input by the program PREGEOM. The file ARNOD contains a list of the nodes at the surface, together with the Dominion Land Survey (DLS) and x-y coordinates for graphical representation and location in the regular grids. The program NODIN (NODes INput) reads the file ARNOD and creates a similar file at output, INNOD (INput NODes), with added information about the node type (corner node or mid-node). The file AREL contains a list of the areal elements covering the model area at the surface, the element type (quadrilateral, mixed order, etc.), and the list of surface nodes defining each element. The files HEADBC and FLUXBC each contain a list of the nodes with prescribed boundary conditions (hydraulic head or flux, respectively), and the boundary value associated with each node in the list.

The program PREGEOM (PREpare GEOMetry) prepares, in an interactive mode, the file MODIN which is the input file as required by PROG1 of the FE3DGW model. It reads the files MATINF, INNOD, AREL,

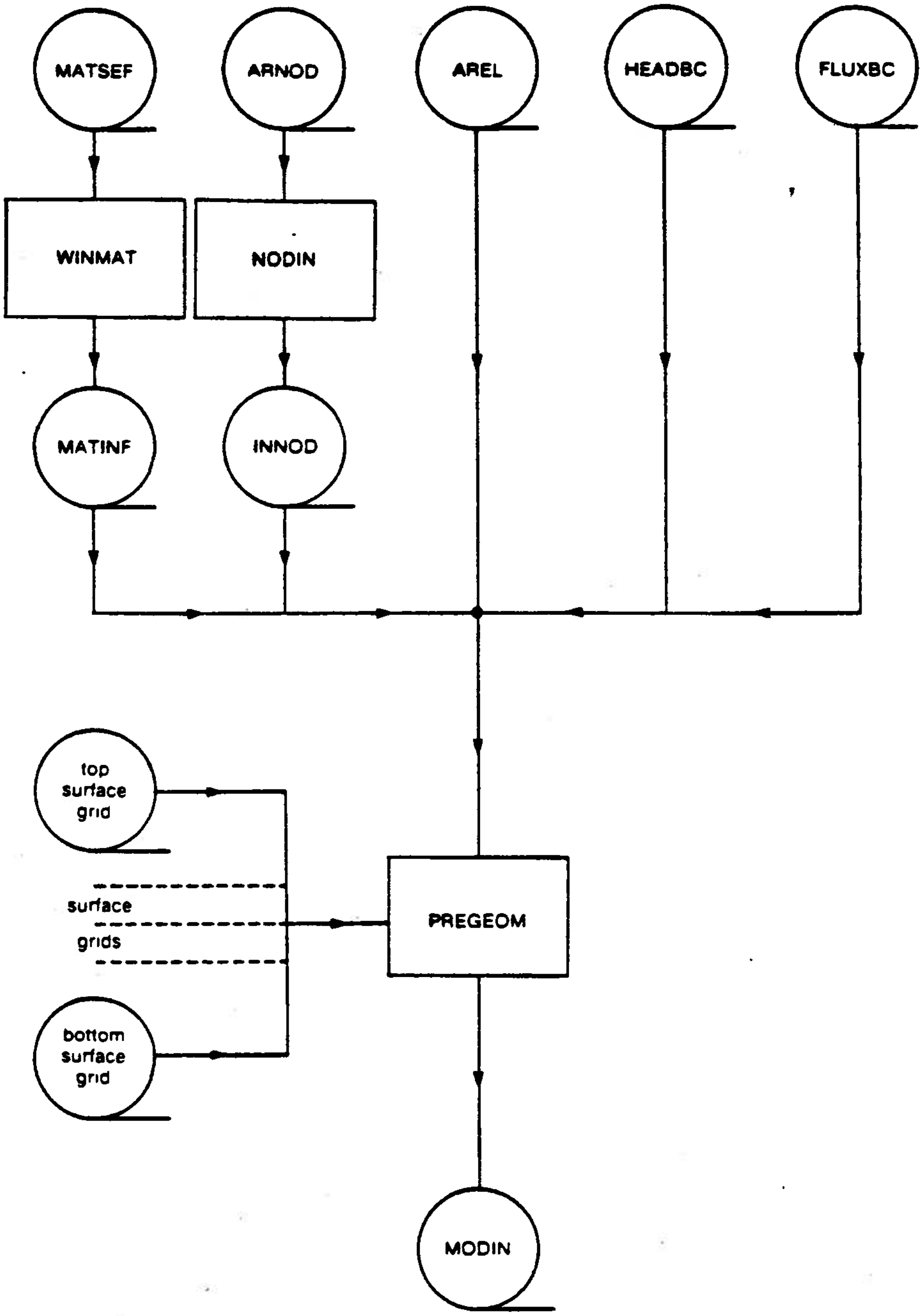

Figure 6-4 Flow chart of data processing to prepare the input for FE3DGW model

HEADBC, FLUXBC, as well as the files with the surfaces describing the hydrostratigraphic structure in the model area, which are defined as values at nodes in regular grids. The surface nodes listed in INNOD are interpolated in the grids to produce the logs of the nodes at each vertical.

The program PRECOND (PREpare boundary CONDitions) prepares, interactively, the file CONDIN (boundary CONDitions INput) which represents the input file for PROG3I (fig. 6-5). If needed, it changes the initial boundary conditions, defines the time steps for runs in the unsteady state, and changes the distribution and time variation of the sources and/or sinks.

The program PROG3 of the FE3DGW model was modified to produce at output a file on magnetic device, HEADLST (HEADs LiST), with the list of the nodes and the computed hydraulic head at each node (fig. 6-5, bottom diagram). The program PREMAP (PREpare MAP) reads the file HEADLST and produces at output the same information per node, plus the x-y coordintes in the system which fits the map representation of all synthesized data. Then, using the SURFACE II software package (Kansas Geological Survey), the distribution of values at all nodes in the finite element grid is transformed into a distribution of values at nodes in a regular grid, which are graphically represented as potentiometric surface maps. Using the final grids and maps, the results of the numerical simulation can be compared with other synthesized data stored in the same form.

The result of the programming effort in creating PREGEOM, PRECOND and PREMAP is the integration of the FE3DGW model software into a system which allows the user to go from synthesized data, to numerical simulation, and back again, with the results in the same synthesized form. However, it must be stressed that these programs are compatible with FE3DGW software only, and therefore they have to be changed or modified when using a different numerical model.

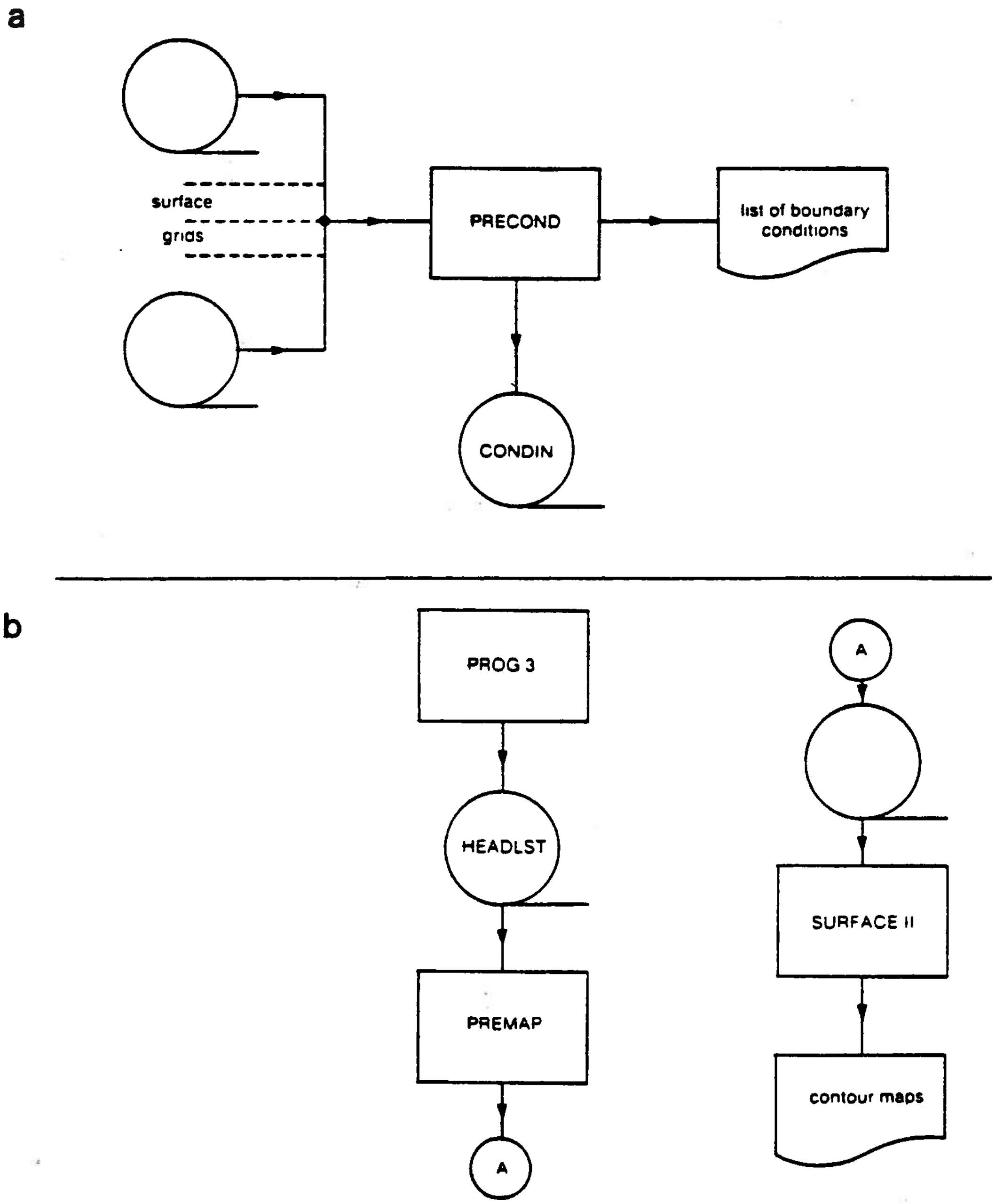

Figure 6-5 Flow charts of data processing for: (a) input of time dependent boundary conditions; (b) graphical representation of the results of numerical simulation

NUMERICAL SIMULATION OF STEADY STATE NATURAL FLOW

The first step in running a finite element numerical model for a real case is to define the distribution of nodes where the unknown values are to be computed, and to cover the region with elements. The model area was divided into 100 surface elements with a total of 120 surface nodes (fig. 6-6). The distribution of the surface nodes and the shape of the surface elements was chosen to reflect subsurface features of the hydrostratigraphic structure from the top of the Prairie Formation aquiclude to the top of the bedrock. For example, a string of nodes and element sides follows the boundary of the Ireton Formation aquitard, while other nodes and elements describe the highs and lows of the Pre-Cretaceous unconformity, or the top of the bedrock. The areal distribution of surface nodes and elements was transformed into a three-dimensional structure with nodes along vertical axes from the surface, resulting in a discrete system of 547 volume elements defined by 765 nodes.

In order to solve equation 6.2 it is necessary to define appropriate boundary conditions. As a first approximation, the hydraulic heads at the top of the system were considered to be those at the water table. The Prairie Formation aquiclude at the bottom introduces a no-flux basal boundary condition. For the lateral boundaries of the system the problem is more difficult, in the sense that there are no hydraulic boundaries to maintain an imposed hydraulic head or a prescribed flux. In the case of steady state natural flow, there are no flow sources or sinks in the model area, and equation 6.2 becomes an elliptic partial differential equation:

$$\nabla.(\bar{\bar{K}}\nabla H)=0 \qquad (6.3)$$

whose solution requires definition of the lateral boundary conditions. The hydraulic heads were imposed at the nodes along the lateral boundary of the model area for each aquifer in the hydrostratigraphic sequence. In this manner, the number of nodes in the sytem where the

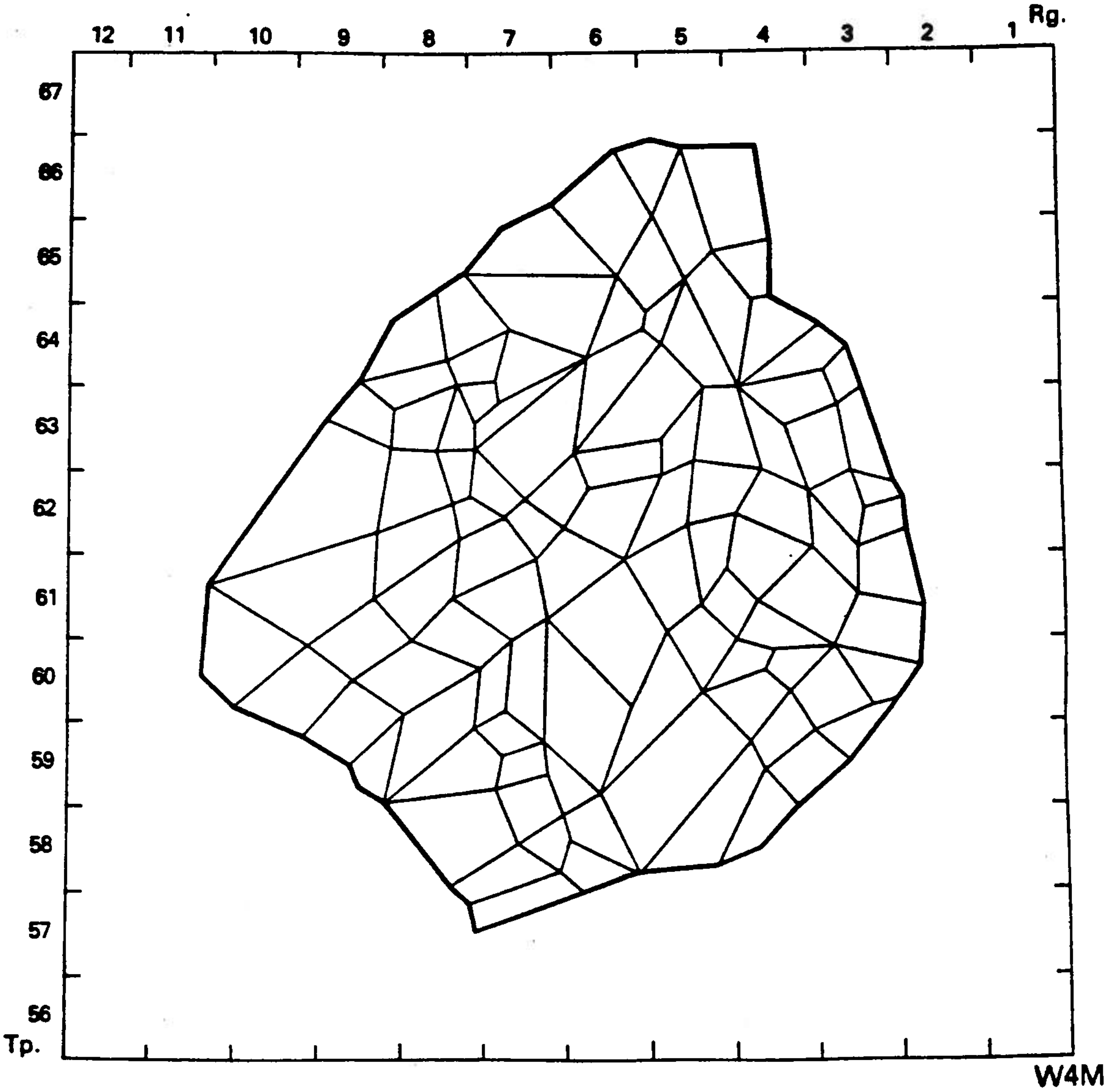

Figure 6-6 Distribution of nodes and elements in the model area, Cold Lake Study Area

hydraulic head has to be computed is reduced to 555. This number defines the size of the matrix of unknowns in the numerical solution of equation 6.3 for the model area. The stiffness of the matrix depends on the numbering of the nodes and elements, and in this case it is equal to 42. It must be added here that a trial run of the numerical model was performed for the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer only (single layer aquifer), in order to test the software with in-house data, before a full scale simulation of the model area was run.

In order to assess the results of the numerical simulation, these have to be compared with the results of the flow analysis of Part 4. This comparison is made three ways: observed versus computed potentiometric surfaces of aquifers; computed hydraulic heads at the nodes in the finite element model versus hydraulic heads at the same locations in the regular grids describing the potentiometric surfaces; and measured hydraulic head at real wells in the model area versus computed hydraulic heads at the same locations. In assessing these comparisons, one has to take into account the approximations and assumptions made at each step in each of the data processing procedures and in the numerical simulation.

A first approximation is made when values at nodes in a regular grid are obtained out of an irregular distribution of real (measured) values. The regular grid distribution depends, among many factors, on its resolution, on the initial data size and sample distribution, on the gridding method, on the parameters and constraints of the method itself, and on the interpolation and extrapolation procedures. In the graphical representation of the regular grids as contour maps there are approximations and differences depending on the grid resolution and on the interpolation method. In the mathematical modelling there are basic assumptions about the flow (for example, homogeneous saturated single fluid and isothermal flow), the porous matrix (for example, isotropic or nondeformable) and the boundary conditions. In the numerical simulation there are assumptions (for example, in this study, considering a constant hydraulic conductivity for each layer) and approximations inherent to the discretization process, as well as to the method (finite element or finite difference). In addition, there are approximations in the gridding and contouring of the computed values at the nodes in the finite element grid, for comparison with the initial potentiometric surface maps. As a result, one cannot expect a complete match between observed and computed data.

To illustrate some of the points above, Table 6-2 shows the difference between observed hydraulic heads at well locations, and the value of the hydraulic head at the same location in the regular grid of values describing the potentiometric surfaces (synthesized data).

Table 6-2

Comparison between observed hydraulic heads and values at the same locations in the potentiometric surface grids, model area, Cold Lake Study Area

Aquifer	Number of wells	Average error (%)	Maximum error (%)	Number of errors >5%	Number of errors >10%
"Upper Mannville" Group	216	1.34	10.88	8	1
"Lower Mannville" Group	54	1.31	9.03	2	-
Cooking Lake-Beaverhill Lake-Watt Mountain	4	0.77	2.74	-	-

The dependence of the contour maps on the data distribution is illustrated in figure 6-7. If one considers the regular grid of values describing the potentiometric surface of the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer (see fig. 4-33), then the upper diagram in figure 6-7 represents the contour lines in this grid, at

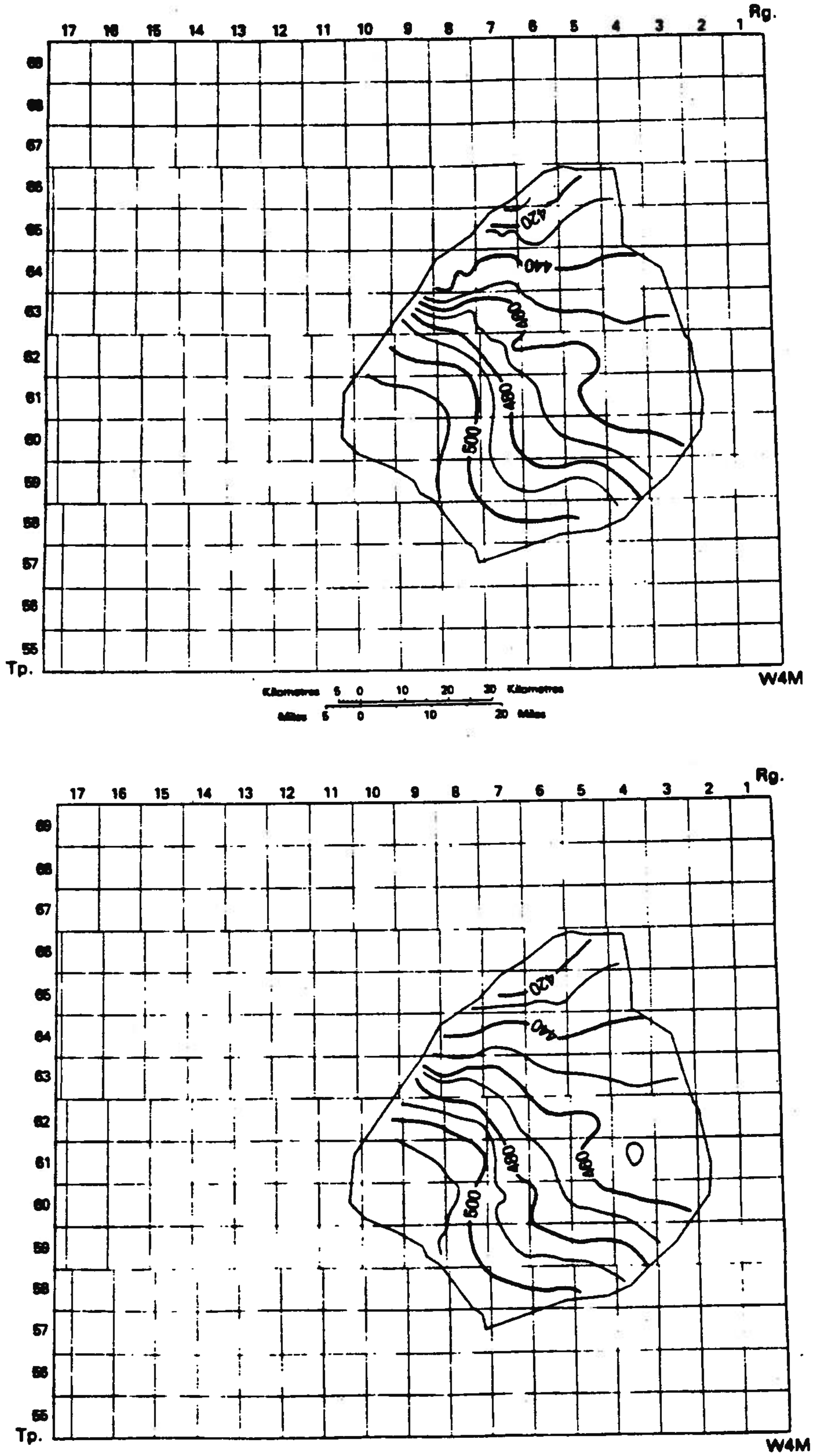

Figure 6-7 Influence of data distribution on the gridding and contouring of the potentiometric surfaces of the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, Cold Lake Study Area. Upper diagram: based on regular grid values (see fig. 4-33, Atlas map E-h-3); Lower diagram: map based on values at finite element nodes

10 m intervals, in the model area only. In the lower diagram the map is based only on the values of the hydraulic heads at the location of the nodes in the finite element grid, as derived from the regular grid. Figure 6-8 shows the potentiometric surface for this same aquifer obtained from computed hydraulic heads for the model area. The computed flow is smoother than the observed one, and this is a direct result of the basic assumptions involved in mathematical modelling (for example, the homogeneity of the fluid and solid matrices). In the southwest part of the model area the hydraulic gradient in this aquifer is steeper than the observed one, to allow for an increased inflow to close the mass balance. This result is quite expected because the continuity equation (6.2), is in fact an expression derived from the mass conservation law. Figure 6-9 shows similarly computed potentiometric surface maps for the "Lower Mannville" and "Upper Mannville" group aquifers.

The computed hydraulic heads at 96 nodes in each aquifer are compared with corresponding values at the same locations in the regular grid of observed data. For the other 24 nodes along the lateral boundary in each aquifer, the hydraulic head was prescribed. The synthesis of the comparison is presented in Table 6-3.

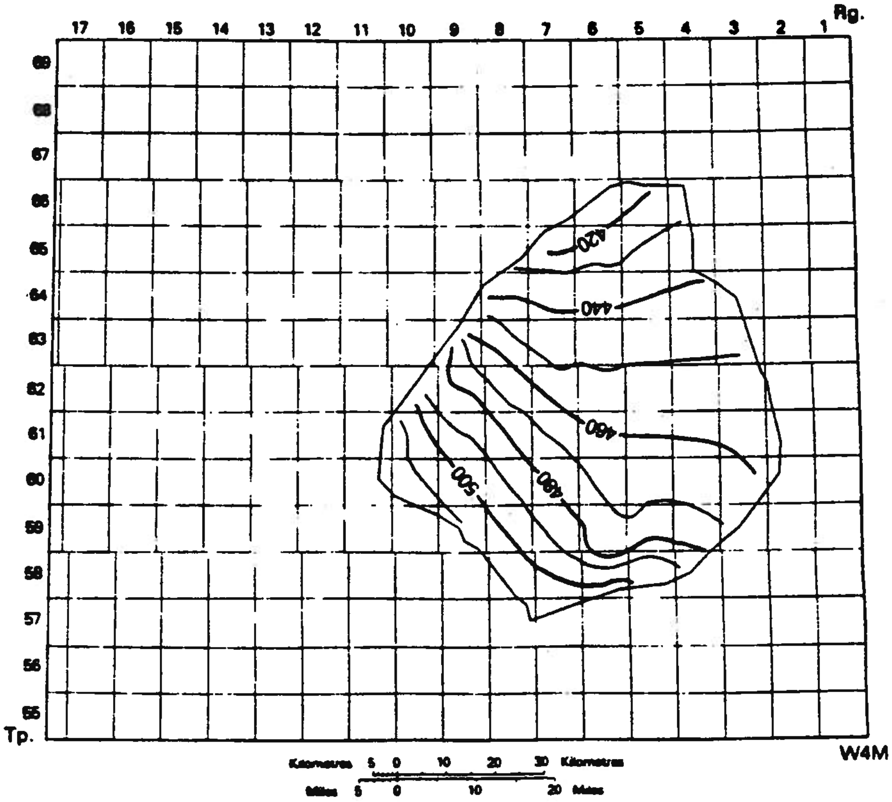

Figure 6-8 Computed potentiometric surface of the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer, model area, Cold Lake Study Area

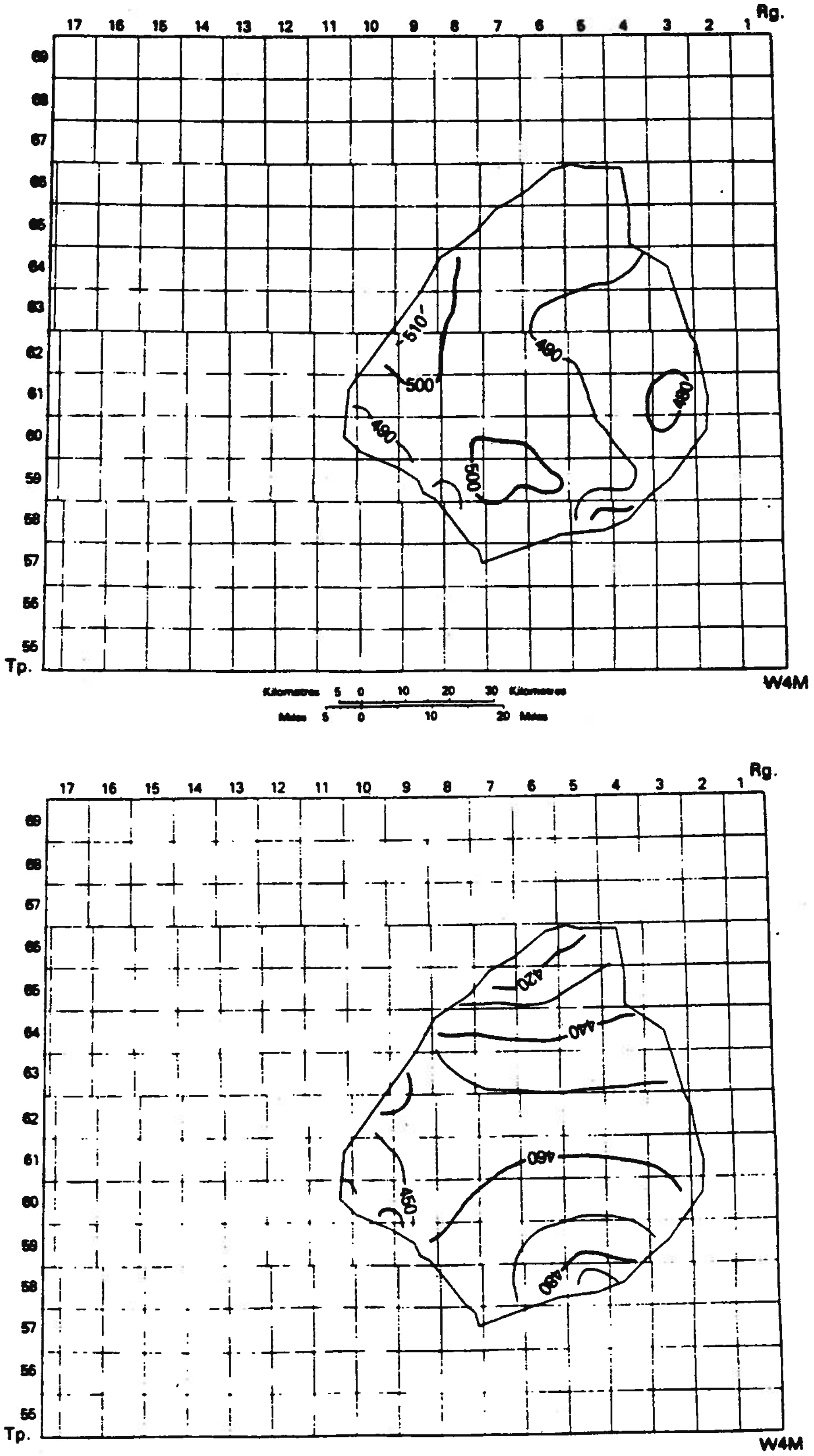

Figure 6-9 Computed potentiometric surfaces of the "Upper Mannville" Group aquifer (upper diagram) and "Lower Mannville" Group aquifer (lower diagram), model area, Cold Lake Study Area

Table 6-3

Comparison between computed hydraulic heads at FEM nodes and values at the same locations in the potentiometric surface grids (765 nodes, 547 elements), model area, Cold Lake Study Area

Aquifer	Number of data points	Average error (%)	Maximum error (%)	Absolute max. error (m)
"Upper Mannville" Group	96	1.4	5.5	27
"Lower Mannville" Group	96	1.3	6.7	30
Cooking Lake-Beaverhill Lake-Watt Mountain	96	1.3	6.2	29

Table 6-4 shows the results of a comparison between observed hydraulic heads at real well locations in the model area, and computed hydraulic heads at the same locations obtained by gridding and interpolation of the computed values at finite elements (FEM) nodes.

Table 6-4

Comparison between observed hydraulic heads and computed values at the same locations (FEM grid with 765 nodes, 547 elements), model area, Cold Lake Study Area.

Aquifer	Number of wells	Average error (%)	Maximum error (%)	Number of errors >5%	Number of errors >10%
"Upper Mannville" Group	216	2.6	13.6	28	6
"Lower Mannville" Group	54	2.8	10.1	8	1
Cooking Lake-Beaverhill Lake-Watt Mountain	4	2.8	6.3	1	-

The higher difference between observed and computed values (Table 6-4) than between synthesized and computed values (Table 6-3) is due to the facts that the model itself is run on synthesized data, and that there are differences between observed and synthesized values as well (see Table 6-2). The comparisons between computed values at FEM nodes and values in the grids of potentiometric surfaces, as well as between observed hydraulic heads at well locations and computed values were done automatically using a program for interpolations in the various grids.

In order to check the accuracy of the numerical simulation and the sensitivity of the model to the FEM grid size, the number of the surface elements was increased from 100 to 168, with a corresponding increase in the number of surface nodes from 120 to 192. The finer distribution of surface elements is shown in figure 6-10. The increase in the number of surface nodes and elements translates into an increase of the number of nodes and volume elements in the three-dimensional structure to 1226 and 916, respectively. Out of the 1226 nodes, 302 have an imposed hydraulic head because they represent the boundary conditions (at the top and laterally), resulting in a matrix of 924 unknowns with a stiffness of 45. Tables 6-5 and 6-6 show comparisons between computed hydraulic heads at FEM nodes and values at the same locations in the potentiometric grids, and between observed hydraulic heads at well locations and computed values, respectively.

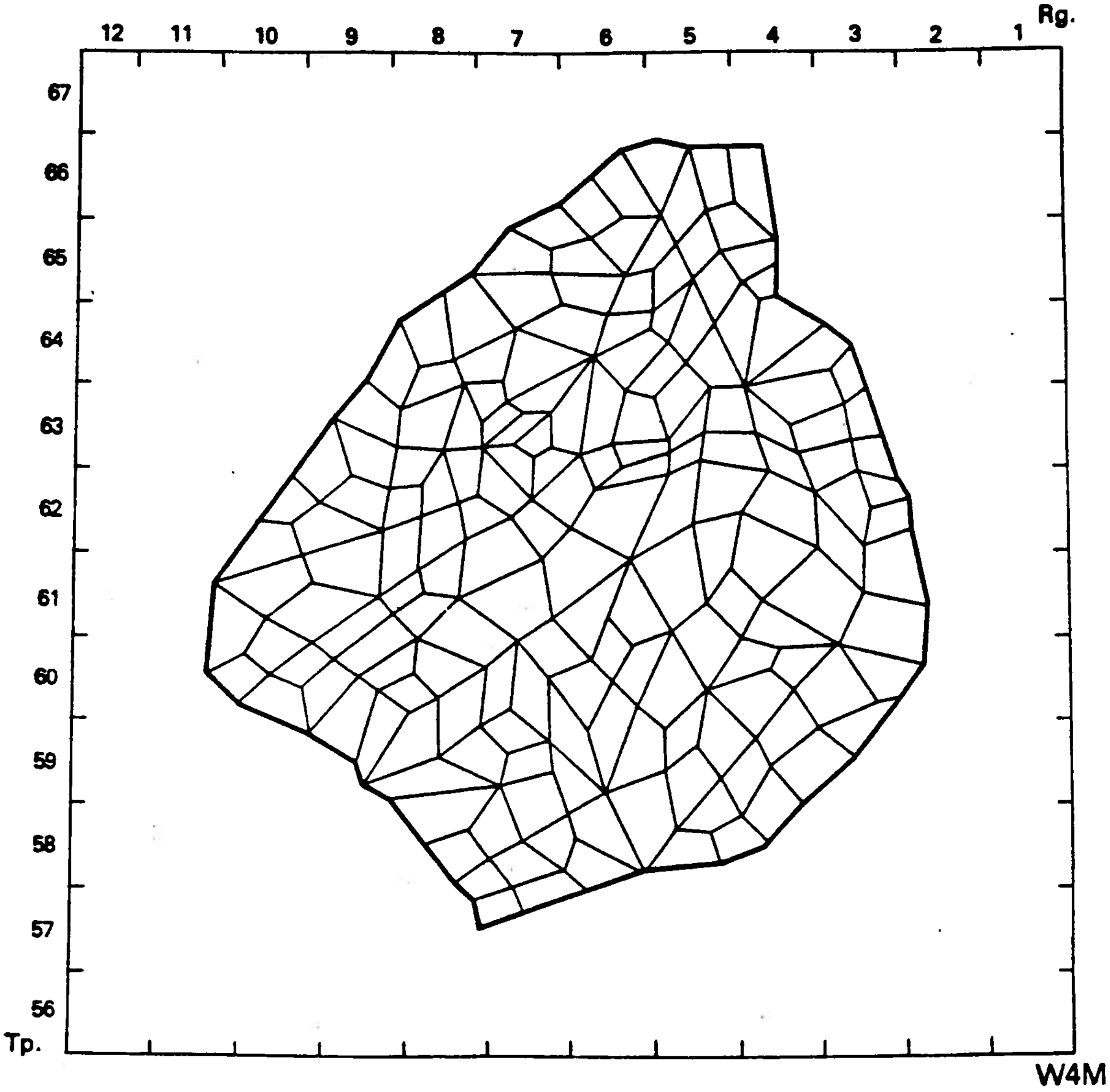

Figure 6-10 Increased distribution of nodes and elements in the model area

Table 6-5

Comparison between computed hydraulic heads at FEM nodes and values at the same locations in the potentiometric surface grids (1226 nodes, 916 elements), model area, Cold Lake Study Area

Aquifer	Number of points	Average error (%)	Maximum error (%)	Absolute max. error (m)
"Upper Mannville" Group	145	1.5	5.7	26.5
"Lower Mannville" Group	146	1.5	6.8	29.3
Cooking Lake-Beaverhill Lake-Watt Mountain	148	1.7	6.1	28.6

Table 6-6

Comparison between observed hydraulic heads and computed values at the same locations (FEM grid with 1226 nodes, 916 elements), model area, Cold Lake Study Area

Aquifer	Number of wells	Average error (%)	Maximum error (%)	Number of errors 5%	Number of errors 10%
"Upper Mannville" Group	216	2.4	13.0	20	3
"Lower Mannville" Group	54	2.3	7.7	6	-
Cooking Lake-Beaverhill Lake-Watt Mountain	4	1.4	1.9	1	-

Comparing the results presented in Tables 6-3 and 6-5, one can see that there is no increase in the accuracy of the computed values with the increase of the number of surface nodes from 120 to 192, and of surface elements from 100 to 168, to justify the increase in the computer time and memory needed for numerical simulation. However, there is an improvement in the matching between observed and computed hydraulic heads (compare Tables 6-4 and 6-6). Taking into account both this improvement and the necessary increase in the computational effort, it was decided to retain the latter finite element grid.

In terms of boundary conditions, there are not many possibilities to appreciate their influence. Along the lateral boundary the hydraulic heads had to be assigned from the observed potentiometric surfaces of the aquifers because of the lack of hydraulic boundaries. However, the hydraulic heads at the top of the bedrock were approximated by the water table. In order to have a feeling of the importance of this boundary, two numerical simulations were performed with different values of the hydraulic heads at the top of the bedrock. In the first run, the water table values were assigned only along the lateral boundary of the model area. In the second run, the hydraulic head was assigned at all the nodes at the top of the bedrock, but the values used were picked from the potentiometric surfaces of Quaternary aquifers immediately above the Phanerozoic sequence, instead of the water table.

The result of this comparison was to demonstrate that the influence of the boundary condition at the top on the fluid flow in the Phanerozoic hydrostratigraphic sequence is most pronounced in the uppermost aquifer ("Upper Mannville" Group), and less in the deeper aquifers, being dampened by each aquitard in succession down the sequence. Figure 6-11 shows the potentiometric surfaces in the "Upper Mannville" Group aquifer, based on computed hydraulic heads at FEM nodes, with the water table boundary conditions at the top of the bedrock assigned along the lateral boundary of the model area only

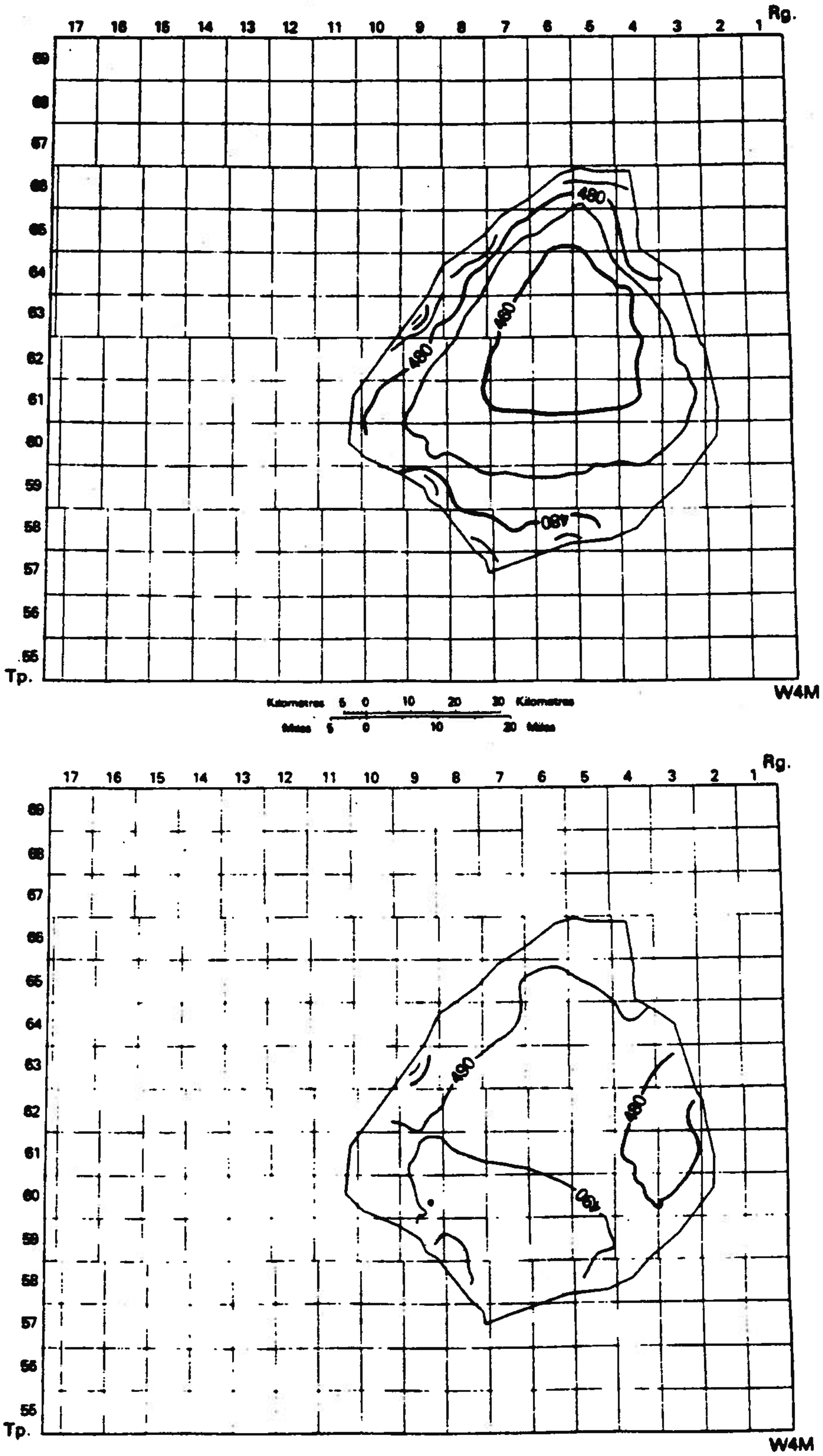

Figure 6-11 Comparison of potentiometric surfaces of the "Upper Mannville" Group aquifer using different assigned hydraulic head distributions at the upper boundary (bedrock). Upper diagram: based on assigned hydraulic heads along only the lateral boundary of the model area; Lower diagram: based on assigned hydraulic heads equal to those in the Quaternary aquifers immediately above the bedrock

(upper diagram); and hydraulic heads at the top of the bedrock equal to the values in the Quaternary aquifers immediately above it (lower diagram). The influence of this boundary condition on the flow in all the aquifers is presented in Table 6-7 for both cases. It can be seen that in case A the boundary condition at the top is not sufficiently defined and therefore the flow in the "Upper Mannville" Group aquifer is distorted, having the characteristics of a "sink" draining the Quaternary aquifers. This effect is not felt in the "Lower Mannville" Group aquifer because of the dampening effect of the Clearwater Formation aquitard. In any case, the differences between computed heads and values in the potentiometric grids are greater than in the case where the water table values are used throughout the top surface over the model area (see table 6-5); in case B, on the contrary, the accuracy of the numerical modelling is improved for the "Upper Mannville" Group aquifer, but with no effect on the aquifers below.

Table 6-7

Comparison between computed hydraulic heads at FEM nodes and values at the same locations in the potentiometric surface grids for different upper boundary conditions.
Case A: for water table values along only the lateral boundary;
Case B: for values equal to the hydraulic heads in the Quaternary aquifers

Aquifer	Number of points	Average error (%)		Maximum error (%)	
		A	B	A	B
"Upper Mannville" Group	145	4.45	1.6	8.65	4.75
"Lower Mannville" Group	146	1.7	1.5	7.3	6.9
Cooking Lake-Beaverhill Lake-Watt Mountain	148	2.0	1.7	6.5	6.1

The results of this analysis are that the boundary conditions have to be assigned at the top of the model throughout the model area, that the water table represents a good initial approximation, and that, whenever possible, the hydraulic heads in the aquifers immediately above the top of the bedrock have to be used. Taking into account the slight improvement of the numerical simulation in the uppermost aquifer only ("Upper Mannville" Group), it is believed that the annual variations of the hydraulic heads in the Quaternary aquifers do not have any effect on the Phanerozoic sequence below due to the thick aquitard at the top (Colorado Supergroup). Therefore, the long-term average of the hydraulic heads in the Quaternary aquifers can be used as boundary condition at the top of the model.

In choosing the initial areal boundary for the model area, a few oil sands pilot plants were left out in the north and northeast, due to reasons already noted. However, after the successful numerical simulation of the steady state natural flow, it was felt that the original model area could be safely expanded in include these pilot plants. The new model area, shown in figure 6-12, is divided into 185 surface elements defined by 211 surface nodes. The total number of nodes and elements in the hydrostratigraphic structure is 1340 and 1001, respectively, with 329 nodes with assigned hydraulic heads at the top and along the lateral boundaries. The potentiometric surfaces obtained by numerical simulation with the expanded area and improved boundary conditions at the top are presented in figure 6-13. These maps exhibit very close comparison (in the model area) with those shown in Atlas maps E-h-3, J-h-4 and L-h-3 (figs. 4-33, 4-37 and 4-39, respectively).

The comparisons between computed hydraulic heads at FEM nodes, and the potentiometric surfaces (regular grids), and between computed and observed values at well locations are presented in tables 6-8 and 6-9, respectively.

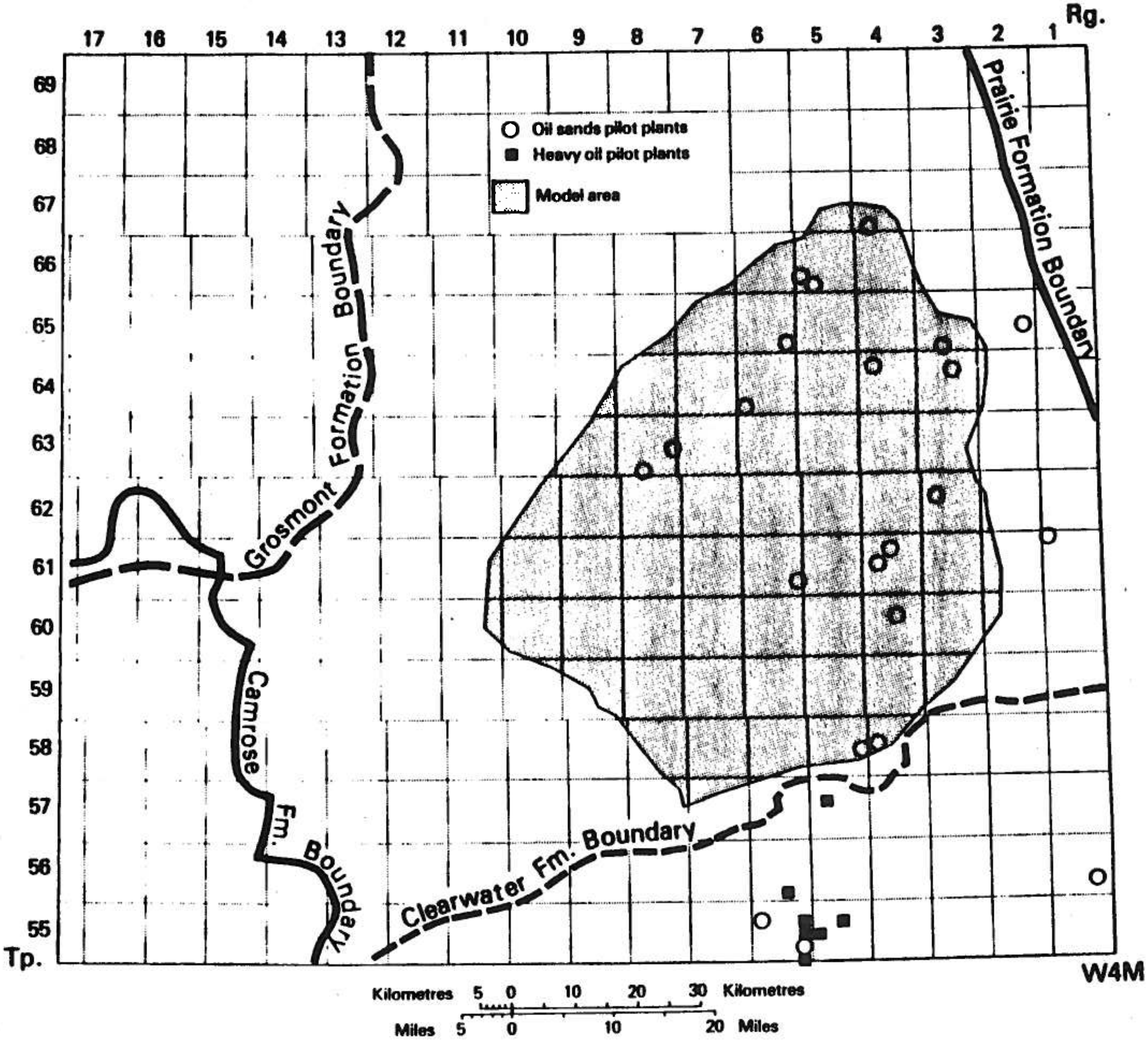

Figure 6-12 Expanded model area

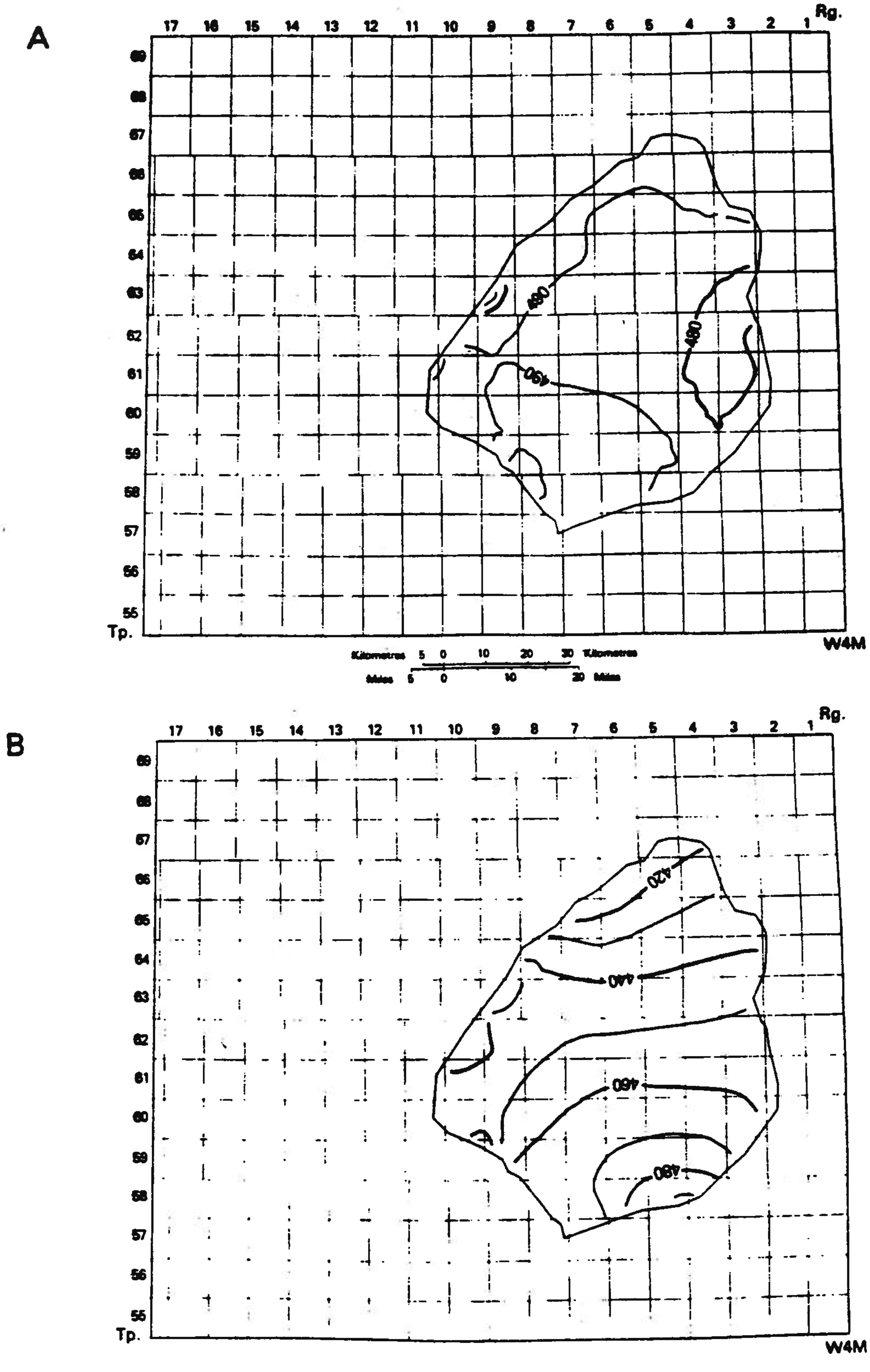

Figure 6-13 Potentiometric surfaces of A: "Upper Mannville" Group aquifer, B: "Lower Mannville" Group aquifer, and C: Cooking Lake-Beaverhill Lake-Watt Mountain aquifer for the expanded model area and representative upper boundary conditions

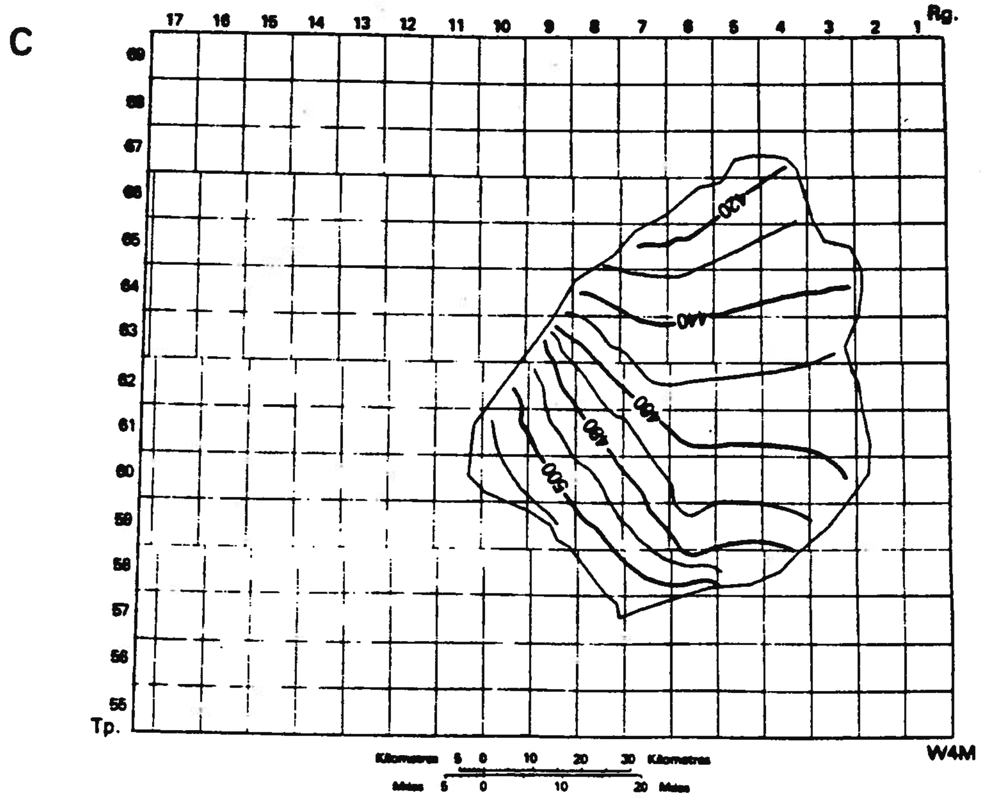

Figure 6-13 Continue

Table 6-8

Comparison between computed hydraulic heads at FEM nodes and values at the same locations in the potentiometric surface grids, expanded model area, Cold Lake Study Area

Aquifer	Number of points	Average error (%)	Maximum error (%)	Absolute max. error (m)
"Upper Mannville" Group	163	1.6	4.7	25.3
"Lower Mannville" Group	162	1.5	6.9	29.8
Cooking Lake-Beaverhill Lake-Watt Mountain	165	1.7	6.2	29.2

Table 6-9

Comparison between observed hydraulic heads and computed values at the same locations, expanded model area, Cold Lake Study Area

Aquifer	Number of wells	Average error (%)	Maximum error (%)	Number of errors >5%	Number of errors >10%
"Upper Mannville" Group	216	2.4	12.0	15	3
"Lower Mannville" Group	56	2.4	7.8	8	-
Cooking Lake-Beaverhill Lake-Watt Mountain	4	1.4	2.0	-	-

Taking into account all the approximations and assumptions involved in the data processing from point data to synthesized data, in the computer-aided graphical representation, in the mathematical modelling, and in the numerical simulation, it is considered that the above results are quite satisfactory, and that better matching between the observed and simulated hydraulic heads cannot be obtained with the model FE3DGW used here. The most probable way to attain an increased accuracy would be to use a model with variable (nonhomogeneous) hydraulic properties in the same hydrostratigraphic unit. This implies a significant increase in the amount of data processing and in the computational effort, which may be not justified by the improvement in the results of the numerical simulation.

The numerical simulation of the steady state natural flow in the model area of the Cold Lake Study Area represents a validation of the synthesized results and a calibration of the numerical model. This calibration now allows for predictive modelling of the effects of in-situ oil recovery activity in the model area on the flow of formation waters in the Phanerozoic hydrostratigraphic sequence above the Prairie Formation aquiclude. For the predictive modelling stage it will be necessary to know the actual sites, depths, and rates of injection and/or pumping. However, it must be stressed here that this model allows only for the simulation of fluid flow. Any phenomena related to heat transfer and/or mass transport cannot be studied using the FE3DGW model. Because the oil-recovery processes in the Cold Lake oil sands area use cyclic steam injection methods, it is clear that the high temperatures involved affect both fluid flow and water-rock interaction processes. The numerical simulation of the coupled flows of fluid, heat and mass, including water-rock interaction, may not be possible at this stage of development of computers and numerical methods.

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HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA
Part VIII. Geothermal Regime
Open File Report 1996 - 1g

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PART 8

Geothermal Regime: Dr. S. Bachu

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INTRODUCTION

Information on the geothermal regime of the subsurface environment is important in hydrogeological and environmental studies for several reasons. First, the flow of fluids and heat flow are coupled phenomena, influencing each other in different ways; for example, the convective transport of heat can become important in the case of strong fluid flow driven by hydraulic head differences. On the other hand, natural convection of fluids can occur as a result of significant temperature differences. Second, the thermal field plays an important role in water-rock processes, because many reactions are temperature dependent. Hydrocarbons maturation is a temperature dependent process too. Geothermal anomalies can be due to changes in the thermal properties of the rocks, often pointing to mineral and/or energy resources.

There is an important difference between the flow of fluids and/or contaminants and the flow of heat in the subsurface environment. While the fluid can flow and thereby transport contaminants only through the porous and/or fractured space, the heat flows through both the solid and fluid phases of the porous medium. This aspect is very important when considering the effects of man's activity related to oil recovery or deep waste disposal. Strata separated from the exploitation/disposal sites by impervious layers can be affected by changes in the natural geothermal regime, as well as changes induced by heat sources created by human activity (for example, radioactive wastes).

In the Cold Lake Study Area, oil is recovered using cyclic steam injection methods, by which steam at over 300°C is injected in the oil sands deposits in order the fluidize the bitumen. The thermal stresses created by temperature differences, and the transport of heat to other strata, are of importance from both economic and environmental points of view. In order to study the effects of changes in the temperature distribution, it is necessary to determine the natural geothermal regime of the subsurface environment, which study forms the object of this report. The study is limited to the Phanerozoic sequence in the Cold Lake Study Area for two reasons. First, the fluid flow processes in the Quaternary and Phanerozoic sequences can be separated, being quite independent, as was shown in Parts 4 and 6 of the Report. Second, thermal conditions close to the ground surface are influenced by climatic variations at an annual scale, while thermal conditions in the Phanerozoic sequence change on a geological scale.

Any thermal regime is generally described by temperature distribution(s), thermal properties of the media, and heat fluxes. In the Cold Lake Study Area, the main source of information on temperatures is the data file of the Energy Resources Conservation Board (ERCB). Temperature values from drillstem test hard copy records were also used. Values for the thermal properties of the rocks and heat fluxes are picked from the literature, because no measurements were available.

Temperature point data associated with specific locations in the three-dimensional geological structure were processed, and the resulting information was synthesized as maps of temperature distributions and geothermal gradients. The data processing techniques used to allocate the data to various stratigraphic and hydrostratigraphic units are similar to the techniques used to process the chemistry of formation waters and the hydraulic data, techniques described in Part 1 of the report (Processing of flow data). Only the study of the geothermal gradients required the development of additional software.

DATA COLLECTION AND PROCESSING

As mentioned previously (Part 1 of the Report), by the middle of 1983 the ERCB data files contained information on about 3100 wells drilled in the Cold Lake Study Area. Temperatures of the formations were not measured at every well, but despite this the number of measurements is in the order of hundreds. Most of the data were collected by the producing companies under uncontrolled and unspecified conditions. A study like this must rely entirely on data gathered by a number of different individuals, using a variety of measuring tools and techniques, and taking varied amounts of care in the measurement of the temperatures. Although questions concerning the accuracy of the data must arise, no realistic attempt at error analysis can be made. The data were accepted as reported and all the data were considered initially to be equally valid.

The temperature data were obtained from ERCB data files (1244), as well as from drillstem test reports (515), and it is accepted that they represent the true temperature. Whenever there were values measured at different times since circulation ceased, the last value was picked. Furthermore, when at the same location there were data recorded at successive depths, they were checked for consistency, that is, inversions of temperature and abrupt changes in the local thermal gradient were singled out and checked.

The temperature point data associated with locations in the three-dimensional structure were allocated to the various stratigraphic and hydrostratigraphic units using a data processing procedure similar to the one described in Part 1 of the Report for the processing of flow data. For each unit the temperature data were synthesized as maps of temperature distributions (see Atlas maps: E-t-1, F-t-1, H-t-1, I-t-1, J-t-1, L-t-1, N-t-1 and O-t-1), and geothermal gradients. For the geothermal gradients a computer program was developed to read in the data, compute the geothermal gradient based on statistical analysis, and write on an output file the initial data and the difference between the measured temperature and the value computed according to the geothermal gradient (temperature residuals). The temperature distributions and the temperature residuals were analyzed for trends using the SURFACE II software package. Anomalies were checked again back on the hard copy. All this process of data checking and screening is iterative by nature, especially since the geothermal gradients change with any change in the data sample. In the end only 1363 temperature data were retained (see Appendix to this report).

Any study of heat transfer processes must include information about the thermodynamic properties of the materials involved. No direct measurements were available for the thermal conductivity and the heat capacity of the rocks in the study area, prompting the use of literature values (Clark, 1966; Majorowicz and Jessop, 1981). The effects of pressure, porosity and temperature have not been considered, as being usually very small in the ranges of variation of the respective variables.

NATURAL HEAT TRANSPORT IN THE SEDIMENTARY BASIN

The thermal structure in a sedimentary basin is governed mainly by the transport to the surface of heat that flows upward from the subcontinental mantle and of heat that is generated internally by the decay of radioactive isotopes in the rocks. The main mechanisms of heat transfer are conduction and convection by fluids.

Assuming that the Fourier Law of heat conduction is valid, the partial differential equation for heat transfer in a porous medium can be written as:

$$(\rho c)_m \partial T/\partial t + n\rho_f c_f \underline{v}.\nabla T = \nabla.\lambda_m \nabla T + S \qquad (1)$$

where T is the temperature, v is the fluid velocity, S represents heat sources, n is the porosity of the medium, ρ is the density, c is the specific heat, λ is the thermal conductivity and t is time. The heat capacity $(\rho c)_m$ and the thermal conductivity λ_m of the porous medium are defined by:

$$(\rho c)_m = n\rho_f c_f + (1-n)\rho_s c_s \qquad (2)$$

$$\lambda_m = n\lambda_f + (1-n)\lambda_s \qquad (3)$$

In the above equations, the subscripts f and s refer to the fluid and solid phases respectively, while the subscript m refers to the fluid-saturated porous medium.

In writing the energy equation (1) it is assumed that: the solid matrix is rigid (no fluidization of the porous bed), the viscous dissipation of energy is small and may be neglected, the pressure work is negligible, there is instantaneous thermal equilibrium between the solid and fluid phases at every point in the system, and that the properties of both fluid and solid matrix are isotropic.

The boundary conditions that define the heat flow together with equation (1) are:

$$\text{at the surface:} \qquad T=T_a \quad \text{at} \quad z=0 \tag{4}$$

$$\text{at the base of the basin:} \qquad Q=Q_c \quad \text{at} \quad z=D \tag{5}$$

where z is the vertical coordinate measured from the surface downwards, D is the thickness of the sedimentary column, Q is the heat flux, and the subscripts a and c stand for atmosphere and crust respectively.

The heat transfer processes in the area are characterized by a value $\lambda=2.5$ W/m°C for the thermal conductivity (Majorowicz et al., 1984b), an average thickness of the sediments of about 1500 m, and the maximum value of about 50°C for the temperature difference between the top and the bottom of the sedimentary column (based on the temperature measured at the bottom of a well reaching the Precambrian basement close to the deepest point in the study area).

The heat production, expressed by the source term S in equation (1), is due to radioactive decay and decreases exponentially with depth (Turcotte and Schubert, 1982). The heat generation of the Precambrian basement rocks in the Western Canada Sedimentary Basin has been evaluated on the basis of uranium, thorium and potassium data by

Majorowicz and Jessop (1981). According to these estimations, in the Cold Lake Study Area the heat generation is about 1 $\mu W/m^3$. A dimensional analysis of the terms involved in equation (1) shows that the internal heat production is of the order of magnitude 10^{-2} with respect to other heat transfer processes involved (for example conduction), and as such it can be neglected.

On a geological time scale, the loss to the atmosphere of the Earth's internal heat is an unsteady process due to variations in the Earth's heat flux. On the human time scale, however, the Earth's heat flux, Q, may be considered constant. The only direct variations with time are introduced in the system at the top boundary by the diurnal and annual changes of temperature at the surface.

The temperature changes at the surface propagate in the system with an amplitude which decreases exponentially with depth according to $\exp(-z/d)$, (Turcotte and Schubert, 1982), where d is the skin depth. Considering a thermal diffusivity of $0.70*10^{-6}$ m^2/sec, the skin depth for the daily changes of temperature is d=0.14 m, and for the annual variations is d=2.65 m. Taking into account that the characteristic length of the system is 1500 m, it follows that the temperature variations at the surface can be neglected, and the temperature T_a at the surface can be approximated by the annual average temperature T_o.

So long as fluid flow in any sedimentary basin is steady, the heat transfer in natural conditions is steady also, and equation (1) becomes:

$$n\rho_f c_f \underline{v}.\nabla T=\nabla.\lambda_m \nabla T \qquad (6)$$

In order to solve it with the appropriate boundary conditions, it is necessary to know the geometry of the lithological units, the velocity field of the fluid flow in the basin and the physical properties of the fluid and porous matrix.

The influence of the geometry and lithology of the hydrostratigraphic units and fluid flow on the heat transfer in a sedimentary basin can be studied by analyzing the variation of geothermal gradient with depth, and the temperature distributions for the areal variation. Given the variability of ground topography and of all geomorphological elements, as well as the flow in the hydrostratigraphic structure, the temperature distributions in horizontal planes or at isodepths below the surface are distorted, and it is difficult to discern patterns or anomalies. Thus the heat transfer processes and the temperature distributions have to be analyzed by hydrostratigraphic units; this is the only way to take into account the geometry, the fluid flow, and the properties of the solid matrix and the fluid.

The rates of convective and conductive heat transfer, expressed by the left and right hand sides of equation (6), respectively, are not of the same magnitude. The Peclet number $Pe=\gamma v_o D/\kappa_m$ is a measure of the intensity of convective heat transfer versus conductive heat transfer in porous media. In the above definition, v_o is the characteristic velocity of fluid flow, D is the characteristic length, $\kappa_m=\lambda_m/(\ c)_m$ is the thermal diffusivity of the fluid saturated porous medium, and $\gamma=n\rho_f c_f/(\rho c)_m$ is the ratio of the heat capacity of the fluid fraction to the heat capacity of the saturated medium (Bachu and Dagan, 1979). The Peclet number has to be computed for each hydrostratigraphic unit, using the appropriate values characterizing it, and the results of these computations are presented in table 8-1.

In the computation of the Peclet number for each hydrostratigraphic unit the characteristic length D is the average thickness of the respective unit, and the characteristic velocity v is the average Darcy velocity as given in the flow analysis and in the mass balance computations in Parts 4 and 6 of the Report, respectively. The values used here for fluid density and for porosity are given in Part 3 and Part 4 of the Report. Values for the thermal conductivity of the saturated porous medium were computed according to equation (3), using

Table 8-1
Ratio of intensity of convective versus conductive heat transfer processes (order of magnitude) as expressed by the Peclet number, Pe, for the hydrostratigraphic units in the Cold Lake Study Area.

Hydrostratigraphic unit	Porosity	Fluid density (kg/m^3)	Characteristic length (m)	Characteristic velocity (mm/yr)	Peclet number (magnitude)
Colorado	0.29	n.a.	314	0.006	$5*10^{-5}$
"Viking Sandstone"	0.23	1026	9	0.4	$3*10^{-5}$
"Upper Mannville"	0.33	1028	86	1.0	$1*10^{-3}$
Clearwater	n.a.	n.a.	4	0.006	$8*10^{-7}$
"Lower Mannville"	0.34	1027	44	5.0	$3*10^{-3}$
Winterburn	0.12	1029	8	5.0	$2*10^{-4}$
Grosmont	0.12	1018	68	5.0	$1*10^{-3}$
Camrose	0.12	1043	9	5.0	$1*10^{-4}$
Ireton	n.a.	n.a.	103	0.0002	$6*10^{-7}$
Cooking Lake-Beaverhill Lake	0.13	1048	240	0.3	$4*10^{-4}$
Prairie	0.00	--	124	0.0	0.0
Keg River-Winnipegosis	0.02	1195	36	0.06	$2*10^{-6}$
Chinchaga-Contact Rapids	n.a.	n.a.	57	n.a.	n.a.
Cold Lake	0.00	--	32	0.0	0.0
Ernestina Lake	n.a.	n.a.	26	n.a.	n.a.
Lotsberg	0.00	--	213	0.0	0.0
Cambrian	n.a.	n.a.	75	n.a.	n.a.
Basal Cambrian Sandstone	0.21	1180	64	150	$8*10^{-2}$

the following values for the thermal conductivity (W/m°C) of the rocks: sandstone 4.2, limestone 2.9, shale 1.5, dolomite 5.0, anhydrite 5.5, salt 5.5 (Majorowicz and Jessop, 1981). For the thermal conductivity and the heat capacity of the water, standard values were used. For hydrostratigraphic units where data were not available for all parameters needed values from adjacent or similar strata were used whenever possible. For the purpose of this study the implicit error of these approximations is of no consequence because here we are interested in the order of magnitude of Pe, and not in its exact value. In the impervious salt layers (aquicludes) there is no fluid, therefore the Peclet number is zero.

From the values of Peclet number presented in table 8-1, it follows that the convective heat transfer is negligible throughout the Cold Lake Study Area and therefore the mechanism for the natural transport of heat from the basement to the atmosphere is thermal conduction through the sedimentary column. Mathematically, this conclusion translates into having to solve the one-dimensional steady-state conduction equation for a multilayered structure of infinite lateral extent:

$$d/dz(\lambda_m(z)dT/dz)=0 \qquad (7)$$

with the boundary conditions (4) and (5).

In the above equation the variation of the thermal conductivity with depth can be approximated by a stepwise function following the geometry of the strata. Therefore, at a given location, the heat flux crossing the sedimentary basin produces a vertical temperature distribution and a geothermal gradient depending ultimately on lithology. This variation is shown schematically in figure 8-1.

GEOTHERMAL GRADIENTS

The geothermal gradients, $G=dT/dz$, for each unit are given by the slope of the regression line fitted to the temperature-versus-depth data in the respective unit. The temperature distribution maps in the Atlas show, for each unit, the locations of the wells where temperature measurements were used in the analysis. The temperature variation with depth and the respective geothermal gradient are presented in figures 8-2 to 8-8 for the units where data were available. There are no temperature measurements in the Cambrian; the bottom hole temperature (BHT) for the wells penetrating the Cambrian is measured at the Precambrian basement. Also, there are no measurements in the most conductive layers in the sequence, namely the halite beds. The Clearwater Formation aquitard is too thin in the area, and was neglected. In the Camrose Tongue aquifer there are only four temperature measurements, ranging between 28 and 30°C, so no geothermal gradient could be computed.

As expected, the less conductive layers (shales) have a higher temperature gradient than the more conductive ones (sandstones and carbonates).

The value of the intercept of the regression lines at the surface ($z=0$) is meaningless for all stratigraphic units but the Quaternary because the geothermal gradient changes through the stratigraphic sequence. The standard deviations of the estimations are less than 2.5°C, as can be seen in table 8-2, where the results are presented by hydrostratigraphic units.

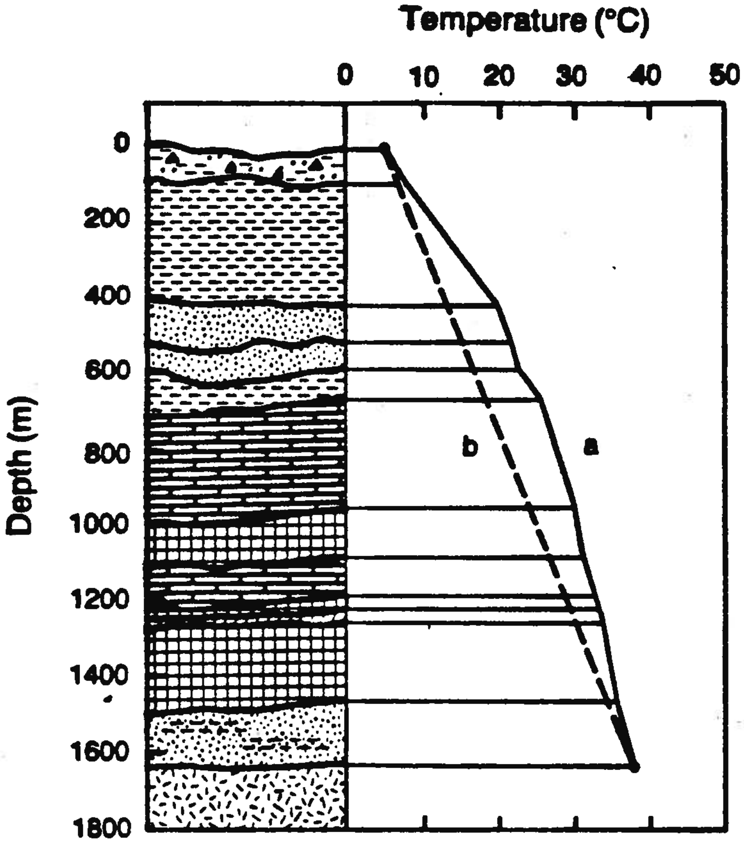

Figure 8-1 Scehmatic representation of the variation of the geothermal gradient (a) and of the integral (average) geothermal gradient (b)

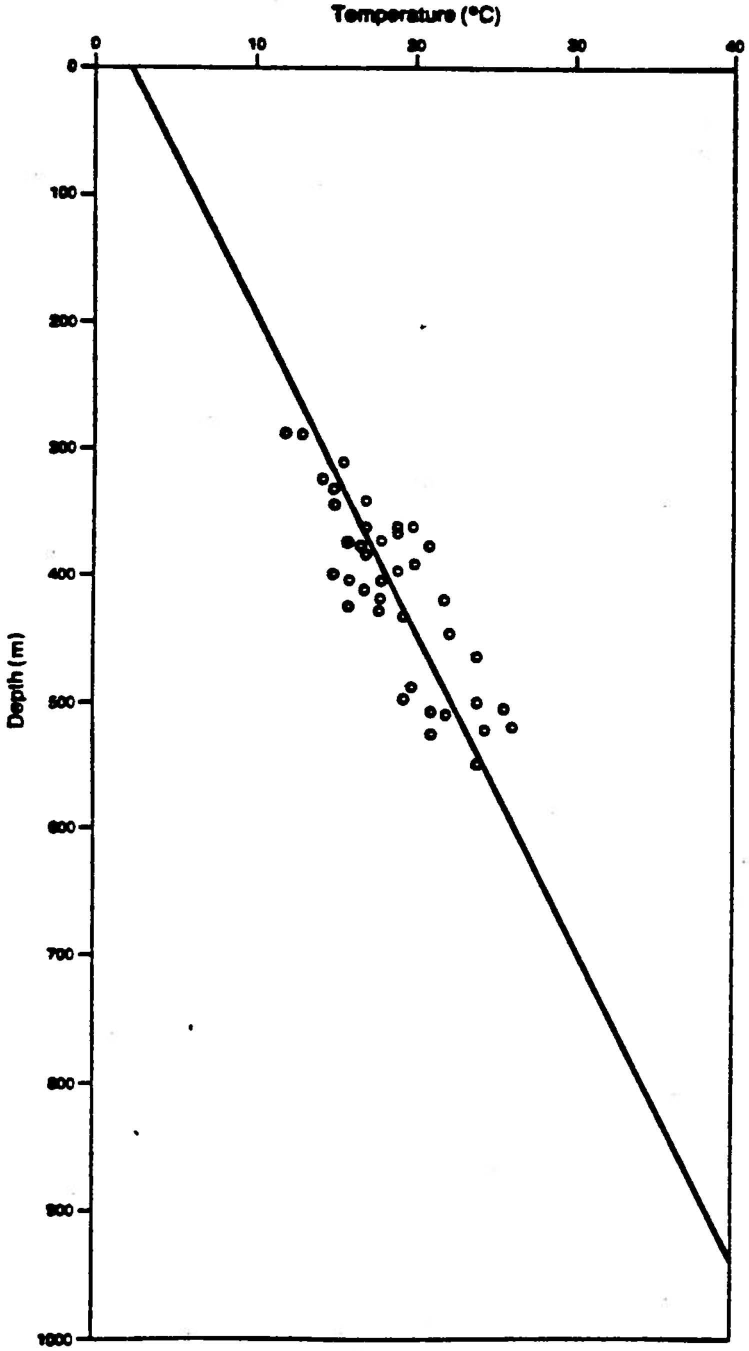

Figure 8-2 Temperature variation with depth in Colorado Group aquitard

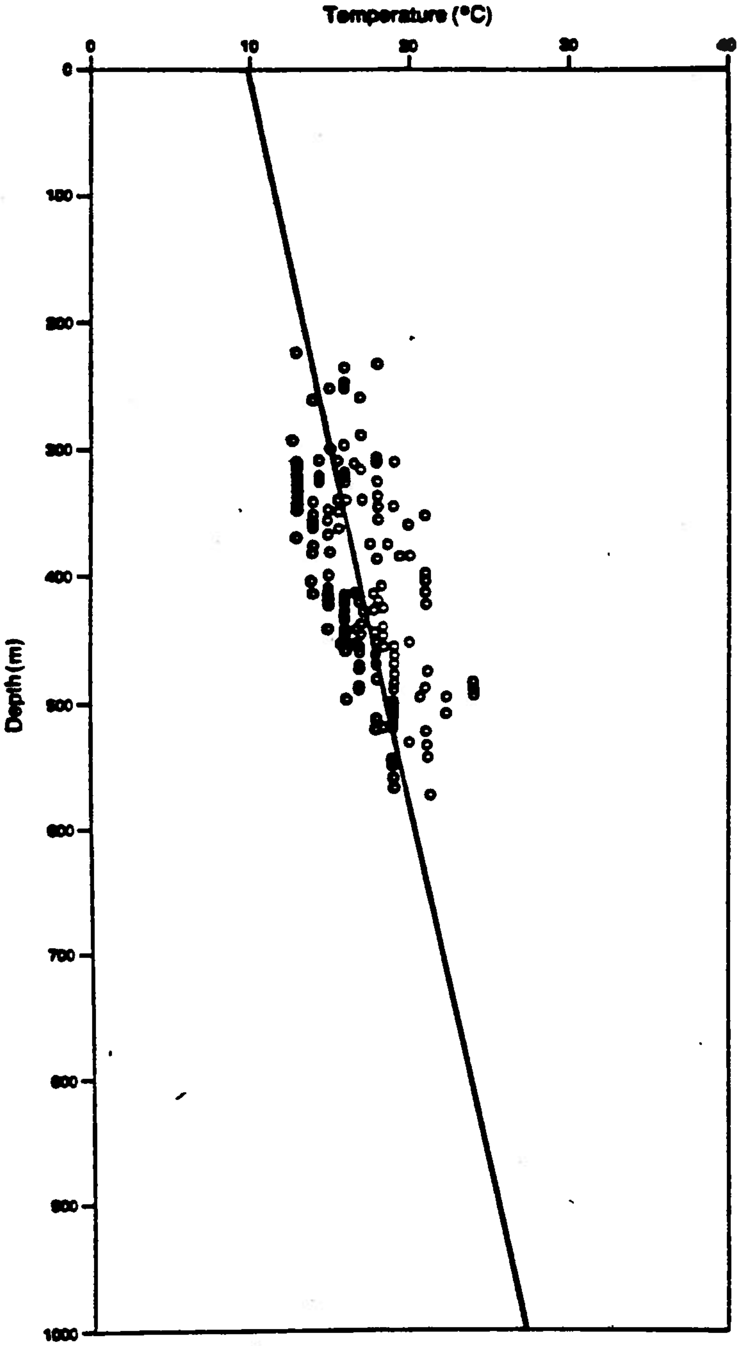

Figure 8-3 Temperature variation with depth in "Viking sandstone" aquifer

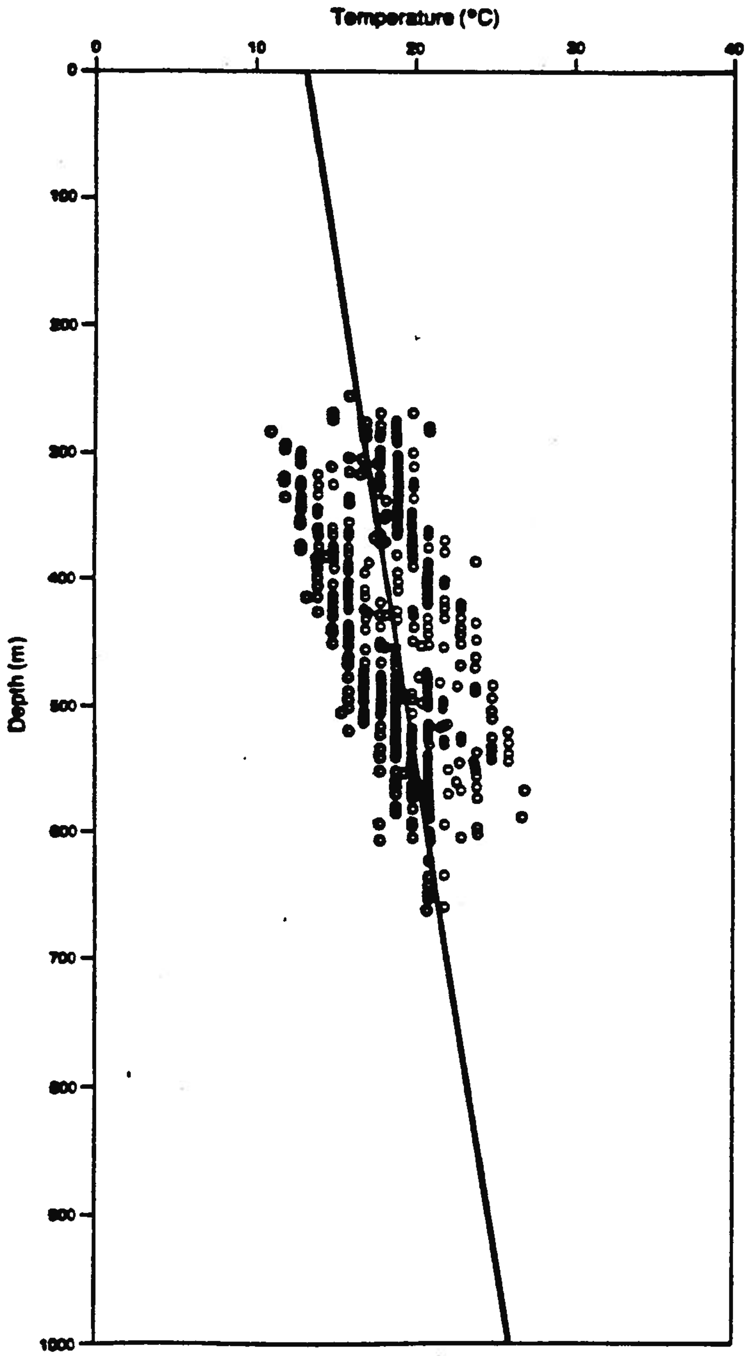

Figure 8-4 Temperature variation with depth in "Upper Mannville" Group aquifer

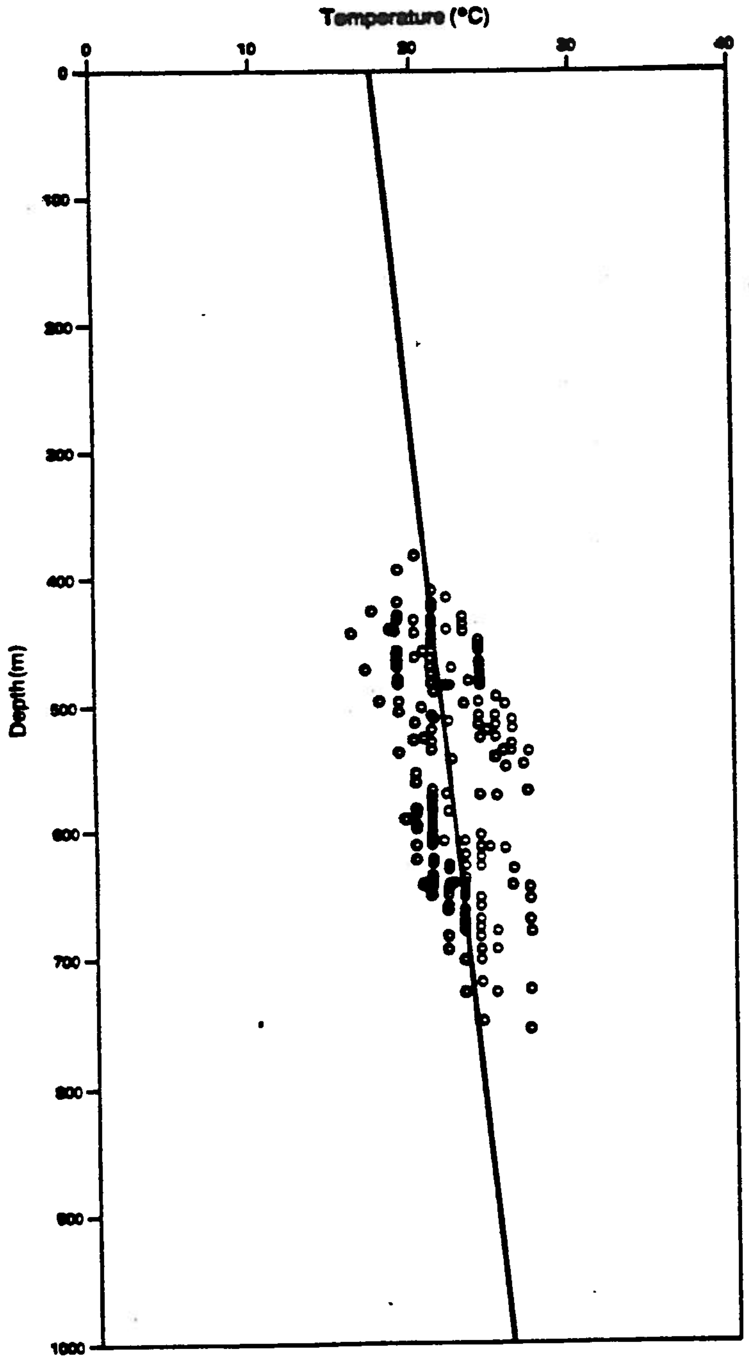

Figure 8-5 Temperature variation with depth in "Lower Mannville" Group aquifer

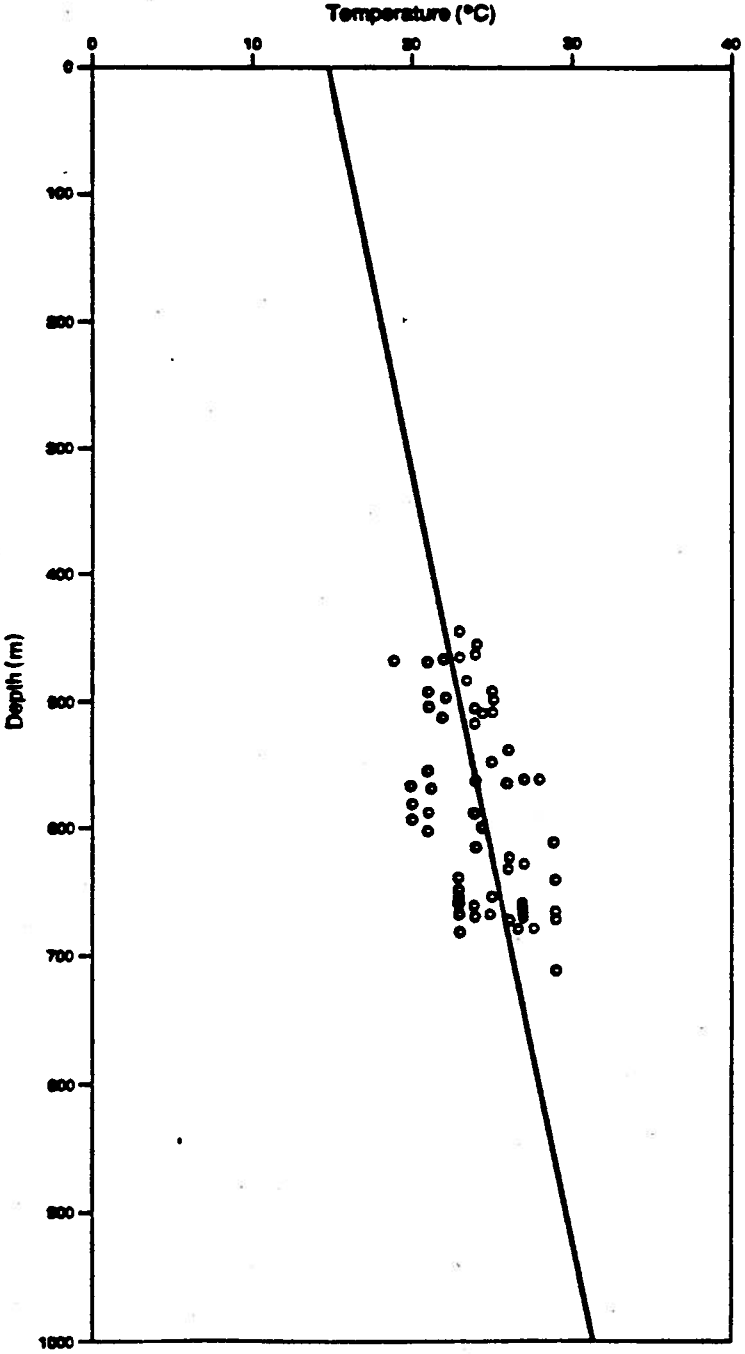

Figure 8-6 Temperature variation with depth in Grosmont and Winterburn aquifers

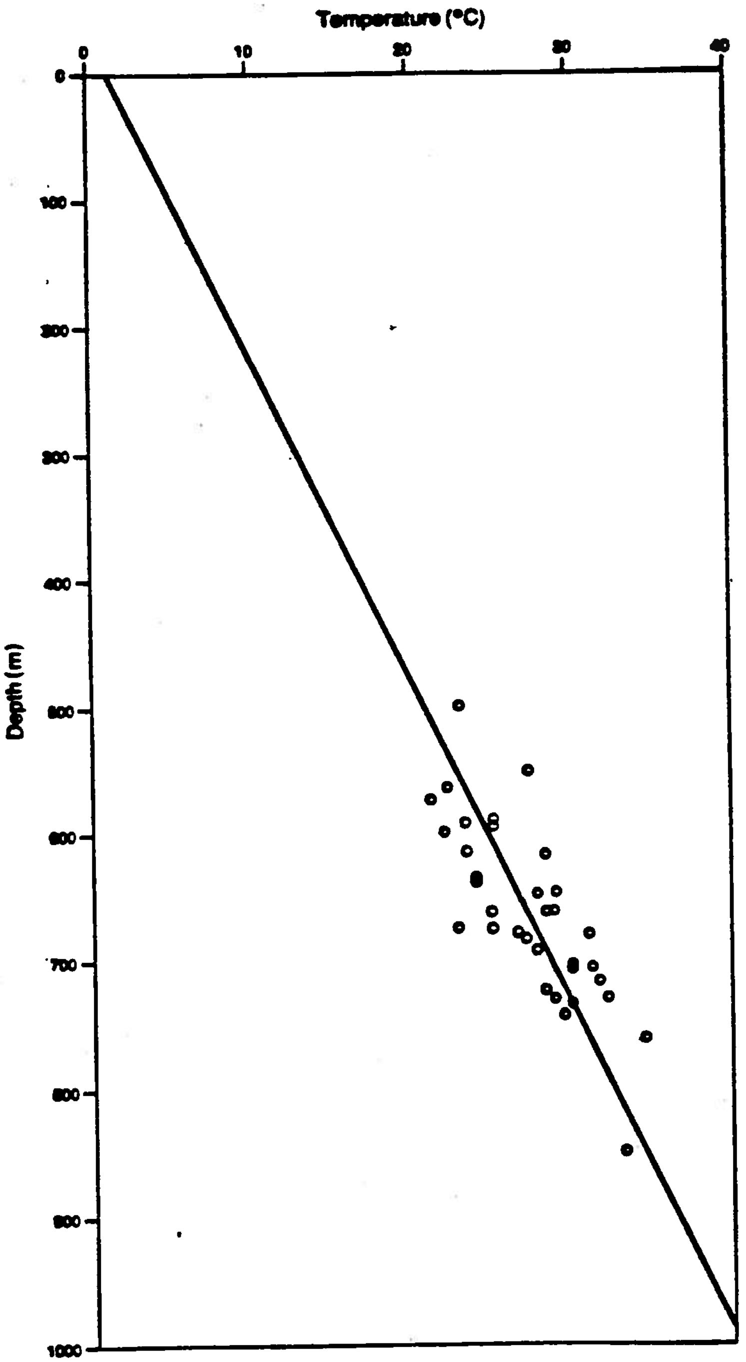

Figure 8-7 Temperature variation with depth in Ireton Formation aquitard

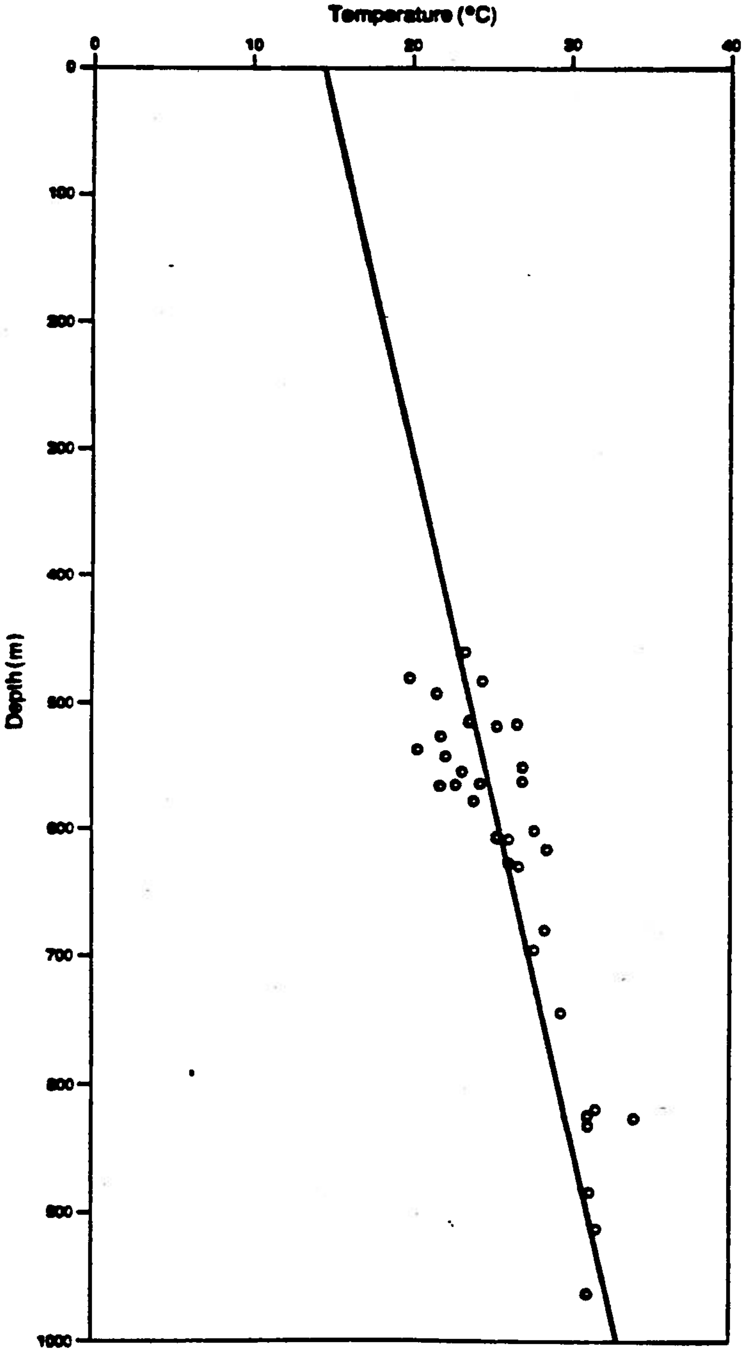

Figure 8-8 Temperature variation with depth in Cooking Lake-Beaverhill Lake-Watt Mountain aquifer

Table 8-2
Geothermal gradients in different hydrostratigraphic units, Cold Lake Study Area

Hydrostratigraphic unit	No. of data	Correlation Coefficient (r)	Standard Deviation (°C)	Geothermal Gradient (°C/km)
Colorado Group	50	0.83	2.0	45.4
"Viking Sandstone"	184	0.57	1.9	17.4
"Upper Mannville" Group	756	0.45	2.4	18.0
"Lower Mannville" Group	307	0.42	2.0	17.0
Winterburn-Grosmont	63	0.48	2.2	16.5
Ireton Formation	36	0.79	2.1	40.1
Cooking Lake-Beaverhill Lake-Watt Mountain	36	0.84	2.0	18.5

A map of the geothermal gradient in Alberta was published previously (USGS, 1976), based on a different method of computing the gradients (called here the "temperature difference" method). The geothermal gradient G_R at every location was calculated using the recorded temperature T_R at the depth z_R and the mean annual temperature at the surface, T_o. It can be easily shown that the geothermal gradient G_R computed this way represents, in fact, the weighted average gradient $\bar{G}$ of the entire stratigraphic sequence above the recording point.

The two methods for computing the geothermal gradient give different results with different meanings. The linear regression method used for data from individual units gives the geothermal gradient in that particular unit, while the "temperature difference" method gives the integral or weighted average gradient over all the layers above the measuring point (see lines a and b, respectively, in figure 8-1). Therefore, in using the "temperature difference" method, the value obtained depends on the depth of the recording point, even in the same unit, and can bring false results, as pointed out also by Majorowicz et al. (1984a).

A distribution map of the integral geothermal gradient for the study area is presented in figure 8-9. This map is based on a total of 47 BHT data from wells reaching the Precambrian basement both within and immediately adjacent to the study area. In computing the average gradients to the Precambrian, the value used for the temperature at the surface was T_0=5°C. The values of the geothermal gradient compare well with typical values of 20 to 30°C/km (Turcotte and Schubert, 1982).

The analysis of the geothermal gradient through the stratigraphic sequence in the Cold Lake Study Area shows a clear dependence on lithology, due to the variation of the thermodynamic properties of the strata.

TEMPERATURE DISTRIBUTIONS

As discussed previously, the areal distribution of temperature has to be studied by hydrostratigraphic units. There are only 27 wells penetrating below the Prairie Formation. The bottom hole temperatures measured at the 18 wells reaching the Precambrian basement were used to compute the integral geothermal gradient whose distribution is shown in figure 8-9. Between the Precambrian and the Beaverhill Lake Formation there are practically no temperature measurement data, so no analysis could be performed.

In the following, referral is made to the temperature distribution maps in the Atlas.

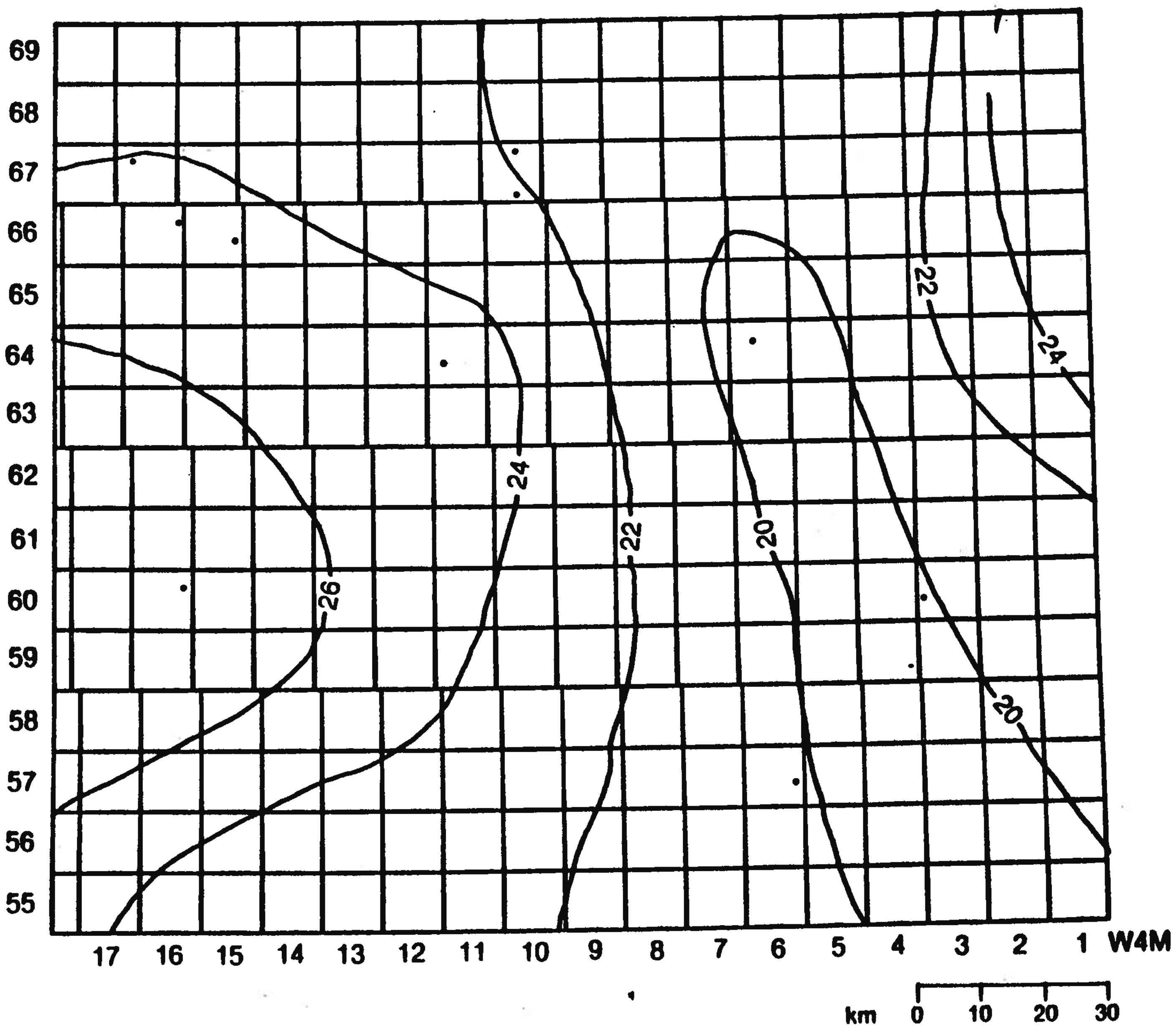

Figure 8-9 Contour map of the distribution of the intergral (average) geothermal gradient (°C/km) for the entire thickness of the sedimentary column (the dots represent BHT measurement points at the Precambrian basement)

COOKING LAKE-BEAVERHILL LAKE-WATT MOUNTAIN AQUIFER

The temperature distribution in this hydrostratigraphic unit shows a distinctive regime trend which closely follows the structure, namely an updip decrease of temperature from southwest to northeast (see Atlas map E-t-1), in the range from 33 to 20°C. Isotherms outside this temperature interval are the result of computer extrapolation, which are not substantiated by data measurements. This gradual decrease of temperature towards the northeast is as expected, given the temperature dependence on depth and the southwest tilt of this aquifer (see Atlas maps E-g-7 and E-g-9).

CAMROSE TONGUE AQUIFER

For this aquifer only four points in the range 28 to 30°C are available, so no attempt was made to analyze for trend.

IRETON FORMATION AQUITARD

In this aquitard the same updip decrease of temperature from southwest to northeast is evident (see Atlas map F-t-1), and due to the same stratigraphic tilt of the Paleozoic sequence. Temperatures vary between 34°C in the southwest corner of the area, to 21°C at the subcrop margin.

GROSMONT FORMATION AQUIFER

The Grosmont Formation aquifer is present only in the northwest corner of the Cold Lake Study Area. The temperatures vary between 19°C and 29°C, but no specific trend could be detected (Atlas map H-t-1).

WINTERBURN GROUP AQUIFER

This unit is present only along the western boundary of the study area, R 16 to 17 W4. The measured values vary between 20°C and 29°C, but in this aquifer there is clearly a trend of temperature decrease from south to north, consistent with the structure trends of the Paleozoic strata (see Atlas map I-t-1).

"LOWER MANNVILLE" GROUP AQUIFER

The Cretaceous sequence has a shallower dip toward southwest than the Paleozoic sequence. Moreover, the porous media is less homogeneous, both with respect to the solid matrix, and the fluid content and saturation. This heterogeneity influences the thermal properties, and as a result the heat transfer processes, and the temperature distributions are therefore less dependent on the structure than is the case for the Paleozoic strata.

In the "Lower Mannville" Group aquifer the measured temperatures vary between 16°C and 27°C. Downdip in the south-southwest, the temperatures are higher, as expected according to the structure (see Atlas map J-t-1). Temperature trends are difficult to discern, but clearly in the west-centre of the study area there is a region of higher temperatures than in the surrounding areas to the northwest, east and southeast.

"UPPER MANNVILLE" GROUP AQUIFER

The range of temperatures measured in this unit is between 11°C and 27°C, but it is not possible to discern any trend or pattern in the distribution of these values (Atlas map L-t-1).

"VIKING SANDSTONE" AQUIFER

The temperatures measured in this unit vary between 12°C and 24°C. There is a structurally-related trend of the temperature distribution, in the sense that generally higher temperatures are found downdip in the southwest corner (Atlas map N-t-1). The temperatures generally decrease towards the northeast, with a few anomalous areas of low or high values.

COLORADO GROUP AQUITARD

This mainly shaly aquitard is more homogeneous than the Mannville Group strata. The temperatures measured vary between 12°C and 26°C, with a clear structurally related trend of updip decrease (see Atlas map O-t-1).

The areal representation of the thermal field using isotherms is misleading to a certain degree because of the natural increase of temperature with depth. As a result of this increase, the trends in the temperature field will always follow the structure; that is, the temperatures will increase downdip. In the Cold Lake Study Area this aspect is most evident in the Paleozoic strata. Another misleading situation could arise in the case of thick strata, when temperatures are measured at relatively close locations, but one is close to the top and the other is close to the bottom of the respective layer. On an areal representation as isotherms these two measurements will appear as an anomaly when actually they are consistent with the temperature increase with depth. One way to take care of the natural increase of temperature with depth in an areal representation is to contour the difference between the measured temperature and the value computed according to the geothermal gradient. These differences (or residuals) are relative by their very definition. A different method of computing the geothermal gradient, or new data added to the sample, will change the values of the residuals, therefore changing the areal representation. For this reason maps of the differences between measured and computed temperatures were not included in the Atlas.

A map of the temperature deviation from geothermal gradient is shown in figure 8-10 for the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer.

The positive values represent "warmer than average" areas where the temperature in the aquifer is higher than the value according to the geothermal gradient, while the negative values represent "colder than average" areas. The trend of the temperature residuals in this aquifer reflects overlying stratigraphic features. The warmer area in the center is where the Ireton Formation is present, while the colder area in the east is where it is absent. It could be argued that this is due to the mixing between the formation waters of the Cooking Lake-Beaverhill Lake-Watt Mountain and "Lower Mannville" Group aquifers where they are in contact. However, for the fluid flow velocities involved here thermal conduction processes overwhelm convective heat transfer, such that by the time the waters in the two aquifers mix their temperature is already equalized by the natural geothermal gradient. Also, in the west there is a colder area, where the Winterburn and Grosmont stratigraphic units overlie the Ireton Formation.

The thickness of the sedimentary layers above the PreCretaceous unconformity is roughly constant in the western half of the study area, so it can be assumed that, for a constant heat flux, the temperature at the unconformity is generally the same. But the temperature increase from the top of the Paleozoic to any point in the Beaverhill Lake Formation aquifer follows a different path depending on the presence or absence of the Ireton Formation. Because the geothermal gradient in the Ireton Formation is higher than that in the Beaverhill Lake Formation aquifer, the temperature at the same depth in the latter is higher, or lower, than the value predicted by the geothermal gradient of the formation, depending on the presence, or absence, respectively, of the Ireton Formation.

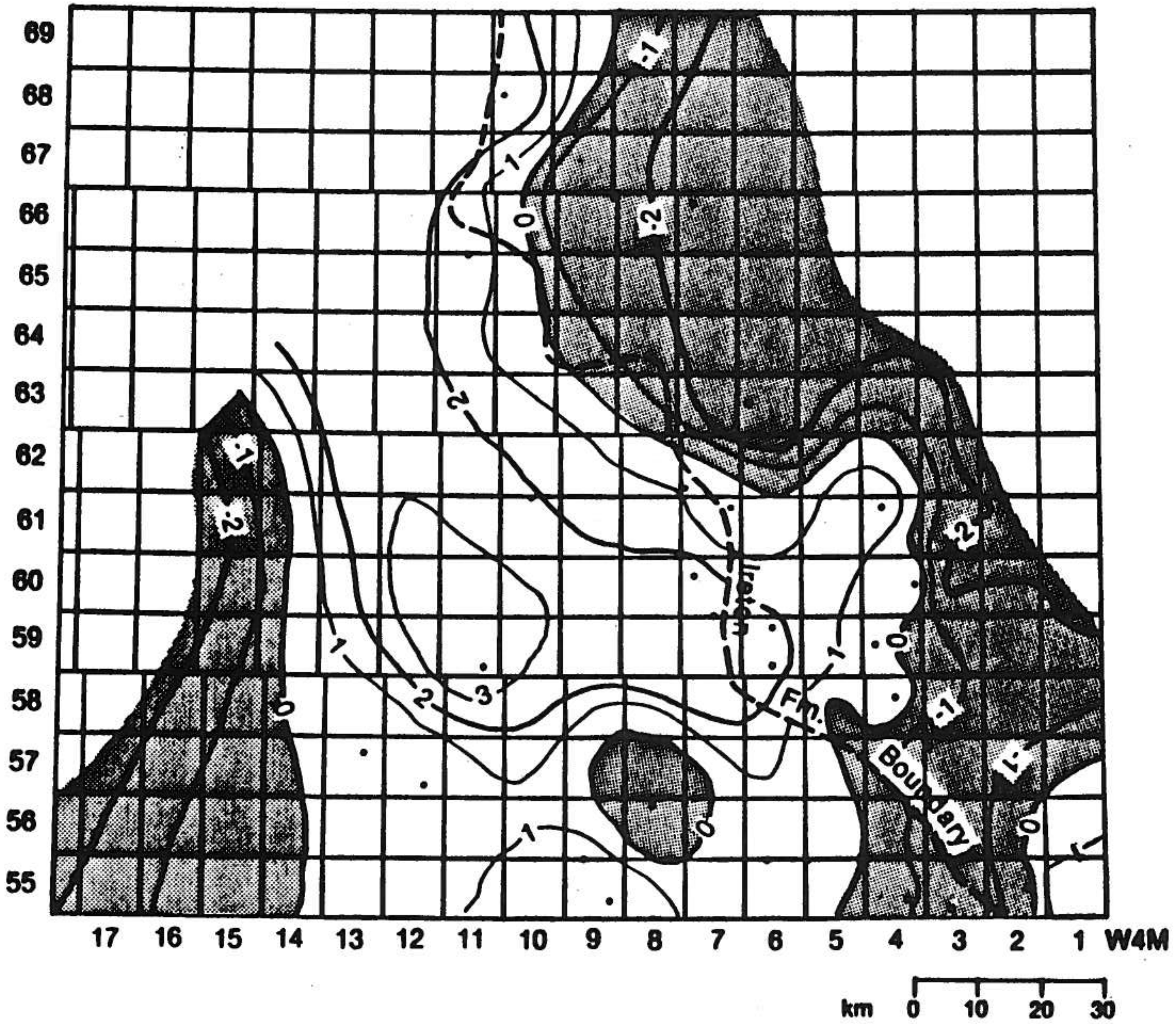

Figure 8-10 Contour map of the temperature deviation (°C) from the geothermal gradient in the Cooking Lake-Beaverhill Lake-Watt Mountain aquifer (the dots represent measurement points; screened areas represent "colder" regions)

The Grosmont and Winterburn aquifers are too little represented in the study area to be able to discern major trends or influences in the temperature residuals.

The temperature residuals in the Cretaceous do not exhibit any dependence on geometry or lithology. For one thing, there are no sudden major changes in the stratigraphy above the PreCretaceous unconformity to influence drastically the geothermal gradients from the surface to the respective unit. Actually, no trend can be discerned in the distribution of temperature deviation from the geothermal gradient in the Cretaceous strata.

In figure 8-11 the areal distribution of the temperature deviation from the geothermal gradient is presented for the "Upper Mannville" Group aquifer. The reasons for the scattered pattern are local, and they do not apply at a regional scale. First, the solid matrix is far than homogeneous than, for example, the Paleozoic strata. In the sandstones there are the Cold Lake oil sands deposits, and also discontinuous layers and pockets of shale and coal. Second, the fluid is not homogeneous. There is gas, oil and water in these units, at various degrees of saturation. The nonhomogeneity of the solid matrix and of the flowing fluids has a great influence on the thermal properties of the porous medium as a whole thereby locally affecting the heat transfer processes.

HEAT FLOW AND THERMAL CONDUCTIVITY ESTIMATES

The Cold Lake Study Area is relatively small in comparison with the entire Western Canada Sedimentary Basin. It is far from any faults, volcanic activity, or tectonic areas. Therefore, it is safe to assume that the Earth's heat flux in the region is constant along the basement, and to consider that, in the absence of convective heat transport, any variation of the geothermal gradient or temperature distribution is the

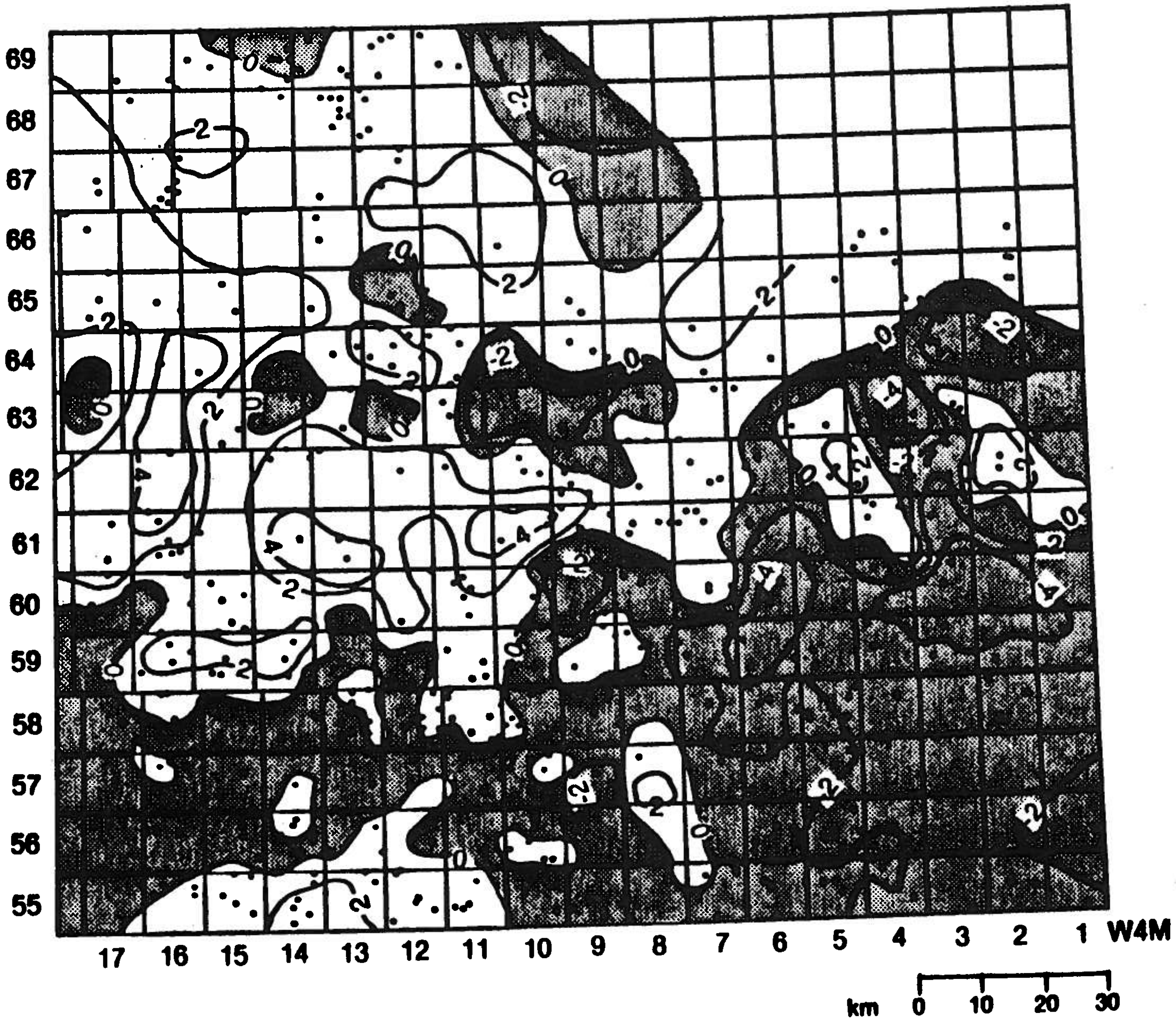

Figure 8-11 Contour map of the temperature deviation (°C) from the geothermal gradient in the "Upper Manville" Group aquifer (the dots represent measurement points, screened areas represent "colder" regions)

result of changes in thermal conductivity rather than the result of variations in the heat flux.

Direct measurements of the thermal properties of fluid and rock samples in the area were not available for the study. Although the literature contains values for the thermal conductivity of the type of rocks found in the area (Clark, 1966; Majorowicz and Jessop, 1981), the geothermal gradients could be used for the estimation of the heat flux and of the average effective thermal conductivity of the different units.

The most credible estimation of the heat flux would be the one obtained considering the thermal conductivity and the geothermal gradient in a monomineral formation such as the thick halite beds. Unfortunately, there are no data for these, and the next best is water-saturated shale. For Colorado shales both porosity and geothermal gradient are available, and for a thermal conductivity for shales of λ=1.5 W/m°C (Majorowicz and Jessop, 1981), a value of Q=55 mW/m^2 is obtained for the heat flux. This value is in good agreement with published data for the area (Majorowicz et al., 1984b) and with data for other Precambrian platforms (Turcotte and Schubert, 1982).

If this value of the heat flux is accepted then the average effective thermal conductivity of heterogeneous layers and permeable strata can be computed. As an example, λ=2.9 W/m°C for "Upper Mannville" Group, λ=3.24 W/m°C for "Lower Mannville" Group, λ=3.3 W/m°C for the Grosmont-Winterburn aquifer, and λ=3 W/m°C for the Beaverhill Lake Formation. These values are lower than those for pure sandstone or dolomite and in the right range for limestone (Majorowicz et al., 1984b). As for the whole sedimentary column, the effective thermal conductivity varies between λ=2.1 W/m°C and λ=2.8 W/m°C in the study area, depending on the geometry and lithology of the sediments.

The inverse procedure can be used to estimate the geothermal gradient in homogeneous and relatively pure layers where temperature measurements are absent, such as the halite beds. For λ=5.5 W/m°C (Clark, 1966; Majorowicz et al., 1984b) the geothermal gradient in the salt formations is only 10°C/km.

These estimates of the effective thermal properties of the rocks in the stratigraphic sequence are important to define the general geothermal structure of the sedimentary column. They are needed further in modelling the effects of oil recovery processes and of deep waste disposal.

CONCLUSIONS

In the Cold Lake Study Area, the flow of Earth heat from the basement to the atmosphere is controlled generally by lithology. The stratigraphy (lithology) reflects the heat flow in two ways. First, different stratigraphic units have different thermal properties and geometry, with a direct influence on the conductive heat transfer. Second, there is a succession of aquifers, aquitards and aquicludes, allowing or not the movement of fluids in prefered directions. Depending on the strength of the fluid flow, heat can be convected by the fluid in aquifers, thus modifying the vertical heat flow and introducting a strong lateral component of the heat flux.

A measure of the strength of the convective heat transfer versus conductive heat transfer is the Peclet number. When the Peclet number of the flow in a permeable formation is significantly smaller than unity, conductive heat transfer is predominant and the convection of heat by moving fluids can be neglected. The dimensional analysis of the natural fluid and heat flow processes in the Cold Lake Study Area proved that convective heat transfer is negligible with respect to conduction.

For a constant vertical heat flux the characteristics of the heat flow change from one formation to another. The natural heat flow is best characterized by the geothermal gradient in the vertical direction, and by the temperature distribution in the horizontal direction. The geothermal gradient changes in every formation to allow the flow of the heat flux according to the respective thermal conductivity. Geothermal gradients were computed by fitting the best regression line to the temperature versus depth distribution for every hydrostratigraphic unit where data were available. As expected, the geothermal gradients are higher in the less conductive strata (usually shale aquitards) and lower in the more conductive ones (that is, sandstone and carbonate aquifers).

Given the general temperature increase with depth, the temperature distribution in any unit is best represented by the deviations of the actual temperature values from the geothermal gradient in the respective unit. The distribution of the residuals sometimes show trends due to the influences of geometry, lithology and formation water flow. In heterogeneous strata it is very difficult to discern any pattern because the geostatistical variability of the hydraulic and thermal properties of the fluids and solid matrix strongly influence the heat flow. This heterogeneity produces local anomalies in the geothermal gradient pattern and temperature distribution, which can possibly be linked to the presence of hydrocarbons.

Estimations of the Earth's heat flux can be made if there are enough hydraulic and thermal data for a relatively homogeneous and pure unit. For the study area, a heat flux of 55 mW/m^2 was found, in good agreement with previous published data for the area and for other Precambrian platforms. By the same procedure, the average effective thermal conductivity can be estimated for heterogeneous formations with variable degrees of fluids saturation, and for formations where direct measurement data are not available, as the evaporites.

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APPENDIX

Temperature data by hydrostratigraphic units

TEMPERATURE DATA FOR COLORADO GROUP AQUITARD,
COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
4	11	55	1	4	277.0	335.3	13.00
10	29	55	1	4	281.7	378.6	15.00
7	2	56	2	4	271.1	385.5	15.00
11	6	56	4	4	274.9	306.0	13.00
10	7	56	6	4	274.6	341.1	13.00
8	16	57	14	4	172.4	455.3	16.00
11	9	67	12	4	275.2	286.7	12.00
6	9	69	12	4	299.0	288.0	13.00
5	30	60	6	4	263.6	309.7	15.56
11	29	61	7	4	260.3	321.3	14.44
6	17	57	5	4	252.1	330.1	15.00
4	5	66	4	4	308.3	338.9	17.00
6	1	67	12	4	272.0	342.5	15.00
10	3	65	13	4	251.5	342.6	15.00
6	31	55	4	4	232.7	360.0	20.00
6	21	55	4	4	219.7	360.0	19.00
15	1	65	10	4	272.3	360.0	17.00
10	32	56	5	4	217.0	363.0	19.00
6	5	65	11	4	266.7	364.5	19.00
6	15	55	4	4	220.5	370.0	18.00
7	28	59	3	4	247.2	371.8	16.00
11	25	66	9	4	276.4	374.3	16.67
1	36	55	5	4	225.2	375.0	21.00
6	35	55	5	4	227.6	380.0	17.00
11	1	55	4	4	208.3	390.0	20.00
10	5	55	4	4	213.8	395.0	19.00
6	17	59	5	4	243.3	398.0	15.00
11	30	66	17	4	214.9	402.3	16.00
6	8	59	3	4	238.1	402.9	18.00
10	17	56	6	4	203.2	410.0	17.00
1	21	56	6	4	210.2	416.5	18.00
2	13	55	5	4	209.6	418.0	22.00
10	15	65	17	4	191.9	422.9	16.00
11	1	56	9	4	172.8	426.7	17.78
6	8	64	15	4	220.0	430.1	19.44
6	31	55	5	4	223.7	445.0	22.22
11	1	59	11	4	189.0	463.3	23.89
10	3	56	11	4	151.3	487.0	20.00
11	11	57	9	4	187.2	497.1	19.44
7	28	55	11	4	141.7	499.9	23.89

TEMPERATURE DATA FOR COLORADO GROUP AQUITARD, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
10	34	55	10	4	160.9	505.1	25.56
11	3	55	9	4	158.8	506.0	21.11
9	28	58	14	4	159.0	508.0	22.00
10	23	55	10	4	128.6	518.2	26.11
10	10	56	10	4	143.9	521.2	24.44
10	8	56	9	4	175.2	525.2	21.11
14	11	56	16	4	84.8	548.0	24.00

TEMPERATURE DATA FOR "VIKING SANDSTONE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(C)
10	18	55	1	4	240.1	342.6	13.00
10	29	55	1	4	243.7	416.6	15.00
6	31	55	1	4	249.1	413.0	16.00
16	8	55	2	4	244.6	361.0	14.00
11	11	55	2	4	240.8	337.7	13.00
6	14	55	2	4	246.0	340.2	15.56
6	29	55	2	4	237.1	376.0	14.00
10	33	55	2	4	238.8	451.5	15.90
10	36	55	2	4	245.9	407.0	18.30
6	22	55	3	4	239.0	361.2	15.56
11	6	55	4	4	203.1	417.1	17.00
6	29	55	4	4	261.2	324.6	14.44
6	29	55	4	4	231.0	354.8	14.00
6	4	55	5	4	216.1	414.5	17.78
11	29	55	5	4	234.1	427.0	16.00
11	29	55	5	4	231.7	429.4	16.00
12	34	55	5	4	231.6	380.0	15.00
6	11	55	6	4	219.4	453.7	17.00
7	13	55	6	4	228.6	412.4	16.67
4	21	55	6	4	230.2	458.5	17.00
6	27	55	6	4	227.9	422.6	18.00
6	33	55	6	4	231.6	424.9	17.78
4	36	55	6	4	221.0	443.5	16.00
6	11	55	7	4	199.2	421.7	16.00
7	29	55	7	4	208.8	442.6	16.67
6	6	55	8	4	195.2	444.9	17.00
10	7	55	8	4	173.2	460.2	18.00
10	11	55	8	4	176.8	413.3	15.00
10	28	55	8	4	178.0	426.7	17.22
11	31	55	8	4	191.4	417.6	16.00
11	3	55	9	4	175.9	488.9	17.00
3	13	55	9	4	171.2	434.0	16.00
8	17	55	9	4	180.4	436.6	17.00
10	6	55	12	4	129.5	506.3	19.00
13	15	55	12	4		466.9	18.00
6	17	55	12	4	137.9	471.5	17.00
6	24	55	12	4	143.0	440.7	16.00
6	26	55	12	4	148.5	420.9	16.00
7	31	55	12	4	146.0	447.4	16.00
12	32	55	12	4	140.5	448.1	16.00

TEMPERATURE DATA FOR "VIKING SANDSTONE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(C)
15	12	55	13	4	141.6	479.5	18.00
11	14	55	13	4	135.3	486.8	19.00
10	26	55	13	4	115.5	508.1	22.22
13	15	55	14	4		488.4	21.00
10	26	55	14	4	131.4	494.7	22.22
13	15	55	15	4		510.8	19.00
10	23	55	16	4	90.8	558.1	19.00
9	34	55	16	4	70.3	574.0	21.20
6	6	56	1	4	247.1	418.6	18.00
11	1	56	2	4	245.3	415.0	16.90
8	34	56	4	4	249.3	327.4	16.00
8	34	56	4	4	245.4	331.3	13.00
6	10	56	5	4	244.6	351.0	14.00
11	29	56	5	4	240.7	340.2	14.00
10	32	56	5	4	241.0	339.0	13.00
11	1	56	6	4	230.5	443.6	18.00
7	24	56	7	4	214.9	378.9	15.00
11	7	56	10	4	181.1	450.8	20.00
10	21	56	10	4	166.1	488.9	19.00
10	4	56	13	4	140.1	547.5	19.00
6	6	56	13	4	144.8	523.6	19.00
10	8	56	13	4	131.3	530.4	20.00
15	18	56	13	4	140.2	544.7	19.00
2	26	56	13	4	154.5	500.8	19.00
7	25	56	14	4	127.2	540.9	21.00
7	25	56	14	4	146.2	521.9	21.00
7	25	56	14	4	134.9	533.2	21.00
16	16	56	15	4	126.0	512.8	18.00
7	22	56	15	4	132.0	500.2	19.00
11	22	56	15	4	114.1	519.2	18.00
7	27	56	15	4	114.3	518.5	18.33
3	29	56	15	4	124.3	506.0	19.00
7	34	56	15	4	114.9	515.4	19.00
16	24	56	17	4	87.2	564.4	19.00
12	10	57	1	4	207.0	455.5	17.00
2	21	57	5	4	270.1	362.7	14.00
6	24	57	5	4	246.7	399.0	15.00
5	9	57	7	4	216.1	412.1	15.00
11	22	57	7	4	224.3	455.4	18.00
6	8	57	8	4	222.2	439.2	18.33

TEMPERATURE DATA FOR "VIKING SANDSTONE AQUIFER",
COLD LAKE STUDY AREA

LOCATION					ELEVATION (m)	DEPTH (m)	TEMPERATURE (C)
LSD	SEC	TP	R	M			
6	29	57	8	4	211.5	467.0	19.00
13	15	57	9	4		475.0	19.00
7	19	57	9	4	196.6	452.3	16.67
10	28	57	12	4	179.1	454.5	17.00
7	14	57	13	4	146.6	440.4	15.00
6	4	57	14	4	149.4	496.8	19.00
6	25	57	15	4	160.3	481.6	19.00
13	15	57	17	4		513.2	19.00
11	11	58	5	4	268.5	380.7	14.00
5	1	58	8	4	220.2	385.0	18.00
6	26	58	9	4	217.5	445.9	17.00
16	28	58	9	4	219.4	455.1	19.00
10	30	58	9	4	214.3	446.8	16.00
10	17	58	10	4	201.2	457.5	16.00
6	2	58	13	4	177.4	478.8	18.00
13	15	58	13	4		480.0	18.00
13	15	58	16	4		468.2	18.00
10	31	58	16	4	148.8	464.5	19.00
11	14	59	4	4	271.3	368.5	13.00
10	17	59	4	4	275.8	366.7	15.00
6	21	59	4	4	279.3	343.4	13.00
13	5	59	6	4		340.3	13.00
10	9	59	6	4		341.8	13.00
11	12	59	6	4	252.1	326.2	13.00
2	22	59	6	4	262.6	321.2	13.00
6	27	59	6	4	261.6	310.6	13.00
7	30	59	6	4	256.7	347.8	13.00
2	18	59	7	4	235.7	403.1	14.00
9	24	59	8	4	237.4	408.4	15.00
7	8	59	9	4	231.4	411.4	21.00
7	9	59	9	4	232.6	420.9	21.00
11	24	59	9	4	238.6	403.6	21.00
13	9	59	12	4	196.9	456.0	17.00
13	16	59	12	4	201.7	445.8	17.00
9	22	59	12	4	211.1	434.0	16.00
11	33	59	12	4	205.4	451.1	18.00
11	34	59	12	4	208.5	456.7	17.00
13	15	59	14	4		454.0	18.00
13	15	59	15	4		487.3	17.00
11	16	59	15	4	159.7	451.7	18.33

TEMPERATURE DATA FOR "VIKING SANDSTONE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION (m)	DEPTH (m)	TEMPERATURE (C)
LSD	SEC	TP	R	M			
5	19	59	16	4	156.9	494.5	20.60
7	21	59	16	4	164.0	445.0	18.33
10	25	60	6	4	280.7	296.0	16.00
5	30	60	6	4	263.9	309.4	19.00
12	12	60	7	4	263.3	339.2	17.00
12	15	60	7	4	263.0	288.0	17.00
7	19	60	8	4	261.8	354.5	18.00
6	6	60	9	4	244.6	410.4	15.00
13	15	60	9	4		366.0	15.00
15	14	60	10	4	245.7	411.9	14.00
13	3	60	11	4	239.9	417.9	16.00
13	3	60	11	4	220.4	437.4	17.00
13	15	60	11	4		420.0	15.00
9	25	60	11	4	237.8	450.0	16.00
4	2	60	12	4	206.3	496.2	16.00
6	4	60	12	4	210.6	463.6	19.00
2	31	60	12	4	211.6	469.9	17.00
6	9	60	15	4	186.6	490.7	24.00
11	25	60	16	4	195.3	485.9	19.00
10	31	61	6	4	291.4	259.1	17.00
11	30	61	7	4	280.7	322.8	18.00
6	14	61	11	4	242.0	423.7	18.33
10	30	61	12	4	235.9	352.3	21.00
7	10	61	13	4	236.5	399.0	21.00
7	1	61	16	4	196.0	483.7	24.00
10	2	61	16	4	207.2	474.6	21.11
11	23	61	16	4	210.3	487.7	24.00
10	30	61	16	4	199.7	504.4	19.00
6	20	62	8	4	284.1	312.4	16.67
16	31	62	9	4	285.9	322.2	16.00
13	15	62	10	4		316.0	13.00
13	15	62	10	4		309.0	18.00
10	29	62	14	4	222.9	383.3	20.00
1	8	62	16	4	209.4	499.6	19.00
9	23	63	6	4	261.7	318.0	16.04
11	20	63	9	4	283.2	307.5	14.44
10	24	63	9	4	295.7	292.9	12.78
13	18	63	11	4	277.9	355.8	15.00
10	25	63	11	4	274.6	321.6	14.44
10	26	63	13	4	262.7	347.5	15.56

TEMPERATURE DATA FOR "VIKING SANDSTONE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION (m)	DEPTH (m)	TEMPERATURE (C)
LSD	SEC	TP	R	M			
11	1	64	9	4	292.2	299.0	15.10
7	3	64	9	4	283.2	316.0	17.00
9	22	64	9	4	280.4	348.0	15.00
7	24	64	11	4	285.6	307.5	15.56
3	28	64	12	4	260.2	338.1	16.00
10	32	64	12	4	283.9	311.1	18.00
13	15	64	13	4		338.1	16.00
6	27	64	15	4	246.6	384.0	19.44
10	30	65	8	4	269.5	374.5	17.50
10	30	65	8	4	269.5	374.5	18.70
12	6	65	9	4	298.2	339.4	16.00
15	1	65	10	4	288.4	343.9	18.00
4	31	66	8	4	288.6	337.0	18.00
6	29	66	13	4	305.4	261.2	14.00
10	34	67	13	4	325.8	251.8	16.00
11	23	67	16	4	271.5	359.4	20.00
7	9	68	13	4	332.9	222.8	13.00
10	10	68	13	4	332.8	253.0	16.00
4	26	68	13	4	339.2	248.1	16.00
11	15	69	10	4	367.7	344.6	19.00
13	15	69	13	4		233.0	18.00
14	20	69	13	4	341.0	232.6	18.00
11	7	69	15	4	317.0	235.0	16.00
6	20	69	16	4	313.9	251.5	15.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER,
COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
7	3	55	1	4	188.4	414.2	16.00
7	30	55	1	4	183.5	404.2	16.00
6	31	55	1	4	208.7	453.4	18.33
6	14	55	2	4	207.3	378.9	15.00
12	16	55	2	4	202.2	392.6	14.00
6	2	55	3	4	173.4	388.3	17.22
6	11	55	4	4	176.9	426.3	16.00
6	11	55	4	4	183.5	419.7	16.00
6	29	55	4	4	133.5	452.3	20.56
6	29	55	4	4	148.7	437.1	20.00
6	31	55	4	4	86.7	506.0	20.00
7	32	55	4	4	208.4	359.7	15.00
2	13	55	5	4	199.8	427.8	15.00
6	15	55	5	4	71.6	555.0	19.50
6	20	55	5	4	174.5	478.6	17.00
6	21	55	5	4	182.8	449.9	18.00
16	30	55	5	4	194.5	469.9	17.00
2	4	55	6	4	153.7	482.7	17.00
2	4	55	6	4	173.2	463.2	16.00
11	20	55	6	4	177.2	499.2	18.00
4	21	55	6	4	172.2	516.5	19.00
7	24	55	6	4	56.4	584.0	21.00
11	35	55	6	4	152.7	512.4	19.00
11	35	55	6	4	65.7	599.4	21.00
6	4	55	7	4	148.9	474.1	17.00
10	26	55	7	4	174.3	435.0	16.00
7	29	55	7	4	153.4	498.0	20.56
6	6	55	8	4	79.6	560.5	20.56
10	7	55	8	4	92.7	540.7	20.00
10	7	55	8	4	98.2	535.2	20.00
11	31	55	8	4	159.7	449.3	20.00
11	31	55	8	4	155.8	453.2	16.00
11	3	55	9	4	137.5	527.3	19.00
7	7	55	9	4	121.6	536.8	20.00
3	13	55	9	4	22.2	583.0	19.00
8	17	55	9	4	136.3	480.7	18.00
7	11	55	10	4	120.8	561.4	19.00
7	20	55	10	4	115.4	536.1	19.00
10	23	55	10	4	41.5	605.3	18.00
10	23	55	10	4	118.1	528.7	19.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER,
COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
5	28	55	10	4	122.8	496.2	18.00
15	7	55	11	4	110.4	548.6	20.00
11	8	55	11	4	101.4	580.7	20.00
8	17	55	11	4	96.5	566.1	23.00
7	28	55	11	4	126.5	515.1	22.22
7	28	55	11	4	116.4	525.2	23.00
10	6	55	12	4	117.6	518.2	21.67
11	11	55	12	4	74.4	534.3	25.00
13	15	55	12	4		534.3	25.00
10	16	55	12	4	98.4	506.9	19.00
7	31	55	12	4	118.5	474.9	21.00
12	32	55	12	4	108.2	480.4	19.00
12	32	55	12	4	37.2	551.4	21.00
10	26	55	13	4	57.6	566.0	20.00
10	34	55	13	4	95.8	555.3	24.00
10	4	55	14	4	83.5	549.9	24.00
5	11	55	14	4	94.6	529.6	20.00
13	15	55	14	4		563.3	21.00
13	15	55	14	4		561.5	21.00
13	15	55	14	4		561.4	21.00
13	15	55	14	4		541.0	21.00
7	16	55	14	4	84.1	538.6	24.00
10	24	55	14	4	102.8	525.8	25.00
10	26	55	14	4	102.9	523.2	19.00
7	35	55	14	4	91.5	541.0	25.00
7	35	55	14	4	91.0	541.5	25.00
7	35	55	14	4	91.5	541.0	21.00
11	11	55	15	4	81.1	553.5	21.00
10	16	55	15	4	81.1	560.5	21.00
11	20	55	15	4	69.5	569.1	21.00
10	33	55	15	4	68.0	564.8	21.00
7	35	55	15	4	79.2	550.2	22.22
10	19	55	16	4	0.3	659.6	22.00
10	23	55	16	4	47.2	601.7	24.00
7	26	55	16	4	55.2	589.8	21.00
10	29	55	16	4	36.5	620.3	21.00
10	32	55	16	4	10.8	649.1	21.00
9	34	55	16	4	51.8	592.5	20.00
7	25	55	17	4	29.1	634.4	21.00
10	11	56	1	4	211.9	447.4	19.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
10	23	56	1	4	199.6	457.5	19.00
10	1	56	4	4	217.2	391.8	14.00
11	6	56	4	4	185.3	395.6	19.00
11	3	56	5	4	198.6	407.8	16.00
10	8	56	5	4	207.9	334.3	13.00
10	9	56	5	4	182.3	412.7	16.00
11	12	56	5	4	197.0	384.6	15.00
4	13	56	5	4	185.6	340.7	13.00
7	16	56	5	4	112.1	478.9	16.00
7	26	56	5	4	196.6	364.2	16.00
7	26	56	5	4	194.4	366.4	20.00
7	26	56	5	4	140.2	420.6	18.00
10	6	56	6	4	54.5	575.8	21.00
10	7	56	6	4	188.6	427.1	16.00
7	11	56	6	4	187.1	493.8	18.00
4	13	56	6	4	195.1	468.1	16.00
11	14	56	6	4	186.8	487.4	19.00
1	21	56	6	4	186.8	439.9	17.00
16	34	56	6	4	205.2	402.6	19.00
11	1	56	9	4	156.3	443.2	19.00
7	19	56	9	4	147.8	541.0	19.00
6	29	56	9	4	32.7	644.3	21.00
6	29	56	9	4	152.4	524.6	19.00
6	30	56	9	4	6.4	660.2	21.00
6	2	56	10	4	129.6	546.1	23.89
6	3	56	10	4	126.2	541.6	19.00
11	7	56	10	4	131.4	500.5	21.11
6	15	56	10	4	136.5	532.8	20.00
8	17	56	10	4	19.2	634.5	22.00
8	17	56	10	4	135.4	518.3	19.00
10	19	56	10	4	137.8	498.3	19.00
10	21	56	10	4	132.4	522.6	19.00
6	25	56	10	4	144.7	538.4	19.00
7	28	56	10	4	123.1	522.8	18.00
7	33	56	10	4	140.2	516.6	19.00
7	33	56	10	4	131.6	525.2	21.11
7	35	56	10	4	134.9	533.2	19.00
10	3	56	11	4	121.8	516.5	18.00
7	10	56	11	4	125.0	501.1	19.00
6	14	56	12	4	123.4	467.6	18.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
10	6	56	13	4	105.5	560.5	20.00
7	7	56	13	4	25.6	639.5	21.00
11	12	56	13	4		480.4	19.00
2	26	56	13	4	109.7	545.6	21.00
7	32	56	13	4	110.3	546.8	21.00
10	33	56	13	4	112.2	549.3	19.00
10	9	56	14	4	91.6	567.9	19.00
6	10	56	14	4	93.3	535.2	21.00
7	12	56	14	4	65.8	601.1	21.00
10	14	56	14	4	99.0	568.8	20.00
6	20	56	14	4	96.6	565.4	21.00
7	23	56	14	4	95.7	603.2	21.00
7	28	56	14	4	66.9	592.1	21.00
16	28	56	14	4	68.0	603.5	23.00
16	28	56	14	4	110.0	561.5	21.00
6	36	56	14	4	70.2	595.7	20.00
4	12	56	15	4	89.3	533.8	18.00
4	12	56	15	4	82.9	540.2	18.00
7	22	56	15	4	83.3	548.9	19.00
7	27	56	15	4	41.0	591.8	21.00
7	34	56	15	4	98.9	531.4	19.00
7	34	56	15	4	47.5	582.8	21.00
6	35	56	15	4	47.9	572.4	21.00
6	36	56	15	4	87.2	527.0	19.00
13	20	56	16	4	59.5	578.5	19.00
11	22	56	16	4	38.7	590.1	21.00
16	34	56	16	4	70.6	561.2	19.00
16	24	56	17	4	49.0	602.6	20.00
12	28	56	17	4	40.5	602.9	21.00
7	30	56	17	4	36.3	609.0	21.00
7	30	56	17	4	43.9	601.4	21.00
7	36	56	17	4	54.2	583.4	21.00
7	35	57	1	4	184.1	492.5	17.00
2	12	57	2	4	214.3	446.5	16.00
10	25	57	2	4	202.2	440.4	15.00
5	32	57	3	4	215.5	411.9	15.00
10	12	57	4	4	210.7	418.7	15.00
6	33	57	4	4	212.6	430.5	15.00
11	10	57	5	4	199.5	376.7	14.00
13	15	57	5	4		381.9	20.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER,
COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
15	16	57	5	4	214.4	427.0	15.00
6	26	57	5	4	214.7	432.0	17.00
11	6	57	6	4	180.4	412.1	17.00
9	28	57	6	4	198.4	394.7	16.00
11	22	57	7	4	187.1	492.6	19.00
13	26	57	7	4	184.6	493.4	17.00
13	26	57	7	4	179.7	498.3	17.00
16	34	57	7	4	190.0	496.4	17.00
6	8	57	8	4	175.9	485.5	22.78
6	29	57	8	4	178.3	500.2	21.11
11	11	57	9	4	163.7	520.6	16.00
13	15	57	9	4		498.3	17.00
10	31	57	9	4	165.5	474.6	19.00
10	2	57	10	4	139.0	507.9	17.00
11	6	57	10	4	144.9	491.2	20.00
6	9	57	10	4	138.0	505.4	18.00
7	9	57	10	4	137.0	508.0	18.00
11	19	57	10	4	140.4	497.2	18.00
14	21	57	10	4	146.0	493.8	18.00
7	22	57	10	4	157.0	491.9	24.00
12	26	57	10	4	115.5	531.3	19.00
6	28	57	10	4	95.9	546.8	20.00
10	30	57	10	4	146.0	489.2	17.00
6	36	57	10	4	128.4	512.0	21.07
7	10	57	11	4	137.5	503.6	17.00
11	13	57	11	4	143.6	490.4	21.00
6	18	57	11	4	88.7	550.5	21.00
10	25	57	11	4	150.7	484.2	19.00
10	29	57	11	4	150.7	480.2	17.00
10	35	57	11	4	116.7	519.7	19.00
10	35	57	11	4	97.2	539.2	19.00
10	35	57	11	4	151.0	485.4	21.00
6	16	57	12	4	95.1	533.7	21.00
10	28	57	12	4	138.6	495.0	18.00
7	14	57	13	4	126.0	461.0	16.00
7	28	57	13	4	93.0	572.4	20.00
8	16	57	14	4	111.4	516.3	20.00
6	8	57	15	4	50.0	588.6	21.00
6	8	57	15	4	85.7	552.9	20.00
10	22	57	15	4	55.5	572.7	20.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
LSD	SEC	TP	R	M			
10	4	57	16	4	28.1	605.6	21.00
10	4	57	16	4	82.9	550.8	21.00
8	27	57	16	4	91.3	539.5	18.00
11	28	57	16	4	81.6	549.6	21.00
6	29	57	16	4	82.0	539.2	21.00
16	1	57	17	4	63.6	568.0	19.00
13	15	57	17	4		560.9	19.00
13	15	57	17	4		541.0	21.00
11	31	58	1	4	205.0	498.5	18.00
10	34	58	1	4	201.0	478.7	17.00
12	4	58	2	4	108.2	540.2	19.00
12	4	58	2	4	153.1	495.3	17.00
12	4	58	2	4	199.0	449.4	16.00
10	5	58	2	4		504.1	18.00
10	5	58	2	4		424.4	15.00
7	23	58	2	4	209.8	473.6	17.00
15	30	58	2	4	228.3	441.7	16.00
6	22	58	4	4	208.5	453.5	16.00
11	7	58	5	4	200.9	497.1	20.00
11	11	58	5	4	224.9	424.3	16.00
4	18	58	5	4	232.3	463.9	16.00
10	23	58	5	4	209.4	455.3	17.00
10	25	58	5	4	158.5	506.6	15.56
7	13	58	6	4	124.3	570.0	22.22
7	20	58	6	4	199.4	490.1	16.00
7	20	58	6	4	194.3	495.2	16.00
10	21	58	6	4	219.7	501.8	16.00
10	31	58	6	4	208.5	344.1	13.00
6	35	58	6	4	172.0	599.8	21.00
6	21	58	7	4	186.8	467.9	19.00
11	12	58	9	4	176.8	476.7	19.00
13	15	58	9	4		477.3	16.00
6	26	58	9	4	130.0	533.4	19.00
6	2	58	10	4	173.6	489.0	19.00
6	3	58	10	4	149.4	503.5	19.00
6	3	58	10	4	157.7	495.2	19.00
6	5	58	10	4	117.3	524.9	19.00
10	5	58	10	4	136.2	512.4	21.11
6	6	58	10	4	161.1	477.0	17.00
12	7	58	10	4	161.3	477.6	21.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
10	8	58	10	4	143.3	515.1	21.11
6	12	58	10	4	166.1	487.4	19.00
7	18	58	10	4	155.2	498.3	19.00
15	28	58	10	4	162.5	501.7	18.00
7	32	58	10	4	172.5	487.1	18.00
2	34	58	10	4	158.0	500.1	19.00
2	34	58	10	4	164.0	494.1	19.00
11	1	58	11	4	155.6	481.4	21.00
7	2	58	11	4	113.4	520.0	19.00
4	3	58	11	4	151.6	494.2	18.00
4	3	58	11	4	157.2	488.6	17.00
2	4	58	11	4	164.4	476.9	21.00
2	4	58	11	4	158.3	483.0	21.00
10	5	58	11	4	103.9	531.6	19.00
10	5	58	11	4	118.9	516.6	19.00
15	7	58	11	4	144.1	481.0	18.00
2	9	58	11	4	160.0	477.6	21.00
11	14	58	11	4	158.8	480.4	21.00
11	14	58	11	4	161.6	477.6	19.00
10	18	58	11	4	144.7	479.8	21.00
15	24	58	11	4	157.1	486.3	18.00
11	30	58	11	4		487.4	19.00
6	31	58	11	4	122.5	518.8	21.00
11	36	58	11	4	165.5	487.7	17.00
13	9	58	12	4	148.7	494.4	19.00
10	10	58	12	4	134.4	475.8	21.00
10	12	58	12	4	151.0	465.5	17.00
10	15	58	12	4	128.4	485.5	19.00
13	15	58	12	4		477.6	21.00
13	15	58	12	4		481.0	18.00
13	15	58	12	4		476.3	17.00
13	15	58	12	4		485.4	21.00
13	15	58	12	4		481.4	21.00
13	15	58	12	4		477.0	21.00
13	15	58	12	4		486.6	21.00
13	15	58	12	4		498.3	19.00
13	15	58	12	4		484.2	19.00
13	15	58	12	4		483.0	21.00
13	15	58	12	4		489.8	18.00
13	15	58	12	4		480.4	21.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER,
COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
13	15	58	12	4		434.3	21.00
13	15	58	12	4		486.9	19.00
7	20	58	12	4	143.5	500.5	18.00
11	24	58	12	4	154.0	477.9	21.00
10	32	58	12	4	157.9	482.2	21.00
6	33	58	12	4	130.1	501.4	21.00
6	33	58	12	4	155.7	475.8	21.00
1	35	58	12	4	155.3	481.1	19.00
10	5	58	13	4	135.3	521.8	19.00
7	8	58	13	4	135.6	518.8	19.00
7	8	58	13	4	142.6	511.8	17.00
7	9	58	13	4	137.4	535.5	20.00
6	11	58	13	4	70.8	580.9	21.00
6	14	58	13	4	100.0	571.8	21.00
10	17	58	13	4	100.9	554.4	20.00
11	21	58	13	4	140.3	515.7	18.00
12	25	58	13	4	135.1	503.4	19.00
10	28	58	13	4	147.5	505.1	19.00
7	33	58	13	4	144.2	509.0	25.00
10	35	58	13	4	157.3	477.6	20.39
10	36	58	13	4	155.2	484.3	21.00
15	5	58	14	4	116.1	527.3	19.00
4	24	58	14	4	127.7	527.9	22.00
16	25	58	14	4	146.6	525.2	19.00
5	5	58	15	4	109.7	521.1	20.00
6	8	58	15	4	70.1	531.0	19.00
5	20	58	15	4	114.9	476.1	19.00
6	30	58	15	4	77.5	516.3	19.00
13	4	58	16	4	36.4	592.8	18.00
13	4	58	16	4	48.5	580.7	20.00
6	8	58	16	4	90.6	539.8	18.00
13	15	58	16	4		522.0	21.00
10	32	58	16	4	112.0	500.6	22.00
11	33	58	16	4	55.1	557.2	21.00
11	33	58	16	4	118.5	493.8	19.44
6	1	58	17	4	41.5	580.3	21.00
10	15	58	17	4	85.7	541.7	19.00
6	12	59	1	4	201.0	419.3	15.00
11	21	59	1	4	219.3	392.8	14.00
7	36	59	1	4	212.1	387.4	16.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
11	5	59	2	4	237.9	438.7	15.00
14	18	59	2	4	243.8	406.5	14.00
11	19	59	2	4	235.0	388.3	14.00
11	19	59	2	4	238.0	385.3	14.00
6	8	59	3	4	229.9	411.1	15.00
7	28	59	3	4	237.1	381.9	14.00
10	17	59	4	4	177.7	464.8	16.00
7	26	59	4	4	236.4	386.0	14.00
7	26	59	4	4	213.0	409.4	15.00
16	30	59	4	4	218.0	389.8	16.00
16	30	59	4	4	199.4	408.4	17.00
10	33	59	4	4	237.2	375.9	14.00
10	5	59	5	4	216.2	459.6	16.00
10	5	59	5	4	204.4	471.4	17.00
6	17	59	5	4	208.2	433.1	16.00
13	5	59	6	4		381.8	14.00
7	10	59	6	4	176.8	403.2	15.00
7	10	59	6	4	207.8	372.2	13.00
11	12	59	6	4	211.7	366.6	14.00
11	19	59	6	4	222.3	362.9	14.00
2	18	59	7	4	199.5	439.3	16.00
12	25	59	7	4	221.0	399.1	14.00
8	35	59	7	4	221.9	386.2	14.00
4	21	59	8	4	190.5	424.9	19.00
9	24	59	8	4	155.4	490.4	17.00
11	29	59	8	4	203.3	419.7	16.00
9	30	59	8	4	208.8	414.5	21.00
7	8	59	9	4	149.9	492.9	21.00
7	8	59	9	4	190.8	452.0	21.00
7	25	59	9	4	197.2	443.2	21.00
7	35	59	9	4	150.0	481.9	21.67
8	7	59	10	4	176.8	477.0	18.00
6	10	59	10	4	167.4	484.9	19.00
6	10	59	10	4	136.0	516.3	18.00
6	25	59	10	4	195.7	453.8	18.00
11	33	59	10	4	184.5	453.8	19.00
10	2	59	11	4	158.2	487.4	24.00
10	2	59	11	4	149.4	496.2	21.00
6	3	59	11	4	157.9	489.2	21.00
3	14	59	11	4	163.4	490.4	24.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
8	19	59	11	4	178.6	462.1	24.00
6	3	59	12	4	147.8	493.5	21.00
10	5	59	12	4	151.5	497.4	19.00
8	6	59	12	4	156.8	481.3	17.00
3	12	59	12	4	156.0	507.5	18.00
3	12	59	12	4	159.5	504.0	18.00
6	12	59	12	4	151.2	513.3	19.00
9	22	59	12	4	170.1	475.0	18.00
15	8	59	13	4	141.1	507.2	19.00
6	16	59	13	4	150.9	497.7	19.00
10	18	59	13	4	150.6	491.3	18.00
6	20	59	13	4	47.2	593.8	22.00
10	34	59	13	4	165.2	480.7	19.00
10	34	59	13	4	156.4	489.5	17.00
3	10	59	14	4	140.8	537.7	20.00
6	14	59	14	4	147.5	506.9	19.00
13	15	59	14	4		522.0	26.00
10	27	59	14	4	145.2	522.3	26.00
15	33	59	14	4	150.3	523.3	19.00
10	8	59	15	4	131.4	468.9	23.00
10	8	59	15	4	93.3	507.0	19.00
6	9	59	15	4	71.3	526.4	20.00
6	9	59	15	4	77.1	520.6	20.00
13	15	59	15	4		504.6	22.00
13	15	59	15	4		536.8	26.00
13	15	59	15	4		569.1	20.00
13	15	59	15	4		528.2	22.00
13	15	59	15	4		557.0	21.00
11	16	59	15	4	127.2	484.2	25.00
11	16	59	15	4	81.3	530.1	26.00
10	33	59	15	4	95.1	560.2	22.78
16	35	59	15	4	105.5	564.5	24.00
10	36	59	15	4	145.1	527.6	19.00
10	7	59	16	4	99.8	517.1	22.00
10	15	59	16	4	94.6	504.6	22.00
11	24	59	16	4	132.6	496.5	22.00
6	27	59	16	4	122.2	470.6	24.00
10	33	59	16	4	88.1	513.0	21.00
11	25	59	17	4	118.0	501.7	19.00
10	16	60	3	4	271.0	334.6	12.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
11	27	60	3	4	246.6	326.7	12.00
6	4	60	4	4	237.8	415.1	13.33
11	22	60	4	4	268.4	340.6	13.00
12	27	60	4	4	243.8	334.7	16.00
7	29	60	4	4	215.2	367.0	19.00
6	36	60	4	4	225.2	367.0	21.00
6	36	60	4	4	217.3	374.9	21.00
7	29	60	5	4	237.7	347.2	14.00
11	36	60	5	4	240.6	322.1	12.00
5	10	60	6	4	230.3	336.1	13.00
10	18	60	6	4	227.4	341.4	13.00
6	23	60	6	4	225.1	352.8	13.00
11	35	60	6	4	239.2	326.0	14.00
6	36	60	6	4	238.1	326.6	13.00
12	12	60	7	4	227.2	375.3	20.00
12	15	60	7	4	226.5	324.5	18.00
4	22	60	7	4	199.1	338.7	20.00
4	22	60	7	4	230.1	307.7	19.00
4	22	60	7	4	211.8	326.0	20.00
4	22	60	7	4	225.8	312.0	20.00
4	22	60	7	4	207.7	330.1	20.00
3	24	60	7	4	230.1	373.9	20.00
3	24	60	7	4	233.4	370.6	20.00
3	24	60	7	4	197.5	406.5	21.00
3	24	60	7	4	214.5	389.5	20.00
11	21	60	8	4	181.0	430.7	17.00
7	30	60	8	4	229.6	383.0	20.00
7	30	60	8	4	175.2	437.4	18.00
6	32	60	8	4	185.0	425.2	17.00
6	32	60	8	4	181.4	428.9	18.33
10	2	60	9	4	211.0	408.4	19.00
11	5	60	9	4	212.4	441.4	15.00
6	6	60	9	4	206.0	449.0	16.00
10	8	60	9	4	206.1	414.2	14.00
9	23	60	9	4	226.0	388.6	14.00
7	25	60	9	4	178.4	432.7	19.00
7	25	60	9	4	230.1	381.0	16.00
11	31	60	9	4	221.3	410.6	16.00
10	12	60	10	4	197.8	462.4	19.00
15	14	60	10	4	206.3	451.3	15.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
10	15	60	10	4	200.5	453.9	22.00
15	26	60	10	4	209.7	424.9	14.00
13	3	60	11	4	144.6	513.2	19.00
13	3	60	11	4	169.4	488.4	21.00
13	3	60	11	4	190.9	466.9	18.00
13	15	60	11	4		475.0	18.00
10	16	60	11	4	190.8	425.8	19.00
16	20	60	11	4	182.8	448.1	18.00
16	20	60	11	4	202.4	428.5	18.00
6	22	60	11	4	189.8	435.3	24.00
10	28	60	11	4	182.8	431.0	23.00
6	4	60	12	4	171.3	502.9	25.00
6	36	60	12	4	176.7	447.8	19.00
5	1	60	13	4	156.1	486.7	17.00
5	1	60	13	4	147.2	495.6	21.00
7	3	60	15	4	149.4	536.1	20.00
10	16	60	15	4	134.4	569.1	20.00
10	16	60	15	4	129.3	574.2	24.00
7	29	60	15	4	100.3	582.8	21.00
11	6	60	16	4	127.4	507.8	19.00
7	13	60	16	4	150.3	523.3	20.00
13	15	60	16	4		528.0	22.00
13	15	60	16	4		531.0	22.00
13	15	60	16	4	83.8	602.9	20.00
8	20	60	16	4	137.8	488.5	16.00
8	20	60	16	4	102.8	523.5	18.00
8	20	60	16	4	87.6	538.7	18.00
5	36	60	16	4	141.4	522.1	23.00
10	5	60	17	4	110.3	511.8	19.00
11	8	60	17	4	110.7	503.8	17.00
7	17	60	17	4	115.5	544.7	23.00
6	34	60	17	4	125.3	541.0	25.00
11	28	61	2	4	234.1	317.0	16.67
7	20	61	3	4	251.4	308.5	13.00
6	20	61	4	4	243.3	316.9	19.00
7	26	61	4	4	250.0	306.5	18.00
9	29	61	4	4	244.8	307.5	19.00
13	29	61	4				

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
LSD	SEC	TP	R	M			
16	12	61	6	4	232.3	317.9	14.00
7	20	61	6	4	244.4	309.7	18.00
10	31	61	6	4	246.0	304.5	17.00
6	19	61	7	4	241.1	335.0	19.00
9	21	61	7	4	240.5	316.4	19.00
9	21	61	7	4	222.2	334.7	19.00
12	28	61	7	4	240.7	325.4	15.00
11	29	61	7	4	228.9	352.7	19.00
11	29	61	7	4	154.0	427.6	17.22
10	17	61	8	4	231.9	350.0	18.30
7	20	61	8	4	238.3	338.7	19.00
11	23	61	8	4	232.3	339.5	19.00
11	23	61	8	4	196.1	375.7	21.00
6	24	61	8	4	251.2	320.6	18.00
10	20	61	9	4	222.8	411.5	21.00
10	20	61	9	4	235.3	399.0	21.00
6	21	61	9	4	230.2	395.2	17.00
7	25	61	9	4	238.6	347.8	19.00
7	31	61	9	4		364.5	21.00
7	34	61	9	4	200.0	402.3	21.00
7	34	61	9	4	210.6	391.7	21.00
7	34	61	9	4	237.9	364.4	20.00
10	3	61	10	4	167.3	461.8	19.00
10	3	61	10	4	206.3	422.8	23.00
2	18	61	10	4	206.0	448.7	24.00
11	24	61	10	4	226.7	393.8	21.00
7	25	61	10	4	232.5	386.5	24.00
12	3	61	13	4	78.7	566.9	27.00
13	15	61	13	4		399.0	21.00
11	16	61	13	4	193.8	444.1	23.00
10	14	61	14	4	190.2	491.3	24.00
6	19	61	15	4	167.9	530.7	21.00
6	9	61	16	4	147.8	555.7	19.00
6	9	61	16	4	121.9	581.6	21.00
7	10	61	16	4	147.7	551.2	18.00
10	11	61	16	4	155.4	537.4	24.00
11	15	61	16	4	160.6	533.1	25.00
11	28	61	16	4	171.3	536.4	25.00
11	32	61	16	4	159.0	541.7	26.00
7	27	61	17	4	102.4	597.7	24.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER,
COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
10	30	62	1	4	229.8	312.1	15.00
15	9	62	2	4	262.9	279.6	21.00
13	15	62	2	4		280.0	21.00
10	1	62	3	4	260.0	281.6	21.00
7	10	62	3	4	240.5	299.0	13.00
7	13	62	3	4	251.2	288.1	18.00
10	17	62	3	4	231.9	310.0	17.78
5	21	62	3	4	260.0	282.5	16.00
6	27	62	3	4	258.5	282.2	16.00
11	34	62	3	4	165.2	374.5	14.00
6	6	62	4	4	226.4	328.9	19.00
11	6	62	4	4	239.2	315.2	19.00
10	14	62	4	4	253.4	302.5	13.00
10	10	62	5	4	253.9	304.8	16.00
10	14	62	5	4	253.9	301.0	20.00
11	17	62	6	4	256.0	303.6	19.00
11	21	62	6	4	156.1	393.1	15.00
7	10	62	7	4	250.9	299.9	18.00
10	11	62	7	4	248.1	307.2	18.00
7	20	62	7	4	230.7	316.1	19.00
10	31	62	7	4	239.0	313.0	19.00
10	31	62	7	4	247.1	304.9	18.00
10	7	62	8	4	250.9	339.5	16.00
6	9	62	8	4	234.0	338.1	19.00
11	32	62	8	4	247.1	277.2	17.00
11	34	62	8	4	238.3	333.5	19.00
10	3	62	9	4	239.5	366.4	18.89
10	6	62	9	4	224.0	398.4	21.00
10	8	62	9	4	193.8	423.4	22.00
9	18	62	9	4	239.1	376.8	15.00
6	21	62	9	4	237.0	381.4	16.00
6	29	62	9	4	240.3	365.9	16.00
8	29	62	9	4	237.7	370.0	18.26
16	31	62	9	4	247.1	361.0	14.00
10	14	62	10	4	216.1	395.0	21.00
13	15	62	10	4		340.0	19.00
6	28	62	10	4	220.5	375.6	20.00
12	20	62	11	4	225.8	429.5	21.00
7	21	62	12	4	222.2	392.4	21.00
7	31	62	13	4	195.1	418.2	23.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
10	25	62	14	4	152.0	447.8	19.00
10	29	62	14	4	205.4	400.8	21.00
11	34	62	14	4	175.3	439.2	23.00
11	17	62	16	4	176.5	550.8	19.00
10	20	62	16	4	121.9	589.5	27.00
7	34	62	16	4	189.3	521.5	26.00
12	31	63	2	4	270.3	276.5	16.00
11	4	63	3	4	249.0	296.7	12.00
3	6	63	3	4	261.9	285.6	11.00
6	7	63	3	4	251.7	299.5	12.00
12	12	63	3	4	274.0	270.1	18.00
7	14	63	3	4	274.4	269.1	20.00
2	36	63	3	4	181.6	365.8	14.00
10	3	63	5	4	248.2	310.4	19.00
11	6	63	5	4	246.3	297.7	18.00
11	6	63	5	4	244.3	299.7	18.00
11	20	63	5	4	251.4	303.6	16.00
10	30	63	6	4	255.5	320.6	18.00
10	26	63	7	4	236.3	333.2	19.00
10	10	63	8	4	252.3	314.9	19.00
10	12	63	8	4	260.2	301.2	18.00
10	12	63	8	4	245.9	315.5	16.00
10	15	63	8	4	245.4	326.7	18.00
7	17	63	8	4	233.8	349.6	19.00
4	27	63	8	4	242.6	338.3	13.00
10	30	63	8	4	240.3	341.0	13.00
7	32	63	8	4	258.6	322.3	18.00
6	8	63	9	4	239.0	357.2	16.00
7	28	63	10	4	240.8	350.3	14.00
8	11	63	11	4	244.2	373.9	15.00
11	16	63	11	4	230.7	342.0	19.00
13	18	63	11	4	237.2	396.5	21.00
15	20	63	11	4	238.3	357.0	20.00
2	24	63	11	4	245.4	376.4	13.00
6	26	63	11	4	240.6	364.7	15.00
11	33	63	11	4	237.0	356.0	19.00
10	36	63	11	4	238.2	355.2	13.00
7	21	63	12	4	234.8	365.0	18.00
6	23	63	12	4	223.7	401.7	16.00
6	31	63	12	4	216.7	366.1	16.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER,
COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
1	36	63	12	4	237.8	367.2	20.00
6	2	63	13	4	204.8	393.5	21.00
10	10	63	13	4	228.3	411.8	21.00
6	13	63	13	4	219.1	417.9	16.00
11	35	63	13	4	223.5	358.1	19.00
7	8	63	14	4	207.8	381.1	15.00
7	8	63	14	4	208.5	380.4	20.00
10	26	63	14	4	185.4	415.1	16.00
7	3	63	15	4	124.4	528.8	20.00
11	12	63	15	4	202.1	381.3	19.00
11	12	63	15	4	216.7	366.7	17.78
11	20	63	17	4	165.8	532.2	20.00
6	5	64	2	4	163.3	382.0	14.61
8	1	64	3	4	266.0	282.9	17.00
6	10	64	3	4	259.7	288.6	16.00
5	15	64	3	4	271.0	298.4	12.00
11	16	64	3	4	270.6	289.6	16.00
10	27	64	3	4	275.1	332.7	14.00
6	11	64	6	4	271.3	309.4	18.00
7	3	64	7	4	255.7	319.3	19.00
10	28	64	7	4	259.2	349.6	20.00
13	7	64	8	4	242.9	345.0	20.00
10	14	64	9	4	240.8	349.3	19.00
11	21	64	9	4	253.9	368.2	19.00
5	3	64	11	4	239.7	364.4	19.00
10	22	64	11	4	245.3	347.5	18.33
11	30	64	11	4	246.4	369.6	18.00
6	33	64	11	4	246.3	357.5	19.00
10	9	64	12	4	214.3	374.5	21.00
7	13	64	12	4	227.1	379.8	22.00
11	18	64	12	4	176.5	414.8	21.00
9	21	64	12	4	235.6	372.0	22.00
10	24	64	12	4	240.1	377.7	20.00
11	26	64	12	4	246.5	365.8	20.00
10	32	64	12	4	243.4	351.6	20.00
13	15	64	13	4		369.6	18.00
13	15	64	13	4		380.4	20.00
13	15	64	13	4		381.6	16.00
13	15	64	13	4		355.4	20.00
11	24	64	13	4	226.5	356.3	20.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
11	24	64	13	4	224.4	358.4	20.00
6	8	64	15	4	211.2	438.9	23.00
7	15	64	16	4	200.8	431.9	22.00
12	26	64	16	4	215.5	406.0	22.00
12	26	64	16	4	127.1	494.4	25.00
12	26	64	16	4	218.2	403.3	22.00
10	31	64	16	4	193.2	430.1	20.00
3	16	64	17	4	180.1	481.3	19.00
10	14	65	2	4	253.9	338.3	18.33
10	14	65	2	4	285.0	307.2	18.00
10	26	65	2	4	285.0	304.2	17.00
10	26	65	2	4	257.0	332.2	17.78
10	5	65	3	4	285.1	348.4	20.00
16	1	65	4	4	291.9	320.7	19.00
12	25	65	4	4	304.0	308.8	18.00
4	24	65	5	4	295.1	336.1	19.00
10	30	65	8	4	202.0	442.0	19.00
7	3	65	9	4	251.5	364.0	21.00
11	9	65	9	4	248.2	358.5	19.00
4	19	65	11	4	244.4	352.6	19.00
4	19	65	11	4	252.3	344.7	19.00
6	1	65	12	4	228.9	381.6	16.00
10	10	65	12	4	241.1	374.9	16.00
10	16	65	12	4	237.2	363.3	16.00
10	7	65	13	4	241.4	349.0	20.00
5	12	65	15	4	228.3	346.9	19.00
5	12	65	15	4	156.4	418.8	23.00
1	27	65	15	4	138.7	451.7	23.00
7	35	65	15	4	228.9	362.4	19.00
7	12	65	16	4	210.3	392.9	21.00
6	15	65	16	4	209.7	397.5	21.00
15	4	65	17	4	199.0	438.0	23.00
10	15	65	17	4	197.8	417.0	22.00
7	35	65	17	4	202.8	417.2	21.00
11	11	66	2	4	281.6	328.6	19.00
4	5	66	4	4	221.4	425.8	20.00
8	8	66	4	4	311.3	318.8	19.00
12	11	66	4	4	312.2	313.0	17.00
6	8	66	10	4	266.7	390.8	21.00
7	17	66	13	4	256.6	330.4	19.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER,
COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
6	29	66	13	4	263.3	303.3	19.00
6	31	66	14	4	260.1	312.3	18.00
6	31	66	14	4	185.7	386.7	21.00
11	27	66	16	4	179.2	397.2	21.00
11	34	66	16	4	233.8	351.7	19.00
10	21	66	17	4	219.8	402.3	21.00
6	31	66	17	4	217.0	417.0	21.00
11	9	67	12	4	272.9	289.0	19.00
4	26	67	12	4	274.0	318.2	19.00
4	26	67	12	4	287.4	304.8	19.00
4	26	67	12	4	279.8	312.4	19.00
4	26	67	12	4	267.9	324.3	19.00
6	31	67	12	4	274.3	317.6	19.00
6	35	67	12	4	292.9	315.8	19.00
11	4	67	13	4	264.7	313.5	19.00
6	7	67	15	4	189.9	419.7	21.00
6	18	67	15	4	226.8	389.5	20.00
11	30	67	15	4	236.2	369.4	20.00
11	30	67	15	4	191.1	414.5	21.00
6	1	67	16	4	230.4	368.2	19.00
10	2	67	16	4	215.5	381.0	20.00
11	12	67	16	4	250.2	365.2	19.00
6	11	67	17	4	173.4	437.1	21.00
11	14	67	17	4	224.0	391.1	21.00
11	6	68	12	4	287.2	305.6	17.00
6	8	68	12	4	287.1	309.7	19.00
8	30	68	12	4	296.9	294.1	19.00
8	30	68	12	4	278.3	312.7	19.00
6	31	68	12	4	286.2	308.5	19.00
10	10	68	13	4	274.9	310.9	18.00
11	13	68	13	4	292.0	301.8	19.00
11	14	68	13	4	276.1	309.4	19.00
11	14	68	13	4	283.1	302.4	19.00
6	23	68	13	4	295.7	294.1	19.00
6	23	68	13	4	276.8	313.0	19.00
6	26	68	13	4	278.6	310.6	19.00
10	27	68	13	4	286.2	304.2	19.00
10	28	68	13	4	302.4	280.7	19.00
10	26	68	14	4	269.1	286.2	19.00
10	33	68	14	4	280.1	285.3	19.00

TEMPERATURE DATA FOR "UPPER MANNVILLE AQUIFER,
COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	.(m)	(m)	(°C)
11	31	68	15	4	225.8	323.4	18.00
7	29	68	16	4	260.6	306.0	18.00
6	17	69	9	4	319.8	427.5	15.00
8	28	69	10	4	322.0	335.0	13.00
11	9	69	11	4	306.3	324.0	18.00
6	11	69	11	4	295.4	333.1	19.00
10	30	69	11	4	299.3	353.3	19.00
11	4	69	12	4	300.9	300.2	19.00
10	20	69	12	4	307.3	337.4	19.00
10	27	69	12	4	313.6	279.8	19.00
7	28	69	12	4	303.2	284.1	19.00
11	1	69	13	4	288.7	300.8	19.00
7	7	69	13	4	282.0	269.1	16.00
7	7	69	13	4	273.7	277.4	16.00
7	7	69	13	4	294.5	256.6	16.00
7	11	69	13	4	290.5	306.9	19.00
7	11	69	13	4	295.6	301.8	19.00
13	15	69	13	4		294.0	19.00
13	15	69	13	4		313.0	19.00
13	15	69	13	4		281.0	19.00
6	29	69	13	4	295.8	272.5	15.00
6	1	69	14	4	288.8	287.1	17.00
7	10	69	14	4	284.4	275.2	19.00
7	13	69	14	4	289.3	268.5	16.00
7	14	69	14	4	287.5	268.8	15.00
7	15	69	14	4	286.2	278.9	16.00
7	15	69	14	4	282.2	282.9	16.00
6	24	69	14	4	289.9	273.4	16.00
10	10	69	15	4	227.8	324.3	19.00
10	10	69	15	4	279.4	272.7	16.00
11	17	69	15	4	228.3	322.5	18.00
10	27	69	15	4	280.1	285.0	16.00
10	34	69	15	4	284.8	278.6	18.00
10	1	69	16	4	225.8	334.4	19.00
10	1	69	16	4	274.3	285.9	18.00
6	6	69	16	4	264.8	283.2	16.00

TEMPERATURE DATA FOR "LOWER MANNVILLE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
11	31	55	8	4	-20.7	629.7	26.11
11	11	55	2	4	82.0	496.5	19.00
6	2	55	3	4	65.2	496.5	17.78
6	20	55	5	4	46.1	607.0	23.00
11	29	55	5	4	70.4	590.7	21.00
2	4	55	6	4	42.5	593.9	20.00
2	4	55	6	4	49.5	586.9	20.00
10	11	55	6	4	53.7	603.8	24.00
10	11	55	6	4	47.0	610.5	21.00
11	20	55	6	4	50.6	625.8	23.00
11	20	55	6	4	55.0	621.4	22.00
7	29	55	7	4	31.4	620.0	20.00
10	11	55	8	4		590.1	19.44
7	25	55	10	4	8.3	660.5	23.00
7	28	55	11	4	3.0	638.6	22.22
10	6	55	12	4	23.1	612.7	25.56
10	3	55	14	4	2.5	625.1	21.00
7	32	55	14	4		611.7	24.44
10	16	55	15	4	-22.8	664.4	23.00
11	20	55	15	4	-31.0	669.6	23.00
11	20	55	15	4	-17.9	656.5	22.00
7	2	55	16	4	-64.5	724.8	23.00
10	19	55	16	4	-85.9	745.8	24.00
10	19	55	16	4	-57.3	717.2	24.00
10	23	55	16	4	-68.6	717.5	24.00
10	23	55	16	4	-50.9	699.8	24.00
9	34	55	16	4	-47.4	691.7	22.00
9	34	55	16	4	-46.7	691.0	25.00
7	25	55	17	4	-90.3	753.8	27.00
6	3	56	10	4	-9.2	677.0	27.00
6	3	56	10	4	-13.4	681.2	24.00
6	29	56	10	4	-8.6	652.6	27.00
10	36	56	10	4	-52.4	724.0	27.09
14	5	56	13	4	24.0	640.3	22.00
10	9	56	14	4	-16.6	676.1	23.00
7	12	56	14	4	15.8	651.1	24.00
15	12	56	14	4	13.7	659.1	22.00
7	13	56	14	4	17.7	655.3	24.00
11	21	56	14	4	9.8	647.4	23.00
7	22	56	14	4	11.9	656.5	24.00

TEMPERATURE DATA FOR "LOWER MANNVILLE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
LSD	SEC	TP	R	M			
7	28	56	14	4	17.1	641.9	23.00
16	28	56	14	4	18.9	652.6	24.00
4	11	56	15	4	-16.1	654.5	22.00
10	17	56	15	4	-12.5	644.7	22.00
10	21	56	15	4	-11.0	646.5	22.00
11	22	56	15	4	-7.2	640.5	21.00
7	28	56	15	4	-10.6	643.4	21.00
3	29	56	15	4	-16.8	647.1	23.00
10	5	56	16	4	-69.2	723.5	23.00
12	30	56	16	4	-57.4	692.0	22.00
12	30	56	16	4	-65.2	699.8	23.00
16	34	56	16	4	-49.5	681.3	22.00
10	30	57	9	4	71.9	570.9	25.00
11	19	57	10	4	29.8	607.8	21.00
11	25	57	10	4	67.4	577.3	21.00
12	26	57	10	4	65.9	580.9	21.00
6	1	57	11	4	-6.5	640.5	26.00
10	28	57	12	4	-2.6	636.2	23.00
10	32	57	12	4	44.2	601.1	21.00
6	26	57	13	4	30.5	614.2	21.00
6	29	57	13	4	-20.8	677.0	25.00
10	6	57	15	4	-10.4	645.0	27.00
6	8	57	15	4	-12.8	651.4	23.00
7	5	57	16	4	-44.0	674.4	23.00
7	9	57	16	4	-39.9	673.6	24.00
12	23	57	16	4	-26.9	657.4	23.00
10	24	57	16	4	-18.6	667.5	24.00
10	24	57	16	4	14.9	634.0	21.00
6	5	58	10	4	18.3	623.9	21.00
10	5	58	11	4	63.4	572.1	21.00
5	10	58	11	4	3.7	634.0	23.00
10	11	58	11	4	41.4	602.0	21.00
10	11	58	12	4	-37.8	658.0	23.90
10	11	58	12	4	59.4	560.8	20.00
13	15	58	12	4		572.0	21.00
10	30	58	12	4	10.9	626.9	22.00
10	30	58	12	4	53.5	584.3	21.00
10	31	58	12	4	51.9	593.1	21.00
10	31	58	12	4	33.0	612.0	24.00
13	15	58	13	4		614.2	21.00

TEMPERATURE DATA FOR "LOWER MANNVILLE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
15	18	58	13	4	44.1	610.0	20.00
12	25	58	13	4	43.8	594.7	20.00
12	25	58	13	4	4.4	634.1	23.00
10	35	58	13	4	56.7	578.2	21.11
15	5	58	14	4	7.6	635.8	21.00
13	4	58	16	4	-26.7	655.9	22.00
5	12	58	16	4	-6.4	644.7	21.00
10	12	58	16	4	2.6	613.2	21.00
10	12	58	16	4	-9.5	625.3	21.00
7	13	58	16	4	-2.9	643.5	21.00
7	13	58	16	4	1.6	639.0	21.00
7	20	58	16	4	-18.3	641.0	21.00
15	24	58	16	4	-9.5	613.6	21.00
10	26	58	16	4	-12.2	622.7	21.00
6	1	58	17	4	-31.1	652.9	24.00
11	21	59	3	4	48.8	573.0	21.00
9	24	59	8	4	107.7	538.1	19.00
6	3	59	12	4	15.2	626.1	24.00
8	6	59	12	4	12.4	625.7	22.00
16	4	59	13	4	52.1	589.2	21.00
10	8	59	15	4	16.8	583.5	20.00
13	15	59	15	4		638.0	21.00
13	15	59	15	4		668.0	27.00
13	15	59	15	4		725.0	25.00
13	15	59	15	4		583.0	21.00
13	15	59	15	4		566.0	21.00
10	30	59	15	4	51.5	597.4	21.11
16	35	59	15	4	45.2	624.8	21.00
16	35	59	15	4	31.7	638.3	21.00
5	5	59	16	4	17.9	600.1	20.00
5	5	59	16	4		618.0	23.00
2	26	60	2	4	113.4	457.2	20.56
10	9	60	3	4	133.5	487.7	21.11
6	32	60	8	4	90.6	519.6	21.00
6	32	60	8	4	136.0	474.2	17.00
6	6	60	9	4	58.1	596.9	21.00
10	13	60	9	4	83.6	529.4	21.00
12	33	60	9	4	53.7	578.2	21.11
13	3	60	11	4	87.8	570.0	22.00
7	29	60	15	4	62.5	620.6	24.00

TEMPERATURE DATA FOR "LOWER MANNVILLE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(°C)
6	20	60	16	4	14.0	596.5	21.00
10	31	60	16	4	32.0	605.9	21.67
12	21	61	4	4	125.9	439.8	18.89
10	20	61	7	4	150.5	436.2	23.00
10	31	61	7	4	151.8	417.6	19.00
10	31	61	7	4	108.8	460.6	21.00
10	32	61	7	4	117.6	448.1	24.00
6	24	61	8	4	150.0	421.8	21.00
7	34	61	9	4	131.1	471.2	24.00
7	34	61	9	4	91.5	510.8	24.00
6	28	61	10	4	79.6	535.5	21.00
7	29	61	13	4	78.5	554.6	20.00
10	31	61	13	4	80.3	555.0	20.10
11	3	61	16	4	32.9	656.3	24.00
14	20	61	16	4	58.3	641.0	20.50
11	22	61	17	4	13.4	691.6	24.00
7	23	61	17	4	40.5	645.6	23.00
15	9	62	2	4	73.1	469.4	22.22
6	23	62	7	4	122.5	432.2	20.00
6	23	62	7	4	160.6	394.1	19.00
10	25	62	7	4	159.7	380.7	20.00
11	34	62	8	4	114.6	457.2	24.00
7	17	62	9	4	133.1	481.7	24.00
15	3	62	11	4	75.6	567.5	27.00
7	3	62	13	4	97.2	498.4	23.00
6	23	62	13	4	72.8	525.5	24.00
10	28	62	13	4	89.6	495.9	24.00
7	31	62	13	4	101.5	511.8	26.00
10	25	62	14	4	96.6	503.2	19.00
1	8	62	16	4	72.3	636.7	21.00
10	11	63	7	4	118.2	443.5	23.00
7	14	63	9	4	118.6	408.4	21.00
7	36	63	10	4	135.0	481.0	24.00
6	21	63	11	4	115.6	482.7	24.00
7	33	63	11	4	50.3	542.5	22.22
7	33	63	11	4	79.5	513.3	24.00
7	21	63	12	4	65.8	534.0	26.00
10	34	63	12	4	97.9	530.0	21.00
10	34	63	12	4	91.1	536.8	27.00
10	19	63	16	4	52.4	642.8	23.00

TEMPERATURE DATA FOR "LOWER MANNVILLE AQUIFER", COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
8	1	64	3	4	49.0	499.9	25.56
6	11	64	6	4	163.1	417.6	21.00
6	33	64	11	4	57.9	545.9	26.67
6	33	64	11	4	90.2	513.6	25.00
6	8	64	12	4	82.0	517.2	26.00
3	28	64	12	4	68.6	529.7	26.00
3	28	64	12	4	116.7	481.6	19.00
10	12	64	13	4	76.2	519.4	24.44
13	15	64	13	4		529.7	26.00
11	24	64	13	4	103.3	479.5	23.33
11	18	64	16	4	78.1	573.6	21.00
16	24	65	4	4	197.5	414.6	22.00
12	25	65	4	4	198.8	414.0	22.00
10	30	65	8	4	142.0	502.0	20.40
6	11	65	9	4	144.4	461.2	20.00
7	20	65	9	4	29.2	583.4	20.00
6	5	65	11	4	90.8	540.4	25.00
6	5	65	11	4	82.6	548.6	25.56
11	8	65	11	4	65.6	534.9	25.56
10	23	65	11	4	90.5	524.9	25.00
10	23	65	11	4	89.3	525.5	20.56
11	6	65	12	4	86.6	511.1	25.00
10	3	65	13	4	124.1	470.0	24.00
5	12	65	15	4	97.3	477.9	24.00
13	15	65	15	4		482.0	19.00
7	33	65	15	4	138.5	439.5	22.00
10	31	66	5	4	206.7	433.4	19.00
11	25	66	9	4	124.0	526.7	20.00
6	8	66	10	4	147.3	510.2	21.11
6	8	66	10	4	149.1	508.4	21.00
7	4	66	15	4	100.3	481.9	21.00
10	26	66	15	4	101.5	483.7	22.22
11	34	66	15	4	91.8	483.7	22.00
11	30	66	17	4	81.1	536.1	19.00
10	31	67	7	4		416.0	22.00
6	31	67	12	4	124.9	467.0	21.00
11	4	67	13	4	104.2	474.0	24.00
11	9	67	13	4	109.4	474.0	21.00
6	7	67	15	4	125.0	484.6	24.00
13	15	67	17	4		514.0	20.00

TEMPERATURE DATA FOR "LOWER MANNVILLE AQUIFER", COLD LAKE STUDY AREA

LOCATION					ELEVATION (m)	DEPTH (m)	TEMPERATURE (°C)
LSD	SEC	TP	R	M			
13	15	67	17	4		508.0	25.00
13	15	67	17	4		512.0	22.00
11	16	67	17	4	111.9	513.9	20.00
4	31	67	17	4	136.5	441.7	16.00
10	26	68	4	4	242.5	493.2	25.00
15	13	68	11	4	96.9	584.0	22.00
10	18	68	12	4	133.5	461.2	19.00
10	18	68	12	4	129.6	465.1	19.00
7	19	68	12	4	128.3	470.0	19.00
6	31	68	12	4	116.5	478.2	19.00
7	9	68	13	4	109.2	446.5	21.00
7	15	68	13	4	100.0	457.2	19.00
7	15	68	13	4	90.6	466.6	19.00
6	23	68	13	4	131.4	458.4	19.00
10	28	68	13	4	153.3	429.8	21.00
10	28	68	13	4	152.7	430.4	19.00
10	29	68	13	4	128.9	425.5	17.41
10	26	68	14	4	114.6	440.7	19.00
11	31	68	15	4	107.8	441.4	20.00
11	31	68	15	4	117.9	431.3	23.00
11	10	69	10	4	160.0	570.6	24.00
7	7	69	12	4	125.6	476.0	24.00
6	15	69	12	4	145.8	443.0	23.00
6	16	69	12	4	139.9	458.1	21.00
6	16	69	12	4	146.9	451.1	21.00
10	20	69	12	4	179.0	465.7	24.00
6	21	69	12	4	138.1	453.2	24.00
7	28	69	12	4	139.5	447.8	21.00
11	1	69	13	4	153.3	436.2	21.00
11	1	69	13	4	146.0	443.5	21.00
13	15	69	13	4		430.0	19.00
13	15	69	13	4		457.0	19.00
13	15	69	13	4		446.0	21.00
13	15	69	13	4		430.0	21.00
13	15	69	13	4		458.0	19.00
10	10	69	15	4	98.9	453.2	24.00
10	27	69	15	4	110.3	454.8	24.00
10	34	69	15	4	98.4	465.0	24.00
10	34	69	15	4	111.1	452.3	24.00

TEMPERATURE DATA FOR GROSMONT FORMATION,
COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(C)
11	25	62	13	4	78.4	560.2	24.00
7	31	62	13	4	75.6	537.7	26.00
10	10	63	14	4	103.9	493.5	21.00
10	26	63	14	4	104.3	496.2	22.22
7	3	63	15	4	93.0	560.2	27.00
7	3	63	15	4	85.4	567.8	21.11
10	7	63	15	4	53.3	597.4	24.44
11	9	63	16	4	22.2	676.7	26.67
11	9	63	16	4	33.5	665.4	29.00
13	15	64	13	4		545.2	25.00
7	13	64	16	4	58.6	564.1	26.00
7	13	64	16	4	34.7	588.0	24.00
15	14	64	17	4	32.5	601.2	21.00
10	3	65	13	4	48.9	545.2	25.00
6	14	65	17	4	45.7	588.3	21.11
10	15	65	17	4	34.2	580.6	20.00
10	9	66	13	4	90.6	504.1	24.00
6	16	66	13	4	86.0	502.9	21.11
6	16	66	13	4	90.9	498.0	25.00
7	17	66	13	4	94.1	492.9	25.00
6	29	66	13	4	98.4	468.2	21.00
10	12	66	15	4	70.1	508.7	24.44
4	25	66	15	4	93.8	483.0	23.50
7	35	67	13	4	123.7	461.5	24.00
8	2	67	15	4	81.3	516.0	24.00
11	15	67	16	4		609.6	28.89
6	28	67	16	4	82.3	511.8	22.00
7	15	69	13	4	90.6	466.3	22.22
13	15	69	13	4		467.0	19.00
11	17	69	15	4	96.0	454.8	24.00
10	1	69	16	4	116.4	443.8	23.00
10	1	69	16	4	95.7	464.5	23.00

TEMPERATURE DATA FOR WINTERBURN FORMATION, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(C).
10	24	55	14	4	-2.0	630.6	26.00
16	3	55	15	4	-21.3	657.0	23.00
14	14	55	15	4	-5.8	639.2	29.00
14	14	55	15	4	-37.2	670.6	26.00
10	33	55	15	4	-37.8	670.6	26.00
10	22	57	15	4	-37.8	666.0	25.00
8	27	57	16	4	-49.8	680.6	23.00
7	24	57	17	4	-54.0	677.0	27.78
9	28	57	17	4	-26.6	657.5	27.00
11	6	58	15	4	-23.4	669.0	24.00
7	2	58	16	4	-32.3	648.0	23.00
10	36	58	17	4	-23.3	653.0	25.00
13	15	59	15	4		627.0	27.00
10	4	59	16	4	0.4	613.8	24.00
10	15	59	16	4	-28.2	627.4	27.00
14	30	59	16	4	-30.4	660.0	24.00
7	9	59	17	4	-20.1	667.5	27.00
6	6	61	16	4	-1.5	660.2	27.00
10	11	61	16	4	42.3	650.5	23.00
10	19	61	16	4	41.5	665.6	23.00
6	6	62	16	4	39.8	661.2	27.00
10	19	63	16	4	30.1	665.1	27.00
3	16	64	17	4	22.2	639.2	23.00
10	8	65	17	4	3.6	622.8	26.10
10	9	65	17	4	49.7	560.8	28.00
10	9	65	17	4	17.0	593.5	20.00
11	14	66	17	4	63.3	565.5	20.00
11	30	66	17	4	62.8	554.4	21.00
11	29	67	17	4	81.7	508.1	25.00
6	25	61	17	4	31.1	668.4	29.00

TEMPERATURE DATA FOR IRETON FORMATION, COLD LAKE STUDY AREA

LOCATION					ELEVATION	DEPTH	TEMPERATURE
LSD	SEC	TP	R	M	(m)	(m)	(C)
6	31	55	5	4	53.0	615.7	28.33
11	3	55	9	4	-50.0	714.8	31.67
7	20	55	10	4	-72.4	723.9	28.33
10	23	55	10	4	-60.3	707.1	30.00
6	8	55	12	4	-94.1	730.0	29.00
7	32	55	14	4	-49.1	660.8	28.89
7	34	55	14	4	-66.8	704.7	31.11
7	26	55	16	4	-117.0	762.0	34.44
7	25	55	17	4	-186.9	850.4	33.33
11	14	56	8	4	-43.9	704.4	30.00
6	30	56	9	4	-61.9	728.5	32.22
6	6	56	13	4	-22.3	690.7	27.78
6	16	57	15	4	-90.9	734.6	30.00
10	18	58	11	4	-49.1	673.6	22.78
15	24	58	11	4	-29.6	673.0	25.00
11	28	59	9	4	26.2	614.2	23.30
7	2	60	10	4	4.0	663.0	25.00
11	34	60	12	4	-33.8	646.8	27.80
11	24	63	12	4	27.1	591.6	25.00
11	26	69	10	4	85.4	498.0	22.80
6	25	59	10	4	3.3	646.2	28.89
11	16	59	15	4	-22.6	634.0	23.89
7	9	59	17	4	-95.1	742.5	29.44
11	36	59	17	4	-89.0	683.4	27.22
7	19	60	8	4	66.1	550.2	27.22
6	4	60	10	4	-5.5	660.2	28.33
10	27	60	16	4	-5.5	685.8	30.56
11	4	61	9	4	34.4	594.4	25.00
11	8	61	15	4	-0.9	679.7	26.67
6	21	62	9	4	26.5	591.9	23.33
12	20	62	11	4	18.3	637.0	23.89
2	24	63	11	4	24.8	597.0	22.04
6	6	64	10	4	30.1	563.0	22.20
10	23	65	11	4	43.0	571.8	21.11
7	1	56	14	4	-30.4	682.1	28.90
7	12	56	14	4	-43.9	710.8	32.20

TEMPERATURE DATA FOR BEAVERHILL LAKE FORMATION, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	DEPTH (m)	TEMPERATURE (C)
10	18	55	1	4	65.7	517.0	25.55
6	14	55	2	4	72.6	513.6	23.89
7	4	55	3	4	34.8	536.5	20.56
6	11	55	4	4	39.9	563.3	24.44
6	31	55	5	4	-8.0	676.7	28.33
6	33	55	6	4	-37.5	694.0	27.78
7	11	55	9	4	-160.9	816.6	31.67
12	33	55	9	4	-192.7	829.7	31.11
16	28	56	8	4	-332.9	962.9	31.11
7	30	57	3	4	50.0	576.4	23.89
13	2	57	12	4	-253.0	883.6	31.11
4	26	57	13	4	-271.3	911.4	31.67
6	22	58	4	4	34.1	627.9	26.67
7	16	58	5	4	25.3	625.5	26.11
10	17	59	4	4	36.0	606.5	26.11
11	3	59	6	4		599.5	27.78
11	12	59	6	4	16.3	562.0	27.00
6	27	59	6	4	22.2	550.0	27.00
10	34	59	7	4	-2.7	605.6	25.60
10	2	59	11	4	-177.4	823.0	33.33
10	16	60	3	4	41.7	563.9	22.78
10	35	60	3	4	47.5	525.0	22.00
10	13	60	4	4	-142.3	743.7	29.40
10	20	60	7	4	27.8	516.6	26.67
8	26	60	16	4	-547.2	1229.0	33.30
6	28	61	4	4	39.6	518.5	25.56
6	25	61	7	4	89.7	460.3	23.33
6	34	61	10	4	-29.9	601.1	27.78
7	18	62	2	4		541.6	22.22
7	6	62	7	4	74.1	483.1	24.44
10	17	63	6	4	83.0	479.1	20.00
10	15	64	6	4	91.5	491.6	21.70
7	34	65	11	4	-179.6	823.3	31.11
5	28	66	7	4	83.2	552.6	23.30
4	31	66	8	4	59.6	566.0	21.80
7	20	68	10	4	77.5	616.0	28.60

HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA

Data Base: Section 1 - Phanerozoic Data

Open File Report 1996 - 1h

Prepared by
Basin Analysis Group
Alberta Geological Survey
Alberta Research Council
(Project Manager: Dr. Brian Hitchon)

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1985-01-31

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DATA BASE

Section 1: Phanerozoic Data

Stratigraphic Picks: A. Ing and
S.C. O'Connell
Hydrochemistry: Dr. Brian Hitchon
Hydraulic Parameters: C.M. Sauveplane

PREFACE

This Data Base forms an integral part of the study "Hydrogeology of the Cold Lake Study Area, Alberta, Canada" carried out from 1982-04-01 to 1985-01-31, and jointly funded by the Alberta Research Council and Alberta Environment. It is a reference document, most of the information from which is presented in synthesized form in the accompanying Report and Atlas. If effectively represents a hard copy form of new and selected interpreted information present in GWDB as part of this study; as such, both A and B level information is implicitly included. Other than location identification, no data is repeated from the ERCB well data file. The information is organized in three sections, as follows:

Section 1: Phanerozoic Data

This includes new stratigraphic picks by ARC staff, the chemical composition and physical properties of formation waters, and the interpreted hydraulic parameters from drillstem tests and cores, all organized by hydrostratigraphic units.

Section 2: Quaternary Data

This includes the logs of shallow boreholes, the chemical composition of shallow groundwater, and the interpreted hydraulic parameters from well tests and aquifer tests, most organized by stratigraphic units.

Section 3: Instrumentation for Hydrogeological Investigations

The first part is an annotated catalogue of manufacturers and the type of equipment they provide; the second is a reference list of papers on methods for measuring and using some relevant hydrogeological parameters.

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For Sections 1 and 2, it is important that readers refer to the written Report for information on the techniques used to cull out erroneous data from the vast amount of hydrochemical and hydraulic data originally entered into GWDB; it is the resulting selected and interpreted data which is contained in Sections 1 and 2.

TABLE OF CONTENTS

NOTATION FOR INDEXING DATA TABLES IN SECTIONS 1 AND 2

Each table has been identified systematically by a sequence of two letters, from which one can determine the hydrostratigraphic unit and type of information. Tables are numbered sequentially within each class of double letters.

The first letter (capitalized) refers to the hydrostratigraphic unit and is cross-referenced with the alphabetical sequence given in the Atlas. Because most of the information in the Data Base refers specifically to aquifers (rather than aquitards or aquicludes), not all hydrostratigraphic units are represented by tables. The complete alphabetical sequence is presented below, with starred items indicating no data tables:

A	*
B	*
C	*
D	Prairie Formation aquiclude
E	Cooking Lake-Beaverhill Lake-Watt Mountain aquifer
F	Ireton Formation aquitard
G	Camrose Tongue aquifer
H	Grosmont Formation aquifer
I	Wabamun-Winterburn aquifer
J	"Lower Mannville" Group aquifer
K	Clearwater Formation aquitard
L	"Upper Mannville" Group aquifer
M	Joli Fou Formation aquitard
N	"Viking sandstone" aquifer
O	Colorado aquitard
P	Quaternary hydrostratigraphic units
Q	*

The second letter (lower case) refers to the general type of data in the table, as follows:

-a General
-g Geological
-c Hydrochemical
-h Hydrodynamic

CONTENTS AND FORMAT OF DATA BASE

The Data Base for the Phanerozoic contains three types of information from which the regional geology, hydrochemistry and hydrodynamics were evaluated in Parts 2, 3 and 4, respectively, of the Report, and are presented in about 200 maps in the Atlas.

It is organized by hydrostratigraphic units and the types of information are described as follows:

A. Stratigraphic picks of the tops of selected units are based on electric log or other types of mechanical logs and the wells chosen for the study are distributed over the Cold Lake Study Area where ancillary information was required over and above that provided in the ERCB Well Data File.

B. The chemical composition (mg/L) and physical properties are provided for the 852 formation water analyses which were used to produce the seven series of hydrochemical maps in the Atlas. Note that their assignment to their respective hydrostratigraphic units was by interpolation between the pertinent grid surfaces rather than the stratigraphic interval given in the hard copy report.

C. Hydraulic parameters (permeability, hydraulic conductivity, storativity, formation pressure and hydraulic head) were calculated from drillstem test data and are presented by hydrostratigraphic units.

D. Hydraulic parameters (horizontal and vertical permeability) calculated from ERCB core data are given in a separate series of tables and are presented by hydrostratigraphic units.

Table D-g-1

STRATIGRAPHIC PICKS FOR TOP OF PRAIRIE FORMATION (FIRST SALT)
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
LSD	SEC	TP	R	M			
4	11	55	2	4	578.50	782.50	-204.00
2	21	57	5	4	627.90	879.00	-251.10
5	28	64	6	4	604.20	763.27	-159.07
6	17	64	11	4	611.10	931.14	-320.04
2	3	66	15	4	582.20	1015.20	-433.00
6	25	66	16	4	576.40	1024.15	-447.75
4	3	69	10	4	730.60	911.63	-181.03

Table E-g-1

STRATIGRAPHIC PICKS FOR TOP OF ELK POINT GROUP
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
LSD	SEC	TP	R	M			
3	28	64	12	4	596.50	929.36	-332.86

Table E-g-2

STRATIGRAPHIC PICKS FOR TOP OF BEAVERHILL LAKE FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
6	30	55	11	4	573.30	834.24	-260.94
16	27	55	12	4	601.70	876.49	-274.79
11	29	55	12	4	586.10	869.84	-283.74
7	14	57	6	4	593.10	616.29	-23.19
10	29	58	3	4	652.00	625.16	26.84
3	1	59	11	4	652.30	820.03	-167.73
10	2	59	11	4	647.10	824.46	-177.36
6	17	64	11	4	611.10	681.20	-70.10
11	3	67	10	4	707.10	672.92	34.18
11	34	67	10	4	667.20	612.37	54.83
10	11	67	12	4	607.80	638.81	-31.01
11	26	69	10	4	657.00	561.82	95.18

Table E-g-3

STRATIGRAPHIC PICKS FOR TOP OF COOKING LAKE FORMATION
MADE BY ALBERTA RESEARCH COUNCIL. COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
4	11	55	2	4	578.50	500.50	78.00
7	11	55	9	4	620.20	741.69	-121.49
12	33	55	9	4	684.70	803.57	-118.87
6	30	55	11	4	573.30	767.49	-194.19
11	29	55	12	4	586.10	807.36	-221.26
5	23	56	9	4	622.10	705.49	-83.39
5	34	56	9	4	664.80	754.13	-89.33
7	14	57	6	4	593.10	567.52	25.58
6	33	58	12	4	636.40	814.14	-177.74
11	16	59	17	4	666.60	1001.62	-335.02
13	3	60	11	4	662.30	771.07	-108.77
12	19	61	8	4	577.00	553.53	23.47
10	34	61	8	4	566.70	518.21	48.49
6	22	62	7	4	554.70	473.62	81.08
11	6	62	8	4	590.40	555.34	35.06
12	8	62	10	4	618.10	658.02	-39.92
5	12	63	10	4	605.50	600.30	5.20
5	28	64	6	4	604.20	513.52	90.68
6	17	64	11	4	611.10	650.72	-39.62

Table E-c-1

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, COOKING LAKE - BEAVERHILL LAKE - WATT MOUNTAIN AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
12	11	55	1	4	59.9	15395	1555	734	28474	237	25	46420	1.0331	0.1470	7.10
2	26	55	1	4	-63.2	11752	469	252	19335	490	31	32366	1.0190	0.2680	8.30
6	14	55	2	4	76.4	20554	1539	717	36200	249	222	59481	1.0420	0.1210	7.70
6	30	55	11	4	-230.6	42336	2730	1050	72860	350	150	119477	1.0830		
5	11	55	14	4	-295.1	34088	5210	1890	65500	282	2205	109175	1.0750		6.80
2	36	57	17	4	-345.6	32345	5072	1891	63100	287	1486	104182	1.0670	0.0920	6.90
10	17	58	2	4	19.6	14064	1084	465	24800	239	29	40681	1.0290	0.1980	8.30
13	19	58	17	4	-355.6	32776	6915	4200	73482	275	1868	119516	1.0890	0.0820	6.50
14	5	59	15	4	-279.9	28880	3186	1535	53000	270	2016	88887	1.0650	0.1070	7.60
10	12	63	8	4	71.9	9377	471	276	15965	112	31	26270	1.0186	0.2400	8.70
10	22	64	16	4	-316.8	31880	3530	1766	59168	134	1772	98250	1.0680		7.41
11	3	67	10	4	-44.5	10492	1272	643	18300	202	2557	33466	1.0231	0.2100	7.32
7	8	69	13	4	-194.6	9253	435	195	15497	181	6	25567	1.0182	0.2550	7.55

Table E-c-2

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LEDUC AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
2	26	55	15	4	-162.9	44102	560	261	69500	133	244	114800	1.0200		8.40

Table E-h-1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
BEAVERHILL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	18	55	1	4	84.20	0.251E-14	0.129E-08			3767.87	468.8
5	12	63	10	4	-129.54					6135.97	496.8
7	34	65	11	4	-117.40	0.190E-14				6485.06	544.5
11	3	67	10	4	-30.50	0.787E-14	0.105E-06			5368.69	517.5
11	26	69	10	4	22.24					4855.42	517.8

Table E-h-2

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
BEAVERHILL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	16	55	1	4	75.30	0.395E-12		0.266	79.80
10	16	55	1	4	66.30	0.103E-11		0.323	70.80
10	16	55	1	4	57.80	0.104E-11		0.353	61.80
11	21	55	1	4	80.40			0.240	84.90
11	21	55	1	4	71.40	0.163E-11		0.260	75.90
11	21	55	1	4	62.40	0.887E-11		0.348	66.90
9	6	56	2	4	58.21			0.254	62.78
5	12	63	10	4	-145.22	0.209E-15	0.104E-16	0.018	-105.14
5	12	63	10	4	-188.35	0.977E-15	0.202E-15	0.067	-185.30
11	16	68	5	4	181.40			0.382	185.90
11	16	68	5	4	172.40			0.358	176.90
11	16	68	5	4	164.90			0.362	167.90
11	16	68	5	4	159.65			0.380	161.90
15	26	68	5	4	177.60	0.397E-11		0.355	182.60
15	26	68	5	4	168.10	0.361E-11		0.377	172.60
15	26	68	5	4	158.35	0.310E-11		0.354	162.10
15	26	68	5	4	148.60	0.261E-11		0.371	151.60
11	26	69	10	4	29.86	0.144E-13	0.390E-14	0.103	39.00
11	26	69	10	4	11.58	0.195E-14	0.698E-15	0.103	20.72
11	26	69	10	4	-3.66	0.391E-14	0.531E-15	0.101	2.43

Table E-h-3

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA COOKING LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	14	55	2	4	85.10	0.766E-14	0.367E-08				
6	14	55	2	4	79.01					3817.35	468.6
7	11	55	9	4	-159.40					6792.89	533.9
13	2	57	12	4	-194.80					7382.97	558.8
4	26	57	13	4	-213.30					7555.39	557.9
10	34	59	7	4	18.00					4445.53	471.8
10	2	59	11	4	-122.80					6019.48	491.6
10	2	59	11	4	-133.20					6756.86	556.6
10	34	61	8	4	37.50					4574.41	504.4
10	10	62	5	4	43.70					4105.60	462.8
10	17	63	6	4	87.50					3574.35	452.3

Table E-h-4

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
COOKING LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
12	33	55	9	4	-135.61	0.632E-14	0.158E-14	0.130	-131.71
4	35	58	11	4	-127.70	0.740E-15	0.424E-16	0.121	-120.08
4	35	58	11	4	-137.76	0.294E-15	0.127E-16	0.136	-135.32
3	1	59	11	4	-108.28	0.182E-11	0.169E-14	0.167	-99.20
14	5	59	15	4	-275.12	0.908E-14		0.149	-269.18
14	5	59	15	4	-288.68	0.171E-13		0.112	-281.06
14	5	59	15	4	-305.45	0.182E-14		0.144	-296.30
14	5	59	15	4	-322.14	0.326E-15		0.154	-314.59
10	22	59	15	4	-248.46	0.148E-14	0.372E-15	0.139	-240.84
11	5	60	17	4	-346.55	0.130E-14	0.403E-15	0.122	-338.93
10	22	64	16	4	-231.91	0.379E-15		0.098	-224.29

Table F-g-1

STRATIGRAPHIC PICKS FOR TOP OF IRETON FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
LSD	SEC	TP	R	M			
7	11	55	9	4	620.20	635.16	-14.96
12	33	55	9	4	684.70	724.90	-40.20
6	30	55	11	4	573.30	633.90	-60.60
11	29	55	12	4	586.10	651.21	-65.11
5	26	56	5	4	560.80	515.68	45.12
16	28	56	8	4	599.50	623.81	-24.31
5	23	56	9	4	622.10	645.72	-23.62
7	14	57	6	4	593.10	541.61	51.49
6	7	57	9	4	668.70	708.49	-39.79
12	10	57	9	4	684.30	727.52	-43.22
7	26	57	9	4	645.00	673.29	-28.29
10	27	57	9	4	642.80	674.67	-31.87
10	29	57	11	4	623.30	648.82	-25.52
2	34	58	10	4	637.00	614.62	22.38
13	3	60	11	4	662.30	662.81	-0.51
10	33	60	11	4	702.50	721.04	-18.54
12	19	61	8	4	577.00	483.95	93.05
6	17	61	15	4	691.10	643.30	47.80
11	6	62	8	4	590.40	524.12	66.28
5	12	63	10	4	605.50	578.63	26.87
6	17	64	11	4	611.10	552.52	58.58
3	28	64	12	4	596.50	522.46	74.04
12	26	64	13	4	590.70	540.10	50.60
7	34	65	11	4	610.50	557.41	53.09

Table G-c-1

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, CAMROSE TONGUE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
5	11	55	14	4	-41.3	18816	1845	658	33850	494	82	55745	1.0410		6.90
5	11	55	14	4	-95.6	22031	2095	775	39700	383	22	65006	1.0450		6.80
6	14	55	14	4	-40.8	26379	2703	788	47500	430	8	77808	1.0600	0.1030	7.20
11	20	55	15	4	-89.8	32430	2210	1070	56600	537	170	93017	1.0570		6.90
6	27	55	15	4	-45.3	23120	1900	720	40900	320	36	66996	1.0520	0.1190	7.30
10	29	55	16	4	-143.3	24313	2008	829	43200	410	31	70791	1.0520	0.1290	7.00
6	27	55	17	4	-178.9	25042	1642	656	43100	500	58	70998	1.0530	0.1360	6.90
7	20	56	15	4	-1674.2	21595	2979	1245	41922	459	15	68215	1.0479	0.1010	6.10
10	21	56	15	4	-59.5	22734	1978	722	40400	371	62	66267	1.0480	0.1220	7.40
4	29	56	15	4	-70.9	20698	1758	751	37000	368	4	60579	1.0440	0.1150	7.00
10	22	57	15	4	-33.0	22193	1326	544	37900	391	37	62391	1.0440	0.1340	7.30
6	31	57	15	4	-44.0	22923	1544	614	39600	325	109	65115	1.0440	0.1400	7.30
10	24	57	16	4	-62.8	19617	2812	1141	38200	330	216	62316	1.0450	0.1400	7.00
5	5	58	15	4	-44.2	20005	1192	476	34100	376	37	56186	1.0380	0.1400	7.40
3	6	58	15	4	-50.3	20945	1760	572	36900	249	47	60473	1.0470		7.40
7	7	58	15	4	-39.9	19557	1058	504	33400	81	70	54670	1.0400	0.1140	7.40
6	30	58	15	4	-28.0	19729	1532	595	34650	342	25	56873	1.0410	0.1290	7.10
7	22	58	16	4	-60.8	18854	1522	627	33300	427	62	54792	1.0410	0.1350	7.30
10	21	59	15	4	9.1	16850	1143	479	29067	517	47	48103	1.0296	0.1610	7.10
10	30	59	15	4	3.5	14282	953	438	24798	275	40	40786	1.0290	0.1400	6.50
10	33	59	15	4	17.4	13977	1611	606	26100	15	84	42393	1.0310	0.1560	5.40
10	33	59	15	4	17.4	11724	1753	636	22950	56	70	37189	1.0280	0.1980	6.10
11	36	59	17	4	-55.6	16216	1145	470	28100	471	39	46441	1.0340	0.1640	7.50

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, CAMROSE TONGUE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
10	8	60	15	4	-2.8	20103	1751	1075	36928	508	11	60376	1.0407	0.1200	6.95
11	5	60	17	4	-86.6	17291	1149	496	29750	585	72	49343	1.0340	0.1530	7.50
6	19	61	15	4	30.4	18591	1702	680	33449	366		54788	1.0366	0.1400	6.90

Table G-h-1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
CAMROSE TONGUE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	26	55	14	4	-30.78						392.6
7	34	55	14	4	-30.70						390.9
6	6	56	13	4	-9.02					4367.97	420.2
10	14	56	14	4	-25.60	0.185E-13	0.211E-06			4367.97	420.2
10	15	58	16	4	-59.10					4332.17	383.1
10	32	58	16	4	-4.20						366.2
7	20	59	15	4	5.30						382.5
10	30	59	15	4	0.73						390.6
10	8	60	15	4	-4.30						390.7
6	19	61	15	4	44.20						389.9
6	13	61	16	4	32.90						380.7

Table G-h-2

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
CAMROSE TONGUE AQUIFER,. COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
LSD	SEC	TP	R	M					
10	23	55	14	4	-29.89	0.120E-11	0.601E-14	0.083	-25.32

Table H-c-1

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, GROSMONT FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
7	26	61	16	4	37.7	14739	891	696	26000	419	123	42868	1.0300	0.1700	6.90
10	11	62	16	4	53.3	14079	653	491	23750	921	16	39910	1.0220	0.1750	7.30
10	26	63	14	4	80.0	11751	501	297	19223	1110	8	32890	1.0170	0.2300	7.10
11	9	63	16	4	34.5	6438	344	174	10361	1172	2	18491	1.0129	0.3200	7.90
11	13	64	14	4	76.9	8757	245	290	14043	1265	7	24607	1.0160	2.6500	7.50
7	15	64	16	4	39.7	9439	257	198	14760	1281	113	26048	1.0180	0.2390	7.80
10	22	64	16	4	47.3	9242	140	187	14539	844	21	24973	1.0160		8.25
6	5	64	17	4	-22.0	10155	413	273	16600	1000	7	28448	1.0230	0.2830	7.20
6	28	65	15	4	79.9	7530	328	186	12150	930	59	21183	1.0160	0.3360	7.50
10	27	65	17	4	-22.1	10430	537	207	17040	986	33	29233	1.0210	0.2200	7.10
13	29	66	14	4	82.2	6063	180	243	9700	830	263	17279	1.0080	0.3850	8.00
6	31	66	14	4	89.7	11232	451	213	18036	1183	21	31136	1.0213	0.2150	7.60
11	13	66	15	4	78.2	9210	284	338	15100	992	19	25943	1.0180	0.2350	6.70
11	9	68	12	4	127.9	8584	353	180	13802	1005	2	23927	1.0166	0.2550	7.50
10	18	68	12	4	112.1	5846	228	110	8783	1542	83	16593	1.0104	0.4100	7.30
6	24	68	13	4	116.3	9928	498	359	17000	397	10	28192	1.0210	0.2350	7.80
7	15	69	13	4	100.9	9689	384	267	16000	678	7	27025	1.0240	0.3040	8.20
11	20	69	13	4	94.2	8820	350	167	14207	833	23	24400	1.0181	0.2400	7.25
11	4	69	14	4	71.2	7311	348	64	11488	981	26	20218	1.0155	0.3350	8.10
7	10	69	14	4	66.6	8856	515	73	14099	1069	81	24693	1.0190	0.2280	7.95
10	16	69	16	4	81.4	6481	291	100	10153	1078	29	18132	1.0119	0.3500	8.00

Table H-h-1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA GROSMONT FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M							
9	13	61	14	4	11.90	0.119E-14	0.145E-07			3409.90	359.9
11	9	63	16	4	32.30	0.494E-14	0.229E-08	0.170	0.39E-02	3151.85	354.0
8	2	64	16	4	58.50	0.841E-13	0.471E-07				
6	5	64	17	4	-25.00					3575.35	339.9
6	22	66	14	4	52.60						357.3
4	25	66	15	4	102.40	0.592E-13	0.330E-07				
7	33	66	16	4	80.01						361.1
11	13	67	15	4	66.90						355.5
7	28	69	12	4	46.30	0.221E-12	0.174E-05				

Table H-h-2

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
GROSMONT FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	10	63	14	4	95.55	0.465E-12	0.895E-14	0.110	99.66
10	10	63	14	4	82.29	0.162E-11	0.360E-12	0.169	91.43
11	14	63	14	4	94.31	0.150E-12		0.280	98.73
11	14	63	14	4	86.84	0.531E-13		0.251	89.89
10	26	63	14	4	93.87	0.126E-11	0.265E-13	0.112	102.40
10	21	65	13	4	100.42	0.160E-13	0.272E-16	0.073	103.02
10	21	65	13	4	95.85	0.188E-12	0.409E-13	0.095	97.83
6	16	66	13	4	88.42	0.315E-13		0.297	90.86
7	17	66	13	4	91.09	0.659E-12	0.216E-12	0.246	94.75
11	9	67	13	4	86.88	0.826E-13	0.315E-13	0.103	88.40
11	9	67	13	4	77.74	0.388E-12	0.820E-14	0.167	85.36
11	9	67	13	4	64.93	0.832E-12	0.515E-13	0.108	70.12
10	1	69	16	4	104.37	0.569E-13	0.287E-13	0.080	106.35
10	1	69	16	4	99.34	0.294E-11	0.277E-13	0.103	102.39
10	1	69	16	4	104.37	0.378E-14		0.024	106.35
10	1	69	16	4	99.34	0.552E-12		0.044	102.39

Table I-c-1

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, WINTERBURN GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
7	36	56	17	4	-112.3	20756	1136	496	35150	491	37	58066	1.0410	0.1490	7.30
11	26	57	16	4	-48.0	13461	1001	486	23500	537	181	39166	1.0320	0.1790	7.50
6	29	57	16	4	-45.8	19151	1387	466	32911	699	37	54651	1.0380	0.1260	7.00
7	34	57	16	4	-41.8	18575	1197	564	32000	532	130	52998	1.0380	0.1550	7.10
6	8	57	17	4	-114.3	20546	1838	588	36300	586	12	59870	1.0440	0.1540	7.45
9	28	57	17	4	-82.2	19586	1361	516	33800	530	8	55801	1.0410	0.1430	7.20
2	36	57	17	4	-58.3	21926	1324	557	37600	260	35	61702	1.0430	0.1360	8.00
7	20	58	16	4	-38.1	18829	1208	504	32300	554	27	53422	1.0390	0.1480	7.70
10	34	58	17	4	-62.1	16998	1061	419	29000	476	45	47999	1.0320	0.1460	7.80
5	5	59	16	4	-16.8	17069	1152	488	29400	637	16	48762	1.0320	0.1370	6.90
10	15	59	16	4	1.3	12753	850	356	21966	417		36342	1.0270	0.1800	7.10
10	33	59	16	4	-12.1	17752	1174	503	30582	576	1	50588	1.0316	0.1400	7.40
11	3	59	17	4	-54.2	17389	1121	413	29700	440	63	49126	1.0340	0.1660	6.50
7	9	59	17	4	-59.9	16749	1206	459	28888	708		48010	1.0330	1.3411	6.80
7	17	60	17	4	-30.8	14331	905	450	24900	158	28	40772	1.0300	0.1670	7.60
11	2	61	16	4	26.8	14591	769	462	25050	184	68	41124	1.0270	0.1690	5.70
11	3	61	16	4	12.3	14325	928	352	24393	620	7	40625	1.0282	0.1500	7.00
6	13	61	16	4	32.6	16216	1370	595	28888	471	3	47543	1.0318		7.50
11	15	61	16	4	31.6	15050	991	460	26020	460	21	43002	1.0350	0.1850	7.90
11	28	61	16	4	39.1	15174	882	404	25737	683	4	42884	1.0284	1.6000	7.25
11	19	61	17	4	-14.8	12321	703	312	20682	791	15	34824	1.0229	0.2200	7.70
7	21	61	17	4	0.5	12965	1017	226	22057	669	7	36941	1.0206	0.1650	7.40
10	36	61	17	4	9.7	15182	973	425	25950	710	12	43252	1.0330	0.1940	7.00

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, WINTERBURN GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
6	14	62	17	4	10.0	12354	654	298	20538	927		34771	1.0250	0.2060	7.00
6	26	62	17	4	7.1	12314	642	255	20275	1010	8	34504	1.0234	0.2010	8.20
10	8	63	16	4	28.2	11986	459	392	19864	932	45	33678	1.0227	0.2150	7.25
6	15	63	16	4	42.4	13220	514	302	21538	1050	38	36662	1.0220	0.3260	8.20
6	29	63	16	4	33.4	6561	404	155	10859	693	31	18703	1.0140	0.3400	8.00
7	2	63	17	4	7.3	11842	533	228	19200	1132	16	32951	1.0230	0.2220	6.70
6	9	63	17	4	-0.4	9013	325	177	14685	435	71	24706	1.0130	0.3270	8.00
6	18	63	17	4	15.8	12207	609	135	19853	757	2	33563	1.0232	0.2000	7.40
6	22	63	17	4	14.4	12945	523	186	20769	1130	5	35558	1.0200	0.2720	8.00
10	7	64	16	4	38.7	10571	374	208	17000	967	10	29130	1.0220	0.2480	7.80
7	15	64	16	4	54.7	13006	513	334	21400	915	8	36176	1.0260	0.1780	7.40
6	5	64	17	4	11.6	10379	413	208	16710	1060	23	28793	1.0230	0.2860	7.20
11	35	66	16	4	76.7	10479	480	243	17150	910	51	29313	1.0220	0.2240	7.20
11	11	67	16	4	76.6	9649	437	213	15625	1103	10	27037	1.0220	0.2160	8.20

Table I-h-1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA WINTERBURN GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	27	56	16	4	-74.40					4485.70	383.5
6	31	57	15	4	-44.70					4199.65	384.0
7	2	57	16	4	-72.90						381.8
6	29	57	16	4	-46.50					4033.11	365.2
9	28	57	17	4	-93.20					4188.67	377.7
5	5	58	15	4	-30.20					4011.56	379.3
5	19	59	16	4	-9.90					3678.49	365.6
14	30	59	16	4	-19.60					3664.77	354.5
7	9	59	17	4	-59.90						366.6
10	12	59	17	4	-26.85					4035.58	385.0
7	17	60	17	4	-30.80					3798.00	356.9
11	15	61	16	4	31.80					3522.73	391.4
7	18	61	16	4	0.90						393.9
14	20	61	16	4	46.30	0.760E-14	0.426E-08				
10	15	61	17	4	-5.50						352.1
7	21	61	17	4	-0.20					3454.15	352.8
6	14	62	17	4	8.30						358.6
6	14	62	17	4	13.80					3387.54	359.6
6	5	64	17	4	10.80					3440.44	362.0
15	4	65	17	4	42.00	0.456E-14	0.507E-07			3128.80	361.3
11	17	65	17	4	8.87	0.889E-16	0.114E-08			3505.21	366.6
10	9	67	16	4	84.50	0.344E-13	0.193E-07			2770.30	367.2
11	16	67	17	4	59.20					3064.47	372.0

Table I-h-2

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
WINTERBURN GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
10	23	55	14	4	-8.71	0.165E-12	0.120E-13	0.119	-5.51
10	4	55	15	4	-69.11	0.419E-12	0.211E-12	0.227	-66.15
10	15	59	16	4	13.07	0.925E-12	0.746E-13	0.121	17.34
11	3	59	17	4	-57.73	0.227E-13	0.115E-13	0.182	-55.14
11	4	59	17	4	-38.10	0.235E-13	0.140E-13	0.133	-28.95
7	28	62	17	4	12.02	0.568E-11	0.270E-12	0.128	13.70
7	28	62	17	4	7.00	0.119E-11	0.743E-13	0.139	10.35
7	28	62	17	4	12.02	0.103E-10	0.312E-12	0.098	13.70
7	28	62	17	4	7.00	0.310E-11	0.393E-13	0.117	10.35
11	21	67	16	4	93.60			0.204	98.10
13	31	67	16	4	100.65	0.197E-12	0.178E-15	0.139	103.90

Table J-c-1

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
6	11	55	7	4	13.9	23756	2396	870	43206	327	16	70571	1.0478	0.1040	7.10
6	10	55	8	4	13.6	25864	2503	1154	47500	244	45	77310	1.0490	0.0970	7.30
6	10	55	8	4	24.1	25147	2703	911	46000	281	70	75112	1.0490	0.0980	7.30
10	11	55	8	4	26.0	23368	2152	851	42150	278	15	68814	1.0510	0.0970	7.50
10	9	55	11	4	42.3	21062	1916	712	37800	180	54	61724	1.0450	0.1450	6.90
10	33	55	12	4	-12.1	23514	2126	644	41800	156	10	68250	1.0440	0.1030	7.10
13	18	55	13	4	-21.5	22528	2002	685	40100	272	27	65614	1.0460	0.1070	6.70
8	20	55	14	4	-21.9	22667	2274	846	41300	220	21	67328	1.0440	0.1180	7.30
10	24	55	14	4	-4.9	23296	2691	1060	43565	307	41	70960	1.0481	0.9600	6.70
15	18	55	15	4	-76.8	23017	2002	923	41400	490	56	67888	1.0460	0.1170	7.10
15	18	55	15	4	-43.1	23067	2002	802	41100	535	53	67559	1.0460	0.1140	7.10
7	1	55	16	4	-73.4	23313	1901	689	41001	527	18	67449	1.0443	0.1050	7.10
7	1	55	16	4	-73.4	23556	1870	649	41200	492	53	67820	1.0460	0.1260	6.60
1	8	55	16	4	-103.6	23447	1946	608	41000	563	60	67624	1.0450	0.1220	7.20
11	22	55	16	4	-116.4	23539	2292	1015	43000	427	86	70359	1.0420	0.1070	7.60
11	22	55	16	4	-69.9	27783	2052	1154	49550	427	53	81019	1.0380	0.1140	7.60
11	25	55	16	4	-37.4	22168	1650	595	38600	376	25	63414	1.0440	0.1190	7.00
9	34	55	16	4	-80.7	23233	2082	522	40750	471	10	67068	1.0440	0.1110	7.00
4	23	55	17	4	-102.3	18508	1209	724	32500	478	16	53435	1.0380	0.1410	7.10
1	36	55	17	4	-122.2	14959	1301	695	27250	150	78	44433	1.0310	0.1760	7.50
10	36	56	10	4	10.1	19480	1328	590	33900	296	49	55643	1.0380	0.1300	6.90
10	3	56	14	4	-33.9	24638	2162	795	44000	173	47	71815	1.0520	0.1030	6.90
7	22	56	15	4	-2.7	22781	2214	923	41600	208	21	67747	1.0490	0.1150	7.80

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
7	27	56	15	4	17.4	23147	1874	792	41100	310	51	67274	1.0470	0.1050	7.30
14	32	56	15	4	-54.6	23570	2218	479	41400	431	21	68119	1.0460	0.1110	7.50
7	34	56	15	4	-39.7	23689	1986	761	42100	218	47	68801	1.0480	0.1270	7.40
10	5	56	16	4	-57.7	20775	1522	642	36500	124	39	59602	1.0400	0.1270	7.60
3	7	56	16	4	-84.7	19773	1369	496	34000	559	47	56244	1.0320	0.1330	7.20
6	8	56	16	4	-88.9	19524	1574	763	34800	445	78	57184	1.0390	0.1340	7.50
3	15	56	16	4	-6.6	20646	1411	644	36000	278	66	59045	1.0400	0.1350	7.70
13	23	56	16	4	-39.1	22384	1710	795	39600	429	14	64932	1.0440	0.1120	7.20
13	23	56	16	4	-56.8	20619	1750	620	36400	470	35	59894	1.0410	0.1160	6.60
12	30	56	16	4	-65.9	22621	1241	595	38500	449	70	63476	1.0400	0.1240	7.10
16	34	56	16	4	-48.2	22269	1516	692	38700	544	31	63752	1.0450	0.1070	7.20
16	34	56	16	4	-23.5	20171	1372	774	35600	276	37	58230	1.0400	0.1280	6.40
6	25	56	17	4	-73.6	17559	1292	504	30496	522	45	50418	1.0378	0.1250	7.50
6	25	56	17	4	-71.6	19241	1359	708	33831	509	17	55665	1.0410	0.1200	7.40
5	36	57	7	4	79.3	17337	1071	521	30000	238	14	49181	1.0320	0.1560	7.60
8	16	57	14	4	3.2	21022	1702	614	37000	323	41	60702	1.0390	0.1240	7.40
6	5	57	15	4	-29.8	23415	2074	792	41800	473	14	68568	1.0460	0.1180	7.90
13	14	57	15	4	8.5	19687	1666	581	34800	236	84	57054	1.0360	0.1340	6.90
13	14	57	15	4	-23.3	17342	1489	516	30600	368	91	50406	1.0340	0.1430	6.70
13	14	57	15	4	-14.8	24110	2278	656	42900	346	27	70317	1.0500	0.1120	6.70
16	31	57	15	4	-7.2	20515	1425	632	35700	415	78	58765	1.0380	0.1280	7.40
8	15	57	16	4	-52.5	17113	1371	510	30050	388	35	49467	1.0350	0.1510	7.30
12	23	57	16	4	-9.5	17684	1115	541	30500	471	62	50373	1.0320	0.1430	7.80

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
5	33	57	16	4	-31.0	19283	1033	498	32700	417	99	54030	1.0360	0.1360	7.40
16	1	57	17	4	-57.9	19622	1361	589	34150	354	37	56113	1.0350	0.1250	6.50
9	28	57	17	4	-46.3	17215	1151	450	29550	570	19	48955	1.0360	0.1610	7.40
10	31	58	9	4	87.2	13661	745	403	23350	315	35	38509	1.0260	0.1890	7.30
6	8	58	10	4	27.8	15557	914	507	26800	442	37	44257	1.0320	0.1550	7.40
15	7	58	11	4	60.6	14415	736	340	24350	268	23	40132	1.0250	0.1690	7.60
9	15	58	11	4	57.8	13222	629	315	22220	285	47	36718	1.0280	0.1980	7.80
10	31	58	12	4	57.2	15267	881	388	26000	312	70	42918	1.0320	0.1540	7.40
10	31	58	12	4	42.0	13215	737	418	22500	569	95	37534	1.0280	0.1800	7.80
12	25	58	13	4	50.0	15099	845	422	25750	373	56	42545	1.0300	0.1660	7.90
15	5	58	14	4	-10.7	18696	1361	601	32750	397	12	53817	1.0400	0.1290	7.00
13	4	58	16	4	-21.4	19372	1762	719	34960	183	26	57022	1.0300	0.1240	7.50
11	10	58	16	4	-40.3	19134	1341	530	33100	510	36	54651	1.0400	0.1600	7.60
7	20	58	16	4	-16.9	19171	1236	524	33000	464	10	54405	1.0400	0.1440	7.60
1	21	58	16	4	-10.3	18797	1369	501	32600	444	14	53725	1.0340	0.1260	7.00
7	22	58	16	4	-26.0	17529	1417	527	30800	425	37	50735	1.0370	0.1550	7.40
14	22	58	16	4	2.0	18014	1277	712	31850	429	19	52301	1.0350	0.1400	7.50
7	36	58	16	4	-4.8	15374	1007	458	26500	510	38	43887	1.0320	0.1670	7.30
8	2	58	17	4	-25.3	17888	1189	525	30800	671	39	51112	1.0370	0.1490	7.40
8	2	58	17	4	-35.6	17654	1189	556	30600	571	21	50591	1.0370	0.1490	7.50
7	3	58	17	4	-34.8	15868	1296	489	27860	551	11	46075	1.0300	0.1530	6.75
10	9	58	17	4	-74.4	16166	1006	422	27600	534	39	45767	1.0310	0.1470	7.80
9	20	58	17	4	-32.1	18084	1173	442	30900	586	14	51199	1.0320	0.1410	7.00

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
9	28	58	17	4	-13.8	18643	1419	544	32750	138	19	53513	1.0360	0.1350	7.50
11	30	58	17	4	-33.3	15978	1201	394	27650	439	10	45672	1.0360	0.1420	7.00
16	17	59	8	4	46.5	16211	689	403	27250	214	23	44790	1.0260	0.1680	7.80
9	30	59	8	4	76.4	15014	654	336	25050	366	35	41455	1.0300	0.1780	7.20
11	13	59	9	4	41.9	15715	801	443	26700	400	12	44071	1.0310	0.1530	7.10
11	1	59	11	4	38.8	10980	502	284	18400	390	30	30586	1.0240	0.2140	7.80
6	1	59	12	4	51.3	10718	411	249	17760	280	46	29484	1.0210	0.2820	8.80
6	3	59	12	4	16.3	11444	503	267	19120	300	28	31662	1.0240	0.3080	8.20
10	4	59	14	4	3.3	15300	984	415	26247	332	85	43398	1.0300	0.1550	7.99
6	24	59	14	4	-19.5	15848	1130	571	27831	434	25	45839	1.0334	0.1450	7.80
11	16	59	15	4	2.5	17164	1154	488	29700	378	16	48900	1.0350	0.1520	7.80
11	24	59	16	4	14.4	17373	1139	579	30158	545	24	49818	1.0360	0.1220	6.82
11	24	59	16	4	-12.5	17370	1181	541	30128	530	22	49772	1.0360	0.1220	7.00
16	7	59	17	4	-20.1	16782	1029	515	28750	738	29	47843	1.0310	0.1380	7.00
2	26	60	2	4	144.9	10400	407	231	17106	512	38	28694	1.0230		8.00
2	26	60	2	4	150.0	13503	548	308	22389	439	23	37234	1.0280		8.29
10	18	60	6	4	89.5	16006	841	364	27000	378	16	44605	1.0310	0.1320	7.90
10	8	60	7	4	87.3	13791	753	479	23800	322	12	39157	1.0250	0.1730	8.00
6	27	60	8	4	69.8	14784	857	569	25700	450	16	42376	1.0310	0.1540	6.90
7	25	60	9	4	72.3	15330	841	403	26080	370	11	43035	1.0310	0.1670	7.40
7	2	60	10	4	50.0	16501	913	503	28300	370	16	46603	1.0360	0.1610	8.10
7	32	60	11	4	82.6	12381	452	264	20300	573	39	34009	1.0260	0.2340	7.40
6	36	60	12	4	71.6	15499	721	389	25750	881	66	43306	1.0320	0.1970	8.20

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
5	1	60	13	4	-9.3	15343	769	327	25384	952	49	42824	1.0289	0.1600	7.00
2	10	60	13	4	15.5	14250	761	389	24080	610	28	40118	1.0250	0.1620	7.60
15	22	60	13	4	54.1	12649	625	369	21280	622	61	35606	1.0200	0.1850	7.80
10	16	60	15	4	37.2	17095	687	422	28615	317	11	47147	1.0319	0.1400	7.00
6	20	60	15	4	51.6	14900	1122	536	26250	368	82	43258	1.0280	0.3130	7.70
7	26	60	15	4	-19.2	16621	993	532	28500	679	60	47385	1.0320	0.1410	7.60
13	15	60	16	4	8.2	13524	961	510	23750	482	16	39243	1.0260	0.0910	7.40
10	28	60	16	4	9.8	15351	1071	482	26714	408	28	44054	1.0310	0.1350	6.35
10	31	60	16	4	12.4	16120	1100	465	27784	634	10	46113	1.0324	0.1680	7.30
10	18	60	17	4	-1.1	15728	861	437	26690	508	88	44312	1.0320	0.1640	7.00
10	22	60	17	4	-9.1	14513	850	331	24492	595	15	40796	1.0288	0.1600	7.70
6	34	60	17	4	-20.7	13602	1174	233	23416	527	13	38965	1.0288	0.1960	7.20
3	24	61	5	4	101.8	12730	374	212	20620	432	53	34421	1.0260	0.2280	7.90
10	20	61	7	4	108.2	10971	502	256	18200	429	25	30455	1.0230	0.2310	8.60
11	29	61	7	4	136.3	13353	495	255	22020	222	84	36429	1.0270	0.1930	7.20
11	23	61	8	4	110.8	12775	743	380	21918	327	19	36162	1.0265	67.0000	7.20
10	3	61	10	4	91.1	13195	721	365	22400	428	53	37162	1.0260	0.2900	8.20
11	20	61	10	4	73.9	13417	324	386	22000	590	61	36778	1.0270	0.1850	7.90
6	28	61	10	4	64.9	13202	631	322	22000	660	41	36856	1.0280	0.1700	7.90
7	10	61	13	4	68.3	11422	517	255	19000	437	23	31654	1.0260	0.2900	7.70
8	27	61	13	4	50.6	11999	593	321	20100	620	37	33670	1.0230	0.1990	7.50
12	8	61	14	4	60.2	10669	482	424	17900	1020	66	30561	1.0190	0.2300	7.60
9	13	61	15	4	68.6	11793	496	311	19540	620	95	32855	1.0200	0.2080	7.90

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO	SO	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)				3	4	(calc)	(60F)	(ohm m)	
10	8	61	16	4	35.3	14121	1281	570	25600	163	12	41747	1.0310	0.1490	7.40
7	18	61	16	4	39.8	13423	744	336	22546	725	38	37812	1.0272	0.1970	7.09
10	15	61	17	4	3.8	13312	771	340	22500	625	27	37575	1.0270	0.2180	7.10
11	22	61	17	4	32.9	9864	603	226	16528	605	77	27903	1.0189	0.2200	7.40
7	26	61	17	4	3.4	15030	855	413	25500	585	14	42434	1.0270	0.1740	8.20
7	27	61	17	4	4.7	12639	708	246	20924	888	26	35431	1.0242	0.1820	7.70
7	27	61	17	4	7.6	13061	668	258	21528	927	12	36454	1.0262	0.1820	7.60
15	9	62	2	4	140.9	7689	185	131	12266	485	26	20782	1.0137	0.2890	7.56
1	26	62	5	4	150.4	11440	453	255	19000	300	16	31464	1.0220	0.2520	7.80
1	26	62	5	4	149.7	10944	404	229	18000	320	99	29996	1.0150	0.2530	8.30
7	20	62	7	4	134.7	12990	621	303	21820	290	33	36057	1.0260	0.2220	7.60
6	22	62	7	4	120.7	13049	682	370	22193	357	10	36661	1.0240	0.1900	8.20
6	26	62	7	4	107.7	11013	583	383	19000	148	60	31187	1.0220	0.2130	7.10
6	26	62	7	4	107.7	14619	833	330	24800	277	25	40884	1.0280	0.1800	7.20
12	17	62	8	4	99.2	12356	681	665	21950	384	33	36069	1.0250	0.1840	7.90
12	17	62	8	4	99.2	12356	681	665	21950	384	33	36069	1.0250	0.1840	7.90
11	12	62	9	4	86.4	13607	721	409	23250	295	39	38321	1.0260	0.1840	7.50
11	13	62	9	4	89.6	12695	440	409	21320	368	19	35251	1.0250	0.1870	7.80
7	17	62	9	4	91.4	11958	709	323	20500	170	51	33711	1.0240	0.2210	7.10
2	6	62	10	4	76.2	13939	598	311	23100	586	25	38559	1.0270	0.1800	7.80
6	28	62	10	4	116.1	11328	512	231	18700	554	35	31360	1.0200	0.2270	7.50
15	3	62	11	4	74.0	12469	524	304	20600	718	33	34648	1.0260	0.2250	7.60
3	25	62	11	4	80.8	12692	431	261	20680	703	10	34777	1.0250	0.2230	7.50

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
7	21	62	12	4	72.1	12926	432	271	21060	698	29	35416	1.0200	0.1980	8.10
7	26	62	13	4	68.8	9916	456	157	15965	971	37	27503	1.0193	0.2320	7.60
12	29	62	13	4	73.8	11848	393	234	19100	927	12	32514	1.0240	0.2250	7.60
7	31	62	13	4	74.6	10091	364	252	16400	845	66	28018	1.0220	0.2410	7.40
10	11	63	7	4	102.9	10196	472	243	16900	550	63	28424	1.0230	0.2850	7.70
10	11	63	7	4	122.4	11506	553	258	19280	270	49	31916	1.0250	0.2570	6.50
6	31	63	8	4	142.2	9567	745	238	16480	413	60	27503	1.0180	0.2460	7.60
10	6	63	11	4	81.4	11824	306	445	19720	508	78	32881	1.0200	0.2010	8.00
10	9	63	11	4	88.7	11786	486	295	19343	937	9	32856	1.0224	0.2240	7.25
15	20	63	11	4	90.3	12887	496	283	21040	918	2	35626	1.0270	0.1990	7.40
7	33	63	11	4	79.5	10353	466	295	17088	903	51	29156	1.0207	0.2300	8.00
9	19	63	12	4	75.6	11531	444	287	18940	790	7	31999	1.0270	0.2570	7.80
9	19	63	12	4	81.7	10526	496	260	17216	1098	18	29614	1.0208	0.2300	7.40
6	22	63	12	4	88.1	12842	404	356	21020	906	12	35540	1.0280	0.2190	7.60
6	23	63	12	4	81.0	12603	476	321	20700	881	2	34983	1.0270	0.1890	7.80
11	24	63	12	4	44.2	12888	501	349	21360	710	8	35816	1.0270	0.1980	7.90
11	24	63	12	4	90.3	12061	453	286	19720	830	43	33393	1.0250	0.2150	7.80
11	26	63	12	4	94.4	12503	484	322	20600	760	47	34716	1.0260	0.1950	7.90
7	28	63	12	4	91.3	10314	518	201	16855	937	11	28836	1.0200	0.2410	7.10
7	30	63	12	4	79.3	12073	398	334	19720	952	31	33508	1.0250	0.2150	7.00
1	36	63	12	4	92.2	11630	456	292	19000	1002	14	32394	1.0220	0.2070	7.80
10	36	63	12	4	84.7	10968	511	441	18587	844	35	31386	1.0246	0.2020	7.20
7	4	63	13	4	75.8	11182	521	221	18169	1070	26	31189	1.0240	0.2400	7.20

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS,
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO$_3$	SO$_4$	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
LSD	SEC	TP	R	M											
10	30	64	8	4	92.4	11570	406	284	18920	781	19	31980	1.0180	0.2250	7.20
10	31	64	9	4	101.7	10001	437	189	16223	810	71	27731	1.0200	0.2400	7.80
7	17	64	11	4	85.3	11290	338	249	18150	971	27	31025	1.0240	0.2110	6.90
6	2	64	12	4	86.0	11843	492	271	19243	1152	15	33016	1.0223	0.1960	7.20
6	2	64	12	4	86.0	11734	454	351	19243	1147	15	32944	1.0216	0.1960	7.30
7	15	64	12	4	83.2	10844	480	316	17900	986	27	30553	1.0190	0.2190	7.60
11	24	64	13	4	92.7	10786	474	256	17351	861	46	30056	1.0217	0.2270	8.07
11	18	64	16	4	43.7	9923	511	235	16359	800	92	27920	1.0179	0.2450	7.80
11	18	64	16	4	79.4	11884	789	854	22027	312	5	35871	1.0242	0.2200	7.50
15	14	64	17	4	34.7	11925	480	278	19660	620	39	33002	1.0220	0.1930	8.00
2	16	65	5	4	144.8	7950	218	136	12680	620	3	21607	1.0150	0.3140	8.10
7	8	65	6	4	94.5	8408	204	181	13120	1204	47	23164	1.0150	0.2920	8.20
6	27	65	6	4	110.1	8652	200	158	13500	1037	74	23621	1.0130	0.2840	8.10
6	27	65	6	4	154.1	7296	232	193	11880	543	39	20183	1.0100	0.3150	7.30
12	4	65	9	4	40.2	10732	348	267	17200	1259	16	29822	1.0200	0.2560	8.30
11	9	65	9	4	93.7	10156	218	230	16260	778	8	27650	1.0240	0.2260	7.90
10	13	65	9	4	101.2	9234	202	184	14660	795	16	25091	1.0160	0.3110	8.30
6	3	65	10	4	120.9	7985	288	195	12835	703	23	22140	1.0140	0.2860	8.40
6	15	65	11	4	96.7	7405	266	173	11758	1015	63	20680	1.0150	0.3100	7.85
6	2	65	12	4	100.1	12419	478	295	20300	940	15	34447	1.0270	0.2920	7.20
10	10	65	12	4	98.6	11058	577	226	18119	1039	12	31031	1.0216	0.2250	7.65
6	14	65	12	4	95.7	9557	332	227	15206	1274	56	26652	1.0188	0.2400	8.00
6	16	65	12	4	111.2	10718	471	287	17563	1070	18	30127	1.0200	0.2320	7.90

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
1	27	65	15	4	94.3	9735	312	218	15600	952	64	26881	1.0200	0.2750	7.50
1	27	65	15	4	89.8	11424	739	213	19300	366	43	32085	1.0230	0.2360	6.70
7	33	65	15	4	137.0	11684	408	270	19240	423	56	32081	1.0200	0.2220	7.40
6	14	65	17	4	41.5	9060	480	206	14920	752	86	25504	1.0180	0.3160	8.10
7	32	65	17	4	38.5	11491	496	306	19100	654	14	32061	1.0210	0.2140	7.30
10	11	66	15	4	90.8	9241	336	231	14900	990	59	25757	1.0180	0.3170	7.80
7	7	67	16	4	70.9	10878	501	304	17950	903	99	30635	1.0230	0.2410	7.00
11	12	67	16	4	78.9	10406	450	222	16931	942	17	28968	1.0212	0.2410	7.30
11	15	67	16	4	92.3	10791	543	276	17430	1647	25	30712	1.0200	0.2170	8.00
10	8	67	17	4	72.0	10716	458	384	17950	836	25	30369	1.0280	0.2150	8.10
11	27	68	11	4	148.0	8092	120	49	12270	952	14	21497	1.0140	0.3100	7.70
10	18	68	12	4	129.6	9846	428	236	15890	1230	33	27663	1.0192	0.2680	6.90
7	28	68	14	4	119.5	8661	457	147	13921	1108	38	24332	1.0167	0.2460	7.48
10	20	69	12	4	138.1	8539	466	267	14423	517	65	24277	1.0144	0.2650	7.10
11	26	69	12	4	162.0	9465	300	206	15360	583	39	25953	1.0180	0.2490	8.20
7	2	69	14	4	127.8	9566	360	210	15430	957	20	26543	1.0190	0.2380	7.51
7	10	69	14	4	89.2	8191	462	98	13207	819	69	22846	1.0162	0.2640	8.32

Table J-h-1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
McMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
7	34	55	6	4	40.30	0.168E-13	0.154E-06			3960.26	444.5
6	30	55	9	4	12.00					4524.00	473.7
7	25	55	10	4	3.80	0.202E-13	0.113E-07			4542.05	467.4
11	26	55	10	4	-14.30	0.855E-13	0.920E-06			4622.36	457.5
10	23	55	16	4	-59.76	0.147E-13	0.927E-08	0.300	0.15E-02	4208.99	369.8
9	34	55	16	4	-66.20					4339.73	376.8
9	34	55	16	4	-75.70					4449.45	378.5
4	1	56	6	4	52.70	0.313E-13	0.326E-06			3934.89	454.3
10	17	56	6	4	47.70	0.177E-13	0.178E-06			4069.42	463.0
6	29	56	10	4	-7.70	0.436E-13	0.244E-07			4491.72	450.7
6	32	56	10	4	-34.70	0.100E-14	0.109E-07			4836.77	459.0
10	36	56	10	4	13.60					4299.59	452.4
14	19	56	12	4	-26.40					4667.16	450.0
6	26	56	15	4	-31.10	0.873E-15	0.488E-09			4414.06	419.4
12	10	57	1	4	75.50					3823.58	465.7
7	26	57	9	4	35.35					4036.01	447.3
10	2	57	11	4	17.00					4450.87	471.3
10	2	57	11	4	7.00					4743.34	477.2
10	6	57	15	4	-32.40					4493.14	426.2
7	24	58	6	4	66.13	0.120E-13	0.137E-06				
7	28	58	6	4	63.40					3900.35	461.5
7	28	58	6	4	63.20					5069.55	454.3
6	8	58	10	4	27.80					4102.70	446.5
12	25	58	13	4	5.50	0.546E-13	0.305E-07			4051.08	419.0
15	32	58	17	4	-49.20					3902.29	349.1
10	10	59	5	4	71.00					4127.87	492.3

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
McMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M							
6	3	59	12	4	17.07	0.607E-13	0.340E-07			4136.36	439.2
3	10	59	14	4	-2.60					4097.77	415.7
10	12	59	17	4	-8.26					4099.36	410.1
11	36	59	17	4	0.04	0.794E-13	0.445E-07			3668.86	374.5
10	8	60	7	4	87.80					3749.21	470.5
10	20	60	7	4	70.70					3874.33	466.1
10	20	60	7	4	71.02					5209.84	460.8
10	20	60	7	4	50.60					4059.64	464.9
3	24	60	7	4	99.00					3624.92	469.0
10	17	60	8	4	75.94					3415.59	424.5
6	27	60	8	4	72.20					3705.41	450.4
6	32	60	8	4	90.20	0.319E-12	0.175E-06	0.300	0.49E-02	3584.44	456.0
10	2	60	9	4	60.20					3695.14	437.4
10	13	60	9	4	84.20					3610.89	452.8
7	2	60	10	4	49.80					3702.00	427.7
5	1	60	13	4	-9.60					4096.79	408.6
6	20	60	16	4	10.00					3658.55	383.4
10	31	60	16	4	20.70	0.321E-14	0.144E-08		0.14E-02	3372.62	364.9
11	33	60	16	4	30.50					3372.85	374.8
3	24	61	5	4	101.49	0.124E-13	0.116E-06			3420.40	450.6
10	31	61	7	4	111.30					3196.43	437.5
7	20	61	8	4	85.70					3496.28	442.6
7	14	61	9	4	96.00					3655.79	469.1
10	20	61	9	4	97.90	0.309E-14	0.173E-08			3362.73	441.1
6	30	61	9	4	93.50	0.736E-15	0.412E-09			3410.04	441.5
7	34	61	9	4	101.20	0.144E-12	0.802E-07			3405.20	448.7

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
McMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (KPa)	HYDRAULIC HEAD (m amsl)
7	34	61	9	4	91.50					3475.48	446.2
10	4	61	11	4	49.59					3891.16	446.8
11	2	61	14	4	29.10					3678.49	404.6
11	8	61	15	4	49.20					3344.44	390.6
6	9	61	16	4	32.64	0.986E-13	0.551E-07			3432.65	383.0
4	25	62	3	4	91.00					3551.14	453.5
6	22	62	7	4	111.86					3516.26	470.8
11	34	62	8	4	115.20					3187.93	440.6
10	6	62	9	4	83.80					3395.94	430.4
11	13	62	9	4	90.22	0.750E-13	0.738E-06			3374.91	434.7
6	26	62	10	4	83.90					3292.15	419.9
6	26	62	10	4	86.00					3391.99	432.2
7	15	62	11	4	64.60					3644.73	436.6
6	15	63	7	4	101.20					3670.53	475.8
6	15	63	7	4	101.00					3722.57	481.0
10	12	63	8	4	113.80					3622.64	483.6
3	30	63	10	4	93.00					3298.19	429.6
11	16	63	11	4	93.55					3101.38	410.1
6	21	63	11	4	80.10					3050.94	391.5
7	33	63	11	4	79.40					3090.71	394.9
7	33	63	11	4	85.92	0.207E-13	0.116E-07				
7	5	63	12	4	77.00					2752.74	358.0
6	6	63	12	4	79.00					2825.59	367.4
6	6	63	12	4	77.30					2857.56	369.0
6	6	63	12	4	73.80					2819.36	361.6
3	10	63	12	4	79.40					2627.35	347.6

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
McMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD SEC TP R M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6 23 63 12 4	87.40					2743.93	367.5
7 28 63 12 4	78.70					2778.21	362.3
6 2 63 13 4	67.30					3013.32	374.9
7 3 63 15 4	96.50					2836.01	386.0
10 30 64 8 4	93.40					3254.77	425.6
6 31 64 8 4	104.50	0.564E-14	0.575E-07			3259.41	437.2
11 4 64 11 4	81.60	0.132E-14				3269.93	415.3
11 4 64 11 4	81.50					3305.25	418.9
6 33 64 11 4	92.04	0.350E-14	0.196E-08			3196.27	418.3
6 7 64 12 4	76.80					2771.36	359.7
6 8 64 12 4	81.60					2558.08	342.7
10 32 64 12 4	106.40					2596.10	371.4
10 32 64 12 4	99.10					2625.39	367.1
10 1 64 13 4	62.10					2938.47	362.0
10 12 64 13 4	88.72					2760.49	370.4
11 24 64 13 4	99.08					2615.08	366.0
6 5 64 17 4	10.80					3440.44	362.0
11 10 65 4 4	113.80					3440.93	465.0
12 4 65 9 4	41.70	0.170E-12	0.207E-05			3777.10	427.2
11 9 65 9 4	93.70					3338.56	434.5
11 9 65 9 4	45.70	0.731E-14	0.743E-07			3779.41	431.4
10 13 65 9 4	107.70	0.582E-14	0.569E-07			3157.91	430.0
11 17 65 10 4	99.63	0.334E-13	0.200E-07			3208.62	427.1
11 17 65 10 4	90.48	0.488E-15	0.507E-08			3292.63	426.5
11 17 65 10 4	90.30					3257.25	422.8
11 17 65 10 4	99.50					3147.53	420.8

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
McMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	5	65	11	4	103.90	0.861E-14				2976.94	407.7
11	8	65	11	4	102.15					3235.49	432.4
11	8	65	11	4	96.80					3240.60	427.6
10	23	65	11	4	89.20					3251.37	421.1
10	23	65	11	4	89.30	0.514E-14	0.288E-08			3221.17	418.1
10	23	65	11	4	75.90	0.106E-14	0.593E-09			3269.53	409.6
10	8	65	17	4	38.40	0.573E-13	0.320E-07			3119.07	356.7
6	14	65	17	4	45.74	0.700E-14	0.392E-08			3039.43	355.9
4	31	66	8	4	141.60					2903.36	437.9
11	25	66	9	4	123.80					2885.00	418.3
11	25	66	9	4	124.00	0.361E-14				2985.10	428.7
10	4	66	10	4	109.20					3214.15	437.3
10	4	66	10	4	109.40					3248.70	441.0
6	16	66	13	4	107.60	0.912E-14	0.566E-08	0.220	0.57E-02	2614.36	374.4
6	31	66	14	4	90.51	0.364E-13	0.203E-07		0.11E-02	2627.38	358.7
6	31	66	14	4	93.25	0.207E-12	0.116E-06			2593.04	357.9
7	4	66	15	4	90.60	0.209E-13	0.117E-07			2706.07	366.8
11	9	66	15	4	85.80					2578.53	349.0
10	26	66	15	4	106.05	0.212E-14	0.118E-08			2642.38	375.7
11	34	66	15	4	96.43	0.484E-15	0.250E-09	0.260	0.48E-02	2575.96	359.3
10	11	67	12	4	120.40					2879.10	414.2
7	7	67	14	4	100.60					2491.18	354.9
6	9	67	14	4	100.10					2912.34	397.3
6	9	67	14	4	100.10					2690.05	374.7
11	10	67	14	4	94.50					2470.44	346.6
11	10	67	14	4	100.00	0.469E-14	0.262E-08			2613.97	366.8

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
McMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
13	18	67	14	4	98.00	0.480E-15	0.269E-09			2619.26	365.3
13	18	67	14	4	98.00					2660.66	369.6
6	3	67	15	4	88.70	0.392E-14	0.219E-08			2699.35	364.2
11	13	67	15	4	86.00					3166.01	409.1
11	13	67	15	4	85.80					2854.62	377.2
11	13	67	15	4	100.30					2965.20	402.9
11	15	67	16	4	92.20					2626.37	360.3
11	16	67	17	4	82.20					2701.80	358.0
13	20	67	17	4	88.60					2274.53	320.7
13	20	67	17	4	95.10	0.361E-13	0.388E-06			2307.47	330.6
7	20	68	10	4	107.00	0.206E-12				2925.30	405.6
11	27	68	11	4	149.00					2682.64	422.8
11	27	68	11	4	149.00					2643.02	418.8
3	29	68	11	4	139.00					2613.56	405.7
3	29	68	11	4	139.00					2354.04	379.3
10	29	68	13	4	128.90	0.152E-13	0.879E-08			2305.35	364.2
11	31	68	15	4	117.60	0.302E-13	0.169E-07	0.300			
10	4	68	16	4	103.00					2226.69	330.3
11	10	69	10	4	156.10	0.198E-13				2549.14	416.3
6	17	69	12	4	151.30					2392.44	395.5
6	21	69	12	4	143.85	0.448E-15	0.250E-09			2440.95	393.0
7	15	69	13	4	109.15					2454.35	359.6
7	15	69	13	4	142.68	0.312E-13	0.175E-07			2216.09	368.8
7	3	69	14	4	122.38					2040.75	330.7
11	17	69	15	4	96.30					2383.19	339.5
10	34	69	15	4	119.40					2433.50	367.8

Table J-h-2

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
MCMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD SEC TP R M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10 13 55 1 4	58.03			0.314	62.14
6 14 55 1 4	56.05			0.376	59.10
6 14 55 1 4	63.67			0.332	68.25
15 22 55 1 4	58.79			0.326	63.36
15 22 55 1 4	67.93			0.277	72.51
11 23 55 2 4	70.11			0.315	73.77
6 7 55 4 4	64.80	0.336E-12		0.279	69.40
11 4 55 5 4	36.98			0.218	41.10
11 4 55 5 4	36.98	0.695E-12		0.222	41.10
11 4 55 5 4	43.98	0.274E-12		0.322	46.85
11 4 55 5 4	43.98			0.309	46.85
11 4 55 5 4	50.88	0.625E-12		0.336	54.90
11 4 55 5 4	50.88			0.320	54.90
10 7 55 5 4	47.60	0.264E-11		0.337	52.10
6 18 55 5 4	35.10	0.290E-12		0.209	39.40
6 18 55 5 4	35.10			0.137	39.40
5 19 55 5 4	40.58			0.300	42.32
10 9 55 6 4	37.46	0.180E-11		0.304	41.80
7 10 55 6 4	32.80	0.211E-11		0.344	37.30
7 10 55 6 4	32.80			0.310	37.30
7 10 55 6 4	41.80			0.308	46.30
7 10 55 6 4	41.80	0.191E-11		0.345	46.30
6 12 55 6 4	42.20	0.392E-11		0.322	46.70
3 13 55 6 4	22.30	0.111E-11		0.290	26.80
3 13 55 6 4	31.30	0.358E-12		0.307	35.80
13 13 55 6 4	25.00	0.112E-11		0.313	29.50

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
MCMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
13	13	55	6	4	34.00	0.157E-11		0.300	38.50
15	13	55	6	4	24.80	0.171E-11		0.311	29.10
15	13	55	6	4	33.64	0.191E-11		0.309	38.18
6	23	55	6	4	43.40	0.139E-11		0.340	47.80
6	24	55	6	4	27.20			0.271	31.70
6	24	55	6	4	27.20	0.124E-12		0.296	31.70
6	24	55	6	4	36.20			0.322	40.70
6	24	55	6	4	36.20	0.682E-12		0.346	40.70
8	27	55	6	4	17.45			0.316	19.20
8	27	55	6	4	23.70	0.906E-12		0.322	28.20
8	27	55	6	4	32.70	0.121E-11		0.320	37.20
8	27	55	6	4	41.70	0.800E-12		0.305	46.20
13	27	55	6	4	19.23	0.509E-11		0.333	21.17
13	27	55	6	4	26.95	0.321E-11		0.339	31.75
13	27	55	6	4	35.52	0.195E-11		0.311	39.30
13	27	55	6	4	44.30	0.479E-11		0.325	49.30
13	34	55	6	4	38.10			0.306	42.60
13	34	55	6	4	38.10	0.982E-12		0.334	42.60
13	34	55	6	4	45.35			0.293	48.10
13	34	55	6	4	45.35	0.107E-11		0.317	48.10
7	35	55	6	4	35.05	0.689E-12		0.300	39.40
7	35	55	6	4	43.90	0.111E-11		0.289	48.40
13	35	55	6	4	29.85	0.800E-12		0.314	32.60
13	35	55	6	4	37.10	0.228E-11		0.319	41.60
13	35	55	6	4	46.10	0.129E-11		0.287	50.60
10	3	56	1	4	59.73			0.336	63.39

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
MCMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
10	3	56	1	4	67.96			0.311	72.54
6	12	56	1	4	53.78	0.370E-11		0.336	58.35
6	12	56	1	4	53.78			0.308	58.35
6	12	56	1	4	62.53	0.243E-11		0.334	66.70
6	12	56	1	4	62.53			0.288	66.70
6	12	56	1	4	70.90	0.135E-11		0.316	75.10
6	12	56	1	4	70.90			0.271	75.10
10	13	56	1	4	62.44			0.326	65.49
10	13	56	1	4	68.53			0.320	71.58
6	14	56	2	4	68.50			0.237	73.00
7	36	56	2	4	76.70			0.317	81.20
4	2	56	6	4	40.30			0.333	44.90
4	2	56	6	4	49.38			0.286	53.85
11	3	56	6	4	50.70	0.112E-11		0.320	55.20
6	10	56	6	4	52.50	0.140E-11		0.349	57.00
12	10	57	1	4	57.50			0.254	60.50
12	10	57	1	4	63.50	0.834E-12		0.317	66.50
12	10	57	1	4	69.50	0.202E-11		0.317	72.50
10	17	57	1	4	52.00			0.345	56.50
10	17	57	1	4	61.00			0.276	65.50
10	17	57	1	4	70.00			0.263	74.50
7	24	57	17	4	-43.90	0.196E-12	0.220E-13	0.182	-39.94
11	20	59	4	4	83.21	0.466E-11		0.287	87.78
10	34	59	16	4	-3.05	0.404E-13	0.101E-13	0.088	
13	2	60	15	4	31.96	0.348E-12	0.849E-14	0.062	35.01
6	4	63	12	4	65.97	0.524E-14	0.986E-17	0.101	67.34

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
MCMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
6	4	63	12	4	70.84	0.564E-12	0.494E-12	0.149	74.35
6	4	63	12	4	80.91	0.467E-12	0.196E-12	0.266	87.46
10	19	63	16	4	48.26	0.195E-13		0.220	52.07
8	30	64	3	4	125.43			0.395	126.15
11	26	64	12	4	95.51	0.893E-13		0.220	104.20
10	32	64	12	4	99.24	0.252E-13		0.211	105.80
13	11	65	2	4	132.89			0.354	137.46
6	11	65	4	4	135.35			0.323	139.92
10	23	65	4	4	119.66			0.380	120.36
10	23	65	4	4	135.62			0.383	145.08
6	32	65	4	4	136.45	0.875E-11		0.315	141.00
6	32	65	4	4	145.60	0.368E-11		0.297	150.20
6	27	65	5	4	143.50			0.298	146.50
6	27	65	5	4	151.73			0.327	156.95
6	27	65	6	4	119.60			0.347	124.10
6	1	65	12	4	101.18	0.112E-12		0.229	110.32
11	30	65	13	4	102.38	0.148E-13	0.853E-14	0.067	103.91
1	33	66	1	4	115.50			0.346	118.55
1	33	66	1	4	121.59			0.340	124.64
12	11	66	4	4	163.43			0.293	166.48
11	4	66	5	4	162.20			0.365	166.70
10	9	66	5	4	162.45			0.334	163.37
10	9	66	5	4	166.57			0.410	169.77
10	31	66	5	4	165.52			0.425	170.10
10	10	66	6	4	157.10			0.354	161.60
6	13	66	6	4	164.90			0.370	169.40

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
MCMURRAY - DINA FORMATIONS AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
6	4	66	13	4	99.07	0.877E-12	0.453E-13	0.156	103.64
6	4	66	13	4	106.99	0.449E-13	0.771E-14	0.196	110.35
6	16	66	13	4	95.43	0.126E-13		0.210	100.00
7	16	67	4	4	160.20			0.300	164.20
7	16	67	4	4	177.08			0.313	181.65
13	3	67	5	4	189.20	0.116E-11		0.334	192.70
6	16	67	5	4	169.20	0.272E-11		0.329	173.70
6	16	67	5	4	178.20	0.759E-12		0.329	182.70
6	16	67	5	4	190.20	0.259E-11		0.364	192.70
6	16	67	5	4	194.95			0.325	197.20
6	10	67	13	4	103.51	0.129E-12	0.313E-13	0.207	107.93
6	9	67	14	4	106.60	0.918E-13		0.189	111.10
5	16	67	14	4	90.00	0.714E-13		0.247	94.63
5	16	67	14	4	98.74	0.104E-12		0.255	102.85
11	21	67	16	4	102.82			0.198	107.55
15	22	67	16	4	97.83			0.233	102.20
6	21	68	12	4	130.47	0.491E-13		0.284	135.04
6	21	68	12	4	139.62	0.160E-12		0.299	144.19
11	12	68	13	4	131.02			0.258	132.55
11	12	68	13	4	135.60			0.243	138.65
11	12	68	13	4	141.69	0.282E-14		0.198	144.74
10	29	68	13	4	127.53	0.334E-13		0.266	135.00
7	1	68	17	4	95.86	0.437E-11	0.225E-11	0.096	101.19
7	18	69	12	4	137.10			0.273	140.60
7	18	69	12	4	144.36			0.254	148.12

Table J-h-3

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	23	55	16	4	-42.40	0.964E-14	0.610E-08	0.260	0.13E-02	4263.40	392.7
9	34	55	16	4	-46.70	0.845E-14	0.445E-08			4585.58	421.3
6	29	56	9	4	35.70	0.102E-12	0.568E-07				
6	29	56	10	4	22.20	0.940E-13	0.525E-07			4321.93	463.3
10	36	56	10	4	28.60	0.557E-13	0.312E-07			4220.58	459.4
6	26	56	15	4		0.655E-14	0.366E-08			4310.35	439.9
6	26	56	15	4	-16.40	0.288E-14	0.161E-08			4412.53	434.0
7	27	56	15	4	-2.40	0.423E-14	0.237E-08			4192.00	425.5
7	27	56	15	4	-14.60					4312.92	425.6
7	27	56	15	4	-28.00					4414.54	422.6
16	21	56	16	4	-22.00	0.665E-14	0.372E-08				
10	31	57	11	4	67.00	0.113E-12	0.631E-07			3922.57	467.4
10	6	57	15	4	-9.40	0.114E-13	0.640E-08			4440.03	443.8
11	32	57	15	4	11.00					4116.93	431.2
10	24	57	16	4	-17.10	0.222E-13	0.124E-07			4252.23	416.9
10	24	57	16	4	4.86					4061.88	419.4
10	24	57	16	4	17.66	0.203E-13	0.114E-07			4068.02	432.9
11	28	57	16	4	-16.50					4286.00	420.9
6	29	57	16	4	4.70	0.214E-14	0.105E-08	0.240	0.67E-02	4144.52	427.7
6	29	57	16	4	-15.22	0.174E-13	0.853E-08	0.320	0.77E-02	4032.23	396.3
7	24	57	17	4	-6.41					4199.18	422.2
7	24	57	17	4	-14.64					4093.82	403.2
7	24	57	17	4	-20.60						396.0
9	28	57	17	4	-16.80					4186.82	410.5
6	26	58	9	4	51.40					4121.23	472.0
7	18	58	10	4	65.20					3847.95	457.9

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	11	58	11	4	42.90	0.798E-14	0.447E-08			3962.55	447.3
10	11	58	11	4	62.10	0.515E-13	0.288E-07			3723.74	442.2
15	18	58	13	4	47.60	0.157E-13	0.879E-08			3875.02	443.1
12	25	58	13	4	51.50	0.344E-14	0.192E-08			3731.50	432.3
10	35	58	13	4	56.70					3826.15	447.2
6	8	58	16	4	-11.60	0.243E-14	0.262E-07			4004.83	397.1
10	26	58	16	4	-12.50					3925.74	388.2
10	31	58	16	4	18.60					3853.12	411.9
10	31	58	16	4	9.20					3728.87	389.8
11	33	58	16	4	17.80						393.1
9	30	59	8	4	76.50	0.322E-13	0.180E-07			3663.66	450.4
10	6	59	9	4	126.49					3446.47	478.2
10	6	59	9	4	91.43	0.499E-13	0.285E-07	0.300	0.38E-02	3652.34	464.2
6	15	59	9	4	75.30					3771.89	460.3
11	1	59	11	4	40.90					4116.56	461.1
11	32	59	11	4	77.72						467.8
11	32	59	11	4	74.90					3859.94	468.9
11	16	59	15	4	33.80					3818.11	423.5
11	16	59	15	4	73.12	0.398E-13	0.209E-07				
10	30	59	15	4	68.26	0.569E-14				3978.83	474.4
10	15	59	16	4	12.00						393.8
10	15	59	16	4	20.10						404.0
10	12	59	17	4	-7.04	0.448E-14	0.542E-07				
2	26	60	2	4	113.70					3402.77	461.0
11	27	60	3	4	151.30					2996.44	457.1
10	27	60	6	4	145.50	0.446E-13	0.411E-06			3175.83	469.6

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
11	27	60	6	4	145.20						471.0
3	24	60	7	4	99.00	0.101E-12	0.566E-07				
10	17	60	8	4	89.96					3527.36	450.0
6	27	60	8	4	92.60					3499.03	449.7
6	4	60	12	4	60.78						458.9
7	3	60	15	4	48.80					3872.20	444.0
7	29	60	15	4	100.90	0.667E-14	0.372E-08				
7	29	60	15	4	63.70	0.787E-14	0.440E-08			3809.97	452.6
7	29	60	15	4	49.40	0.405E-13	0.226E-07			3699.24	427.0
10	27	60	16	4	40.50	0.103E-14	0.638E-09		0.65E-02		
10	31	60	16	4	32.00	0.211E-13	0.226E-06			3391.05	378.1
10	31	60	16	4	19.20	0.465E-14	0.208E-08		0.10E-02		
10	31	60	16	4	19.20	0.156E-13	0.698E-08	0.220	0.23E-02	3610.66	387.7
10	20	61	7	4	150.80	0.240E-13	0.134E-07			3113.71	468.6
11	29	61	7	4	122.71						453.9
11	29	61	7	4	154.00	0.129E-13	0.723E-08			3177.21	478.3
10	31	61	7	4	149.70	0.641E-14	0.358E-08			2985.88	454.4
10	31	61	7	4	154.00					2965.72	456.7
7	34	61	9	4	132.00	0.873E-13	0.489E-07			3285.42	467.3
7	25	61	10	4	94.70	0.944E-14	0.528E-08			3423.03	444.1
6	28	61	10	4	82.30	0.571E-13	0.319E-07			3507.36	440.3
6	16	61	12	4	50.90					3583.46	416.6
10	31	61	13	4	80.30					3315.11	418.6
9	13	61	14	4	71.90	0.962E-15	0.112E-07			3159.65	394.4
6	9	61	16	4	45.74	0.131E-14	0.731E-09			3870.76	440.8
14	20	61	16	4	58.30	0.445E-14	0.249E-08			3055.52	370.1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION	PERMEABILITY	HYDRAULIC	POROSITY	STORATIVITY	FORMATION	HYDRAULIC
LSD	SEC	TP	R	M	(m amsl)	(m**2)	CONDUCTIVITY (m/s)			PRESSURE (kPa)	HEAD (m amsl)
12	33	61	16	4	51.40	0.975E-14	0.638E-08	0.280	0.37E-02	3052.47	362.9
6	23	62	7	4	162.10	0.916E-13	0.522E-07			2993.80	467.6
6	23	62	7	4	123.70	0.531E-13	0.303E-07			3186.14	448.9
6	35	62	8	4	134.37	0.818E-13	0.753E-06	0.200	0.15E-01	3224.40	463.5
7	17	62	9	4	134.10	0.706E-13	0.395E-07				
12	17	62	11	4	88.08					3626.10	458.2
7	14	63	9	4	155.14						464.1
10	24	63	9	4	154.23						475.5
10	24	63	9	4	153.96	0.966E-14	0.540E-08				
7	28	63	10	4	137.10	0.147E-14	0.820E-09			3226.18	466.4
15	4	64	8	4	154.30	0.230E-13	0.129E-07				
11	21	64	9	4	110.30					3287.52	445.8
10	31	64	9	4	103.90					3221.99	432.7
10	22	64	11	4	97.20					3262.37	430.2
6	33	64	11	4	117.60					3395.93	464.2
10	32	64	12	4	135.40					2903.53	431.7
7	23	64	13	4	111.50					3176.68	435.7
11	24	64	13	4	110.66					3381.48	455.8
7	13	64	16	4	66.30	0.659E-14	0.347E-08	0.210	0.39E-02	2826.30	354.8
11	10	65	4	4	170.14	0.693E-14				2338.55	408.8
10	30	65	8	4	142.00					2707.80	418.4
6	11	65	9	4	144.44					2728.68	422.9
11	1	65	15	4	98.90	0.121E-13	0.676E-08			2836.67	388.4
5	12	65	15	4	101.50					2636.42	370.6
1	27	65	15	4	99.67	0.294E-14	0.300E-07			2655.14	370.7
10	8	65	17	4	52.40	0.108E-12	0.604E-07			3113.69	370.2

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPd)	HYDRAULIC HEAD (m amsl)
10	8	65	17	4	46.40						364.9
10	9	65	17	4	48.75	0.411E-13	0.281E-07	0.140	0.12E-02	3112.03	366.4
6	8	66	10	4	147.26	0.452E-14	0.325E-08			3092.14	462.9
10	12	66	15	4	107.90	0.128E-13					
6	18	66	16	4	78.60					2945.03	379.2
11	34	66	16	4	101.32						377.0
9	27	66	17	4	77.50	0.204E-13	0.114E-07			2830.64	366.4
8	2	67	15	4	103.20	0.228E-13	0.149E-07	0.270	0.47E-02		
11	31	68	15	4	117.47						372.5
11	32	68	16	4	115.40						380.2
10	22	69	11	4	200.90					2736.14	480.1
10	27	69	12	4	157.80					2226.99	385.1
7	28	69	12	4	153.00	0.316E-13	0.177E-07			2405.68	398.5
7	28	69	12	4	140.80	0.168E-13	0.940E-08			2527.03	398.7
7	2	69	14	4	128.90	0.198E-13	0.111E-07			2060.70	339.2
7	14	69	14	4	136.46						342.1
11	28	69	16	4	115.10						344.0

Table J-h-4

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
12	11	55	1	4	68.75	0.287E-13		0.278	82.62
10	13	55	1	4	66.71			0.266	71.28
10	13	55	1	4	74.33			0.279	77.38
6	14	55	1	4	70.53			0.226	72.82
7	6	55	5	4	62.40	0.285E-11		0.346	66.90
7	6	55	5	4	62.40			0.332	66.90
7	6	55	5	4	71.38	0.486E-12		0.313	75.85
7	6	55	5	4	71.38			0.272	75.85
10	7	55	5	4	56.60	0.640E-12		0.344	61.10
7	2	55	6	4	40.07	0.959E-12		0.340	44.40
7	2	55	6	4	40.07			0.302	44.40
7	2	55	6	4	48.90			0.296	53.40
7	2	55	6	4	48.90	0.154E-11		0.347	53.40
7	11	55	6	4	48.80	0.208E-11		0.331	53.30
7	11	55	6	4	48.80			0.311	53.30
7	11	55	6	4	57.80			0.314	62.30
7	11	55	6	4	57.80	0.294E-11		0.334	62.30
6	12	55	6	4	50.20	0.818E-12		0.305	53.70
10	23	55	14	4	-0.93	0.574E-12	0.933E-13	0.193	3.64
10	4	55	15	4	-58.84	0.486E-13	0.173E-13	0.161	-56.09
10	4	55	15	4	-63.11	0.259E-13	0.418E-14	0.151	-61.58
10	33	55	15	4	-11.55	0.638E-13	0.219E-13	0.063	-8.80
10	33	55	15	4	-20.57	0.315E-12	0.908E-15	0.041	-15.20
10	33	55	15	4	-27.00	0.217E-11	0.408E-15	0.050	-25.93
6	12	56	1	4	79.45			0.263	83.80
6	12	56	1	4	79.45	0.670E-12		0.310	83.80

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	13	56	1	4	73.26			0.364	74.94
10	13	56	1	4	77.68			0.354	80.42
10	13	56	1	4	84.38			0.315	88.35
6	10	56	6	4	61.50	0.146E-11		0.325	66.00
7	24	57	17	4	-32.16	0.231E-12	0.443E-13	0.258	-29.88
7	24	57	17	4	-37.20	0.142E-12	0.463E-13	0.230	-34.45
7	20	58	12	4	39.25			0.280	43.50
7	20	58	12	4	39.25			0.203	43.50
7	20	58	12	4	45.75			0.268	48.00
7	20	58	12	4	45.75			0.344	48.00
7	20	58	12	4	52.50			0.281	57.00
7	20	58	12	4	52.50			0.233	57.00
10	33	59	15	4	34.73	0.257E-12	0.101E-12	0.245	37.78
11	3	59	17	4	-26.49	0.446E-14	0.119E-14	0.266	-22.83
11	4	59	17	4	-24.99	0.879E-13	0.641E-13	0.155	-21.03
2	26	60	2	4	132.90			0.411	139.00
2	26	60	2	4	153.17			0.429	167.35
13	29	60	5	4	133.45	0.133E-11		0.317	141.99
11	27	61	5	4	135.06			0.399	137.54
15	9	62	2	4	150.83	0.310E-12		0.370	159.98
10	1	62	3	4	147.49			0.327	150.54
10	1	62	3	4	153.62			0.329	156.64
10	1	62	3	4	159.68			0.353	162.73
11	20	62	3	4	140.24	0.331E-11	0.282E-11	0.388	144.81
11	20	62	3	4	144.66			0.359	144.81
11	20	62	3	4	149.38			0.398	153.96

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
5	21	62	3	4	127.27	0.594E-14		0.338	133.58
5	21	62	3	4	142.05	0.106E-11		0.374	150.53
4	25	62	3	4	137.16			0.404	149.35
4	25	62	3	4	158.80			0.392	167.94
11	31	62	3	4	152.80			0.343	157.30
11	34	62	3	4	156.20			0.346	160.70
10	13	62	4	4	144.63			0.346	146.55
10	13	62	4	4	151.13			0.342	155.70
10	14	62	4	4	143.40	0.178E-11		0.366	147.90
10	36	62	4	4	145.10	0.869E-12		0.321	149.60
10	36	62	4	4	154.10	0.122E-11		0.367	158.60
10	36	62	4	4	163.10	0.210E-11		0.333	167.60
10	14	62	5	4	145.40			0.364	149.90
1	26	62	5	4	143.57			0.373	146.32
1	26	62	5	4	151.03			0.435	155.15
12	7	63	2	4	158.15	0.388E-11		0.365	164.47
12	7	63	2	4	161.88			0.322	174.07
5	19	63	2	4	158.00	0.378E-11		0.349	162.50
3	6	63	3	4	149.00			0.364	153.50
3	6	63	3	4	158.00			0.345	162.50
4	7	63	3	4	134.98			0.279	138.96
4	7	63	3	4	143.23			0.322	147.49
4	7	63	3	4	152.07			0.292	156.64
6	7	63	3	4	148.77			0.361	153.35
6	23	63	3	4	152.52	0.194E-11		0.337	157.10
6	23	63	3	4	161.60	0.506E-11		0.380	166.10

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
11	25	63	3	4	165.00	0.740E-11		0.405	169.50
3	26	63	3	4	144.74	0.111E-11		0.339	149.31
3	26	63	3	4	153.88	0.121E-11		0.358	158.45
7	6	63	4	4	138.49			0.276	141.69
7	6	63	4	4	150.68			0.346	150.84
11	33	63	4	4	138.18			0.362	141.08
11	33	63	4	4	150.06			0.399	150.22
7	16	63	5	4	127.23			0.347	129.70
7	16	63	5	4	133.30			0.334	136.90
10	30	63	5	4	128.35			0.334	132.70
5	13	63	9	4	140.60	0.242E-11		0.313	145.60
5	13	63	9	4	150.10	0.284E-11		0.266	154.60
7	28	63	12	4	89.94	0.283E-12		0.251	94.51
6	5	63	17	4	17.96	0.121E-11	0.300E-12	0.165	22.53
5	17	64	2	4	140.51			0.316	154.22
10	3	64	3	4	130.10			0.385	136.20
10	3	64	3	4	145.35			0.376	154.49
10	4	64	3	4	132.56			0.390	135.60
10	4	64	3	4	138.65			0.349	141.70
10	4	64	3	4	150.85			0.357	153.89
6	10	64	3	4	130.72			0.343	133.77
6	10	64	3	4	136.82			0.370	139.87
6	10	64	3	4	142.91			0.380	145.96
6	10	64	3	4	149.01			0.371	152.06
6	10	64	3	4	155.13			0.355	158.16
5	15	64	3	4	131.40			0.405	136.58

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
5	15	64	3	4	148.78	0.398E-12		0.404	160.97
11	16	64	3	4	138.05			0.338	141.10
11	16	64	3	4	144.15			0.353	147.20
11	16	64	3	4	150.24			0.359	153.29
11	16	64	3	4	156.34			0.367	159.39
10	27	64	3	4	149.91	0.156E-12	0.537E-13	0.103	162.18
10	27	64	3	4	152.14			0.360	162.79
8	30	64	3	4	147.05			0.370	158.97
8	17	64	4	4	148.44			0.314	149.96
10	19	64	4	4	135.80			0.343	140.30
10	19	64	4	4	135.80	0.570E-11		0.368	140.30
10	19	64	4	4	143.30			0.342	146.30
10	19	64	4	4	143.30	0.148E-11		0.366	146.30
10	19	64	4	4	150.80	0.350E-11		0.392	155.30
10	19	64	4	4	150.80			0.383	155.30
2	20	64	4	4	149.00			0.346	153.50
2	20	64	4	4	149.00	0.564E-11		0.381	153.50
10	21	64	4	4	127.60	0.552E-11		0.361	132.10
10	21	64	4	4	127.60			0.340	132.10
10	21	64	4	4	136.60			0.352	141.10
10	21	64	4	4	136.60	0.463E-11		0.368	141.10
10	21	64	4	4	145.60	0.557E-11		0.372	150.10
10	21	64	4	4	145.60			0.344	150.10
10	21	64	4	4	154.60	0.415E-11		0.367	159.10
10	21	64	4	4	154.60			0.346	159.10
13	21	64	4	4	116.50	0.337E-11		0.357	119.50

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
13	21	64	4	4	122.50	0.828E-11		0.363	125.50
13	21	64	4	4	128.50	0.802E-11		0.379	131.50
13	21	64	4	4	134.50	0.942E-11		0.374	137.50
13	21	64	4	4	140.50	0.118E-10		0.381	143.50
13	21	64	4	4	146.60	0.308E-11		0.359	149.70
13	21	64	4	4	154.25	0.182E-11		0.368	158.80
2	28	64	4	4	126.10			0.341	130.60
2	28	64	4	4	126.10	0.522E-11		0.357	130.60
2	28	64	4	4	135.10	0.590E-11		0.364	139.60
2	28	64	4	4	135.10			0.345	139.60
2	28	64	4	4	144.10	0.447E-11		0.362	148.60
2	28	64	4	4	144.10			0.340	148.60
2	28	64	4	4	153.10	0.416E-11		0.365	157.60
2	28	64	4	4	153.10			0.354	157.60
6	28	64	4	4	135.30			0.329	139.80
6	28	64	4	4	144.30			0.354	148.80
6	28	64	4	4	153.30			0.360	157.80
6	28	64	4	4	171.30			0.358	175.80
11	28	64	4	4	128.00	0.221E-11		0.368	132.58
11	28	64	4	4	136.77	0.182E-12		0.357	140.96
11	28	64	4	4	145.50	0.556E-11		0.391	149.28
11	28	64	4	4	145.91			0.382	150.87
11	28	64	4	4	155.44			0.422	160.01
11	28	64	4	4	155.83	0.809E-11		0.402	158.79
11	28	64	4	4	159.79			0.396	160.01
15	28	64	4	4	128.20	0.265E-11		0.345	132.70

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
15	28	64	4	4	128.20			0.350	132.70
15	28	64	4	4	136.68	0.571E-11		0.365	140.65
15	28	64	4	4	136.68			0.351	140.65
15	28	64	4	4	145.15			0.346	149.65
15	28	64	4	4	145.15	0.543E-11		0.349	149.65
15	28	64	4	4	155.27			0.354	159.80
15	28	64	4	4	155.27	0.608E-11		0.382	159.80
15	28	64	4	4	164.25	0.441E-11		0.357	168.70
15	28	64	4	4	164.25			0.336	168.70
7	29	64	4	4	129.80	0.444E-11		0.366	134.30
7	29	64	4	4	129.80			0.342	134.30
7	29	64	4	4	138.80			0.327	143.30
7	29	64	4	4	138.80	0.578E-11		0.361	143.30
7	29	64	4	4	147.90	0.714E-11		0.371	152.50
7	29	64	4	4	147.90			0.354	152.50
7	29	64	4	4	156.82			0.358	161.15
7	29	64	4	4	156.82	0.589E-11		0.376	161.15
7	29	64	4	4	165.80	0.410E-11		0.375	170.45
7	29	64	4	4	165.80			0.346	170.45
10	29	64	4	4	135.79	0.355E-11		0.365	140.28
10	29	64	4	4	135.79			0.345	140.28
10	29	64	4	4	144.75			0.345	149.23
10	29	64	4	4	144.75	0.324E-11		0.351	149.23
10	29	64	4	4	153.72	0.502E-11		0.367	158.22
10	29	64	4	4	153.72			0.360	158.22
11	30	64	4	4	143.06	0.568E-11		0.377	147.57

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
11	30	64	4	4	143.06			0.348	147.57
11	30	64	4	4	152.08	0.372E-11		0.368	156.60
11	30	64	4	4	152.08			0.345	156.60
6	32	64	4	4	134.98	0.315E-11		0.369	139.55
6	32	64	4	4	134.98			0.329	139.55
6	32	64	4	4	143.98	0.401E-11		0.378	148.40
6	32	64	4	4	143.98			0.352	148.40
6	32	64	4	4	153.03	0.526E-11		0.376	157.65
6	32	64	4	4	153.03			0.344	157.65
6	32	64	4	4	161.45			0.342	165.25
6	32	64	4	4	161.45	0.262E-11		0.362	165.25
7	32	64	4	4	128.30	0.239E-11		0.355	131.30
7	32	64	4	4	135.80	0.333E-11		0.363	140.30
7	32	64	4	4	144.80	0.532E-11		0.375	149.30
7	32	64	4	4	153.80	0.395E-11		0.373	158.30
7	32	64	4	4	162.80	0.168E-11		0.352	167.30
10	32	64	4	4	137.25	0.278E-11		0.367	141.80
10	32	64	4	4	137.25			0.330	141.80
10	32	64	4	4	146.25			0.352	150.70
10	32	64	4	4	146.25	0.470E-11		0.367	150.70
10	32	64	4	4	155.20			0.339	159.70
10	32	64	4	4	155.20	0.601E-11		0.370	159.70
10	32	64	4	4	164.20	0.478E-11		0.364	168.70
10	32	64	4	4	164.20			0.350	168.70
10	34	64	4	4	138.64			0.351	147.78
10	34	64	4	4	160.23			0.403	163.02

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	34	64	4	4	169.17	0.543E-12	0.491E-12	0.215	172.47
10	34	64	4	4	169.38			0.365	175.61
10	34	64	5	4	151.96			0.372	154.84
10	34	64	5	4	157.89			0.381	160.94
10	34	64	5	4	164.06			0.370	167.18
10	34	64	5	4	170.46			0.364	173.74
11	26	64	12	4	120.81	0.413E-13		0.230	127.67
10	32	64	12	4	119.66	0.855E-13		0.280	133.53
13	19	65	1	4	138.97			0.368	143.54
13	19	65	1	4	148.11			0.364	152.69
13	19	65	1	4	157.26			0.330	161.83
11	21	65	1	4	143.14	0.135E-11		0.361	146.34
11	21	65	1	4	150.75	0.424E-12		0.357	155.15
11	21	65	1	4	159.74	0.180E-11		0.385	164.32
11	21	65	1	4	168.90	0.902E-12		0.391	173.47
11	31	65	1	4	141.77			0.348	146.35
11	31	65	1	4	150.92			0.361	155.49
11	31	65	1	4	160.06			0.340	164.64
7	33	65	1	4	159.72	0.132E-12		0.354	174.65
4	11	65	2	4	137.75			0.350	142.32
4	11	65	2	4	146.89			0.399	151.47
4	11	65	2	4	156.04			0.340	160.61
4	11	65	2	4	165.18			0.334	169.75
13	11	65	2	4	142.04			0.369	146.61
13	11	65	2	4	151.18			0.381	155.75
13	11	65	2	4	160.33			0.354	164.90

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
LSD	SEC	TP	R	M					
14	13	65	2	4	137.42			0.371	141.99
14	13	65	2	4	146.57			0.329	151.14
14	13	65	2	4	155.71			0.385	160.28
11	14	65	2	4	142.95			0.325	147.53
11	14	65	2	4	152.10			0.395	156.67
11	14	65	2	4	161.24			0.343	165.82
11	14	65	2	4	170.39			0.369	174.96
2	3	65	3	4	142.23			0.362	147.31
2	3	65	3	4	158.99			0.366	167.94
10	5	65	3	4	140.33			0.369	143.38
10	5	65	3	4	146.43			0.366	149.48
10	5	65	3	4	152.52			0.372	155.57
10	5	65	3	4	158.62			0.351	161.67
10	5	65	3	4	164.76			0.345	167.86
10	5	65	3	4	169.49			0.374	171.12
10	5	65	3	4	174.16			0.352	177.21
9	6	65	3	4	145.77			0.374	154.39
9	6	65	3	4	168.15			0.351	181.79
10	31	65	3	4	177.81			0.382	183.10
10	31	65	3	4	187.83			0.340	191.30
16	1	65	4	4	139.85			0.378	142.90
16	1	65	4	4	145.80			0.366	147.48
16	1	65	4	4	150.52			0.380	153.57
16	1	65	4	4	156.62			0.368	159.67
16	1	65	4	4	162.71			0.351	165.76
16	1	65	4	4	168.81			0.363	171.86

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
16	1	65	4	4	174.91			0.374	177.96
14	3	65	4	4	144.21			0.352	156.79
14	3	65	4	4	170.52			0.370	184.25
11	10	65	4	4	138.59			0.299	141.18
11	10	65	4	4	145.75			0.377	150.33
11	10	65	4	4	154.90			0.378	159.47
11	10	65	4	4	164.04			0.382	168.62
11	10	65	4	4	173.19			0.362	177.76
11	10	65	4	4	182.33			0.340	186.90
11	10	65	4	4	189.95			0.395	193.00
6	11	65	4	4	144.49			0.353	149.06
6	11	65	4	4	153.63			0.356	158.21
6	11	65	4	4	162.78			0.361	167.35
6	11	65	4	4	171.92			0.362	176.49
6	11	65	4	4	181.06			0.378	185.64
5	21	65	4	4	151.82			0.391	152.53
5	21	65	4	4	169.53			0.354	180.08
10	23	65	4	4	156.94			0.359	167.00
10	23	65	4	4	184.61			0.347	193.51
16	24	65	4	4	153.37			0.323	156.42
16	24	65	4	4	159.47			0.356	162.52
16	24	65	4	4	165.57			0.356	168.62
16	24	65	4	4	171.66			0.352	174.71
16	24	65	4	4	177.76			0.352	180.81
16	24	65	4	4	183.85			0.360	186.90
16	24	65	4	4	189.95			0.374	193.00

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
12	25	65	4	4	149.81			0.329	152.86
12	25	65	4	4	155.90			0.352	158.95
12	25	65	4	4	162.00			0.364	165.05
12	25	65	4	4	168.09			0.377	171.14
12	25	65	4	4	174.19			0.342	177.24
12	25	65	4	4	180.29			0.347	183.34
12	25	65	4	4	186.38			0.346	189.43
12	25	65	4	4	192.48			0.349	195.53
6	32	65	4	4	154.75	0.173E-11		0.329	159.30
6	32	65	4	4	163.85	0.340E-11		0.341	168.40
6	32	65	4	4	172.95	0.194E-11		0.340	177.50
6	32	65	4	4	182.00	0.147E-11		0.346	186.50
6	32	65	4	4	191.05	0.300E-11		0.350	195.60
6	32	65	4	4	200.15			0.348	204.70
1	13	65	5	4	164.34			0.324	167.38
1	13	65	5	4	170.43			0.366	173.48
2	16	65	5	4	163.65			0.334	172.79
4	24	65	5	4	153.58			0.291	156.63
4	24	65	5	4	159.67			0.327	162.72
4	24	65	5	4	165.77			0.377	168.82
4	24	65	5	4	171.86			0.348	174.91
4	24	65	5	4	177.96			0.348	181.01
6	27	65	5	4	160.72			0.377	164.50
6	27	65	5	4	168.25			0.360	172.00
6	27	65	5	4	176.50			0.343	181.00
7	31	65	5	4	170.90			0.352	175.40

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
7	31	65	5	4	179.40			0.362	183.40
7	31	65	5	4	187.90			0.368	192.40
10	33	65	5	4	164.42			0.366	168.01
10	33	65	5	4	172.11			0.377	176.20
10	33	65	5	4	180.95			0.363	185.70
6	27	65	6	4	153.10			0.338	157.10
6	27	65	6	4	161.10			0.351	165.10
6	27	65	6	4	169.60			0.332	174.10
6	27	65	6	4	178.60			0.373	183.10
7	7	66	1	4	151.77			0.311	156.34
11	9	66	1	4	146.62			0.340	148.75
11	9	66	1	4	150.88			0.326	153.02
11	9	66	1	4	155.21			0.357	157.41
7	17	66	1	4	155.14	0.193E-11		0.339	158.19
12	17	66	1	4	156.34			0.333	158.78
12	17	66	1	4	161.83			0.345	164.88
6	27	66	1	4	139.44			0.301	140.51
6	27	66	1	4	143.55			0.342	146.60
1	31	66	1	4	160.33			0.304	163.07
1	31	66	1	4	163.83			0.312	164.60
1	31	66	1	4	169.17			0.321	173.74
11	11	66	2	4	151.48			0.346	156.05
11	11	66	2	4	160.47			0.367	164.89
11	11	66	2	4	169.46			0.319	174.03
6	22	66	2	4	143.29			0.328	146.34
6	22	66	2	4	149.38			0.360	152.43

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
6	22	66	2	4	164.01			0.310	166.15
1	2	66	4	4	178.09			0.366	186.38
1	2	66	4	4	195.26			0.350	204.15
4	5	66	4	4	159.52			0.380	162.57
4	5	66	4	4	165.62			0.365	168.66
4	5	66	4	4	171.71			0.361	174.76
4	5	66	4	4	177.81			0.357	180.86
4	5	66	4	4	183.90			0.363	186.95
4	5	66	4	4	190.00			0.356	193.05
4	5	66	4	4	196.10			0.368	199.14
8	8	66	4	4	163.45			0.362	166.50
8	8	66	4	4	169.55			0.359	172.60
8	8	66	4	4	175.64			0.349	178.69
8	8	66	4	4	181.74			0.336	184.79
8	8	66	4	4	187.83			0.337	190.88
8	8	66	4	4	193.93			0.366	196.98
12	11	66	4	4	169.53			0.337	172.57
12	11	66	4	4	175.62			0.355	178.67
12	11	66	4	4	181.71			0.391	184.76
12	11	66	4	4	187.81			0.340	190.86
12	11	66	4	4	193.91			0.337	196.96
11	4	66	5	4	170.95			0.380	175.20
11	4	66	5	4	179.70			0.350	184.20
11	4	66	5	4	188.70			0.385	193.20
6	6	66	5	4	161.20			0.353	165.70
6	6	66	5	4	170.20			0.354	174.70

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
LSD	SEC	TP	R	M					
6	6	66	5	4	179.20			0.354	183.70
10	9	66	5	4	174.34			0.445	178.92
10	9	66	5	4	183.49			0.365	188.06
10	9	66	5	4	192.63			0.368	197.21
6	10	66	5	4	167.20			0.363	171.70
6	10	66	5	4	176.20			0.384	180.70
6	10	66	5	4	185.20			0.344	189.70
10	31	66	5	4	183.81			0.402	188.39
10	31	66	5	4	192.96			0.373	197.53
10	31	66	5	4	201.95			0.405	206.37
10	31	66	5	4	210.63			0.391	214.90
11	9	66	6	4	162.50			0.333	167.00
11	9	66	6	4	171.50			0.354	176.00
11	9	66	6	4	180.42			0.340	184.85
11	9	66	6	4	189.22			0.331	193.60
10	10	66	6	4	166.10			0.373	170.60
10	10	66	6	4	175.10			0.361	179.60
10	10	66	6	4	184.10			0.360	188.60
7	11	66	6	4	166.70			0.344	171.20
7	11	66	6	4	175.70			0.392	180.20
7	11	66	6	4	184.75			0.360	189.30
6	13	66	6	4	173.90			0.389	178.40
6	13	66	6	4	182.90			0.360	187.40
6	13	66	6	4	191.90			0.361	196.40
11	15	66	6	4	163.60			0.328	168.00
11	15	66	6	4	172.51			0.387	177.01

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
11	15	66	6	4	181.03			0.367	185.05
11	15	66	6	4	189.02			0.360	193.00
11	11	67	3	4	179.20	0.871E-12		0.353	180.70
11	11	67	3	4	185.20	0.303E-11		0.376	189.70
11	11	67	3	4	194.20	0.545E-11		0.384	198.70
10	14	67	3	4	170.30	0.414E-11		0.370	174.80
10	14	67	3	4	179.30	0.469E-11		0.374	183.80
10	14	67	3	4	188.30	0.515E-11		0.360	192.80
10	28	67	3	4	191.17			0.437	194.90
10	28	67	3	4	217.90	0.341E-11		0.410	222.30
10	2	67	4	4	179.85	0.933E-12		0.386	184.35
10	2	67	4	4	209.60	0.276E-11		0.394	214.10
10	2	67	4	4	216.10	0.192E-11		0.385	218.10
10	5	67	4	4	192.40	0.341E-11		0.345	194.20
10	5	67	4	4	198.40	0.357E-11		0.369	202.60
10	5	67	4	4	206.60	0.564E-11		0.378	210.60
10	7	67	4	4	194.72	0.132E-11		0.327	197.15
10	7	67	4	4	201.50	0.264E-11		0.349	205.85
10	7	67	4	4	209.57	0.261E-11		0.359	213.30
7	16	67	4	4	184.92			0.348	188.20
7	16	67	4	4	196.45			0.376	197.20
7	16	67	4	4	201.70			0.362	206.20
7	16	67	4	4	209.20			0.352	212.20
13	3	67	5	4	197.20	0.281E-11		0.368	201.70
13	3	67	5	4	206.20	0.144E-11		0.358	210.70
6	16	67	5	4	201.51	0.322E-11		0.343	205.82

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
LOWER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
LSD	SEC	TP	R	M					
6	16	67	5	4	210.01	0.242E-11		0.389	214.20
6	16	67	5	4	216.75	0.176E-11		0.355	219.30
11	2	68	4	4	217.90	0.236E-11		0.302	222.40
11	2	68	4	4	226.90	0.494E-12		0.323	231.40
10	26	68	4	4	210.20	0.272E-11		0.357	214.70
10	26	68	4	4	239.20	0.406E-11		0.353	243.70

Table K-g-1

STRATIGRAPHIC PICKS FOR TOP OF CLEARWATER FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
LSD	SEC	TP	R	M			
11	19	57	7	4	679.70	580.97	98.73
11	23	57	7	4	678.00	587.45	90.55
11	7	57	8	4	661.40	588.86	72.54
3	22	57	8	4	678.50	593.70	84.80
6	29	57	8	4	655.60	578.17	77.43
12	10	57	9	4	684.30	616.97	67.33
10	27	57	9	4	642.80	571.74	71.06
10	30	57	9	4	640.10	563.31	76.79
11	3	57	10	4	645.50	588.80	56.70
7	9	57	10	4	638.90	577.29	61.61
6	28	57	10	4	639.50	561.80	77.70
10	12	57	11	4	634.00	570.29	63.71
10	28	57	11	4	630.90	561.11	69.79
13	2	57	12	4	631.90	583.47	48.43
10	28	57	12	4	645.30	593.70	51.60
6	7	58	4	4	583.10	472.42	110.68
6	13	58	5	4	665.40	538.27	127.13
10	24	58	5	4	665.10	539.40	125.70
11	25	58	6	4	765.40	644.07	121.33
11	26	58	6	4	707.10	583.30	123.80
7	28	58	6	4	552.60	430.72	121.88
4	5	58	7	4	678.80	571.54	107.26
10	14	58	7	4	677.60	573.32	104.28
6	8	58	8	4	649.50	564.81	84.69
7	28	58	8	4	655.30	563.85	91.45
11	31	58	8	4	640.40	533.74	106.66
11	12	58	9	4	657.10	569.31	87.79
6	26	58	9	4	674.50	569.49	105.01
6	6	58	10	4	638.90	564.80	74.10
15	28	58	10	4	659.90	563.85	96.05
2	34	58	10	4	637.00	541.87	95.13
7	8	58	11	4	637.60	565.95	71.65
5	10	58	11	4	643.40	568.20	75.20
15	24	58	11	4	620.00	533.60	86.40
6	28	58	11	4	627.90	567.27	60.63
1	33	58	11	4	630.00	566.34	63.66
13	9	58	12	4	610.20	553.54	56.66
7	28	58	12	4	631.90	562.97	68.93
11	21	59	1	4	599.50	460.40	139.10
7	18	59	2	4	650.30	490.57	159.73

STRATIGRAPHIC PICKS FOR TOP OF CLEARWATER FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
7	31	59	2	4	641.30	492.27	149.03
10	35	59	2	4	641.00	478.85	162.15
10	31	59	4	4	613.10	473.46	139.64
11	8	59	6	4	580.00	452.89	127.11
11	12	59	6	4	578.80	453.50	125.30
7	30	59	6	4	570.00	436.50	133.50
10	36	59	6	4	638.30	505.08	133.22
11	17	59	7	4	638.80	523.60	115.20
8	35	59	7	4	629.70	495.60	134.10
12	15	59	8	4	622.10	507.85	114.25
9	30	59	8	4	621.80	503.86	117.94
6	35	59	8	4	654.40	537.65	116.75
6	15	59	9	4	647.10	534.96	112.14
6	18	59	9	4	642.20	498.02	144.18
2	31	59	9	4	631.90	507.40	124.50
8	7	59	10	4	652.30	567.87	84.43
15	31	59	10	4	638.30	561.54	76.76
11	33	59	10	4	659.80	569.53	90.27
8	19	59	11	4	661.50	578.58	82.92
11	34	59	11	4	640.10	550.21	89.89
7	16	59	12	4	647.50	588.68	58.82
11	31	59	12	4	656.50	600.08	56.42
7	36	59	12	4	641.30	550.14	91.16
11	26	60	1	4	561.40	434.70	126.70
5	16	60	2	4	570.60	419.45	151.15
3	26	60	2	4	605.00	440.14	164.86
10	12	60	3	4	605.60	444.09	161.51
10	13	60	4	4	609.00	462.97	146.03
12	27	60	4	4	582.20	435.92	146.28
11	31	60	4	4	592.20	448.36	143.84
11	29	60	5	4	592.20	449.21	142.99
10	11	60	6	4	591.00	455.06	135.94
11	17	60	6	4	568.80	429.47	139.33
5	30	60	6	4	578.50	441.67	136.83
6	36	60	6	4	577.30	434.60	142.70
10	8	60	7	4	602.50	473.26	129.24
10	13	60	7	4	587.70	442.03	145.67
11	31	60	7	4	620.60	480.07	140.53
6	12	60	8	4	613.00	494.48	118.52
10	17	60	8	4	616.30	484.27	132.03

STRATIGRAPHIC PICKS FOR TOP OF CLEARWATER FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
6	25	60	8	4	612.60	518.45	94.15
6	32	60	8	4	619.40	475.54	143.86
11	11	60	9	4	613.00	487.60	125.40
6	18	60	9	4	614.60	503.66	110.94
10	27	60	9	4	631.90	507.28	124.62
12	33	60	9	4	662.50	533.52	128.98
11	8	60	10	4	660.20	558.40	101.80
10	15	60	10	4	667.80	569.36	98.44
15	26	60	10	4	677.00	569.40	107.60
11	29	60	10	4	657.80	552.00	105.80
10	16	60	11	4	628.50	537.38	91.12
10	18	60	11	4	618.40	540.37	78.03
10	33	60	11	4	702.50	611.41	91.09
12	14	60	12	4	651.70	587.66	64.04
3	18	60	12	4	630.00	573.30	56.70
2	31	60	12	4	613.00	541.10	71.90
11	34	60	12	4	624.50	551.00	73.50
6	36	60	12	4	642.80	555.36	87.44
11	6	61	1	4	557.30	415.22	142.08
11	31	61	1	4	535.80	394.35	141.45
10	33	61	4	4	559.30	401.69	157.61
7	15	61	5	4	551.70	398.96	152.74
3	24	61	5	4	553.20	409.04	144.16
6	34	61	5	4	560.20	405.68	154.52
7	20	61	6	4	555.70	388.70	167.00
10	31	61	6	4	559.60	399.24	160.36
11	36	61	6	4	555.30	397.30	158.00
11	15	61	7	4	576.10	424.04	152.06
10	20	61	7	4	556.90	397.53	159.37
6	25	61	7	4	566.10	411.53	154.57
10	32	61	7	4	585.20	424.27	160.93
10	17	61	8	4	584.30	433.40	150.90
11	23	61	8	4	571.80	412.70	159.10
3	32	61	8	4	563.60	446.60	117.00
11	35	61	8	4	603.50	450.80	152.70
7	14	61	9	4	639.80	494.71	145.09
10	18	61	9	4	634.30	504.43	129.87
7	32	61	9	4	611.70	478.50	133.20
7	34	61	9	4	631.90	485.89	146.01
10	14	61	10	4	654.70	532.47	122.23

STRATIGRAPHIC PICKS FOR TOP OF CLEARWATER FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
2	18	61	10	4	644.30	537.63	106.67
6	34	61	10	4	609.00	486.42	122.58
6	14	61	11	4	662.30	565.97	96.33
6	27	61	11	4	650.70	546.80	103.90
11	30	61	11	4	607.50	506.66	100.84
10	12	61	12	4	626.90	540.00	86.90
6	16	61	12	4	610.00	531.10	78.90
15	29	61	12	4	588.20	490.98	97.22
16	9	62	1	4	550.80	432.84	117.96
10	30	62	1	4	538.30	399.96	138.34
4	18	62	2	4	541.60	373.64	167.96
7	21	62	2	4	545.60	371.87	173.73
10	18	62	3	4	544.10	378.00	166.10
5	21	62	3	4	539.80	372.20	167.60
3	16	62	4	4	562.70	406.60	156.10
10	36	62	4	4	554.70	386.10	168.60
4	13	62	5	4	554.70	398.35	156.35
10	16	62	5	4	558.10	402.30	155.80
11	17	62	6	4	549.20	388.28	160.92
2	35	62	6	4	557.20	399.34	157.86
7	20	62	7	4	577.90	432.22	145.68
6	23	62	7	4	540.40	373.10	167.30
10	31	62	7	4	554.70	401.99	152.71
6	20	62	8	4	552.40	402.43	149.97
7	23	62	8	4	536.80	391.38	145.42
6	35	62	8	4	605.90	452.63	153.27
7	17	62	9	4	615.90	476.59	139.31
9	18	62	9	4	618.40	481.50	136.90
11	23	62	9	4	591.60	452.94	138.66
16	31	62	9	4	618.70	470.60	148.10
2	6	62	10	4	613.40	498.23	115.17
10	22	62	10	4	626.40	493.48	132.92
12	31	62	10	4	643.10	521.76	121.34
6	18	62	11	4	655.30	546.49	108.81
3	25	62	11	4	655.00	538.30	116.70
14	3	62	12	4	622.70	513.30	109.40
10	15	62	12	4	603.70	486.35	117.35
10	16	62	12	4	636.40	517.70	118.70
6	24	62	12	4	647.40	529.15	118.25
11	34	62	12	4	662.50	542.67	119.83

STRATIGRAPHIC PICKS FOR TOP OF CLEARWATER FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
7	3	63	1	4	542.80	427.02	115.78
4	11	63	1	4	531.90	417.65	114.25
10	17	63	2	4	538.90	372.81	166.09
11	5	63	3	4	547.50	381.99	165.51
7	22	63	3	4	542.50	366.91	175.59
7	6	63	4	4	551.10	393.25	157.85
12	10	63	4	4	550.20	399.00	151.20
11	33	63	4	4	558.60	399.54	159.06
10	3	63	5	4	544.00	394.90	149.10
11	6	63	5	4	561.10	412.10	149.00
7	16	63	5	4	557.10	401.20	155.90
9	23	63	6	4	576.10	423.40	152.70
12	36	63	6	4	557.80	391.94	165.86
10	1	63	7	4	560.50	398.94	161.56
6	15	63	7	4	571.50	413.04	158.46
10	26	63	7	4	567.80	407.30	160.50
6	4	63	8	4	573.00	426.41	146.59
7	17	63	8	4	577.50	426.92	150.58
6	25	63	8	4	579.70	462.20	117.50
6	3	63	9	4	596.20	438.06	158.14
7	14	63	9	4	587.00	424.54	162.46
11	20	63	9	4	588.60	442.60	146.00
3	6	63	10	4	599.50	490.35	109.15
10	10	63	10	4	608.70	474.32	134.38
12	18	63	10	4	585.80	453.30	132.50
6	23	63	10	4	596.80	456.30	140.50
7	36	63	10	4	568.00	426.27	141.73
10	9	63	11	4	618.10	493.74	124.36
13	18	63	11	4	595.30	463.60	131.70
2	24	63	11	4	596.20	466.40	129.80
6	26	63	11	4	592.80	459.94	132.86
6	6	63	12	4	605.90	479.39	126.51
9	19	63	12	4	599.80	484.01	115.79
6	22	63	12	4	625.40	497.13	128.27
6	5	64	2	4	551.60	419.10	132.50
5	17	64	2	4	569.70	413.34	156.36
10	3	64	3	4	554.40	395.34	159.06
10	22	64	3	4	607.80	436.82	170.98
6	28	64	3	4	616.60	443.52	173.08
4	8	64	4	4	585.20	427.60	157.60

STRATIGRAPHIC PICKS FOR TOP OF CLEARWATER FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
13	20	64	4	4	577.50	412.03	165.47
13	21	64	4	4	616.60	447.53	169.07
10	17	64	5	4	570.00	427.38	142.62
9	21	64	6	4	612.00	444.96	167.04
16	22	64	6	4	607.50	444.47	163.03
8	2	64	7	4	575.00	412.54	162.46
10	28	64	7	4	603.50	448.70	154.80
15	4	64	8	4	587.90	415.60	172.30
10	22	64	8	4	596.40	433.68	162.72
10	30	64	8	4	603.50	454.10	149.40
7	3	64	9	4	605.90	463.70	142.20
10	5	64	9	4	606.90	468.56	138.34
11	21	64	9	4	628.40	472.64	155.76
9	22	64	9	4	621.80	483.40	138.40
6	6	64	10	4	604.40	464.30	140.10
10	21	64	10	4	595.90	454.80	141.10
5	3	64	11	4	607.40	479.40	128.00
10	22	64	11	4	593.10	453.84	139.26
11	30	64	11	4	624.20	484.30	139.90
6	2	64	12	4	611.70	486.08	125.62
10	6	64	12	4	596.50	470.88	125.62
11	18	64	12	4	588.00	456.95	131.05
9	21	64	12	4	610.90	472.30	138.60
5	29	65	1	4	594.10	420.08	174.02
4	11	65	2	4	547.10	379.17	167.93
12	25	65	2	4	589.20	408.16	181.04
13	35	65	2	4	647.70	473.32	174.38
15	6	65	3	4	601.70	416.09	185.61
10	20	65	3	4	615.70	421.21	194.49
6	11	65	4	4	609.30	418.48	190.82
6	32	65	4	4	650.40	438.70	211.70
10	3	65	5	4	631.90	451.50	180.40
1	29	65	5	4	643.70	451.34	192.36
10	14	65	6	4	645.90	469.15	176.75
4	14	65	7	4	694.00	525.72	168.28
11	30	65	7	4	644.00	477.61	166.39
10	30	65	8	4	615.50	453.50	162.00
12	4	65	9	4	637.60	495.40	142.20
6	11	65	9	4	644.00	496.82	147.18
6	3	65	10	4	649.80	510.25	139.55

STRATIGRAPHIC PICKS FOR TOP OF CLEARWATER FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
LSD	SEC	TP	R	M			
11	8	65	11	4	634.30	493.13	141.17
6	15	65	11	4	604.70	466.61	138.09
4	19	65	11	4	615.40	478.40	137.00
10	23	65	11	4	643.70	498.91	144.79
6	2	65	12	4	612.00	469.69	142.31
11	6	65	12	4	612.60	481.55	131.05
10	18	65	12	4	586.10	456.29	129.81
7	26	65	12	4	594.10	459.00	135.10

Table L-g-1

STRATIGRAPHIC PICKS FOR TOP OF MANNVILLE GROUP
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
LSD	SEC	TP	R	M			
12	10	57	1	4	653.50	444.00	209.50
7	35	57	1	4	660.80	463.35	197.45
2	12	57	2	4	635.70	420.52	215.18
10	25	57	2	4	657.70	437.10	220.60
10	28	57	2	4	639.20	428.00	211.20
4	10	57	3	4	626.10	414.56	211.54
7	30	57	3	4	627.40	405.16	222.24
10	19	57	4	4	645.00	451.76	193.24
11	2	57	5	4	611.70	407.20	204.50
6	26	57	5	4	634.60	417.40	217.20
14	29	57	5	4	654.70	438.29	216.41
13	2	57	6	4	589.50	392.31	197.19
11	29	57	6	4	660.80	447.44	213.36
6	7	57	7	4	628.20	448.37	179.83
11	19	57	7	4	679.70	497.76	181.94
11	23	57	7	4	678.00	494.18	183.82
10	3	57	8	4	660.80	486.16	174.64
11	7	57	8	4	661.40	491.33	170.07
3	22	57	8	4	678.50	504.70	173.80
6	29	57	8	4	655.60	482.46	173.14
6	7	57	9	4	668.70	520.52	148.18
12	10	57	9	4	684.30	552.66	131.64
10	27	57	9	4	642.80	463.53	179.27
10	30	57	9	4	640.10	470.65	169.45
11	3	57	10	4	645.50	508.64	136.86
7	9	57	10	4	638.90	487.98	150.92
6	28	57	10	4	639.50	479.30	160.20
7	10	57	11	4	653.80	504.70	149.10
10	12	57	11	4	634.00	489.22	144.78
10	25	57	11	4	631.90	474.32	157.58
10	28	57	11	4	630.90	480.64	150.26
13	2	57	12	4	631.90	503.00	128.90
6	26	57	12	4	633.60	491.86	141.74
10	28	57	12	4	645.30	501.20	144.10
13	3	58	1	4	680.00	490.76	189.24
7	18	58	1	4	692.50	495.91	196.59
16	27	58	1	4	703.50	503.88	199.62
7	2	58	2	4	648.40	446.30	202.10
10	29	58	2	4	670.00	403.31	266.69
10	22	58	3	4	652.90	417.57	235.33

STRATIGRAPHIC PICKS FOR TOP OF MANNVILLE GROUP
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
6	7	58	4	4	583.10	364.83	218.27
6	36	58	4	4	643.40	426.64	216.76
10	8	58	5	4	657.80	446.92	210.88
6	13	58	5	4	665.40	438.90	226.50
10	24	58	5	4	665.10	436.40	228.70
2	29	58	5	4	696.80	479.13	217.67
11	14	58	6	4	639.40	432.71	206.69
11	25	58	6	4	765.40	552.63	212.77
11	26	58	6	4	707.10	490.95	216.15
7	28	58	6	4	552.60	341.71	210.89
4	5	58	7	4	678.80	480.40	198.40
10	14	58	7	4	677.60	486.15	191.45
13	30	58	7	4	605.20	414.90	190.30
6	8	58	8	4	649.50	471.54	177.96
13	10	58	8	4	598.90	413.61	185.29
11	31	58	8	4	640.40	455.10	185.30
11	12	58	9	4	657.10	477.56	179.54
6	26	58	9	4	674.50	492.99	181.51
10	30	58	9	4	669.70	495.06	174.64
6	3	58	10	4	657.10	495.54	161.56
6	6	58	10	4	638.90	473.80	165.10
15	28	58	10	4	659.90	478.50	181.40
2	34	58	10	4	637.00	454.69	182.31
7	8	58	11	4	637.60	490.97	146.63
5	10	58	11	4	643.40	492.20	151.20
15	24	58	11	4	620.00	456.60	163.40
6	28	58	11	4	627.90	467.90	160.00
1	33	58	11	4	630.00	463.93	166.07
13	9	58	12	4	610.20	458.44	151.76
10	11	58	12	4	617.50	465.30	152.20
10	12	58	12	4	613.90	458.40	155.50
7	28	58	12	4	631.90	475.49	156.41
6	33	58	12	4	636.40	471.85	164.55
6	12	59	1	4	612.10	406.80	205.30
11	21	59	1	4	599.50	374.40	225.10
7	18	59	2	4	650.30	406.45	243.85
7	31	59	2	4	641.30	405.71	235.59
10	35	59	2	4	641.00	395.33	245.67
11	16	59	3	4	628.50	398.42	230.08
11	27	59	3	4	619.00	387.34	231.66

STRATIGRAPHIC PICKS FOR TOP OF MANNVILLE GROUP
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
4	30	59	3	4	615.70	377.93	237.77
10	9	59	4	4	632.50	390.14	242.36
10	31	59	4	4	613.10	378.97	234.13
10	33	59	4	4	627.90	387.80	240.10
11	8	59	5	4	630.30	413.31	216.99
11	8	59	6	4	580.00	360.84	219.16
11	12	59	6	4	578.80	365.50	213.30
7	30	59	6	4	570.00	320.50	249.50
10	36	59	6	4	638.30	416.38	221.92
6	1	59	7	4	639.70	422.02	217.68
11	17	59	7	4	638.80	438.25	200.55
8	35	59	7	4	629.70	402.60	227.10
10	13	59	8	4	619.00	419.66	199.34
12	15	59	8	4	622.10	422.50	199.60
9	30	59	8	4	621.80	409.98	211.82
6	35	59	8	4	654.40	445.60	208.80
6	15	59	9	4	647.10	441.69	205.41
6	18	59	9	4	642.20	456.57	185.63
2	31	59	9	4	631.90	420.40	211.50
8	7	59	10	4	652.30	472.16	180.14
6	10	59	10	4	655.30	473.00	182.30
15	31	59	10	4	638.30	553.00	85.30
11	33	59	10	4	659.80	473.52	186.28
8	19	59	11	4	661.50	478.00	183.50
11	34	59	11	4	640.10	454.51	185.59
7	16	59	12	4	647.50	487.18	160.32
11	31	59	12	4	656.50	497.97	158.53
7	36	59	12	4	641.30	468.45	172.85
7	2	60	1	4	599.20	400.51	198.69
7	17	60	1	4	585.70	382.13	203.57
11	26	60	1	4	561.40	336.70	224.70
7	35	60	1	4	592.50	382.50	210.00
5	16	60	2	4	570.60	331.67	238.93
3	26	60	2	4	605.00	353.58	251.42
10	12	60	3	4	605.60	359.36	246.24
10	32	60	3	4	568.10	316.40	251.70
12	11	60	4	4	601.40	357.28	244.12
10	13	60	4	4	609.00	361.78	247.22
12	27	60	4	4	582.20	332.28	249.92
11	31	60	4	4	592.20	352.04	240.16

STRATIGRAPHIC PICKS FOR TOP OF MANNVILLE GROUP MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
11	29	60	5	4	592.20	354.72	237.48
4	33	60	5	4	562.70	328.65	234.05
11	36	60	5	4	557.50	315.45	242.05
10	11	60	6	4	591.00	363.01	227.99
11	17	60	6	4	568.80	344.73	224.07
5	30	60	6	4	578.50	348.40	230.10
11	33	60	6	4	562.70	293.28	269.42
6	36	60	6	4	577.30	338.10	239.20
10	8	60	7	4	602.50	381.21	221.29
10	13	60	7	4	587.70	448.43	139.27
11	31	60	7	4	620.60	389.24	231.36
6	12	60	8	4	613.00	397.86	215.14
10	17	60	8	4	616.30	393.44	222.86
6	25	60	8	4	612.60	402.01	210.59
6	32	60	8	4	619.40	384.10	235.30
11	11	60	9	4	613.00	393.60	219.40
6	18	60	9	4	614.60	404.29	210.31
10	27	60	9	4	631.90	410.36	221.54
12	33	60	9	4	662.50	442.08	220.42
11	8	60	10	4	660.20	465.74	194.46
10	15	60	10	4	667.80	465.11	202.69
15	26	60	10	4	677.00	465.40	211.60
11	29	60	10	4	657.80	455.68	202.12
10	16	60	11	4	628.50	433.13	195.37
10	18	60	11	4	618.40	437.96	180.44
10	33	60	11	4	702.50	510.21	192.29
12	14	60	12	4	651.70	480.98	170.72
3	18	60	12	4	630.00	465.30	164.70
2	31	60	12	4	613.00	439.91	173.09
11	34	60	12	4	624.50	448.89	175.61
6	36	60	12	4	642.80	451.42	191.38
11	6	61	1	4	557.30	335.06	222.24
4	13	61	1	4	544.70	306.31	238.39
11	31	61	1	4	535.80	319.67	216.13
6	34	61	1	4	562.10	341.30	220.80
14	36	61	2	4	539.40	320.55	218.85
11	9	61	3	4	550.50	300.90	249.60
10	13	61	3	4	559.90	309.93	249.97
10	34	61	3	4	562.10	304.40	257.70
6	20	61	4	4	560.20	317.30	242.90

STRATIGRAPHIC PICKS FOR TOP OF MANNVILLE GROUP
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
10	33	61	4	4	559.30	314.22	245.08
7	15	61	5	4	551.70	306.61	245.09
3	24	61	5	4	553.20	309.67	243.53
6	34	61	5	4	560.20	314.24	245.96
10	36	61	5	4	558.70	308.79	249.91
10	13	61	6	4	554.10	312.72	241.38
7	20	61	6	4	555.70	305.79	249.91
10	31	61	6	4	559.60	302.62	256.98
11	36	61	6	4	555.30	306.30	249.00
11	15	61	7	4	576.10	325.89	250.21
10	20	61	7	4	556.90	304.57	252.33
6	25	61	7	4	566.10	316.12	249.98
10	32	61	7	4	585.20	327.65	257.55
10	17	61	8	4	584.30	339.40	244.90
11	23	61	8	4	571.80	320.34	251.46
3	32	61	8	4	563.60	319.60	244.00
11	35	61	8	4	603.50	354.80	248.70
7	14	61	9	4	639.80	401.14	238.66
10	18	61	9	4	634.30	409.95	224.35
7	32	61	9	4	611.70	380.05	231.65
7	34	61	9	4	631.90	386.22	245.68
10	14	61	10	4	654.70	434.32	220.38
2	18	61	10	4	644.30	437.05	207.25
6	34	61	10	4	609.00	435.87	173.13
6	14	61	11	4	662.30	462.33	199.97
6	27	61	11	4	650.70	446.22	204.48
11	30	61	11	4	607.50	405.47	202.03
10	12	61	12	4	626.90	434.84	192.06
6	16	61	12	4	610.00	451.10	158.90
15	29	61	12	4	588.20	387.35	200.85
16	9	62	1	4	550.80	347.19	203.61
10	19	62	1	4	549.20	326.06	223.14
10	30	62	1	4	538.30	304.25	234.05
4	18	62	2	4	541.60	280.98	260.62
7	21	62	2	4	545.60	277.69	267.91
11	36	62	2	4	541.60	314.56	227.04
10	18	62	3	4	544.10	283.82	260.28
5	21	62	3	4	539.80	276.19	263.61
3	16	62	4	4	562.70	309.07	253.63
10	36	62	4	4	554.70	293.10	261.60

STRATIGRAPHIC PICKS FOR TOP OF MANNVILLE GROUP
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
4	13	62	5	4	554.70	301.42	253.28
10	16	62	5	4	558.10	312.30	245.80
12	12	62	6	4	559.60	328.89	230.71
11	17	62	6	4	549.20	292.27	256.93
2	35	62	6	4	557.20	302.72	254.48
7	20	62	7	4	577.90	333.16	244.74
6	23	62	7	4	540.40	277.70	262.70
10	31	62	7	4	554.70	301.71	252.99
6	20	62	8	4	552.40	298.80	253.60
7	23	62	8	4	536.80	287.74	249.06
6	35	62	8	4	605.90	350.83	255.07
7	17	62	9	4	615.90	373.87	242.03
9	18	62	9	4	618.40	373.50	244.90
11	23	62	9	4	591.60	351.44	240.16
16	31	62	9	4	618.70	368.60	250.10
2	6	62	10	4	613.40	393.38	220.02
10	22	62	10	4	626.40	387.41	238.99
12	31	62	10	4	643.10	416.30	226.80
6	18	62	11	4	655.30	440.72	214.58
3	25	62	11	4	655.00	431.31	223.69
14	3	62	12	4	622.70	413.30	209.40
10	15	62	12	4	603.70	386.68	217.02
10	16	62	12	4	636.40	414.70	221.70
6	24	62	12	4	647.40	425.82	221.58
11	34	62	12	4	662.50	437.51	224.99
7	3	63	1	4	542.80	320.95	221.85
4	11	63	1	4	531.90	313.71	218.19
5	6	63	2	4	537.70	275.32	262.38
10	17	63	2	4	538.90	279.54	259.36
5	2	63	3	4	545.70	288.14	257.56
11	5	63	3	4	547.50	285.37	262.13
7	22	63	3	4	542.50	266.94	275.56
7	6	63	4	4	551.10	294.19	256.91
12	10	63	4	4	550.20	302.07	248.13
8	14	63	4	4	551.40	289.32	262.08
4	30	63	4	4	573.00	318.45	254.55
11	33	63	4	4	558.60	304.44	254.16
10	3	63	5	4	544.00	294.40	249.60
11	6	63	5	4	561.10	311.10	250.00
7	16	63	5	4	557.10	303.20	253.90

STRATIGRAPHIC PICKS FOR TOP OF MANNVILLE GROUP
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
9	25	63	5	4	595.00	344.33	250.67
9	23	63	6	4	576.10	318.40	257.70
12	36	63	6	4	557.80	292.58	265.22
10	1	63	7	4	560.50	301.40	259.10
6	15	63	7	4	571.50	314.28	257.22
10	26	63	7	4	567.80	308.30	259.50
6	4	63	8	4	573.00	318.21	254.79
10	5	63	8	4	572.10	318.53	253.57
7	17	63	8	4	577.50	319.63	257.87
6	3	63	9	4	596.20	345.40	250.80
7	14	63	9	4	587.00	331.88	255.12
11	20	63	9	4	588.60	340.50	248.10
3	6	63	10	4	599.50	388.60	210.90
10	10	63	10	4	608.70	371.30	237.40
12	18	63	10	4	585.80	343.30	242.50
6	23	63	10	4	596.80	355.30	241.50
7	36	63	10	4	568.00	323.86	244.14
10	9	63	11	4	618.10	389.50	228.60
13	18	63	11	4	595.30	352.60	242.70
2	24	63	11	4	596.20	307.40	288.80
6	26	63	11	4	592.80	355.70	237.10
6	6	63	12	4	605.90	381.85	224.05
9	19	63	12	4	599.80	371.84	227.96
6	22	63	12	4	625.40	391.97	233.43
6	5	64	2	4	551.60	313.80	237.80
5	17	64	2	4	569.70	311.23	258.47
10	3	64	3	4	554.40	293.54	260.86
10	22	64	3	4	607.80	337.45	270.35
6	28	64	3	4	616.60	343.24	273.36
4	8	64	4	4	585.20	331.90	253.30
13	20	64	4	4	577.50	309.00	268.50
10	17	64	5	4	570.00	320.70	249.30
9	21	64	6	4	612.00	339.50	272.50
16	22	64	6	4	607.50	336.27	271.23
8	2	64	7	4	575.00	311.95	263.05
4	5	64	7	4	568.50	307.03	261.47
10	28	64	7	4	603.50	340.70	262.80
15	4	64	8	4	587.90	315.10	272.80
10	22	64	8	4	596.40	334.01	262.39
10	30	64	8	4	603.50	354.10	249.40

STRATIGRAPHIC PICKS FOR TOP OF MANNVILLE GROUP
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
7	3	64	9	4	605.90	355.70	250.20
10	5	64	9	4	606.90	367.37	239.53
11	21	64	9	4	628.40	369.01	259.39
9	22	64	9	4	621.80	369.40	252.40
6	6	64	10	4	604.40	359.30	245.10
10	21	64	10	4	595.90	345.70	250.20
5	3	64	11	4	607.40	361.74	245.66
10	22	64	11	4	593.10	342.90	250.20
11	30	64	11	4	624.20	370.00	254.20
6	2	64	12	4	611.70	374.52	237.18
10	6	64	12	4	596.50	361.76	234.74
11	18	64	12	4	588.00	345.39	242.61
9	21	64	12	4	610.90	364.30	246.60
5	29	65	1	4	594.10	308.83	285.27
4	11	65	2	4	547.10	271.28	275.82
12	25	65	2	4	589.20	299.66	289.54
13	35	65	2	4	647.70	363.28	284.42
15	6	65	3	4	601.70	320.38	281.32
10	20	65	3	4	615.70	320.63	295.07
6	11	65	4	4	609.30	314.24	295.06
6	32	65	4	4	650.40	339.20	311.20
10	3	65	5	4	631.90	344.21	287.69
1	29	65	5	4	643.70	351.06	292.64
10	14	65	6	4	645.90	358.82	287.08
4	14	65	7	4	694.00	420.87	273.13
11	30	65	7	4	644.00	368.19	275.81
10	30	65	8	4	615.50	346.50	269.00
12	4	65	9	4	637.60	379.90	257.70
6	11	65	9	4	644.00	389.83	254.17
6	3	65	10	4	649.80	402.35	247.45
11	8	65	11	4	634.30	379.14	255.16
6	15	65	11	4	604.70	358.11	246.59
4	19	65	11	4	615.40	360.40	255.00
10	23	65	11	4	643.70	392.83	250.87
6	2	65	12	4	612.00	358.74	253.26
11	6	65	12	4	612.60	368.47	244.13
10	18	65	12	4	586.10	350.83	235.27
7	26	65	12	4	594.10	346.00	248.10

Table L-c-1

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
7	4	55	1	4	185.6	18723	2402	874	35500	181	86	57766	1.0430	0.1230	7.70
10	20	55	1	4	179.8	20917	2132	851	38300	354	3	62557	1.0390	0.1280	8.20
7	22	55	1	4	145.1	21513	2234	1055	40100	146	23	65071	1.0470	0.1230	6.90
7	30	55	1	4	198.4	21036	1902	917	38300	195	86	62436	1.0430	0.1230	6.90
4	18	55	2	4	156.7	19650	2046	1091	37000	149	21	59957	1.0420	0.1350	7.00
11	6	55	4	4	133.7	22135	1760	841	39600	104	51	64491	1.0420	0.1230	7.40
6	31	55	4	4	206.9	19084	1658	904	34900	142	19	56707	1.0390	0.1260	7.40
1	7	55	5	4	173.6	17380	1653	882	32169	202	13	52299	1.0370	0.1400	7.30
10	7	55	5	4	131.1	21942	1970	768	39400	177	76	64333	1.0420	0.1320	7.40
2	13	55	5	4	200.6	17128	1654	897	31800	229	27	51735	1.0370	0.1370	7.70
7	29	55	5	4	61.8	22149	1778	1081	40200	409	19	65636	1.0440	0.1110	7.50
2	4	55	6	4	170.4	20080	1850	799	36400	232	43	59404	1.0380	0.1280	7.30
10	36	55	6	4	181.0	20075	1778	889	36550	193	43	59528	1.0430	0.1320	7.10
7	29	55	7	4	154.6	23168	2101	870	41850	220	1	68210	1.0466	0.1060	6.70
10	30	55	7	4	12.5	21163	1425	719	37000	376	45	60728	1.0430	0.1240	6.90
15	36	55	7	4	100.9	22760	1768	758	40250	254	49	65839	1.0460	0.1180	7.50
6	8	55	8	4	94.9	22756	2082	948	41400	218	16	67420	1.0480	0.1110	7.50
6	8	55	8	4	96.8	24416	2190	1025	44400	171	19	72221	1.0520	0.1110	7.50
10	11	55	8	4	140.2	23174	1986	904	41700	220	76	68060	1.0500	0.1010	7.20
10	11	55	8	4	88.7	24157	2106	880	43400	210	28	70781	1.0510	0.0960	7.20
10	19	55	8	4	147.8	21978	2321	938	40606	181	28	66052	1.0461	0.1300	7.00
10	35	55	8	4	113.7	22917	1885	810	40881	220	35	66748	1.0451	0.1040	6.80
15	1	55	9	4	142.6	23871	2202	851	43000	270	41	70235	1.0520	0.1160	7.00

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS,
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO	SO	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)				3	4	(calc)	(60F)	(ohm m)	
8	17	55	9	4	135.0	25772	2322	948	46500	173	16	75731	1.0520	0.1190	7.50
6	25	55	9	4	10.3	21786	2010	1101	40200	230	37	65364	1.0430	0.1170	7.20
4	13	55	11	4	109.6	23859	2466	841	43500	173	8	70847	1.0450	0.1080	6.50
4	13	55	11	4	109.6	23859	2466	841	43500	173	8	70847	1.0450	0.1080	6.50
11	11	55	12	4	97.4	22548	2001	867	40700	210	20	66346	1.0490	0.1390	7.20
11	11	55	12	4	97.4	27251	2379	760	48285	234	35	78944	1.0560	0.1130	6.80
11	23	55	12	4	73.3	20133	1858	617	35950	268	35	58861	1.0420	0.1220	7.60
5	34	55	12	4	77.9	21458	1810	685	38154	200	25	62332	1.0460		
16	1	55	13	4	97.9	23116	2226	880	42000	154	82	68458	1.0480	0.1160	7.90
11	18	55	13	4	78.6	24129	2291	734	43300	168	5	70627	1.0510	0.1100	7.40
16	27	55	13	4	87.3	21714	2100	900	39700	195	12	64621	1.0510	0.1059	6.42
16	27	55	13	4	87.3	23516	1900	850	41900	332	13	68512	1.0530	0.1036	6.46
7	29	55	13	4	89.6	22764	1944	882	40881	400	1	66872	1.0461	0.1030	6.90
10	34	55	13	4	96.7	20042	2002	923	37000	200	31	60198	1.0450	0.1630	7.70
9	13	55	14	4	83.7	23838	2370	734	42900	283	37	70162	1.0480	0.1100	5.90
10	26	55	14	4	103.4	20078	1700	600	35400	499	37	58315	1.0450	0.1184	7.50
7	32	55	14	4	89.6	21158	1768	738	37707	342	1	61714	1.0427	0.1300	7.00
11	20	55	15	4	71.9	23901	2202	705	42700	120	51	69679	1.0500	0.1110	6.80
1	21	55	15	4	46.5	22682	1810	967	40700	429	66	66654	1.0420	0.1220	7.90
14	28	55	15	4	82.0	26792	1700	800	46500	215	40	76047	1.0550	0.1066	6.83
14	28	55	15	4	82.0	26792	1700	800	46500	215	40	76047	1.0550	0.1066	6.83
7	35	55	15	4	78.9	23199	1966	841	41500	342	7	67855	1.0530	0.1360	7.00
13	35	55	15	4	80.4	22405	2074	962	40800	342	33	66616	1.0460	0.1190	7.30

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
13	35	55	15	4	85.0	22893	2058	914	41400	301	45	67611	1.0470	0.1180	7.10
11	25	55	16	4	60.3	23521	2130	710	42000	142	35	68538	1.0460	0.1110	7.10
11	12	55	17	4	7.3	20801	1590	661	36700	160	31	59943	1.0470	0.1440	7.20
4	34	55	17	4	51.3	19522	1481	556	34100	394	21	56074	1.0360	0.1390	7.40
10	8	56	5	4	98.4	23926	2122	1112	43750	122	95	71127	1.0430	0.0980	7.00
7	2	56	6	4	55.7	25861	2282	1015	46700	275	21	76154	1.0510	0.1010	7.20
6	8	56	6	4	170.1	20566	1678	787	36850	190	23	60094	1.0480		
10	17	56	6	4	45.2	21997	1906	770	39300	354	43	64370	1.0440	0.1090	7.50
7	25	56	6	4	109.8	19101	1281	587	33350	134	6	54459	1.0360	0.1530	7.80
7	25	56	6	4	183.8	19074	1614	766	34350	215	37	56056	1.0340	1.4000	7.40
15	31	56	6	4	182.6	16893	1357	741	30458	230	27	49706	1.0370	0.1580	6.50
7	24	56	7	4	43.3	19199	1481	626	33800	348	66	55520	1.0380	0.1340	7.80
7	24	56	7	4	36.0	16220	1071	632	28550	287	45	46805	1.0330	0.1520	7.80
7	24	56	7	4	37.1	17751	1101	608	30950	211	29	50650	1.0350	0.1400	7.70
7	18	56	8	4	43.3	21304	1522	821	37700	329	63	61739	1.0400	0.1120	6.90
7	18	56	8	4	43.3	21304	1522	821	37700	329	63	61739	1.0400	0.1120	6.90
6	13	56	9	4	119.3	22431	1712	880	40000	195	95	65313	1.0470	0.1190	6.10
10	19	56	10	4	136.2	18903	1886	847	34800	171	76	56683	1.0420	0.1360	7.10
3	5	56	12	4	110.8	21625	2000	850	39200	264	12	63951	1.0490	0.1112	6.64
6	14	56	12	4	125.8	25232	2110	962	45300	162	71	73837	1.0450	0.1120	7.50
7	32	56	13	4	109.4	23338	2074	748	41700	200	29	68089	1.0490	0.1340	6.80
7	2	56	14	4	102.4	20299	1522	729	35900	365	10	58825	1.0360	0.1440	6.80
7	2	56	14	4	102.4	24966	2154	933	44900	221	2	73176	1.0460	0.1190	6.80

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS,
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
7	2	56	14	4	60.8	21822	2035	742	39200	300	53	64152	1.0460	0.1310	8.00
6	10	56	14	4	61.1	26996	2362	948	48500	107	12	78925	1.0570	0.1070	6.90
8	10	56	14	4	98.3	20621	1900	700	37100	146	22	60489	1.0440	0.1190	6.60
8	10	56	14	4	62.3	24474	2571	1011	45100	203	23	73382	1.0480	0.1100	7.00
8	11	56	14	4	99.8	25035	2382	831	45100	201	33	73582	1.0490	0.1160	7.30
10	14	56	14	4	93.6	22347	1996	869	40400	137	60	65809	1.0480	0.1320	8.00
7	35	56	14	4	97.6	22901	1922	756	40800	171	25	66575	1.0470	0.1140	8.00
7	1	56	15	4	85.6	22913	2226	680	41000	371	51	67241	1.0430	0.1120	7.80
4	13	56	16	4	67.2	21515	2286	639	39000	128	12	63580	1.0460	0.1120	6.80
13	20	56	16	4	71.5	22775	2042	705	40700	130	16	66368	1.0480	0.1120	7.50
16	34	56	16	4	68.8	20070	1716	723	36000	139	16	58664	1.0400	0.1210	6.70
9	35	56	16	4	85.5	18423	1540	609	32800	173	12	53557	1.0350	0.1350	6.90
4	6	56	17	4	7.6	19630	1690	656	35000	232	51	57259	1.0370	0.1310	7.90
7	32	57	2	4	207.8	16563	1682	899	30880	366	61	50451	1.0330	0.1340	7.10
7	30	57	3	4	210.4	17832	1834	761	32800	240	30	53497	1.0430	0.1540	7.80
5	32	57	3	4	216.9	18725	1862	851	34500	193	51	56182	1.0390	0.1400	7.00
2	25	57	4	4	157.5	19089	1654	700	34200	291	45	55979	1.0400	0.1260	7.90
11	21	57	5	4	215.7	18543	1598	730	33423	211	5	54510	1.0359	0.1520	6.90
6	24	57	5	4	199.2	14713	1135	540	26100	232	49	42769	1.0300	0.1510	8.00
6	26	57	5	4	216.4	12986	1037	454	23000	283	25	37785	1.0260	0.1740	7.60
11	23	57	7	4	177.6	17753	1361	510	31100	244	38	51006	1.0360	0.1350	7.60
10	32	57	7	4	177.8	16828	1300	560	29735	220	26	48669	1.0345	0.1560	7.50
14	10	57	8	4	168.6	15654	999	493	27200	191	45	44582	1.0310	0.1590	7.40

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO	SO	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)				3	4	(calc)	(60F)	(ohm m)	
11	12	57	8	4	179.3	18718	1285	503	32500	151	21	53178	1.0380	0.1440	7.50
1	15	57	9	4	166.4	14148	1085	603	25300	309	21	41466	1.0260	0.1690	7.90
1	15	57	9	4	119.4	19025	1241	588	33100	242	8	54204	1.0380	0.1520	7.80
11	5	57	11	4	116.6	23310	2074	807	41900	112	2	68205	1.0460	1.0900	6.50
10	28	57	11	4	148.8	17169	1369	711	30800	190	82	50321	1.0360	0.1510	7.70
10	28	57	11	4	148.8	16540	1278	537	29200	200	21	47776	1.0360	0.1440	7.60
10	32	57	12	4	134.1	19325	1702	668	34675	128	12	56510	1.0400	0.1300	7.70
7	35	57	12	4	133.2	18868	1710	657	33905	210	11	55361	1.0364	0.1280	7.80
1	6	57	13	4	105.6	16197	1401	527	28900	120	29	47174	1.0320	0.1510	7.30
6	29	57	13	4	64.0	16858	1257	500	29505	249	38	48407	1.0334	0.1610	7.80
7	35	57	13	4	128.9	19199	1613	637	34200	171	23	55843	1.0380	0.1270	7.50
6	6	57	16	4	59.8	19326	1534	654	34300	205	4	56023	1.0400	0.1310	7.20
11	28	57	16	4	80.4	19266	1409	602	33750	244	89	55360	1.0400	0.1300	7.60
7	34	57	16	4	90.0	20606	1502	656	36200	222	21	59207	1.0420	0.1350	7.70
7	34	57	16	4	90.8	19902	1441	644	35000	198	2	57187	1.0400	0.1480	6.90
15	34	57	16	4	51.9	21451	1341	237	36050	138	16	59233	1.0380	0.1400	7.50
16	1	57	17	4	66.6	16888	1391	686	30400	116	49	49530	1.0300	0.1410	6.50
9	2	57	17	4	60.6	19402	1642	680	34700	157	21	56602	1.0380	0.1430	7.50
10	34	57	17	4	80.6	16923	1272	566	29851	224	21	48857	1.0365	0.1400	7.00
7	11	58	1	4	181.4	10909	621	287	18620	130	84	30651	1.0220	0.2160	7.90
7	11	58	1	4	186.4	10846	609	295	18560	146	25	30481	1.0220	0.2120	7.90
5	21	58	1	4	146.0	12775	937	462	22600	155	19	36948	1.0240	0.1880	7.80
15	30	58	2	4	228.0	17121	1738	620	31150	179	41	50849	1.0360	0.1380	7.30

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
15	30	58	2	4	235.0	16470	1706	868	30850	138	21	50053	1.0380	0.1350	7.40
15	30	58	2	4	228.3	17388	1562	814	31850	165	6	51785	1.0320	0.1650	7.80
4	8	58	3	4	140.4	20119	1654	729	35900	228	58	58688	1.0400	0.1250	7.40
15	11	58	4	4	224.9	15774	1431	644	28500	285	91	46725	1.0320	0.1470	7.20
7	21	58	4	4	183.3	15348	1401	442	27300	173	47	44711	1.0300	0.1510	7.00
7	21	58	4	4	219.3	17548	1365	576	31000	262	2	50753	1.0360	0.1390	7.30
6	22	58	4	4	218.3	14842	1484	507	26916	122	6	43877	1.0309	0.1530	6.60
6	22	58	4	4	210.0	13493	1066	671	24458	317	10	40015	1.0303	0.1570	7.20
10	28	58	4	4	172.2	16132	1321	525	28574	180	88	46820	1.0318	0.1450	7.10
10	28	58	4	4	213.7	16114	1392	562	28724	314	58	47164	1.0320	0.1450	7.30
1	33	58	4	4	198.7	14874	1251	643	26900	171	33	43872	1.0309	0.1550	7.50
3	9	58	5	4	218.6	14520	1001	680	25975	259	25	42460	1.0300	0.1630	7.90
10	17	58	5	4	154.6	16134	1081	473	27950	293	69	46000	1.0340	0.1560	7.60
10	21	58	6	4	153.8	13552	743	366	23138	218	21	38038	1.0260	0.1890	7.90
11	25	58	6	4	133.7	15279	694	324	25600	166	51	42114	1.0310	0.1850	7.90
6	12	58	8	4	181.6	13869	923	462	24200	195	72	39721	1.0290	0.1870	7.70
15	19	58	8	4	170.5	14273	1137	639	25750	203	23	42025	1.0250	0.1740	7.20
11	31	58	8	4	201.4	12341	797	355	21300	203	79	35075	1.0300	0.1730	8.00
7	18	58	10	4	114.5	12512	562	270	20950	210	6	34510	1.0260	0.2150	7.70
15	7	58	11	4	147.1	13724	695	322	23100	374	19	38234	1.0240	0.1800	7.90
10	12	58	11	4	116.1	9802	581	277	16760	256	58	27734	1.0180	0.2500	8.00
6	31	58	11	4	97.5	11742	755	313	20150	327	21	33308	1.0250	0.1700	7.80
1	33	58	11	4	154.5	12156	792	308	20843	217	102	34418	1.0230		7.90

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS,
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO 3	SO 4	TDS (calc)	DENSITY (60F)	RESIST. (onm m)	pH
10	22	58	12	4	143.5	14808	1498	206	25906	298	8	42724	1.0275	0.1620	7.85
6	6	58	13	4	114.2	17365	1425	505	30600	251	33	50179	1.0350	0.1420	7.40
16	6	58	13	4	138.6	14387	1304	569	26000	246	12	42518	1.0300	0.1600	8.00
7	8	58	13	4	145.4	17379	1506	578	31000	212	35	50710	1.0370	0.1560	7.40
10	10	58	13	4	138.9	16519	1281	517	29100	200	41	47658	1.0350	0.1630	6.90
6	13	58	13	4	125.4	14861	1101	486	26050	293	82	42873	1.0310	0.1630	7.20
6	13	58	13	4	91.4	17886	1337	591	31450	268	86	51618	1.0360	0.1400	7.20
6	23	58	13	4	113.4	16115	1302	522	28450	320	54	46763	1.0330	0.1470	8.10
6	23	58	13	4	92.2	16390	1322	353	28500	170	58	46793	1.0030	0.1470	7.70
15	5	58	14	4	114.4	13747	1311	595	25075	238	53	41019	1.0310	0.1590	7.30
5	5	58	15	4	110.6	19974	1642	772	35800	238	25	58451	1.0310	0.1170	7.10
5	5	58	15	4	71.6	17737	1180	554	30800	343	74	50688	1.0340	0.1320	6.90
5	5	58	15	4	110.6	18560	1311	564	32400	275	33	53143	1.0360	0.1330	6.90
5	5	58	15	4	110.6	19038	1305	549	33100	261	21	54274	1.0370	0.1410	7.10
6	12	58	15	4	84.4	19611	1572	686	34850	269	21	57009	1.0400	0.1230	7.40
10	7	58	16	4	50.6	18194	1391	577	32050	178	62	52452	1.0340	0.1430	7.40
6	1	58	17	4	41.5	19414	1301	588	33850	166	10	55329	1.0390	0.1360	7.10
10	9	58	17	4	79.6	18423	1354	597	32400	224	21	53019	1.0380	0.1320	7.60
10	34	58	17	4	52.9	17976	1397	588	31800	124	45	51930	1.0340	0.1420	7.40
6	35	58	17	4	67.3	15001	1226	519	26600	290	62	43698	1.0320	0.1490	7.30
11	6	59	2	4	238.8	12851	991	431	22750	115	14	37152	1.0260	0.1610	7.60
10	35	59	2	4	240.5	13893	901	389	24070	110	25	39388	1.0280	0.1870	7.50
10	35	59	2	4	240.5	13893	901	389	24070	110	25	39388	1.0280	0.1870	7.50

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
9	13	59	3	4	230.8	14906	1011	498	26100	179	31	42725	1.0320	0.1630	7.70
4	30	59	3	4	233.2	13176	812	422	22816	268	18	37512	1.0259	0.2010	7.20
11	10	59	4	4	201.2	15734	1185	569	27850	263	20	45621	1.0328	0.1320	5.70
11	7	59	5	4	203.5	14652	797	412	25000	244	86	41191	1.0290	0.1490	8.10
11	16	59	5	4	175.0	15522	1001	486	27000	208	3	44220	1.0320	0.1480	7.50
6	17	59	5	4	203.1	14426	989	476	25250	200	23	41364	1.0300	0.2490	6.90
6	2	59	6	4	156.1	14861	841	388	25300	305	79	41774	1.0310	0.1560	7.70
13	5	59	6	4	167.0	13923	650	334	23400	238	74	38620	1.0270	0.1800	7.57
10	20	59	8	4	198.4	14909	1033	505	26150	203	31	42831	1.0320	0.1640	7.70
11	29	59	8	4	154.3	14556	889	365	24810	398	56	41074	1.0300	0.1750	8.00
12	34	59	8	4	142.2	11563	665	338	19700	427	61	32754	1.0230	0.1910	8.00
6	35	59	8	4	208.1	15017	1041	388	26000	181	33	42660	1.0300	0.1460	7.50
8	4	59	9	4	148.3	14571	841	425	25050	187	51	41125	1.0280	0.1610	6.80
10	6	59	9	4	179.6	10519	951	147	18114	342	25	30098	1.0207	0.2150	7.10
7	8	59	9	4	190.5	14180	809	323	24150	122	25	39609	1.0280	0.1900	8.20
7	8	59	9	4	168.2	13242	761	481	23020	218	29	37751	1.0280	0.1970	8.00
6	4	59	10	4	175.6	15262	500	400	25500	137	7	41806	1.0310	0.1643	7.14
8	7	59	10	4	178.9	14093	776	366	24050	149	49	39483	1.0290	0.1850	7.30
8	7	59	10	4	176.9	14997	651	300	25020	190	29	41187	1.0300	0.1890	7.80
8	7	59	10	4	176.9	14848	650	310	24810	198	35	40851	1.0290	0.1900	7.80
8	7	59	10	4	176.9	14752	680	326	24800	166	8	40732	1.0300	0.1880	6.90
10	18	59	11	4	180.6	12755	741	406	22000	234	37	36173	1.0240	0.1860	7.90
10	29	59	11	4	185.8	12737	841	258	21750	217	6	35809	1.0250	0.1950	7.30

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS,
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
6	3	59	12	4	148.0	13885	1109	292	24100	210	4	39600	1.0310	0.2560	8.00
11	33	59	12	4	170.6	14491	791	328	24500	305	33	40448	1.0300	0.1750	8.30
15	8	59	13	4	145.7	14240	1049	418	24900	195	28	40830	1.0290	0.1670	7.60
15	8	59	13	4	51.7	13660	733	374	23225	354	28	38374	1.0270	0.1750	7.80
6	11	59	13	4	140.4	13045	729	403	22350	366	25	36918	1.0260	0.1910	8.30
10	18	59	13	4	147.1	13455	915	422	23200	574	86	38652	1.0280	0.1810	8.10
6	27	59	13	4	101.7	14261	605	325	23640	535	80	39446	1.0290	0.1900	7.50
13	2	59	14	4	85.4	17359	1666	496	31050	185	6	50762	1.0350	0.1590	6.80
12	8	59	14	4	137.1	18370	1642	744	33300	165	8	54229	1.0350	0.1390	7.00
7	31	59	14	4	145.1	18370	1642	744	33300	165	8	54229	1.0350	0.1390	7.00
7	32	59	14	4	145.7	17195	1634	406	30500	153	2	49890	1.0340	0.1450	7.40
11	3	59	15	4	92.2	18244	1145	595	31600	352	76	52040	1.0380	0.1340	8.50
10	8	59	15	4	132.8	18166	1487	626	32400	107	8	52794	1.0360	0.1290	7.10
6	9	59	15	4	74.9	18300	1253	625	32100	212	47	52537	1.0380	0.1460	7.50
6	21	59	15	4	130.1	17151	1412	634	30700	107	43	50047	1.0360	0.1420	7.60
6	21	59	15	4	137.1	17051	1519	652	30800	134	6	50162	1.0360	0.1400	7.30
10	30	59	15	4	89.8	18428	1764	804	33780	146	22	54944	1.0420	0.1260	6.55
10	33	59	15	4	89.8	17734	1417	728	31832	229	15	51955	1.0380	0.1200	7.60
10	33	59	15	4	142.9	20403	1378	829	36200	166	29	59005	1.0430	0.1300	7.90
3	6	59	16	4	109.3	15520	1158	487	27250	207	41	44663	1.0310	0.1520	7.60
11	11	59	16	4	118.8	19019	1221	790	33700	110	37	54877	1.0380	0.1300	7.40
10	15	59	16	4	93.7	17976	1280	776	32140	180	2	52354	1.0380		6.71
5	19	59	16	4	117.9	16488	1465	607	29700	134	12	48406	1.0340	0.1390	7.10

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
11	24	59	16	4	132.9	15638	1181	613	27858	191	29	45510	1.0340	0.1340	6.60
10	33	59	16	4	90.1	15223	1255	540	27161	156	23	44358	1.0292	0.1480	6.70
11	24	59	17	4	113.7	18240	1392	592	32200	159	31	52614	1.0380	0.1470	7.10
7	17	60	1	4	185.4	9366	452	244	15790	230	41	26123	1.0190	0.2590	8.00
9	15	60	2	4	252.6	14491	1001	504	25450	232	2	41680	1.0300	0.1710	7.10
9	15	60	2	4	252.6	14491	1001	504	25450	232	2	41680	1.0300	0.1710	7.10
9	22	60	2	4	202.4	14227	1015	514	25100	200	23	41079	1.0270	0.1720	7.30
10	12	60	3	4	241.1	13805	855	399	23800	276	4	39139	1.0290	0.1920	7.50
6	36	60	4	4	215.9	14187	945	525	24900	232	60	40849	1.0300	0.1670	7.70
7	9	60	6	4	196.9	13249	697	383	22600	266	35	37230	1.0240	0.1770	7.80
11	17	60	6	4	173.6	11624	653	317	19740	395	47	32776	1.0250	0.1970	7.80
6	24	60	6	4	201.4	12679	821	492	22175	397	45	36609	1.0300	0.1800	7.80
10	26	60	6	4	189.6	14120	721	365	23900	295	58	39459	1.0280	0.1720	8.00
10	27	60	6	4	145.5	14890	729	460	25440	234	21	41774	1.0280	0.1620	7.60
10	27	60	6	4	197.0	14578	701	395	24700	203	74	40651	1.0260	0.1730	7.80
10	8	60	7	4	215.4	10442	553	231	17600	220	35	29081	1.0210	0.2430	8.30
12	8	60	7	4	199.9	11851	637	253	20000	175	51	32967	1.0180	0.2130	7.70
10	20	60	7	4	136.0	14807	737	637	25800	298	29	42308	1.0320	0.1610	7.60
10	20	60	7	4	214.8	10562	456	279	17700	282	43	29332	1.0220	0.2340	8.40
4	22	60	7	4	213.3	13889	674	306	23300	317	25	38511	1.0200	0.1800	7.70
3	32	60	7	4	183.9	11252	519	281	18900	222	80	31254	1.0160	0.2530	7.70
10	2	60	9	4	210.4	13193	650	268	22085	215	89	36500	1.0258	0.2200	7.40
11	17	60	9	4	199.6	10482	436	265	17500	348	7	29038	1.0170	0.2280	8.10

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
7	25	60	9	4	217.1	13062	657	332	22080	320	9	36460	1.0260	0.1930	7.90
10	27	60	9	4	187.1	13190	593	258	22020	160	38	36259	1.0260	0.2680	8.30
12	33	60	9	4	219.2	9670	444	205	16000	427	64	26810	1.0210	0.2490	7.90
10	18	60	11	4	198.1	13506	773	330	23000	250	16	37875	1.0270	0.1780	7.60
10	19	60	11	4	185.3	13943	677	316	23500	200	4	38640	1.0280	0.1800	6.90
10	19	60	11	4	185.3	14253	725	296	24000	212	1	39487	1.0280	0.1830	6.80
10	19	60	11	4	204.3	12432	633	284	21000	176	23	34548	1.0240	0.2130	7.30
10	29	60	11	4	185.3	11420	681	255	19395	264	13	32028	1.0228	0.2100	7.70
10	1	60	12	4	110.5	12874	641	292	21650	281	33	35771	1.0240	0.1920	7.20
4	2	60	12	4	168.8	12887	788	381	22220	237	27	36540	1.0250	0.1730	7.80
12	14	60	12	4	168.6	12416	745	325	21250	232	36	35004	1.0270	0.1970	7.70
2	31	60	12	4	168.2	12636	615	315	21360	193	27	35146	1.0230	0.2410	7.90
2	10	60	13	4	173.0	10917	561	377	18680	366	46	30947	1.0170	0.2020	7.70
4	16	60	13	4	179.9	11535	649	311	19650	317	12	32474	1.0250	0.2120	7.30
15	22	60	13	4	174.4	12943	741	377	22180	305	15	36561	1.0200	0.1840	7.70
6	27	60	14	4	159.7	13996	861	534	24300	357	82	40210	1.0270	0.1800	8.50
10	8	60	15	4	138.4	19224	1876	645	34642	332	11	56730	1.0386	0.1300	6.70
10	8	60	15	4	127.5	19043	1813	721	34466	346	11	56400	1.0380	0.1300	6.75
10	8	60	15	4	118.3	19238	1897	645	34642	434	11	56867	1.0389	0.1300	7.00
11	10	60	15	4	127.4	19191	1563	721	34290	288	4	56057	1.0389	0.1190	7.10
10	22	60	15	4	118.7	16434	1261	680	29400	195	58	48028	1.0370	0.1760	7.90
10	22	60	15	4	107.9	17631	1361	668	31400	193	43	51296	1.0380	0.1700	7.60
11	23	60	15	4	151.3	17858	1385	651	31800	144	4	51842	1.0380	0.1590	7.30

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
15	12	60	16	4	147.5	16917	1694	620	30800	134	19	50184	1.0350	0.1390	7.50
7	2	60	17	4	119.8	17664	1228	530	30876	124	12	50434	1.0370	0.1570	7.70
6	1	61	4	4	216.6	13537	937	399	23500	303	27	38703	1.0250	0.1920	7.20
6	18	61	4	4	239.6	16626	1001	481	28700	176	13	46997	1.0320	0.1860	7.50
6	20	61	4	4	240.9	14059	805	437	24200	268	31	39800	1.0300	0.1730	7.90
9	8	61	6	4	207.3	14371	881	355	24600	240	21	40468	1.0250	0.1970	7.40
6	19	61	7	4	181.4	13038	681	304	21950	317	84	36374	1.0270	1.8800	7.90
11	30	61	7	4	237.0	12755	613	318	21527	250	12	35475	1.0251	0.1800	7.60
11	30	61	7	4	234.6	11586	521	298	19400	405	29	32239	1.0220	0.2100	8.10
7	2	61	8	4	238.9	13622	641	328	22900	308	23	37822	1.0270	0.1790	7.60
11	16	61	8	4	199.6	8783	772	308	15620	298	20	25801	1.0196	0.2360	8.10
10	34	61	8	4	179.1	11147	509	266	18700	260	20	30902	1.0260	0.2650	7.80
7	2	61	9	4	234.1	13059	799	286	22128	390	42	36704	1.0243	0.2020	7.00
7	14	61	9	4	229.5	11842	733	283	20206	303	2	33369	1.0216	70.0000	7.50
10	17	61	9	4	221.1	12282	635	242	20500	425	29	34113	1.0250	0.2260	8.20
6	27	61	9	4	167.9	12421	765	258	21050	281	62	34837	1.0270	0.2080	8.00
6	36	61	10	4	175.6	10136	601	231	17050	427	94	28539	1.0220	0.2360	8.00
12	26	61	11	4	207.6	10466	511	239	17560	249	49	29074	1.0220	0.2180	7.80
11	33	61	13	4	203.3	12974	565	306	21680	342	27	35894	1.0260	0.2100	7.60
11	33	61	13	4	203.3	12583	626	300	21160	344	27	35045	1.0250	0.2290	8.25
11	2	61	14	4	181.3	14296	809	380	24450	216	12	40163	1.0290	0.1720	7.40
12	8	61	14	4	133.7	14398	769	550	24950	325	37	41029	1.0280	0.1640	8.00
7	1	61	16	4	161.5	15807	1392	587	28483	112	2	46383	1.0322	0.1400	6.60

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
10	11	61	16	4	153.9	15494	1276	633	27899	161	3	45466	1.0306	0.1620	6.90
6	4	61	17	4	125.8	14980	1161	503	26500	155	41	43340	1.0270	0.1580	7.50
11	19	61	17	4	76.1	11944	998	312	20903	278	40	34475	1.0232	0.2200	7.90
10	36	61	17	4	159.4	14821	1141	510	26150	332	23	42977	1.0330	0.1980	7.20
15	9	62	2	4	168.6	8949	280	180	14605	357	11	24382	1.0162	0.2530	7.55
4	18	62	2	4	259.5	12181	594	312	20600	230	15	33932	1.0200	0.1760	7.60
7	25	62	2	4	175.6	7584	225	102	12100	335	63	20451	1.0170	0.3390	8.50
10	1	62	3	4	256.3	10764	519	314	18340	154	4	30095	1.0230	0.2040	7.40
7	10	62	3	4	222.0	11542	465	261	18980	634	45	31927	1.0240	0.1990	7.50
15	12	62	3	4	245.1	9915	417	178	16160	571	74	27315	1.0190	0.2370	8.30
10	17	62	3	4	257.7	11138	543	263	18700	300	39	30983	1.0220	0.2300	7.40
11	20	62	3	4	256.3	9985	340	182	16375	160	84	27126	1.0240	0.2170	7.30
6	6	62	4	4	230.4	13530	721	352	23000	260	20	37883	1.0280	0.2220	7.70
10	11	62	4	4	260.4	10578	580	446	18400	395	13	30412	1.0215	0.2180	7.50
7	6	62	7	4	194.8	12798	611	291	21450	281	69	35500	1.0250	0.1930	8.20
7	10	62	7	4	252.4	10729	737	345	18750	159	16	30736	1.0140	0.2800	7.80
6	23	62	7	4	161.6	12287	572	279	20620	242	16	34016	1.0250	0.2100	7.60
11	23	62	9	4	238.6	10969	509	224	18290	288	16	30296	1.0210	0.2200	8.20
6	29	62	9	4	233.1	10923	591	296	18650	160	13	30633	1.0250	0.2360	6.50
6	29	62	9	4	239.6	10410	559	288	17750	210	12	29229	1.0230	0.2510	6.80
2	6	62	10	4	215.6	12368	677	304	21000	242	21	34612	1.0260	0.1940	7.50
6	26	62	10	4	175.4	10713	621	231	18060	354	35	30014	1.0230	0.2270	8.00
1	12	62	11	4	208.8	9283	537	213	15725	225	41	26024	1.0210	0.2630	7.60

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (onm m)	pH
12	29	62	13	4	173.4	12574	465	278	20900	195	14	34426	1.0250	0.2260	7.80
11	4	62	14	4	150.8	13463	669	337	22700	371	16	37556	1.0270	0.2030	7.20
6	20	62	15	4	186.4	13613	1005	484	24000	305	5	39412	1.0250	0.1710	7.50
6	14	62	17	4	146.8	15577	1226	531	27590	249	3	45176	1.0296	0.1570	7.30
4	7	63	3	4	231.8	9060	441	313	15531	218	8	25571	1.0177	0.3140	7.80
14	11	63	8	4	254.2	9521	438	208	15880	290	21	26358	1.0200	0.2360	7.30
10	26	63	8	4	258.6	10180	466	269	17060	327	78	28380	1.0190	0.2320	7.90
11	29	63	8	4	254.6	9538	417	222	15970	168	35	26350	1.0180	0.2490	7.70
6	3	63	9	4	152.4	11887	517	337	20000	344	37	33122	1.0240	0.2280	7.60
7	18	63	9	4	252.2	11502	506	216	19000	383	53	31660	1.0230	0.2310	7.80
7	24	63	10	4	260.0	10929	541	272	18450	244	16	30452	1.0200	0.2110	8.10
6	31	63	10	4	131.1	9352	366	242	15490	410	62	25922	1.0200	0.2610	7.60
7	36	63	10	4	241.1	9607	388	174	15800	305	43	26317	1.0210	0.2600	7.40
10	6	63	11	4	229.1	10373	545	234	17400	364	41	28957	1.0200	0.2370	7.80
6	9	63	12	4	213.7	11493	641	291	19500	293	48	32266	1.0260	0.2360	7.00
6	22	63	12	4	229.0	9120	484	250	15460	264	49	25627	1.0230	0.2680	7.70
6	31	63	12	4	219.8	12601	701	379	21604	292	5	35582	1.0210	0.2030	8.00
10	36	63	12	4	230.4	9514	542	338	16401	322	37	27154	1.0200	0.2610	7.10
6	2	63	13	4	218.9	10611	705	255	18177	277	21	30046	1.0183	0.2010	7.63
7	4	63	13	4	210.9	12359	753	321	21120	340	12	34905	1.0230	0.2070	6.90
7	8	63	13	4	216.7	11990	632	333	20360	349	21	33685	1.0250	0.2270	6.90
7	11	63	13	4	219.8	12165	691	339	20800	290	3	34288	1.0260	0.2360	7.60
7	11	63	13	4	173.6	12111	619	320	20440	450	3	33943	1.0260	0.2360	7.40

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS,
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
11	14	63	14	4	215.1	12945	759	353	22200	220	8	36485	1.0290	0.2110	7.40
11	12	63	15	4	202.7	13708	1047	273	23647	229	9	38913	1.0254	0.1670	7.40
11	12	63	15	4	210.6	13366	730	398	22938	122	74	37628	1.0241	0.1600	6.10
10	34	63	15	4	206.4	13359	921	495	23550	171	31	38527	1.0280	0.1810	7.70
10	19	63	16	4	102.3	15830	1125	613	28000	200	69	45855	1.0300	0.1470	8.50
6	22	63	17	4	162.1	11229	1462	296	20521	220	63	33850	1.0220	0.2490	8.10
10	3	64	3	4	256.3	10116	423	193	16760	240	15	27747	1.0160	0.2670	7.60
11	16	64	3	4	264.0	9295	437	157	15338	356	26	25609	1.0185	0.2470	8.20
11	16	64	3	4	270.2	11061	488	258	18380	427	61	30675	1.0200	0.2080	8.10
10	22	64	3	4	262.0	10378	480	234	17340	325	9	28766	1.0230		7.90
10	27	64	3	4	275.0	9188	520	176	15423	253	44	25605	1.0166	0.2450	7.48
6	31	64	8	4	236.0	8207	308	212	13350	752	43	22872	1.0180	0.2670	7.70
6	31	64	8	4	252.0	9530	448	258	16080	217	47	26580	1.0200	0.2370	7.90
11	1	64	9	4	242.4	10209	409	188	16830	300	14	27950	1.0180	0.2560	7.70
5	3	64	11	4	226.4	9618	456	267	16180	351	44	26916	1.0200	0.2310	7.90
7	24	64	11	4	239.9	10225	470	208	17060	173	62	28198	1.0200	0.2320	7.70
6	2	64	12	4	221.9	10086	509	286	16984	488	28	28381	1.0174	0.2300	7.40
6	2	64	12	4	221.9	10176	513	286	17129	498	21	28623	1.0193	0.2300	7.45
6	5	64	12	4	234.8	10869	549	280	18300	369	47	30414	1.0220	0.2480	8.00
6	7	64	12	4	236.9	13580	596	324	22820	195	10	37525	1.0280	0.1930	7.40
11	26	64	12	4	250.4	10905	577	281	18453	214	29	30508	1.0212	0.2080	8.05
10	30	64	12	4	235.9	11200	567	270	18797	439	12	31285	1.0204	0.2300	7.95
11	13	64	13	4	168.9	9924	754	228	17159	234	9	28308	1.0220	0.2220	7.80

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
10	3	64	14	4	224.8	10836	715	342	18797	190	88	30968	1.0224	0.3710	7.75
10	3	64	14	4	216.6	11677	719	338	20142	189	16	33081	1.0230	0.2180	7.71
7	5	64	14	4	220.7	12710	780	340	21860	180	8	35878	1.0280	0.2140	7.30
11	13	64	14	4	227.9	12320	725	423	21309	130	4	35018	1.0240	1.9900	8.70
10	31	64	16	4	201.3	14652	1241	559	26300	183	18	42953	1.0290	0.1490	7.70
6	1	65	12	4	246.9	8976	386	217	14896	322	101	24898	1.0187	0.2210	7.51
6	2	65	12	4	250.5	9181	447	222	15450	183	53	25536	1.0220	0.3110	7.90
6	2	65	12	4	243.4	10421	496	258	17540	249	21	28985	1.0230	0.2770	7.70
10	10	65	12	4	243.1	8406	297	139	13606	444	40	22932	1.0165	0.3100	8.15
7	12	65	12	4	249.6	8187	394	184	13536	512	35	22848	1.0161	0.2852	7.90
6	16	65	12	4	246.5	8818	408	192	14572	400	40	24469	1.0160	0.2830	8.90
6	16	65	12	4	246.5	10147	480	268	17081	106	12	28201	1.0180	0.2410	8.60
10	3	65	13	4	241.9	10527	562	293	17756	400	25	29627	1.0220	0.2300	8.20
10	7	65	13	4	241.1	11868	703	335	20342	290	16	33554	1.0190	0.2200	7.00
10	7	65	13	4	232.7	12039	718	338	20651	270	18	34034	1.0190	0.2180	6.90
10	21	65	13	4	245.6	10484	536	321	17892	222	40	29495	1.0202	0.2340	7.80
11	30	65	13	4	246.4	11965	633	350	20500	150	5	33603	1.0250	0.2210	7.50
5	17	65	14	4	233.8	12970	696	294	21980	159	23	36122	1.0270	0.2180	7.70
5	12	65	15	4	226.8	12445	602	270	20900	215	25	34457	1.0250	0.2260	7.60
1	27	65	15	4	234.6	11602	616	286	19680	200	25	32409	1.0240	0.2300	7.40
1	27	65	15	4	135.9	12425	622	304	20940	349	6	34646	1.0250	0.2200	6.70
6	28	65	15	4	226.1	12002	781	332	20750	160	20	34045	1.0270	0.2170	8.10
7	35	65	15	4	230.0	12882	775	388	22250	184	13	36492	1.0210	0.1980	7.80

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
16	6	65	16	4	191.6	13931	1044	454	24481	282	10	40202	1.0279	0.1600	8.10
16	6	65	16	4	191.6	13212	974	464	23242	249	10	38198	1.0270	0.1600	8.40
7	13	65	16	4	215.3	9474	648	253	16280	308	47	27010	1.0210	0.2830	8.20
6	15	65	16	4	211.7	13113	939	384	22920	129	10	37495	1.0270	0.1870	7.20
6	29	65	16	4	194.0	14334	838	356	24500	161	41	40230	1.0300	0.1900	7.60
7	32	65	17	4	195.5	13165	901	590	23500	154	35	38345	1.0260	0.1800	7.50
6	8	66	10	4	266.0	8778	333	143	14400	208	30	23892	1.0160	0.3630	7.80
8	32	66	11	4	269.2	7990	325	141	13120	275	37	21888	1.0140	0.3480	8.20
12	35	66	12	4	268.5	9290	633	146	15730	218	19	26036	1.0160	0.2450	7.00
7	17	66	13	4	263.0	10075	591	224	17000	373	25	28288	1.0210	0.2640	7.70
7	1	66	14	4	244.4	9843	544	252	16598	130	44	27555	1.0180	0.2480	8.50
16	24	66	14	4	261.9	9845	621	486	17580	185	14	28731	1.0180	0.2300	7.70
11	9	66	15	4	160.8	11675	663	321	19980	187	33	32859	1.0220	0.2020	7.40
11	34	66	15	4	184.0	8644	501	175	14580	136	91	24127	1.0200	0.2650	7.80
11	34	66	15	4	204.5	9663	565	262	16500	275	6	27271	1.0160	0.2260	7.20
11	27	66	16	4	204.5	10141	673	275	17480	200	47	28816	1.0210	0.2320	7.30
7	28	66	17	4	217.6	12335	808	355	21350	230	2	35080	1.0290	0.1780	8.00
6	3	67	14	4	179.3	10353	478	341	17627	222	67	29088	1.0206	0.2200	8.00
12	8	67	14	4	187.4	9670	494	295	16440	327	21	27247	1.0180	0.2460	7.70
12	8	67	14	4	161.9	10520	629	352	18140	364	14	30019	1.0200	0.2220	7.80
6	9	67	14	4	186.6	10469	437	255	17480	257	43	28941	1.0180	0.2380	7.70
11	10	67	14	4	213.8	10809	377	217	17800	281	6	29490	1.0160	0.2330	8.00
11	10	67	14	4	261.5	11004	470	223	18360	149	6	30212	1.0160	0.2260	7.80

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
5	16	67	14	4	198.6	10044	498	260	16920	321	29	28072	1.0180	0.2430	7.90
6	7	67	15	4	179.4	8010	586	186	13773	239	26	22820	1.0172	0.2550	7.70
11	12	67	15	4	251.8	11575	690	251	19712	143	10	32381	1.0228	0.2090	7.70
2	3	67	16	4	227.5	12896	797	299	22050	199	4	36245	1.0240	0.1990	7.50
6	11	67	17	4	126.2	11822	441	202	19400	295	37	32197	1.0220	0.2240	7.55
14	30	68	11	4	295.7	7804	241	125	12690	212	16	21088	1.0150	0.2910	8.20
10	26	68	14	4	278.7	8951	436	232	15122	220	1	24962	1.0179	0.2620	7.93
7	28	68	14	4	272.6	8478	511	124	14099	351	50	23613	1.0170	0.2460	8.10
10	33	68	14	4	227.1	8470	340	180	13999	293	26	23308	1.0177	0.2550	8.10
10	33	68	14	4	279.8	8952	446	271	15229	195	56	25149	1.0190	0.2380	7.90
11	31	68	15	4	227.4	8639	337	163	14120	342	16	23670	1.0170	0.2790	8.50
10	27	69	12	4	314.8	7477	240	116	12140	254	8	20235	1.0190	0.3180	7.80
11	1	69	13	4	288.0	8694	356	164	14373	239	5	23831	1.0159	0.3300	7.60
7	10	69	14	4	279.1	9068	409	176	14992	102	7	24893	1.0173	0.2580	9.20
7	9	69	15	4	272.1	8391	340	170	13900	200	27	23028	1.0180	0.3060	7.80
11	17	69	15	4	227.7	7720	241	130	12620	120	29	20860	1.0160	0.3420	7.80
10	27	69	15	4	280.5	8852	266	134	14407	166	12	23837	1.0180	0.2980	7.60
10	1	69	16	4	271.5	8126	391	160	13526	244	29	22476	1.0155	0.3000	7.90

Table L-h-1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	31	55	1	4	182.10					2714.58	459.1
6	31	55	1	4	208.70	0.630E-14	0.326E-08			2550.03	469.0
6	31	55	1	4	158.10					3121.12	476.6
6	31	55	1	4	144.10					3151.87	465.8
6	14	55	2	4	163.07					3217.67	491.5
10	16	55	2	4	141.00					3474.66	495.6
10	36	55	2	4	161.90					3040.15	472.2
10	36	55	2	4	205.90					2733.71	484.9
6	22	55	3	4	69.80	0.902E-16	0.885E-09			4216.21	500.1
3	13	55	4	4	187.00					2926.93	485.7
6	15	55	4	4	165.50					2789.86	450.2
6	15	55	4	4	185.50	0.339E-15	0.312E-08			2565.12	447.3
6	15	55	4	4	138.50					3128.46	457.8
6	29	55	4	4	97.50	0.708E-14	0.813E-07				
6	29	55	4	4	156.34					3098.19	472.5
6	29	55	4	4	148.72					3009.63	455.9
6	31	55	4	4	208.20					2633.26	476.9
6	31	55	4	4	162.70					3361.40	505.8
7	32	55	4	4	205.60	0.138E-12	0.771E-07			2737.87	485.0
6	15	55	5	4	181.60	0.340E-13	0.190E-07			2902.48	477.8
6	20	55	5	4	174.10	0.369E-13	0.206E-07			3002.83	480.6
6	21	55	5	4	186.50	0.755E-13	0.423E-07			3017.69	494.5
6	21	55	5	4	144.40					3317.21	483.0
16	30	55	5	4	74.22					4092.67	492.0
6	31	55	5	4	127.38	0.780E-15	0.912E-08				
6	31	55	5	4	146.88	0.918E-15	0.112E-07			3208.13	474.3

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	35	55	5	4	197.60					2592.13	462.1
4	21	55	6	4	174.70					3014.69	482.4
7	34	55	6	4	178.00	0.136E-14	0.128E-07			3168.69	501.4
11	35	55	6	4	154.30	0.168E-14	0.942E-09			3099.97	470.7
11	35	55	6	4	181.70	0.274E-13	0.153E-07			3048.67	492.8
11	35	55	6	4	177.40	0.545E-13	0.304E-07				
11	35	55	6	4	65.90	0.119E-12	0.665E-07			3959.06	470.0
7	29	55	7	4	90.57	0.226E-14	0.228E-07	0.200	2.7	3769.92	475.3
7	29	55	7	4	153.36	0.268E-13	0.256E-06	0.200	3.2	3243.03	484.3
10	19	55	8	4	88.10	0.914E-15	0.511E-09			3692.36	465.0
10	19	55	8	4	147.50	0.337E-14	0.305E-07				
11	31	55	8	4	159.72	0.360E-13	0.201E-07	0.300	0.53E-02	3402.39	507.0
11	3	55	9	4	130.50	0.240E-13	0.134E-07				
7	7	55	9	4	121.60	0.181E-13	0.188E-06			3489.33	477.7
3	13	55	9	4	23.20	0.513E-13	0.286E-07			4567.61	489.4
8	17	55	9	4	136.00	0.643E-14	0.360E-08				
12	19	55	9	4	133.70	0.393E-13	0.220E-07			2939.37	433.7
7	11	55	10	4	121.20	0.824E-14	0.461E-08				
7	11	55	10	4	87.20					3413.97	435.6
10	23	55	10	4	43.30	0.830E-13	0.465E-07			4291.82	481.3
5	28	55	10	4	91.00					3602.98	458.7
10	34	55	10	4	-0.30	0.914E-14	0.512E-08			4474.31	456.4
7	28	55	11	4	3.04	0.191E-13		0.220		4257.01	437.5
6	8	55	12	4	95.50	0.912E-13	0.597E-07	0.300	0.25E-02	3424.77	445.0
12	32	55	12	4	39.00	0.455E-13	0.255E-07			4415.55	489.7
12	32	55	12	4	110.40					3571.30	474.9

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	26	55	13	4	30.46	0.569E-13	0.318E-07			4451.36	484.8
10	26	55	13	4	57.73					4280.76	494.7
10	26	55	13	4	57.90	0.519E-14	0.290E-08			4291.93	496.0
10	24	55	14	4	68.28					4393.12	516.7
13	30	55	14	4	72.70					4580.18	540.2
6	27	55	15	4	0.30					4855.41	495.9
11	17	55	16	4	15.88	0.785E-15	0.440E-09				
7	26	55	16	4	47.29	0.590E-13	0.373E-07	0.250	0.92E-03		
9	34	55	16	4	52.30	0.303E-14	0.160E-08				
6	6	56	1	4	166.70					2888.87	461.5
6	6	56	1	4	209.53					2573.08	472.1
6	6	56	1	4	303.40			0.200			
11	1	56	2	4	200.80					2693.02	475.6
10	1	56	4	4	220.00	0.118E-13	0.659E-08				
11	6	56	4	4	189.90					2862.10	482.0
10	8	56	5	4	98.30					3681.43	474.1
6	15	56	5	4	200.40					2801.39	486.3
6	20	56	5	4	107.10					3626.30	477.2
6	20	56	5	4	202.10					2804.54	488.3
10	32	56	5	4	200.85					2724.24	478.9
7	25	56	6	4	186.16					2767.24	468.6
7	25	56	6	4	100.66					3577.59	465.8
7	25	56	6	4	197.16					2674.47	470.1
6	4	56	8	4	153.60					3297.79	490.2
11	14	56	8	4	173.73	0.302E-15	0.169E-09	0.270	0.42E-02	3174.72	497.7
6	13	56	9	4	158.20					3412.03	506.4

TERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
PER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
D	SEC	TP	R	M							
1	25	56	9	4	159.56					3438.68	510.5
6	29	56	9	4	35.70	0.102E-12	0.568E-07				
6	29	56	9	4	155.80	0.136E-13	0.760E-08			3313.86	494.0
6	30	56	9	4	26.50	0.637E-13	0.356E-07				
6	2	56	10	4	129.56	0.818E-13	0.509E-07	0.260	0.17E-02		
0	6	56	10	4	46.60					4403.37	496.0
1	7	56	10	4	131.40					3864.96	525.9
6	29	56	10	4	55.10	0.290E-14	0.162E-08				
7	33	56	10	4	131.63					3655.76	504.7
10	36	56	10	4	152.60					3393.61	499.0
10	3	56	11	4	120.22	0.137E-13	0.794E-08	0.280	0.22E-02	3812.48	509.3
7	10	56	11	4	125.62	0.650E-13	0.364E-07			3806.94	514.2
7	28	56	11	4	117.40					3861.41	511.5
7	28	56	11	4	123.19					3827.05	513.8
11	12	56	12	4	113.96					4119.80	534.4
11	12	56	12	4	127.98					3901.46	526.2
11	12	56	12	4	125.54	0.104E-13	0.583E-08			3953.59	529.1
10	29	56	13	4	105.70	0.292E-14	0.279E-07				
7	1	56	14	4	-7.00	0.156E-12	0.875E-07				
10	9	56	14	4	-16.50	0.622E-13	0.348E-07				
10	9	56	14	4	91.50	0.542E-13	0.303E-07			4009.64	500.7
10	9	56	14	4	-10.50	0.550E-15	0.308E-09				
7	12	56	14	4	-6.40	0.764E-15	0.428E-09				
10	14	56	14	4	94.50	0.443E-14	0.452E-07			4286.58	532.0
10	14	56	14	4	17.40	0.671E-16	0.845E-09			4607.99	487.7
6	20	56	14	4	89.60	0.237E-13	0.133E-07			4242.29	522.6

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
JPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION .SD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	36	56	14	4	72.90	0.839E-13	0.470E-07				
6	26	56	15	4	48.80	0.621E-13	0.348E-07			4599.21	518.2
16	21	56	16	4	71.00	0.791E-13	0.443E-07			4461.08	526.3
12	10	57	1	4	208.50	0.121E-12	0.675E-07			2498.26	463.5
10	25	57	2	4	221.20	0.163E-12	0.910E-07			2542.83	480.7
10	8	57	3	4	218.88	0.149E-13	0.832E-08			2673.63	491.7
7	30	57	3	4	212.50	0.114E-13	0.637E-08			2704.83	488.6
10	12	57	4	4	208.40	0.256E-15	0.270E-08			2765.53	490.6
10	12	57	4	4	215.40	0.847E-14	0.473E-08				
10	21	57	4	4	201.52					2638.43	470.8
10	21	57	4	4	201.35					2783.31	485.4
10	29	57	4	4	201.35					2689.26	475.8
6	33	57	4	4	199.30	0.416E-13	0.233E-07			2694.85	474.3
6	33	57	4	4	199.16					2730.80	477.9
11	10	57	5	4	208.20	0.344E-14	0.192E-08			2649.83	478.6
6	24	57	5	4	215.70					2744.00	495.7
6	26	57	5	4	209.70					2687.19	484.0
6	26	57	5	4	216.70	0.296E-14	0.166E-08				
9	28	57	6	4	201.13					2872.26	494.3
9	28	57	6	4	200.99					2843.95	491.3
9	28	57	6	4	194.42	0.275E-14	0.154E-08			2808.64	481.1
6	7	57	7	4	176.78	0.600E-14	0.336E-08			2942.26	477.1
11	22	57	7	4	186.80					2940.29	486.9
6	8	57	8	4	175.85					3065.90	488.8
11	12	57	8	4	180.50					3151.87	502.2
6	29	57	8	4	178.16					3226.59	507.5

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
11	11	57	9	4	174.19					3185.93	499.4
7	26	57	9	4	159.70					3301.50	496.7
10	31	57	9	4	171.60	0.124E-12	0.693E-07			2969.50	474.7
11	3	57	10	4	137.50					3509.38	495.7
7	5	57	10	4	150.20					3551.27	512.7
11	6	57	10	4	128.30					3783.50	514.5
11	6	57	10	4	149.03					3703.08	527.0
6	9	57	10	4	149.60	0.139E-14				3719.11	529.2
7	9	57	10	4	137.51	0.173E-14	0.968E-09			3609.61	505.9
6	18	57	10	4	147.48	0.303E-14	0.169E-08			3591.26	514.0
11	35	57	10	4	154.80					3372.85	499.0
6	36	57	10	4	159.70	0.718E-13	0.402E-07				
7	10	57	11	4	149.10	0.889E-14	0.498E-08				
10	28	57	11	4	144.20	0.463E-14	0.466E-07				
10	28	57	11	4	149.65	0.178E-13	0.169E-06				
6	29	57	13	4	131.03	0.336E-14	0.188E-08			3566.20	495.0
7	35	57	13	4	135.90	0.597E-14	0.333E-08				
10	22	57	15	4	70.11	0.440E-13	0.278E-07	0.280	0.17E-02	4153.92	494.1
7	34	57	16	4	91.10					4251.96	525.1
7	34	57	16	4	87.76					4314.79	528.1
9	28	57	17	4	71.90	0.343E-14	0.398E-07			4551.21	536.4
7	18	58	1	4	147.20					3174.00	471.1
10	34	58	1	4	207.70	0.366E-13	0.205E-07			2606.63	473.7
7	2	58	2	4	167.60					2918.21	465.4
6	7	58	4	4	143.00					3192.16	468.8
6	22	58	4	4	220.60	0.352E-13	0.222E-07	0.180	0.50E-02	2592.16	485.2

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
7	16	58	5	4	209.65	0.509E-14	0.285E-08			2606.44	475.7
10	24	58	5	4	233.70	0.904E-14	0.515E-08			2404.84	479.1
10	25	58	5	4	159.44					2902.27	455.6
10	32	58	5	4	218.90	0.316E-14	0.177E-08			2782.08	502.8
7	13	58	6	4	214.50	0.225E-13	0.126E-07			2768.73	497.1
7	20	58	6	4	194.20	0.318E-14	0.178E-08			2848.75	484.9
7	20	58	6	4	201.20	0.463E-14	0.259E-08			2920.88	499.3
7	20	58	6	4	207.92	0.153E-13	0.857E-08			2869.56	500.8
10	21	58	6	4	199.80					2828.76	488.5
10	21	58	6	4	207.60					2830.68	496.5
11	23	58	6	4	199.94	0.107E-13	0.597E-08			2733.72	478.9
7	28	58	6	4	209.40	0.134E-13	0.748E-08			2816.60	496.9
6	35	58	6	4	209.14	0.189E-13	0.106E-07				
6	35	58	6	4	215.20	0.117E-12	0.658E-07			2786.50	499.6
6	21	58	7	4	188.10	0.550E-13	0.308E-07			2880.40	482.1
6	21	58	7	4	151.50					3150.14	473.0
6	5	58	8	4	184.10	0.409E-15	0.229E-09			3178.33	508.5
6	8	58	8	4	157.20	0.218E-14	0.122E-08				
6	12	58	8	4	182.54	0.114E-14	0.637E-09			2903.00	478.8
6	12	58	8	4	139.26					3324.56	478.6
7	28	58	8	4	177.40					3012.48	484.9
6	26	58	9	4	132.10	0.426E-14	0.220E-08			3145.68	453.2
9	34	58	9	4	185.30	0.117E-12	0.653E-07			2905.25	481.8
6	3	58	10	4	160.65	0.253E-13	0.142E-07				
6	6	58	10	4	165.10	0.662E-13	0.370E-07			3458.52	518.1
6	8	58	10	4	152.80					3059.09	465.0

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M							
7	18	58	10	4	163.38	0.530E-13	0.296E-07				
7	19	58	10	4	168.70	0.904E-14	0.506E-08				
7	20	58	10	4	163.90	0.135E-13	0.755E-08				
7	20	58	10	4	149.90					3267.43	483.4
15	28	58	10	4	185.70	0.114E-12	0.635E-07			3033.63	495.3
5	10	58	11	4	99.20					3898.68	497.1
5	10	58	11	4	150.70	0.767E-15	0.415E-09				
10	18	58	11	4	149.30	0.324E-13	0.173E-07				
15	24	58	11	4	168.25					3297.32	504.8
11	23	58	12	4	161.00	0.110E-12	0.617E-07			3376.37	505.6
11	24	58	12	4	157.00	0.693E-13	0.387E-07			3489.69	513.2
7	27	58	12	4	150.60	0.438E-13	0.420E-06				
10	29	58	12	4	160.07	0.419E-14	0.234E-08			3483.66	515.6
6	6	58	13	4	136.20	0.395E-13	0.221E-07			3523.09	495.8
6	13	58	13	4	136.50	0.354E-14	0.198E-08				
10	28	58	13	4	148.20	0.168E-13	0.942E-08				
10	28	58	13	4	142.10	0.184E-14	0.103E-08				
10	35	58	13	4	157.30					3521.13	516.7
5	5	58	15	4	72.30	0.946E-13	0.948E-06				
10	32	58	16	4	113.90	0.681E-13	0.380E-07				
6	35	58	17	4	95.90					4100.43	514.4
11	5	59	2	4	238.60	0.214E-13	0.120E-07			2528.36	496.6
11	6	59	2	4	226.80	0.166E-14	0.159E-07			2711.46	503.5
14	18	59	2	4	244.30					2496.61	499.1
11	19	59	2	4	236.30	0.129E-12	0.718E-07			2500.60	491.5
10	35	59	2	4	242.32	0.120E-14	0.106E-07			2437.72	491.1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	8	59	3	4	238.10					2529.35	496.2
9	13	59	3	4	236.00	0.229E-13	0.206E-06				
11	21	59	3	4	234.80					2413.57	481.1
11	21	59	3	4	181.40					2917.13	479.1
7	28	59	3	4	247.20	0.268E-12	0.150E-06			2467.25	499.0
10	5	59	4	4	218.24					2558.49	479.4
10	9	59	4	4	228.95	0.258E-13	0.145E-07			2262.24	459.8
10	19	59	4	4	172.55	0.344E-13	0.321E-06			2890.84	467.6
7	20	59	4	4	219.70					2502.79	475.1
6	21	59	4	4	241.70	0.369E-13	0.207E-07				
7	26	59	4	4	240.40	0.424E-13	0.237E-07			2427.53	488.1
7	26	59	4	4	215.40	0.290E-13	0.163E-07			2550.91	475.7
10	33	59	4	4	239.60	0.101E-13	0.565E-08			2278.35	472.1
11	7	59	5	4	217.90	0.716E-13	0.401E-07			2755.80	499.2
11	8	59	5	4	215.50	0.514E-14	0.473E-07			2771.84	498.4
10	10	59	5	4	152.37					3117.48	470.5
10	10	59	5	4	194.44					2949.32	495.4
11	16	59	5	4	156.10					3016.85	464.0
5	19	59	5	4	214.87	0.813E-13	0.455E-07				
11	3	59	6	4	220.07					2838.70	509.8
11	4	59	6	4	212.40					2358.21	453.1
11	4	59	6	4	212.75					2586.30	476.7
11	12	59	6	4	211.58	0.354E-13	0.232E-07	0.300	0.30E-02	2713.52	488.5
11	12	59	6	4	258.34	0.149E-15	0.832E-10			2346.20	500.5
13	13	59	6	4	224.90	0.351E-14	0.196E-08			2731.94	503.7
6	27	59	6	4	229.70	0.236E-12	0.137E-06	0.350	0.33E-02	2714.93	506.8

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	27	59	6	4	229.50					2804.86	515.8
7	30	59	6	4	229.20	0.335E-13	0.187E-07				
10	36	59	6	4	221.00	0.318E-14	0.178E-08			2744.27	501.1
10	36	59	6	4	220.86					2766.75	503.2
6	1	59	7	4	214.58					2630.00	483.0
10	20	59	8	4	200.60					2856.54	492.1
11	29	59	8	4	206.90					2833.23	496.1
6	35	59	8	4	208.80	0.115E-12	0.105E-05			2662.33	480.5
10	6	59	9	4	126.49	0.114E-12	0.627E-07	0.300	0.41E-02	3446.47	478.2
7	8	59	9	4	143.50	0.288E-14	0.278E-07			3458.11	496.4
7	8	59	9	4	190.50	0.400E-13	0.224E-07			2957.20	492.3
7	9	59	9	4	196.60					2907.13	493.3
11	13	59	9	4	192.00	0.631E-13	0.586E-06				
6	15	59	9	4	203.30					2905.60	499.8
7	25	59	9	4	200.00	0.402E-13	0.225E-07				
7	26	59	9	4	209.70	0.420E-13	0.448E-06			2856.90	501.3
7	35	59	9	4	150.26					3224.34	479.4
7	35	59	9	4	150.01	0.141E-13	0.128E-06				
6	4	59	10	4	169.09					3098.82	485.4
6	4	59	10	4	175.50	0.185E-13	0.203E-06				
6	10	59	10	4	136.24					3369.32	480.1
11	1	59	11	4	164.00	0.319E-14	0.358E-07			3369.81	507.9
10	9	59	11	4	172.82					3171.43	496.5
3	14	59	11	4	167.90	0.157E-13	0.879E-08			3108.21	485.1
11	32	59	11	4	187.40					2988.03	492.4
6	3	59	12	4	148.74					3466.11	502.5

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	5	59	12	4	154.50					3314.85	492.8
8	6	59	12	4	154.95					3369.81	498.9
6	12	59	12	4	165.69					3240.40	496.4
9	22	59	12	4	172.10	0.279E-13	0.156E-07			3178.36	496.5
6	16	59	13	4	151.78	0.183E-14	0.102E-08				
9	25	59	14	4	54.34					4316.71	494.9
9	25	59	14	4	134.34					3663.99	508.3
9	25	59	14	4	134.50	0.368E-15					
15	33	59	14	4	152.43					3659.78	526.0
11	35	59	14	4	166.70	0.471E-13	0.252E-07	0.300	0.30E-02	3509.23	524.9
11	35	59	14	4	160.70					3495.40	517.4
10	30	59	15	4	82.90	0.155E-14					
10	30	59	15	4	135.00					3782.28	521.0
10	33	59	15	4	95.08	0.330E-14	0.316E-07			3857.37	488.8
10	33	59	15	4	143.54	0.321E-15	0.179E-09				
3	6	59	16	4	109.92					4038.79	522.2
5	19	59	16	4	117.88					3723.08	497.9
7	9	59	17	4	60.05	0.818E-13	0.400E-07			4572.01	526.7
7	17	60	1	4	204.50					2687.09	478.7
7	17	60	1	4	198.40					2562.90	460.0
10	7	60	3	4	237.70					2458.95	488.7
10	9	60	3	4	241.70					2379.98	484.6
10	16	60	3	4	251.70					2362.16	492.8
7	19	60	3	4	252.00					2369.95	493.9
11	27	60	3	4	247.30	0.180E-13	0.101E-07			2325.69	484.7
6	28	60	3	4	253.20	0.925E-13	0.518E-07			2327.39	490.7

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M							
6	33	60	3	4	252.10	0.766E-13	0.429E-07			2268.36	483.6
6	34	60	3	4	254.20					2341.81	493.2
10	35	60	3	4	255.50					2329.35	493.2
11	31	60	4	4	229.50	0.535E-14	0.451E-07				
11	31	60	4	4	243.80					2426.20	491.4
11	31	60	4	4	238.60	0.112E-14	0.935E-08			2437.85	487.4
7	9	60	6	4	196.70	0.321E-13	0.179E-07			2708.48	473.1
5	10	60	6	4	232.40	0.344E-12	0.193E-06				
10	11	60	6	4	225.60					2506.13	481.4
11	17	60	6	4	160.40	0.187E-13	0.175E-06			3020.40	468.7
10	18	60	6	4	228.60	0.294E-12	0.165E-06			2533.31	487.1
6	24	60	6	4	231.90	0.542E-14	0.303E-08			2557.79	492.9
10	25	60	6	4	237.70					2179.75	460.2
10	26	60	6	4	234.60					2330.11	472.4
10	26	60	6	4	187.60	0.163E-13	0.144E-06			2812.39	474.6
10	27	60	6	4	197.50					2808.42	484.1
11	27	60	6	4	145.20					3191.71	471.0
6	29	60	6	4	230.40					2577.52	493.5
10	8	60	7	4	174.66	0.292E-13	0.270E-06			2998.56	480.7
12	12	60	7	4	229.50					2646.52	499.6
12	12	60	7	4	217.50	0.796E-15	0.805E-08			2627.85	485.7
12	15	60	7	4	228.00	0.705E-13	0.394E-07			2569.65	490.3
12	15	60	7	4	220.00	0.136E-12	0.759E-07			2602.47	485.6
10	20	60	7	4	190.50					2674.44	463.4
10	20	60	7	4	210.30					2472.36	462.6
10	20	60	7	4	169.20					2982.83	473.6

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	20	60	7	4	222.50					2535.67	481.3
4	22	60	7	4	199.80	0.133E-13	0.743E-08			2679.25	473.2
4	22	60	7	4	225.80	0.187E-13	0.105E-07				
4	22	60	7	4	230.80	0.162E-14	0.908E-09			2644.24	500.7
4	22	60	7	4	206.80	0.218E-13	0.122E-07			2591.23	471.3
3	24	60	7	4	175.00	0.524E-13	0.293E-07			2951.79	476.3
3	24	60	7	4	236.00					2489.30	490.1
3	24	60	7	4	200.00					2804.36	486.2
10	28	60	7	4	233.80	0.277E-13	0.155E-07			2602.37	499.4
6	12	60	8	4	217.60					2631.92	486.2
7	19	60	8	4	225.20	0.181E-13					
7	19	60	8	4	219.10	0.281E-14				2431.76	467.3
11	21	60	8	4	211.80					2765.57	494.1
11	21	60	8	4	227.00					2449.76	477.0
11	21	60	8	4	216.70					2592.87	481.3
7	30	60	8	4	181.31					2903.35	477.6
6	32	60	8	4	181.35					2950.90	482.5
6	32	60	8	4	232.55	0.255E-14	0.152E-08	0.250	0.35E-02		
10	2	60	9	4	208.83	0.787E-14	0.440E-08				
11	11	60	9	4	213.60					2584.12	477.3
11	17	60	9	4	219.00					2699.84	494.6
6	4	60	10	4	41.70					4251.32	475.6
10	15	60	10	4	194.20					2807.86	480.8
15	26	60	10	4	200.60					2480.22	453.7
10	19	60	11	4	193.20	0.676E-13	0.378E-07			2964.45	495.8
9	25	60	11	4	193.80	0.340E-13	0.190E-07			2803.29	479.9

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
4	2	60	12	4	168.32					3055.84	480.2
6	4	60	12	4	167.46					3250.69	499.2
6	36	60	12	4	166.35					3061.13	478.8
7	3	60	15	4	121.00	0.995E-13	0.557E-07			3586.88	487.1
7	3	60	15	4	149.70	0.456E-14	0.255E-08				
7	3	60	15	4	104.90	0.491E-14	0.275E-08			3922.97	505.3
10	27	60	16	4	143.24					3395.09	489.8
10	27	60	16	4	143.07					3421.04	492.2
11	28	61	2	4	145.70					3125.63	464.7
7	3	61	3	4	250.40	0.887E-14	0.497E-08			2443.45	499.8
11	9	61	3	4	227.96					2551.94	488.4
10	13	61	3	4	256.37	0.153E-14	0.853E-09			2323.53	493.5
6	20	61	4	4	241.68	0.172E-14	0.964E-09			2148.61	461.0
6	1	61	5	4	240.49	0.104E-13	0.647E-08	0.230	0.16E-01	2452.30	490.8
1	3	61	5	4	274.88	0.838E-15	0.468E-09				
6	34	61	5	4	235.60					2443.89	485.0
6	34	61	5	4	259.98					2100.89	474.4
10	36	61	5	4	255.70	0.217E-13	0.135E-07	0.230	0.15E-01		
7	20	61	6	4	248.40	0.557E-14	0.311E-08			2532.28	506.8
7	20	61	6	4	237.41	0.957E-15	0.536E-09				
10	31	61	6	4	246.60	0.150E-14	0.838E-09				
6	19	61	7	4	241.40					2558.38	502.5
10	20	61	7	4	233.10					2577.00	496.1
9	21	61	7	4	225.30					2691.56	500.0
9	21	61	7	4	240.50	0.102E-13	0.568E-08			2549.45	500.7
9	21	61	7	4	252.10	0.408E-13	0.228E-07			2525.48	509.8

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
9	21	61	7	4	233.80	0.986E-14	0.552E-08			2573.17	496.4
6	25	61	7	4	248.10	0.360E-15	0.201E-09			2455.78	498.7
12	28	61	7	4	241.10					2574.61	503.9
12	28	61	7	4	251.60	0.398E-13	0.223E-07			2488.38	505.6
12	28	61	7	4	234.10	0.875E-14	0.490E-08			2546.37	494.0
12	28	61	7	4	221.10	0.494E-14	0.276E-08			2663.41	492.9
11	29	61	7	4	243.00	0.172E-13	0.959E-08			2574.27	505.7
11	29	61	7	4	260.30	0.266E-13	0.149E-07			2566.06	522.2
11	30	61	7	4	253.60	0.160E-14	0.897E-09			2427.82	501.4
10	31	61	7	4	240.20	0.115E-13	0.641E-08			2431.79	488.4
10	31	61	7	4	253.90	0.412E-15	0.231E-09			2345.80	493.3
10	31	61	7	4	234.10	0.398E-14	0.223E-08			2420.04	481.1
11	16	61	8	4	201.47					2717.09	478.8
10	17	61	8	4	231.90	0.383E-14	0.219E-08			2460.29	483.0
10	34	61	8	4	242.30	0.507E-16		0.180		2327.90	479.9
10	34	61	8	4	182.90					2875.40	476.4
11	35	61	8	4	228.70	0.815E-14	0.456E-08			2458.81	479.6
6	10	61	9	4	230.10	0.612E-14	0.343E-08				
7	14	61	9	4	182.27					2853.23	473.5
10	20	61	9	4	219.80	0.338E-14	0.189E-08			2546.57	479.7
10	20	61	9	4	236.84					2513.22	493.3
6	21	61	9	4	234.00					2595.45	498.9
7	34	61	9	4	200.00					2922.34	498.3
7	34	61	9	4	199.34					2912.22	496.6
7	34	61	9	4	211.20					2782.09	495.1
7	34	61	9	4	243.90	0.126E-12	0.708E-07				

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
11	2	61	10	4	215.80	0.123E-13	0.687E-08			2692.96	490.6
10	3	61	10	4	169.50					3020.65	477.8
10	3	61	10	4	216.10	0.485E-13	0.272E-07			2603.05	481.8
2	18	61	10	4	175.26					3054.17	487.0
11	33	61	10	4	228.30	0.855E-13	0.479E-07			2477.94	481.2
6	34	61	10	4	171.90	0.344E-13	0.193E-07				
11	8	61	11	4	203.00					2829.22	491.7
6	14	61	11	4	181.10					3037.83	491.1
10	27	61	12	4	187.00	0.291E-13	0.163E-07			2926.85	485.7
11	2	61	14	4	182.14					3091.26	497.7
6	9	61	16	4	123.47	0.112E-11	0.628E-06				
11	15	61	16	4	156.64	0.152E-13	0.851E-08				
14	20	61	16	4	116.30					3705.67	494.5
15	9	62	2	4	185.58	0.212E-13	0.230E-06			2816.19	473.0
15	9	62	2	4	182.23					2885.08	476.7
8	10	62	2	4	255.10	0.124E-12	0.170E-07			2280.78	487.9
4	18	62	2	4	260.79					2240.69	489.5
10	1	62	3	4	255.70					2248.42	485.2
7	10	62	3	4	239.10	0.505E-14	0.282E-08			2214.98	465.1
7	13	62	3	4	166.80	0.678E-14	0.579E-07				
7	13	62	3	4	252.80	0.258E-13	0.144E-07			2219.15	479.3
10	14	62	4	4	149.90					3215.05	478.0
10	14	62	4	4	261.40	0.303E-14	0.170E-08				
10	36	62	4	4	259.60	0.828E-14	0.463E-08			2092.68	473.2
10	14	62	5	4	258.20	0.494E-13	0.277E-07	0.300		2311.52	494.1
10	7	62	6	4	245.00	0.289E-14	0.162E-08			2409.50	490.9

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	29	62	6	4	252.10	0.473E-14	0.265E-08			2341.44	491.1
7	6	62	7	4	227.70	0.216E-14	0.121E-08			2519.21	484.8
10	11	62	7	4	242.90	0.233E-14	0.131E-08			2255.90	473.1
10	11	62	7	4	249.60	0.647E-14	0.362E-08			2329.89	487.4
7	20	62	7	4	243.80	0.138E-13	0.774E-08			2386.41	487.3
7	20	62	7	4	283.40	0.481E-14	0.269E-08			2165.96	504.4
7	20	62	7	4	229.20	0.190E-14	0.106E-08			2477.07	482.0
6	22	62	7	4	245.97					2419.28	492.9
6	23	62	7	4	246.20					2430.98	494.3
6	23	62	7	4	228.60					2479.37	481.6
10	31	62	7	4	249.90	0.254E-14	0.142E-08			2319.85	486.7
10	31	62	7	4	239.30	0.471E-14	0.264E-08			2343.09	478.4
10	3	62	8	4	249.00	0.415E-13	0.232E-07			2551.17	509.4
6	9	62	8	4	237.40	0.690E-14	0.386E-08			2506.75	493.2
6	20	62	8	4	284.08	0.264E-14	0.148E-08				
6	20	62	8	4	242.63	0.417E-14	0.233E-08			2433.52	491.0
6	20	62	8	4	193.20					2221.82	471.0
6	20	62	8	4	256.04	0.883E-14	0.494E-08			2232.21	483.8
2	22	62	8	4	240.40	0.743E-14	0.628E-07				
12	29	62	8	4	242.10	0.243E-14	0.252E-07			2368.96	483.9
11	34	62	8	4	240.20					2508.86	496.2
6	35	62	8	4	253.24	0.149E-13	0.130E-06	0.200	0.15E-01		
10	6	62	9	4	234.70	0.245E-14	0.137E-08				
10	6	62	9	4	224.00	0.644E-14	0.361E-08			2503.80	479.5
6	21	62	9	4	245.30	0.218E-12	0.136E-06	0.230	0.26E-02	2553.20	505.9
11	23	62	9	4	203.30					2632.57	472.0

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
11	23	62	9	4	236.80	0.491E-14	0.504E-07			2603.52	502.5
6	29	62	9	4	232.80	0.855E-13	0.478E-07			2505.06	488.5
6	29	62	9	4	238.90	0.245E-13	0.137E-07				
10	14	62	10	4	216.70	0.179E-13	0.100E-07			2640.57	486.2
10	14	62	10	4	242.30	0.512E-13	0.286E-07			2504.65	497.9
10	22	62	10	4	238.10	0.460E-13	0.258E-07			2498.85	493.1
6	28	62	10	4	220.10	0.180E-14	0.101E-08			2690.28	494.7
6	28	62	10	4	215.10					2700.88	490.7
12	17	62	11	4	211.52					2711.03	488.2
12	20	62	11	4	228.60					2636.63	497.7
12	20	62	11	4	117.30					3707.64	495.7
14	3	62	12	4	233.90					2491.03	488.1
10	16	62	12	4	218.53					2519.30	475.7
11	4	62	14	4	150.89					3317.17	489.4
11	28	62	15	4	180.60	0.303E-14	0.170E-08				
7	34	62	16	4	90.80	0.316E-14	0.163E-08			3716.27	470.1
7	34	62	16	4	133.32					3565.83	497.3
7	3	63	1	4	229.50					2461.76	480.7
4	11	63	1	4	218.20					2488.77	472.2
12	31	63	2	4	273.30					1992.97	476.7
11	5	63	3	4	255.12					2230.44	482.7
8	14	63	4	4	269.70					2185.40	492.7
10	3	63	5	4	254.60	0.232E-14	0.130E-08			2243.30	483.5
11	18	63	5	4	256.10					2274.79	488.3
1	25	63	5	4	258.46	0.258E-14	0.150E-08			2253.25	488.4
9	23	63	6	4	261.70	0.327E-15	0.183E-09			2285.43	494.9

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	3	63	7	4	255.10					2357.02	495.6
7	17	63	7	4	260.50	0.103E-14	0.577E-09			2315.90	496.9
6	4	63	8	4	249.60	0.127E-14	0.128E-07			2364.29	490.9
10	5	63	8	4	252.40					2457.78	503.2
10	5	63	8	4	245.00					2447.72	494.8
14	11	63	8	4	255.70	0.373E-13	0.209E-07			2405.90	501.2
10	12	63	8	4	247.46	0.352E-13	0.197E-07			2467.73	499.3
10	15	63	8	4	247.20					2368.52	488.9
11	29	63	8	4	261.00					2392.62	505.2
10	30	63	8	4	258.80					2544.82	518.5
7	32	63	8	4	258.40	0.286E-13	0.160E-07				
6	34	63	8	4	254.20	0.377E-13	0.315E-06			2504.16	509.8
6	34	63	8	4	201.20					3113.69	519.0
7	18	63	9	4	236.20	0.476E-14	0.434E-07			2740.91	515.9
7	18	63	9	4	250.80					2512.80	507.2
11	20	63	9	4	246.60					2736.01	525.8
11	30	63	9	4	250.10	0.352E-13	0.197E-07			2350.98	490.0
7	24	63	10	4	238.70					2485.69	492.4
7	28	63	10	4	241.60					2407.03	487.3
7	28	63	10	4	242.60					2503.45	498.1
3	30	63	10	4	238.00	0.944E-14	0.528E-08			2517.96	495.0
7	36	63	10	4	135.90	0.301E-13	0.169E-07				
7	36	63	10	4	242.60					2349.37	482.4
8	11	63	11	4	234.60					2501.48	489.9
11	16	63	11	4	235.90					2381.02	478.9
2	24	63	11	4	239.30	0.410E-13	0.230E-07			2412.13	485.5

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	25	63	11	4	236.50	0.168E-13	0.807E-08			2456.03	487.2
10	36	63	11	4	240.40					2477.49	493.2
7	8	63	13	4	221.56					2572.38	484.1
10	26	63	13	4	229.20	0.214E-13	0.120E-07			2641.49	498.8
15	3	63	14	4	173.50					3133.80	493.3
15	3	63	14	4	219.34					2673.10	492.2
10	26	63	14	4	189.02					3053.28	500.6
7	3	63	15	4	126.20	0.160E-14	0.897E-09				
7	3	63	15	4	146.93	0.132E-14	0.736E-09			3169.62	470.4
10	7	63	15	4	132.54					3277.57	467.1
11	9	63	16	4	131.06	0.594E-13	0.275E-07	0.270	0.32E-02	3489.35	487.2
6	5	64	2	4	163.30					3095.62	479.2
10	28	64	7	4	262.80					2310.48	498.6
15	4	64	8	4	161.30	0.116E-13	0.652E-08				
15	4	64	8	4	270.30					2420.11	517.3
10	30	64	8	4	189.90	0.262E-14	0.279E-07			3007.24	496.8
10	30	64	8	4	248.40	0.456E-14	0.403E-07				
6	31	64	8	4	258.50	0.865E-13	0.483E-07			2417.90	505.3
6	31	64	8	4	237.50	0.743E-14	0.668E-07			2573.02	500.1
10	14	64	9	4	240.80	0.622E-13	0.348E-07			2394.70	485.2
10	14	64	9	4	216.87					2697.10	492.1
10	31	64	9	4	254.50					2371.73	496.5
6	6	64	10	4	239.10					2499.75	494.2
10	21	64	10	4	253.30					2595.40	518.2
6	2	64	11	4	231.53					2578.47	494.7
11	4	64	11	4	239.50	0.177E-13	0.989E-08			2263.29	470.5

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
16	9	64	11	4	242.00	0.473E-13	0.265E-07			2105.89	456.9
10	22	64	11	4	245.30	0.439E-13	0.245E-07				
7	24	64	11	4	243.50	0.222E-13	0.195E-06				
10	1	64	13	4	187.10					3070.37	500.5
10	12	64	13	4	235.90	0.435E-13	0.243E-07			2489.12	489.9
7	23	64	13	4	243.20					2311.67	479.1
11	35	64	14	4	231.06	0.535E-13	0.462E-06			2555.16	491.8
6	8	64	15	4	220.03	0.359E-14	0.227E-08	0.320	0.91E-02	2914.07	517.4
6	27	64	15	4	258.40	0.741E-16	0.460E-10	0.180	0.57E-02		
11	9	64	16	4	204.10					2922.62	502.4
11	9	64	16	4	187.10					3013.50	494.7
7	15	64	16	4	215.55					2913.99	513.0
10	14	65	2	4	292.90	0.490E-13	0.329E-07	0.200	0.16E-02	2005.98	497.6
10	26	65	2	4	285.62	0.891E-13	0.499E-07			2068.61	496.7
10	30	65	8	4	269.50					2223.78	496.4
10	30	65	8	4	202.00	0.431E-13				2741.93	481.8
7	3	65	9	4	263.50	0.164E-13	0.916E-08			2452.02	513.7
12	4	65	9	4	253.70	0.467E-14	0.261E-08			2269.63	485.3
12	4	65	9	4	242.70	0.260E-14	0.272E-07			2494.03	497.2
11	9	65	9	4	255.70	0.415E-14	0.232E-08				
6	11	65	9	4	259.04					2399.27	503.9
9	16	65	9	4	258.50	0.281E-13	0.157E-07			2263.01	489.5
15	1	65	10	4	262.30					2179.21	484.7
11	8	65	11	4	258.20	0.482E-14	0.484E-07			2385.26	501.6
10	23	65	11	4	164.90	0.243E-13	0.237E-06			3164.72	487.9
10	23	65	11	4	248.70	0.662E-13	0.640E-06			2332.63	486.8

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
7	26	65	12	4	246.15					2421.04	493.2
7	26	65	12	4	247.10					2307.22	482.6
10	21	65	13	4	242.30					2476.87	495.1
5	17	65	14	4	233.80					2604.69	499.6
5	12	65	15	4	155.80	0.843E-14	0.472E-08			3231.22	485.6
5	12	65	15	4	232.60	0.234E-14	0.131E-08			2636.33	501.7
1	27	65	15	4	184.10					3159.03	506.5
1	27	65	15	4	239.88	0.115E-15	0.641E-10			2575.16	502.7
6	36	65	15	4	224.63	0.345E-13	0.304E-06			2604.46	490.4
7	12	65	16	4	213.06					2879.51	506.9
6	29	65	16	4	212.75					2814.31	500.0
15	4	65	17	4	193.20					3109.23	510.5
10	8	65	17	4	191.40					3127.69	510.6
10	8	65	17	4	151.40	0.233E-13	0.130E-07			3366.00	494.9
11	17	65	17	4	191.75					3275.14	526.0
10	10	66	2	4	288.30	0.191E-13	0.107E-07			1965.28	488.9
4	31	66	8	4	201.60					2891.85	496.8
4	31	66	8	4	288.60	0.453E-14	0.254E-08				
11	25	66	9	4	276.40	0.349E-14				2132.86	494.1
10	4	66	10	4	266.10					2263.32	497.1
10	4	66	10	4	268.50					2237.99	496.9
6	8	66	10	4	274.81					2226.89	502.1
6	8	66	10	4	265.80	0.233E-13	0.140E-07			2223.94	492.8
7	15	66	10	4	275.60	0.186E-13	0.104E-07			2136.78	493.7
8	32	66	11	4	270.20					2249.21	499.7
6	16	66	13	4	191.75					2929.48	490.7

NTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
PPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION SD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	30	66	14	4	180.60					2974.91	484.2
11	9	66	15	4	233.30					2563.80	495.0
11	34	66	15	4	182.71					3067.19	495.7
11	34	66	15	4	202.71	0.881E-15	0.800E-08	0.330	8.6	2899.73	498.7
11	27	66	16	4	180.80	0.313E-13	0.175E-07			2993.52	486.3
11	27	66	16	4	228.90	0.723E-13	0.405E-07			2658.19	500.2
11	34	66	16	4	208.61					2803.19	494.7
11	34	66	16	4	231.16					2588.85	495.4
9	27	66	17	4	170.00	0.221E-13	0.124E-07			3208.98	497.5
9	27	66	17	4	161.00					3170.85	484.6
7	7	67	14	4	192.60					3152.16	514.3
7	7	67	14	4	257.60					2439.29	506.5
6	9	67	14	4	196.10	0.611E-13	0.548E-06			2955.12	497.7
6	9	67	14	4	188.10	0.374E-14	0.209E-08				
6	9	67	14	4	188.10	0.333E-13	0.300E-06			2976.57	491.9
11	10	67	14	4	261.50	0.171E-14	0.955E-09			2227.28	488.8
11	10	67	14	4	185.00	0.134E-14	0.750E-09			3035.07	494.8
11	10	67	14	4	190.00	0.372E-13	0.208E-07			2953.71	491.5
11	10	67	14	4	194.00	0.507E-13	0.284E-07			2902.43	490.2
13	18	67	14	4	189.00					2953.05	490.4
6	7	67	15	4	125.73					3276.25	460.1
6	7	67	15	4	236.37					2546.83	496.3
6	7	67	15	4	175.72					3054.86	487.5
6	1	67	16	4	231.77					2551.32	492.3
10	2	67	16	4	216.11	0.376E-13	0.234E-07	0.330	0.45E-02	2749.35	496.7
10	9	67	16	4	228.90					2538.28	487.9

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD SEC TP R M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6 11 67 17 4	175.69					2542.71	485.3
6 11 67 17 4	218.66					2695.73	493.8
11 16 67 17 4	87.50	0.183E-15	0.103E-09				
7 35 67 17 4	246.30	0.420E-16	0.235E-10			2518.48	503.3
7 20 68 10 4	304.00					1773.10	484.9
15 13 68 11 4	301.48					1919.28	497.4
15 13 68 11 4	304.70	0.481E-14					
11 27 68 11 4	311.00					1639.43	478.3
11 31 68 15 4	226.72					2522.48	484.2
11 29 69 11 4	299.30	0.265E-13				1850.20	488.1
7 28 69 12 4	312.10	0.531E-13	0.297E-07			1755.28	491.2
10 10 69 15 4	283.49					2032.82	491.0
10 10 69 15 4	274.85					2215.71	501.0

Table L-h-2

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
15	22	55	1	4	191.07			0.283	195.65
15	22	55	1	4	200.22			0.281	204.79
11	23	55	2	4	192.64			0.356	197.21
11	23	55	2	4	201.78			0.369	206.36
7	8	55	4	4	137.25	0.142E-11		0.402	141.00
7	8	55	4	4	145.50	0.159E-11		0.361	150.00
7	8	55	4	4	154.50	0.150E-12		0.304	159.00
6	17	55	4	4	150.80	0.398E-11		0.383	155.30
2	13	55	5	4	67.45			0.303	71.60
2	13	55	5	4	186.10			0.268	190.60
2	13	55	5	4	194.70			0.307	198.80
6	16	55	5	4	53.89			0.302	58.40
6	16	55	5	4	53.89	0.670E-12		0.322	58.40
6	16	55	5	4	62.90	0.106E-12		0.298	67.40
6	16	55	5	4	62.90			0.292	67.40
7	17	55	5	4	52.50	0.182E-12		0.169	57.50
7	17	55	5	4	62.25	0.103E-11		0.317	67.00
4	18	55	5	4	50.30			0.327	54.80
6	18	55	5	4	43.90			0.333	48.40
6	18	55	5	4	43.90	0.522E-11		0.352	48.40
6	18	55	5	4	52.91	0.214E-11		0.320	57.41
6	18	55	5	4	52.91			0.276	57.41
6	18	55	5	4	61.91			0.293	66.41
6	18	55	5	4	61.91	0.861E-12		0.323	66.41
14	18	55	5	4	49.40			0.281	53.90
14	18	55	5	4	58.40			0.284	62.90

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
5	19	55	5	4	47.32			0.306	52.32
5	19	55	5	4	57.14			0.357	61.97
12	20	55	5	4	52.10			0.316	56.60
12	20	55	5	4	61.10	0.266E-11		0.295	65.60
6	27	55	5	4	75.50			0.260	80.00
6	27	55	5	4	140.50			0.356	145.00
6	27	55	5	4	149.50			0.301	154.00
12	30	55	5	4	60.30	0.533E-11		0.333	64.80
12	30	55	5	4	69.30	0.235E-11		0.354	73.80
3	13	55	6	4	40.30	0.288E-11		0.309	44.80
3	13	55	6	4	49.30	0.252E-11		0.301	53.80
3	13	55	6	4	167.30	0.394E-11		0.305	171.80
3	13	55	6	4	176.30	0.292E-11		0.297	180.80
13	13	55	6	4	43.00	0.451E-11		0.321	47.50
13	13	55	6	4	52.00	0.134E-11		0.296	56.50
13	13	55	6	4	163.00	0.973E-12		0.302	167.50
13	13	55	6	4	172.00	0.267E-11		0.320	176.50
13	13	55	6	4	181.00	0.119E-11		0.335	185.50
15	13	55	6	4	42.57	0.437E-12		0.303	46.95
15	13	55	6	4	50.97	0.127E-11		0.286	55.00
15	13	55	6	4	164.08	0.364E-12		0.297	168.35
15	13	55	6	4	172.67	0.232E-11		0.318	177.00
7	14	55	6	4	39.25	0.153E-11		0.318	42.10
7	14	55	6	4	39.25			0.292	42.10
7	14	55	6	4	46.60	0.298E-11		0.334	51.10
7	14	55	6	4	46.60			0.307	51.10

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
7	14	55	6	4	55.60			0.286	60.10
7	14	55	6	4	55.60	0.731E-12		0.306	60.10
6	23	55	6	4	52.25	0.121E-11		0.345	56.70
6	24	55	6	4	45.20	0.116E-11		0.330	49.70
6	24	55	6	4	45.20			0.314	49.70
6	24	55	6	4	54.20			0.294	58.70
6	24	55	6	4	54.20	0.235E-11		0.335	58.70
7	25	55	6	4	61.61	0.372E-14		0.203	66.19
8	27	55	6	4	50.70	0.114E-11		0.309	55.20
13	27	55	6	4	53.80	0.102E-11		0.308	58.30
7	35	55	6	4	52.90	0.259E-11		0.332	57.40
7	35	55	6	4	61.90	0.906E-12		0.308	66.40
13	35	55	6	4	55.10	0.305E-11		0.310	59.60
13	35	55	6	4	64.10	0.112E-11		0.337	68.60
6	30	55	9	4	136.39	0.541E-12		0.302	140.96
7	20	55	10	4	99.82	0.371E-12		0.313	101.95
7	20	55	10	4	106.52	0.608E-12		0.329	111.09
7	20	55	10	4	115.66	0.330E-12		0.290	120.23
8	14	55	11	4	96.90			0.306	97.90
8	14	55	11	4	96.90	0.238E-11		0.313	97.90
8	17	55	11	4	85.91	0.815E-12		0.310	90.49
8	17	55	11	4	95.06	0.298E-11		0.324	99.63
8	17	55	11	4	104.20	0.233E-11		0.332	108.78
15	12	55	13	4	67.70	0.535E-11		0.286	72.20
15	12	55	13	4	76.70	0.227E-11		0.244	81.20
15	12	55	13	4	85.70	0.437E-11		0.280	90.20

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
15	12	55	13	4	94.65	0.147E-11		0.263	99.10
6	21	55	13	4	91.70	0.811E-12		0.329	96.27
6	21	55	13	4	96.58	0.218E-13		0.238	96.88
11	35	55	13	4	97.88			0.280	102.45
11	35	55	13	4	107.02			0.237	111.59
6	14	55	14	4	91.76	0.561E-14		0.180	97.86
7	35	55	14	4	107.64	0.728E-12	0.957E-13	0.289	109.77
7	25	56	1	4	185.76	0.132E-12		0.320	189.57
6	14	56	2	4	164.50			0.310	169.00
6	14	56	2	4	187.50			0.273	192.00
6	14	56	2	4	196.50			0.267	201.00
6	14	56	2	4	205.50			0.325	210.00
7	36	56	2	4	181.70			0.316	186.20
7	36	56	2	4	190.70			0.297	195.20
7	36	56	2	4	199.70			0.312	204.20
7	36	56	2	4	208.70			0.261	213.20
6	10	56	3	4	137.65	0.131E-11		0.340	140.24
6	10	56	3	4	143.44	0.478E-11		0.392	146.64
6	10	56	3	4	151.21	0.369E-12		0.382	155.79
6	10	56	3	4	171.03	0.242E-11		0.383	174.08
6	10	56	3	4	178.65	0.643E-12		0.380	183.22
6	19	56	5	4	147.10	0.861E-12		0.327	151.60
6	19	56	5	4	160.10	0.209E-11		0.344	168.60
16	23	56	5	4	133.65	0.637E-12		0.398	139.29
16	23	56	5	4	166.26	0.571E-13		0.302	177.39
16	23	56	5	4	192.17	0.204E-12		0.350	206.95

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
11	1	56	6	4	65.60			0.294	70.10
4	2	56	6	4	58.32			0.301	62.80
6	4	56	8	4	118.69	0.551E-13		0.254	122.50
6	4	56	8	4	127.07	0.362E-13		0.224	131.64
10	19	56	10	4	129.21	0.293E-13		0.222	138.36
11	26	56	10	4	135.38	0.120E-11		0.329	139.95
11	26	56	10	4	144.53	0.612E-12		0.314	149.10
11	34	56	10	4	102.72	0.197E-12		0.315	107.29
11	34	56	10	4	108.05	0.159E-12		0.324	108.82
11	34	56	10	4	110.34	0.242E-12		0.315	111.87
11	34	56	10	4	116.44	0.106E-12		0.300	121.01
11	34	56	10	4	126.19	0.431E-14		0.226	131.07
10	36	56	10	4	135.08	0.948E-13		0.271	139.51
10	36	56	10	4	143.78	0.112E-13		0.239	148.06
10	36	56	10	4	150.83	0.902E-14		0.204	153.60
16	28	56	14	4	90.85	0.120E-12	0.964E-13	0.257	95.43
16	28	56	14	4	100.00	0.293E-13	0.151E-13	0.223	104.57
10	17	57	1	4	147.50			0.303	151.50
10	17	57	1	4	155.00			0.322	158.50
10	17	57	1	4	177.00			0.314	181.50
10	17	57	1	4	186.00			0.304	190.50
10	17	57	1	4	195.00			0.334	199.50
10	13	57	2	4	143.20			0.313	147.70
10	13	57	2	4	152.20			0.303	156.70
10	13	57	2	4	175.20			0.343	179.70
10	13	57	2	4	184.20			0.340	188.70

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	13	57	2	4	193.20			0.340	197.70
10	13	57	2	4	202.20			0.313	206.70
10	7	57	5	4	150.84			0.278	155.41
10	7	57	5	4	159.98			0.282	164.56
10	7	57	5	4	197.78			0.299	202.35
10	7	57	5	4	206.32			0.302	210.28
9	9	57	5	4	192.30	0.365E-12		0.302	196.30
9	9	57	5	4	192.30			0.271	196.30
9	9	57	5	4	200.80			0.318	205.30
9	9	57	5	4	200.80	0.123E-11		0.342	205.30
15	16	57	5	4	200.90			0.314	202.40
15	16	57	5	4	206.90			0.295	211.40
15	16	57	5	4	215.90			0.265	220.40
5	36	57	7	4	182.50	0.157E-11		0.297	186.95
7	26	57	9	4	157.42	0.156E-12		0.337	160.62
10	30	57	9	4	155.73	0.557E-12		0.299	160.30
10	30	57	9	4	164.87	0.137E-11		0.312	169.45
10	2	57	10	4	136.28	0.466E-12		0.284	140.70
10	2	57	10	4	145.07	0.208E-12		0.266	149.50
7	31	57	10	4	144.45			0.230	145.20
7	31	57	10	4	149.70			0.307	154.20
7	31	57	10	4	158.70			0.232	163.20
6	36	57	10	4	148.89	0.174E-12		0.245	153.40
6	36	57	10	4	155.87	0.101E-11		0.318	158.40
6	36	57	10	4	161.40	0.126E-11		0.293	164.40
10	28	57	12	4	110.55			0.310	115.30

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
LSD	SEC	TP	R	M					
10	28	57	12	4	118.45			0.314	121.60
10	28	57	12	4	126.10			0.278	130.60
10	28	57	12	4	135.10			0.283	139.60
7	35	57	16	4	72.58	0.214E-11	0.100E-11	0.270	77.15
7	35	57	16	4	81.72	0.116E-11	0.546E-12	0.269	86.30
7	35	57	16	4	90.87	0.205E-11	0.927E-12	0.295	95.44
7	35	57	16	4	100.02	0.152E-11	0.820E-12	0.297	104.59
10	22	58	3	4	136.57			0.363	141.15
10	22	58	3	4	145.72			0.360	150.29
10	22	58	3	4	154.55			0.337	158.82
10	29	58	3	4	137.41	0.335E-13		0.363	146.78
10	29	58	3	4	160.12	0.528E-13		0.377	173.45
6	22	58	4	4	143.23			0.358	146.28
6	22	58	4	4	149.32			0.361	152.37
6	22	58	4	4	155.43			0.303	158.47
10	28	58	4	4	122.40			0.333	127.10
10	8	58	5	4	147.18			0.297	156.63
10	15	58	5	4	145.88			0.341	151.21
10	15	58	5	4	145.88	0.193E-11		0.369	151.21
10	15	58	5	4	151.21			0.331	161.88
10	24	58	5	4	137.70	0.150E-11		0.360	140.70
10	24	58	5	4	143.70	0.229E-11		0.382	146.70
10	24	58	5	4	147.70	0.307E-11		0.384	148.70
10	24	58	5	4	151.70	0.310E-11		0.371	154.70
10	24	58	5	4	157.70	0.536E-11		0.353	160.70
10	25	58	5	4	144.80			0.211	149.38

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	25	58	5	4	173.15			0.172	177.72
10	27	58	5	4	150.91			0.341	155.48
7	34	58	6	4	196.30	0.815E-12		0.323	200.80
7	34	58	6	4	203.80	0.269E-12		0.317	206.80
7	34	58	6	4	209.84	0.144E-11		0.321	212.88
6	2	58	10	4	139.86	0.452E-13		0.297	144.44
6	2	58	10	4	149.04	0.481E-12		0.310	153.58
6	2	58	10	4	157.08	0.641E-12		0.355	160.59
6	2	58	10	4	163.94	0.459E-12		0.349	167.30
6	8	58	10	4	136.85	0.429E-12		0.268	139.90
6	8	58	10	4	142.72	0.156E-11		0.308	145.60
6	8	58	10	4	148.86	0.767E-12		0.298	152.10
6	8	58	10	4	155.15	0.644E-12		0.309	158.20
2	4	58	11	4	131.52	0.553E-13		0.274	135.94
2	4	58	11	4	146.91	0.893E-13		0.280	157.89
15	7	58	11	4	95.10	0.214E-11	0.938E-12	0.300	99.19
15	7	58	11	4	103.64	0.107E-11	0.259E-12	0.302	108.10
10	12	58	12	4	148.00			0.248	152.50
10	12	58	12	4	157.00			0.229	161.50
7	20	58	12	4	136.50			0.283	141.00
7	20	58	12	4	136.50			0.230	141.00
7	20	58	12	4	145.50			0.160	150.00
7	20	58	12	4	145.50			0.263	150.00
1	35	58	12	4	137.52			0.350	150.70
1	35	58	12	4	159.16	0.596E-12		0.291	167.62
11	5	59	2	4	136.25			0.326	139.60

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
11	5	59	2	4	143.10	0.281E-11		0.326	146.60
11	6	59	2	4	145.30	0.280E-11		0.355	149.80
11	6	59	2	4	154.30	0.177E-11		0.367	158.80
14	17	59	2	4	137.60	0.259E-11		0.376	142.20
14	17	59	2	4	146.70	0.222E-11		0.349	151.20
14	17	59	2	4	155.70	0.193E-11		0.357	160.20
14	17	59	2	4	164.60	0.426E-12		0.299	169.00
14	18	59	2	4	140.80	0.189E-11		0.388	145.30
14	18	59	2	4	149.80	0.181E-11		0.374	154.30
14	18	59	2	4	158.80	0.225E-11		0.348	163.30
11	19	59	2	4	151.30			0.304	155.80
11	19	59	2	4	160.30	0.316E-11		0.325	164.80
6	20	59	2	4	144.73			0.281	148.75
6	20	59	2	4	153.23	0.186E-11		0.327	157.70
6	20	59	2	4	161.70	0.124E-11		0.321	165.70
6	20	59	2	4	170.20	0.887E-12		0.346	174.70
10	24	59	2	4	138.70			0.300	141.70
10	24	59	2	4	150.70	0.740E-12		0.340	153.70
10	24	59	2	4	156.70			0.149	159.70
10	24	59	2	4	168.70	0.225E-11		0.328	171.70
10	24	59	2	4	174.70	0.234E-11		0.349	177.70
10	24	59	2	4	180.70	0.447E-12		0.306	183.70
10	24	59	2	4	186.70			0.290	189.70
10	24	59	2	4	192.70			0.301	195.70
10	35	59	2	4	145.54			0.408	158.50
10	35	59	2	4	188.52			0.338	199.34

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
2	23	59	3	4	147.37			0.364	168.25
10	5	59	4	4	152.86	0.713E-13		0.391	161.55
10	5	59	4	4	168.40	0.121E-11		0.362	173.13
10	5	59	4	4	233.18	0.307E-13		0.293	245.68
6	9	59	4	4	178.02	0.131E-11		0.303	182.59
6	9	59	4	4	187.17	0.116E-11		0.324	191.74
10	16	59	4	4	136.67			0.392	137.74
10	16	59	4	4	142.61	0.278E-11		0.364	147.19
10	16	59	4	4	151.15	0.299E-11		0.362	155.11
11	20	59	4	4	147.25	0.221E-11		0.332	151.79
11	20	59	4	4	156.36	0.109E-11		0.322	160.93
10	26	59	4	4	139.91			0.377	141.74
10	26	59	4	4	146.01			0.377	150.28
10	26	59	4	4	182.89			0.305	187.46
10	26	59	4	4	192.03			0.327	196.61
4	28	59	4	4	142.05			0.293	145.09
4	28	59	4	4	148.14			0.406	151.19
4	28	59	4	4	149.67	0.147E-11		0.387	151.19
4	28	59	4	4	154.24			0.385	157.29
4	28	59	4	4	155.31	0.175E-11		0.383	157.29
4	28	59	4	4	157.91	0.144E-11		0.358	158.23
4	28	59	4	4	159.27			0.327	161.25
10	30	59	4	4	138.06			0.326	141.11
10	30	59	4	4	145.68	0.169E-11		0.335	150.26
10	30	59	4	4	154.83	0.869E-12		0.335	159.40
16	30	59	4	4	229.69	0.173E-13		0.330	240.82

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
10	31	59	4	4	148.79	0.298E-11		0.345	153.36
10	31	59	4	4	157.93	0.107E-11		0.327	162.50
10	34	59	4	4	144.49			0.400	146.32
10	34	59	4	4	149.37			0.420	152.41
10	34	59	4	4	185.94			0.364	188.99
10	1	59	5	4	139.59			0.398	142.64
10	1	59	5	4	144.16			0.413	145.69
10	1	59	5	4	148.74			0.381	151.79
10	10	59	5	4	145.67	0.114E-12		0.304	148.72
10	10	59	5	4	151.76	0.342E-12		0.303	154.81
10	10	59	5	4	157.86	0.140E-11		0.329	160.91
14	4	59	6	4	210.90	0.444E-12		0.278	213.40
10	9	59	6	4	205.30	0.875E-11		0.343	209.80
10	9	59	6	4	214.20	0.381E-11		0.364	218.60
10	9	59	6	4	219.40			0.312	220.20
7	30	59	6	4	212.59			0.330	215.50
7	30	59	6	4	220.00	0.614E-11		0.330	224.50
1	27	59	7	4	210.60			0.337	213.96
6	21	59	10	4	174.02	0.818E-12		0.362	178.59
11	24	59	16	4	134.56	0.290E-12	0.279E-12	0.262	141.42
7	17	60	1	4	187.72			0.392	192.29
7	17	60	1	4	196.86	0.107E-11		0.335	201.44
11	27	60	3	4	151.80	0.682E-11		0.363	156.30
11	27	60	3	4	159.80	0.296E-11		0.382	163.30
6	28	60	3	4	156.17			0.389	158.20
6	28	60	3	4	162.61	0.267E-11		0.374	167.02

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
6	28	60	3	4	171.61	0.124E-11		0.349	176.20
6	33	60	3	4	152.60	0.565E-11		0.373	157.10
6	33	60	3	4	161.60	0.277E-11		0.381	166.10
6	33	60	3	4	170.60	0.214E-11		0.338	175.10
10	35	60	3	4	153.00	0.977E-12		0.344	157.50
10	35	60	3	4	161.98	0.236E-11		0.365	166.45
10	35	60	3	4	170.98	0.439E-11		0.365	175.50
12	11	60	4	4	175.66			0.347	206.57
11	25	60	5	4	235.13	0.263E-12		0.281	255.40
13	28	60	5	4	221.10	0.618E-13		0.272	229.48
13	28	60	5	4	235.42	0.288E-12		0.265	241.36
6	29	60	5	4	224.34	0.879E-13		0.286	241.10
7	29	60	5	4	233.89	0.543E-13	0.627E-13	0.243	245.32
9	29	60	5	4	225.10	0.398E-12		0.248	234.40
10	29	60	5	4	230.61	0.371E-13		0.260	240.82
10	29	60	5	4	228.93	0.225E-12		0.281	239.30
12	29	60	5	4	228.88	0.382E-13		0.290	241.68
12	29	60	5	4	224.96	0.569E-12		0.288	238.68
13	29	60	5	4	156.42	0.247E-12		0.271	170.86
13	29	60	5	4	197.16	0.126E-12		0.296	214.84
13	29	60	5	4	230.23	0.948E-13		0.294	245.62
16	29	60	5	4	218.93	0.346E-13		0.303	225.58
16	29	60	5	4	230.91	0.583E-13		0.281	236.25
6	29	60	8	4	218.20	0.697E-11		0.339	221.20
6	29	60	8	4	224.20	0.741E-11		0.341	227.20
6	29	60	8	4	230.20	0.163E-11		0.318	233.20

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	8	60	15	4	92.34	0.658E-13		0.297	96.91
10	8	60	15	4	101.48	0.104E-12		0.306	106.06
10	8	60	15	4	110.63	0.460E-13		0.310	115.20
10	8	60	15	4	119.77	0.553E-12		0.305	124.34
10	8	60	15	4	128.18	0.316E-12		0.319	132.02
10	8	60	15	4	134.59	0.764E-13		0.291	137.15
10	8	60	15	4	141.72	0.962E-13		0.282	146.29
11	8	60	17	4	117.67	0.163E-12	0.226E-13	0.257	122.25
6	22	61	1	4	203.60			0.340	206.60
6	22	61	1	4	209.60			0.342	212.60
6	22	61	1	4	215.60			0.329	218.60
6	23	61	1	4	207.23	0.610E-12		0.319	210.28
6	23	61	1	4	213.32	0.171E-11		0.351	216.37
6	23	61	1	4	219.42	0.226E-11		0.341	222.47
6	23	61	1	4	225.36	0.637E-11		0.379	228.26
11	31	61	1	4	138.10			0.344	141.15
11	31	61	1	4	142.83			0.361	144.50
11	31	61	1	4	147.55			0.349	150.60
11	31	61	1	4	153.65			0.361	156.69
11	31	61	1	4	159.74			0.364	162.79
11	31	61	1	4	165.84			0.319	168.88
11	31	61	1	4	171.32			0.319	173.76
11	31	61	1	4	176.81			0.392	179.86
11	31	61	1	4	182.91			0.379	185.95
11	31	61	1	4	189.00			0.388	192.05
11	31	61	1	4	195.10			0.340	196.62

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
11	31	61	1	4	199.67			0.365	202.72
11	31	61	1	4	205.77			0.341	208.81
6	32	61	1	4	189.51	0.684E-12		0.333	192.45
6	32	61	1	4	194.69	0.780E-12		0.374	196.93
6	32	61	1	4	199.98	0.426E-11		0.355	203.03
6	32	61	1	4	205.93	0.526E-12		0.316	208.82
8	36	61	2	4	143.53			0.387	145.94
8	36	61	2	4	152.18			0.403	158.43
8	36	61	2	4	152.55			0.379	154.84
8	36	61	2	4	195.92			0.373	197.14
8	36	61	2	4	201.71			0.360	206.29
8	36	61	2	4	209.64			0.352	212.99
16	36	61	2	4	131.70			0.323	134.75
16	36	61	2	4	137.80			0.332	140.85
16	36	61	2	4	143.89			0.351	146.94
16	36	61	2	4	149.99			0.314	153.04
16	36	61	2	4	156.08			0.312	159.13
16	36	61	2	4	162.18			0.311	165.23
16	36	61	2	4	168.28			0.323	171.33
16	36	61	2	4	174.38			0.287	177.42
16	36	61	2	4	180.47			0.304	183.52
16	36	61	2	4	185.96			0.383	188.39
16	36	61	2	4	191.14			0.337	193.88
16	36	61	2	4	206.07			0.344	209.12
16	36	61	2	4	210.79			0.342	212.47
16	36	61	2	4	214.76			0.303	217.05

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
9	21	61	4	4	233.22	0.160E-12		0.284	246.93
13	29	61	4	4	189.15			0.292	191.44
13	29	61	4	4	194.64	0.146E-11		0.322	197.84
13	29	61	4	4	200.91	0.277E-11		0.332	203.93
13	29	61	4	4	207.01	0.337E-11		0.349	210.03
13	29	61	4	4	213.07	0.325E-11		0.346	216.12
10	33	61	4	4	215.38	0.272E-11		0.369	217.65
10	33	61	4	4	220.70	0.646E-12		0.315	223.75
16	1	61	6	4	218.27	0.622E-13		0.289	225.89
16	1	61	6	4	238.08	0.463E-15		0.222	250.27
10	31	61	6	4	225.58	0.444E-12		0.321	230.16
10	31	61	6	4	234.73	0.115E-11		0.322	239.30
10	31	61	6	4	242.80	0.484E-12		0.313	246.31
10	31	61	6	4	250.62	0.420E-12		0.309	254.84
11	36	61	6	4	241.38			0.299	245.88
7	13	61	9	4	232.28	0.474E-13		0.270	233.20
6	6	62	1	4	139.33			0.345	142.38
6	6	62	1	4	145.43			0.368	148.48
6	6	62	1	4	151.53			0.345	154.57
6	6	62	1	4	157.62			0.302	160.67
6	6	62	1	4	163.72			0.316	166.76
6	6	62	1	4	169.81			0.381	172.86
6	6	62	1	4	175.91			0.330	178.96
6	6	62	1	4	188.10			0.347	191.15
6	6	62	1	4	194.20			0.327	197.24
6	6	62	1	4	200.29			0.345	203.34

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
6	6	62	1	4	205.63			0.320	207.91
6	6	62	1	4	211.11			0.353	214.31
7	1	62	2	4	139.31			0.367	142.36
7	1	62	2	4	145.41			0.358	148.46
7	1	62	2	4	151.51			0.324	154.56
7	1	62	2	4	157.60			0.350	160.65
7	1	62	2	4	163.70			0.325	166.75
7	1	62	2	4	169.79			0.363	172.84
7	1	62	2	4	175.89			0.377	178.94
7	1	62	2	4	183.51			0.380	185.04
7	1	62	2	4	188.08			0.378	191.13
7	1	62	2	4	199.97			0.300	202.72
7	1	62	2	4	212.47			0.321	215.52
7	1	62	2	4	218.26			0.310	221.00
15	9	62	2	4	172.17			0.394	184.36
4	29	62	2	4	195.80			0.325	216.98
4	29	62	2	4	229.33			0.322	241.67
10	1	62	3	4	165.78			0.366	168.83
10	1	62	3	4	171.91			0.318	174.93
11	20	62	3	4	158.53			0.345	163.10
5	21	62	3	4	157.85	0.592E-15		0.362	163.94
5	21	62	3	4	182.32	0.207E-12		0.353	200.70
5	21	62	3	4	206.86			0.345	213.01
4	25	62	3	4	182.57			0.349	196.29
4	25	62	3	4	210.00			0.380	223.72
11	31	62	3	4	161.80			0.347	166.30

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
11	31	62	3	4	185.80			0.331	190.30
11	31	62	3	4	194.80			0.347	199.30
11	31	62	3	4	203.80			0.323	208.30
11	31	62	3	4	212.80			0.333	217.30
10	14	62	4	4	152.40	0.155E-11		0.355	156.90
10	14	62	4	4	170.28			0.392	171.90
10	14	62	4	4	177.15	0.265E-11		0.329	182.40
10	14	62	4	4	186.58	0.165E-11		0.340	190.75
10	14	62	4	4	195.33	0.857E-12		0.328	199.90
10	14	62	4	4	204.80	0.315E-12		0.311	209.69
10	14	62	4	4	212.60	0.208E-12		0.339	215.51
10	14	62	4	4	219.21	0.358E-12		0.331	222.90
10	36	62	4	4	172.10	0.655E-11		0.378	176.60
10	36	62	4	4	181.10	0.301E-11		0.328	185.60
10	36	62	4	4	190.10	0.520E-11		0.338	194.60
10	36	62	4	4	199.10			0.291	203.60
10	14	62	5	4	204.40			0.316	208.90
10	14	62	5	4	213.25			0.286	217.60
10	14	62	5	4	221.85			0.388	226.10
10	14	62	5	4	230.43			0.355	234.75
10	14	62	5	4	238.83			0.303	242.90
10	16	62	5	4	235.55			0.322	242.30
1	26	62	5	4	183.80			0.385	185.94
11	17	62	6	4	201.76			0.286	204.81
11	17	62	6	4	207.86			0.305	210.91
11	17	62	6	4	213.95			0.340	217.00

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
11	17	62	6	4	220.05			0.332	223.10
11	21	62	6	4	190.70			0.309	195.20
11	21	62	6	4	199.70			0.335	204.20
11	21	62	6	4	208.70			0.332	213.20
11	21	62	6	4	217.70			0.338	222.20
11	21	62	6	4	226.70			0.333	231.20
10	29	62	6	4	199.34	0.815E-12		0.343	202.39
10	29	62	6	4	205.43	0.161E-11		0.317	208.48
10	29	62	6	4	211.53	0.309E-12		0.345	214.58
10	29	62	6	4	217.63	0.242E-11		0.371	220.68
10	29	62	6	4	223.73	0.354E-12		0.305	226.77
10	29	62	6	4	229.82	0.238E-12		0.375	232.87
10	29	62	6	4	235.76	0.442E-12		0.334	238.66
7	14	62	7	4	177.17			0.265	181.30
7	14	62	7	4	185.80			0.296	190.30
7	14	62	7	4	194.80			0.345	199.30
7	14	62	7	4	203.80			0.314	208.30
7	14	62	7	4	212.80			0.346	217.30
7	14	62	7	4	221.80			0.313	226.30
6	23	62	7	4	214.24			0.287	218.81
6	23	62	7	4	223.42	0.207E-11		0.331	227.95
10	25	62	7	4	195.66			0.343	199.30
10	25	62	7	4	199.68			0.346	200.06
10	25	62	7	4	200.44			0.359	200.82
10	25	62	7	4	205.03			0.359	209.23
10	25	62	7	4	213.43			0.349	217.62

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
10	25	62	7	4	218.54			0.374	219.45
10	25	62	7	4	222.19			0.361	224.93
6	26	62	7	4	211.70			0.341	216.20
6	26	62	7	4	220.70			0.343	225.20
6	26	62	7	4	229.70			0.218	234.20
6	26	62	7	4	238.70			0.331	243.20
10	36	62	7	4	177.20			0.319	182.35
10	36	62	7	4	186.20			0.305	190.05
10	36	62	7	4	194.55			0.315	199.05
10	36	62	7	4	203.50			0.352	207.95
10	36	62	7	4	212.70			0.338	217.45
10	36	62	7	4	221.37			0.298	225.30
12	29	62	8	4	242.32	0.594E-11		0.374	246.84
12	29	62	8	4	251.49	0.471E-11		0.382	256.07
6	4	63	2	4	239.60			0.318	262.15
5	19	63	2	4	177.38			0.360	178.50
5	19	63	2	4	192.63			0.359	195.50
5	19	63	2	4	200.00			0.356	204.50
5	19	63	2	4	216.25			0.343	220.00
5	19	63	2	4	224.50			0.308	229.00
11	5	63	3	4	180.60			0.357	188.37
11	5	63	3	4	210.93			0.359	233.48
11	5	63	3	4	244.76			0.402	256.04
4	7	63	3	4	208.00			0.303	212.42
4	7	63	3	4	216.99			0.302	221.56
6	7	63	3	4	157.77			0.333	162.20

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
6	7	63	3	4	188.95			0.358	193.20
6	7	63	3	4	197.70			0.313	202.20
6	7	63	3	4	206.70			0.332	211.20
6	7	63	3	4	215.70			0.350	220.20
6	7	63	3	4	238.70			0.263	257.20
6	23	63	3	4	170.60	0.442E-11		0.379	175.10
6	23	63	3	4	179.60	0.256E-11		0.335	184.10
6	23	63	3	4	199.60	0.826E-11		0.373	204.10
6	23	63	3	4	208.60	0.301E-11		0.358	213.10
6	23	63	3	4	217.60	0.283E-11		0.360	222.10
6	23	63	3	4	226.60	0.951E-12		0.338	231.10
6	23	63	3	4	235.60	0.200E-11		0.342	240.10
6	23	63	3	4	244.60	0.650E-12		0.331	249.10
11	25	63	3	4	174.00	0.574E-11		0.377	178.50
11	25	63	3	4	193.50			0.316	196.50
11	25	63	3	4	201.00			0.384	205.50
11	25	63	3	4	210.00			0.381	214.50
11	25	63	3	4	219.00			0.346	223.50
11	25	63	3	4	228.00			0.317	232.50
11	25	63	3	4	237.00			0.352	241.50
11	25	63	3	4	246.00			0.295	250.50
3	26	63	3	4	163.03	0.272E-11		0.358	167.60
3	26	63	3	4	172.17	0.138E-11		0.368	176.74
3	26	63	3	4	193.21	0.443E-11		0.376	195.36
3	26	63	3	4	200.07	0.217E-11		0.369	204.78
3	26	63	3	4	209.35	0.237E-11		0.364	213.92

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
3	26	63	3	4	218.50	0.126E-11		0.329	223.07
3	26	63	3	4	227.92	0.679E-12		0.324	232.76
3	26	63	3	4	236.32	0.360E-11		0.331	239.83
7	6	63	4	4	146.26			0.380	150.84
11	33	63	4	4	145.65			0.364	150.22
11	33	63	4	4	154.79			0.368	159.36
11	6	63	5	4	205.50			0.311	210.00
11	18	63	5	4	207.57			0.347	212.10
11	20	63	5	4	191.38			0.351	195.95
9	25	63	5	4	205.86			0.298	208.91
9	25	63	5	4	211.96			0.265	215.01
9	25	63	5	4	218.06			0.305	221.11
9	25	63	5	4	224.15			0.324	227.20
9	25	63	5	4	230.25			0.263	233.30
9	25	63	5	4	236.35			0.297	239.39
9	25	63	5	4	242.44			0.338	245.49
9	25	63	5	4	248.54			0.281	251.59
16	25	63	5	4	245.39			0.382	249.66
10	30	63	5	4	170.20			0.257	207.70
13	15	63	6	4	211.33	0.171E-12		0.376	223.37
10	17	63	6	4	194.36			0.392	194.82
10	17	63	6	4	199.39	0.411E-12		0.326	203.96
9	23	63	6	4	208.45			0.350	212.95
9	23	63	6	4	216.83			0.360	220.70
10	30	63	6	4	176.50			0.360	180.77
10	30	63	6	4	185.05			0.359	189.30

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	30	63	6	4	193.88			0.390	198.45
10	30	63	6	4	203.02			0.357	207.59
10	30	63	6	4	212.17			0.341	216.74
10	30	63	6	4	221.34			0.404	225.88
10	1	63	7	4	197.06	0.177E-11		0.304	199.96
10	1	63	7	4	204.38	0.178E-11		0.331	208.80
10	1	63	7	4	212.61	0.333E-12		0.305	216.42
10	1	63	7	4	220.99	0.171E-11		0.342	225.57
10	3	63	7	4	195.35			0.323	198.40
10	3	63	7	4	195.35	0.497E-13		0.354	198.40
10	3	63	7	4	201.45	0.313E-13		0.341	204.49
10	3	63	7	4	201.45			0.310	204.49
10	3	63	7	4	206.93	0.229E-11		0.384	209.37
10	3	63	7	4	206.93			0.337	209.37
10	3	63	7	4	211.20	0.773E-12		0.400	213.03
10	3	63	7	4	211.20			0.363	213.03
10	3	63	7	4	216.38			0.360	219.73
10	3	63	7	4	216.38	0.120E-11		0.410	219.73
10	3	63	7	4	221.71			0.321	223.70
10	3	63	7	4	221.71			0.372	223.70
7	7	63	7	4	209.00			0.323	213.50
7	7	63	7	4	218.00			0.347	222.50
7	7	63	7	4	226.50			0.314	230.50
10	9	63	7	4	190.70			0.344	195.20
10	9	63	7	4	199.70			0.271	204.20
10	9	63	7	4	208.70			0.359	213.20

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	9	63	7	4	216.70			0.246	220.20
10	13	63	7	4	173.25			0.196	178.00
10	13	63	7	4	182.82			0.300	187.65
10	13	63	7	4	192.36			0.344	197.07
10	13	63	7	4	201.69			0.341	206.31
10	13	63	7	4	210.92			0.361	215.53
10	13	63	7	4	219.88			0.337	224.22
6	15	63	7	4	190.01			0.275	192.60
6	15	63	7	4	195.65	0.290E-11		0.272	198.70
6	15	63	7	4	201.74	0.170E-11		0.277	204.79
6	15	63	7	4	205.55	0.239E-11		0.366	206.32
6	15	63	7	4	209.36	0.245E-11		0.371	212.41
6	15	63	7	4	215.46	0.671E-12		0.370	218.51
6	15	63	7	4	219.73	0.114E-13		0.279	220.95
6	15	63	7	4	229.94	0.262E-12		0.259	238.93
7	17	63	7	4	203.00			0.298	207.50
7	17	63	7	4	232.00	0.445E-12		0.334	236.50
7	17	63	7	4	241.00	0.177E-12		0.311	245.50
7	17	63	7	4	250.00	0.107E-11		0.336	254.50
10	19	63	7	4	181.25			0.360	185.50
10	19	63	7	4	189.59			0.357	193.68
10	19	63	7	4	197.96			0.379	202.25
10	19	63	7	4	206.38			0.340	210.50
10	19	63	7	4	214.75			0.315	219.00
10	19	63	7	4	223.04			0.338	227.07
10	19	63	7	4	229.54			0.362	232.00

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
6	2	63	8	4	180.00			0.346	184.50
6	2	63	8	4	189.00			0.326	193.50
6	2	63	8	4	198.00			0.358	202.50
6	2	63	8	4	206.63			0.352	210.75
6	2	63	8	4	215.25			0.335	219.75
6	2	63	8	4	224.25			0.317	228.75
3	4	63	8	4	238.32	0.474E-11		0.328	240.26
3	4	63	8	4	245.03	0.212E-11		0.317	249.80
14	11	63	8	4	187.20	0.144E-11		0.335	191.70
14	11	63	8	4	196.20	0.204E-11		0.326	200.70
14	11	63	8	4	205.20	0.265E-11		0.329	209.70
14	11	63	8	4	214.20	0.262E-12		0.324	218.70
14	11	63	8	4	223.20	0.354E-11		0.384	227.70
10	12	63	8	4	183.45	0.236E-11		0.349	188.02
10	12	63	8	4	192.59	0.201E-11		0.346	197.16
10	12	63	8	4	201.74	0.127E-11		0.347	206.31
10	12	63	8	4	210.88	0.175E-11		0.324	215.45
6	13	63	8	4	181.84	0.131E-11		0.358	185.88
6	13	63	8	4	190.84	0.194E-11		0.366	195.80
6	13	63	8	4	200.30	0.292E-11		0.357	204.80
6	13	63	8	4	209.35	0.360E-11		0.342	213.90
6	13	63	8	4	218.40	0.259E-12		0.332	222.90
6	13	63	8	4	227.53	0.116E-11		0.356	232.15
6	13	63	8	4	236.03			0.233	239.90
6	25	63	8	4	183.68	0.134E-11		0.359	188.47
6	25	63	8	4	192.98	0.191E-11		0.359	197.49

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
6	25	63	8	4	201.79	0.185E-11		0.387	206.10
6	25	63	8	4	210.50			0.329	214.90
6	25	63	8	4	253.00	0.759E-12		0.320	257.50
10	26	63	8	4	177.35			0.351	181.85
10	26	63	8	4	186.35			0.383	190.85
10	26	63	8	4	195.35			0.373	199.85
10	26	63	8	4	204.35			0.359	208.85
10	26	63	8	4	212.26			0.341	215.68
10	26	63	8	4	221.09			0.304	226.50
5	13	63	9	4	208.10	0.698E-12		0.309	212.60
5	13	63	9	4	217.10	0.116E-11		0.371	221.60
5	13	63	9	4	243.10	0.101E-11		0.331	247.60
5	13	63	9	4	252.60			0.340	257.60
10	10	63	14	4	211.83	0.301E-12		0.421	216.40
6	18	63	17	4	48.75	0.191E-13		0.225	56.37
6	18	63	17	4	158.48	0.843E-13		0.257	166.10
5	17	64	2	4	182.26			0.312	191.41
8	1	64	3	4	182.53			0.368	206.30
10	4	64	3	4	144.75			0.332	147.80
10	27	64	3	4	166.37			0.379	167.91
1	8	64	4	4	164.39	0.938E-12		0.385	167.59
12	15	64	4	4	155.70	0.490E-11		0.358	160.20
12	15	64	4	4	164.20	0.337E-11		0.351	168.20
12	15	64	4	4	198.63	0.701E-11		0.379	203.10
12	15	64	4	4	207.65	0.389E-11		0.359	212.20
12	15	64	4	4	259.32	0.897E-12		0.325	263.18

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
12	15	64	4	4	267.69	0.424E-11		0.347	272.20
10	19	64	4	4	217.87			0.320	222.45
10	19	64	4	4	217.87	0.168E-11		0.362	222.45
10	19	64	4	4	226.87			0.328	231.30
10	19	64	4	4	226.87	0.385E-12		0.336	231.30
10	19	64	4	4	244.80			0.315	249.30
10	19	64	4	4	244.80	0.106E-11		0.343	249.30
10	19	64	4	4	253.80	0.158E-11		0.330	258.30
10	19	64	4	4	253.80			0.314	258.30
10	19	64	4	4	262.80	0.762E-12		0.356	267.30
10	19	64	4	4	262.80			0.320	267.30
2	20	64	4	4	158.00			0.343	162.50
2	20	64	4	4	158.00	0.571E-11		0.373	162.50
2	20	64	4	4	263.00			0.316	267.50
2	20	64	4	4	263.00	0.337E-11		0.350	267.50
10	21	64	4	4	163.60			0.323	168.10
10	21	64	4	4	163.60	0.171E-11		0.341	168.10
10	21	64	4	4	211.60	0.102E-12		0.295	216.10
10	21	64	4	4	211.60			0.288	216.10
10	21	64	4	4	233.60			0.304	251.10
10	21	64	4	4	233.60	0.312E-12		0.326	251.10
10	21	64	4	4	255.60			0.302	260.10
10	21	64	4	4	255.60	0.128E-12		0.316	260.10
10	21	64	4	4	263.10			0.360	266.10
10	21	64	4	4	263.10	0.760E-11		0.366	266.10
10	21	64	4	4	268.35	0.906E-11		0.365	270.60

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	21	64	4	4	268.35			0.347	270.60
13	21	64	4	4	163.35	0.370E-11		0.366	167.90
13	21	64	4	4	172.45	0.220E-11		0.372	177.00
13	21	64	4	4	181.55	0.104E-11		0.351	186.10
13	21	64	4	4	190.65	0.249E-11		0.368	195.20
13	21	64	4	4	200.10	0.230E-11		0.367	205.00
13	21	64	4	4	209.20	0.305E-11		0.353	213.40
13	21	64	4	4	217.95	0.366E-11		0.346	222.50
13	21	64	4	4	227.05	0.482E-12		0.322	231.60
13	21	64	4	4	236.15	0.104E-11		0.321	240.70
13	21	64	4	4	245.25	0.566E-12		0.318	249.80
13	21	64	4	4	252.55	0.116E-12		0.335	255.30
13	21	64	4	4	259.85	0.332E-11		0.330	264.40
2	28	64	4	4	162.10	0.240E-11		0.365	166.60
2	28	64	4	4	162.10			0.347	166.60
2	28	64	4	4	170.35			0.345	174.10
2	28	64	4	4	170.35	0.469E-11		0.358	174.10
6	28	64	4	4	162.30			0.359	166.80
11	28	64	4	4	164.58			0.427	169.15
11	28	64	4	4	164.78	0.701E-11		0.408	166.59
11	28	64	4	4	173.72			0.374	178.30
11	28	64	4	4	174.34	0.317E-11		0.388	177.51
11	28	64	4	4	182.87	0.272E-11		0.407	187.44
11	28	64	4	4	210.22	0.259E-11		0.395	214.87
11	28	64	4	4	217.64	0.121E-10		0.395	217.95
11	28	64	4	4	219.44			0.397	224.02

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
11	28	64	4	4	223.74			0.396	224.02
11	28	64	4	4	228.59	0.406E-12		0.386	233.16
11	28	64	4	4	237.73	0.159E-12		0.371	242.31
11	28	64	4	4	240.01	0.241E-11		0.404	240.32
11	28	64	4	4	246.91	0.168E-12		0.354	251.51
11	28	64	4	4	256.02	0.100E-12		0.303	260.59
11	28	64	4	4	265.13	0.120E-12		0.353	269.68
11	28	64	4	4	274.28	0.446E-12		0.336	278.88
15	28	64	4	4	173.15	0.425E-11		0.345	177.60
15	28	64	4	4	173.15			0.326	177.60
15	28	64	4	4	182.15			0.287	186.70
15	28	64	4	4	182.15	0.124E-11		0.311	186.70
7	29	64	4	4	212.05	0.218E-11		0.374	216.30
7	29	64	4	4	212.05			0.339	216.30
7	29	64	4	4	220.89	0.173E-11		0.368	225.48
7	29	64	4	4	220.89			0.342	225.48
7	29	64	4	4	229.89			0.339	234.30
7	29	64	4	4	229.89	0.188E-11		0.386	234.30
10	29	64	4	4	162.84			0.360	167.46
10	29	64	4	4	162.84	0.447E-11		0.369	167.46
10	29	64	4	4	171.88			0.343	176.30
10	29	64	4	4	171.88	0.364E-11		0.354	176.30
10	29	64	4	4	215.79			0.353	220.49
10	29	64	4	4	215.79	0.468E-11		0.364	220.49
10	29	64	4	4	224.96			0.330	229.43
10	29	64	4	4	224.96	0.193E-11		0.341	229.43

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	29	64	4	4	233.86			0.347	238.30
10	29	64	4	4	233.86	0.152E-11		0.359	238.30
11	30	64	4	4	161.10	0.465E-11		0.362	165.60
11	30	64	4	4	161.10			0.360	165.60
11	30	64	4	4	218.12	0.152E-11		0.361	222.60
11	30	64	4	4	218.12			0.320	222.60
11	30	64	4	4	227.10	0.210E-11		0.368	231.60
11	30	64	4	4	227.10			0.338	231.60
11	30	64	4	4	236.10			0.290	240.60
11	30	64	4	4	236.10	0.662E-12		0.341	240.60
11	30	64	4	4	254.10	0.122E-12		0.315	258.60
11	30	64	4	4	254.10			0.288	258.60
11	30	64	4	4	263.10	0.242E-11		0.372	267.60
11	30	64	4	4	263.10			0.325	267.60
6	32	64	4	4	170.33			0.337	175.40
6	32	64	4	4	170.33	0.330E-11		0.354	175.40
7	32	64	4	4	180.80	0.262E-11		0.356	185.30
7	32	64	4	4	196.80	0.113E-11		0.350	201.30
7	32	64	4	4	205.30	0.172E-11		0.371	209.30
7	32	64	4	4	213.80	0.481E-11		0.363	218.30
7	32	64	4	4	222.80	0.178E-11		0.371	227.30
7	32	64	4	4	231.80	0.175E-11		0.351	236.30
7	32	64	4	4	240.80	0.179E-11		0.370	245.30
7	32	64	4	4	249.80	0.100E-11		0.348	254.30
7	32	64	4	4	258.80	0.370E-11		0.382	263.30
7	32	64	4	4	267.80	0.859E-12		0.366	272.30

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	32	64	4	4	219.20	0.274E-11		0.367	223.70
10	32	64	4	4	219.20			0.331	223.70
10	32	64	4	4	226.70	0.391E-11		0.372	229.70
10	32	64	4	4	226.70			0.345	229.70
10	32	64	4	4	234.20	0.352E-11		0.380	238.70
10	32	64	4	4	234.20			0.365	238.70
10	32	64	4	4	243.20	0.318E-11		0.373	247.70
10	32	64	4	4	243.20			0.355	247.70
10	34	64	4	4	222.34			0.392	227.39
3	24	64	5	4	248.74	0.321E-12		0.359	255.45
10	34	64	5	4	176.63			0.341	179.53
6	11	64	6	4	206.10			0.325	210.55
6	11	64	6	4	214.63			0.373	218.70
7	30	64	6	4	219.20			0.328	223.20
7	30	64	6	4	227.70			0.335	232.20
7	3	64	7	4	204.50			0.220	209.00
7	3	64	7	4	213.50			0.317	218.00
7	3	64	7	4	222.50			0.352	227.00
10	28	64	7	4	227.30			0.353	231.80
10	28	64	7	4	235.30			0.319	238.80
10	28	64	7	4	243.30			0.312	247.80
11	30	64	11	4	234.85			0.316	238.05
11	30	64	11	4	241.10	0.312E-12		0.377	244.14
11	30	64	11	4	247.95	0.149E-12		0.247	251.76
11	30	64	11	4	256.33	0.918E-13		0.222	260.91
10	30	64	12	4	235.89	0.290E-12		0.353	240.46

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
10	30	64	12	4	245.03	0.502E-12		0.327	249.60
10	3	64	14	4	217.07	0.221E-12		0.354	221.64
10	3	64	14	4	231.09	0.265E-12		0.345	240.54
13	19	65	1	4	166.40			0.346	170.98
13	19	65	1	4	175.55			0.427	180.12
13	19	65	1	4	190.79			0.408	195.36
13	19	65	1	4	199.93			0.418	204.50
13	19	65	1	4	209.07			0.370	213.65
11	31	65	1	4	169.21			0.408	173.78
11	31	65	1	4	193.29			0.388	197.86
11	31	65	1	4	202.43			0.378	207.00
11	31	65	1	4	211.57			0.345	216.15
4	11	65	2	4	192.61			0.429	197.19
11	14	65	2	4	175.87			0.417	176.79
11	14	65	2	4	181.36			0.384	185.93
11	14	65	2	4	190.50			0.389	195.08
11	14	65	2	4	195.99			0.345	196.90
11	14	65	2	4	201.47			0.376	206.05
11	14	65	2	4	210.47			0.508	214.89
11	14	65	2	4	219.46			0.378	224.03
11	14	65	2	4	276.30			0.340	280.42
2	3	65	3	4	219.35			0.324	220.00
10	5	65	3	4	180.26			0.338	183.31
9	6	65	3	4	207.47			0.308	233.15
10	31	65	3	4	236.80			0.307	240.64
10	31	65	3	4	288.68			0.345	293.34

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
5	21	65	4	4	225.75			0.372	226.35
10	23	65	4	4	225.74			0.369	238.32
10	3	65	5	4	172.93			0.409	177.35
14	18	65	5	4	218.30			0.379	222.80
14	18	65	5	4	227.30			0.361	231.80
14	18	65	5	4	236.30			0.348	240.80
14	18	65	5	4	245.30			0.354	249.80
14	18	65	5	4	254.30			0.338	258.80
4	24	65	5	4	184.06			0.372	187.11
7	31	65	5	4	238.05			0.368	242.40
7	31	65	5	4	246.90			0.356	251.40
7	31	65	5	4	256.20			0.352	261.00
10	33	65	5	4	189.90			0.354	194.10
10	33	65	5	4	222.90			0.373	251.70
11	1	65	6	4	208.30			0.377	212.80
11	1	65	6	4	217.30			0.380	221.80
11	1	65	6	4	226.30			0.354	230.80
11	1	65	6	4	235.30			0.345	239.80
11	1	65	6	4	244.30			0.359	248.80
11	10	65	6	4	226.00			0.378	229.00
11	10	65	6	4	232.00			0.338	235.00
11	10	65	6	4	238.00			0.345	241.00
11	10	65	6	4	244.25			0.356	247.50
10	25	65	6	4	221.80			0.367	226.30
10	25	65	6	4	230.80			0.343	235.30
10	25	65	6	4	239.80			0.350	244.30

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
10	25	65	6	4	248.80			0.361	253.30
10	25	65	6	4	257.80			0.363	262.30
12	6	65	9	4	246.39			0.334	248.69
12	6	65	9	4	255.14			0.346	261.60
10	7	65	13	4	234.24	0.212E-12		0.313	238.05
10	7	65	13	4	242.02	0.295E-12		0.333	245.98
11	9	66	1	4	160.55			0.366	163.69
12	17	66	1	4	167.92			0.403	170.97
6	27	66	1	4	149.65			0.344	152.70
6	27	66	1	4	155.74			0.337	158.79
11	11	66	2	4	204.82			0.369	209.39
11	11	66	2	4	213.96			0.401	218.53
6	22	66	2	4	223.14			0.332	226.19
6	22	66	2	4	229.24			0.311	232.29
1	2	66	4	4	219.74			0.390	235.33
4	5	66	4	4	202.19			0.366	205.24
8	8	66	4	4	200.03			0.360	203.08
12	11	66	4	4	200.01			0.351	203.05
6	6	66	5	4	187.20			0.353	190.70
6	6	66	5	4	239.20			0.378	242.70
6	6	66	5	4	247.20			0.364	251.70
6	6	66	5	4	256.20			0.355	260.70
6	6	66	5	4	265.20			0.366	269.70
6	6	66	5	4	287.20			0.342	304.70
10	9	66	5	4	205.89			0.367	214.58
6	10	66	5	4	193.90			0.351	198.10

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
UPPER MANNVILLE GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
7	11	66	6	4	193.75			0.337	198.20
10	14	67	3	4	218.00	0.125E-11		0.364	222.50
10	2	67	4	4	222.58			0.343	227.07
10	2	67	4	4	231.08	0.102E-11		0.346	235.10
6	16	67	5	4	225.20	0.940E-12		0.355	229.70
11	9	67	12	4	264.90			0.342	269.51
11	9	67	12	4	273.80			0.328	278.10
8	22	67	12	4	274.27			0.299	278.58
8	22	67	12	4	282.85			0.298	287.12
6	10	67	13	4	266.88	0.579E-12	0.281E-12	0.295	271.00
5	16	67	14	4	190.89	0.248E-12		0.316	194.50
5	16	67	14	4	199.00	0.583E-13		0.297	203.50
8	28	68	17	4	226.18	0.183E-11		0.368	230.76
8	28	68	17	4	244.47	0.321E-12		0.270	249.05
8	28	68	17	4	253.62	0.212E-12		0.270	258.19

Table M-g-1

STRATIGRAPHIC PICKS FOR TOP OF JOLI FOU FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
LSD	SEC	TP	R	M			
10	28	57	2	4	639.20	393.50	245.70
10	19	57	4	4	645.00	417.01	227.99
6	26	57	5	4	634.60	378.90	255.70
14	29	57	5	4	654.70	398.66	256.04
13	2	57	6	4	589.50	354.51	234.99
11	7	57	8	4	661.40	455.06	206.34
6	29	57	8	4	655.60	444.66	210.94
12	10	57	9	4	684.30	483.77	200.53
10	27	57	9	4	642.80	442.20	200.60
10	30	57	9	4	640.10	434.38	205.72
7	9	57	10	4	638.90	451.10	187.80
6	28	57	10	4	639.50	441.80	197.70
7	10	57	11	4	653.80	467.70	186.10
10	12	57	11	4	634.00	450.81	183.19
10	25	57	11	4	631.90	435.61	196.29
10	28	57	11	4	630.90	442.24	188.66
13	2	57	12	4	631.90	465.51	166.39
6	26	57	12	4	633.60	453.76	179.84
10	28	57	12	4	645.30	467.70	177.60
7	2	58	2	4	648.40	407.80	240.60
6	7	58	4	4	583.10	324.90	258.20
6	36	58	4	4	643.40	386.41	256.99
10	8	58	5	4	657.80	409.73	248.07
6	13	58	5	4	665.40	399.58	265.82
10	24	58	5	4	665.10	397.90	267.20
2	29	58	5	4	696.80	443.16	253.64
11	14	58	6	4	639.40	393.69	245.71
11	25	58	6	4	765.40	517.58	247.82
11	26	58	6	4	707.10	456.81	250.29
4	5	58	7	4	678.80	451.14	227.66
6	8	58	8	4	649.50	433.13	216.37
13	10	58	8	4	598.90	381.61	217.29
7	28	58	8	4	655.30	441.02	214.28
11	31	58	8	4	640.40	418.53	221.87
11	12	58	9	4	657.10	443.12	213.98
6	26	58	9	4	674.50	457.02	217.48
10	30	58	9	4	669.70	456.66	213.04
6	3	58	10	4	657.10	456.52	200.58
6	6	58	10	4	638.90	438.30	200.60
15	28	58	10	4	659.90	446.19	213.71

STRATIGRAPHIC PICKS FOR TOP OF JOLI FOU FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
2	34	58	10	4	637.00	420.86	216.14
7	8	58	11	4	637.60	445.25	192.35
5	10	58	11	4	643.40	451.70	191.70
15	24	58	11	4	620.00	419.60	200.40
6	28	58	11	4	627.90	428.28	199.62
1	33	58	11	4	630.00	427.66	202.34
13	9	58	12	4	610.20	421.86	188.34
10	11	58	12	4	617.50	427.30	190.20
10	12	58	12	4	613.90	422.90	191.00
7	28	58	12	4	631.90	438.92	192.98
6	33	58	12	4	636.40	438.33	198.07
7	18	59	2	4	650.30	373.22	277.08
7	31	59	2	4	641.30	372.18	269.12
11	16	59	3	4	628.50	365.50	263.00
11	8	59	5	4	630.30	382.22	248.08
7	30	59	6	4	570.00	317.50	252.50
11	17	59	7	4	638.80	405.34	233.46
10	13	59	8	4	619.00	387.35	231.65
6	35	59	8	4	654.40	416.34	238.06
6	18	59	9	4	642.20	420.60	221.60
2	31	59	9	4	631.90	386.40	245.50
8	7	59	10	4	652.30	435.89	216.41
6	10	59	10	4	655.30	438.25	217.05
15	31	59	10	4	638.30	421.33	216.97
8	19	59	11	4	661.50	442.03	219.47
11	34	59	11	4	640.10	416.71	223.39
7	16	59	12	4	647.50	452.13	195.37
11	31	59	12	4	656.50	462.00	194.50
7	36	59	12	4	641.30	436.44	204.86
3	26	60	2	4	605.00	321.27	283.73
12	27	60	4	4	582.20	305.46	276.74
11	29	60	5	4	592.20	321.19	271.01
10	11	60	6	4	591.00	332.83	258.17
5	30	60	6	4	578.50	320.36	258.14
10	8	60	7	4	602.50	350.73	251.77
11	31	60	7	4	620.60	359.37	261.23
6	12	60	8	4	613.00	369.20	243.80
10	17	60	8	4	616.30	369.06	247.24
6	25	60	8	4	612.60	359.34	253.26
11	11	60	9	4	613.00	362.60	250.40

STRATIGRAPHIC PICKS FOR TOP OF JOLI FOU FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
6	18	60	9	4	614.60	378.08	236.52
10	27	60	9	4	631.90	381.71	250.19
12	33	60	9	4	662.50	415.26	247.24
11	8	60	10	4	660.20	437.09	223.11
10	15	60	10	4	667.80	437.38	230.42
15	26	60	10	4	677.00	434.40	242.60
11	29	60	10	4	657.80	428.25	229.55
10	16	60	11	4	628.50	397.17	231.33
10	18	60	11	4	618.40	401.99	216.41
12	14	60	12	4	651.70	445.01	206.69
3	18	60	12	4	630.00	427.30	202.70
2	31	60	12	4	613.00	402.72	210.28
11	34	60	12	4	624.50	413.23	211.27
6	36	60	12	4	642.80	417.89	224.91
14	36	61	2	4	539.40	280.93	258.47
10	34	61	3	4	562.10	270.40	291.70
6	20	61	4	4	560.20	283.46	276.74
3	24	61	5	4	553.20	276.45	276.75
10	36	61	5	4	558.70	277.09	281.61
10	31	61	6	4	559.60	268.79	290.81
11	36	61	6	4	555.30	273.30	282.00
11	15	61	7	4	576.10	299.98	276.12
10	20	61	7	4	556.90	275.00	281.90
6	25	61	7	4	566.10	287.78	278.32
10	32	61	7	4	585.20	285.90	299.30
10	17	61	8	4	584.30	310.40	273.90
11	23	61	8	4	571.80	291.39	280.41
3	32	61	8	4	563.60	291.10	272.50
11	35	61	8	4	603.50	324.80	278.70
7	14	61	9	4	639.80	376.45	263.35
10	18	61	9	4	634.30	380.68	253.62
7	32	61	9	4	611.70	351.70	260.00
7	34	61	9	4	631.90	353.60	278.30
10	14	61	10	4	654.70	409.33	245.37
2	18	61	10	4	644.30	407.79	236.51
6	34	61	10	4	609.00	407.22	201.78
6	14	61	11	4	662.30	430.64	231.66
11	30	61	11	4	607.50	375.60	231.90
10	12	61	12	4	626.90	406.50	220.40
6	16	61	12	4	610.00	401.10	208.90

STRATIGRAPHIC PICKS FOR TOP OF JOLI FOU FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
15	29	61	12	4	588.20	361.44	226.76
16	9	62	1	4	550.80	317.63	233.17
10	19	62	1	4	549.20	285.52	263.68
11	36	62	2	4	541.60	276.76	264.84
10	36	62	4	4	554.70	273.10	281.60
11	17	62	6	4	549.20	255.39	293.81
7	17	62	9	4	615.90	349.18	266.72
9	18	62	9	4	618.40	347.50	270.90
11	23	62	9	4	591.60	303.89	287.71
16	31	62	9	4	618.70	339.60	279.10
2	6	62	10	4	613.40	367.17	246.23
12	31	62	10	4	643.10	386.12	256.98
6	18	62	11	4	655.30	412.99	242.31
3	25	62	11	4	655.00	402.97	252.03
14	3	62	12	4	622.70	384.30	238.40
10	16	62	12	4	636.40	387.20	249.20
6	24	62	12	4	647.40	395.65	251.75
11	34	62	12	4	662.50	408.55	253.95
7	3	63	1	4	542.80	284.37	258.43
4	11	63	1	4	531.90	275.00	256.90
5	6	63	2	4	537.70	244.23	293.47
10	17	63	2	4	538.90	244.19	294.71
11	5	63	3	4	547.50	249.10	298.40
7	6	63	4	4	551.10	261.58	289.52
10	3	63	5	4	544.00	258.40	285.60
7	16	63	5	4	557.10	267.20	289.90
9	23	63	6	4	576.10	291.40	284.70
10	1	63	7	4	560.50	264.83	295.67
6	15	63	7	4	571.50	279.23	292.27
6	4	63	8	4	573.00	284.99	288.01
10	5	63	8	4	572.10	285.00	287.10
7	17	63	8	4	577.50	289.76	287.74
11	20	63	9	4	588.60	312.45	276.15
3	6	63	10	4	599.50	353.24	246.26
10	10	63	10	4	608.70	339.60	269.10
12	18	63	10	4	585.80	312.30	273.50
6	23	63	10	4	596.80	323.30	273.50
7	36	63	10	4	568.00	292.77	275.23
10	9	63	11	4	618.10	362.07	256.03
13	18	63	11	4	595.30	323.60	271.70

STRATIGRAPHIC PICKS FOR TOP OF JOLI FOU FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING	FORMATION DEPTH	FORMATION ELEVATION
LSD	SEC	TP	R	M	ELEVATION (m)	(m)	(m)
2	24	63	11	4	596.20	329.40	266.80
6	26	63	11	4	592.80	327.05	265.75
6	6	63	12	4	605.90	353.81	252.09
6	22	63	12	4	625.40	363.02	262.38
6	5	64	2	4	551.60	277.30	274.30
5	17	64	2	4	569.70	272.83	296.87
10	3	64	3	4	554.40	257.57	296.83
6	28	64	3	4	616.60	304.53	312.07
4	8	64	4	4	585.20	292.58	292.62
13	21	64	4	4	616.60	308.85	307.75
10	17	64	5	4	570.00	276.20	293.80
9	21	64	6	4	612.00	301.09	310.91
16	22	64	6	4	607.50	306.40	301.10
8	2	64	7	4	575.00	277.82	297.18
10	22	64	8	4	596.40	301.70	294.70
10	30	64	8	4	603.50	315.10	288.40
10	5	64	9	4	606.90	333.23	273.67
9	22	64	9	4	621.80	334.40	287.40
5	3	64	11	4	607.40	333.09	274.31
10	22	64	11	4	593.10	313.63	279.47
11	30	64	11	4	624.20	337.38	286.82
6	2	64	12	4	611.70	345.26	266.44
10	6	64	12	4	596.50	334.94	261.56
11	18	64	12	4	588.00	307.29	280.71
9	21	64	12	4	610.90	335.30	275.60
5	29	65	1	4	594.10	273.17	320.93
4	11	65	2	4	547.10	233.48	313.62
12	25	65	2	4	589.20	257.59	331.61
13	35	65	2	4	647.70	322.13	325.57
15	6	65	3	4	601.70	283.81	317.89
10	20	65	3	4	615.70	288.32	327.38
6	11	65	4	4	609.30	282.54	326.76
10	3	65	5	4	631.90	308.55	323.35
1	29	65	5	4	643.70	318.75	324.95
4	14	65	7	4	694.00	388.26	305.74
11	30	65	7	4	644.00	334.05	309.95
12	4	65	9	4	637.60	346.90	290.70
6	11	65	9	4	644.00	360.88	283.12
6	3	65	10	4	649.80	370.35	279.45
11	8	65	11	4	634.30	348.35	285.95

STRATIGRAPHIC PICKS FOR TOP OF JOLI FOU FORMATION
MADE BY ALBERTA RESEARCH COUNCIL, COLD LAKE STUDY AREA

LOCATION					KELLY BUSHING ELEVATION (m)	FORMATION DEPTH (m)	FORMATION ELEVATION (m)
LSD	SEC	TP	R	M			
6	15	65	11	4	604.70	320.92	283.78
4	19	65	11	4	615.40	325.40	290.00
10	23	65	11	4	643.70	355.04	288.66
11	6	65	12	4	612.60	336.16	276.44
10	18	65	12	4	586.10	314.56	271.54
7	26	65	12	4	594.10	308.00	286.10

Table N-c-1

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO	SO	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)				3	4	(calc)	(60F)	(ohm m)	
6	9	55	4	4	187.4	17635	1473	702	31700	186	53	51749	1.0380	0.1510	7.80
11	22	55	6	4	225.3	17036	1201	559	29900	112	80	48888	1.0340	0.1580	7.60
4	25	55	6	4	223.9	10786	913	301	18940	197	97	31234	1.0200	0.2130	7.40
4	25	55	6	4	223.9	10786	913	301	18940	197	97	31234	1.0200	0.2130	7.40
7	25	55	6	4	230.8	11432	749	384	19900	198	80	32743	1.0250	0.1950	7.90
10	9	55	11	4	136.6	21017	2062	875	38400	340	15	62709	1.0460	0.1430	7.30
10	9	55	11	4	136.6	18915	1794	761	34350	350	10	56180	1.0430	0.1500	7.10
6	14	55	12	4	137.5	21238	1754	826	38100	234	33	62185	1.0410	0.1280	7.10
10	16	55	12	4	138.4	22674	1904	820	40500	327	45	66270	1.0480	0.1230	7.60
11	22	55	12	4	135.6	20306	1700	243	34790	181	10	57336	1.0370	0.1100	8.60
6	8	55	13	4	123.1	21972	1878	683	39100	159	4	63796	1.0460	0.1200	8.20
10	15	55	13	4	140.1	20446	1922	778	37000	290	39	60475	1.0430	0.1430	7.20
10	33	55	13	4	126.6	21224	1802	1094	39000	150	26	63296	1.0460	0.1570	7.30
6	36	55	13	4	150.1	20382	1741	728	36400	351	39	59641	1.0430	0.1410	7.40
9	28	55	14	4	130.8	22217	1700	990	40000	244	16	65167	1.0480	0.1100	6.50
11	29	55	14	4	123.7	20097	1762	729	36000	329	56	58973	1.0400	0.1220	7.40
14	5	55	15	4	95.1	21574	2042	644	38600	244	21	63125	1.0440	0.1090	6.70
14	5	55	15	4	95.1	21423	1744	758	38205	204	10	62344	1.0460	0.1100	7.10
4	12	55	15	4	99.4	20174	1665	618	35700	232	29	58418	1.0400	0.1510	7.60
11	20	55	15	4	99.1	23590	1912	741	41850	105	12	68210	1.0460	0.1130	7.60
15	30	55	16	4	75.5	20612	2090	773	37300	726	19	61520	1.0410	0.1250	7.40
9	31	55	16	4	82.1	21764	1852	790	38750	647	20	63823	1.0410	0.1140	7.40
11	1	56	6	4	225.1	13206	871	416	22900	265	88	37746	1.0240	0.1860	7.40

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
16	1	56	13	4	145.7	20630	1918	731	37200	190	35	60704	1.0420	0.1190	7.80
4	3	56	13	4	135.9	22272	1852	869	40000	251	12	65256	1.0410	0.1160	8.40
6	16	56	13	4	142.9	21982	1762	819	39100	486	27	64176	1.0460	0.1280	7.70
9	21	56	13	4	144.1	21197	1898	734	38000	264	41	62134	1.0420	0.1410	7.00
9	27	56	13	4	149.6	19779	2113	933	36800	268	4	59897	1.0420	0.1250	7.70
9	31	56	13	4	148.0	18688	1834	367	32900	299	80	54168	1.0360	0.1280	7.40
7	32	56	13	4	151.9	22181	1878	719	39500	195	12	64485	1.0490	0.1490	7.10
11	35	56	13	4	159.8	19193	1726	724	34700	100	4	56447	1.0400	0.1280	7.40
7	2	56	14	4	144.4	21787	1946	820	39240	240	69	64102	1.0470	0.1320	7.20
10	3	56	14	4	137.2	21644	1934	773	38900	188	56	63495	1.0460	0.1090	7.20
10	9	56	14	4	127.0	22778	1833	853	40700	229	29	66422	1.0440	0.1160	7.70
6	10	56	14	4	125.6	21590	2074	705	38850	260	21	63500	1.0470	0.1130	7.60
6	10	56	14	4	125.6	21590	2074	705	38850	260	21	63500	1.0470	0.1130	7.60
14	10	56	14	4	133.2	22307	2022	838	40300	177	21	65665	1.0460	0.1180	7.00
14	15	56	14	4	127.6	19874	1534	649	35100	220	33	57410	1.0410	0.1360	7.10
7	28	56	14	4	140.9	20100	1968	881	36700	510	66	60225	1.0440	0.1320	7.60
7	35	56	14	4	138.7	22335	1922	812	40100	183	4	65356	1.0460	0.1170	6.90
6	36	56	14	4	142.9	22393	1922	603	39500	295	23	64736	1.0440	0.1270	7.30
13	14	56	15	4	122.3	22521	2074	719	40400	132	23	65869	1.0450	0.1200	7.10
12	15	56	15	4	126.5	20178	1810	699	36150	256	76	59169	1.0430	0.1210	7.80
7	22	56	15	4	101.5	21390	1970	972	39200	162	12	63706	1.0470	0.1220	8.00
7	27	56	15	4	128.1	19141	1771	663	34389	229	81	56274	1.0403	0.1280	7.90
12	29	56	15	4	95.8	17429	1887	566	31760	146	26	51814	1.0360	0.1400	7.20

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
11	30	56	15	4	120.9	18513	1738	685	33500	170	29	54635	1.0380	0.1970	6.60
14	32	56	15	4	127.9	19863	1782	626	35500	138	37	57946	1.0440	0.1280	7.70
10	5	56	16	4	77.8	22240	2114	549	39300	525	41	64769	1.0420	0.1180	7.50
6	8	56	16	4	90.1	19657	1898	902	36000	468	37	58962	1.0400	0.1310	7.30
4	13	56	16	4	113.7	18112	1690	462	32000	427	25	52716	1.0360	0.1350	7.30
13	23	56	16	4	115.4	20545	1754	688	36600	315	10	59912	1.0420	0.1280	7.60
10	4	57	9	4	191.8	16883	1301	638	30000	276	49	49147	1.0380	0.1300	8.30
10	4	57	9	4	197.3	17372	1451	456	30500	271	38	50088	1.0380	0.1300	8.30
7	35	57	9	4	205.6	16342	1277	535	28750	451	10	47365	1.0310	0.1560	7.20
11	6	57	12	4	156.4	21413	1714	727	38000	247	37	62138	1.0450	0.1270	6.70
14	34	57	12	4	176.8	20380	1537	632	35900	139	10	58598	1.0400	0.1460	7.10
1	6	57	13	4	152.1	20069	1954	761	36500	207	4	59495	1.0420	0.1230	6.90
11	31	57	13	4	157.6	18487	1642	619	33050	220	53	54071	1.0380	0.1360	7.10
6	21	57	14	4	146.9	18206	1910	644	33100	390	6	54256	1.0370	0.1370	7.80
7	3	57	15	4	127.2	22382	1982	595	39600	249	14	64822	1.0450	0.1250	7.30
6	6	57	16	4	102.3	20246	1762	377	35300	220	12	57917	1.0380	0.1310	6.70
7	9	57	16	4	117.1	19659	2032	790	36100	168	20	58769	1.0460	0.1400	7.00
12	23	57	16	4	125.0	16755	1472	631	30200	100	31	49189	1.0340	0.1350	7.40
11	26	57	16	4	140.1	20580	1456	594	35800	393	19	58842	1.0430	0.1370	6.70
15	34	57	16	4	132.9	20567	1882	741	37100	163	14	60467	1.0400	0.1350	7.60
7	3	57	17	4	84.9	18945	1690	731	34200	214	14	55794	1.0390	0.1390	7.40
5	12	57	17	4	99.9	15849	1203	524	27900	258	62	45796	1.0300	0.1540	7.30
10	34	57	17	4	117.9	17541	1293	643	31065	224	22	50788	1.0341	0.1400	7.70

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO$_3$	SO$_4$	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
10	18	58	11	4	194.4	14283	1166	359	25029	166	12	41015	1.0292	0.1610	6.90
10	18	58	11	4	194.4	14878	1214	405	26155	190	8	42850	1.0307	0.1630	7.00
16	6	58	13	4	160.1	17671	1477	537	31200	380	10	51275	1.0360	0.1480	7.70
6	11	58	13	4	168.8	17829	1449	602	31260	756	76	52020	1.0370	0.1320	8.40
11	22	58	13	4	159.4	16838	1365	447	29550	225	4	48429	1.0350	0.1640	7.20
10	28	58	13	4	185.1	17639	1337	537	31000	207	14	50734	1.0370	0.1570	7.20
7	33	58	13	4	188.4	15638	1391	365	27475	232	41	45142	1.0340	0.1590	7.40
7	2	58	15	4	148.1	17337	1481	583	30900	240	19	50560	1.0350	0.1310	7.60
14	22	58	16	4	141.0	17714	1578	865	32500	183	31	52871	1.0360	0.1360	7.40
6	29	58	16	4	123.3	18223	1627	555	32447	151	84	53087	1.0373	0.1350	7.00
8	2	58	17	4	116.4	17964	1465	586	31900	134	32	52081	1.0380	0.1430	7.30
12	14	58	17	4	120.4	15356	1049	542	26750	561	53	44311	1.0320	0.1600	7.60
7	26	58	17	4	100.7	17295	1365	549	30500	283	27	50019	1.0330	0.1330	7.40
7	26	58	17	4	129.7	17145	1405	510	30250	258	14	49582	1.0310	0.1360	7.10
10	27	58	17	4	118.7	16139	1485	367	28400	234	66	46691	1.0310	0.1530	7.70
15	32	58	17	4	116.8	17144	1217	583	30200	149	4	49297	1.0330	0.1590	7.70
9	24	59	8	4	236.8	13637	726	339	23050	344	70	38166	1.0240	0.3070	8.00
7	26	59	9	4	221.9	13822	805	345	23540	312	31	38855	1.0280	0.1710	7.70
6	3	59	11	4	200.7	10580	1108	306	19007	249	22	31272	1.0218	0.1780	6.50
12	11	59	12	4	191.8	14337	1461	287	25400	217	4	41706	1.0280	0.1600	7.10
7	32	59	14	4	183.2	13946	1013	403	24300	214	66	39942	1.0280	0.1810	7.70
6	7	59	15	4	153.1	12950	1176	366	22903	307	48	37750	1.0255	0.1550	7.60
7	21	59	16	4	163.4	16633	1204	505	29100	234	21	47697	1.0360	0.1520	7.10

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	 SEC	 TP	 R	 M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
12	8	60	7	4	248.9	11345	645	258	19200	262	49	31759	1.0200	0.2180	7.60
12	12	60	7	4	262.5	12623	596	302	21100	456	47	35124	1.0240	0.1850	8.30
8	18	60	8	4	254.2	12707	625	360	21500	417	10	35619	1.0240	0.1900	7.50
10	12	60	10	4	220.4	10798	597	216	18200	150	68	30029	1.0220	0.2100	7.80
6	13	60	10	4	215.4	13305	1001	301	23000	242	33	37882	1.0280	0.1920	7.60
15	22	60	13	4	210.6	11910	717	382	20500	366	48	33923	1.0210	0.1930	7.80
7	29	60	15	4	195.8	16468	1100	620	29000	220	28	47436	1.0370	0.1610	7.40
16	14	60	16	4	170.3	13186	1554	238	23580	239	78	38875	1.0270	0.1830	7.90
10	16	60	17	4	154.9	15192	1324	600	27400	154	39	44709	1.0330	0.1630	7.60
7	25	61	9	4	276.1	13695	486	326	22700	310	66	37583	1.0280	0.1920	8.00
6	1	61	11	4	210.1	11769	896	360	20650	210	15	33900	1.0260	0.2180	7.30
6	7	61	15	4	205.0	13160	1160	587	23955	156	15	39033	1.0259	0.1700	7.30
10	2	61	16	4	199.9	14403	924	458	25050	193	25	41053	1.0300	0.1840	7.60
10	11	61	16	4	200.6	14995	1160	469	26438	166	10	43238	1.0285	0.1740	7.65
7	17	61	16	4	160.2	14820	1238	469	26312	137	26	43002	1.0290	0.1700	6.80
10	19	61	16	4	186.5	15528	1354	516	27753	146	9	45306	1.0300	0.1500	6.85
6	4	61	17	4	162.5	14797	1065	510	26050	148	72	42642	1.0280	0.1550	7.50
12	9	61	17	4	161.6	21360	1420	501	36800	175	12	60268	1.0350		7.50
11	4	62	14	4	225.7	11821	735	322	20340	215	4	33437	1.0250	0.2170	7.50
10	20	62	14	4	237.7	12475	609	335	21030	415	28	34892	1.0220	0.2080	8.10
7	8	62	16	4	202.4	14448	1089	199	24700	122	20	40578	1.0300	0.1820	7.70
11	7	62	17	4	175.9	16074	1481	583	29000	171	10	47319	1.0350	0.1480	7.30
11	30	63	9	4	279.1	9101	395	171	15050	209	82	25008	1.0160	0.2530	7.50

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS, VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Na (calc)	Ca	Mg	Cl	HCO_3	SO_4	TDS (calc)	DENSITY (60F)	RESIST. (ohm m)	pH
6	36	63	16	4	231.3	11179	797	324	19410	260	43	32013	1.0230	0.2480	8.20
2	18	63	17	4	197.6	11484	1411	784	22400	121	9	36221	1.0350		7.55
6	2	64	11	4	269.1	8934	498	152	14867	322	63	24836	1.0168	0.2750	8.10
6	5	64	17	4	205.6	11763	792	358	20280	330	64	33642	1.0270	0.2420	8.40
6	30	65	15	4	261.4	14371	1017	435	25080	200	43	41146	1.0260	0.1490	7.70
2	18	65	17	4	231.8	13743	1241	255	23950	187	99	39475	1.0250	0.1880	6.50
14	20	65	17	4	215.6	9226	613	258	15860	271	64	26293	1.0180	0.2500	7.90
7	32	65	17	4	235.0	12070	853	338	21000	105	62	34428	1.0220	0.1980	6.60
10	9	66	13	4	290.7	9920	495	264	16800	210	28	27717	1.0170	0.2650	7.40
11	32	66	13	4	304.7	11457	674	278	19580	144	10	32143	1.0250	0.2080	7.80
6	22	66	14	4	285.0	11875	763	340	20548	151	24	33701	1.0248	0.2100	7.60
6	7	66	15	4	264.1	13572	942	395	23640	170	10	38729	1.0270	0.1890	7.40
10	11	66	15	4	275.8	12670	815	365	21950	124	10	35946	1.0280	0.2410	8.40
11	3	67	13	4	307.3	11111	583	244	18740	150	68	30896	1.0200	0.2140	7.80
11	10	67	14	4	281.8	11171	483	213	18600	160	12	30639	1.0160	0.2270	7.80
8	2	67	15	4	268.3	8665	497	145	14570	145	3	24031	1.0157	0.2600	8.40
14	17	67	16	4	253.7	11253	801	216	19250	230	21	31771	1.0220	0.2060	7.50
4	31	67	17	4	275.5	10296	557	290	17520	279	35	28977	1.0210	0.2260	7.30
7	35	67	17	4	261.8	10701	465	227	17840	198	43	29474	1.0190	0.2260	8.00
5	27	68	11	4	341.5	8991	366	139	14800	184	15	24495	1.0190		7.80
10	22	68	13	4	331.5	9842	516	192	16475	278	17	27320	1.0191	0.2300	7.60
10	26	68	14	4	317.1	8532	365	190	14277	107	23	23494	1.0171	0.2530	7.53
11	12	68	17	4	290.2	10314	408	216	17120	190	35	28283	1.0210	0.2200	8.10

CHEMICAL COMPOSITION (mg/L) AND PHYSICAL PROPERTIES OF FORMATION WATERS,
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Na	Ca	Mg	Cl	HCO_3	SO_4	TDS	DENSITY	RESIST.	pH
LSD	SEC	TP	R	M	(m)	(calc)						(calc)	(60F)	(ohm m)	
7	30	68	17	4	282.5	8968	396	115	14720	205	35	24439	1.0180	0.3060	7.80
6	31	69	11	4	357.5	8437	328	160	13880	244	49	23098	1.0230	0.2720	7.30
10	20	69	12	4	339.9	8169	511	221	13944	249	78	23172	1.0166	0.2660	7.90
7	15	69	13	4	331.4	8280	296	158	13650	161	2	22554	1.0190	0.3630	8.70
7	2	69	14	4	327.3	8949	535	146	15032	225	12	24899	1.0162	0.2530	8.00

Table N-h-1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	31	55	1	4	249.20					3083.51	563.9
10	36	55	2	4	245.90	0.546E-15	0.327E-09			3062.48	558.5
6	22	55	3	4	239.00	0.867E-15	0.494E-09			2932.08	538.2
11	31	55	8	4	213.98					3834.76	605.4
6	30	55	9	4	184.25					4161.45	609.0
10	34	55	10	4	174.05					4100.29	592.5
6	6	56	1	4	264.40	0.313E-15	0.179E-09	0.200	0.14E-01	2950.92	565.6
11	1	56	2	4	245.30	0.531E-15	0.284E-09			2732.20	524.1
11	1	56	2	4	291.30	0.661E-15	0.370E-09				
8	34	56	4	4	256.70	0.201E-14	0.112E-08			2957.94	558.6
10	32	56	5	4	271.00					2817.91	558.6
11	14	56	8	4	208.18					3419.53	557.2
11	1	56	9	4	206.00	0.199E-14	0.986E-09	0.290	0.16E-01	3729.14	586.6
10	8	56	9	4	178.00	0.463E-14	0.211E-08	0.280	0.34E-02	4118.95	598.4
11	25	56	9	4	193.70						584.6
6	29	56	9	4	196.00	0.473E-14	0.264E-08			3940.37	598.2
6	30	56	9	4	182.00	0.849E-15	0.475E-09			4116.49	602.1
10	10	56	10	4	174.40	0.291E-14	0.150E-08			4092.20	592.1
6	16	56	10	4	173.70					4062.90	588.4
6	29	56	10	4	181.90	0.342E-14	0.191E-08			3882.07	578.1
6	32	56	10	4	186.60	0.736E-15	0.412E-09			3917.90	586.5
10	21	57	4	4	232.60	0.966E-15	0.541E-09			2867.95	525.3
6	33	57	4	4	254.80	0.731E-15	0.409E-09			3085.21	569.7
11	10	57	5	4	250.20	0.392E-15	0.219E-09			3047.01	561.2
6	17	57	5	4	273.13	0.173E-14	0.107E-08	0.250	0.11E-01	2893.73	568.5
6	24	57	5	4	246.70	0.914E-15	0.490E-09			3110.02	564.1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	26	57	5	4	251.70					3185.34	576.8
5	9	57	7	4	218.20	0.308E-15	0.172E-09			3575.66	583.1
11	19	57	7	4	218.50					3479.25	573.6
11	22	57	7	4	225.37						577.6
10	3	57	8	4	209.52						585.6
6	8	57	8	4	222.18	0.234E-14	0.114E-08	0.320	0.22E-01		
11	12	57	8	4	210.97					3761.65	594.9
6	29	57	8	4	222.20	0.335E-15	0.187E-09			3768.84	606.9
10	4	57	9	4	198.47					4003.10	607.0
10	4	57	9	4	197.30	0.442E-14	0.414E-07			4221.82	628.2
11	11	57	9	4	215.82	0.249E-14	0.114E-08	0.320	0.12E-01	3946.28	618.6
7	19	57	9	4	196.58	0.505E-15	0.282E-09			4004.54	605.3
10	30	57	9	4	209.68	0.222E-14	0.124E-08			4024.58	620.4
11	3	57	10	4	191.10	0.644E-14	0.361E-08			3976.17	596.9
7	5	57	10	4	190.40					4104.45	609.3
11	6	57	10	4	186.20	0.139E-14	0.778E-09			4162.24	611.0
11	20	57	10	4	199.60	0.287E-14	0.161E-08			3976.73	605.5
14	21	57	10	4	195.30	0.612E-15	0.342E-09			4609.47	665.8
11	35	57	10	4	199.43						601.7
10	28	57	11	4	189.88	0.415E-14	0.232E-08			4009.76	599.1
10	31	57	11	4	194.89						615.2
14	34	57	12	4	177.06					4152.04	600.8
6	7	58	4	4	266.70	0.769E-15	0.431E-09			3082.27	581.3
10	32	58	5	4	255.80					3524.62	615.5
6	21	58	7	4	221.60					3956.61	625.4
5	1	58	8	4	248.40					3645.24	620.4

NTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
IKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION	PERMEABILITY	HYDRAULIC	POROSITY	STORATIVITY	FORMATION	HYDRAULIC
SD	SEC	TP	R	M	(m amsl)	(m**2)	CONDUCTIVITY (m/s)			PRESSURE (kPa)	HEAD (m amsl)
6	5	58	8	4	223.73					3858.45	617.5
6	8	58	8	4	218.20	0.111E-14	0.622E-09			3918.00	618.1
6	12	58	8	4	214.85	0.338E-15	0.189E-09			3784.88	601.1
11	31	58	8	4	225.37						610.8
11	12	58	9	4	217.64	0.313E-14	0.175E-08			3820.67	607.6
14	32	58	9	4	225.70					4059.77	640.1
9	34	58	9	4	229.82	0.327E-15	0.200E-09	0.220	0.90E-02	3971.55	635.2
6	6	58	10	4	201.10	0.582E-15	0.326E-09			3994.43	608.8
7	20	58	10	4	208.90	0.369E-14	0.207E-08			4131.61	630.6
5	10	58	11	4	188.70					4442.16	642.1
10	11	58	11	4	196.90					3973.26	602.4
10	13	58	11	4	204.50	0.228E-14	0.127E-08			4029.39	615.8
15	24	58	11	4	206.40	0.377E-15	0.211E-09			3927.74	607.3
6	28	58	11	4	199.60	0.335E-14	0.187E-08			4204.58	628.7
10	11	58	12	4	193.20	0.135E-14	0.753E-09			4240.19	626.0
11	23	58	12	4	196.90					4006.71	605.8
10	29	58	12	4	198.20	0.296E-14	0.166E-08			4105.77	617.3
6	13	58	13	4	178.60	0.116E-14	0.649E-09			4113.70	598.5
15	18	58	13	4	181.60					4183.87	608.6
10	28	58	13	4	186.60					4128.97	608.0
10	35	58	13	4	195.10	0.515E-15	0.288E-09			4009.59	604.3
9	28	58	14	4	186.40						617.3
7	2	58	15	4	161.88					4101.19	580.5
10	31	58	16	4	157.01	0.719E-15	0.410E-09			4130.55	578.6
15	32	58	17	4	127.65						592.1
6	35	58	17	4	131.90					4326.77	573.5

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION	PERMEABILITY	HYDRAULIC	POROSITY	STORATIVITY	FORMATION	HYDRAULIC
LSD	SEC	TP	R	M	(m amsl)	(m**2)	CONDUCTIVITY (m/s)			PRESSURE (kPa)	HEAD (m amsl)
10	17	59	4	4	278.30	0.791E-15	0.442E-09			3006.12	585.1
6	21	59	4	4	280.10	0.193E-14	0.108E-08			2896.59	575.7
6	17	59	5	4	254.20	0.463E-15	0.259E-09			2985.30	558.9
5	19	59	5	4	253.88	0.863E-15	0.483E-09			3002.41	560.3
11	12	59	6	4	258.34						555.6
13	13	59	6	4	252.60					2837.32	542.2
6	27	59	6	4	279.00	0.986E-15	0.552E-09			2779.81	562.7
7	30	59	6	4	279.90					2790.56	564.7
10	36	59	6	4	263.40	0.118E-14	0.659E-09			2780.78	547.2
2	18	59	7	4	237.30	0.759E-15	0.425E-09			3490.56	593.6
9	24	59	8	4	243.80	0.428E-15	0.239E-09			3470.61	598.0
7	8	59	9	4	229.50	0.101E-14	0.564E-09			3815.66	618.9
7	9	59	9	4	233.50	0.371E-15	0.207E-09			3894.35	631.0
11	13	59	9	4	231.70					3906.16	630.4
6	15	59	9	4	251.76						616.3
6	18	59	9	4	227.38						623.5
11	24	59	9	4	238.17						600.3
7	25	59	9	4	244.20					3494.04	600.8
6	4	59	10	4	219.70	0.461E-14	0.258E-08			3874.47	615.1
6	25	59	10	4	231.00	0.100E-14	0.558E-09			3886.67	627.7
6	25	59	10	4	194.40	0.526E-14	0.294E-08				
15	31	59	10	4	220.90	0.265E-14	0.148E-08			3872.64	616.2
11	1	59	11	4	208.50	0.179E-14	0.100E-08			3817.69	598.1
7	6	59	11	4	205.00	0.193E-14	0.108E-08			4023.70	615.7
8	7	59	11	4	214.30	0.871E-15	0.488E-09			4113.09	634.1
3	14	59	11	4	204.50					3898.68	602.4

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	23	59	11	4	217.50						598.2
7	26	59	11	4	220.70	0.209E-14	0.117E-08			3843.95	613.0
11	32	59	11	4	225.20	0.460E-14	0.258E-08			3988.39	632.3
6	3	59	12	4	195.07					3919.70	595.1
10	5	59	12	4	191.10	0.400E-14	0.404E-07			4213.08	621.1
7	10	59	12	4	191.70					4110.95	611.3
9	22	59	12	4	213.10					3878.56	609.0
11	33	59	12	4	206.92	0.237E-14	0.133E-08			4105.49	625.9
6	16	59	13	4	202.07					3957.36	606.0
9	25	59	14	4	195.50	0.359E-15	0.201E-09			4215.62	625.8
15	33	59	14	4	192.60	0.668E-15	0.373E-09			4184.12	619.6
11	16	59	15	4	188.34	0.755E-15	0.397E-09			4028.72	599.5
7	20	59	15	4	159.20	0.177E-14	0.993E-09			4309.00	599.0
5	19	59	16	4	156.90	0.216E-14	0.114E-08	0.250	0.20E-02	4235.74	589.2
7	21	59	16	4	164.00	0.998E-15	0.524E-09			4168.97	589.5
10	12	59	17	4	147.50	0.834E-15	0.811E-08			4267.06	583.0
8	3	60	6	4	260.90					2947.91	561.8
10	11	60	6	4	263.30	0.122E-14	0.684E-09			2837.09	552.9
6	24	60	6	4	270.30	0.644E-15	0.361E-09			2941.25	570.5
10	25	60	6	4	280.70					2765.11	562.9
10	26	60	6	4	278.60	0.719E-15	0.403E-09			2753.84	559.7
10	27	60	6	4	274.50						560.4
5	30	60	6	4	263.60	0.220E-14	0.129E-08			2819.10	551.3
10	8	60	7	4	257.25						550.8
12	12	60	7	4	262.50	0.112E-14	0.627E-09			2808.06	549.1
12	15	60	7	4	264.00					2754.02	545.1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	20	60	7	4	261.50	0.524E-14	0.293E-08			2625.83	529.5
10	23	60	7	4	269.00						551.8
10	28	60	7	4	268.80	0.250E-14	0.140E-08			2772.15	551.7
6	12	60	8	4	250.50					2816.30	537.9
7	19	60	8	4	264.30	0.125E-14	0.701E-09			2827.72	552.9
6	27	60	8	4	261.80	0.502E-15	0.281E-09			2734.42	540.9
11	5	60	9	4	250.80	0.185E-14	0.104E-08			3353.09	593.0
10	8	60	9	4	248.30	0.173E-14	0.971E-09			3213.45	576.3
11	11	60	9	4	259.10	0.136E-14	0.764E-09			2971.64	562.4
11	17	60	9	4	255.10	0.327E-15	0.183E-09			3056.73	567.1
6	18	60	9	4	246.60	0.625E-15	0.349E-09			3185.47	571.7
12	33	60	9	4	254.60					2964.15	557.1
6	1	60	10	4	242.50	0.334E-14	0.187E-08			3590.70	609.0
6	4	60	10	4	230.70	0.204E-14	0.114E-08			3786.13	617.1
11	8	60	10	4	234.40	0.256E-14	0.143E-08			3681.68	610.2
10	12	60	10	4	242.30					3629.01	612.7
15	14	60	10	4	244.10	0.103E-14	0.577E-09			3271.12	578.0
10	15	60	10	4	239.60	0.269E-15	0.151E-09			3496.83	595.5
10	19	60	10	4	236.50	0.298E-14	0.167E-08			3663.24	610.4
10	18	60	11	4	219.80	0.219E-14	0.123E-08			3886.03	616.4
10	19	60	11	4	222.80	0.127E-14	0.710E-09			3783.10	608.9
6	22	60	11	4	227.95	0.392E-14	0.219E-08			3830.50	618.9
9	25	60	11	4	237.80	0.336E-14	0.188E-08			3478.31	592.8
11	34	60	12	4	213.70	0.125E-14	0.700E-09			3713.16	592.7
10	26	60	14	4	228.90					3854.64	622.3
7	3	60	15	4	195.80						599.3

NTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
IKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION SD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
7	29	60	15	4	188.10	0.400E-14	0.222E-08			4309.86	628.0
10	27	60	16	4	192.62	0.521E-15	0.292E-09			4104.07	611.5
7	2	60	17	4	163.40	0.134E-14	0.748E-09			4233.26	595.5
4	9	61	2	4	281.38	0.252E-14					
11	9	61	3	4	317.11						570.4
1	3	61	5	4	274.88					2751.71	555.7
7	20	61	6	4	289.20	0.753E-15	0.421E-09			2749.62	569.8
10	31	61	6	4	292.00	0.168E-14	0.940E-09			2869.79	584.9
7	6	61	7	4	267.80	0.238E-15	0.133E-09			2787.49	552.3
6	19	61	7	4	289.60	0.104E-14	0.579E-09			2798.24	575.2
10	20	61	7	4	291.70	0.272E-14	0.152E-08			2692.86	566.5
9	21	61	7	4	286.80	0.379E-14	0.212E-08			2632.70	555.5
6	25	61	7	4	281.70	0.334E-14	0.187E-08			2745.95	561.9
12	28	61	7	4	286.10	0.836E-15	0.468E-09			2774.95	569.3
11	30	61	7	4	287.70	0.218E-14	0.122E-08			2751.11	568.5
10	31	61	7	4	289.30	0.973E-15	0.545E-09			2719.56	566.9
6	6	61	8	4	284.24	0.118E-14	0.659E-09			2826.25	572.7
11	12	61	8	4	285.00	0.105E-14	0.589E-09			2760.11	566.7
11	16	61	8	4	273.10	0.728E-15	0.407E-09			2724.40	551.1
10	17	61	8	4	279.90	0.499E-14	0.286E-08			2701.56	555.6
6	22	61	8	4	304.10	0.303E-14	0.169E-08			2690.18	578.7
3	32	61	8	4	280.00	0.653E-14	0.366E-08			2738.09	559.4
11	35	61	8	4	285.70	0.270E-14	0.151E-08			2740.40	565.4
11	4	61	9	4	272.20	0.106E-14	0.594E-09			2784.20	556.4
9	8	61	9	4	271.00					2811.23	557.9
6	9	61	9	4	270.20	0.542E-14	0.303E-08			2788.45	554.8

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	10	61	9	4	270.60	0.206E-14	0.115E-08			2848.85	561.4
10	17	61	9	4	264.30	0.213E-14	0.119E-08			2933.79	563.7
10	20	61	9	4	272.80	0.656E-14	0.367E-08			2808.50	559.4
6	21	61	9	4	268.80	0.452E-14	0.252E-08			2885.45	563.3
6	27	61	9	4	277.10	0.179E-14	0.100E-08			2394.42	521.5
6	30	61	9	4	266.40	0.385E-14	0.216E-08			2887.27	561.1
7	32	61	9	4	267.30	0.328E-14	0.184E-08			2888.92	562.1
7	33	61	9	4	270.90					2708.84	547.4
11	2	61	10	4	255.50					3116.74	573.6
11	2	61	10	4	249.40	0.113E-14	0.630E-09			3120.77	567.9
10	3	61	10	4	246.60					3049.62	557.8
10	3	61	10	4	254.80	0.292E-14	0.163E-08			2933.97	554.2
10	5	61	10	4	247.20					3099.45	563.5
7	10	61	10	4	251.70	0.220E-14	0.123E-08			2956.37	553.4
7	25	61	10	4	271.50					2901.44	567.6
10	26	61	10	4	262.10	0.735E-15	0.410E-09			2988.16	567.1
6	28	61	10	4	256.00	0.143E-14	0.800E-09			3107.95	573.2
11	33	61	10	4	258.80	0.551E-14	0.308E-08			3005.13	565.5
6	34	61	10	4	208.50	0.310E-14	0.174E-08				
6	36	61	10	4	263.70					2934.70	563.2
6	1	61	11	4	238.10	0.434E-14	0.413E-07			3129.13	557.5
11	8	61	11	4	236.50	0.365E-15	0.204E-09			3652.16	609.2
11	30	61	11	4	239.50					3588.51	605.8
6	16	61	12	4	220.90					3467.39	574.8
9	13	61	14	4	232.90	0.558E-15	0.313E-09			3596.87	600.0
10	2	61	16	4	207.23					3989.37	614.4

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	16	62	5	4	247.80					2845.04	538.2
10	7	62	6	4	288.00	0.767E-15	0.430E-09				
11	17	62	6	4	258.50					2486.81	512.3
7	6	62	7	4	280.10	0.125E-14	0.698E-09			2608.08	546.3
6	23	62	7	4	264.20					2433.00	512.5
10	3	62	8	4	286.80					2754.66	567.9
10	7	62	8	4	282.90	0.135E-14	0.755E-09			2778.16	566.4
6	8	62	8	4	282.20					2699.94	557.8
7	23	62	8	4	286.20						550.0
11	28	62	8	4	291.10					2551.90	551.5
12	29	62	8	4	290.82	0.197E-14	0.110E-08			2658.00	562.1
11	31	62	8	4	287.80	0.171E-14	0.957E-09			2728.28	566.2
11	33	62	8	4	292.40					2664.75	564.4
11	34	62	8	4	290.50	0.113E-14	0.632E-09			2657.66	561.7
10	3	62	9	4	273.10	0.199E-14	0.111E-08			2888.94	567.9
10	6	62	9	4	273.71	0.340E-14	0.191E-08			2794.89	559.0
11	23	62	9	4	276.40	0.373E-14	0.209E-08			2673.02	549.2
6	25	62	9	4	284.10	0.306E-14	0.171E-08			2696.07	559.3
8	29	62	9	4	286.70	0.241E-14	0.127E-08	0.180	0.79E-02	2874.23	580.0
16	31	62	9	4	285.90	0.603E-15	0.317E-09	0.200	0.91E-02	2970.24	589.0
7	8	62	10	4	274.20	0.656E-15	0.304E-09	0.260	0.30E-01	3053.52	585.8
6	11	62	10	4	264.50	0.221E-14	0.124E-08			2823.01	552.6
10	14	62	10	4	275.80	0.162E-14	0.904E-09			2941.55	576.0
14	16	62	10	4	266.30						575.1
10	22	62	10	4	274.70	0.153E-14	0.859E-09			3019.35	582.9
6	26	62	10	4	273.10					3027.43	582.1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
6	28	62	10	4	265.10	0.188E-14	0.105E-08			3077.21	579.2
7	15	62	11	4	271.90					3087.32	587.0
12	17	62	11	4	254.81						602.6
12	20	62	11	4	274.62						610.0
14	3	62	12	4	260.90					3291.10	596.8
7	3	62	13	4	261.50	0.427E-15	0.238E-09			3274.64	595.7
11	4	62	14	4	231.67	0.822E-15	0.857E-08			3709.61	610.3
10	5	63	8	4	291.40	0.577E-14	0.322E-08			2513.59	547.9
10	15	63	8	4	299.00	0.208E-14	0.116E-08			2578.25	562.1
10	30	63	8	4	290.80	0.171E-14	0.955E-09			2666.90	563.0
6	34	63	8	4	287.10					2952.87	588.5
6	3	63	9	4	285.60	0.167E-14	0.935E-09			2658.43	556.9
11	20	63	9	4	283.20	0.114E-14	0.635E-09			3042.40	593.7
10	24	63	9	4	295.69	0.105E-14	0.586E-09			2871.22	588.7
9	27	63	9	4	287.40	0.227E-14	0.127E-08			2883.15	581.7
11	30	63	9	4	282.10					3062.91	594.7
10	10	63	10	4	272.80	0.249E-14	0.140E-08			3131.10	592.4
6	23	63	10	4	277.00	0.594E-14	0.332E-08			3065.15	589.8
7	24	63	10	4	284.40	0.127E-14	0.711E-09			3084.06	599.2
8	26	63	10	4	283.20					2948.32	584.1
3	30	63	10	4	277.00	0.879E-15	0.492E-09			3092.80	592.7
8	11	63	11	4	269.10	0.429E-14	0.240E-08			3189.36	594.6
11	16	63	11	4	271.25	0.649E-15	0.363E-09			3138.58	591.6
13	18	63	11	4	277.90					3159.78	600.4
15	20	63	11	4	275.54						611.4
2	24	63	11	4	288.40	0.272E-15	0.196E-09	0.210	0.12E-01	3246.84	619.8

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	25	63	11	4	274.60	0.513E-15	0.238E-09			3167.07	597.8
10	36	63	11	4	291.90	0.265E-15	0.168E-09	0.180	0.16E-01	3117.25	610.0
7	8	63	13	4	250.52	0.376E-15	0.210E-09			3287.21	586.0
10	26	63	13	4	262.59						605.2
6	31	64	8	4	295.00	0.490E-15	0.274E-09			2888.93	589.8
11	1	64	9	4	292.20	0.982E-15	0.550E-09			2764.83	574.4
7	3	64	9	4	295.16					2972.09	598.5
10	14	64	9	4	290.80	0.142E-14	0.794E-09			2947.90	591.7
9	22	64	9	4	291.80					3066.86	604.8
6	6	64	10	4	280.60	0.649E-15	0.362E-09			3186.59	605.8
10	21	64	10	4	288.90	0.441E-15	0.247E-09			3236.03	619.2
11	4	64	11	4	281.60	0.561E-14	0.314E-08			3337.41	622.2
16	9	64	11	4	277.50					3398.77	624.4
10	22	64	11	4	289.07						616.8
7	24	64	11	4	285.60	0.488E-15	0.283E-09			3132.57	605.3
10	9	64	12	4	281.66						622.7
11	28	64	12	4	279.96						619.7
10	32	64	12	4	291.72	0.631E-15	0.353E-09			3239.42	622.3
10	32	64	12	4	288.83					3174.45	612.8
10	1	64	13	4	269.72	0.809E-15	0.453E-09			3307.00	607.2
7	23	64	13	4	275.50					3238.63	606.0
6	11	64	14	4	269.40	0.465E-15	0.260E-09			3211.68	597.2
7	32	64	14	4	263.00					3179.80	587.5
11	35	64	14	4	271.60					3124.94	590.5
6	27	64	15	4	258.40					3438.89	609.4
11	9	64	16	4	239.60					3529.40	599.8

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
12	6	65	9	4	298.20	0.352E-15	0.259E-09	0.250	0.12E-01	3257.80	630.7
15	1	65	10	4	306.74	0.480E-15	0.309E-09	0.070	0.39E-02	3178.19	631.1
10	18	65	12	4	278.40						588.9
7	13	65	14	4	290.00	0.587E-15	0.329E-09				
7	13	65	14	4	279.08						609.4
6	36	65	15	4	276.75					2842.40	566.8
11	17	65	16	4	232.52					3478.48	587.5
6	29	65	16	4	249.33					3251.56	581.2
10	15	65	17	4	227.70					2988.88	532.7
7	35	65	17	4	231.70					2784.66	515.9
7	15	66	10	4	309.10					3170.60	632.7
10	12	66	15	4	279.50					2792.01	564.5
11	34	67	10	4	331.60					2664.72	603.6
7	35	67	17	4	291.30					2333.22	529.4
15	13	68	11	4	348.70					2405.61	594.2

Table N-h-2

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
7	29	55	10	4	149.68	0.483E-13		0.222	158.83
7	29	55	10	4	163.55	0.255E-13		0.227	168.28
10	34	55	10	4	166.58	0.495E-13	0.115E-13	0.188	172.22
7	34	55	12	4	148.32	0.195E-12	0.286E-13	0.175	153.96
11	2	55	14	4	126.75	0.269E-13		0.214	131.00
11	2	55	14	4	126.75	0.597E-14		0.148	131.00
6	14	55	14	4	133.06	0.647E-14		0.163	139.62
10	24	55	14	4	140.91	0.186E-13	0.612E-15	0.127	145.49
16	23	56	5	4	249.47	0.479E-13		0.318	252.67
10	8	56	9	4	182.09	0.916E-13	0.370E-14	0.201	188.95
10	19	56	10	4	167.93	0.163E-13		0.181	170.98
10	6	56	13	4	146.62	0.548E-12	0.417E-13	0.176	152.72
10	17	57	1	4	204.00			0.314	208.50
14	21	57	10	4	196.31			0.281	199.67
7	31	57	10	4	192.20			0.286	195.20
10	28	57	12	4	176.00			0.228	179.40
15	7	58	11	4	188.90	0.986E-13		0.219	193.40
10	12	58	12	4	189.50			0.182	192.50
7	20	58	12	4	189.27	0.592E-13	0.174E-14	0.258	192.02
6	9	60	15	4	182.76	0.404E-13		0.231	186.57
6	9	60	15	4	191.14	0.156E-12		0.242	195.72
16	36	61	2	4	217.51			0.371	217.96
16	36	61	2	4	219.02			0.325	220.09
10	3	62	9	4	267.57	0.355E-12		0.264	272.14
10	3	62	9	4	276.72	0.822E-13		0.212	281.29
11	25	62	13	4	254.55	0.378E-13		0.213	259.12

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
VIKING SANDSTONE AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION, (m amls)
10	24	63	9	4	295.99	0.161E-13		0.201	300.56
9	19	63	12	4	259.65	0.311E-12		0.320	262.70
9	19	63	12	4	264.99	0.174E-12		0.322	267.28
6	18	63	17	4	208.01	0.208E-13		0.280	211.82
11	30	64	4	4	272.10	0.108E-11		0.366	276.60
11	30	64	4	4	272.10			0.323	276.60
11	14	65	2	4	284.99			0.364	289.56
10	7	65	13	4	273.72	0.385E-12		0.284	277.07
10	7	65	13	4	281.34	0.481E-13		0.251	285.60
11	30	65	13	4	282.52	0.414E-12		0.315	287.09
11	30	65	13	4	290.59	0.414E-13		0.277	294.10
10	1	69	16	4	310.88	0.484E-12		0.308	313.01
10	1	69	16	4	315.75	0.213E-12		0.306	318.49
10	1	69	16	4	320.12	0.185E-13		0.244	321.75

Table 0-h-1

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
BASE OF FISH SCALE ZONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	29	55	1	4	304.26	0.330E-16	0.182E-10				
6	6	56	1	4	303.40	0.129E-16	0.738E-11	0.200	0.14E-01		
7	33	63	11	4	327.60	0.252E-15	0.141E-09				

Table 0-h-2

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA
BASE OF FISH SCALE ZONE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	MID-INTERVAL ELEVATION (m amsl)	HORIZONTAL PERMEABILITY (m**2)	VERTICAL PERMEABILITY (m**2)	POROSITY	TOP OF INTERVAL ELEVATION (m amls)
12	11	55	1	4	276.32	0.129E-13		0.306	280.13
7	18	55	11	4	148.85	0.249E-12	0.208E-13	0.176	153.10
11	2	55	14	4	135.00	0.324E-12		0.194	139.00
11	2	55	14	4	135.00	0.815E-12		0.173	139.00
6	14	55	14	4	142.21	0.533E-16		0.068	144.80
10	28	67	3	4	227.08	0.396E-11		0.380	231.85
10	1	69	16	4	322.87	0.215E-14		0.183	323.98

Table 0-h-3

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
SECOND WHITE SPECKLED SHALE AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
10	29	55	1	4	304.26					2920.22	602.3
10	33	55	2	4	319.80	0.512E-15	0.297E-09			2759.60	601.4
6	6	56	1	4	303.40					3185.33	628.5
6	33	57	4	4	281.00	0.524E-16	0.292E-10			3069.50	594.3
6	33	57	4	4	292.58	0.275E-16	0.160E-10			3044.64	603.3
6	21	59	4	4	329.40					2890.07	624.4
6	21	59	4	4	341.60	0.910E-16	0.509E-10			2629.68	610.0
2	31	59	9	4	255.50	0.267E-14	0.150E-08			3622.97	625.3
6	28	60	3	4	335.20					2396.24	579.8
6	34	60	3	4	336.20	0.381E-15	0.213E-09			2392.46	580.4
10	20	60	7	4	349.33						598.1
10	20	61	9	4	355.41						550.7
7	34	61	9	4	293.80					2977.39	597.7
7	33	63	11	4	327.60					2935.56	627.2

Table 0-h-4

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER COLORADO GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					RECORDER ELEVATION	PERMEABILITY	HYDRAULIC	POROSITY	STORATIVITY	FORMATION	HYDRAULIC
LSD	SEC	TP	R	M	(m amsl)	(m**2)	CONDUCTIVITY (m/s)			PRESSURE (kPa)	HEAD (m amsl)
10	19	55	8	4	293.20	0.836E-17	0.468E-11			3650.68	665.8
11	31	55	8	4	306.30	0.284E-16	0.159E-10			3483.43	661.8
11	31	55	8	4	306.33						664.5
16	20	55	9	4	588.30						599.2
6	4	56	8	4	326.10	0.336E-16	0.188E-10			3531.87	686.6
13	32	56	9	4	577.30						617.8
16	31	56	10	4	573.05						624.2
13	32	56	10	4	577.15						625.8
1	13	56	11	4	589.05						607.8
2	35	56	11	4	563.90						609.6
1	5	57	7	4	573.45						600.5
1	24	57	7	4	612.35						645.3
10	26	57	8	4	611.15						618.1
3	5	57	10	4	580.80						595.9
3	5	57	10	4	582.35						597.4
13	15	57	10	4	587.65						627.3
1	16	57	10	4	579.25						627.9
4	21	57	10	4	571.65						630.6
4	19	57	11	4	527.45						616.6
4	1	57	12	4	580.15						597.7
9	1	57	12	4	558.85						597.4
13	11	57	12	4	540.70						614.5
1	14	57	12	4	557.95						594.4
6	25	57	13	4	576.25						605.3
1	19	58	8	4	564.50						637.0
12	15	58	13	4	587.80						637.0

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER COLORADO GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
8	19	58	13	4	593.00						648.3
1	20	58	13	4	603.95						634.9
4	12	58	14	4	585.95						636.4
13	14	58	14	4	604.25						634.0
1	22	58	17	4	549.55						574.5
3	30	58	17	4	562.95						573.9
1	26	59	16	4	580.80						600.5
16	3	59	17	4	566.75						582.5
4	4	59	17	4	560.35						581.9
9	4	59	17	4	565.85						579.4
1	5	59	17	4	572.70						581.6
16	8	59	17	4	573.90						584.6
13	10	59	17	4	570.75						579.4
1	16	59	17	4	569.10						583.1
1	16	59	17	4	562.50						583.7
8	16	59	17	4	566.60						585.2
4	17	59	17	4	563.75						581.9
3	18	59	17	4	556.85						585.2
2	27	59	17	4	568.75						589.2
16	29	59	17	4	572.75						591.9
16	24	60	2	4	497.75						567.2
4	16	60	16	4	547.90						602.6
12	16	60	16	4	573.00						605.9
1	5	60	17	4	561.90						598.9
2	5	60	17	4	586.45						602.3
13	6	60	17	4	587.50						588.9

INTERPRETED HYDRAULIC PARAMETERS FOR DRILL STEM TEST DATA
UPPER COLORADO GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	RECORDER ELEVATION (m amsl)	PERMEABILITY (m**2)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	STORATIVITY	FORMATION PRESSURE (kPa)	HYDRAULIC HEAD (m amsl)
5	14	60	17	4	594.20						612.0
14	19	60	17	4	583.70						605.6
4	17	61	16	4	603.55						644.7
13	4	61	17	4	627.30						640.4
1	17	61	17	4	613.75						647.7
7	3	63	1	4	229.50					2461.76	480.7
4	11	63	1	4	218.20	0.307E-14	0.285E-07			2488.77	472.2

Table 0-h-5

INTERPRETED HYDRAULIC PARAMETERS FOR CORE DATA UPPER COLORADO GROUP AQUIFER, COLD LAKE STUDY AREA

LOCATION					MID-INTERVAL	HORIZONTAL	VERTICAL	POROSITY	TOP OF INTERVAL
LSD	SEC	TP	R	M	ELEVATION (m amsl)	PERMEABILITY (m**2)	PERMEABILITY (m**2)		ELEVATION (m amls)
16	9	62	1	4	193.85			0.352	198.42
16	9	62	1	4	184.71			0.337	189.28
16	9	62	1	4	175.56			0.352	180.14
10	28	67	3	4	248.40	0.141E-11		0.373	264.40
11	2	68	4	4	264.90	0.254E-11		0.303	269.40
11	2	68	4	4	255.90	0.327E-12		0.307	260.40

HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA

Data Base: Section 2 - Quaternary Data

Open File Report 1996 - 1i

Prepared by
Basin Analysis Group
Alberta Geological Survey
Alberta Research Council
(Project Manager: Dr. Brian Hitchon)

Project jointly funded by Alberta Research Council
and Alberta Environment

1985-01-31

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DATA BASE

Section 2: Quaternary Data

Borehole Logs:	L.D. Andriashek
Hydrochemistry:	Dr. D.M. Borneuf
Hydraulic Parameters:	Dr. D.M. Borneuf and C.M. Saveplane

PREFACE

This Data Base forms an integral part of the study "Hydrogeology of the Cold Lake Study Area, Alberta, Canada" carried out from 1982-04-01 to 1985-01-31, and jointly funded by the Alberta Research Council and Alberta Environment. It is a reference document most of the information from which is presented in synthesized form in the accompanying Report and Atlas. It effectively represents a hard copy form of new and selected interpreted information present in GWDB as part of this study; as such, both A and B level information is implicitely included. Other than location identification no data is repeated from the ERCB well data file. The information is organized in three sections, as follows:

Section 1: Phanerozoic Data

This includes new stratigraphic picks by ARC staff, the chemical composition and physical properties of formation waters, and the interpreted hydraulic parameters from drillstem tests and cores, all organized by hydrostratigraphic units.

Section 2: Quaternary Data

This includes the logs of shallow boreholes, the chemical composition of shallow groundwater, and the interpreted hydraulic parameters from well tests and aquifer tests, most organized by stratigraphic units.

Section 3: Instrumentation for Hydrogeological Investigations

The first part is an annotated catalogue of manufacturers and the type of equipment they provide; the second is a reference list of papers on methods for measuring and using some relevant hydrogeological parameters.

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For Sections 1 and 2 it is important that readers refer to the written Report for information on the techniques used to cull out erroneous data from the vast amount of hydrochemical and hydraulic data originally entered into GWDB; it is the resulting selected and intepreted data which is contained in Sections 1 and 2.

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TABLE OF CONTENTS

NOTATION FOR INDEXING DATA TABLES IN SECTIONS 1 AND 2

Each table has been identified systematically by a sequence of two letters, from which one can determine the hydrostratigraphic unit and type of information. Tables are number sequentially within each class of double letters.

The first letter (capitalized) refers to the hydrostratigraphic unit and is cross-referenced with the alphabetic sequence given in the Atlas. Because most of the information in the Data Base refers specifically to aquifers (rather than aquitards or aquicludes) not all hydrostratigraphic units are represented by tables. The complete alphabetic sequence is presented below, with starred items indicating no data tables:

A	*
B	*
C	*
D	*
E	Cooking Lake - Beaverhill Lake - Watt Mountain aquifer
F	*
G	Camrose Tongue aquifer
H	Grosmont Formation aquifer
I	Wabamun - Winterburn aquifer
J	"Lower Mannville" Group aquifer
K	Clearwater Formation aquitard
L	"Upper Mannville" Group aquifer
M	Joli Fou Formation aquitard
N	"Viking sandstone" aquifer
O	Colorado aquitard
P	Quaternary hydrostratigraphic units
Q	*

The second letter (lower case) refers to the general type of data in the table, as follows:

-a	General
-g	Geological
-c	Hydrochemical
-h	Hydrodynamic

CONTENTS AND FORMAT OF DATA BASE

The Data Base for the Quaternary contains three types of information from which the regional geology, hydrochemistry and hydrodynamics were evaluated in Parts 2, 3 and 4, respectively, of the Report. It is organized in three parts as follows:

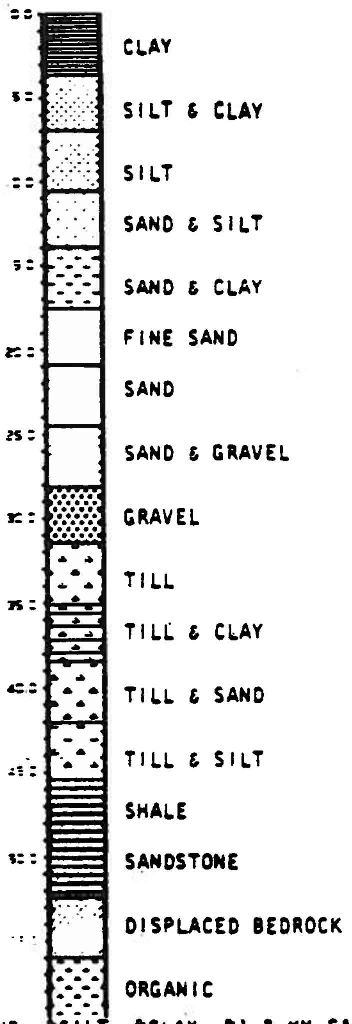
1. This comprises a complete description of nearly 110 auger testholes drilled and logged by the Alberta Geological Survey. Information is provided on the stratigraphy and lithology, as well as the texture and moisture content, matrix carbonate composition if appropriate, and the lithology of the coarse sand fraction. The location and distribution of these auger testholes can be found in Atlas map P-g-1.
2. The chemical composition (mg/L) and salinity is given for 280 formation waters, together with the location and elevation of the well. The distribution of these wells is shown in Atlas map P-c-1. Note that the stratigraphic interval has not been assigned, as explained in Part 3 of the Report.
3. Hydraulic heads and interpreted hydraulic parameters are provided for well tests and aquifer tests, allocated by formations, as well as the vertical hydraulic conductivity and leakage factor for two aquitards. Atlas maps P-h-1 and P-h-2 show the distribution and locations for the transmissivity and hydraulic head data, respectively.

Table P-g-1
Stratigraphy and lithology of auger testholes drilled and logged by Alberta Geological Survey.

TESTHOLE NAME - LOCATION - ELEVATION - DATE DRILLED

FORMATION NAME	DEPTH (METRES)	LITHOLOGY	TEXTURE[1]	MATRIX[2] CARBONATE	COARSE SAND[3] LITHOLOGY

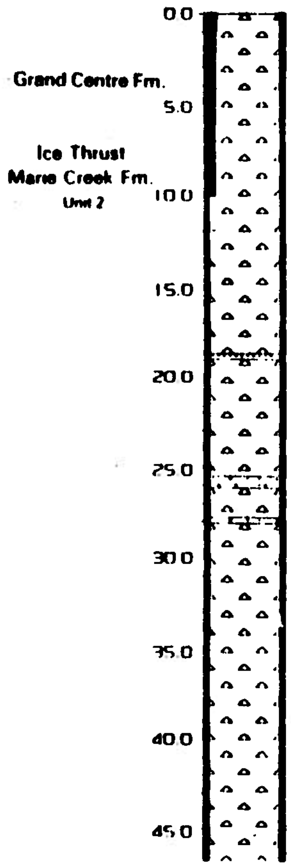
HEAVY BARS
DENOTE
OXIDIZED
PROFLIES



TEXTURE[1] - %SAND, %SILT, %CLAY, %1-2 MM SAND, % MOISTURE CONTENT
MATRIX CARBONATE[2] - VOLUME CO_2, $\%CO_3$, CALCITE/DOLOMITE RATIO
COARSE SAND LITHOLOGY[3] - IGN-METH = %IGNEOUS & METAMORPHIC ROCKS, QTZ = %QUARTZ, QTZT-QSS = %QUARTZITE & QUARTZ SANDSTONE, LST = %LIMESTONE, DST = %DOLOSTONE, LOC = %LOCAL BEDROCK (SHALE, SILTSTONE, SANDSTONE, IRONSTONE), OTH = %OTHER ROCKS, N = TOTAL NUMBER OF GRAINS

T1

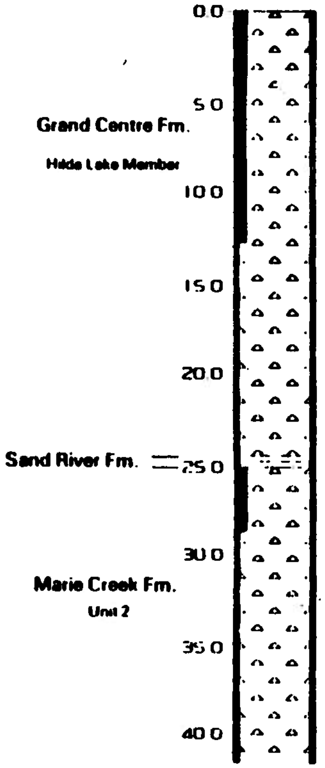
Alberta Geological Survey Testhole T 1
Location SE of LSD 14 Sec 27 Twp 66 Rng 1 W of 4 Mer . NTS 73L
Elevation 2190 Ft 668 M Source 1:50,000 NTS 73L/9
Date drilled 197510 25 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	38.0	23.0	39.0	42.0	24.0	34.0	2.49	13.7				56.0	32.0	4.0	2.0	2.0	3.0	0.0	308
3.00	41.0	24.0	35.0	45.0	25.0	30.0	2.58	9.6				56.0	34.0	23.0	2.0	5.0	0.6	0.0	338
4.00	40.0	28.0	32.0	44.0	28.0	27.0	2.46	10.0				51.0	32.0	35.0	4.0	7.0	1.2	0.0	342
5.00	41.0	25.0	33.0	45.0	26.0	29.0	2.43	11.6				45.0	35.0	1.4	3.0	7.0	2.0	0.0	298
7.00	39.0	27.0	14.0	41.0	29.0	30.0	5.70	9.4				45.0	37.0	7.6	2.0	7.0	1.2	0.0	344
8.00	41.0	28.0	31.0	43.0	30.0	27.0	4.41	8.7				51.0	30.0	6.3	3.0	9.0	1.5	0.0	342
9.00	40.0	28.0	32.0	44.0	29.0	27.0	2.81	8.2				63.0	21.0	4.0	3.0	7.0	1.2	0.0	338
10.00	41.0	28.0	31.0	45.0	28.0	27.0	2.50	8.2				58.0	27.0	2.3	5.0	6.0	2.1	0.0	345
11.00	41.0	26.0	33.0	44.0	27.0	29.0	2.51	9.0				57.0	26.0	2.3	5.0	8.0	2.4	0.0	326
12.00	43.0	26.0	31.0	47.0	27.0	26.0	3.16	8.6				55.0	24.0	6.3	6.0	8.0	1.6	0.0	401
13.00	44.0	25.0	31.0	47.0	26.0	27.0	2.77	9.1				59.0	25.0	5.6	4.0	6.0	0.6	0.0	364
14.00	42.0	27.0	31.0	46.0	28.0	26.0	2.83					62.0	24.0	2.0	4.0	8.0	0.8	0.0	376
17.00	43.0	26.0	30.0	46.0	28.0	26.0	2.99	9.1				60.0	23.0	5.0	4.0	8.0	0.8	0.0	401
18.00	45.0	28.0	27.0	50.0	28.0	23.0	3.38	9.2				56.0	26.0	3.5	6.0	6.0	1.8	0.0	438
18.50								12.4											
19.00	49.0	26.0	26.0	52.0	28.0	21.0	2.84	10.3				57.0	29.0	5.5	4.0	5.0	0.3	0.0	368
21.00	46.0	25.0	29.0	49.0	27.0	24.0	2.83	10.0				52.0	29.0	7.3	5.0	4.0	1.8	0.0	380
22.00	46.0	27.0	27.0	50.0	28.0	21.0	3.00	10.1				51.0	32.0	7.7	3.0	3.0	3.5	0.0	408
23.00	41.0	29.0	30.0	46.0	30.0	24.0	2.54	10.0				50.0	28.0	5.6	6.0	5.0	3.3	0.0	343
24.00	43.0	30.0	27.0	46.0	31.0	23.0	2.51	10.7				48.0	33.0	8.9	4.0	6.0	0.6	0.0	326
25.00	48.0	27.0	25.0	52.0	28.0	20.0	3.16					57.0	28.0	5.7	4.0	3.0	1.4	0.0	412
26.00	56.0	24.0	20.0	59.0	24.0	17.0	3.85	10.4				60.0	27.0	5.4	3.0	5.0	1.2	0.0	507
27.00	50.0	26.0	24.0	55.0	26.0	20.0	4.39	10.9				64.0	23.0	6.0	3.0	5.0	0.2	0.0	513
28.00	49.0	25.0	25.0	53.0	27.0	20.0	3.38	11.4				57.0	30.0	2.8	4.0	4.0	1.8	0.0	400
29.00	49.0	27.0	24.0	53.0	26.0	21.0	2.81	10.8				59.0	29.0	2.5	5.0	3.0	1.8	0.0	382
31.00	49.0	25.0	25.0	53.0	25.0	23.0	3.20	10.3				62.0	27.0	1.5	4.0	3.0	1.9	0.0	412
33.00	49.0	28.0	24.0	53.0	26.0	21.0	3.14	9.8				58.0	32.0	1.1	3.0	4.0	2.1	0.0	389
33.50	51.0	26.0	24.0	54.0	26.0	21.0	2.97	9.0				60.0	30.0	1.5	4.0	3.0	0.8	0.0	383
34.00	47.0	29.0	25.0	51.0	27.0	22.0	3.17	9.1				61.0	30.0	2.5	3.0	2.0	0.3	0.0	420
35.00	48.0	25.0	27.0	52.0	25.0	23.0	3.19	9.1				59.0	28.0	3.0	5.0	5.0	1.4	0.0	405
36.00	48.0	25.0	27.0	52.0	27.0	22.0	3.19	9.5				59.0	28.0	3.7	3.0	5.0	1.5	0.0	405
37.00	47.0	26.0	28.0	51.0	28.0	22.0	3.04	9.4				57.0	31.0	9.0	4.0	3.0	1.0	0.0	404
38.00	47.0	25.0	29.0	50.0	28.0	22.0	3.25	8.6				56.0	32.0	9.0	4.0	4.0	0.9	0.0	412
39.00	45.0	26.0	29.0	49.0	27.0	23.0	3.20	9.5				60.0	29.0	4.0	2.0	5.0	0.8	0.0	394
40.00	47.0	25.0	28.0	50.0	27.0	23.0	3.20	9.4				63.0	27.0	4.0	2.0	3.0	0.8	0.0	389
42.00	46.0	26.0	29.0	50.0	28.0	23.0	2.99	10.0				62.0	25.0	4.0	4.0	3.0	1.8	0.0	391
42.50	47.0	24.0	29.0	50.0	27.0	23.0	3.07	8.6				61.0	25.0	7.0	3.0	3.0	2.5	0.0	398
43.00	45.0	25.0	29.0	49.0	27.0	24.0	2.90	8.9				55.0	33.0	5.3	4.0	2.0	1.0	0.0	379
44.00	47.0	24.0	29.0	50.0	27.0	24.0	3.01	9.6				57.0	27.0	9.0	4.0	3.0	0.8	0.0	388
46.00	45.0	26.0	30.0	49.0	28.0	23.0	3.02	9.8				61.0	26.0	6.0	3.0	3.0	1.1	0.0	388

T2

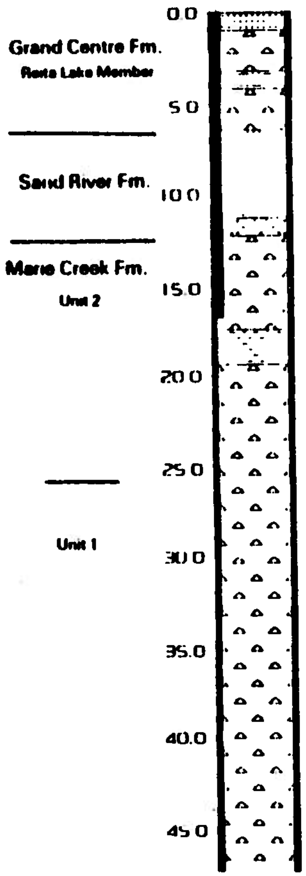
Alberta Geological Survey Testhole T 2
Location of LSD 4 Sec 15 Twp 65 Rng 2 W of 4 Mer . NTS 73L
Elevation 1900 Ft 579 M Source 1 50,000 NTS 73L/9
Date drilled 197510 28 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET M	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	28 0	31 0	42 0	31 0	33 0	36 0	0 83	16 6				62 7	25 4	4 4	3 1	2 7	1 8	0 0	552
2 50	26 0	34 0	41 0	30 0	36 0	34 0	0 46	16 0				53 0	27 7	7 2	0 0	3 6	9 6	0 0	83
3 00	27 0	31 0	42 0	31 0	33 0	36 0	0 75	15 0				66 5	24 3	3 9	1 0	1 8	2 4	0 0	510
4 00	26 0	31 0	44 0	30 0	33 0	37 0	0 78	15 5				61 0	26 9	0 8	0 0	2 5	8 4	0 0	119
5 00	28 0	28 0	44 0	31 0	31 0	38 0	0 76	15 1				62 4	21 5	3 1	1 3	4 0	7 5	0 0	452
7 00	27 0	31 0	43 0	31 0	33 0	36 0	0 70					64 8	26 9	4 9	1 6	1 0	0 8	0 0	386
7 50	26 0	33 0	41 0	30 0	35 0	35 0	0 72	14 6				62 4	21 4	12 0	1 7	2 6	0 9	0 0	117
8 50	26 0	30 0	44 0	30 0	32 0	38 0	0 72	14 2				61 8	28 4	2 0	2 8	2 3	0 6	0 3	356
9 00	28 0	28 0	44 0	31 0	31 0	38 0	0 74	14 1				59 3	18 9	2 6	0 7	1 8	1 1	15 4	455
10 00	26 0	30 0	43 0	31 0	32 0	37 0	0 73	14 0				65 8	20 9	3 2	1 3	1 5	1 3	5 5	474
11 00	28 0	28 0	44 0	31 0	32 0	37 0	0 72	13 8				58 4	27 0	6 7	3 4	3 4	1 1	0 0	89
13 00	27 0	28 0	45 0	31 0	31 0	38 0	1 02	14 3				67 8	22 5	4 4	2 3	1 1	0 6	0 0	565
14 00	28 0	28 0	44 0	31 0	32 0	37 0	0 67	14 3				68 4	24 5	1 0	1 0	3 1	1 0	0 0	98
15 00	28 0	28 0	44 0	31 0	32 0	37 0	0 77	14 1				72 1	22 5	0 9	0 9	1 8	1 8	0 0	111
17 00	28 0	26 0	46 0	31 0	31 0	38 0	0 70	14 5				71 4	17 5	4 0	2 7	1 9	2 5	0 0	371
18 00	27 0	28 0	45 0	31 0	32 0	37 0	0 88	14 1				68 7	21 2	5 0	2 0	3 0	0 0	0 0	99
19 00	27 0	28 0	46 0	32 0	31 0	37 0	0 99	14 2				65 5	26 7	3 6	2 9	0 9	1 3	0 0	660
20 00	29 0	28 0	43 0	32 0	32 0	36 0	1 34	14 4				65 6	25 8	3 0	2 5	1 8	1 0	0 3	395
21 00	26 0	30 0	44 0	30 0	33 0	37 0	0 97	14 1				70 1	24.2	2 4	2 4	0 0	0 8	0 0	124
22 00	28 0	27 0	44 0	31 0	32 0	37 0	0 91	14 1				73 2	21 1	2 7	0 8	1 6	0 6	0 0	489
23 00	26 0	30 0	44 0	30 0	33 0	37 0	0 63	13 7				75 7	20 2	1 6	1 6	0 7	0 0	0 2	440
24 00	7 0	12 0	81 0	8 0	19 0	73 0	0 25	21 5											
26 00	40 0	29 0	31 0	45 0	28 0	27 0	3 42	10 0				57 2	20 6	1 1	5 5	14 2	1 7	0 0	360
27 00	47 0	26 0	27 0	50 0	26 0	24 0	3 31	8 7				60 1	29 4	1 6	4 0	3 1	1 8	0 0	449
28 00	43 0	27 0	30 0	48 0	26 0	26 0	3 41	9 1				61 4	27 0	1 5	4 2	3 4	2 5	0 0	474
29 00	45 0	26 0	30 0	48 0	26 0	26 0	3 57	8 2				57 5	31 6	0 9	3 5	4 8	1 7	0 0	459
30 00	42 0	26 0	32 0	46 0	26 0	28 0	2 72	10 0				64 4	25 3	1 0	4 3	3 1	1 5	0 0	419
32 00	44 0	24 0	33 0	47 0	25 0	28 0	3 31	10 0				64 0	25 8	0 4	4 9	4 2	0 6	0 0	450
34 00	48 0	27 0	25 0	52 0	27 0	21 0	3 26	9 8				58 9	30 5	1 1	4 4	2 7	2 2	0 0	452

T3

Alberta Geological Survey Testhole T3
Location SE of LSD 8 Sec 36 Twp 61 Rng 1 W of 4 Mer , NTS 73L
Elevation 1775 Ft 541 M Source 1 50,000 NTS 73L/8
Date drilled 197606 01 Logged by ANDRIASHEK

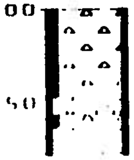


	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00																			
2.00	44.3	24.5	31.2	48.0	24.0	28.0	2.14	10.8				66.3	25.9	1.3	1.3	4.2	0.3	0.0	309
3.00	38.4	30.5	31.1	43.3	29.4	27.3	1.08	11.5				61.1	28.1	5.8	0.0	2.9	0.0	0.0	139
3.50								16.9											
5.00	50.1	17.0	32.9	51.4	19.2	29.5	2.13	17.1				64.3	27.0	1.3	3.3	1.7	1.7	0.0	300
6.00	42.8	23.3	33.9	46.9	21.7	31.3	2.46	14.6				67.4	23.6	0.7	2.3	5.3	0.3	0.0	301
12.50	44.2	29.1	26.7	47.8	29.1	23.0	2.98	11.3				58.3	20.4	0.3	4.1	15.5	1.1	0.0	367
14.00	45.3	30.2	24.5	49.4	29.5	21.1	2.96	11.1				55.5	19.1	1.5	5.8	16.5	0.9	0.0	346
15.00	46.5	30.3	23.2	50.5	29.6	20.0	2.91	10.5				55.0	20.3	1.1	5.0	16.4	1.9	0.0	360
17.00	47.6	29.5	22.9	51.9	28.1	20.0	2.98	10.4				54.8	23.4	0.5	4.1	15.0	1.4	0.0	367
18.00	56.2	22.5	21.3	59.1	22.6	18.4	3.46	16.8				60.2	29.2	1.7	3.1	4.2	1.4	0.0	425
20.00	42.7	32.0	25.3	47.1	31.0	21.9	3.25	10.1				58.1	24.6	1.3	4.4	10.2	0.8	0.0	391
21.00								8.2											
23.00	43.4	24.8	31.7	46.9	26.8	26.3	2.60	10.0				53.8	33.1	0.6	5.6	4.5	2.3	0.0	357
24.00	48.9	24.4	26.7	52.9	25.1	22.0	3.68	12.7				56.9	29.9	0.5	3.8	3.8	4.1	0.0	448
26.00	34.1	25.7	40.2	37.4	31.1	31.5	2.25	12.6				46.0	30.5	0.3	9.5	4.0	9.1	0.0	328
27.00	30.0	30.3	39.7	33.8	35.5	30.7	2.02	12.7				48.4	27.5	1.1	6.6	2.8	13.3	0.0	287
29.00	31.6	27.7	40.6	34.6	31.8	30.6	2.13	12.7				41.3	34.4	0.7	8.2	2.6	11.8	0.0	305
30.00	37.7	26.4	35.9	41.1	31.8	27.1	2.92	13.3				48.0	33.9	0.8	4.7	4.2	7.2	0.0	381
32.00	28.4	32.1	39.5	31.4	39.9	28.7	2.08	13.5				40.3	37.8	0.4	9.0	5.0	6.1	0.0	278
33.50	35.5	27.8	36.7	38.9	32.4	28.7	3.49	12.7				54.5	25.1	1.3	5.9	4.4	9.2	0.0	455
35.00	35.8	25.9	38.3	38.9	31.4	29.6	2.71	11.9				49.6	32.0	0.3	6.5	4.7	8.2	0.0	341
36.50	39.5	27.9	32.6	43.2	30.4	26.5	3.33	11.3				48.2	35.8	0.4	6.0	2.4	6.9	0.0	452
38.00	34.0	26.9	39.0	37.2	31.8	31.0	2.48	12.5				49.5	30.6	0.0	6.1	3.4	10.4	0.0	327
39.50	34.8	27.1	38.1	38.4	31.2	30.3	2.13	11.8				42.7	38.4	0.0	6.4	1.4	10.3	0.0	281
41.00	34.7	26.0	39.2	37.8	29.6	32.6	2.28	13.0				45.3	34.5	0.0	9.1	4.6	7.2	0.0	307
42.50	33.6	28.7	37.7	37.0	31.9	31.1	1.86	12.2				51.7	31.6	0.0	8.2	4.1	4.9	0.0	269
44.00	36.5	28.7	34.8	39.7	32.8	27.5	1.89	12.6				51.4	32.2	0.0	5.5	3.5	5.5	0.0	255
46.00	31.4	30.6	38.1	34.8	34.0	31.2	1.73	11.7				48.2	27.5	0.5	10.6	6.9	5.6	0.0	218
47.00	38.1	26.4	35.5	41.0	31.0	28.0	1.88	13.2				47.2	30.9	0.0	10.4	7.8	2.6	0.0	269

T4

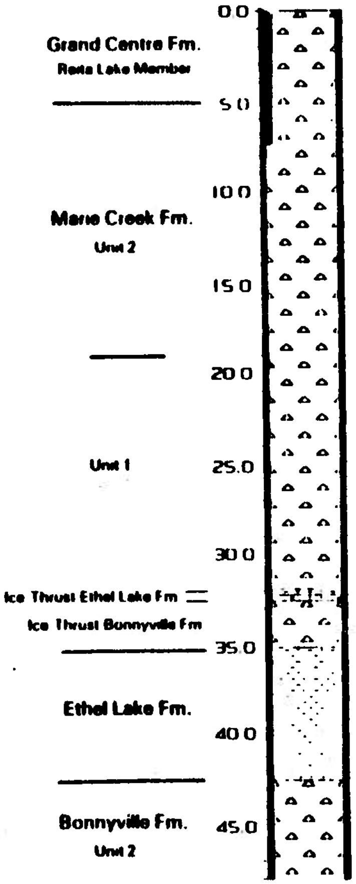
```
Alberta Geological Survey Testhole    1  1
Location       of LSD 10 Sec 17 Twp  58 Rng  3 W of 4 Mer  ,  NTS  73L
Elevation   2075 Ft      633 M   Source  1 50,000 NTS 73L/
Date drilled    197510 29  Logged by  ANDRIASHEK

                      TEXTURE (%)                        MATRIX CARBONATE          COARSE SAND LITHOLOGY (%)
 DEPTH  SAND SILT CLAY  SAND SILT CLAY VC SD   H2O    CO2  CO3 CA/DO    IGN   QTZ  QTZT  LST  DST  LOC  OTH    N
  (M) >62.5um     <4um  >50um     <2um 1 2mm   (%)   (cc)  (%)          METM        QSS
```



T5

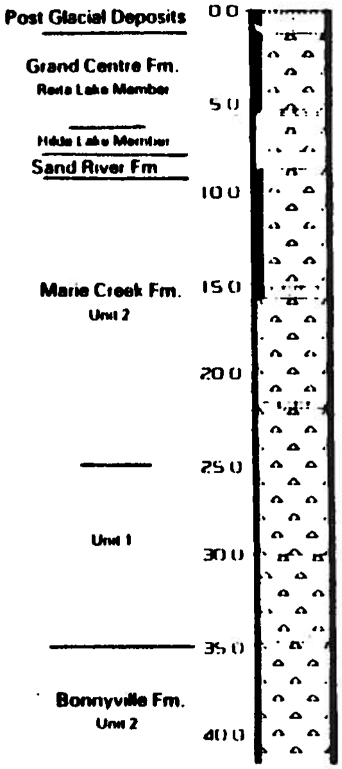
Alberta Geological Survey Testhole T 5
Location of LSD 2 Sec 16 Twp 59 Rng 4 W of 4 Mer , NTS 73L
Elevation 2070 Ft 631 M Source 1 50,000 NTS 73L/1
Date drilled 197510 29 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	35 0	28 0	38 0	39 0	29 0	32 0	1 36	15 1	30 7	12 9	0 39	70 9	21 4	1 1	3 9	1 7	1 7	0 0	182
2 00	36 0	26 0	38 0	39 0	29 0	33 0	1 28	15 7	29 9	12 6	0 39	68 5	25 4	0 0	2 2	2 2	1 1	0 0	181
3 00	34 0	28 0	39 0	38 0	28 0	33 0	1 51	15 6	28 6	12 0	0 30	70 9	22 6	1 0	1 5	1 5	1 0	0 0	199
4 00	33 0	25 0	42 0	36 0	28 0	37 0	1 32	16 1	26 1	10 9	0 25	63 0	28 7	1 7	2 2	4 4	0.0	0 0	181
5 00	37 0	23 0	40 0	41 0	24 0	35 0	2 13	15 0	26 5	11 1	0 28	60 3	30 6	0 3	4 4	3 7	1 3	0 0	297
6 00	37 0	33 0	30 0	41 0	34 0	25 0	2 92	10 0	48 5	20 2	0 16	55 8	17 6	0 0	4 4	18 4	1 3	3 4	387
7 00	37 0	34 0	29 0	40 0	38 0	23 0	2 91	8 9				60 7	20 5	0 9	5 4	11 4	1 2	0 0	351
8 00	38 0	32 0	30 0	41 0	35 0	24 0	2 81	8 9	44 3	18 4	0 14	63 3	21 8	0 3	4 6	9 4	0 9	0 0	330
9 00	32 0	35 0	33 0	36 0	39 0	25 0	2 48	9 7				63 0	19 9	0 3	3 9	11 4	1 3	0 0	306
10 00	39 0	34 0	27 0	43 0	35 0	22 0	3 15	8 5	46 7	19 4	0 12	57 9	20 7	1 0	4 3	14 4	1 6	0 0	416
11 00	39 0	34 0	27 0	43 0	34 0	23 0	1 49	8 8				61 2	21 3	1 2	3 9	11 1	1 4	0 0	441
12 00	37 0	35 0	27 0	42 0	35 0	23 0	2 86	8 1	47 9	20 0	0 20	56 6	19 7	0 6	7 4	13 4	0 3	0.0	366
13 00	44 0	32 0	23 0	48 0	33 0	19 0	4 82	9 4				61 6	20 1	0 6	4 9	11 8	0 5	0 0	568
14 00	38 0	35 0	27 0	42 0	35 0	23 0	2 77	8 9	47 0	19 6	0 23	61 0	19 2	0 6	4 2	14 5	0 6	0 0	359
14 50	39 0	32 0	30 0	42 0	33 0	25 0	2 88	9 2				61 2	20 9	0 6	5 2	9 9	1 9	0 0	363
15 00	36 0	38 0	26 0	42 0	36 0	22 0	2 46	9 1	47 5	19 7	0 11	58 4	26 3	1 2	2 9	10 8	0 3	0 0	315
17 00	42 0	31 0	27 0	46 0	32 0	23 0	3 33	8 3				61 7	25 6	0 9	3 2	7 9	0 7	0 0	407
18 00	39 0	33 0	28 0	44 0	33 0	23 0	3 21	10 3	43 3	18 0	0 15	61 7	20 0	0 9	4 0	10 4	1 0	0 0	424
19 00	36 0	30 0	35 0	39 0	34 0	28 0	2 33	9 6	38 6	16 1	0 21	64 9	21 9	0 6	3 6	8 9	0 3	0 0	302
21 00	33 0	32 0	35 0	38 0	34 0	28 0	2 50		36 8	15 4	0 20	67 9	20 7	1 0	2 6	5 6	1 6	0 0	305
21 50	33 0	32 0	35 0	36 0	36 0	29 0	1 98	10 4	37 7	15 8	0 21	64 3	22 5	2 0	2 3	7 4	0 4	0 0	258
23 00	31 0	32 0	37 0	35 0	36 0	30 0	2 36	9 5	35 9	14 9	0 16	63 5	23 2	0 3	2 5	8 6	0 9	0 0	315
24 00	32 0	32 0	36 0	35 0	35 0	30 0	2 49	12 7	41 8	17 5	0 24	61 9	16 8	0 9	4 8	13 5	1 3	0 0	310
25 00	35 0	31 0	34 0	38 0	36 0	26 0	2 44	11 3	43 6	18 2	0 17	57 4	26 8	0 3	3 9	11 0	0 6	0 0	310
26 00	33 0	32 0	35 0	37 0	36 0	27 0	2 41	11 0	40 9	17 1	0 22	65 0	21 1	0 0	2 7	8 8	2 5	0 0	317
27 00	35 0	31 0	34 0	38 0	36 0	26 0	2 29	10 7	39 6	16 5	0 18	63 6	19 9	0 6	8	9 6	1 7	0 0	291
28 00	35 0	30 0	34 0	39 0	34 0	27 0	2 79	11 2	45 9	19 1	0 17	62 8	17 9	0 6	5	11 1	1 6	0 0	379
29 00	27 0	38 0	35 0	29 0	44 0	27 0	1 62	11 9	34 2	14 2	0 14	64 2	28 8	0 4	1 8	3 5	1 2	0 0	226
30 00	30 0	36 0	34 0	34 0	40 0	27 0	2 41	11 9	39 3	16 3	0 11	62 4	22 6	1 0	1 7	8 7	2 4	0 0	287
31 00	28 0	35 0	37 0	31 0	39 0	30 0	1 57	12 9	39 3	16 3	0 12	64 8	21 8	0 0	3 1	9 3	0 5	0.0	193
32 00								12 7											
33 00	46 0	26 0	28 0	50 0	27 0	23 0	2 99	11 3	23 5	9 9	0 39	57 4	33 3	2 3	2 5	1 8	2 8	0 0	399
34 00	47 0	25 0	28 0	51 0	30 0	20 0	2 82	10 6	23 9	10 0	0 27	56 4	32 5	0 5	4 3	3 5	2 3	0 0	369
35 00	46 0	25 0	29 0	50 0	29 0	21 0	2 93	10 1	23 8	10 0	0 35	52 1	37 3	1 9	4 8	2 9	1 1	0 0	378
36 00								15 9											
37 00								15 6											
38 00								16 0											
39 00								15 8											
40 00								16 4											
41 00								15 8											
42 00								15 4											
43 00	33 0	30 0	37 0	37 0	33 0	30 0	1 47	12 9	20 3	8 6	0 37	58 4	31 5	2 5	3 6	1 5	2 5	0 0	197
44 00	38 0	27 0	35 0	41 0	32 0	27 0	1 89	11 0	19 7	8 3	0 38	54 0	36 8	1 4	1 8	3 7	1 6	0 0	272
45 00	37 0	28 0	35 0	42 0	33 0	26 0	2 32	11 2	20 5	8 7	0 54	57 9	33 4	1 0	4 2	1 6	1 6	0 0	311
46 00	37 0	27 0	36 0	41 0	32 0	27 0	2 13	11 0	22 0	9 3	0 41	63 8	26 5	1 7	4 9	2 1	1 0	0 0	287

T6

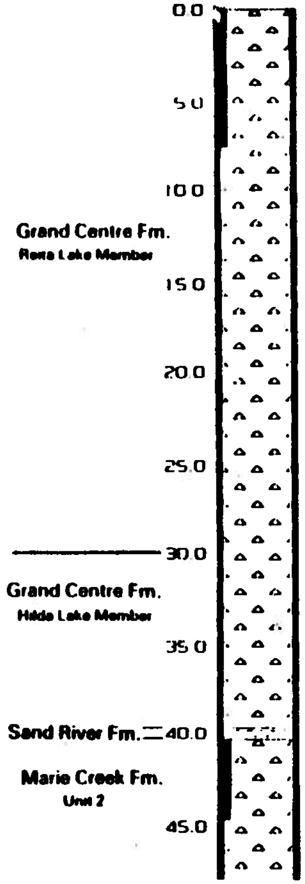
Alberta Geological Survey Testhole T6
Location of LSD 15 Sec 11 Twp 62 Rng 3 W of 4 Mer , NTS 73L
Elevation 1775 Ft 541 M Source 1 50,000 NTS 73L/8
Date drilled 197510 29 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY 2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00																			
2 00	33 0	28 7	38 1	36 4	33 6	30 0	1 91	14 6	23 1	9 7	0 35	77 6	18 5	1 6	1 2	0 4	0 8	0 0	254
3 00	36 8	23 9	39 3	40 1	27 6	32 4	2 01	15 1	19 3	8 1	0 34	75 3	19 1	1 1	1 5	1 9	0 8	0 0	267
4 00	36 9	24 6	38 5	40 1	28 2	31 7	1 77	15 0	23 4	10 2	0 24	76 9	19 7	0 8	0 4	1 7	0 4	0 0	234
5 00	34 2	29 7	36 1	38 2	32 7	29 1	1 07	14 6	26 5	11 1	0 24	78 3	18 1	0 7	1 5	0 7	0 7	0 0	138
6 00									29 4	12 2	0 15								
6 50	26 5	34 2	39 3	30 7	39 1	30 2	0 92	12 0	25 1	10 5	0 26	78 2	16 9	3 2	1 6	0 0	0 0	0 0	124
I																			
9 00	43 8	29 5	26 7	47 7	31 1	21 2	1 33	9 8	44 6	18 6	0 14	61 7	15 9	1 0	2 0	18 4	1 0	0 0	402
10 00	44 6	28 9	26 5	48 5	31 1	20 0	1 62	11 4	44 1	18 4	0 16	68 3	14 4	2 9	2 0	11 5	0 6	0 0	451
11 00	40 4	29 0	30 6	44 2	31 2	24 5	2 81	7 9	44 1	18 3	0 09	56 5	19 7	0 6	4 1	17 7	1 5	0 0	345
12 00	43 0	28 8	28 2	46 6	30 6	22 8	1 08	8 1	44 7	18 6	0 17	60 8	20 8	0 8	3 6	13 3	0 8	0 0	385
13 00	45 2	22 6	32 3	48 7	25 5	25 8	2 80	9 8	28 9	12 1	0 29	58 8	29 9	0 9	3 7	2 8	3 7	0 0	354
14 00	44 6	24 5	30 8	48 1	26 9	25 0	2 46	9 0	36 5	15 3	0 24	61 9	27 6	0 3	2 8	6 8	0 6	0 0	352
15 00	45 0	26 5	28 6	48 8	28 0	21 2	2 61	8 7	37 4	15 5	0 15	59 7	26 8	1 5	3 2	7 1	1 8	0 0	340
16 50	45 1	24 4	30 5	48 4	27 5	24 2	2 82	9 0	27 6	11 5	0 15	56 4	31 8	1 1	2 9	4 6	3 2	0 0	374
18 00	41 5	26 3	32 2	44 9	29 7	25 4	2 48	10 2	26 5	11 1	0 23	62 4	25 8	3 1	2 8	3 7	2 2	0 0	322
19 00	44 5	24 9	30 6	48 2	27 8	24 0	2 47	10 1	28 2	11 7	0 11	59 8	30 6	1 3	3 3	3 7	1 4	0 0	301
20 00	36 9	24 1	39 0	39 9	29 7	30 5	2 15	11 8	25 5	10 6	0 20	64 2	24 3	0 7	4 5	3 8	2 1	0 0	288
21 00	38 7	24 8	36 6	42 0	29 4	28 6	2 54	10 8	27 5	11 5	0 21	64 1	24 7	0 0	4 1	2 7	4 4	0 0	340
22 00	52 5	22 4	25 1	56 0	24 7	19 3	2 94	9 4	25 0	10 4	0 11	59 7	31 2	0 5	3 4	2 9	2 1	0 0	382
23 00	45 6	24 7	29 7	49 3	27 4	23 3	6 26	9 5	27 0	11 3	0 27	61 9	28 5	2 2	1 1	2 9	3 3	0 0	281
24 00	36 0	25 6	38 4	39 2	31 0	29 8	2 10	11 6	29 3	12 3	0 11	61 1	25 1	1 4	5 5	5 2	1 5	0 0	271
25 00	28 1	25 7	46 1	30 7	32 1	37 1	1 58	12 9	25 7	10 7	0 14	63 6	28 7	0 5	2 6	2 6	2 1	0 0	195
26 00	25 0	26 9	48 1	27 7	33 9	38 4	1 20	13 7	26 4	11 0	0 14	61 3	27 4	1 2	3 6	4 2	2 4	0 0	168
27 00	30 2	28 0	41 8	33 1	33 4	33 6	1 80	12 2	24 8	10 3	0 14	62 2	27 8	1 2	2 5	4 2	2 1	0 0	241
27 50	29 5	27 3	43 3	32 4	33 3	34 3	1 86	12 8	34 0	14 2	0 25	71 2	18 2	0 4	1 7	2 1	6 4	0 0	236
29 00	25 3	26 5	48 2	28 2	33 1	38 5	1 34	13 5	28 1	11 7	0 21	70 3	23 2	1 1	2 2	1 1	2 1	0 0	185
30 00									31 5	14 3	0 15								
30 50	22 7	27 1	50 3	25 2	34 7	40 1	1 30	13 6	26 8	11 3	0 24	51 2	32 5	0 0	6 0	7 2	2 4	0 0	166
31 00								13 7	30 9	12 9	0 27								
33 00	19 7	23 5	56 8	21 8	32 8	45 5	1 38	13 2	25 5	10 7	0 26	55 3	30 0	3 0	3 5	5 9	2 4	0 0	170
34 00	31 7	26 9	41 5	34 5	33 3	32 2	2 18	8 9	35 9	15 1	0 30	62 9	26 0	0 4	3 5	6 3	1 0	0 0	288
35 00	48 2	25 4	26 4	51 6	27 4	20 9	5 27	9 7	19 4	8 1	0 29	79 3	17 6	0 5	0 5	1 3	0 0	0 0	641
36 00	46 2	28 8	25 0	50 1	31 0	18 9	3 25	9 1	31 8	13 4	0 41	66 8	22 7	1 3	2 5	4 5	2 4	0 0	401
37 00	49 2	27 2	23 6	52 7	29 7	17 6	4 05	9 1	30 4	12 8	0 33	56 2	31 0	0 8	6 6	3 0	2 4	0 0	504
38 00	48 2	28 3	23 5	52 0	30 3	17 7	3 02	9 2	32 2	13 5	0 34	58 9	29 5	1 9	2 3	4 7	2 1	0 0	387
39 00	51 5	24 9	23 5	55 2	28 0	16 9	3 59	8 9	29 3	12 4	0 15	58 1	30 4	1 0	4 1	3 4	2 5	0 0	437
40 00	54 4	22 8	22 7	57 7	24 9	17 4	1 38	9 3	27 8	11 7	0 40	54 1	32 3	1 4	1 4	4 8	2 8	0 0	436
41 00	57 2	21 7	21 1	61 0	23 2	15 8	1 07	9 1	24 7	10 4	0 45	59 2	27 1	1 0	3 5	6 3	2 8	0 0	395

T7

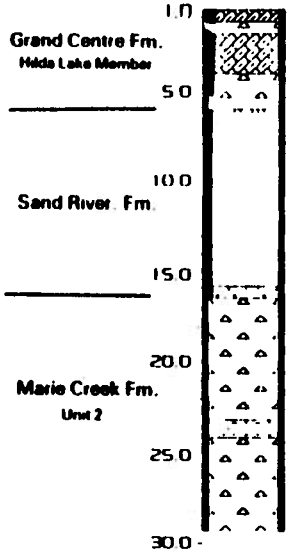
Alberta Geological Survey Testhole T 7
Location of LSD 4 Sec 1 Twp 61 Rng 6 W of 4 Mer , NTS 73L
Elevation 1925 Ft 587 M Source 1:50,000 NTS 73L/10
Date drilled 197510 10 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	COT (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1.00	36.4	26.5	37.1	40.4	28.2	31.4	1.57	12.5	31.1	13.1	0.30	68.4	22.4	2.0	1.1	3.1	1.0	0.0	196
2.00								11.3				66.2	28.0	1.3	1.8	0.9	1.0	0.0	224
3.00	34.6	24.7	40.7	37.5	28.1	34.4	1.51		26.9	11.2	0.22	70.1	26.4	0.0	1.2	1.7	0.0	0.6	174
4.00	36.4	25.6	38.0	40.3	27.4	32.3	1.74	14.0				65.8	24.0	0.9	4.0	1.8	3.6	0.0	225
5.00	31.7	24.6	43.7	34.3	28.4	37.3	1.52	14.4	25.8	10.8	0.22	65.6	26.3	1.6	2.1	3.8	0.5	0.0	186
6.00	30.1	24.7	45.1	33.5	28.8	37.7	1.10	15.9				75.2	22.0	2.1	0.0	0.0	0.7	0.0	141
7.00	28.3	23.5	48.1	30.7	27.3	42.0	1.11	15.5				70.2	24.1	2.5	0.6	1.8	0.0	0.6	162
8.00	21.4	36.5	42.2	25.6	38.7	35.7	0.52	14.2	25.6	10.7	0.26	70.3	20.3	3.1	4.7	1.6	0.0	0.0	64
9.00	33.0	31.8	35.2	37.3	33.6	29.1	1.45	13.9	28.2	11.8	0.29	74.9	22.0	1.6	0.5	0.5	0.5	0.0	191
10.00	32.7	30.9	36.5	36.0	34.3	29.7	1.41	12.9	27.7	11.6	0.25	72.3	23.9	1.6	1.1	1.1	0.0	0.0	184
10.50	32.9	33.8	33.3	37.5	34.6	27.9	1.28	11.7				73.7	21.7	1.1	1.7	1.1	0.0	0.6	175
12.00	38.5	31.0	30.5	43.9	31.0	25.1	1.75	11.0	29.5	12.4	0.28	71.2	25.1	0.4	0.9	0.4	0.0	0.0	231
13.00	37.9	33.2	28.9	42.8	33.1	24.1	1.80	11.5	30.0	12.5	0.24	61.1	27.1	1.8	2.2	3.5	2.2	0.0	225
14.00	41.4	26.4	32.2	45.3	28.3	26.4	2.16	10.9				66.3	29.2	1.9	1.1	1.5	0.0	0.0	264
15.00	39.3	30.3	30.3	44.7	29.4	25.9	1.96	10.9	25.3	10.5	0.20	61.0	32.4	0.4	1.2	1.6	0.4	0.0	250
16.00	41.1	26.9	32.0	44.8	29.0	26.2	2.10	9.8				67.7	25.6	1.1	0.7	2.6	2.3	0.0	266
17.00	39.8	29.5	30.8	43.1	31.4	25.5	1.68	9.7	28.9	12.1	0.18	71.5	25.2	0.9	0.9	1.4	0.0	0.0	218
18.00	34.7	32.3	33.0	39.1	31.4	26.5	1.18	10.8	29.3	12.2	0.20	65.2	29.8	0.6	0.0	3.4	1.2	0.0	178
19.00	34.5	31.0	34.4	38.1	32.9	29.0	1.31	11.7				79.4	17.6	1.2	1.2	0.6	0.0	0.0	165
20.00								11.6				60.7	21.1	1.6	3.2	3.2	0.4	0.0	220
21.00	21.8	27.8	50.3	24.7	33.0	42.3	1.01	12.7	25.0	10.4	0.16	69.9	25.2	0.0	0.8	2.4	1.6	0.0	123
21.50	25.5	29.9	44.6	28.1	34.0	37.9	1.00	13.3	28.7	12.0	0.21	73.7	20.3	1.5	1.5	3.0	0.0	0.0	133
23.00	32.6	30.3	37.1	37.0	34.1	31.6	1.45	11.8				71.2	23.4	0.5	2.2	2.7	0.0	0.0	184
24.50	34.2	30.9	34.9	37.7	32.8	29.5	1.17	11.2				67.1	27.6	0.6	1.3	2.6	0.0	0.0	152
25.00								11.2	29.2	12.2	0.25								
26.00	34.8	31.2	34.0	39.1	32.1	28.8	1.67	11.7				66.3	27.6	0.5	1.8	3.7	0.0	0.0	217
27.00	34.3	27.6	38.1	37.6	0.0	32.4	1.81	11.6	26.5	11.1	0.21	67.5	26.8	0.9	2.2	2.6	0.0	0.0	231
28.00	26.1	38.7	35.3	30.9	39.0	30.2	0.92	13.5				72.4	18.9	0.8	2.4	4.7	0.8	0.0	127
29.00	25.6	38.6	35.8	29.7	39.5	30.8	0.58	12.9	27.4	11.6	0.28	63.9	33.7	0.0	1.2	1.2	0.0	0.0	86
30.00	24.0	39.3	36.7	29.0	39.5	31.5	0.81	12.6	26.7	11.2	0.35	71.2	26.1	0.0	0.0	0.9	0.9	0.9	111
31.00	25.7	41.5	32.8	30.4	41.0	28.5	0.54	12.6				76.9	17.9	1.3	2.6	1.3	0.0	0.0	78
32.00	26.1	38.8	35.1	31.0	38.8	30.2	0.81	12.5	27.7	11.6	0.35	75.0	23.0	1.0	0.0	1.0	0.0	0.0	100
33.00	31.8	32.4	35.8	36.8	32.6	30.6	0.67	33.5	27.2	11.4	0.32	71.3	26.6	1.1	1.1	0.0	0.0	0.0	94
34.00	23.8	41.5	34.7	29.0	42.3	28.7	0.82	12.2				71.9	21.9	2.4	2.4	1.2	0.0	0.0	82
35.00	25.9	37.2	36.9	29.4	39.0	31.6	0.77	12.3	25.5	10.6	0.21	71.5	22.9	1.8	2.7	0.9	0.0	0.0	109
36.00	25.2	40.0	34.8	29.1	40.7	30.2	0.72	12.1	25.5	10.6	0.20	72.2	21.6	3.1	1.0	2.1	0.0	0.0	97
37.00	28.3	27.6	44.1	31.7	31.7	36.6	1.03	12.6				72.0	26.3	0.0	0.0	0.8	0.0	0.8	118
38.00	10.9	20.1	68.9	11.9	25.8	62.3	0.54	17.1	24.8	10.3	0.19	84.8	15.1	0.0	0.0	0.0	0.0	0.0	33
39.00	0.0	0.0	39.5	0.0	0.0	0.0	0.00	10.3	27.1	11.3	0.17								
40.00	36.7	32.4	30.9	40.6	32.4	27.0	3.01	10.8				53.9	16.6	0.0	6.6	19.6	3.3	0.0	362
41.00	37.1	33.1	29.8	41.3	32.8	25.9	2.42	10.8	45.8	19.1	0.18	52.1	24.1	0.3	3.2	19.9	0.3	0.0	307
42.00	39.6	29.1	31.3	42.9	31.0	26.1	2.68	10.4	42.5	18.5	0.17	54.7	20.6	0.0	5.9	16.5	2.4	0.0	340
43.50	38.2	32.5	29.3	42.5	33.8	23.7	2.63	10.0				57.9	21.2	0.3	2.0	17.6	0.9	0.0	340
44.00	40.0	29.7	30.3	43.2	31.8	25.0	2.53	10.7	40.7	16.9	0.15	59.1	21.2	0.0	4.1	14.7	0.9	0.0	320
45.00	38.2	32.0	29.8	42.5	33.0	24.5	2.40	10.5	45.0	18.7	0.13	59.1	23.1	0.3	3.3	12.4	1.7	0.0	298
46.00								10.3	41.5	18.1	0.16	57.8	21.5	0.3	4.5	14.9	0.8	0.0	340
48.00	57.9	12.3	29.8	61.1	14.4	24.5	2.45	10.7	43.7	18.2	0.14	60.2	18.8	0.3	3.2	16.8	0.7	0.0	309

T8

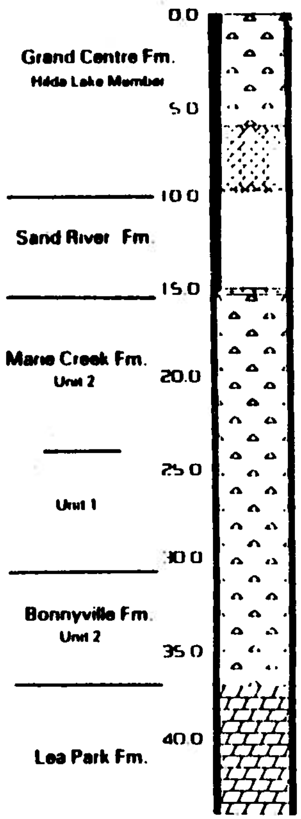
Alberta Geological Survey Testhole T 8
Location of LSD 11 Sec 16 Twp 62 Rng 2 W of 4 Mer NTS 73L
Elevation 1790 ft 546 M Source 1:50,000 NTS 73L/8
Date drilled 197607 08 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZI OSS	LST	DST	LOC	OTH	N
2.00	58.0	11.0	31.0	60.0	12.0	28.0	1.44	13.1				75.7	18.9	1.2	0.0	0.0	4.1	0.0	243
3.00	3.0	39.0	58.0	5.0	46.0	49.0	0.25	21.7				46.6	22.3	2.0	1.9	1.0	26.2	0.0	103
5.00	26.0	30.0	45.0	29.0	32.0	39.0	1.01	13.2				54.0	14.5	1.3	7.9	5.3	17.1	0.0	76
6.00	35.0	29.0	37.0	38.0	30.0	32.0	1.58	11.3				68.3	24.6	0.0	2.4	2.8	2.0	0.0	211
16.00	45.0	28.0	27.0	49.0	28.0	23.0	3.04	9.4				65.8	23.6	0.3	3.3	4.0	3.2	0.0	398
19.50	46.0	26.0	27.0	50.0	27.0	23.0	3.13	9.4				60.2	28.3	0.6	5.5	3.8	1.8	0.0	399
21.00	46.0	26.0	28.0	50.0	26.0	24.0	3.18	9.4				58.5	28.8	0.4	2.6	4.3	2.1	3.1	417
22.00	48.0	27.0	26.0	51.0	28.0	21.0	3.35	9.9				63.1	24.5	0.0	4.6	4.4	3.1	0.2	453
24.00	51.0	34.0	15.0	56.0	31.0	13.0	2.19	10.7				57.0	35.2	0.0	4.2	1.6	2.0	0.0	307
25.00	60.0	20.0	20.0	63.0	20.0	17.0	2.93	7.8				65.9	26.3	0.0	4.3	1.9	1.7	0.0	369
27.00	60.0	24.0	16.0	63.0	23.0	14.0	1.64	8.3				61.1	31.7	0.6	3.2	2.0	1.4	0.0	496
28.00	47.0	27.0	26.0	51.0	28.0	22.0	3.51	8.8				59.8	27.1	0.5	3.6	8.1	0.7	0.0	420
29.00	46.0	28.0	25.0	50.0	30.0	21.0	3.08	9.8				58.8	24.4	0.9	4.9	9.8	0.7	0.0	410

T9

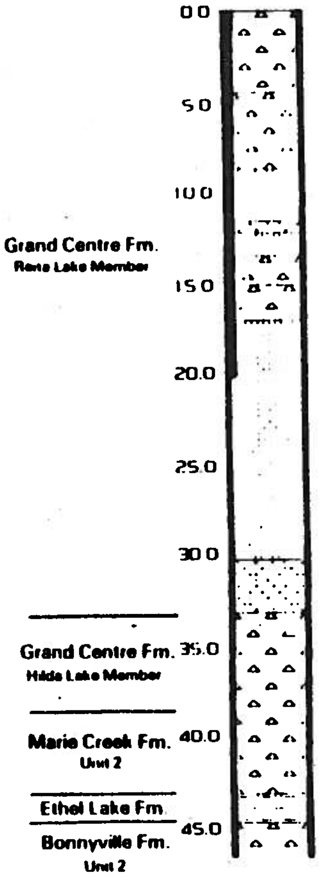
Alberta Geological Survey Testhole T 9
Location SE of LSD 13 Sec 10 Twp 62 Rng 2 W of 4 Mer . NTS 73L
Elevation 1775 Ft 541 M Source 1 50,000 NTS 73L/8
Date drilled 197607 09 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
2 00	9 0	19 0	73 0	10 0	26 0	64 0	0 41	20 0				68 4	21 1	0 0	0 0	0 0	10 6	0 0	57
3 00	26 0	29 0	46 0	29 0	31 0	39 0	1 15	12 6				77 5	15 2	0 7	2 0	3 3	1 3	0 0	151
5 00	28 0	27 0	45 0	32 0	30 0	38 0	1 43	12 6				64 7	29 4	0 5	1 6	2 1	1 6	0 0	187
6 00	4 0	41 0	54 0	5 0	51 0	44 0	0 12	15 2											
8 00	2 0	48 0	50 0	1 0	57 0	41 0	0 21	14 6											
9 00	4 0	34 0	62 0	5 0	45 0	50 0	0 27	15 6											
17 00	40 0	33 0	27 0	45 0	33 0	22 0	3 12	8 9				57 3	18 7	0 3	3 8	13 6	4 1	0 0	396
18 00	42 0	31 0	28 0	46 0	32 0	22 0	2 62	8 7				59 2	20 7	1 2	2 7	15 6	6 0	0 0	328
20 00	39 0	33 0	28 0	43 0	34 0	23 0	2 80	8 9				64 9	16 4	0 0	2 7	14 3	1 7	0 0	365
22 00	46 0	26 0	28 0	50 0	28 0	22 0	2 81	9 6				61 1	26 8	0 9	1 5	8 2	1 5	0 0	329
23 00	41 0	26 0	33 0	44 0	29 0	27 0	3 53	9 1				74 4	18 4	0 4	1 5	3 7	1 5	0 0	457
24 00	35 0	31 0	34 0	38 0	35 0	27 0	2 20	9 8				68 3	26 0	0 3	2 0	3 3	0 0	0 0	300
26 00	32 0	34 0	34 0	36 0	37 0	27 0	2 20	9 6				64 0	24 7	1 7	3 1	4 5	2 0	0 0	292
27 00	32 0	33 0	35 0	35 0	36 0	28 0	2 18	9 8				66 2	25 1	0 0	3 8	1 5	1 1	0 0	287
28 00	28 0	32 0	40 0	31 0	38 0	32 0	2 03	11 0				62 5	27 6	0 4	3 9	3 9	1 8	0 0	283
31 00	48 0	29 0	24 0	51 0	31 0	18 0	3 05	9 1				63 4	26 8	0 0	2 3	5 7	1 8	0 0	385
32 00	48 0	29 0	23 0	52 0	31 0	18 0	3 01	8 6				58 4	29 1	1 0	4 8	4 6	1 9	0 0	413
33 00	42 0	28 0	30 0	46 0	30 0	25 0	2 43	8 6				60 8	27 5	1 9	4 9	0 6	4 0	0 0	324
34 00	40 0	30 0	30 0	44 0	31 0	25 0	2 66	10 2				53 0	31 9	2 6	6 6	1 7	2 3	0 0	351
35 00	42 0	27 0	31 0	46 0	29 0	25 0	3 00	8 2				61 3	30 3	2 1	2 6	2 1	1 8	0 0	390
36 00	39 0	30 0	32 0	43 0	31 0	26 0	2 80	10 1				57 8	32 5	0 5	6 1	1 9	1 3	0 0	379
40 00								14 9											
42 00								14 8											
44 00																			

T10

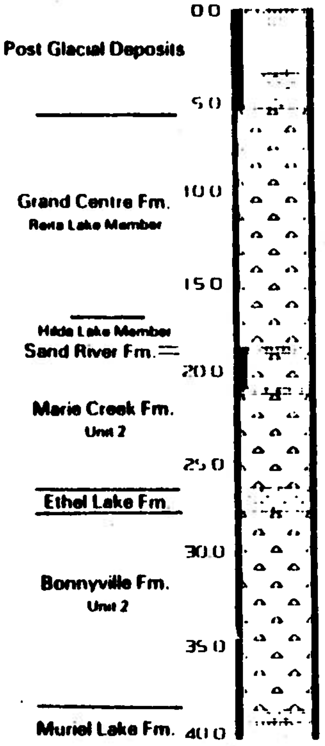
Alberta Geological Survey Testhole T 10
Location of LSD 9 Sec 16 Twp 63 Rng 4 W of 4 Mer NTS 73L
Elevation 1800 Ft 549 M Source 1 50,000 NTS 73L/7
Date drilled 197607 10 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
2 00	35 6	40 7	23 7	38 1	44 4	17 4	1 43	8 1				73 8	20 3	0 0	0 6	3 5	1 2	0 6	172
3 00	33 2	42 3	24 5	35 7	41 7	20 7	1 55	9 0				70 1	23 7	1 0	2 1	2 1	1 0	0 0	194
4 00	21 2	57 6	21 2	23 7	59 8	16 5	0 53	11 8				71 8	22 3	2 3	3 5	0 0	0 0	0 0	85
5 00								12 6											
6 00								12 5											
7 00								12 4											
8 00								10 4											
9 00								11 5											
14 00	16 1	64 2	19 7	17 9	67 2	14 9	0 56	14 4				73 7	22 4	2 6	0 0	0 0	1 3	0 0	76
15 00								13 1											
16 00	52 6	38 3	9 1	54 8	38 4	6 8	0 90					74 3	20 5	0 8	0 0	1 7	2 5	0 0	117
31 00												65 6	28 3	1 0	1 9	3 2	0 0	0 0	526
34 00	25 0	46 2	28 7	26 5	51 4	22 1	1 50	12 4				64 6	31 2	0 0	2 6	3 1	3 1	0 5	192
35 00	27 5	44 5	28 0	30 2	47 8	22 0	1 43	11 9				62 5	25 0	0 6	4 2	3 6	4 2	0 0	168
35 50	27 8	44 7	27 5	29 6	49 7	20 8	1 67	12 0				60 1	29 2	0 6	3 9	5 6	0 6	0 0	178
37 00	18 9	47 8	33 4	20 5	53 4	26 1	1 10	14 6				61 9	21 0	0 8	5 0	5 0	4 2	0 0	119
38 00	17 9	46 3	35 7	19 6	53 0	27 4	1 02	17 7				67 5	23 9	0 0	2 6	5 1	0 8	0 0	117
39 00	32 4	42 7	24 9	34 5	46 3	19 2	2 00	13 4				60 0	24 7	0 0	6 4	6 1	2 4	0 0	235
40 00	36 9	40 7	22 4	39 4	43 5	17 1	2 23	11 5				64 0	22 1	0 0	5 2	6 7	1 9	0 0	267
41 00	40 8	39 7	19 5	43 6	42 3	14 1	2 41	11 1				57 0	28 3	0 0	6 1	6 8	1 7	0 0	279
44 00								14 1											
45 00								11 4											
45 50	44 2	40 4	15 5	47 0	41 6	11 4	2 88					67 9	21 7	0 6	1 4	2 8	1 7	0 0	355
46 00	47 5	40 9	11 6	50 6	41 7	7 7	3 49	10 5				70 0	21 1	0 0	4 4	2 2	1 9	0 3	364

T11

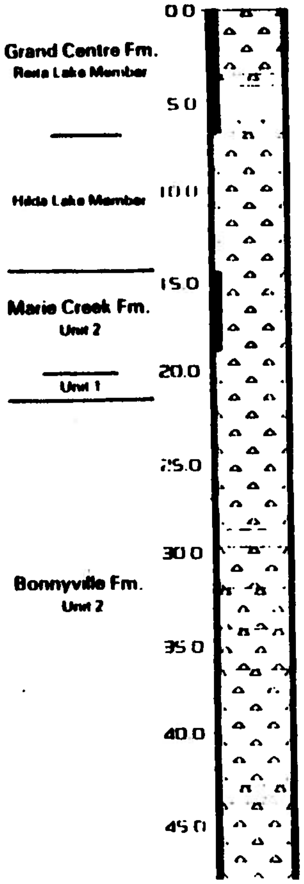
Alberta Geological Survey Testhole T 11
Location of LSD 9 Sec 11 Twp 62 Rng 5 W of 4 Mer. NTS 73L
Elevation 1805 FT 550 M Source 1:50,000 NTS 73L/7
Date drilled 1976/07/11 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET M	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
2.00																			
3.00																			
3.50								26.6											
5.00								26.6											
5.50								24.9											
6.50	40.9	29.5	29.6	45.3	31.9	22.8	1.56	15.8				70.9	21.8	0.0	0.9	2.8	1.5	0.0	210
8.00	29.4	11.6	16.9	35.6	16.2	28.2	1.26	16.8				61.0	26.1	0.6	3.1	4.3	1.2	0.6	161
9.00	38.0	27.7	34.3	42.0	31.9	26.2	1.59					69.4	24.1	0.4	1.3	3.1	1.1	0.0	222
10.00	47.0	28.2	24.8	51.9	29.3	18.9	2.25	11.2				71.2	24.2	1.4	0.3	1.8	0.9	0.0	281
11.00	40.5	30.3	29.2	44.1	32.5	23.2	1.46	11.0				65.8	27.3	1.6	1.6	1.6	1.6	0.5	187
12.00								11.5											
13.00	48.5	29.5	22.0	54.0	29.0	17.1	2.03	10.6				69.7	24.9	0.7	1.1	2.5	0.7	0.4	277
14.00	44.5	33.4	22.1	52.3	30.2	17.5	1.55	9.3				72.2	18.2	2.0	2.0	5.5	0.0	0.0	198
15.00	37.9	33.4	28.7	42.6	33.8	23.6	1.15	11.6				72.5	21.6	1.3	3.3	0.0	1.3	0.0	153
16.00	36.4	33.9	29.7	42.0	33.3	23.7	1.14	11.3				72.5	22.2	3.3	0.0	0.6	0.6	0.6	153
17.00	28.4	34.5	37.1	35.7	34.4	30.0	0.80	13.4				75.4	20.2	0.9	1.7	0.9	0.9	0.0	114
18.00	26.5	34.8	38.7	30.4	39.6	30.0	0.54	13.7				72.3	21.7	1.2	2.4	2.4	0.0	0.0	83
19.00	44.5	32.3	23.2	48.7	33.7	17.6	2.85	10.4				65.1	19.3	0.3	3.2	11.1	0.9	0.0	341
20.00	39.7	32.4	27.9	44.4	34.6	21.0	2.43	10.1				60.6	27.9	0.0	3.9	9.8	1.6	0.0	305
21.00	42.0	33.2	24.7	46.7	35.6	17.7	2.19					71.2	16.2	0.4	2.6	6.8	0.4	0.4	265
22.00	42.8	29.9	27.3	46.5	32.9	20.5	2.68	9.9				66.4	23.5	0.3	3.5	4.9	0.9	0.6	345
23.00	52.3	28.1	19.6	56.3	30.1	13.6	3.27	9.4				65.5	29.4	0.0	2.4	1.4	1.2	0.0	412
24.00	44.6	27.6	27.8	47.5	31.3	21.2	3.15	11.2				70.4	21.4	0.3	2.6	3.4	0.8	0.3	379
25.00	42.3	31.5	26.2	46.4	34.1	19.6	2.57	11.6				62.4	27.3	0.8	2.8	5.1	0.3	1.2	351
26.00	44.7	27.1	28.2	47.7	30.9	21.4	3.36	11.9				64.2	28.7	0.0	3.0	1.9	1.8	0.2	428
27.00																			
28.00	52.9	27.4	19.6	56.9	29.4	13.7	3.30	11.2				59.6	29.2	1.1	3.7	2.3	3.6	0.2	431
29.00	52.8	23.4	22.8	57.0	26.1	16.6	2.71	11.6				59.3	33.8	1.6	2.2	1.6	1.4	0.0	364
30.00	52.5	27.6	20.0	56.5	29.6	13.9	2.80	10.8				64.0	26.6	1.4	4.7	1.6	0.8	0.3	364
31.00	51.6	26.2	22.2	54.8	28.9	16.3	2.91	12.7				64.9	27.9	1.1	2.4	1.9	1.1	0.5	376
32.00	51.1	26.2	20.7	57.1	29.0	13.9	2.81	12.5				58.3	34.9	0.8	3.0	0.8	1.4	0.0	367
33.50	54.5	23.6	21.9	57.5	26.7	15.8	2.74	11.0				56.2	31.0	0.6	3.4	3.6	1.4	0.3	356
34.00	51.0	26.6	20.4	57.0	28.2	14.8	3.47	12.0				58.8	33.0	0.9	3.5	2.8	0.7	0.0	427
35.00	48.4	28.2	23.4	54.7	28.0	17.3	2.81	12.0				58.7	35.7	0.3	2.8	1.4	0.9	0.3	361
36.00	52.8	23.3	23.8	57.0	24.7	18.3	3.05	12.3				68.5	27.3	0.0	1.0	1.5	1.3	0.0	388
37.00	38.9	19.4	41.7	41.6	25.2	33.2	2.22	15.2				57.5	31.2	0.7	3.1	1.7	2.0	0.7	292
38.00	38.7	21.9	39.4	41.7	26.9	31.4	2.84	12.9				64.7	31.3	0.3	1.7	1.7	0.3	0.0	354

T12

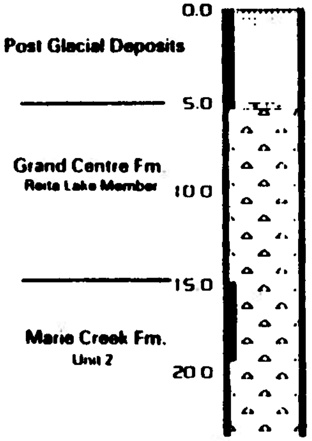
Alberta Geological Survey Testhole T 12
Location of LSD 4 Sec 1 Twp 62 Rng 4 W of 4 Mer . NTS 73L
Elevation 1830 Ft 558 M Source 1 50,000 NTS 73L/7
Date drilled 197607 12 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)								
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	37 4	24 0	38 6	41 6	25 7	32 8	1 94	16 1				69 7	24 9	2 1	1 6	1 6	0 0	0 0	241
2 00	39 0	27 9	33 2	44 4	28 6	27 0	1 46	15 4				65 2	30 8	1 5	0 5	1 5	0 5	0 0	201
3 00	36 4	26 4	37 2	40 5	28 4	31 1	1 77	16 8				66 0	26 8	0 9	3 3	2 4	0 5	0 0	209
4 00	40 8	27 2	32 0	45 4	28 5	26 1	1 86	13 9				67 8	26 1	1 3	1 3	2 2	1 3	0 0	230
5 00																			
6 00								15 5											
7 00	31 9	27 7	40 4	36 3	31 0	32 7	0 97	11 2				68 8	24 6	1 6	4 1	0 8	0 0	0 0	122
8 00	20 0	42 1	38 0	33 9	37 2	28 9	0 86	11 9				62 4	29 3	0 9	3 7	2 7	0 9	0 0	109
9 00	31 6	28 7	37 7	38 4	30 8	30 8	1 00	11 6				73 1	22 0	2 8	1 4	0 0	0 0	0 0	141
10 00	28 8	31 9	39 3	35 5	34 6	29 9	0 74	13 2				67 6	29 4	1 0	1 0	1 0	0 0	0 0	102
11 00	34 5	26 5	39 0	39 1	30 4	30 6	1 02	11 5				72 0	24 6	0 0	0 8	2 5	0 8	0 0	119
12 00	32 3	28 5	39 1	36 2	33 7	30 1	0 80	12 9				70 7	25 9	0 9	1 7	0 0	0 9	0 0	116
13 00	29 3	26 2	44 5	33 2	31 7	35 1	0 81					73 1	23 7	0 9	0 9	0 9	0 0	0 0	114
14 00	33 0	31 3	35 6	39 0	33 0	28 0	1 21	11 3				70 1	21 0	1 9	2 5	3 8	0 0	0 0	157
15 00	41 7	31 7	26 6	45 8	33 7	20 5	2 85	9 6				56 6	22 3	0 0	4 8	15 1	1 0	0 0	376
16 00	36 5	38 5	25 0	45 5	35 6	18 9	3 41	8 7				60 4	19 3	0 2	5 7	13 6	0 7	0 0	419
17 00	44 8	31 1	24 2	50 2	31 8	18 0	3 63	9 0				58 3	22 5	0 2	0 4	13 5	1 4	0 0	422
18 00	42 7	30 5	26 8	46 8	32 0	21 2	3 71	8 9				60 3	21 6	0 4	5 2	10 3	2 1	0 0	476
19 00	40 0	29 2	30 8	46 8	26 9	26 3	1 71					61 5	27 8	0 0	1 9	4 1	1 2	0 3	316
20 00	28 0	34 0	38 0	32 1	38 2	29 7	2 36	12 7				62 6	30 9	0 0	2 1	3 4	0 7	0 0	139
21 00	26 8	34 4	38 7	30 5	38 9	30 5	1 23					59 0	32 9	0 0	2 5	3 7	1 8	0 0	161
22 00	52 2	26 6	21 2	56 1	27 3	16 6	3 57	10 9				58 6	31 9	0 4	4 1	2 6	2 0	0 4	464
23 00	52 9	21 5	25 6	55 8	25 3	18 9	2 91	10 1				61 8	31 3	0 0	3 3	1 9	1 3	0 3	367
24 00	49 1	27 0	23 9	53 1	29 1	17 8	2 64	13 5				59 9	30 6	0 0	4 3	2 3	2 3	0 8	349
25 00	47 0	27 6	25 4	50 3	29 8	19 9	2 25	11 0				60 4	32 7	0 3	3 6	1 8	0 6	0 3	278
26 00	46 3	27 7	26 0	49 8	30 6	19 7	2 50	10 5				61 0	32 4	0 3	1,8	2 4	1 8	0 3	336
27 00	44 6	28 0	27 4	48 4	29 8	21 8	2 17	10 8				60 3	33 1	0 0	2 6	2 2	1 8	0 0	272
28 00	47 3	28 8	24 0	52 5	29 9	17 7	2 90	10 9				58 0	34 1	0 0	4 4	2 3	1 2	0 0	343
29 00	62 6	25 3	12 0	67 5	23 1	9 2	3 64	10 2				53 7	32 8	0 6	6 1	1 9	4 8	0 0	475
30 00	58 7	21 9	19 4	62 3	23 6	14 1	3 11	11 7				54 3	36 1	0 2	6 1	1 0	1 7	0 2	390
31 00	45 5	31 1	23 4	49 4	32 2	18 4	2 29	11 4				50 3	41 3	0 0	4 0	2 3	2 0	0 0	298
32 00	22 6	17 0	60 4	24 2	29 5	46 4	1 10					65 7	29 4	0 0	2 0	1 4	0 7	0 0	146
33 50	46 4	27 1	26 5	50 1	29 6	20 3	2 73	13 2				58 6	35 8	0 3	2 5	1 7	1 1	0 0	355
34 00	66 4	15 7	17 9	69 2	17 0	11 7	1 91	14 5				61 1	31 0	0 0	4 6	1 7	1 7	0 0	239
35 00	58 5	20 5	21 0	61 5	20 4	18 0	2 42	13 5				59 5	30 1	0 6	4 6	3 7	1 2	0 3	326
36 00	48 2	30 4	21 4	55 8	26 2	18 0	3 65	11 5				58 3	34 2	0 4	4 0	2 3	0 6	0 0	473
37 00	50 2	28 1	21 6	54 3	27 5	18 2	3 35					51 2	38 3	0 2	3 8	2 0	2 3	0 0	389
38 00	48 5	27 3	24 3	51 9	28 5	19 6	3 14	9 3				59 1	32 4	0 2	2 7	2 5	2 1	0 2	401
39 50	51 7	25 3	23 0	55 1	24 7	20 2	3 41	10 3				54 7	36 2	0 4	4 3	2 0	2 0	0 2	442
40 00	56 9	25 9	17 2	60 8	24 6	14 6	4 06	9 3				62 5	29 9	0 2	1 7	2 1	1 1	0 0	511
41 00	59 9	23 9	16 2	63 1	22 3	14 7	3 18	10 3				58 4	34 2	0 4	2 7	2 0	2 2	0 0	442
42 50	57 7	24 5	17 9	61 3	24 0	14 6	3 60	9 5				58 9	33 0	0 0	3 4	2 3	1 6	0 6	475
43 00	57 2	28 9	13 9	61 3	26 3	12 4	3 21	13 9				63 0	30 3	0 2	4 0	2 1	0 2	0 0	419
44 00	52 3	30 2	17 5	56 6	28 5	14 9	3 33	13 3				61 4	30 6	0 5	3 1	2 7	1 2	0 2	412
46 00	52 8	25 5	21 7	55 8	25 3	18 9	2 78	11 5				66 0	25 6	0 3	3 9	2 3	1 9	0 0	383
47 00	50 3	27 1	22 5	54 2	27 1	18 4	3 24	10 1				62 4	27 4	0 2	3 7	4 0	0 9	0 2	476
48 00	47 9	27 4	24 7	51 7	27 1	21 0	3 52					67 5	24 8	0 6	2 2	1 7	0 8	0 2	455

T13

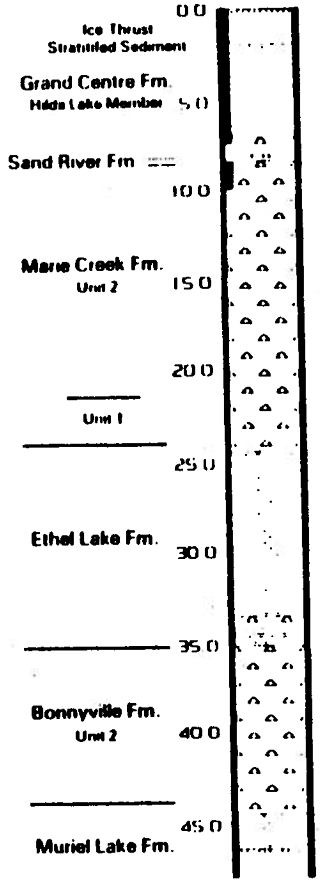
Alberta Geological Survey Testhole T 13
Location SW of LSD 4 Sec 27 Twp 60 Rng 2 W of 4 Mer , NTS 73L
Elevation 1950 Ft 595 M Source 1 50,000 NTS 73L/1
Date drilled 197607 14 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)					
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC-SD 1-2mm	H2O (%)	CO2 (cc)	COT (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
6.00	20.0	35.0	45.0	25.0	38.0	37.0	0.47	15.8				64.7	30.9	2.9	1.5	0.0	0.0	0.0	68
7.00	39.0	30.0	31.0	41.0	30.0	27.0	1.57	11.0				78.8	13.6	0.5	3.0	4.0	0.5	0.0	198
8.00	40.0	27.0	33.0	44.0	29.0	27.0	1.59	13.6				70.2	22.9	0.5	2.4	3.9	0.0	0.0	205
9.00	36.0	25.0	39.0	40.0	28.0	32.0	1.05	14.2				77.5	16.9	0.6	3.1	1.9	0.0	0.0	160
10.00	36.0	28.0	36.0	40.0	31.0	29.0	0.90	14.7				71.1	20.7	0.0	2.8	5.0	0.0	0.0	140
11.00	39.0	24.0	37.0	41.0	26.0	32.0	1.71	11.5				69.6	24.1	0.1	3.1	2.2	0.4	0.0	224
12.00	38.0	24.0	38.0	42.0	25.0	33.0	1.18	13.6				70.0	23.7	1.2	2.5	2.5	0.0	0.0	160
13.00	39.0	24.0	37.0	43.0	25.0	32.0	1.54	12.9				69.1	24.6	0.8	0.8	4.8	0.0	0.0	126
14.00	31.0	25.0	44.0	34.0	31.0	35.0	1.09	21.1				76.0	20.8	1.9	0.6	0.6	0.0	0.0	154
15.00	41.0	29.0	31.0	44.0	30.0	26.0	2.62	10.5				63.7	21.4	0.6	4.2	9.6	0.6	0.0	355
16.00	35.0	34.0	31.0	39.0	35.0	27.0	2.74	11.7				61.3	18.9	0.3	5.3	12.4	2.1	0.0	339
17.00	38.0	31.0	32.0	42.0	32.0	27.0	2.29	10.7				58.0	18.6	0.3	7.0	13.5	2.6	0.0	312
18.00	37.0	31.0	32.0	41.0	32.0	27.0	3.17	10.8				61.0	17.7	0.5	6.6	13.2	0.8	0.0	362
19.00	38.0	29.0	34.0	41.0	30.0	29.0	2.52	10.6				64.6	15.0	0.0	4.2	15.3	0.9	0.0	333
20.00	38.0	30.0	33.0	42.0	30.0	28.0	2.89	10.7				64.8	20.2	0.3	3.3	10.2	0.8	0.0	361
21.00	38.0	29.0	34.0	41.0	32.0	27.0	2.34	10.0				60.6	20.8	0.9	3.5	13.6	0.6	0.0	317
22.00	37.0	30.0	32.0	41.0	33.0	25.0	2.88	9.9				62.4	20.3	1.4	2.5	9.6	4.1	0.3	364
23.00	38.0	30.0	32.0	41.0	34.0	25.0	2.74	10.6				57.8	24.4	0.0	4.5	14.4	1.4	0.3	353

13B

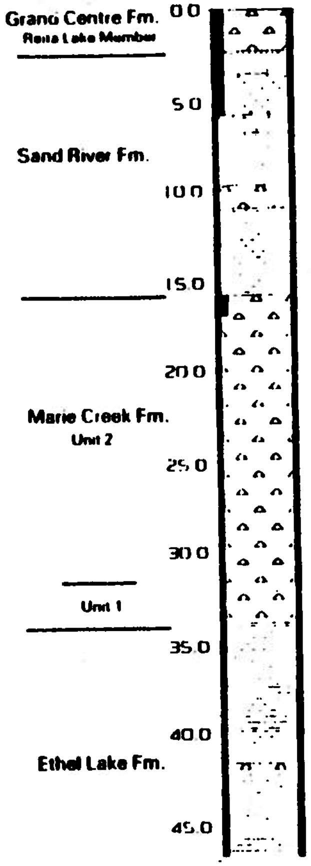
Alberta Geological Survey Testhole [illegible]
Location SE of LSD 1 Sec 10 Twp 60 Rng 2 W of 4 Mer NTS 73L
Elevation 1875 Ft 572 M Source 1:50,000 NTS 73L/1
Date drilled 197610 22 Logged by ANDRIASHEK



DEPTH (M)	TEXTURE (%) SAND >62 5um	SILT	CLAY <4um	SAND 50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00																			
2 00																			
3 00																			
4 00																			
5 00								17 3											
6 00												66 2	22 1	1 1	6 5	2 6	1 3	0 0	77
7 00	49 0	33 0	18 0	25 0	33 0	42 0	0 60					62 4	19 6	0 1	3 8	12 5	1 1	0 0	190
8 00	32 0	27 0	40 0	36 0	29 0	36 0	1 60	11 8				67 4	23 2	0 5	4 2	3 7	1 1	0 0	167
9 00	37 0	32 0	31 0	41 0	34 0	25 0	2 80	10 2				64 3	18 5	0 6	3 1	12 0	1 2	0 0	325
10 00	39 0	30 0	31 0	42 0	34 0	25 0	2 50	10 0				60 1	22 8	0 5	4 7	10 1	1 6	0 0	386
11 00	38 0	32 0	31 0	42 0	34 0	24 0	2 90	9 6				60 0	19 7	0 9	3 1	14 2	1 8	0 0	325
12 00	38 0	31 0	31 0	41 0	35 0	24 0	2 60	9 4				59 4	23 9	0 9	4 0	10 7	1 2	0 0	347
13 00	38 0	30 0	32 0	41 0	34 0	25 0	2 60	9 2				62 8	20 6	0 0	4 8	11 3	0 6	0 0	355
14 00	37 0	31 0	33 0	41 0	33 0	26 0	2 90	9 7				68 4	18 4	0 0	3 7	8 5	0 9	0 0	354
15 00	39 0	29 0	32 0	42 0	33 0	25 0	3 00	9 4				61 5	25 5	0 6	2 8	8 0	1 2	0 0	325
16 00	38 0	30 0	32 0	42 0	32 0	26 0	2 40	8 6				60 5	25 9	0 6	3 0	8 7	1 8	0 0	334
17 00	38 0	28 0	34 0	42 0	30 0	28 0	2 60	9 1				61 2	23 2	0 9	3 5	9 9	1 5	0 0	345
18 00	40 0	26 0	34 0	43 0	29 0	28 0	2 70	9 4				66 8	22 2	0 7	2 1	8 0	0 4	0 0	289
19 00	38 0	28 0	34 0	41 0	30 0	29 0	2 20	9 4				63 5	23 5	0 3	3 8	7 9	1 2	0 0	340
20 00	39 0	27 0	34 0	42 0	29 0	29 0	2 60	9 2				65 2	23 5	0 0	4 1	5 3	2 0	0 0	247
21 00	31 0	35 0	34 0	35 0	37 0	28 0	1 90	10 1				64 0	23 3	0 0	4 7	5 8	2 4	0 0	172
22 00	28 0	34 0	38 0	31 0	37 0	33 0	1 10	11 2				57 9	30 3	0 7	4 1	5 5	1 4	0 0	145
23 00	25 0	37 0	38 0	30 0	39 0	31 0	1 00	11 1				66 2	20 0	0 0	5 5	6 2	2 1	0 0	145
24 00	24 0	38 0	38 0	27 0	42 0	32 0	1 00	11 7											
25 00	8 0	36 0	56 0	11 0	42 0	47 0	0 20	16 8											
26 00	4 0	42 0	54 0	5 0	51 0	44 0	0 20	17 6											
27 00	10 0	33 0	57 0	11 0	43 0	46 0	0 40	13 1											
28 00	11 0	53 0	36 0	20 0	51 0	29 0	0 20												
29 00	15 0	35 0	50 0	18 0	41 0	40 0	0 30												
30 00	9 0	43 0	48 0	13 0	49 0	38 0	0 10	11 8											
31 00	7 0	41 0	52 0	8 0	50 0	42 0	0 10	14 1											
32 00	5 0	62 0	33 0	9 0	66 0	26 0	0 00	13 5				66 0	21 4	0 0	5 3	3 4	1 9	0 0	265
33 50	19 0	40 0	42 0	22 0	46 0	32 0	1 00	15 4				60 9	35 0	0 0	2 9	0 0	1 5	0 0	69
34 00	12 0	37 0	51 0	14 0	47 0	40 0	0 50	11 8				61 7	30 1	0 0	3 7	1 6	1 6	0 0	376
35 00	56 0	20 0	24 0	60 0	22 0	19 0	2 90	8 4				64 7	30 8	0 0	2 4	1 6	0 5	0 0	377
36 00	56 0	19 0	25 0	59 0	23 0	19 0	2 80	8 6				58 1	35 2	0 0	1 1	3 0	2 2	0 0	267
37 00	43 0	23 0	35 0	46 0	29 0	25 0	2 20	9 3				59 2	34 5	0 4	3 4	1 7	1 3	0 0	278
38 00	38 0	32 0	30 0	41 0	37 0	23 0	1 80	13 1				65 7	27 2	0 7	2 7	1 0	3 0	0 0	294
39 50	47 0	28 0	25 0	50 0	31 0	20 0	2 40	9 1				56 5	33 1	0 0	5 6	2 8	2 1	0 0	287
40 00	46 0	32 0	22 0	51 0	32 0	17 0	2 20					58 1	33 9	0 4	2 8	2 1	2 5	0 0	283
41 00	44 0	30 0	27 0	47 0	32 0	21 0	2 10	10 5				61 3	29 0	0 1	5 3	2 1	1 2	0 0	341
42 50	42 0	27 0	31 0	46 0	28 0	25 0	2 40	10 1				58 5	32 0	0 7	2 3	2 1	2 0	0 0	434
43 00	56 0	28 0	16 0	60 0	28 0	12 0	3 50	8 9											
44 00	11 0	59 0	31 0	12 0	66 0	23 0	0 50												
46 00	17 0	54 0	29 0	19 0	61 0	20 0	0 20												

T14

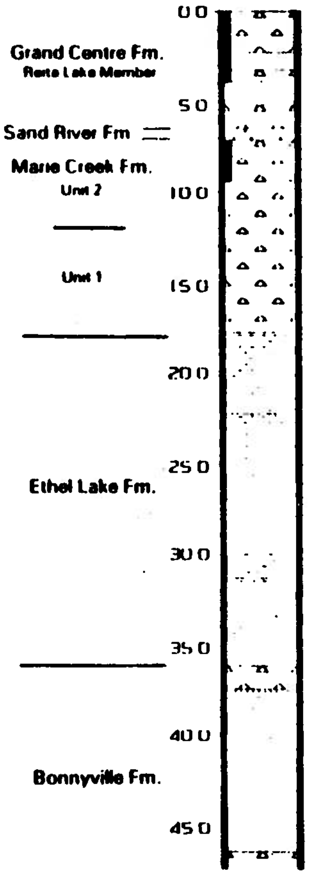
Alberta Geological Survey Testhole T 14
Location SW of LSD 4 Sec 17 Twp 60 Rng 1 W of 4 Mer . NTS 73L
Elevation 1950 Ft 595 M Source 1:50,000 NTS 73L/1
Date drilled 197607 14 Logged by ANDRIASHEK



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	44.0	22.0	35.0	47.0	21.0	32.0	2.03	12.6				76.5	21.6	1.6	0.0	0.0	0.4	0.0	255
2.00	47.0	23.0	30.0	50.0	24.0	26.0	1.55	11.1				72.3	19.6	1.0	1.4	5.3	0.5	0.0	209
6.00								10.2											
7.00								11.8											
8.00								13.9											
9.50	33.0	28.0	39.0	37.0	31.0	33.0	1.34	9.9				71.9	21.7	1.6	0.0	1.6	1.0	0.0	184
10.00								12.0											
11.00								18.9											
12.00								15.3											
13.00								16.7											
16.00	40.0	36.0	25.0	44.0	35.0	21.0	2.87	7.9				65.0	17.8	0.3	5.2	11.6	0.3	0.0	388
17.00	39.0	35.0	26.0	43.0	36.0	21.0	2.60	9.6				60.6	20.9	0.3	2.7	14.2	1.2	0.0	330
18.00	39.0	36.0	25.0	43.0	36.0	21.0	2.89	9.9				59.4	22.2	0.5	1.6	12.2	4.2	0.0	369
19.00	40.0	36.0	24.0	44.0	36.0	20.0	2.51	9.5				60.3	17.7	0.3	5.1	13.3	3.5	0.0	317
20.00	39.0	35.0	26.0	43.0	36.0	21.0	2.69	9.2				64.8	16.8	0.0	4.6	11.4	2.5	0.0	369
21.00	40.0	34.0	26.0	44.0	35.0	21.0	3.21	9.9				61.1	18.8	0.2	5.1	12.8	1.9	0.0	414
22.00	39.0	34.0	28.0	43.0	35.0	22.0	2.81	9.1				62.3	19.7	0.1	4.3	11.1	2.5	0.0	371
23.00	43.0	31.0	26.0	47.0	33.0	21.0	5.17	9.7				62.2	18.5	0.5	3.2	13.3	2.3	0.0	405
24.00	37.0	35.0	29.0	41.0	35.0	23.0	2.33	7.4				61.3	20.3	0.3	2.8	14.4	0.9	0.0	320
25.00	38.0	33.0	29.0	42.0	36.0	23.0	2.67	8.4				62.8	18.9	0.6	4.5	11.8	1.1	0.0	355
26.00	36.0	33.0	31.0	40.0	36.0	24.0	2.12	8.6				63.9	25.8	1.0	1.3	7.4	0.7	0.0	310
27.00	39.0	31.0	31.0	42.0	33.0	25.0	2.78	10.0				66.1	17.5	0.3	2.8	12.2	1.2	0.0	354
28.00	37.0	33.0	30.0	40.0	36.0	24.0	2.69	9.7				63.8	22.6	0.3	4.1	8.7	0.6	0.0	345
29.00	37.0	32.0	31.0	41.0	37.0	23.0	2.68	9.1				66.9	17.9	1.1	2.8	8.5	2.3	0.3	363
30.00	37.0	32.0	31.0	41.0	36.0	24.0	2.91	9.0				62.5	24.0	0.6	2.8	8.5	1.4	0.3	363
31.00	39.0	32.0	29.0	42.0	36.0	22.0	2.87	10.0				64.8	21.1	0.8	2.4	7.3	1.1	0.3	372
32.00	21.0	41.0	39.0	24.0	45.0	31.0	1.18	11.2				61.0	27.9	0.7	2.6	7.8	0.0	0.0	154
33.50	21.0	41.0	39.0	24.0	45.0	32.0	1.34	11.5				57.6	32.6	0.0	0.6	8.1	0.6	0.0	172
34.00								16.5											
35.00								14.4											
36.00								11.0											
37.00								14.3											
38.00								14.6											
39.50								13.8											
40.00								12.6											
41.00	24.0	37.0	39.0	28.0	42.0	31.0	1.53	10.8				60.1	25.9	0.0	1.0	9.8	3.1	0.0	193
42.50	8.0	44.0	48.0	11.0	51.0	38.0	0.25	13.0											
43.00								11.6											
44.00								15.7											
46.00								17.8											
47.00								17.2											

T15

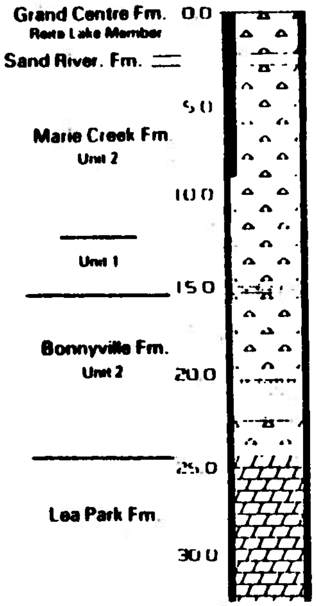
Alberta Geological Survey Testhole T 15
Location NE of LSD 16 Sec 20 Twp 60 Rng 1 W of 4 Mer , NTS 73L
Elevation 1875 Ft 572 M Source 1 50,000 NTS 73L/1
Date drilled 197607 15 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QZS	CST	DST	LOC	OTH	N
1 00	41 0	25 0	34 0	45 0	27 0	28 0	1 94	10 6				71 1	22 1	1 2	0 4	4 8	0 4	0 0	249
2 00	40 0	24 0	35 0	44 0	26 0	30 0	1 91	11 3				75 8	18 4	1 2	2 3	1 6	0 8	0 0	256
3 00																			
3 50	42 0	25 0	33 0	47 0	25 0	28 0	2 44	17 9				75 8	18 2	1 3	1 6	0 6	2 5	0 0	314
6 00	41 0	26 0	34 0	45 0	27 0	28 0	2 00	14 5				74 8	18 9	0 8	2 4	2 8	0 4	0 0	254
8 00	39 0	34 0	28 0	41 0	35 0	22 0	2 61	11 8				66 7	17 1	0 0	3 8	11 1	1 3	0 0	315
9 00	39 0	33 0	28 0	43 0	36 0	21 0	2 10	10 3				59 9	15 8	0 6	6 5	14 3	2 8	0 0	322
10 00	39 0	35 0	27 0	43 0	36 0	21 0	2 14	10 6				59 1	17 9	1 1	7 4	11 6	2 6	0 0	352
11 00	40 0	33 0	28 0	41 0	35 0	22 0	3 41	9 9				59 5	16 3	0 0	6 2	14 6	3 4	0 0	417
12 00	34 0	32 0	34 0	37 0	36 0	27 0	2 48	9 9				63 8	26 .6	0 0	2 8	6 8	0 0	0 0	323
13 00	35 0	32 0	33 0	38 0	36 0	26 0	1 78	10 6				65 5	22 6	0 0	1 8	8 8	0 9	0 0	328
14 00	34 0	34 0	32 0	37 0	38 0	25 0	2 50	10 7				65 3	19 7	. 0	3 1	10 2	1 6	0 0	294
15 00	33 0	33 0	34 0	36 0	38 0	26 0	1 72	11 7				66 0	24 3	0 0	2 1	5 9	0 3	0 0	288
16 00	33 0	33 0	34 0	37 0	36 0	27 0	1 94	10 7				67 3	23 5	0 0	2 3	3 8	2 7	0 4	260
17 00	35 0	32 0	33 0	39 0	36 0	26 0	1 64	9 9				66 4	24 0	0 5	2 3	5 5	1 4	0 0	217
18 00								16 1											
19 00								16 5											
20 00								17 4											
21 00								18 3											
22 00								18 5											
23 00								18 1											
24 00								16 4											
25 00								17 9											
26 00								18 0											
27 00								18 1											
28 00								16 9											
29 00								18 0											
30 00								18 7											
31 00								17 8											
32 00								18 9											
33 50								18 8											
34 00								18 3											
35 00								15 4											
36 00	45 0	28 0	27 0	49 0	32 0	20 0	2 43	11 2				62 6	31 2	0 0	1 2	1 2	1 7	0 0	321
37 00	53 0	32 0	16 0	56 0	32 0	11 0	1 41	11 3				61 5	30 7	0 5	2 5	2 3	2 5	0 0	436
46 00	52 0	31 0	18 0	56 0	31 0	13 0	3 19	10 0				56 0	35 6	0 5	4 1	1 5	1 9	0 5	393

T16

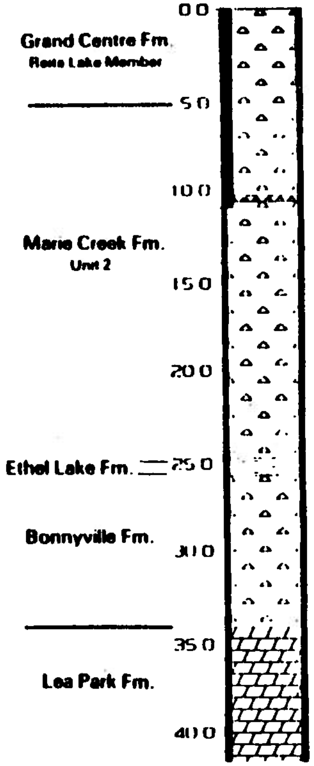
Alberta Geological Survey Testhole T 16
Location SW of LSD 4 Sec 30 Twp 61 Rng 1 W of 4 Mer . NTS 73L
Elevation 1780 Ft 543 M Source 1 50,000 NTS 73L/8
Date drilled 197607 16 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	42 5	25 7	31 8	46 7	26 4	27 0	1 83												
2 00	44 0	27 8	28 2	48 0	28 4	23 6	2 22	8 9				72 3	21 0	0 9	1 9	3 3	0 5	0 0	577
3 00																			
4 00	51 3	27 9	20 8	55 0	28 0	17 0	1 32	8 7				61 4	19 3	0 7	5 4	9 2	1 9	0 0	571
5 00	40 3	33 2	26 5	44 6	33 5	21 9	3 00	9 9				62 1	23 5	0 2	2 4	9 5	2 4	0 0	422
6 00	40 5	30 3	29 2	44 2	33 9	21 9	2 59	10 1				66 3	18 5	1 1	3 5	9 5	1 1	0 0	655
7 00	42 0	31 2	26 7	46 5	32 0	21 5	2 85	9 6				65 2	21 3	0 5	3 9	7 6	1 4	0 0	592
8 00	46 7	28 5	24 8	50 5	29 6	19 9	2 85	9 9				64 0	24 9	0 0	3 1	7 9	0 0	0 0	417
9 00	37 7	32 8	29 8	42 1	34 5	23 4	2 96	10 4				72 4	17 1	0 2	2 4	6 8	0 9	0 0	457
10 00	36 7	31 1	32 2	39 9	34 8	25 4	2 62	10 5				67 9	18 1	0 2	4 7	7 4	1 5	0 0	580
11 00	37 5	30 3	32 2	41 7	32 9	25 4	3 59	9 9				70 6	16 2	0 2	3 1	8 0	1 7	0 0	687
12 00	36 8	31 5	31 7	39 9	35 2	24 9	2 98	11 7				69 9	20 3	0 0	4 0	3 1	2 3	0 0	479
13 00	28 3	36 6	35 2	31 7	40 6	27 7	2 04	12 6				59 6	28 1	0 3	2 8	6 1	3 1	0 0	359
14 00	29 8	34 1	36 0	32 4	39 4	28 2	1 92	12 9				62 3	24 4	0 5	3 6	5 7	3 1	0 0	385
15 00								13 2											
16 00	41 3	35 4	23 4	45 6	36 7	17 7	2 55	9 4				62 0	26 7	0 4	3 4	5 1	2 1	0 0	468
17 00	45 7	32 4	21 8	49 4	34 0	16 6	2 79	8 9				57 6	29 1	0 2	3 7	6 2	2 5	0 0	484
18 00	54 5	24 4	21 1	59 1	25 1	15 8	3 05	8 7				55 0	36 9	0 0	1 8	1 6	2 2	0 0	705
19 00	54 2	23 1	22 7	57 3	25 7	17 0	2 85	9 6				56 6	32 8	0 0	3 7	4 2	2 4	0 0	378
20 00	51 0	25 9	23 1	54 9	28 1	17 0	2 85	11 4				59 5	31 9	0 3	3 1	3 1	1 7	0 0	351
23 00	40 7	34 8	24 5	45 0	37 1	17 9	2 81	10 6				46 3	44 5	0 8	3 5	2 8	2 0	0 0	508
24 00								15 1											
25 00								18 4											
26 00								19 2											
27 00								15 5											
28 00								16 7											
29 00								15 4											
30 00								15 2											
31 00								21 8											
32 00								18 9											

T17

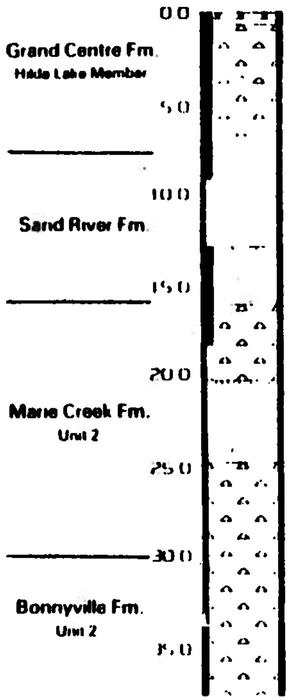
Alberta Geological Survey Testhole T 17
Location NE of LSD 7 Sec 36 Twp 61 Rng 3 W of 4 Mer . NTS 73L
Elevation 1800 Ft 549 M Source 1 50,000 NTS 73L/8
Date drilled 19760717 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	40.0	27.0	33.0	43.0	23.0	34.0	2.10	12.8				68.1	25.8	1.9	2.2	1.9	0.0	0.0	271
2.00	41.0	23.0	36.0	44.0	25.0	32.0	1.90	10.8				73.2	21.1	1.9	1.5	2.3	0.0	0.0	261
3.00	36.0	29.0	35.0	40.0	30.0	30.0	1.40	11.7				68.6	24.6	1.0	2.6	2.1	0.5	0.5	191
4.00	44.0	26.0	30.0	47.0	26.0	27.0	1.80	11.1				67.1	24.3	0.8	2.1	4.9	0.8	0.0	243
5.00	47.0	24.0	29.0	52.0	22.0	26.0	1.60	10.9				74.1	19.0	1.4	2.3	1.9	1.9	0.0	216
6.00	42.0	33.0	25.0	45.0	34.0	21.0	2.90	8.5				64.0	15.6	1.1	4.5	13.1	1.6	0.0	358
7.00	44.0	34.0	22.0	48.0	34.0	18.0	3.50	7.6				61.9	22.1	0.2	2.8	12.3	0.7	0.0	430
8.00	45.0	32.0	23.0	49.0	32.0	20.0	3.20	8.5				60.9	20.0	0.3	4.5	13.2	1.3	0.0	401
9.00	43.0	29.0	28.0	47.0	29.0	24.0	2.50	9.8				64.1	23.5	1.2	2.5	7.3	1.5	0.0	354
10.00	44.0	24.0	32.0	47.0	27.0	26.0	2.90	9.3				63.3	22.2	0.6	2.0	10.3	1.8	0.0	351
11.00	50.0	22.0	28.0	53.0	21.0	24.0	2.90	9.9				70.1	22.4	0.5	2.9	2.9	1.3	0.0	375
12.00	47.0	23.0	30.0	50.0	23.0	26.0	2.90	10.4				65.7	24.5	0.0	2.2	3.5	4.1	0.0	367
13.00	42.0	25.0	34.0	44.0	28.0	28.0	2.50	10.7				60.7	30.1	0.3	4.3	2.2	2.5	0.0	326
14.00	50.0	21.0	29.0	54.0	22.0	25.0	2.50	9.6				64.4	29.0	0.3	1.6	2.1	0.6	0.0	331
15.00	50.0	20.0	30.0	53.0	21.0	25.0	2.60	9.9				57.4	32.3	0.9	2.3	1.7	0.6	4.9	350
16.00	47.0	22.0	31.0	51.0	23.0	26.0	2.70	9.2				62.0	22.9	0.6	4.5	2.0	1.4	6.7	358
17.00	42.0	23.0	35.0	44.0	26.0	30.0	2.50	10.5				61.7	20.5	0.3	4.0	0.6	1.4	11.7	352
18.00	49.0	21.0	30.0	51.0	23.0	25.0	2.50	9.5				61.7	29.1	1.0	3.5	2.2	2.3	0.3	316
19.00	50.0	20.0	30.0	54.0	21.0	25.0	2.80	9.7				68.8	25.3	0.0	3.2	1.6	1.1	0.0	372
20.00	50.0	22.0	28.0	54.0	24.0	23.0	3.10	9.2				71.6	21.1	0.3	0.3	0.3	1.1	5.4	355
21.00	50.0	20.0	29.0	54.0	21.0	26.0	2.40	9.0				64.0	28.0	0.0	3.7	2.2	2.5	0.0	325
22.00	53.0	19.0	28.0	56.0	20.0	24.0	2.60	9.2				60.9	25.7	0.6	3.7	3.4	2.0	3.7	350
23.00	50.0	21.0	28.0	54.0	22.0	24.0	2.60	9.4				54.7	32.5	0.6	2.7	3.0	1.5	5.3	338
24.00	46.0	24.0	30.0	49.0	27.0	24.0	2.30	15.1				62.0	32.9	0.3	2.5	4.1	1.3	0.0	316
25.00	16.0	25.0	59.0	17.0	37.0	46.0	0.50	11.0				47.6	40.5	1.2	1.2	3.6	6.0	0.0	84
26.00	37.0	25.0	38.0	39.0	30.0	30.0	2.10	10.3				53.6	38.0	2.4	1.6	1.2	2.4	0.8	250
27.00	37.0	25.0	39.0	40.0	30.0	30.0	2.40	10.9				53.8	38.3	0.3	3.7	3.0	0.6	0.3	329
28.00	40.0	23.0	37.0	42.0	28.0	29.0	2.30	10.0				57.8	35.2	1.0	3.7	2.3	0.0	0.3	301
29.00	46.0	24.0	30.0	50.0	27.0	23.0	2.50	7.9				64.2	30.8	1.7	1.7	0.8	0.8	0.0	357
30.00	46.0	24.0	30.0	50.0	27.0	23.0	3.00	12.7				52.7	41.3	1.7	2.0	1.2	1.1	0.0	404
31.00	49.0	24.0	28.0	51.0	27.0	22.0	1.20	9.3				55.5	40.5	0.8	2.0	0.8	0.6	0.0	400
32.00	49.0	23.0	28.0	52.0	26.0	22.0	3.20	7.1				56.7	32.1	0.0	4.6	3.1	3.6	0.0	418
33.50	30.0	18.0	52.0	35.0	40.0	26.0	1.10	10.1				46.8	43.3	2.8	1.4	3.5	1.4	0.0	143
34.00	1.0	28.0	72.0	1.0	39.0	60.0	0.00	13.6											
35.00	1.0	34.0	65.0	1.0	45.0	54.0	0.00	18.4											
36.00	1.0	35.0	65.0	2.0	45.0	54.0	0.00	17.4											
37.00	5.0	37.0	58.0	7.0	44.0	49.0	0.00	18.5											
38.00	2.0	34.0	65.0	2.0	44.0	54.0	0.10	17.8											
39.50	1.0	31.0	67.0	3.0	41.0	56.0	0.00	13.5											
40.00	3.0	32.0	66.0	4.0	42.0	54.0	0.00	17.9											
41.00	2.0	33.0	65.0	4.0	42.0	54.0	0.00	14.5											

T18

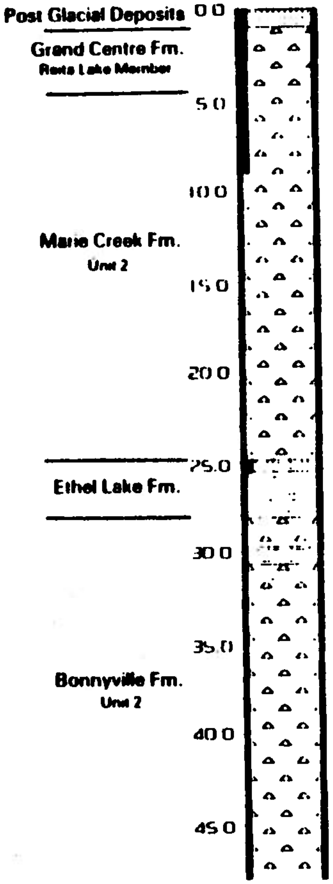
Alberta Geological Survey Testhole T 18
Location NE of LSD 9 Sec 18 Twp 61 Rng 3 W of 4 Mer . NTS 73L
Elevation 1825 Ft 556 M Source 1 50,000 NTS 73L/8
Date drilled 197607 18 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	32 0	25 0	41 0	36 0	28 0	37 0	1 60	13 2				70 7	22 4	1 0	3 9	2 4	0 5	0 0	205
2 00	33 0	24 0	43 0	37 0	27 0	36 0	1 40	17 9				74 7	21 4	0 6	1 1	1 7	0 6	0 0	182
3 00	34 0	25 0	41 0	37 0	28 0	35 0	1 78	14 7				73 3	24 0	0 9	0 9	1 3	0 0	0 0	225
4 00	34 0	26 0	40 0	37 0	30 0	33 0	1 71	15 1				70 6	23 4	1 7	1 7	2 6	0 0	0 0	235
5 00	32 0	26 0	42 0	36 0	30 0	35 0	1 30	14 7				71 1	21 4	1 6	1 1	0 5	2 2	0 0	187
6 00	37 0	26 0	37 0	42 0	28 0	31 0	1 78	13 2				75 7	18 5	0 9	1 4	2 7	0 9	0 0	222
7 00	41 0	26 0	33 0	45 0	28 0	27 0	1 94	12 1				72 1	20 5	0 4	2 0	3 9	1 2	0 0	254
9 00								17 2											
10 00								9 8											
11 00								26 6											
12 00								16 5											
13 00	20 0	48 0	32 0	22 0	55 0	23 0	1 54	13 4				56 9	23 1	0 5	3 1	14 9	1 0	0 0	195
14 00	13 0	55 0	32 0	15 0	61 0	22 0	0 70	16 2				74 7	14 7	0 0	6 7	2 7	1 3	0 0	75
15 00								15 6											
16 00	41 0	35 0	23 0	47 0	35 0	18 0	3 06	9 0				61 2	17 7	0 3	3 3	16 1	1 4	0 0	361
17 00	41 0	34 0	24 0	46 0	35 0	19 0	3 77	8 1				63 3	15 0	0 5	4 2	15 4	1 4	0 0	448
18 00	41 0	33 0	25 0	47 0	33 0	20 0	3 27	9 6				62 4	16 4	0 7	3 8	15 0	1 6	0 0	420
19 00	46 0	31 0	24 0	49 0	32 0	19 0	2 18	9 4				65 0	13 7	1 3	4 1	12 7	2 8	0 0	314
20 00	40 0	32 0	28 0	44 0	33 0	23 0	2 89	7 8				65 6	18 0	0 8	3 8	11 0	0 6	0 0	372
24 50	39 0	32 0	29 0	41 0	33 0	26 0	2 51	8 9				68 4	20 5	0 6	1 5	9 0	0 6	0 0	332
25 00	44 0	25 0	30 0	47 0	27 0	26 0	2 88	8 1				72 8	21 1	0 0	1 7	4 2	1 1	0 0	356
26 00	47 0	25 0	29 0	50 0	26 0	23 0	2 59	8 1				70 8	23 1	0 0	3 2	1 8	1 5	0 0	342
27 00	42 0	33 0	25 0	46 0	33 0	21 0	2 66	7 7				67 6	22 1	0 0	1 8	8 3	0 6	0 0	339
28 00	39 0	31 0	30 0	43 0	32 0	25 0	2 55	9 0				67 5	20 1	0 1	2 1	8 6	1 8	0 0	378
29 00	35 0	27 0	38 0	38 0	30 0	32 0	2 69	8 9				68 5	20 5	0 1	1 7	7 8	1 4	0 0	352
30 00	44 0	28 0	28 0	47 0	29 0	24 0	2 44	8 9				60 9	31 4	1 0	4 2	1 0	1 0	0 6	312
31 00	46 0	28 0	27 0	49 0	29 0	21 0	2 30	9 1				57 7	33 5	0 0	4 1	2 5	2 2	0 0	319
32 00	45 0	39 0	16 0	49 0	37 0	13 0	3 39	9 1				57 3	35 3	0 2	3 6	2 2	1 3	0 0	450
33 50	49 0	29 0	22 0	53 0	27 0	20 0	2 18	10 7				67 4	28 3	0 0	3 2	1 1	0 4	0 4	279
35 00	50 0	24 0	25 0	54 0	24 0	22 0	2 52	10 7				63 0	29 4	1 8	3 9	1 8	0 6	0 0	330
36 00	53 0	22 0	25 0	56 0	22 0	22 0	3 16	9 8				64 2	29 8	0 7	1 6	4 2	0 2	0 0	430

T19

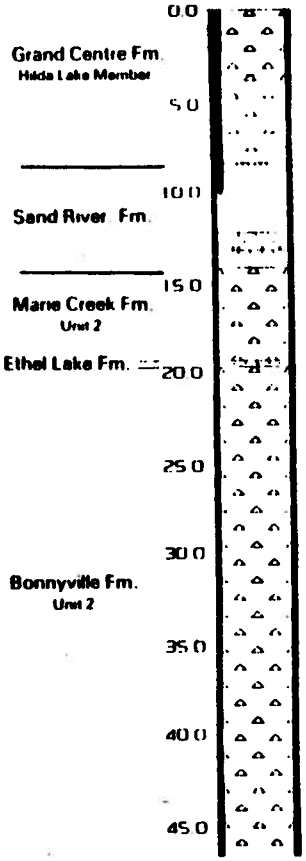
Alberta Geological Survey Testhole T 19
Location SW of LSD 16 Sec 10 Twp 64 Rng 2 W of 4 Mer . NTS 73L
Elevation 1875 Ft 572 M Source 1 50,000 NTS 73L/9
Date drilled 197608 07 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	IOC	OTH	N
1 00																			
2 00	41 0	25 0	34 0	45 0	27 0	29 0	1 63	13 9				70 2	24 0	0 9	0 0	0 0	4 9	0 0	225
3 00	39 0	27 0	35 0	41 0	29 0	28 0	1 45	15 9				70 4	25 2	0 0	0 5	2 4	0 5	0 0	206
4 00	35 0	25 0	41 0	39 0	28 0	34 0	1 45	16 9				66 0	28 1	1 6	0 0	3 2	0 5	0 0	185
5 00	41 0	31 0	27 0	47 0	32 0	21 0	3 31	12 9				58 5	20 8	0 2	4 3	14 6	1 7	0 0	419
6 00	41 0	31 0	28 0	45 0	32 0	23 0	2 60	11 4				56 7	22 5	0 8	3 9	13 2	2 8	0 0	356
7 00	49 0	27 0	24 0	53 0	27 0	20 0	3 31	9 6				61 1	27 7	0 2	4 1	4 5	2 4	0 0	419
8 00	50 0	27 0	23 0	54 0	28 0	18 0	3 61	9 9				59 3	28 6	0 7	6 4	3 1	1 8	0 2	455
9 00	51 0	27 0	22 0	55 0	29 0	16 0	3 37	10 0				61 7	25 6	0 5	4 7	4 0	1 6	0 0	430
10 00	51 0	28 0	21 0	55 0	30 0	15 0	3 29	10 2				56 9	31 9	0 3	4 2	4 7	2 0	0 0	404
11 00	49 0	29 0	22 0	53 0	31 0	16 0	3 43	9 8				58 0	30 3	0 5	3 4	5 8	1 8	0 2	445
12 00	58 0	25 0	17 0	62 0	26 0	12 0	3 17	10 0				58 1	30 3	0 5	5 0	4 3	1 6	0 0	442
13 00	46 0	29 0	24 0	49 0	33 0	17 0	3 47	10 4				70 0	24 9	0 0	0 7	3 7	0 4	0 2	437
14 00	46 0	29 0	26 0	49 0	33 0	18 0	3 15	10 5				58 6	27 0	0 5	5 1	5 6	3 1	0 3	396
15 00	46 0	29 0	26 0	50 0	30 0	20 0	2 66	9 9				64 2	28 1	0 5	2 4	3 6	1 2	0 0	416
16 00	47 0	27 0	26 0	51 0	29 0	21 0	3 86	10 6				64 5	26 0	0 4	2 9	3 3	2 6	0 4	273
17 00	46 0	27 0	27 0	50 0	28 0	22 0	2 06					64 9	27 1	0 4	2 0	3 3	2 4	0 0	458
18 00	48 0	29 0	23 0	51 0	30 0	19 0	3 55					73 0	21 9	0 4	2 6	1 7	0 2	0 2	466
19 00	48 0	27 0	25 0	52 0	28 0	20 0	4 11					73 3	22 7	0 2	1 4	1 6	0 8	0 0	506
20 00	48 0	25 0	27 0	51 0	27 0	22 0	3 98					70 6	24 5	0 2	1 9	1 9	1 2	0 0	531
21 00	46 0	28 0	26 0	50 0	29 0	21 0	3 00					67 6	27 3	0 3	1 9	2 4	0 6	0 0	370
24 00	47 0	26 0	27 0	51 0	27 0	22 0	3 42					71 8	22 2	0 0	3 7	1 2	1 1	0 0	432
28 00	51 0	28 0	21 0	55 0	29 0	16 0	3 16					51 6	41 6	1 7	1 7	2 2	0 2	0 9	411
29 00	48 0	29 0	24 0	51 0	31 0	18 0	3 30					47 7	44 8	0 2	4 3	2 5	0 4	0 0	438
30 50	49 0	28 0	24 0	52 0	28 0	19 0	2 89					51 3	39 7	0 8	3 5	1 6	2 8	0 2	491
31 00	46 0	29 0	26 0	49 0	32 0	19 0	2 80					49 1	43 9	1 0	2 1	1 0	1 1	0 8	383
32 00	45 0	30 0	25 0	49 0	32 0	19 0	3 09					51 0	41 5	0 5	1 2	1 5	2 1	0 2	414
33 00	47 0	29 0	25 0	51 0	31 0	19 0	2 57					49 2	44 9	1 7	1 1	2 0	0 9	0 3	352
34 00	46 0	29 0	24 0	50 0	32 0	18 0	3 07					52 1	40 3	2 4	1 7	1 0	1 9	0 5	409
35 00	45 0	31 0	24 0	49 0	32 0	19 0	3 39					50 0	40 6	1 6	4 3	1 8	1 5	0 0	418
36 00	48 0	28 0	23 0	52 0	30 0	18 0	3 08					51 5	44 4	0 9	1 6	0 9	0 7	0 0	437
37 00	51 0	21 0	26 0	55 0	25 0	21 0	3 02					56 8	37 6	0 5	2 1	1 2	1 7	0 2	426
38 00	47 0	28 0	25 0	51 0	30 0	20 0	2 77					51 8	42 8	1 3	1 6	1 8	0 6	0 3	388
39 00	45 0	29 0	26 0	49 0	32 0	19 0	2 84					52 1	40 9	1 1	1 9	0 5	2 2	1 3	374
40 00	49 0	27 0	24 0	53 0	29 0	19 0	2 39					45 0	46 2	0 7	1 9	1 2	5 1	0 0	416
42 00	46 0	31 0	24 0	49 0	32 0	19 0	2 76					56 6	39 2	0 8	1 4	0 8	0 8	0 3	362
43 00	49 0	29 0	22 0	53 0	30 0	17 0	3 15					57 2	36 1	1 5	2 4	1 2	1 5	0 0	407
44 00	51 0	28 0	22 0	54 0	29 0	17 0	3 11					49 5	42 7	2 1	0 9	1 4	3 0	0 2	426
46 00	52 0	27 0	21 0	55 0	28 0	17 0	3 14					62 6	33 2	0 9	1 1	0 7	1 4	0 0	419
47 00	52 0	28 0	20 0	56 0	28 0	16 0	3 41					55 6	38 1	0 8	1 6	1 0	2 2	0 6	491
48 00	52 0	29 0	20 0	56 0	29 0	15 0	2 89					49 3	41 5	1 0	1 5	1 0	1 1	0 8	398

T20

Alberta Geological Survey Testhole T 20
Location of LSD 1 Sec 26 Twp 61 Rng 5 W of 4 Mer. NTS 73L
Elevation 1985 FT 605 M Source 1:50,000 NTS 73L/10
Date drilled 197607 20 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC.	OTH	N
1.00								11.1											
2.00	24.1	26.4	49.5	27.0	28.1	44.9	0.88	14.7				65.6	12.1	2.3	0.0	0.0	0.0	0.0	131
3.00	24.1	20.6	55.1	27.1	25.4	47.5	0.97	17.3				71.5	23.6	1.4	0.0	0.0	1.4	0.0	140
4.00	24.4	24.5	51.1	27.0	30.3	42.7	0.87	16.4				71.2	22.3	0.0	1.8	1.8	0.0	1.8	112
5.00								18.9											
6.00								12.6											
7.00								20.8											
8.00								12.6											
15.00	49.6	27.2	23.2	54.9	26.1	18.7	2.87					56.3	11.4	0.0	3.7	6.4	2.2	0.0	373
16.00	51.7	27.3	21.0	55.7	27.7	16.7	2.91					62.8	26.7	0.0	4.1	5.3	1.0	0.0	393
17.00	49.3	29.0	21.7	59.4	28.1	12.5	2.56	10.3				58.6	28.0	0.9	3.8	6.7	2.0	0.0	343
18.00	49.7	27.1	23.3	51.4	29.7	16.9	2.89	9.4				59.4	31.6	0.6	3.3	3.3	1.4	0.0	361
19.00	47.6	27.6	21.8	52.7	29.6	17.7	2.57	9.9				61.6	30.6	0.6	3.4	2.6	0.6	0.3	349
20.00	41.7	28.8	29.5	45.1	33.9	21.0	2.71	10.6				64.9	28.7	0.0	2.8	3.1	0.6	0.0	359
21.00	44.3	26.1	29.7	48.7	29.6	21.7	2.60					62.2	31.3	0.0	4.9	1.3	0.3	0.0	370
22.00	45.5	25.9	28.6	48.9	30.7	20.5	3.00	10.4				67.3	27.5	0.0	0.8	2.9	1.1	0.3	382
23.00	44.4	25.4	30.3	48.7	28.2	23.1	2.49	10.3				63.4	32.0	0.0	3.8	0.6	0.3	0.0	344
24.00	44.3	26.8	28.9	48.4	29.8	21.8	2.52	9.2				67.0	28.9	0.0	1.7	1.7	0.6	0.0	349
25.00	48.1	22.1	29.7	51.5	25.0	23.5	2.20	9.6				57.0	34.7	0.0	4.0	2.3	1.6	0.0	300
26.00	44.7	26.0	29.3	48.7	28.6	22.6	2.79	10.0				65.6	29.2	0.0	2.2	1.9	1.1	0.0	363
27.00	46.4	25.2	28.4	49.5	27.9	22.6	2.94	9.2				68.6	26.6	0.0	2.6	1.6	0.6	0.0	379
28.00	44.6	26.2	29.1	48.6	28.8	22.6	2.73	11.0				67.0	27.2	0.0	3.4	1.3	1.0	0.0	379
29.00	44.3	23.6	32.1	47.4	27.5	25.1	2.62	9.8				61.1	31.0	0.3	3.5	2.3	0.9	0.3	339
30.00	44.9	21.0	33.1	48.9	27.4	23.8	2.70	9.8				68.1	27.4	0.1	1.1	2.2	0.3	0.3	357
31.00	45.9	24.1	29.9	49.1	27.2	23.8	2.81	9.6				64.6	28.9	0.0	2.6	2.3	1.2	0.3	342
32.00	45.0	25.2	29.8	49.1	27.7	23.2	3.01	8.0				68.4	27.4	0.5	1.7	1.5	0.4	0.0	402
33.50	46.0	23.5	30.5	49.0	26.8	24.2	2.63	8.8				62.7	33.2	0.0	2.2	0.8	0.8	0.3	370
34.00	44.6	25.4	30.0	48.5	28.5	22.9	2.90	8.5				63.3	31.0	0.2	1.5	3.1	0.6	0.0	387
35.00	45.6	23.9	30.5	48.8	27.2	24.1	2.79					67.0	28.4	0.3	2.3	1.1	0.9	0.0	352
36.00	45.1	25.8	29.0	49.3	27.0	23.7	2.98	8.7				66.5	30.0	0.0	0.8	1.1	1.3	0.0	371
37.00	45.2	23.4	31.3	48.9	26.1	25.0	2.81	9.0				68.4	25.1	0.5	3.2	1.6	0.8	0.0	370
38.00	44.8	24.0	31.2	49.0	27.1	23.7	2.61	9.4				61.8	31.6	0.3	1.5	1.5	0.6	0.3	327
39.50	45.9	23.5	30.6	49.2	26.3	24.4	3.02	9.1				61.5	30.2	0.1	1.8	2.4	1.6	0.0	381
40.00	44.4	24.9	30.7	48.8	27.0	24.1	3.04	9.1				64.9	28.5	0.2	4.3	1.5	0.5	0.0	393
41.00	45.0	22.6	32.3	48.3	26.5	25.2	2.81	8.8				70.2	24.2	0.5	3.6	0.8	0.5	0.0	363
42.50	44.3	21.7	30.9	48.5	26.7	24.9	2.93	9.7				66.5	28.8	0.2	1.2	1.5	1.6	0.0	406
43.00	45.6	22.8	31.6	48.9	25.2	25.8	3.01					66.2	28.1	0.2	2.2	2.0	1.0	0.0	406
44.00	44.8	24.5	30.8	49.2	27.2	23.6	2.83	9.1				71.1	25.5	0.0	1.1	1.1	0.4	0.2	388
45.00	46.5	23.3	30.1	49.9	25.7	24.4	3.30	9.4				65.1	29.4	0.0	2.6	1.7	0.9	0.0	415
47.00	44.5	24.0	31.6	48.7	27.0	24.4	3.15	9.0				66.4	29.8	0.0	1.2	1.7	0.6	0.0	402

T21

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Alberta Geological Survey Testhole   T 21
Location      of LSD  4 Sec 13 Twp  64 Rng  5 W of 4 Mer  ,  NTS  73L
Elevation   1825 ft     556 M   Source  1:50,000 NTS 73L/10
Date drilled     197607 26  Logged by  M  FENTON

                       TEXTURE (%)                      MATRIX CARBONATE          COARSE SAND LITHOLOGY (%)
 DEPTH  SAND SILT CLAY  SAND SILT CLAY VC SD   H2O    CO2  CAL CA/DO    IGN   QTZ  QTZT  LST  DST  LOC  OTH    N
  (M) >62.5um     <4um  <50um     <2um 1-2mm   (%)   (cc)  (%)          METM        OSS
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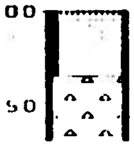
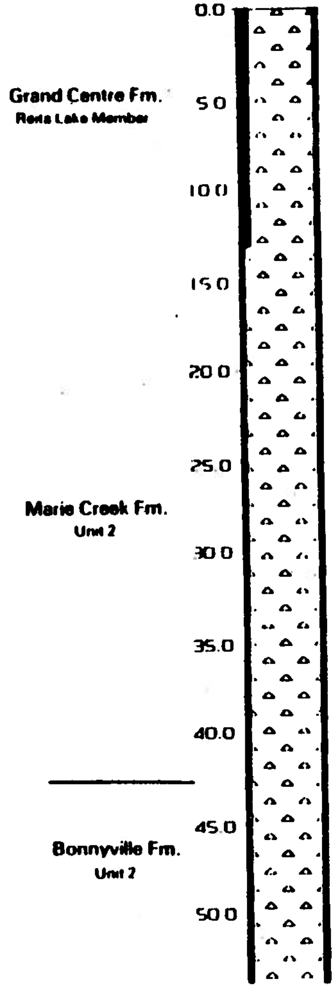


T22

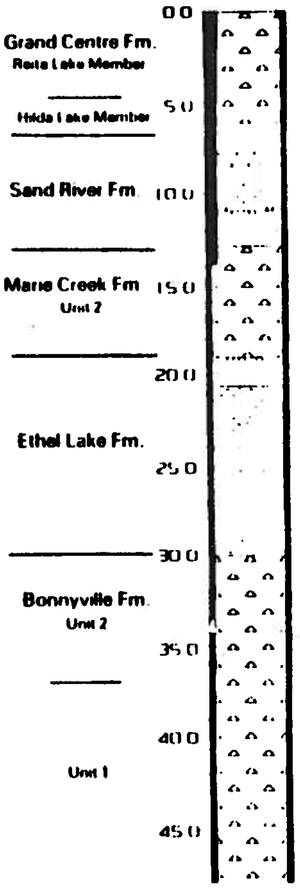
Alberta Geological Survey Testhole T 22
Location of LSD 7 Sec 19 Twp 65 Rng 5 W of 4 Mer , NTS 73L
Elevation 2125 Ft 648 M Source 1 50,000 NTS 73L/10
Date drilled 197607 27 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	41 2	23 6	35 1	45 5	25 3	29 2	1 50	13 9				72 1	21 9	3 0	0 0	0 5	2 0	0 5	201
2 00	40 6	28 7	30 7	44 9	30 4	24 7	1 66	12 4				62 4	26 8	3 0	2 0	5 4	0 5	0 0	205
3 00	38 2	29 1	32 7	43 0	29 8	27 3	1 61	13 2				68 7	24 0	1 7	1 7	3 4	0 6	0 0	179
4 00	40 6	29 0	30 4	45 3	30 3	24 4	1 44	11 9				70 0	20 4	3 2	3 8	2 2	0 5	0 0	186
5 00	49 8	18 0	32 2	51 2	21 9	26 9	2 11	12 7				70 6	20 8	1 3	1 7	5 0	0 4	0 4	238
6 00	38 8	28 8	32 4	42 8	30 7	26 5	1 65	12 8				74 8	18 3	0 5	2 0	4 5	0 0	0 0	202
7 00	39 5	26 2	34 3	43 4	28 7	27 9	2 50	12 8				71 9	20 2	0 3	0 9	6 1	0 0	0 6	327
8 00	45 8	26 7	27 5	49 9	28 2	21 9	3 87	10 0				78 3	16 6	0 8	0 6	3 4	0 2	0 0	494
9 00	39 9	26 6	33 5	44 3	28 1	27 6	2 80	10 4				71 5	20 8	0 8	2 2	3 6	1 1	0 0	361
10 00	44 2	25 7	30 0	48 1	28 2	23 6	3 28	10 3				81 8	14 0	0 2	1 0	1 5	1 5	0 0	406
11 00	45 3	24 8	29 9	49 6	25 5	25 0	3 56	9 5				73 3	23 4	0 4	0 9	1 8	0 2	0 0	457
12 00	41 1	26 3	32 6	44 5	29 5	26 0	2 72	10 0				71 0	21 5	0 9	1 2	3 6	1 5	0 3	335
13 00	39 9	20 2	39 9	43 8	25 1	31 0	2 59	10 2				72 3	20 1	0 3	2 7	3 6	0 6	0 3	329
14 00	41 5	28 5	30 0	45 1	32 2	22 7	2 75	9 8				70 3	18 9	0 6	2 8	6 4	1 1	0 0	360
15 00	42 3	26 1	31 6	45 8	28 9	25 3	2 75	10 0				75 2	18 7	0 6	1 4	4 0	0 0	0 0	347
16 00	42 7	26 8	30 4	46 2	31 2	22 6	2 81	10 1				68 6	22 2	1 1	2 4	5 4	0 3	0 0	369
17 00	40 9	27 2	32 0	43 4	33 2	23 4	2 56	10 4				68 7	25 4	0 0	0 9	4 5	0 6	0 0	335
18 00	41 7	25 6	32 8	45 4	30 6	24 0	2 77	10 1				71 8	20 4	0 0	2 2	4 1	0 8	0 3	362
19 00	30 4	32 8	36 8	30 9	41 6	27 5	0 13	11 9				70 5	23 0	0 0	0 0	4 9	0 0	1 6	61
20 00	44 0	26 0	30 0	47 9	29 8	22 3	3 08	10 2				70 6	20 8	0 0	3 9	3 7	0 7	0 2	408
21 00	46 6	25 7	27 7	49 1	29 5	21 5	4 07	10 1				60 2	29 5	0 6	1 9	7 0	1 1	0 0	359
22 00								12 0											
23 00	51 1	24 4	24 5	53 7	27 6	18 7	1 46	10 2				66 5	27 8	1 2	0 4	3 7	0 4	0 0	514
24 00								10 3											
25 00	50 7	23 2	26 1	52 7	27 3	20 0	5 66	9 4				64 9	21 9	0 0	3 9	2 9	1 0	5 5	416
26 00								9 8											
27 00	56 8	26 7	16 5	59 8	27 8	12 4	5 82	10 1				61 8	29 7	0 4	3 9	2 4	1 1	0 9	464
28 00								9 5											
29 00	53 5	27 8	18 6	56 6	30 0	13 4	3 56	9 9				62 9	27 1	0 0	1 0	1 6	1 3	1 0	310
30 00								9 7											
31 00	54 3	29 8	16 0	57 4	31 1	11 5	4 96	10 0				62 3	30 6	0 3	2 5	1 8	2 5	0 0	284
32 00								11 6											
33 00	53 7	28 9	17 4	56 5	30 8	12 7	3 81	10 1				53 6	35 5	0 3	4 2	4 2	2 2	0 3	358
34 00								10 3											
35 00	49 0	26 5	24 5	51 7	29 5	18 9	2 93	9 4				51 5	41 6	0 4	2 1	4 0	0 4	0 0	478
36 00								10 8											
37 00	56 2	24 3	19 5	59 1	26 7	14 2	3 37	10 1				53 2	39 6	0 0	4 0	2 6	0 6	0 3	346
38 00	55 6	25 3	19 2	58 3	27 7	14 0	3 10	10 0											
39 00	54 2	27 1	18 7	57 0	28 7	14 3	3 66	9 6				53 7	38 3	0 2	3 0	3 5	1 2	0 2	426
40 00	57 4	24 7	17 8	60 1	26 5	13 3	2 20	10 1											
41 00	58 6	25 3	16 1	61 4	25 2	13 4	3 34					51 6	47 3	1 3	2 1	0 0	0 3	0 0	374
42 00								12 7											
43 00								12 7				54 5	41 8	0 0	2 0	0 5	1 5	0 0	407
44 00								9 4											
45 00								10 6				60 5	40 1	0 9	1 2	0 3	1 2	0 0	332
46 00								9 5											
48 00	40 4	29 1	30 5	43 1	33 4	23 5	2 60	10 3				48 8	34 8	0 0	1 2	8 3	6 8	0 0	316
49 00	40 6	27 1	32 3	43 4	33 8	23 8	2 47	11 3				45 4	41 8	0 0	5 1	3 6	4 0	0 0	275
50 00	43 4	27 7	28 9	46 1	32 9	21 0	2 68	10 6				41 2	43 8	0 6	3 9	5 1	3 6	0 3	333
51 00	41 1	28 7	28 2	46 1	33 0	20 9	2 70	10 1											
52 00	41 7	26 5	29 8	46 5	31 1	22 4	2 91	10 2				51 6	41 7	1 1	1 9	1 6	0 9	0 0	316
53 00	36 5	17 0	26 5	40 0	41 1	18 6	1 66	12 1											
54 00	40 1	32 8	27 1	42 9	37 7	19 4	1 78	11 5											

T23

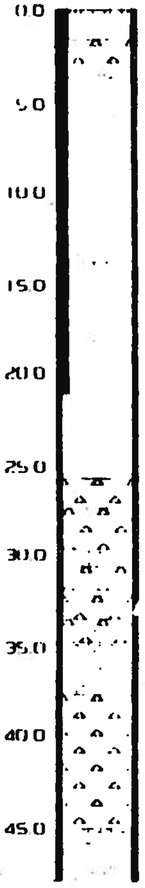
Alberta Geological Survey Testhole T 21
Location of LSD 15 Sec 22 Twp 61 Rng 6 W of 4 Mer . NTS 73L
Elevation 2000 Ft 610 M Source 1 50,000 NTS 73L/10
Date drilled 197607 27 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	COT (%)	CA/DO	IGN MET M	QTZ	QTZT OSS	LST	DST	COC	OTH	N
1 00	40 1	27 0	32 8	42 9	29 7	27 4	1 64	10 6				61 5	30 7	0 0	2 7	4 6	0 4	0 0	218
2 00	41 2	27 2	31 6	44 7	30 2	25 2	1 90	9 8				64 6	29 9	0 4	2 0	2 7	0 4	0 0	254
3 00	40 4	27 1	32 6	43 0	30 3	26 6	1 55	11 4				63 7	30 0	1 5	2 1	1 5	1 0	0 0	193
4 00	27 2	36 0	36 8	31 6	37 9	30 5	1 00	14 0				66 2	26 2	1 4	2 1	1 4	2 8	0 0	145
5 00								15 1											
6 00								15 5											
12 00								12 7											
13 00	48 8	31 4	19 8	52 6	32 7	14 7	2 56	10 5				55 8	31 7	0 0	3 6	8 2	0 3	0 0	328
14 00	49 1	29 4	21 4	54 0	30 6	15 4	2 98	10 9				53 1	33 5	0 5	3 4	7 5	1 1	0 0	388
15 00	44 9	27 1	28 0	47 7	29 8	22 5	2 14	11 8				57 3	35 2	0 9	3 6	1 9	0 6	0 0	307
16 00	38 5	30 5	31 0	41 8	37 3	20 9	2 52	12 2				58 0	34 0	0 1	2 4	3 9	1 2	0 0	329
17 00	36 5	28 9	34 6	38 8	34 6	26 5	1 91	12 2				52 9	37 9	0 8	3 8	3 1	1 5	0 0	261
18 00	35 4	29 6	35 0	38 0	34 9	27 2	2 22	11 4				55 6	36 9	0 3	4 4	2 0	0 6	0 0	295
21 00								16 0											
24 00								17 0											
25 00								15 1											
26 00								13 6											
27 00								17 1											
28 00								17 2											
29 00								15 2											
30 00	47 4	24 5	28 1	45 2	33 1	21 5	2 71	12 1				51 4	38 3	0 3	5 4	3 4	0 9	0 0	352
31 00	54 3	21 5	24 2	57 4	24 3	18 1	1 58	10 3				48 7	40 7	0 2	4 6	2 5	2 7	0 0	476
32 00	46 9	23 8	29 3	50 7	27 1	22 1	2 61	9 5				44 3	46 6	0 0	4 5	2 5	1 8	0 0	352
33 50	50 8	21 8	27 5	51 6	25 2	23 2	2 68	10 2				50 8	40 7	0 0	4 3	3 4	0 9	0 0	354
34 00	47 2	23 2	29 7	51 1	26 3	22 5	2 22	9 6				50 2	43 2	0 3	1 6	3 1	1 3	0 0	301
35 00	47 6	22 4	29 9	50 5	26 6	22 9	2 36	9 2				54 5	37 6	0 6	2 1	2 4	2 4	0 0	332
36 00	47 4	22 5	30 1	51 2	25 4	23 4	2 66	10 2				53 1	35 6	0 3	6 6	1 9	1 9	0 3	365
37 00	35 4	23 8	40 8	38 1	30 2	31 7	1 66	8 3				60 8	35 8	0 4	1 3	0 4	1 2	0 0	212
38 00	29 2	22 9	48 0	32 6	30 7	36 7	1 25	12 0				65 9	33 0	0 0	0 5	0 5	0 0	0 0	179
39 50	30 2	27 8	42 0	32 7	36 6	30 7	1 78	11 3				59 4	35 1	0 0	4 6	0 8	0 0	0 0	239
40 00	29 3	28 1	42 7	32 9	36 2	30 9	1 64	11 5				64 9	32 2	0 0	1 4	1 4	0 0	0 0	214
41 00	26 7	27 9	45 4	29 2	38 1	32 7	1 27	10 1				60 5	33 7	1 2	2 3	1 7	0 6	0 0	172
42 00	28 9	28 1	43 0	32 4	36 4	31 2	1 45	10 0				71 2	21 6	1 0	1 0	1 0	1 0	0 0	191
43 00	28 4	29 1	42 4	31 0	37 7	31 2	1 18	11 1				57 1	37 2	1 2	1 0	0 0	1 2	0 0	164
44 00	28 0	26 6	45 5	31 6	35 0	33 4	1 16	11 1				53 6	42 8	0 5	1 0	0 0	2 0	0 0	194
46 00	31 1	26 9	42 0	33 8	36 0	30 2	1 15	11 2				61 0	33 7	1 6	1 6	0 5	0 5	0 0	187
47 00	30 2	28 1	41 7	33 9	35 3	30 8	1 55	10 6				53 1	42 6	0 5	2 1	0 9	0 5	0 0	209
48 00	29 4	26 5	44 2	32 0	35 5	32 5	1 07	11 0				63 0	34 8	0 7	1 1	0 0	0 0	0 0	138

T24

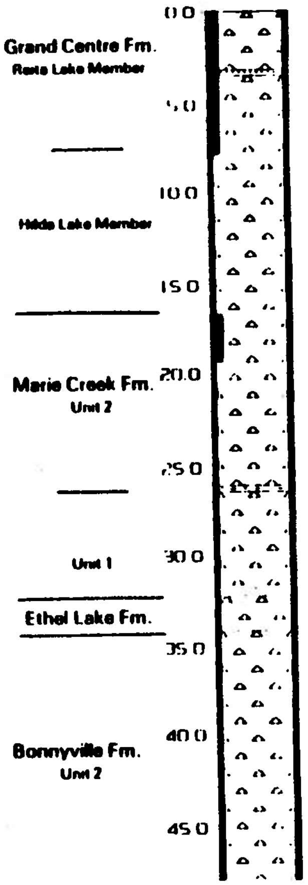
Alberta Geological Survey Testhole 1 21
Location of LSD 14 Sec 11 Twp 62 Rng 7 W of 4 Mer . NTS 73L
Elevation 1840 Ft 561 M Source 1 50,000 NTS 73L/7
Date drilled 197607 29 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC 1	SD 2mm	H2O (%)	CO2 (cc)	CDT (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00																				
2 00									12 6											
3 00									10 8											
14 00									20 6											
26 00									9 6											
27 00									10 5											
28 00									11 6											
29 00									9 2											
30 00									12 1											
32 00									10 2											
38 00									11 0											
39 50									9 8											
40 00									9 1											
41 00									14 6											
42 50									10 3											
44 00									8 0											
46 00									17 1											
47 00									16 6											
48 00									15 9											

T25

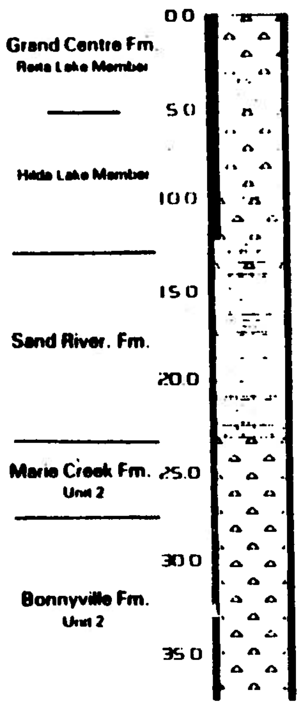
Alberta Geological Survey Testhole T 25
Location of LSD 4 Sec 24 Twp 62 Rng 6 W of 4 Mer . NTS 73L
Elevation 1820 Ft 555 M Source 1 50,000 NTS 73L/7
Date drilled 197607 30 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	46 5	22 0	31 5	50 1	22 4	27 5	1 28	11 7	7 3	3 1	1 23	69 9	26 6	3 5	0 0	0 0	0 4	0 0	229
2 00	43 8	20 2	35 9	46 5	22 6	30 9	1 82	12 8	27 7	10 0	0 33								
3 00	36 0	27 2	36 8	38 9	30 6	30 4	1 58	14 5	26 5	11 1	0 30	71 1	24 5	1 2	0 8	2 4	0 4	0 0	253
4 00	37 3	27 6	35 1	41 7	29 6	28 6	1 89	10 9	25 3	10 7	0 40								
5 00	41 0	26 6	32 5	44 2	29 3	26 5	1 81	9 8	24 6	10 3	0 27	64 4	30 0	2 2	2 2	0 9	0 0	0 0	223
6 00	38 4	24 7	36 9	43 0	23 6	33 4	1 68	10 8				65 9	31 3	0 0	1 6	1 1	0 0	0 0	182
7 00	38 6	26 9	34 5	41 9	29 3	28 8	1 38	10 6	25 8	10 8	0 20								
8 00	32 3	29 9	37 8	37 3	33 0	29 8	1 38	12 2	25 9	10 8	0 19	67 9	27 7	1 9	1 2	1 2	0 0	0 0	159
9 00	31 0	29 7	39 3	35 7	32 9	31 4	1 18	12 2	30 8	12 9	0 23								
10 00	25 7	51 2	23 1	28 1	46 5	25 3	0 94	12 9	34 3	14 4	0 24	61 0	32 6	1 0	1 0	3 1	1 0	0 0	95
11 00	27 3	32 0	40 7	30 7	38 0	31 3	0 76	11 3	32 3	11 5	0 23								
12 00	28 8	30 2	41 0	31 4	37 3	31 3	0 85	12 1	29 8	12 5	0 27	69 4	24 0	4 1	0 8	0 8	0 8	0 0	121
13 00	28 5	30 1	41 4	31 6	36 3	32 1	0 84	11 9	33 0	11 7	0 19								
14 00	27 7	32 3	40 1	30 8	38 2	31 0	0 70	11 3	29 9	12 5	0 29	63 4	21 5	7 5	4 3	3 2	0 0	0 0	93
15 00	28 2	29 9	41 8	30 5	37 2	32 3	0 77	11 7	21 8	9 1	0 27	66 2	25 6	0 6	1 2	5 0	0 6	0 0	160
16 00	31 2	32 6	36 3	34 8	36 0	29 2	1 21	11 3	29 3	12 3	0 34								
17 00	40 4	31 5	28 1	43 6	32 5	23 9	2 78	9 1	50 2	20 8	0 11	56 3	21 9	0 0	4 8	15 7	1 0	0 0	311
18 00	38 0	34 2	27 7	42 3	34 9	22 8	2 26	9 8	50 1	30 8	0 16								
19 00	42 1	33 6	24 3	45 6	34 9	19 5	2 65	9 6	39 7	21 6	0 16	59 5	23 1	0 6	4 9	11 6	0 0	0 0	363
20 00	40 6	35 7	23 6	45 2	35 9	18 9	2 79	9 6	48 6	20 2	0 14								
21 00	42 5	33 0	24 5	45 6	36 8	17 6	2 96	9 6	47 9	19 9	0 16	57 8	24 2	0 0	2 6	14 7	0 6	0 0	339
22 00	39 6	38 9	21 5	43 8	34 7	21 5	2 55	8 6	46 8	19 4	0 12								
23 00	45 8	32 4	21 9	49 5	33 6	16 9	3 08	8 6	49 8	20 7	0 17	55 4	28 2	0 3	2 4	13 6	0 0	0 0	330
24 00	38 9	36 8	24 2	43 2	38 0	18 8	2 65	8 2	44 4	18 4	0 13								
25 00	37 9	33 2	28 9	42 1	64 4	22 3	2 45	8 1	42 8	17 8	0 15								
26 00												64 7	29 4	0 3	3 1	2 5	0 0	0 0	323
27 00	38 5	28 6	33 0	41 1	29 9	29 0	2 41	10 2	34 4	14 4	0 20	64 0	28 6	0 0	2 0	4 1	1 2	0 0	342
28 00	35 7	28 0	36 3	39 0	31 3	29 7	2 61	10 6	35 1	14 6	0 18								
29 00	35 9	27 5	36 6	39 0	30 6	30 4	2 13	10 2	29 7	12 4	0 18	61 4	28 1	0 0	1 4	8 8	0 3	0 0	285
30 00	35 9	28 9	35 2	39 2	31 4	29 4	2 19		32 0	13 4	0 23								
31 00	32 5	26 0	41 5	35 7	28 7	35 6	2 52		29 9	12 5	0 25	59 4	33 1	0 3	0 3	5 5	1 3	0 0	308
32 00	37 3	30 5	32 1	40 1	33 6	26 3	2 32		31 0	12 9	0 22								
33 50	55 4	21 8	22 9	58 8	23 6	17 6	3 55	10 0	24 1	10 1	0 36								
34 00	70 4	16 4	13 2	72 9	16 7	10 4	5 14		27 9	11 7	0 30	55 3	36 2	0 0	3 5	4 5	0 2	0 2	425
35 00	61 4	23 7	14 8	65 5	22 9	11 6	5 37	9 8	32 4	13 6	0 36								
36 00	62 0	21 5	16 5	65 0	21 9	13 1	3 91	8 9	24 9	10 4	0 20	53 7	37 7	0 2	3 6	3 8	0 9	0 2	557
37 00	59 1	23 6	17 3	63 1	23 3	13 6	4 45		25 1	10 5	0 20								
38 00	65 0	21 4	13 6	68 0	21 2	10 8	3 77	11 1	23 0	9 6	0 19								
39 50								11 5	24 5	10 2	0 21								
40 00									29 4	12 3	0 23								
41 00									33 2	13 9	0 24								
42 50									30 6	12 8	0 23								
43 00								11 1	29 4	12 3	0 24								
44 00								11 4	27 7	11 6	0 24								
46 00	53 7	23 8	22 5	57 7	24 2	18 1	2 45	8 9	30 5	12 8	0 35								
47 00	56 6	24 7	18 7	59 3	26 6	14 1	3 27	8 3	31 7	13 3	0 25								
48 00	57 2	26 0	16 8	60 8	26 1	13 1	2 96	8 6	30 9	12 9	0 27								

T27

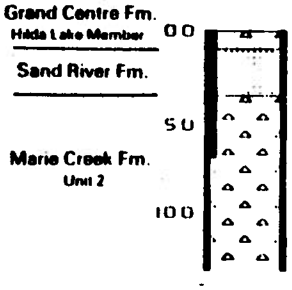
Alberta Geological Survey Testhole T 27
Location of LSD 4 Sec 6 Twp 64 Rng 3 W of 4 Mer , NTS 73L
Elevation 1830 Ft 558 M Source 1 50,000 NTS 73L/9
Date drilled 197607 31 Logged by P WATERS



DEPTH (M)	TEXTURE (%) SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	39 7	27 0	33 3	43 1	29 4	27 5	1 38	12 6				69 0	25 5	1 3	2 9	1 1	0 3	0 0	377
2 00	35 6	29 6	34 9	39 2	31 5	29 3	1 27	12 7				70 4	20 7	2 0	3 3	2 8	0 9	0 0	362
3 00	32 8	27 8	39 4	36 1	30 3	33 5	1 41	13 8				61 4	30 3	2 6	1 6	3 1	1 1	0 0	386
6 00	27 2	34 2	38 6	31 3	36 5	32 2	0 80	14 8				70 9	24 5	0 9	0 9	1 7	0 4	0 0	234
7 00	27 3	33 9	38 7	32 2	35 5	32 3	0 84	14 5				71 2	25 0	1 4	1 4	0 5	0 5	0 0	212
8 00	28 4	31 6	40 0	32 0	34 0	33 9	0 98	14 9				66 7	24 9	2 5	2 5	1 8	0 4	0 0	285
9 00	28 8	28 7	42 5	31 9	33 0	35 1	0 98	14 9				69 9	25 3	1 6	0 8	1 6	0 8	0 0	249
10 00	20 7	39 2	40 2	24 7	41 0	34 3	0 97	16 4				76 8	20 5	0 9	0 0	1 4	0 5	0 0	220
11 00	28 1	30 8	41 1	31 4	34 3	34 3	1 11	15 5				72 8	21 4	2 4	1 5	1 0	1 0	0 0	206
12 00	40 8	33 4	25 8	46 0	32 9	21 1	2 23	13 7				71 8	21 5	0 5	1 8	3 3	1 1	0 0	571
14 00	38 9	27 9	33 2	43 4	29 4	27 2	1 95	12 1				70 7	23 9	1 0	1 8	1 9	0 8	0 0	515
16 00								18 5											
17 00								18 6											
18 00								20 9											
19 00								20 4											
21 00								19 1											
22 00								17 7											
24 00	40 7	33 5	25 8	44 4	35 6	20 0	2 88	9 1				64 2	18 9	1 0	2 8	12 8	0 4	0 0	721
25 00	38 2	33 6	28 1	41 8	35 7	22 5	2 45	8 8				63 4	23 6	0 0	3 1	9 1	0 9	0 0	352
26 00	40 5	31 3	28 2	44 0	33 3	22 7	2 64	8 5				66 4	21 2	0 6	3 2	8 7	0 0	0 0	315
27 00	43 2	30 7	26 1	46 8	31 8	21 4	3 11					65 8	23 0	0 6	1 4	8 4	0 3	0 0	357
28 00	51 7	27 0	21 3	55 4	27 8	16 8	3 55					59 2	29 0	0 0	4 3	7 5	0 0	0 0	255
30 00	48 1	28 1	23 8	51 9	30 0	18 1	3 12	8 6				62 8	27 6	0 6	3 8	4 6	1 2	0 0	521
31 50	47 1	28 9	24 0	50 8	30 6	18 5	3 09	9 1				62 3	28 1	0 4	4 1	2 5	3 0	0 0	517
32 00	48 4	27 5	24 1	52 2	29 5	18 4	3 19	8 4				53 1	34 8	0 0	6 4	3 9	2 0	0 0	546
33 50	48 5	27 7	23 8	52 2	29 9	17 9	3 15	8 3				59 0	30 3	0 6	4 0	2 5	3 5	0 0	476
34 00	46 1	27 5	26 4	49 8	29 8	20 4	3 01					63 3	28 1	0 3	3 3	2 4	2 4	0 0	335

T28

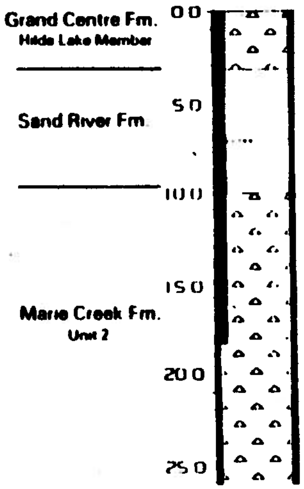
Alberta Geological Survey Testhole T 28
Location of LSD 9 Sec 34 Twp 63 Rng 2 W of 4 Mer . NTS 73L
Elevation 1850 FT 564 M Source 1 50,000 NTS 73L/8
Date drilled 197608 02 Logged by P WATERS



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
4 00	40 8	31 8	27 5	44 4	31 7	23 8	2 75	9 2				59 1	19 1	0 3	4 4	15 2	2 0	0 0	362
5 00	38 8	31 1	30 0	42 9	31 6	25 5	2 47	9 8				62 9	14 6	0 3	3 1	18 3	0 9	0 0	323
6 00	46 0	26 2	27 7	49 6	26 0	24 4	2 98	9 2				63 5	24 6	0 5	2 1	7 5	1 7	0 0	386
7 00	17 6	30 2	52 2	19 3	42 1	38 6	1 21	18 2				71 2	21 2	0 5	2 7	3 8	0 5	0 0	184
8 00								15 7											
9 00	42 7	25 6	31 7	46 2	29 0	24 7	2 76	10 8				59 0	26 3	0 9	4 9	4 6	4 1	0 0	346
10 00	44 2	26 2	29 6	48 1	29 1	22 8	2 95	9 5				60 0	28 5	0 3	3 8	4 5	2 6	0 0	397
11 00	44 5	28 9	26 6	48 4	31 4	20 3	3 25	9 7				62 8	26 1	0 2	5 1	3 3	2 8	0 0	449
12 00	47 6	28 0	24 4	51 3	29 9	18 8	3 39	9 4				67 1	23 2	0 9	4 2	2 7	1 8	0 0	453
13 00	46 9	29 5	23 6	51 1	31 0	17 9	3 87	9 2				63 6	25 8	0 4	4 7	2 4	3 0	0 0	450

T29

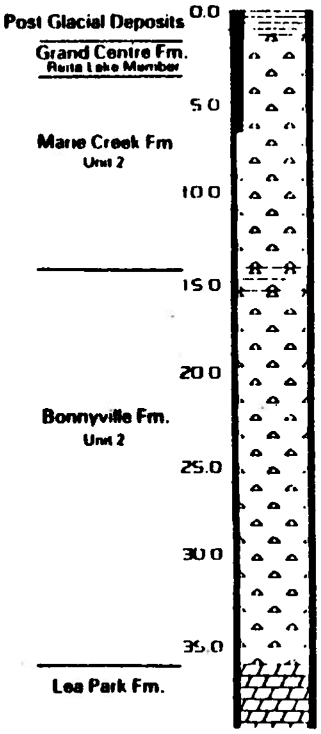
Alberta Geological Survey Testhole T 29
Location of LSD 9 Sec 34 Twp 63 Rng 2 W of 4 Mer , NTS 73L
Elevation 1825 Ft 556 M Source 1 50,000 NTS 73L/8
Date drilled 197608 03 Logged by P WATERS



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET M	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	21 0	25 4	53 7	23 1	29 8	47 1	1 07	13 5				61 6	25 9	1 4	2 7	4 1	1 4	0 0	147
2 00	12 3	30 5	57 1	14 4	36 3	49 3	0 52	17 6				63 6	28 6	0 0	2 6	2 6	2 6	0 0	77
3 00	32 9	23 6	43 5	35 7	25 1	39 0	1 56	12 7				69 9	23 8	0 0	1 5	1 9	1 9	0 0	206
10 00	40 5	30 7	28 9	44 5	30 8	24 7	2 95					62 5	20 5	0 9	5 1	10 5	0 6	0 0	352
11 00	39 7	32 1	28 2	43 7	32 1	24 2	3 07	10 9				55 4	23 8	0 5	4 2	14 3	1 9	0 0	379
12 00	39 7	31 2	29 1	43 3	32 3	24 4	2 66	9 6				58 0	18 5	1 7	3 1	16 5	2 3	0 0	352
13 00	39 6	31 1	29 3	43 7	31 8	24 5	3 01	10 4				54 2	20 4	0 8	5 0	16 4	3 2	0 0	378
14 00	39 8	30 0	30 2	43 5	31 3	25 3	2 59	9 9				56 5	20 9	1 8	4 5	15 4	0 9	0 0	331
15 00	43 8	26 9	29 3	47 7	27 8	24 5	2 74	10 0				62 8	25 9	0 9	3 8	5 5	1 2	0 0	344
16 00	46 9	22 5	30 6	50 6	23 8	25 6	3 29	9 1				65 6	21 7	2 2	3 1	6 0	1 4	0 0	419
17 00	43 4	24 8	31 8	47 4	25 9	26 7	2 92	9 5				58 4	31 6	0 5	2 7	5 4	1 4	0 0	370
18 00	40 6	25 3	34 1	43 9	30 1	26 0	2 56	10 1				60 2	26 9	0 0	4 3	3 7	4 3	0 0	327
19 00	44 7	25 9	29 4	42 7	29 0	22 2	1 01	8 7				56 6	30 6	0 8	4 9	5 1	2 1	0 0	392
20 00	45 3	26 5	28 2	48 9	28 0	23 1	3 14	9 2				60 4	26 3	0 7	3 8	3 6	4 7	0 0	419
21 00	53 4	24 4	22 3	57 1	26 7	16 2	7 49	8 9				59 4	28 4	0 2	4 5	4 8	2 1	0 0	419
22 00	48 4	27 9	23 8	52 2	30 3	17 5	3 74	10 3				60 2	26 7	1 6	5 7	3 7	2 2	0 0	510
23 00	47 4	29 2	23 4	51 5	31 6	16 9	3 76	9 7				62 0	27 8	0 4	4 1	3 7	1 7	0 0	460
24 00	47 6	28 2	24 2	51 5	30 5	18 0	3 45	9 8				64 0	28 4	0 7	1 7	3 0	1 9	0 0	461
25 00	46 9	29 2	24 0	50 8	32 6	16 6	3 24	10 3				63 3	26 5	1 0	4 6	3 4	0 9	0 0	411
26 00	47 1	29 2	23 8	50 9	31 7	17 4	3 68	11 7				59 6	27 6	0 4	5 0	3 3	4 1	0 0	485

T30

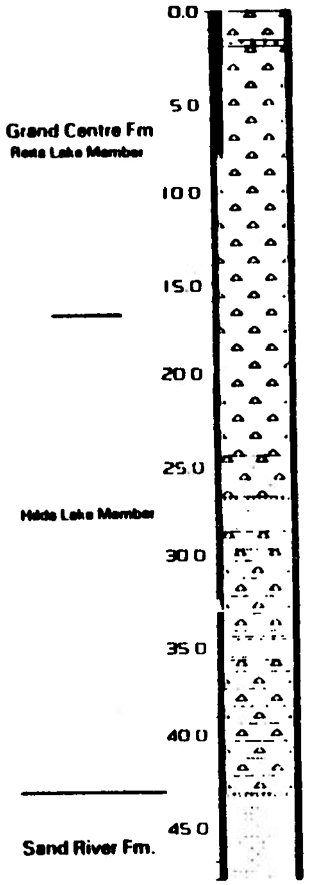
Alberta Geological Survey Testhole T 30
Location of LSD 13 Sec 4 Twp 62 Rng 1 W of 4 Mer . NTS 73L
Elevation 1775 Ft 541 M Source 1 50,000 NTS 73L/8
Date drilled 197608 04 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00																			
2 00	35 0	25 4	39 5	37 2	28 5	34 3	1 71	12 5	28 0	11 8	0 36	68 6	23 8	2 7	2 2	1 8	1 8	0 0	223
3 00	38 9	21 7	39 5	47 0	24 2	33 8	3 27	14 8				75 0	19 8	1 1	0 8	3 0	0 4	0 0	268
4 00	46 9	32 3	20 8	51 3	31 8	17 0	2 78	8 7	46 9	19 6	0 19	61 1	19 8	0 0	5 9	12 3	0 8	0 0	373
5 00	40 5	32 5	27 0	44 2	31 9	22 0	3 04	8 4				62 0	19 4	0 3	2 6	11 0	7 5	0 0	382
6 00	38 6	31 7	29 7	42 1	34 3	23 5	2 56	9 3	36 4	15 2	0 20	64 9	22 7	1 2	2 4	7 6	1 2	0 0	330
7 00	42 7	30 2	27 1	46 6	31 2	22 2	2 57	7 6	39 7	16 6	0 19	64 8	21 7	0 3	2 7	9 9	0 6	0 0	332
8 00	45 6	29 4	25 0	49 3	30 4	20 3	3 00	9 5				61 5	24 9	0 5	3 1	9 2	0 8	0 0	382
9 00	37 2	27 1	35 7	40 5	35 2	24 3	2 60	9 2	13 1	13 8	0 17	59 5	25 1	1 7	3 7	8 9	0 6	0 0	348
10 00	30 8	28 5	40 8	33 5	31 9	34 5	2 31	9 9				70 4	21 9	0 3	2 3	4 3	0 7	0 0	301
11 00	38 9	28 8	32 3	42 3	29 5	28 2	2 04	10 6	27 0	11 3	0 25	62 6	30 0	0 4	1 8	4 4	0 7	0 0	273
12 00	46 8	25 1	28 1	50 0	25 4	24 6	2 42	8 8				56 6	37 5	0 3	3 0	1 2	1 2	0 3	319
13 00	41 0	23 7	35 4	43 6	25 5	30 8	2 09	9 0				54 7	34 2	0 3	3 3	4 9	2 2	0 0	307
14 00	53 3	21 8	24 9	56 7	21 1	22 2	3 21	8 5				61 3	29 0	0 3	4 0	1 3	2 1	0 0	373
15 00	45 9	25 0	29 1	48 8	26 2	25 0	2 79	13 5				64 6	26 1	0 0	4 4	4 1	0 9	0 0	345
16 00	50 9	23 1	26 0	54 2	23 2	22 5	3 41	7 2				57 5	34 1	0 4	3 9	2 8	1 3	0 0	463
17 00	52 0	20 9	22 1	55 1	21 8	23 1	3 47	7 0	25 3	10 6	0 30	54 7	35 6	0 8	3 2	3 0	2 7	0 0	475
18 00	53 6	21 5	24 9	56 6	21 7	21 7	3 55	8 8				56 8	35 6	0 7	3 6	2 5	0 9	0 0	444
19 00	54 9	22 5	22 6	57 7	22 2	20 1	3 34	6 3	26 6	11 2	0 34	62 2	30 8	0 4	3 2	2 6	0 8	0 0	471
20 50	57 3	19 3	23 4	60 4	21 2	18 4	3 62	10 9				60 4	31 4	0 7	3 5	2 6	1 5	0 0	462
21 00	54 5	19 9	25 6	57 5	22 6	19 9	2 61	8 4	27 2	11 4	0 25	59 1	30 4	0 7	3 7	3 0	3 0	0 0	428
22 00	52 1	22 3	25 7	55 6	24 8	19 6	3 91	7 6				57 6	33 7	0 6	4 8	2 6	0 8	0 0	502
23 00	49 7	24 3	25 9	53 2	27 1	19 7	2 91	8 5	28 6	12 0	0 30	59 3	31 1	0 7	4 4	2 5	2 1	0 0	437
24 50	45 0	24 0	31 0	48 7	27 2	24 1	3 60	9 3				63 2	23 7	0 4	5 0	4 1	2 8	0 0	464
25 00	44 0	25 7	30 2	47 6	28 8	23 6	3 43	8 6	35 6	14 8	0 19	65 6	22 0	0 5	3 3	8 1	0 2	0 0	422
26 00	47 6	24 8	27 5	51 3	27 9	20 8	3 03	8 6				66 5	23 9	0 5	2 5	5 3	1 1	0 0	397
27 50	47 8	23 0	29 2	51 2	25 8	23 0	3 45	8 4	32 1	13 4	0 25	64 6	28 2	0 4	3 0	3 2	0 7	0 0	440
28 50	45 6	25 1	29 3	49 2	27 9	22 9	3 19	8 6				68 7	21 8	0 0	3 1	4 6	1 6	0 0	390
29 00	44 9	24 3	30 8	48 5	27 8	23 7	2 97	8 9	34 3	14 3	0 23	64 3	22 1	0 5	4 8	6 9	1 4	0 0	375
30 50	44 8	27 1	28 1	48 6	30 5	20 9	2 89	9 3				62 9	28 8	0 3	2 9	4 9	0 3	0 0	385
31 50	44 8	25 1	30 1	48 6	29 0	22 4	2 59	9 4	29 0	12 1	0 19	64 9	24 3	0 0	3 9	2 7	4 2	0 0	331
32 00	45 8	26 0	28 2	49 1	29 5	21 4	3 25	9 3				68 2	18 7	1 4	4 7	5 8	1 2	0 0	428
33 50	45 7	25 4	28 9	49 2	29 4	21 4	3 21	9 2	27 4	11 5	0 26	69 0	22 0	1 7	3 3	3 6	0 4	0 0	423
34 50	45 1	26 9	27 9	48 5	31 5	20 7	3 11	9 2				67 5	22 5	1 7	2 2	4 2	1 9	0 0	409
35 50	43 1	27 0	29 8	46 8	30 4	22 8	2 77	9 4	26 3	11 0	0 28	64 3	27 7	0 6	4 9	2 0	0 6	0 0	437
36 50								16 7											
37 50								15 7											
38 50								13 3											
39 50								15 5											

T31

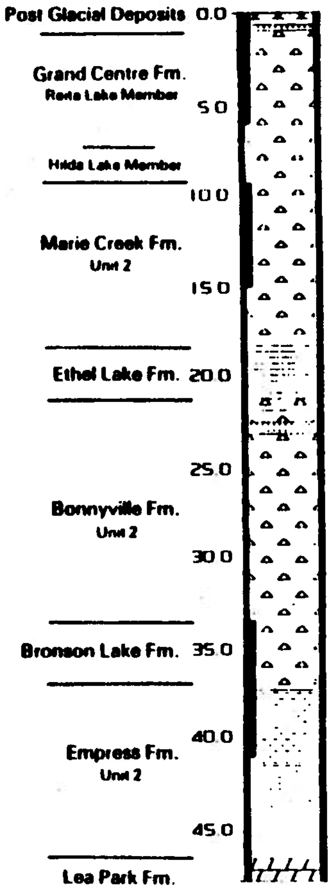
Alberta Geological Survey Testhole T 31
Location of LSD 9 Sec 2 Twp 63 Rng 1 W of 4 Mer . NTS 73L
Elevation 1900 Ft 579 M Source 1 50,000 NTS 73L/8
Date drilled 197608 05 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	41 1	28 2	30 8	45 2	28 8	26 1	1 87	11 9				67 7	26 5	0 0	3 7	2 0	0 0	0 0	245
2 00	40 3	28 5	31 3	44 6	28 6	26 8	1 92	15 4											
3 00												74 2	20 5	1 1	0 7	3 3	0 0	0 0	268
4 00	38 1	29 6	32 3	42 6	29 8	27 6	1 78	12 2				69 7	26 0	0 8	1 3	1 7	0 4	0 0	238
5 00	39 1	26 6	34 3	42 9	27 8	29 4	2 14	13 6				71 8	17 8	0 7	1 4	7 3	1 0	0 0	287
6 00	37 5	26 2	36 3	41 4	27 9	30 7	2 01	12 7				75 3	22 5	0 7	0 4	0 4	0 7	0 0	267
7 00	38 4	25 3	36 3	42 0	27 5	30 6	2 54	12 2				80 2	17 1	0 6	0 3	1 2	0 3	0 0	334
8 00	38 0	27 1	34 9	41 9	28 4	29 7	2 11	13 5				82 3	14 9	0 0	0 7	0 7	1 0	0 0	289
9 00	38 9	26 8	34 3	42 4	28 7	28 9	3 17	12 7				74 9	20 2	0 5	1 2	2 2	0 7	0 0	411
10 00	37 5	26 3	36 3	41 4	27 5	31 2	2 02	11 9				77 2	19 8	0 1	0 4	1 1	1 1	0 0	260
11 00	38 3	25 9	35 8	41 8	27 5	30 7	2 16	12 0				75 5	19 1	1 3	1 0	2 3	0 7	0 0	298
12 00	36 0	27 5	36 5	40 4	28 4	31 3	1 44	12 0				79 9	17 6	1 0	0 5	0 5	0 5	0 0	199
13 00	37 9	24 6	37 5	41 4	27 1	31 5	2 06	10 8				76 6	20 0	0 0	0 7	0 7	1 9	0 0	265
14 00	37 7	26 0	36 3	41 7	26 9	31 4	2 28					78 0	19 4	1 0	0 0	1 6	0 0	0 0	309
15 00	36 1	28 9	34 9	40 5	31 2	28 3	1 11	11 6				73 6	21 2	1 5	1 5	2 1	0 0	0 0	193
16 00	38 3	26 3	35 4	40 4	31 3	28 2	2 36	10 8				82 6	16 8	0 0	0 0	0 3	0 3	0 0	304
17 00	25 0	32 6	42 3	28 0	39 8	32 2	0 78	12 6				69 0	27 4	0 9	0 9	1 8	0 0	0 0	113
18 00	24 6	30 9	44 5	27 3	38 9	33 9	0 99	11 4				75 6	21 5	0 0	0 7	2 2	0 0	0 0	135
19 00	26 2	27 9	46 0	29 2	35 2	35 6	0 92	12 5				76 9	18 5	2 3	0 0	1 5	0 8	0 0	130
20 00	32 1	22 9	45 1	32 6	32 4	35 1	1 16	12 0				72 2	22 5	1 8	2 9	0 0	0 6	0 0	169
21 00	24 5	30 5	45 0	27 5	38 1	34 4	1 10	12 0				80 0	19 4	0 0	0 0	0 7	0 0	0 0	139
22 00	23 1	33 1	43 8	25 7	39 5	34 8	1 04	11 7				80 7	16 0	0 8	2 5	0 0	0 0	0 0	119
23 00	28 5	28 3	43 3	31 8	34 6	33 7	0 92	11 7				66 7	27 9	0 8	3 1	1 5	0 0	0 0	129
24 00	25 8	28 7	45 5	28 3	36 1	35 6	0 80	11 8				72 5	22 0	1 8	1 8	1 8	0 0	0 0	109
25 00	31 0	30 0	39 0	34 6	35 1	30 4	0 96	11 0				75 6	22 1	0 8	0 8	0 0	0 0	0 8	131
26 00	32 1	28 5	39 2	35 4	33 2	31 4	1 07	12 1				78 5	18 5	0 8	0 8	1 5	0 0	0 0	110
27 00	34 2	31 8	34 0	38 7	33 4	27 9	1 16	9 2				75 0	22 4	1 3	0 6	0 6	0 0	0 0	152
28 00	20 3	33 7	46 0	22 4	40 8	36 8	0 64	14 7				70 3	25 3	4 4	0 0	0 0	0 0	0 0	91
29 00	17 3	37 2	45 5	19 1	45 2	35 7	0 70	13 4				70 4	27 5	1 0	0 0	1 0	0 0	0 0	98
30 00	25 1	35 3	39 6	27 7	39 1	33 2	0 99	11 1				71 3	22 9	0 8	0 8	2 4	1 6	0 0	122
31 00	19 6	30 6	49 9	21 9	38 8	39 3	0 82	14 4				79 6	18 4	0 0	1 0	1 0	0 0	0 0	103
32 00	23 8	29 1	47 1	26 2	35 9	37 9	0 82	12 5				70 5	22 8	1 9	1 9	1 9	0 0	0 4	105
33 00	29 6	26 4	44 0	33 0	31 8	35 1	0 82	11 5				77 6	20 6	0 0	0 0	1 9	0 0	0 0	107
34 00								17 1											
35 00								16 5											
36 00	18 4	25 1	56 5	20 1	37 0	42 9	0 57	10 2				75 4	20 3	2 9	0 0	0 0	1 4	0 0	640
37 00	29 3	25 7	45 0	32 5	30 7	36 8	0 88	13 1				75 4	20 9	0 9	0 9	0 9	0 9	0 0	110
38 00	10 1	27 5	62 4	12 4	40 5	47 1	0 37	15 5				59 1	11 8	6 1	1 5	1 5	0 0	0 0	66
39 00	30 4	27 3	42 4	33 7	32 2	34 1	0 97	9 9				76 1	21 5	1 5	0 8	0 0	0 0	0 0	130
40 00								14 3											
41 00								11 6											
42 00								11 9											

T32

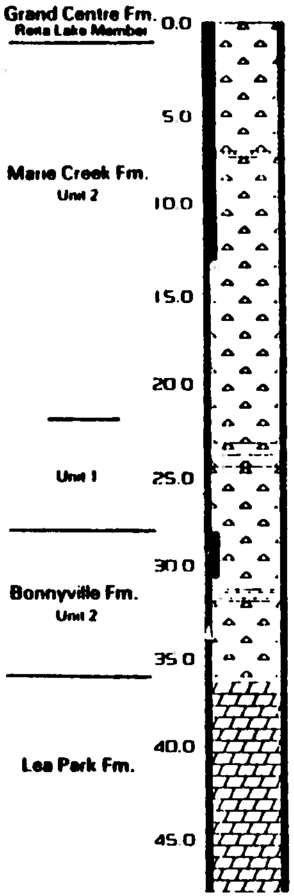
Alberta Geological Survey Testhole T 32
Location SW of LSD 12 Sec. 1 Twp 61 Rng 1 W of 4 Mer., NTS 73L
Elevation 1800 Ft 549 M Source 1:50,000 NTS 73L/9
Date drilled 197608 06 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	37.0	26.0	37.0	40.0	29.0	31.0	1.86	13.3	21.4	8.9	0.24	69.6	24.4	1.2	2.3	3.8	0.0	0.0	266
2.00	36.0	25.0	38.0	40.0	28.0	33.0	1.83	15.4	29.1	12.2	0.37	65.5	28.5	0.8	2.4	2.8	0.4	0.0	249
3.00	36.0	25.0	39.0	40.0	28.0	32.0	2.00	15.6	26.2	10.9	0.24	65.6	27.8	0.7	2.6	2.7	0.4	0.0	270
4.00	37.0	26.0	37.0	41.0	28.0	31.0	1.68	14.6	25.8	10.8	0.30	64.0	27.2	2.9	1.3	4.2	1.2	0.0	239
5.00	34.0	26.0	41.0	37.0	28.0	35.0	2.99	14.5	27.6	11.6	0.28	61.9	27.0	1.3	3.5	4.4	0.4	0.0	230
6.00	32.0	26.0	42.0	35.0	29.0	35.0	1.85	14.2	26.3	11.0	0.21	61.4	26.6	2.2	2.6	4.3	0.0	0.0	233
7.00	33.0	28.0	39.0	36.0	31.0	33.0	1.65	12.3				69.1	19.1	2.7	3.1	5.3	0.8	0.0	225
8.00	26.0	28.0	46.0	30.0	31.0	39.0	1.11	14.1	25.1	10.6	0.24	69.4	22.0	0.0	4.1	4.6	0.0	0.0	173
9.00	20.0	31.0	49.0	24.0	36.0	41.0	0.72	14.1	28.2	11.8	0.25	58.8	29.8	0.0	2.6	8.8	0.9	0.0	114
10.00	38.0	30.0	31.0	42.0	32.0	26.0	2.17	8.3	41.6	18.2	0.21	67.1	16.4	0.3	3.4	10.6	1.6	0.0	161
11.00	40.0	30.0	31.0	43.0	31.0	26.0	2.54		41.3	17.2	0.19	66.3	15.6	0.6	2.8	13.4	1.2	0.0	320
12.00	40.0	28.0	31.0	45.0	29.0	26.0	2.15	10.0	41.7	18.2	0.16	65.9	19.6	0.3	2.4	10.1	2.0	0.0	296
13.00	41.0	28.0	32.0	44.0	31.0	25.0	2.13	8.2	38.6	16.1	0.15	63.1	19.6	2.0	5.1	8.7	1.9	0.0	312
14.00	46.0	27.0	27.0	50.0	29.0	22.0	2.48	8.7				61.4	23.5	1.2	4.0	7.1	2.4	0.0	324
15.00	51.0	27.0	21.0	56.0	27.0	17.0	3.64	7.1	29.3	12.2	0.25	58.7	30.4	1.1	3.4	5.0	1.0	0.0	477
16.00	55.0	23.0	22.0	59.0	24.0	18.0	3.06	6.6	30.1	12.6	0.28	56.7	32.0	0.2	4.6	4.8	1.6	0.0	413
17.00	56.0	23.0	22.0	60.0	21.0	18.0	2.76	7.2	30.7	12.8	0.23	55.5	34.7	0.5	3.7	3.7	2.1	0.0	404
18.00	46.0	27.0	28.0	49.0	30.0	21.0	2.56	7.8	29.1	12.2	0.26	59.2	30.9	0.3	2.1	4.5	3.0	0.0	333
19.00								19.6											
20.00								18.6											
21.00	31.0	25.0	44.0	34.0	31.0	32.0	1.18	15.6	15.5	6.5	0.42	49.0	45.0	3.3	0.7	1.3	0.7	0.0	151
22.00	40.0	25.0	35.0	42.0	35.0	23.0	2.71	11.5				54.4	39.7	2.0	2.6	0.0	1.4	0.0	388
23.00	52.0	30.0	18.0	56.0	33.0	11.0	3.16	8.7	20.5	8.6	0.35	59.1	34.5	1.8	3.0	0.5	1.4	0.0	438
24.00	53.0	28.0	19.0	56.0	30.0	14.0	3.44	8.9				53.4	40.5	1.0	1.9	1.5	1.6	0.0	474
25.00	52.0	29.0	19.0	56.0	31.0	14.0	3.37	8.7	20.7	8.7	0.30	58.4	35.8	0.9	1.3	0.9	2.6	0.0	450
26.00	53.0	29.0	18.0	57.0	30.0	14.0	3.16	8.5				60.7	33.5	1.2	2.1	0.7	1.9	0.0	427
27.00	53.0	28.0	19.0	57.0	30.0	14.0	3.29	8.0	20.5	8.6	0.33	60.1	34.6	0.2	3.0	1.6	0.4	0.0	436
28.00	54.0	26.0	20.0	58.0	28.0	14.0	3.36	8.3				58.7	34.3	1.6	2.0	2.0	1.1	0.0	443
29.00	53.0	26.0	21.0	57.0	27.0	16.0	3.41	8.1	20.0	8.4	0.25	56.0	38.0	0.4	1.9	1.0	2.5	0.0	484
30.00	53.0	26.0	22.0	56.0	28.0	16.0	3.61	9.1				60.5	33.5	1.4	1.9	1.7	1.0	0.0	483
31.00	54.0	25.0	21.0	58.0	27.0	15.0	4.64	10.3	19.0	7.9	0.27	56.2	35.5	1.2	2.7	1.5	2.8	0.0	598
32.00	53.0	25.0	22.0	56.0	27.0	17.0	3.75	7.8				54.1	38.4	1.4	3.2	1.6	1.4	0.0	497
33.50	23.0	34.0	43.0	28.0	35.0	38.0	0.74	12.1	20.4	8.6	0.36	38.3	45.2	2.6	4.4	1.7	7.8	0.0	115
34.00	24.0	34.0	43.0	28.0	35.0	37.0	0.80	13.3				57.5	28.3	0.0	5.0	3.3	5.8	0.0	120
35.00	23.0	34.0	43.0	28.0	35.0	37.0	0.80	13.7	21.4	9.0	0.31	57.5	28.3	0.0	5.0	3.3	5.8	0.0	120
36.50	24.0	31.0	45.0	28.0	33.0	39.0	0.76	12.0				34.3	44.4	0.0	3.7	5.6	12.1	0.0	108
37.00	6.0	41.0	53.0	8.0	48.0	44.0	0.14	16.6				21.4	17.9	0.0	0.0	3.6	57.1	0.0	28
38.00								18.7											
39.50								16.0											
40.00								18.4											
41.00								14.9											
42.50								16.3											
43.00								17.5											
44.00								15.7											
45.00								18.2											
46.00								20.4											
47.00								19.5											

T33

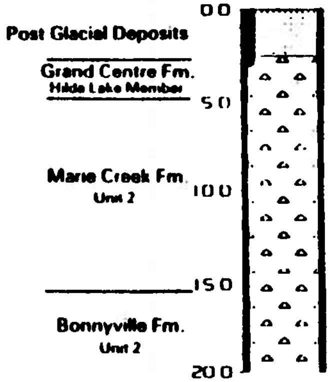
Alberta Geological Survey Testhole T 33
Location of LSD 5 Sec 12 Twp 65 Rng 1 W of 4 Mer NTS 73L
Elevation 1900 Ft 579 M Source 1 50,000 NTS 73L/9
Date drilled 197608 09 Logged by ANDRIASHEK



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	TOT (%)	CA/DO	IGN METM	COARSE SAND LITHOLOGY (%) QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	41.0	17.0	41.0	45.0	19.0	37.0	2.60	12.9				70.0	25.4	0.6	0.9	2.6	0.6	0.0	343
2.00	41.0	26.0	33.0	45.0	28.0	27.0	2.78	11.5	39.5	16.4	0.17	58.6	21.1	0.8	5.2	9.3	4.9	0.0	365
3.00	43.0	26.0	31.0	47.0	27.0	26.0	3.11	10.4	38.0	15.8	0.17	52.5	32.3	0.0	2.8	12.6	0.0	0.0	316
4.00	43.0	26.0	31.0	47.0	27.0	26.0	2.76	10.0	34.9	14.5	0.16	66.8	20.4	1.1	3.7	7.4	0.6	0.0	353
5.00	44.0	27.0	29.0	48.0	28.0	25.0	3.09	10.2	37.1	15.4	0.16	65.1	22.5	0.5	4.2	6.9	0.7	0.0	404
6.00	44.0	34.0	21.0	48.0	34.0	18.0	3.21	10.7	36.8	15.3	0.13	68.0	19.3	0.0	3.8	7.8	1.2	0.0	425
7.00	39.0	23.0	38.0	43.0	25.0	33.0	2.50		28.6	12.0	0.26	69.0	19.7	0.9	2.8	5.9	1.6	0.0	319
8.00	47.0	24.0	29.0	51.0	25.0	24.0	2.76	10.8				61.0	24.7	0.8	4.0	6.2	1.3	0.0	375
9.00	46.0	25.0	29.0	51.0	26.0	24.0	2.70	9.3	27.4	11.5	0.31	63.0	28.3	0.3	4.0	2.0	2.3	0.0	346
10.00	47.0	32.0	21.0	52.0	33.0	15.0	2.52	9.7				64.1	27.3	0.6	4.1	3.3	0.6	0.0	337
11.00	47.0	26.0	27.0	52.0	26.0	22.0	2.57	9.8	28.0	11.8	0.33	64.2	26.2	0.3	3.8	3.5	2.0	0.0	344
12.00	49.0	24.0	27.0	53.0	21.0	23.0	3.07	8.6				60.4	32.2	0.0	3.6	2.4	1.4	0.0	419
13.00	48.0	25.0	27.0	52.0	26.0	21.0	3.13	9.2	28.7	12.1	0.35	65.8	23.3	1.0	4.1	1.8	3.6	0.2	386
14.00	48.0	30.0	23.0	52.0	32.0	16.0	3.06	10.0				62.1	28.3	1.0	2.8	3.0	2.8	0.0	396
15.00	46.0	34.0	20.0	50.0	37.0	13.0	2.73	10.5	28.3	11.9	0.33	60.6	30.4	0.3	3.7	3.4	1.4	0.0	348
16.00	48.0	31.0	21.0	52.0	33.0	15.0	3.28	9.6				63.7	23.1	0.2	6.6	4.0	2.1	0.2	424
17.00	48.0	33.0	18.0	53.0	35.0	12.0	2.92	10.0	28.6	12.0	0.28	62.9	27.8	0.7	3.0	4.3	1.2	0.0	399
18.00	49.0	35.0	17.0	53.0	35.0	12.0	3.40	9.0				57.9	32.0	0.5	3.8	3.8	1.9	0.2	425
19.00	48.0	35.0	17.0	52.0	36.0	12.0	3.11	9.0	29.5	12.4	0.32	66.8	24.7	0.8	1.6	2.5	1.5	0.0	392
20.00	47.0	35.0	18.0	51.0	37.0	12.0	2.78	9.7				64.0	27.1	0.0	2.6	4.4	1.8	0.0	383
21.00	47.0	33.0	20.0	52.0	36.0	12.0	2.95	9.5	32.3	13.5	0.27	63.3	26.1	0.0	4.7	4.2	1.0	0.0	379
22.00	43.0	30.0	27.0	47.0	35.0	18.0	2.80	10.3	25.9	10.8	0.24	67.6	23.2	0.8	2.6	4.0	1.7	0.3	349
23.00	23.0	36.0	42.0	25.0	46.0	30.0	1.64	11.4	14.9	6.3	0.42	66.3	28.0	0.9	2.3	1.9	0.5	0.0	214
24.00	42.0	29.0	29.0	47.0	33.0	20.0	1.39	11.8	13.3	5.6	0.32	66.0	29.2	0.0	3.3	0.9	0.5	0.0	212
25.00	49.0	29.0	22.0	57.0	27.0	16.0	1.18	12.5	15.9	6.7	0.48	68.4	27.1	0.0	1.3	3.2	0.0	0.0	155
26.00	36.0	29.0	35.0	39.0	36.0	25.0	1.72	11.6	10.9	4.6	0.47	67.5	27.9	1.7	2.1	0.4	0.0	0.4	240
27.00	31.0	40.0	29.0	40.0	39.0	21.0	1.54	12.1	14.8	6.3	0.40	66.5	29.5	0.5	1.5	1.0	1.0	0.0	200
28.00	42.0	30.0	28.0	46.0	31.0	23.0	2.70	11.5	19.5	8.2	0.42	60.8	30.5	0.3	5.3	1.9	1.1	0.0	360
29.00	40.0	31.0	29.0	45.0	31.0	24.0	2.41	11.8	23.0	9.7	0.41	57.5	34.7	0.3	3.6	1.5	2.4	0.0	334
30.00	31.0	32.0	37.0	34.0	41.0	25.0	2.10	12.6	31.7	13.3	0.36	51.6	33.1	0.0	10.2	3.3	5.4	0.0	275
31.00								20.4											
32.00	47.0	32.0	21.0	51.0	35.0	14.0	3.13	9.7	32.0	13.4	0.25	56.5	35.5	0.5	3.8	2.4	1.2	0.2	423
33.00	47.0	31.0	21.0	51.0	35.0	14.0	3.61	10.4	30.2	12.7	0.26	58.4	31.9	0.4	4.8	2.2	2.2	0.0	454
34.00	46.0	33.0	21.0	50.0	36.0	14.0	3.23	10.8	31.1	13.0	0.21	54.6	34.6	0.2	5.1	2.5	2.8	0.0	430
35.00	46.0	33.0	21.0	50.0	36.0	13.0	3.21	10.7	30.2	12.7	0.26	58.4	33.0	0.5	5.5	2.2	2.4	0.0	416
36.00								16.3											
37.00								16.5											
38.00								16.0											
39.00								16.0											
40.50								16.9											
41.00								15.9											
42.00								16.3											
43.00								16.1											
44.00																			
45.00								11.7											
46.00								11.2											
47.00								16.5											
48.00								15.3											

T34

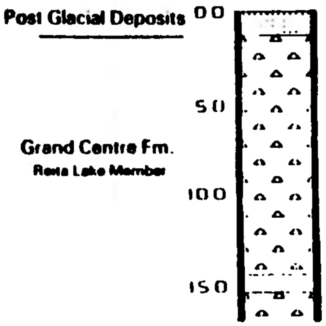
Alberta Geological Survey Testhole T 34
Location SW of LSD 13 Sec 18 Twp 61 Rng 2 W of 4 Mer . NTS 73L
Elevation 1760 Ft 537 M Source 1 50,000 NTS 73L/8
Date drilled 197608 10 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	COC	OTH	N
3 00	32 0	27 6	40 5	35 0	31 6	33 3	1 67	12 3				65 2	28 3	0 6	2 1	3 1	0 6	0 0	477
4 00	33 0	24 2	42 8	36 1	28 6	35 2	1 63	12 3				66 9	24 8	0 9	1 6	5 3	0 5	0 0	435
5 00	30 9	25 5	43 6	34 1	29 8	35 9	1 24	13 8				63 4	26 0	1 6	3 6	4 1	1 1	0 3	366
6 00	50 3	24 5	25 2	54 0	25 9	20 1	3 15	10 0				63 0	26 5	0 0	3 9	2 7	4 7	0 0	259
7 00	58 2	21 8	20 0	62 0	22 1	15 9	3 96					62 5	27 8	0 4	3 5	3 5	2 3	0 0	259
8 00	39 4	24 2	36 4	42 5	27 4	30 1	2 67	11 1				61 2	26 0	0 2	3 1	2 9	6 4	0 0	420
9 00	47 6	25 7	26 7	51 4	27 2	21 5	3 61	9 8				65 8	23 6	1 4	4 2	3 5	1 4	0 0	284
10 00	47 5	26 1	26 4	51 2	27 7	21 1	1 17	9 7				61 2	26 4	0 4	4 3	3 1	4 3	0 4	258
11 00	45 4	24 5	30 1	49 0	27 0	24 0	3 50	9 5				65 8	26 0	0 0	3 5	2 7	2 0	0 0	404
12 00	47 6	23 8	28 6	51 2	26 2	22 7	3 87	8 9				60 3	26 2	2 6	4 6	3 6	2 6	0 0	302
13 00	47 8	26 6	25 6	51 5	29 4	19 1	1 96	9 2				66 1	24 1	0 4	3 9	3 9	1 6	0 0	257
14 00	46 9	26 4	26 7	50 5	29 7	19 8	3 31	9 6				59 3	28 0	0 7	5 1	3 3	3 3	0 4	275
15 00	48 1	25 2	26 7	51 7	28 6	19 6	4 58	9 7				76 6	20 3	0 6	0 8	1 1	0 3	0 3	360
16 00	48 0	25 9	26 1	51 7	29 3	18 9	3 40	9 2				62 1	27 8	0 7	4 0	2 2	2 6	0 4	273
17 00	48 6	25 3	26 1	52 3	28 8	18 9	3 71	9 4				51 9	34 8	0 8	3 5	3 1	3 9	0 0	256
18 00	47 7	26 5	25 8	51 2	30 1	18 7	3 60	9 2				55 0	31 6	0 8	5 0	3 4	2 3	0 0	262
19 00	47 6	25 3	27 2	51 2	28 6	20 2	3 21	10 2				51 1	35 5	0 7	3 0	3 9	2 5	0 2	434
20 00	47 6	27 4	25 0	51 2	31 0	17 9	3 46	10 3				55 8	31 8	0 8	5 0	5 0	1 2	0 0	258

T35

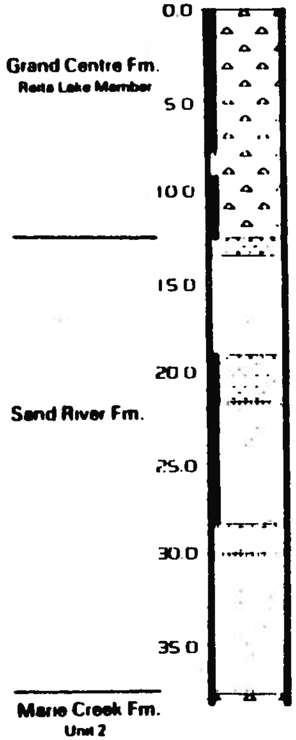
Alberta Geological Survey Testhole T 35
Location of LSD 12 Sec 27 Twp 63 Rng 7 W of 4 Mer NTS 73L
Elevation 1875 Ft 572 M Source 1 50,000 NTS 73L/1
Date drilled 197608 11 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00																			
2 00	35 3	28 4	36 3	38 8	31 6	29 6	1 75	17 3				66 0	30 2	0 5	0 5	1 8	0 9	0 0	218
3 00	30 6	31 0	38 4	34 6	35 0	30 4	1 22	13 0				64 2	27 2	2 3	3 5	2 9	0 0	0 0	173
4 00	33 2	28 3	38 6	36 6	33 3	30 1	1 52	11 9				73 3	22 0	0 5	1 5	2 1	0 5	0 0	195
5 00	34 9	28 4	36 8	38 7	32 7	28 6	1 52	11 4				67 6	25 1	1 0	2 9	2 9	0 5	0 0	207
6 00	33 2	26 1	40 8	36 4	31 5	32 1	1 78	12 0				71 7	21 4	1 3	1 7	3 9	0 0	0 0	233
7 00	35 1	27 9	36 9	39 2	32 1	28 7	1 56	12 1				70 3	24 0	0 5	0 5	2 0	0 0	0 0	200
8 00	32 4	30 6	37 0	36 4	35 8	27 8	1 29	12 6				65 7	29 3	0 0	2 8	1 6	0 5	0 0	181
9 00	31 1	30 6	38 3	34 8	37 1	28 1	1 24	12 9				60 2	27 6	0 0	2 8	3 3	0 5	0 0	171
10 00	33 0	28 6	38 4	37 1	34 6	28 3	1 16	11 6				67 0	27 0	1 7	1 7	2 3	0 0	0 6	171
11 00	32 9	28 9	38 3	36 5	35 1	28 3	1 46	12 1				65 3	28 3	1 2	1 7	2 9	0 6	0 0	173
12 00	36 2	27 9	35 9	40 2	32 9	26 9	1 68	11 3				60 7	32 3	0 4	2 2	3 5	0 9	0 0	229
13 00	36 4	25 7	38 0	40 3	32 8	26 8	1 57	11 4				66 7	26 3	0 5	1 5	4 0	1 0	0 0	201
14 00	34 9	27 4	37 7	39 2	33 4	27 3	1 41	11 8				61 0	32 4	0 0	3 3	3 3	0 0	0 0	182
16 00								11 2											
17 00								10 1											

T36

Alberta Geological Survey Testhole T 36
Location of LSD 13 Sec 4 Twp 63 Rng 6 W of 4 Mer , NTS 73L
Elevation 1860 Ft 567 M Source 1:50,000 NTS 73L/7
Date drilled 197608 11 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC-SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1.00								10.3											
2.00	34.7	25.8	39.5	38.1	27.8	34.1	1.51	10.9				69.8	24.3	2.5	0.9	1.8	0.5	0.0	202
3.00	33.4	26.4	40.2	36.9	28.0	35.1	1.57	11.3				67.6	27.9	1.5	1.0	2.0	0.0	0.0	204
4.00	34.5	26.1	39.3	38.1	27.6	34.3	1.78	11.5				70.4	23.3	0.9	2.2	1.8	1.3	0.0	223
5.00	32.9	25.5	41.6	36.4	27.6	36.0	1.38	11.0				68.9	27.7	0.0	0.6	2.8	0.0	0.0	177
6.00	35.3	26.3	38.3	38.8	27.7	33.5	1.17	11.5				62.6	27.8	2.5	3.5	2.0	2.0	0.0	198
7.00	25.4	28.5	46.1	28.3	31.3	40.4	0.88	15.8				65.5	27.6	1.7	0.0	2.6	2.6	0.0	116
8.00	19.4	25.2	55.5	21.7	29.7	48.5	0.72	15.1				72.5	21.6	2.0	2.0	0.0	2.0	0.0	102
9.00	39.1	26.2	34.6	43.8	26.2	30.0	1.60	10.6				58.6	38.4	0.4	0.4	1.3	1.3	0.0	237
10.00	34.1	30.9	35.0	38.4	31.8	29.8	1.24	9.5				73.9	21.8	0.6	0.6	2.4	0.6	0.0	156
11.00	38.6	29.5	31.9	43.5	29.0	27.5	1.90	8.8				74.9	22.5	1.3	0.0	1.1	0.4	0.0	231
12.00	35.5	32.3	32.2	40.3	32.1	27.5	1.45	10.4				77.5	19.8	0.0	1.1	1.6	0.0	0.0	187
16.00								6.4											
19.00								10.4											
38.00	46.4	34.5	19.1	50.9	33.8	15.2	1.98	10.8				62.8	25.7	0.0	2.8	6.1	0.8	0.4	253

T37

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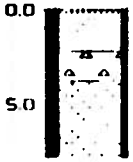
Alberta Geological Survey Testhole    1  17
Location        of LSD  8 Sec 26 Twp  64 Rng  7 W of 4 Mer  ,  NTS  73L
Elevation   1975 Ft      602 M   Source  1 50,000 NTS 73L/11
Date drilled     197608 15  Logged by  M  FENTON

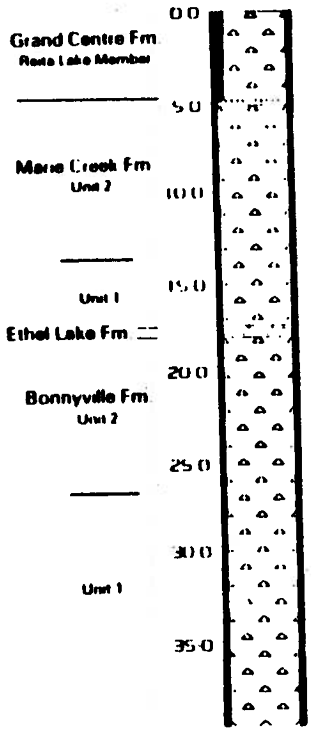
                        TEXTURE (%)                               MATRIX CARBONATE             COARSE SAND LITHOLOGY (%)
 DEPTH  SAND SILT CLAY  SAND SILT CLAY VC SD    H2O    CO2  CO3 CA/DO     IGN   QTZ  QTZT  LST  DST  LOC  OTH    N
  (M) >62 5um     <4um  >50um      <2um 1 2mm   (%)   (cc)  (%)            MFIN        OSS

  3 00                                          11 4
  3 50                                          11 1
```



T38

Alberta Geological Survey Testhole T 38
Location of LSD 4 Sec 36 Twp 64 Rng 7 W of 4 Mer . NTS 73L
Elevation 2000 Ft 610 M Source 1:50,000 NTS 73L/10
Date drilled 19760815 Logged by M FENTON



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	IGN METM	COARSE SAND LITHOLOGY (%) QTZ	QTZT USS	LST	DST	LOC	OTH	N
2.00	46.1	22.9	30.8	50.0	21.5	28.5	1.96	10.6				65.3	27.8	2.8	1.2	2.8	0.0	0.0	248
3.00	42.4	25.8	31.8	46.4	26.1	27.3	1.93	10.7				61.5	25.4	2.8	1.6	5.6	1.2	0.0	252
4.00	43.0	24.4	32.6	46.7	25.2	28.1	1.89	7.7				60.9	29.7	2.3	1.6	5.1	0.4	0.0	256
5.00	41.8	29.0	29.2	45.7	30.1	24.3	2.60	11.3				59.5	25.5	0.6	3.4	10.4	0.6	0.0	326
6.00	42.8	29.1	28.0	46.9	31.9	21.2	2.91	9.3											
7.00	43.0	31.9	25.1	47.1	34.4	18.4	2.47	9.6				53.5	33.2	1.0	3.9	7.0	1.0	0.3	383
8.00	43.8	29.9	26.4	47.7	32.9	19.5	2.61	9.6											
9.00	44.2	29.4	26.5	48.2	32.5	19.3	2.89	10.7				56.8	32.6	0.3	5.0	3.6	1.4	0.3	359
10.00	44.6	28.4	27.0	48.5	31.6	20.0	2.78	10.7											
11.00	40.5	30.4	29.1	44.5	33.6	21.9	2.51	11.4				54.6	35.8	0.3	3.0	5.1	1.5	0.0	335
12.00	43.8	26.5	29.6	47.8	29.6	22.6	2.67	11.6				52.6	33.7	0.9	3.7	7.1	2.2	0.3	327
13.00	41.4	28.5	30.0	45.3	32.4	22.2	2.66	11.4				58.9	32.5	0.3	3.0	3.5	2.4	0.0	338
14.00	36.4	27.9	35.6	40.0	31.9	28.1	2.08	11.4				54.8	37.9	0.0	3.0	2.1	1.2	0.0	270
15.00	35.6	26.1	38.1	39.2	30.5	30.2	2.21	12.1				57.3	35.6	0.3	3.9	1.9	2.3	0.0	309
16.00	34.3	26.2	39.5	38.1	30.8	31.1	2.21	12.2				56.7	33.2	0.7	5.5	1.4	2.0	0.3	289
17.00								12.8											
18.00	49.4	22.5	28.1	53.1	25.8	21.1	2.34	5.8				55.8	37.9	0.6	3.8	1.2	1.2	0.0	319
19.00	48.8	23.6	27.7	52.7	27.6	19.7	2.49	10.6				62.0	28.9	0.0	4.6	1.7	2.9	0.3	350
20.00	47.3	23.0	29.7	51.0	27.6	21.4	2.12	10.4				51.0	40.9	0.3	3.2	2.3	1.9	0.3	308
21.00	46.3	23.2	30.5	50.2	27.5	22.3	2.50	10.4											
22.00	44.4	24.0	31.5	48.3	28.7	22.9	2.62	10.3				60.2	31.6	5.8	2.0	5.0	0.9	0.0	342
23.00	45.6	22.9	31.4	49.4	27.6	22.9	2.20	11.0											
24.00	46.4	31.7	21.8	46.8	38.0	15.1	2.77	10.6				61.0	33.6	0.0	1.6	2.6	1.3	0.3	387
25.00	43.0	31.9	25.1	46.8	37.2	16.0	2.31	10.5											
26.00	43.7	28.9	27.4	47.4	32.8	19.8	2.41	10.8				61.0	29.9	0.6	3.8	4.1	1.3	0.0	318
27.00	36.4	33.2	30.4	39.9	38.6	21.5	1.51	10.1				57.0	34.0	0.5	2.5	0.5	2.0	0.0	200
28.00	34.4	32.9	32.6	37.8	39.6	22.6	1.56	10.4				54.6	39.2	0.0	2.6	3.6	0.5	0.0	194
29.00	32.7	34.1	33.2	36.4	39.7	23.9	1.52	11.5				64.6	28.5	1.1	4.2	2.8	0.0	0.0	144
30.00	33.7	34.9	31.4	35.3	41.8	22.9	1.47	10.6											
31.00	33.2	35.1	31.7	34.7	41.5	23.9	1.19	11.3				67.1	32.1	0.0	4.3	3.7	1.2	0.0	161
32.00	28.6	34.4	37.0	32.1	41.3	26.6	1.45	12.8				51.1	40.1	1.5	2.0	4.1	0.5	0.0	197
33.50	30.1	36.8	33.1	33.4	43.5	23.1	1.23	11.5				52.3	39.0	1.2	4.6	1.2	1.7	0.0	172
34.00	29.6	31.0	39.4	33.2	38.5	28.4	1.44	10.6				64.7	28.3	0.5	4.3	1.6	0.5	0.0	187
35.00	30.3	34.7	35.0	33.7	42.7	23.6	1.50	10.7				60.7	32.0	0.6	3.4	4.5	0.0	0.0	178
36.50	30.1	30.4	39.5	33.8	37.4	28.8	1.55	10.6				59.7	29.8	0.0	4.0	4.0	2.3	0.0	176
37.00	25.1	33.6	41.2	28.4	41.5	30.1	1.27	10.8				59.8	33.9	1.7	3.4	1.7	0.0	0.0	174
38.00	24.1	32.0	43.8	27.7	39.7	32.6	1.09	11.7				58.4	32.3	1.2	3.7	2.5	1.8	0.0	161
39.50	25.0	35.8	39.1	28.8	42.0	29.2	1.23	12.0				54.6	37.9	0.0	2.5	3.1	1.9	0.0	161

T39

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Alberta Geological Survey Testhole   T 39
Location      of LSD  1 Sec 17 Twp  62 Rng  7 W of 4 Mer  ,  NTS  73L
Elevation    1915 FT      584 M   Source  1 50,000 NTS 73L/6
Date drilled    197608 16  Logged by  M  FENTON

                    TEXTURE (%)                          MATRIX CARBONATE         COARSE SAND LITHOLOGY (%)
 DEPTH  SAND SILT CLAY  SAND SILT CLAY VC SD   H2O    CO2  CO3 CA/DO    IGN   QTZ  QTZT  LST  DST  LOC  OTH    N
  (M) >62 5um     <4um  >50um     <2um 1 2mm   (%)   (cc)  (%)          METM       OSS
  4 00                                         8 2
  5 00                                         7 6
  6 00                                         6 2
  7 00                                        11 1
  8 00                                         8 1
  9 00                                        11 7
 10 00                                        10 3
 11 00                                        10 8
 12 00                                        15 1
 13 00                                        14 3
 14 00                                         9 7
 15 00                                        15 1
 16 00                                        13 6
 17 00                                        11 7
 18 00                                        11 4
 19 00                                        11 9
 20 00                                        21 9
 42 50                                         9 8
 43 00                                         9 2
 44 00                                         8 7
 45 00                                         9 1
 46 00                                        13 3
 47 00                                        10 6
```
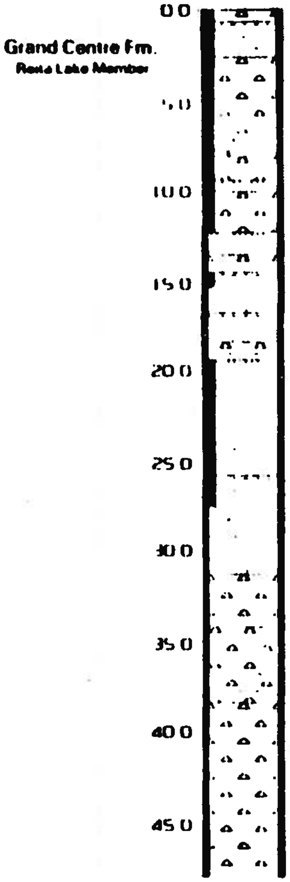
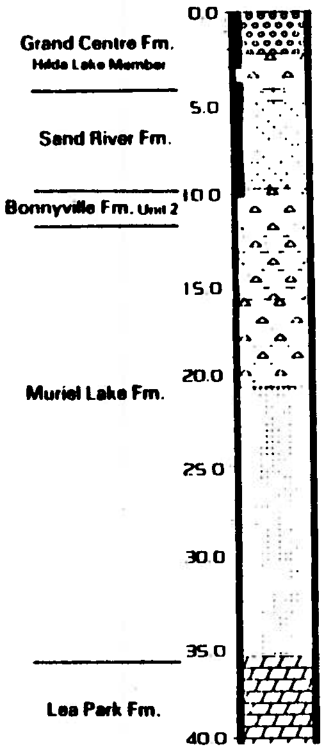



T40

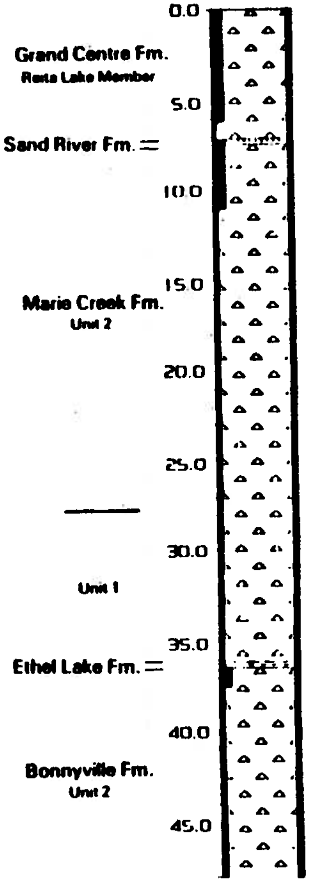


Alberta Geological Survey Testhole T 40
Location of LSD 4 Sec 29 Twp 62 Rng 6 W of 4 Mer , NTS 73L
Elevation 1780 Ft 543 M Source 1:50,000 NTS 73L/7
Date drilled 197608 19 Logged by M FENTON

DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN MTM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00								9.5											
2.00	25.7	29.2	45.1	28.8	34.1	37.0	0.82	12.1				67.9	26.6	1.8	0.9	2.7	0.0	0.0	109
3.00	25.8	26.6	47.6	28.8	33.0	38.2	0.86	12.0				72.3	19.6	1.8	1.8	3.6	0.9	0.0	112
4.00	38.0	26.7	35.3	41.9	28.5	29.6	1.71	10.3				71.6	23.4	0.4	1.3	3.1	0.0	0.0	222
5.00	9.1	69.8	21.2	18.5	64.1	17.4	0.02	16.8				22.2	11.1	0.0	0.0	0.0	66.7	0.0	90
10.00	58.2	23.8	18.1	61.6	24.4	14.1	1.40	9.6				57.0	36.6	0.0	2.9	1.8	1.6	0.0	442
11.00								8.9											
12.00								9.2											
13.00								9.5											
14.00								10.2											
15.00								9.6											
16.00								15.3											
17.00								19.0											
18.00								11.7											
19.00								11.0											
20.00								19.5											
36.50								16.8											
38.00								17.0											

T41

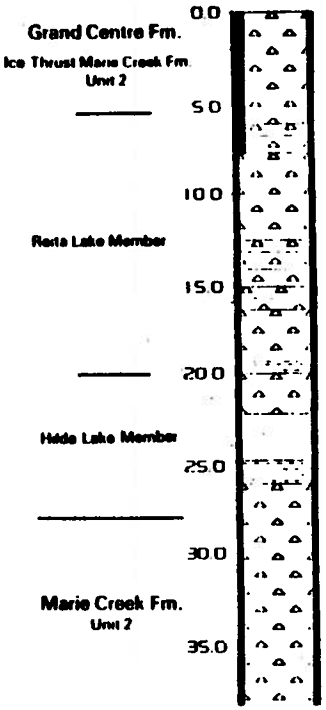
Alberta Geological Survey Testhole 1 11
Location NE of LSD 3 Sec 29 Twp 58 Rng 3 W of 4 Mer , NTS 73L
Elevation 2125 Ft 648 M Source 1 50,000 NTS 73L/1
Date drilled 197608 21 Logged by ANDRIASHEK



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	32.3	25.8	41.9	34.7	28.6	36.7	1.40	13.9				79.6	19.9	0.0	0.0	0.0	0.5	0.0	196
2.00	36.5	28.0	35.5	40.5	29.5	30.0	1.73	12.0				66.8	26.1	0.4	1.7	4.2	0.4	0.4	238
3.00	34.0	27.1	38.9	36.9	29.9	33.2	1.52	15.3				60.9	32.1	0.5	2.8	1.9	1.9	0.0	215
4.00	38.9	26.4	34.7	42.3	28.2	29.5	1.58	14.0				69.0	24.8	0.0	0.8	3.1	2.3	0.0	129
5.00	37.1	29.4	33.5	41.7	29.6	28.7	1.57	14.0				66.1	28.0	0.0	2.8	2.8	0.0	0.0	218
6.00	33.0	25.1	42.0	35.7	27.7	36.6	1.44	13.2				62.7	29.9	0.5	2.0	3.0	2.0	0.0	201
7.00	30.7	27.7	41.5	34.9	30.8	34.3	0.92	11.9				57.5	37.0	0.0	2.4	2.4	0.8	0.0	127
8.00	36.0	32.0	32.0	39.3	33.8	27.0	2.43	10.9				56.8	27.0	0.0	3.4	12.1	0.7	0.0	296
9.00	37.7	31.5	30.8	41.9	32.9	25.2	2.49	9.0				59.4	27.4	0.0	2.9	8.3	1.5	0.0	339
10.00	37.1	29.2	33.6	40.5	31.2	28.3	1.45	8.9				58.0	28.8	0.0	3.7	8.2	1.2	0.0	243
11.00	34.2	30.2	35.5	38.0	32.1	29.9	2.48	9.5				62.7	18.6	0.6	3.9	11.6	2.3	0.3	311
12.00	39.4	28.4	32.1	42.5	28.9	28.6	2.86	9.3				56.2	29.2	0.0	2.8	9.0	2.8	0.0	363
14.00	37.4	31.6	31.0	41.7	32.1	26.2	2.57					59.3	29.1	0.0	2.6	8.5	0.6	0.0	351
15.00	39.6	29.4	31.0	43.1	29.9	27.1	2.88	9.2				62.5	23.7	0.0	2.4	10.3	1.1	0.0	379
16.00	38.1	32.0	29.9	42.6	28.9	28.4	2.71	9.1				63.5	22.4	0.0	5.1	8.8	0.3	0.0	375
17.00	39.5	30.5	30.0	42.8	32.5	24.7	2.41	9.2				63.8	24.7	0.3	2.6	7.9	0.7	0.0	304
18.00	37.6	32.1	30.4	42.3	32.3	25.3	2.40	10.3				61.7	24.1	0.6	3.5	8.9	1.3	0.3	316
19.00	41.0	28.3	30.8	44.6	29.2	26.3	3.03	9.8				60.8	19.1	1.3	4.4	12.4	1.8	0.3	388
20.00	38.4	31.3	30.3	43.1	31.7	25.2	2.63	10.2				59.8	30.3	0.0	3.2	9.0	1.5	0.3	343
21.00	40.2	28.7	31.1	43.6	29.8	26.6	2.59	9.6				60.6	27.4	0.0	2.5	9.2	0.3	0.3	325
22.00	37.7	30.3	32.0	41.8	30.0	28.1	2.69	9.3				63.4	22.6	0.6	3.5	8.9	1.0	0.3	314
23.00	37.7	31.5	30.9	41.8	32.4	25.8	2.98	9.5				57.8	25.5	1.1	4.3	9.4	1.3	0.3	372
24.00	39.8	30.5	29.8	42.7	33.0	24.2	3.50	9.5				60.3	22.1	0.7	4.3	10.2	2.1	0.2	421
25.00	38.5	31.0	30.5	42.5	32.8	24.7	3.03	11.2				58.0	27.5	0.3	2.5	11.0	1.0	0.3	400
29.00	35.7	31.5	32.8	38.5	33.8	27.8	1.72	10.4				62.1	28.0	0.0	2.9	7.0	0.0	0.0	243
30.00	34.7	33.4	31.9	38.7	34.5	26.8	2.71	10.3				61.1	27.8	0.6	2.0	6.8	1.7	0.0	352
31.00	35.0	31.5	33.5	37.9	33.8	28.3	2.46	10.6				60.3	26.8	0.0	1.6	9.0	1.9	0.3	310
32.00	35.8	31.8	32.3	39.7	32.5	27.8	2.75	10.2				64.1	24.0	0.0	2.8	7.2	1.4	0.3	362
33.00	33.2	32.9	33.9	35.8	35.4	28.8	2.08	11.1				67.8	18.1	0.5	2.6	7.9	2.9	0.3	382
34.00	35.9	34.7	29.4	40.1	35.2	24.6	2.97	11.5				58.5	20.4	0.0	5.6	12.7	2.6	0.3	378
35.00	33.0	34.6	32.3	36.0	37.0	27.0	2.27	11.5				56.3	32.9	0.7	2.0	6.4	2.7	0.0	297
36.00	47.8	24.1	28.1	52.1	25.8	22.1	4.06	10.1				60.9	33.7	0.0	0.4	2.5	2.5	0.0	276
37.00	41.8	25.2	33.0	45.8	27.7	26.5	2.41	10.3				61.3	30.3	1.2	2.5	3.7	0.6	0.0	323
38.00	43.9	24.5	31.6	46.7	28.2	25.1	2.58	10.7				68.7	25.9	0.9	1.6	2.8	3.2	0.0	316
39.00	43.2	24.8	32.0	46.4	28.9	24.7	2.84	10.4				60.4	31.3	0.0	2.5	3.6	2.5	0.0	364
40.00	41.5	27.0	31.6	45.6	29.5	24.9	2.53	10.5				60.8	28.7	0.0	3.2	3.8	2.0	1.2	342
41.00	40.9	27.6	31.5	45.1	31.1	23.9	2.63	10.3				63.6	31.0	0.5	1.9	1.9	1.1	0.0	368
42.00	43.2	24.0	32.8	46.0	29.3	24.7	2.53	10.2				55.7	34.8	0.0	3.2	3.9	3.4	0.0	348
43.00	42.0	26.2	31.8	45.9	30.2	23.9	2.47	10.0				56.2	35.4	0.0	1.9	3.4	2.2	0.3	322
44.00	43.2	23.6	33.2	46.2	27.9	25.9	2.82	10.5				55.4	33.1	0.3	4.1	4.7	2.1	0.0	341
46.00	40.6	25.5	34.0	44.6	29.5	26.0	7.91	10.3				57.6	35.3	1.3	2.3	2.6	1.0	0.0	309
47.00	42.3	23.1	34.6	45.1	28.2	26.6	2.51	10.7				54.2	35.3	0.3	4.4	2.0	3.8	0.3	343
48.00	41.0	25.9	33.1	44.9	29.2	25.8	2.37	9.9				59.5	31.8	0.3	2.2	2.8	2.2	0.9	321

T42

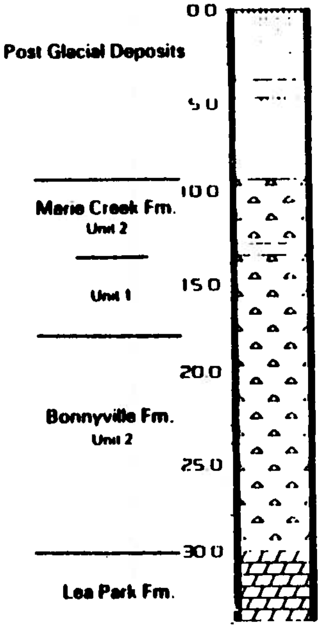
Alberta Geological Survey Testhole T 42
Location of LSD 13 Sec 5 Twp 65 Rng 3 W of 4 Mer . NTS 73L
Elevation 2030 ft 619 M Source 1 50,000 NTS 73L/9
Date drilled 19760822 logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	CST	DST	LOC	OTH	N
1.00	43.5	26.2	30.3	46.9	27.4	25.8	2.56	12.0				71.8	23.3	1.8	0.9	0.6	1.5	0.0	326
2.00	39.6	31.5	28.9	43.6	31.8	24.7	2.83	9.6				60.4	17.7	0.9	5.0	15.2	0.9	0.0	323
3.00	44.3	28.3	27.4	47.9	28.6	23.5	3.29	11.1				63.2	22.8	0.2	4.0	8.6	1.2	0.0	421
4.00	45.5	26.4	28.1	49.5	26.5	24.0	2.70	10.6				64.6	20.8	1.2	3.9	8.6	0.9	0.0	336
5.00	46.1	26.9	27.0	49.8	27.2	23.0	3.30	10.0				60.1	27.0	1.0	2.4	7.1	2.6	0.0	423
6.00	33.0	26.9	40.1	36.4	28.6	35.0	1.89	12.0				63.5	27.8	1.6	3.5	2.0	1.2	0.4	255
7.00	38.4	26.6	35.0	41.6	28.0	30.4	2.59	11.2				67.8	21.4	0.3	4.3	2.9	2.3	1.1	351
8.00	48.4	28.6	23.0	52.5	29.4	18.0	3.51	10.6				63.2	25.3	0.9	4.1	4.6	1.8	0.0	418
9.00	48.7	27.8	23.5	52.4	29.8	17.8	3.24	9.8				58.5	30.4	0.2	4.5	4.7	1.6	0.0	424
10.00	49.1	27.3	23.5	53.3	28.7	18.0	3.53	9.2				59.8	27.7	0.5	4.9	3.5	3.0	0.2	430
11.00	39.5	28.5	32.0	43.1	33.2	23.6	3.03	10.0				72.8	24.1	0.8	0.8	1.6	0.0	0.0	382
12.00	26.2	31.8	42.0	28.9	41.6	29.5	1.59	12.4				65.4	29.8	1.9	1.9	1.0	0.0	0.0	208
13.00	22.0	36.4	41.7	24.7	47.2	28.1	1.11	14.1				64.2	29.6	0.6	2.5	2.5	0.6	0.0	159
14.00	25.8	35.5	38.7	29.3	43.3	27.4	1.04	14.5				70.9	24.8	0.7	2.1	1.4	0.0	0.0	141
15.00	34.2	34.1	31.7	38.5	37.8	23.7	1.12	11.7				66.9	30.6	1.2	0.0	0.0	0.6	0.0	157
16.00	42.1	25.3	32.6	46.9	28.7	24.3	1.76	9.8				70.4	26.1	1.3	0.9	0.4	0.8	0.0	230
17.00	41.1	27.2	31.7	46.2	29.1	24.6	1.83	12.8				67.9	26.6	1.3	1.7	0.8	0.8	0.0	237
18.00	41.8	26.3	32.0	46.3	30.2	23.6	1.45	10.1				69.9	25.2	1.5	1.9	1.5	0.0	0.0	206
19.00	40.9	26.0	33.1	46.0	28.6	25.5	1.20	9.7				70.7	26.2	0.8	1.1	0.4	0.0	0.0	263
20.00								18.0											
21.00	26.6	42.5	31.0	35.4	40.9	23.7	0.88	11.4				56.6	30.1	2.9	0.7	1.5	0.7	0.0	136
22.00	24.5	45.5	29.9	35.3	41.5	23.2	0.80	14.0				62.0	32.7	0.0	1.8	2.7	0.0	0.0	113
25.00								12.7											
26.00	19.4	30.9	49.7	22.9	37.2	39.9	0.74	14.1				64.2	22.1	0.0	3.2	7.4	1.1	0.0	95
27.00	31.6	26.9	41.5	35.2	30.7	34.1	1.72	13.6				67.9	20.8	2.7	1.8	6.8	0.0	0.0	221
28.00	40.6	30.2	29.2	44.2	32.8	23.0	2.50	9.8				56.9	24.4	1.8	4.8	11.3	0.9	0.0	336
29.00	41.6	29.3	29.1	45.6	31.2	23.2	3.32	9.6				60.5	21.5	0.5	3.1	13.2	1.3	0.0	387
30.00	41.9	28.6	29.5	45.4	31.2	23.4	2.96	9.8				55.4	24.0	1.7	4.8	13.8	0.3	0.0	354
31.00	41.1	29.4	29.6	45.1	32.1	22.9	2.71	10.1				60.2	23.0	1.2	2.9	11.1	1.8	0.0	344
32.00	41.6	28.9	29.4	44.9	32.6	22.6	2.40	8.8				57.1	26.7	2.2	4.0	8.7	0.9	0.0	322
33.50	41.6	28.3	30.2	45.6	30.5	23.9	3.14	8.8				62.3	22.6	1.0	2.1	10.1	1.9	0.0	398
34.00	42.8	25.8	31.4	46.0	28.9	25.1	2.92	9.6				62.0	23.1	0.3	2.3	9.8	2.3	0.0	389
35.00	42.4	26.0	31.6	46.2	28.5	25.2	2.61	9.3				63.2	21.8	1.5	2.8	9.8	0.9	0.0	326
36.00	40.9	26.1	33.0	44.0	30.0	26.0	2.65	9.0				63.6	20.1	0.5	3.7	11.5	0.6	0.0	409
37.00	39.8	28.2	32.0	43.4	30.7	25.9	2.53	9.0				61.6	21.2	0.4	2.8	12.8	1.2	0.0	250

T43

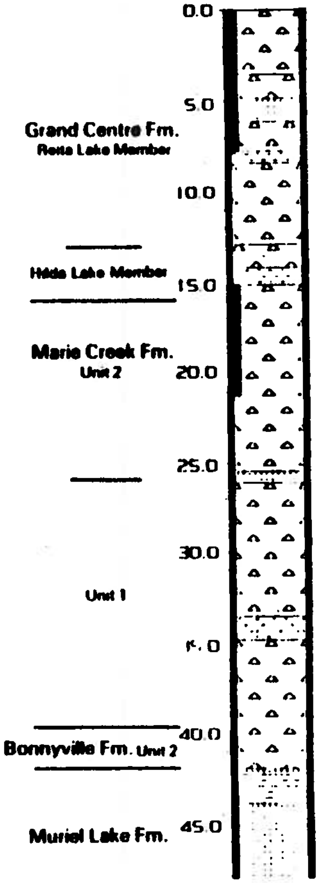
Alberta Geological Survey Testhole T 43
Location of LSD 16 Sec 26 Twp 61 Rng 7 W of 4 Mer , NTS 73L
Elevation 1800 Ft 549 M Source 1 50,000 NTS 73L/7
Date drilled 197608 26 Logged by M FENTON



DEPTH (M)	TEXTURE (%) SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	IGN MET M	COARSE SAND LITHOLOGY (%) QTZ	QTZT QSS	LST	DST	LOC	OTH	N
10 00	40 1	23 7	36 2	44 0	26 8	29 2	1 90	11 8				67 5	26 2	0 8	2 5	2 5	0 4	0 0	240
11 00	35 8	31 1	33 1	39 9	32 6	27 4	2 46	11 7				55 7	20 1	0 0	5 7	16 2	2 2	0 0	314
12 00	39 5	35 1	25 4	44 4	33 5	22 2	2 52	9 9				60 5	18 8	0 3	3 9	13 6	2 9	0 0	309
13 00																			
14 00	37 3	24 7	38 0	40 9	26 6	32 6	2 85	9 9				61 9	26 6	0 0	3 0	7 6	0 8	0 0	368
15 00	34 5	26 5	39 0	37 8	29 4	32 8	2 30	10 0				64 9	18 4	0 1	5 5	9 5	1 5	0 0	326
16 00	34 0	25 3	40 8	37 5	27 1	35 3	2 35	10 2				62 0	25 1	0 6	3 7	8 1	0 6	0 0	326
17 00	28 8	29 4	41 8	32 1	33 8	34 2	1 84	12 1				59 3	24 5	0 8	5 5	8 5	1 2	0 0	236
18 00	53 0	27 7	19 3	56 7	26 5	16 9	3 52	8 9				57 3	33 1	1 5	3 5	2 2	2 2	0 0	450
19 00	52 5	28 2	19 2	56 2	27 5	16 2	3 02	8 4				58 3	33 2	0 5	5 7	1 5	0 4	0 0	385
20 00	54 0	27 9	18 1	57 7	28 6	13 7	3 70					60 1	29 5	2 1	4 5	1 5	1 7	0 0	458
21 00	54 1	27 1	18 8	58 0	27 1	14 9	3 49	8 5				58 2	34 4	1 1	3 2	1 3	1 5	0 0	464
22 00	53 5	27 3	19 2	57 2	27 2	15 6	3 57	9 1				54 2	35 1	1 1	5 6	1 9	0 7	0 0	430
23 00	51 4	26 7	21 9	55 1	26 3	18 5	2 77	9 7				58 0	32 4	0 1	3 7	1 9	3 3	0 0	376
24 00	52 3	25 7	22 0	55 8	26 8	17 4	3 35	8 9				55 4	33 1	1 2	3 5	4 2	2 6	0 0	426
25 00	52 3	27 5	20 2	55 9	27 0	17 0	3 31	8 8				59 4	31 9	0 5	3 7	2 7	1 6	0 0	407
26 00	53 1	26 1	20 8	56 7	26 0	17 2	3 19	9 4				54 9	34 7	1 0	4 2	1 7	8 6	0 0	407
27 00	45 3	23 1	31 6	48 7	23 7	27 6	2 60	12 2				59 1	30 2	0 6	3 7	3 7	2 4	0 0	295
28 00	32 8	18 8	48 3	35 3	22 8	41 9	1 72	14 0				62 9	27 2	0 0	1 8	4 5	3 6	0 0	224
29 00	56 0	30 0	14 0	59 9	28 9	11 3	2 95	8 8				65 0	26 8	0 5	3 2	2 4	2 1	0 0	377

T44

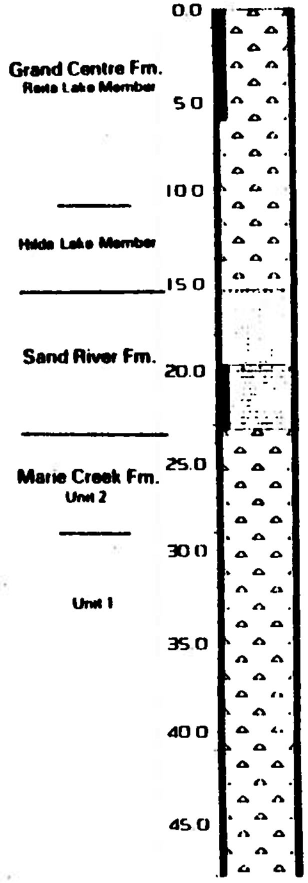
Alberta Geological Survey Testhole T 44
Location of LSD 14 Sec 24 Twp 61 Rng 6 W of 4 Mer , NTS 73L
Elevation 1825 Ft 556 M Source 1 50,000 NTS 73L/7
Date drilled 197608 27 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET M	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	37 0	23 0	40 0	41 0	24 0	35 0	1 40	13 8				72 4	21 0	1 9	0 0	0 0	4 7	0 0	214
2 00	38 0	24 0	39 0	40 0	27 0	33 0	1 70	13 1				69 1	20 6	3 1	3 6	3 6	0 0	0 0	194
3 00	43 0	23 0	34 0	46 0	25 0	28 0	1 70	10 4				68 5	27 2	0 0	1 4	1 9	0 9	0 0	213
4 00								10 3											
6 00								10 4											
7 00	42 0	24 0	33 0	47 0	25 0	28 0	1 90	10 1				68 7	26 5	0 4	1 2	2 8	0 4	0 0	249
8 00	40 0	26 0	34 0	44 0	28 0	28 0	1 60	9 7				75 1	23 5	0 0	0 5	0 5	0 0	0 5	213
9 00								9 7											
10 00	37 0	27 0	37 0	41 0	29 0	31 0	1 40	10 1				64 4	30 3	1 1	1 1	2 1	1 1	0 0	188
11 00								10 4											
12 00	23 0	26 0	52 0	25 0	33 0	42 0	0 71	11 4				67 3	28 0	0 9	0 9	1 9	0 9	0 0	107
13 00								13 3											
14 00	31 0	34 0	35 0	36 0	35 0	30 0	1 10	11 4				63 1	24 8	0 0	2 7	9 4	0 0	0 0	149
15 00	33 0	26 0	42 0	35 0	31 0	34 0	2 10	11 7				61 9	20 9	0 0	2 9	13 7	1 1	0 0	278
16 00	30 0	29 0	41 0	33 0	33 0	33 0	2 50	9 4				61 6	17 1	0 0	4 6	16 1	0 6	0 0	328
17 00	37 0	31 0	32 0	40 0	33 0	27 0	2 50	9 9				50 0	15 6	0 0	7 2	24 5	2 7	0 0	334
18 00	39 0	32 0	29 0	43 0	34 0	23 0	2 80	9 9				61 5	15 0	0 0	5 6	14 7	3 2	0 0	374
19 00	40 0	31 0	29 0	43 0	33 0	24 0	3 10	10 4				55 8	18 9	0 8	3 5	19 3	1 9	0 0	373
20 00	40 0	33 0	28 0	44 0	33 0	23 0	2 60	9 9				55 8	19 8	0 0	4 9	15 7	3 5	0 3	344
21 00	41 0	32 0	27 0	45 0	33 0	22 0	2 80	10 3				60 4	19 5	0 0	3 3	14 0	2 4	0 3	364
22 00	39 0	35 0	26 0	44 0	34 0	22 0	3 00	9 7				63 7	17 1	0 0	5 3	12 5	1 1	0 3	375
23 00	40 0	33 0	27 0	44 0	34 0	23 0	2 80	8 9				67 3	15 6	0 3	3 8	11 3	1 7	0 0	364
24 00	41 0	32 0	27 0	46 0	32 0	23 0	3 60	8 6				64 2	19 8	0 7	2 1	10 5	2 3	0 2	428
25 00	40 0	27 0	32 0	43 0	29 0	29 0	3 10					69 3	16 6	0 2	2 5	9 5	1 4	0 0	398
26 00	34 0	32 0	34 0	38 0	33 0	29 0	2 60	8 9				64 9	23 4	0 0	3 1	7 9	0 7	0 0	291
27 00	35 0	25 0	40 0	37 0	27 0	35 0	2 30	9 6				63 3	24 0	1 7	4 3	6 0	0 6	0 0	300
28 00	33 0	28 0	39 0	37 0	31 0	32 0	2 40	9 8				67 5	21 7	0 3	2 3	7 5	0 3	0 3	308
29 00	35 0	28 0	37 0	38 0	31 0	31 0	2 30					69 4	21 8	1 0	1 4	5 4	0 9	0 0	294
30 00	33 0	28 0	39 0	36 0	32 0	33 0	2 20	10 1				67 6	21 5	0 3	4 1	5 5	0 3	0 3	293
31 00	33 0	28 0	39 0	36 0	33 0	31 0	2 60	10 4				64 6	21 6	0 0	1 2	11 4	0 9	0 3	333
32 00	32 0	25 0	43 0	34 0	30 0	36 0	2 70	10 9				68 4	22 4	0 3	2 1	5 9	0 6	0 0	339
33 50	31 0	27 0	42 0	34 0	31 0	35 0	2 70	8 9				66 9	24 1	0 3	1 4	6 7	0 6	0 0	344
35 00	40 0	26 0	35 0	41 0	29 0	29 0	2 60					65 8	27 4	0 0	1 2	5 2	0 3	0 0	328
36 50	43 0	25 0	33 0	46 0	27 0	27 0	2 40	9 1				65 4	25 4	0 3	3 1	4 8	0 9	0 0	350
39 50	49 0	29 0	22 0	52 0	30 0	18 0	2 40					56 2	35 9	2 4	0 0	1 8	0 3	0 3	292
40 00	45 0	28 0	27 0	49 0	29 0	22 0	1 40	7 5				57 4	36 8	2 1	0 5	0 0	1 5	0 5	190
41 00	45 0	24 0	31 0	48 0	27 0	25 0	1 50	9 8				59 0	32 2	2 4	2 9	2 9	0 0	0 0	205
42 50								15 0											
43 00								16 6											

T45

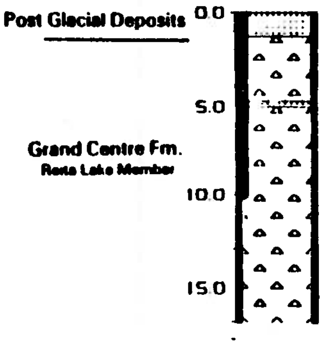
Alberta Geological Survey Testhole 1 15
Location of LSD 1 Sec 9 Twp 60 Rng 7 W of 4 Mer . NTS 73L
Elevation 2000 Ft 610 M Source 1:50,000 NTS 73L/2
Date drilled 19760828 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MTM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00								9.7											
2.00	41.5	40.3	18.2	47.0	39.4	13.7	2.41	8.8	50.0	20.8	0.17	59.3	20.7	0.0	5.2	13.1	1.4	0.0	290
3.00	34.1	31.3	34.6	38.0	33.2	28.8	1.72	10.9	25.3	10.6	0.28	66.7	24.6	0.8	3.6	2.8	1.6	0.0	252
4.00	39.4	22.7	37.9	42.6	25.2	32.1	2.03	13.0	22.8	9.5	0.25	69.5	23.0	2.3	1.9	2.8	0.5	0.0	213
5.00	35.0	27.9	37.1	38.7	30.1	31.2	1.66	12.3	22.4	9.4	0.36	70.5	21.9	0.4	3.4	2.6	1.2	0.0	234
6.00	30.6	28.0	41.4	34.3	29.8	35.8	1.15	11.9	22.5	9.5	0.31	66.5	26.2	0.0	3.0	3.0	0.8	0.0	164
7.00	30.7	27.9	41.4	34.5	30.0	35.5	1.23	11.9	23.8	10.0	0.28	63.0	26.1	1.2	2.5	2.5	4.4	0.0	157
8.00	38.4	28.3	33.3	42.8	29.3	27.9	1.31	11.1	27.6	11.5	0.23	69.6	25.6	0.6	2.4	1.2	0.6	0.0	168
9.00	36.9	27.3	35.7	41.1	28.9	29.9	1.18	11.1	27.3	11.4	0.25	70.8	23.2	1.3	2.0	2.6	0.0	0.0	151
10.00	32.9	28.1	39.0	36.6	30.6	32.7	1.10	10.6	26.9	11.3	0.24	75.9	18.4	0.0	0.7	2.1	2.8	0.0	141
11.00	26.8	25.3	48.0	30.0	29.9	40.1	0.89	12.5	27.9	11.6	0.22	73.0	23.5	0.9	1.7	0.0	0.9	0.0	115
12.00	28.8	26.0	45.2	32.2	29.9	37.9	1.16	11.4	27.7	11.6	0.27	67.8	24.6	1.7	1.7	2.5	1.7	0.0	118
13.00	21.5	29.5	49.0	24.6	34.8	40.7	0.55	11.8	30.6	12.7	0.19	72.8	21.0	1.2	2.5	1.2	1.2	0.0	81
14.00	29.9	23.7	46.4	33.2	28.5	38.3	1.25	11.6	26.4	11.0	0.17	77.8	18.4	1.2	0.0	0.6	1.2	0.0	162
15.00	24.3	23.1	52.6	27.4	28.9	43.8	0.68	11.7	24.9	10.4	0.21	70.7	19.0	0.0	1.7	8.6	0.0	0.0	58
20.00								19.8											
21.00								18.5											
22.00								20.0											
23.00								21.2											
24.00	37.6	32.4	29.9	41.6	34.2	24.2	2.81	10.5	44.9	18.7	0.14	57.3	19.3	0.6	4.0	17.0	1.7	0.0	347
25.00	36.9	32.3	30.8	41.1	34.0	24.9	2.72	10.6				60.1	19.5	0.3	5.0	12.9	2.1	0.0	318
26.00	36.9	32.7	30.3	41.0	34.6	24.4	2.62	10.9	46.7	19.4	0.15	56.4	20.2	0.6	1.0	15.1	2.5	0.0	312
27.00	36.4	33.8	29.9	40.5	35.7	23.8	2.70	10.5				61.4	18.4	1.2	4.1	12.9	2.1	0.0	342
28.00	35.6	34.4	30.0	39.5	36.3	24.2	2.75	10.5	41.8	17.4	0.16	59.3	21.9	0.3	4.1	10.4	3.6	0.0	337
29.00	33.1	31.2	35.6	36.7	34.7	28.6	2.22	10.8				69.5	16.5	0.7	2.8	8.4	2.0	0.0	285
30.00	35.2	29.1	35.7	38.7	32.8	28.5	2.42	10.7	35.5	14.8	0.19	61.7	22.9	0.3	4.4	6.2	1.7	0.0	292
31.00	33.4	31.5	35.1	37.1	35.6	27.3	2.15	11.0				66.3	19.0	1.3	2.7	8.5	1.7	0.0	294
32.00	33.4	31.3	35.3	36.9	34.3	28.8	2.25	11.1	35.1	14.6	0.16	60.3	25.1	1.4	1.7	9.7	1.7	0.0	287
33.50	32.9	30.9	36.2	36.5	34.7	28.8	2.15					61.3	25.3	1.0	2.8	5.6	3.8	0.0	284
34.00	26.6	33.5	39.8	30.4	37.5	32.1	2.12	11.2	41.9	17.4	0.16	63.2	20.1	0.7	3.3	10.8	1.8	0.0	269
35.00	31.0	29.4	39.5	34.4	33.5	32.1	2.31	10.6				60.7	22.7	0.3	4.1	10.0	2.0	0.0	290
36.50	32.5	29.0	38.5	36.2	32.9	30.9	2.07	10.5	35.8	14.9	0.19	66.2	23.3	0.7	3.0	3.7	2.3	0.0	266
37.00	19.6	26.4	54.0	22.4	32.8	44.8	1.07	12.8	32.4	13.5	0.21	64.9	26.3	0.7	2.0	4.0	1.3	0.0	148
38.00	15.1	28.6	56.3	17.6	36.3	46.1	0.80	13.2	31.9	13.3	0.17	70.0	18.2	0.9	0.9	7.3	2.7	0.0	110
39.50	27.0	29.8	43.2	30.4	34.6	35.0	1.76	11.5				70.0	16.7	0.4	1.7	11.0	2.2	0.0	228
40.00	33.1	28.6	38.3	36.6	32.6	30.7	2.61	11.1	35.2	14.7	0.22	69.1	19.9	0.3	2.5	6.9	1.2	0.0	317
41.00	31.6	29.8	38.6	31.9	33.3	31.8	1.94	11.3	34.1	14.2	0.18	65.0	18.7	0.4	5.0	10.1	0.8	0.0	257
42.50	31.7	30.3	37.9	35.3	33.6	31.1	2.22	10.9	35.6	14.8	0.17	69.5	21.5	0.3	1.0	6.1	1.3	0.0	298
43.00	32.3	28.7	39.0	35.6	31.9	32.5	2.13	10.6	36.7	15.3	0.22	65.6	24.5	0.7	1.5	7.3	0.4	0.0	277
44.00																			
45.00	32.1	30.7	37.0	35.8	33.9	30.3	2.47	13.8	36.9	15.1	0.22	65.2	24.4	0.7	1.7	6.7	0.6	0.0	299
46.00	31.5	30.3	38.2	34.9	31.8	33.3	2.00	10.9	36.8	15.4	0.21	62.4	26.9	0.0	5.1	4.3	0.8	0.0	253
47.00	27.6	29.3	43.1	30.9	33.4	35.7	1.74	12.2	35.0	14.6	0.21	58.4	22.5	0.0	5.2	11.7	2.2	0.0	231

T46

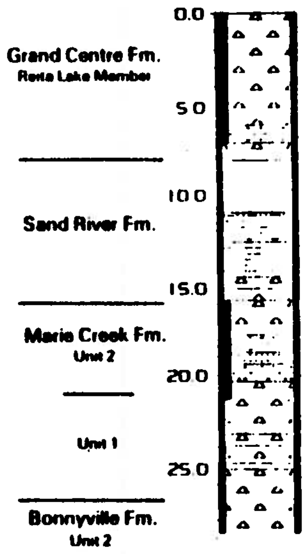
Alberta Geological Survey Testhole T 46
Location of LSD 16 Sec 23 Twp 60 Rng 6 W of 4 Mer , NTS 73L
Elevation 2020 Ft 616 M Source 1 50,000 NTS 73L/2
Date drilled 197608 29 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET M	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
2 00	33 8	25 3	40 9	37 6	26 6	35 7	1 50	13 5				65 0	32 0	2 5	0 0	0 0	0 5	0 0	203
3 00	35 3	27 7	37 0	38 5	29 8	31 7	1 28	12 1				66 1	27 9	1 8	0 0	4 2	0 0	0 0	165
4 00	35 0	27 9	37 1	39 3	28 8	31 9	1 58	13 2				67 2	22 4	0 4	1 7	4 3	3 9	0 0	232
5 00	36 7	26 1	37 2	40 0	28 6	31 3	1 64	13 1											
6 00	44 6	25 8	29 6	49 6	26 5	23 9	2 35	11 2				67 1	26 8	0 7	2 1	3 2	0 3	0 0	280
7 00	35 5	37 8	26 6	40 5	37 9	21 6	1 33	10 2				70 0	21 0	0 0	3 0	1 8	0 6	0 0	167
8 00	35 4	36 0	28 7	41 0	36 0	22 9	1 43	9 8				68 9	26 7	2 2	0 0	1 1	1 1	0 0	180
9 00	41 5	23 5	35 0	44 6	26 4	29 0	1 55	10 8											
10 00	38 4	26 0	35 6	42 9	28 2	28 9	1 62	10 5				71 7	23 6	0 5	0 9	2 8	0 5	0 0	212
11 00	39 4	25 8	34 8	42 7	28 1	29 2	1 76	10 6											
12 00	38 1	26 8	35 2	42 5	29 0	28 5	1 38	10 3				72 2	21 1	0 5	2 6	4 1	0 0	0 0	194
13 00	39 3	26 4	34 3	42 9	29 7	27 4	1 55	10 7											
14 00	36 9	26 0	37 1	41 2	30 3	28 5	1 60	10 4				62 0	33 0	1 3	2 2	0 9	0 4	0 0	224
15 00	38 6	25 4	36 0	41 8	28 3	29 9	1 53	10 5											
16 00	35 6	26 5	38 0	39 7	29 0	31 3	1 50	11 1				64 8	31 2	0 0	1 0	2 5	0 5	0 0	202
17 00	33 9	28 2	37 8	37 4	32 4	30 2	1 48	10 3											

T47

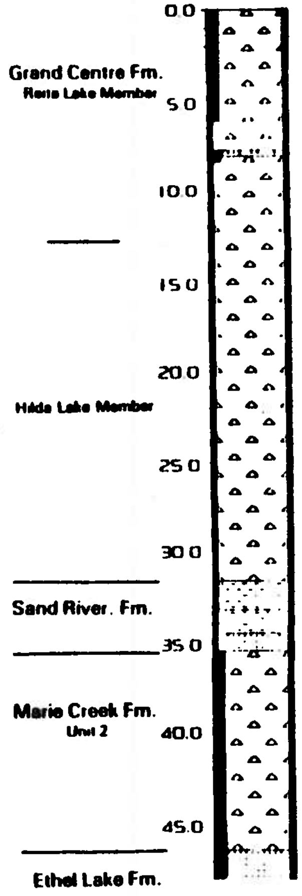
Alberta Geological Survey Testhole T 47
Location of LSD 12 Sec 16 Twp 60 Rng 6 W of 4 Mer . NTS 73L
Elevation 1855 Ft 566 M Source 1 50,000 NTS 73L/2
Date drilled 197608 24 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SU 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	36 6	25 2	38 3	40 4	25 9	33 6	1 38	11 7											
2 00	37 0	23 8	39 2	40 0	26 2	33 9	1 45	8 9				57 8	37 5	0 5	0 0	3 6	0 5	0 0	192
3 00	35 4	28 0	36 6	40 3	28 6	31 0	1 61	13 0											
4 00	36 7	28 0	35 3	40 2	29 9	29 9	1 49	12 8				65 0	25 0	0 5	1 5	7 5	1 0	0 0	200
5 00	32 2	31 9	35 8	37 5	32 1	30 3	1 11	13 7											
6 00	4 3	16 7	59 0	6 3	43 3	50 4	0 12	16 9				54 5	0 0	18 2	9 1	0 0	18 2	0 0	11
7 00	20 1	37 0	42 9	23 2	45 1	31 7	0 70	11 7											
8 00	40 2	26 1	33 6	43 6	29 1	27 4	1 45	9 6				77 0	21 3	1 7	0 6	3 9	0 0	0 0	178
11 00								12 6											
12 00								11 9											
13 00								15 4											
14 00								15 6											
15 00	17 4	23 9	58 7	19 9	37 6	42 5	1 11	14 6				52 6	21 4	0 3	6 9	17 1	1 6	0 0	304
16 00	31 9	34 9	33 2	34 7	38 6	26 7	2 52	12 0											
17 00	31 6	43 5	24 9	35 0	45 7	19 3	2 04	10 6											
17 50	40 3	38 2	21 5	43 0	40 5	16 5	2 67	10 2				54 8	21 8	0 0	3 1	14 0	3 1	0 0	350
19 00																			
20 00																			
21 00	30 3	33 2	36 5	33 8	36 0	30 3	1 97	10 8				59 7	28 4	0 4	1 6	9 3	0 8	0 0	246
22 00	27 6	32 6	39 8	30 2	37 5	32 3	1 70												
23 00	24 6	34 9	40 5	27 9	38 4	33 7	1 80					62 8	27 8	0 0	2 7	4 9	1 8	0 0	223
24 00	6 3	37 0	56 7	7 8	47 0	45 2	0 27	15 9											
25 00	29 8	30 8	39 4	32 9	34 7	32 4	2 06					63 4	27 2	0 0	3 2	6 1	0 7	0 0	279
26 00	25 3	33 3	41 5	28 0	38 3	33 7	1 95	10 4				57 9	31 6	0 0	3 6	6 1	0 8	0 0	247
27 00	41 1	33 9	25 0	46 6	33 8	19 6	1 94	10 1				56 3	37 1	0 0	3 3	2 8	0 4	0 0	245
28 00	38 3	28 0	33 7	41 2	33 5	25 3	1 86	9 8				47 8	42 7	1 5	5 1	2 0	0 8	0 0	255

T48

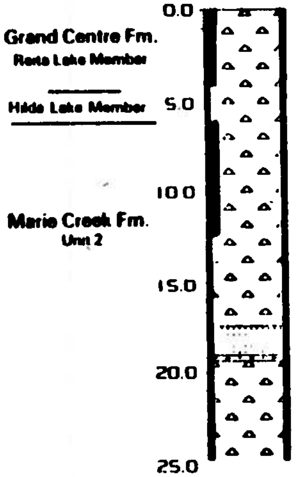
Alberta Geological Survey Testhole T 48
Location of LSD 4 Sec 28 Twp 60 Rng 4 W of 4 Mer , NTS 73L
Elevation 1950 Ft 595 M Source 1 50,000 NTS 73L/2
Date drilled 197608 30 Logged by M FENTON



DEPTH (M)	TEXTURE (%) SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT USS	LST	DST	LOC	OTH	N
1 00	35 4	24 9	39 6	39 5	26 0	34 5	1 38	11 7	7 6	3 3	1 28	69 7	27 4	1 7	0 0	0 0	1 1	0 0	175
2 00	36 0	28 1	35 9	39 5	30 9	29 6	1 33	11 3	32 7	13 8	0 48	67 9	25 5	2 2	1 6	2 2	0 5	0 0	184
3 00	36 3	28 6	35 1	40 5	29 0	30 5	1 73	12 1	30 4	12 7	0 29	70 5	24 2	1 8	1 3	1 8	0 4	0 0	227
4 00	38 7	28 2	33 1	42 5	29 6	27 9	1 73	12 6	31 5	13 2	0 28	68 7	25 1	0 9	0 5	2 4	2 4	0 0	211
5 00	34 8	27 9	37 3	38 6	29 5	31 9	1 45	13 3	31 3	13 1	0 26	69 8	24 3	1 0	1 5	3 0	0 0	0 5	202
6 00	37 5	27 8	34 7	42 0	29 0	29 1	1 48	13 4	33 3	13 9	0 27	70 3	28 2	1 0	0 5	0 0	0 0	0 0	195
7 00	34 0	28 4	37 6	38 2	29 9	31 9	1 37	13 3	36 2	15 1	0 26	65 9	28 1	0 0	2 2	3 2	0 5	0 0	185
8 00								9 8											
9 00	36 1	30 4	33 5	41 8	30 7	27 6	1 64	10 6	28 0	11 7	0 24	77 1	21 3	0 0	1 0	3 5	0 0	0 0	202
10 00	35 4	29 7	35 0	39 6	31 5	28 9	1 57	12 3	26 2	10 9	0 22	78 4	18 4	0 5	2 2	0 0	0 5	0 0	185
11 00	28 2	26 1	45 7	30 8	32 6	36 5	0 71	12 5	28 3	11 8	0 27	75 7	21 4	1 9	1 0	0 0	0 0	0 0	103
12 00	46 2	23 4	30 4	49 7	24 9	25 4	1 94	9 9	21 8	9 1	0 14	79 1	19 8	1 1	0 0	0 0	0 0	0 0	273
13 00								15 9											
14 00								16 1											
15 00								13 7											
16 00								13 4											
17 00								16 0											
18 00	24 0	26 5	49 5	26 9	33 5	39 7	0 72	14 1	28 1	11 7	0 22	77 3	18 2	2 3	0 0	2 3	0 0	0 0	88
19 00	25 9	27 6	46 5	28 8	33 0	38 2	0 82	13 8	26 0	10 8	0 19	76 7	19 8	1 7	0 9	0 9	0 0	0 0	116
20 00	22 5	26 8	50 7	25 2	34 0	40 8	0 72	14 2	28 7	12 0	0 21	70 8	24 0	2 1	2 1	1 0	0 0	0 0	96
21 00	24 1	26 4	49 5	26 6	32 2	41 2	0 69	14 0	25 9	10 8	0 23	77 9	16 3	2 9	2 9	0 0	0 0	0 0	104
22 00	24 8	27 0	48 2	27 8	33 2	38 9	0 75	14 4	28 2	11 8	0 32	79 6	19 4	0 0	0 0	0 0	1 1	0 0	93
23 00	15 8	25 7	58 5	17 7	33 7	48 6	0 62	16 0	27 1	11 4	0 34	81 2	17 4	0 0	1 4	0 0	0 0	0 0	69
24 00	23 8	28 5	47 7	26 7	35 2	38 1	0 75	13 5	28 4	11 9	0 30	71 7	21 7	1 9	1 9	0 0	2 8	0 0	106
25 00	18 5	23 3	58 2	20 3	30 5	49 3	0 53	13 5	26 7	11 2	0 32	81 8	14 3	0 0	2 6	0 0	0 0	1 3	77
26 00	23 9	26 6	49 5	26 6	33 3	40 0	0 70	13 7	29 6	12 4	0 24	75 8	20 0	0 0	2 1	1 1	0 0	1 1	95
27 00	25 6	27 1	47 3	28 6	34 0	37 4	0 99	13 1	29 4	12 3	0 25	75 2	19 7	2 6	0 0	2 6	0 0	0 0	117
28 00	24 4	26 5	49 1	27 2	34 7	38 1	0 75	13 8	27 8	11 7	0 27	77 0	21 0	0 0	0 0	2 0	0 0	0 0	100
29 00	22 8	24 8	52 4	25 5	32 4	42 1	0 70	14 5	26 8	11 2	0 27	78 6	18 8	0 9	1 7	0 0	0 0	0 0	117
30 00	23 9	25 8	50 3	26 4	34 3	39 3	0 91	11 4	28 2	11 8	0 21	75 3	20 4	1 1	1 1	1 1	1 1	0 0	93
31 00	21 4	29 6	49 0	27 0	33 8	39 2	0 82	13 3	27 6	11 5	0 23	71 3	22 2	0 9	3 7	0 0	0 0	1 9	108
32 00								20 0											
33 00								14 2											
35 00	37 2	32 0	30 9	40 9	35 4	23 7	2 16	9 8	49 5	20 6	0 19	56 3	21 1	0 4	5 7	14 0	2 2	0 4	279
36 50	39 8	36 1	24 1	45 1	35 2	19 7	2 54	10 0	45 6	19 0	0 17	54 5	25 4	0 0	4 3	11 8	3 7	0 3	323
37 00	42 0	35 5	22 5	47 0	35 6	17 4	2 64	9 7	48 1	20 0	0 12	61 6	23 8	0 0	4 8	9 2	0 6	0 0	357
38 00	41 0	34 8	24 2	45 3	35 3	19 4	2 93		46 8	19 5	0 16	57 1	23 2	0 0	4 5	13 3	1 9	0 0	375
39 50	39 8	38 6	21 6	44 7	39 1	16 2	2 76	11 2	50 5	21 0	0 13	52 7	25 4	0 0	6 5	13 6	1 8	0 0	338
40 00	33 0	46 4	20 6	37 1	47 5	15 4	2 09	11 9	52 7	21 9	0 10	53 0	21 4	0 0	5 6	17 9	1 7	0 0	234
41 00	33 4	44 5	22 2	35 0	48 7	16 3	6 38	8 6	50 6	21 0	0 13	59 4	17 6	0 0	7 9	14 0	0 7	0 0	278
42 50	35 2	39 3	25 5	38 5	42 9	18 7	2 22	9 1	47 5	19 7	0 12	64 2	21 4	0 0	3 2	10 2	1 1	0 0	285
43 00	33 8	38 4	27 7	38 5	41 5	20 0	2 60	9 1	45 6	19 0	0 19	60 1	22 1	0 0	2 7	13 0	1 8	0 0	331
44 00	37 4	34 7	27 9	41 7	36 5	21 8	2 57	7 8	41 6	17 3	0 13	59 0	23 5	0 3	4 3	12 3	0 3	0 0	324
45 00	38 6	35 4	26 0	42 6	38 6	18 9	2 16	8 8	46 0	19 1	0 17	54 4	23 5	0 3	4 4	16 7	0 7	0 0	294
46 00																			
47 00																			

T49

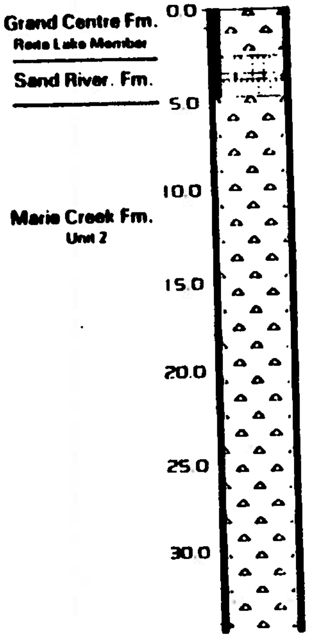
Alberta Geological Survey Testhole T 49
Location of LSD 16 Sec 12 Twp 61 Rng 5 W of 4 Mer . NTS 73L
Elevation 1805 Ft 550 M Source 1 50,000 NTS 73L/7
Date drilled 197706 24 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1.00	37.9	25.7	36.4	42.0	27.2	30.8	1.64	14.5				69.0	26.4	0.0	2.2	2.2	0.0	0.0	223
2.00	38.4	25.7	35.9	41.9	28.4	29.7	1.75	13.1				69.8	16.8	1.5	2.0	4.9	1.0	1.5	202
3.00	41.0	25.5	33.5	45.3	26.4	28.3	1.89	14.0				70.5	24.5	0.0	0.8	3.3	0.8	0.0	241
4.00	39.9	24.6	35.5	43.2	27.0	29.7	1.54	13.7				74.2	19.2	0.5	1.4	4.2	0.5	0.0	213
5.00	32.5	25.0	42.5	36.2	27.8	36.0	1.61	16.2				78.1	16.5	0.0	1.4	3.4	0.5	0.0	206
6.00	21.7	26.2	52.0	24.3	35.0	40.6	1.14	13.7				69.1	19.5	0.0	3.3	8.0	0.0	0.0	149
7.00	42.5	34.2	23.3	47.2	34.5	18.3	3.29	10.3				61.4	17.9	0.2	4.1	14.0	1.9	0.2	386
8.00	39.7	35.8	24.5	44.6	36.4	19.0	3.10	10.7				52.2	18.4	0.0	4.8	22.5	1.7	0.2	391
9.00	41.8	35.5	22.8	46.3	35.9	17.8	3.15	10.5				60.4	16.3	0.2	5.3	15.3	2.2	0.0	392
10.00	42.1	36.7	21.3	46.0	37.6	16.4	3.25	9.9				60.0	22.1	0.2	6.3	10.3	1.0	0.0	398
11.00	40.9	39.5	19.6	48.3	37.7	14.0	3.37	9.3				58.9	18.0	0.2	3.7	16.1	2.6	0.5	428
12.00	43.5	35.8	20.7	49.6	34.8	15.6	3.13	9.8				61.5	21.5	0.5	3.9	11.0	1.6	0.0	382
13.00	39.9	37.8	22.3	46.1	37.3	16.5	2.70	8.6				59.3	18.1	0.0	6.7	14.5	1.1	0.0	359
14.00	44.0	33.9	22.1	49.1	34.2	16.7	4.48					61.0	14.6	0.2	2.3	20.3	1.4	0.0	513
15.00	43.8	35.1	21.0	50.5	34.5	15.0	5.19	6.8				59.2	20.8	0.0	5.3	13.5	1.0	0.0	605
16.00	41.0	40.3	18.7	47.7	38.4	13.9	3.25	8.1				59.6	18.7	0.5	4.2	14.8	0.8	0.5	384
17.00	40.3	40.7	19.0	47.7	39.2	13.1	2.93	6.9				61.6	22.7	0.0	2.7	12.1	0.0	0.0	255
19.00								14.9											
20.00	34.4	48.3	17.2	42.2	45.2	12.6	2.11	12.0				58.4	18.2	0.3	2.9	18.2	1.6	0.3	373
22.00	36.7	31.3	31.9	41.0	34.8	24.2	2.58	8.7				65.3	24.2	0.6	2.4	7.2	0.3	0.0	334
23.00	47.2	32.8	20.0	52.6	32.6	14.9	3.19	8.1				63.2	26.0	0.5	3.4	6.4	0.5	0.0	408
24.00	47.2	32.4	20.5	52.8	31.9	15.3	3.44	8.6				65.9	24.3	0.0	3.0	6.0	0.5	0.0	399
26.00	43.1	32.0	24.9	48.0	32.6	19.4	2.76	8.8				59.4	26.7	0.8	3.5	9.2	0.3	0.0	370

T50

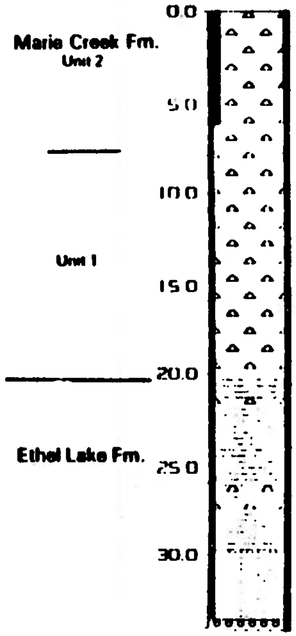
Alberta Geological Survey Testhole T 50
Location of LSD 16 Sec 10 Twp 58 Rng 5 W of 4 Mer , NTS 73L
Elevation 2115 Ft 645 M Source 1 50,000 NTS 73L/2
Date drilled 197609 10 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	43 4	22 9	33 7	47 3	21 3	29 4	1 62	10 8				73 2	23 7	1 5	0 0	0 0	1 5	0 0	198
2 00	45 4	23 5	31 1	48 3	25 1	26 6	1 36	10 1				65 2	25 7	2 1	0 5	3 7	2 1	0 5	187
6 00	45 5	28 3	26 1	50 0	30 3	19 7	2 99	9 1				68 5	26 7	0 3	2 1	1 6	0 6	0 3	375
7 00	48 2	24 7	27 0	51 2	28 6	20 2	3 79	8 7				69 9	26 5	0 0	0 8	1 7	0 6	0 4	479
8 00	42 9	26 8	30 3	46 8	29 8	23 4	2 55	9 5				60 9	31 7	0 6	3 1	1 5	1 8	0 3	322
9 00	43 5	25 8	30 7	46 5	29 7	23 8	2 64	9 4				54 6	34 5	0 0	5 3	3 3	1 3	0 8	359
10 00	44 7	25 5	29 7	48 7	28 4	22 8	2 63	10 1				62 9	30 2	0 3	2 5	2 5	1 3	0 3	364
11 00	42 7	27 0	30 3	45 6	30 8	23 6	2 51	10 7				63 8	26 8	0 3	3 9	3 9	0 9	0 3	332
12 00	45 9	27 4	26 7	50 4	28 8	20 8	2 84	9 9				64 4	27 7	0 5	1 6	4 1	1 2	0 5	365
13 00	43 4	26 3	30 2	46 4	30 0	23 6	2 66	9 9				67 9	25 8	0 9	2 4	1 5	0 9	0 0	337
14 00	41 9	26 7	31 4	45 9	29 6	24 5	2 58	9 7				64 1	26 8	0 3	4 9	2 8	1 2	0 3	351
15 00	43 6	25 4	31 0	46 4	29 2	24 4	2 70	9 9				62 9	27 0	0 3	3 5	3 8	1 5	0 3	340
16 00	41 3	27 2	31 5	45 2	30 1	24 7	2 29	9 7				69 4	24 6	0 3	3 6	0 7	1 3	0 0	301
17 00	43 2	25 2	31 6	46 0	29 0	25 0	2 66	10 1				68 4	24 8	0 3	3 7	1 7	1 2	0 0	351
18 00	40 4	28 5	31 1	44 4	31 6	24 1	2 57	9 9				67 7	22 9	0 6	3 4	2 3	3 1	0 0	353
19 00	43 3	25 2	31 5	46 3	28 7	25 0	2 38	9 8				70 8	23 2	0 0	3 5	1 3	0 6	0 3	315
20 00	41 6	27 2	31 2	45 5	29 8	24 6	2 55	9 8				67 8	27 2	0 0	4 5	3 0	1 2	0 0	336
21 00	43 3	25 7	31 0	46 2	29 2	24 6	2 51	10 9				69 0	24 1	0 3	1 8	2 7	1 8	0 3	336
22 00	41 7	26 1	32 2	45 8	28 5	25 8	2 71	11 0				65 2	26 1	0 8	3 0	2 7	1 3	0 3	371
23 00	43 0	24 1	33 0	45 7	29 1	25 3	2 28	11 0				64 9	25 1	0 3	3 4	3 4	1 8	0 3	319
24 00	43 0	24 9	32 1	45 8	29 4	24 7	2 37	10 8				67 0	24 2	0 0	4 1	3 4	1 2	0 0	318
25 00	41 2	26 1	32 7	45 1	29 8	25 1	2 49	11 1				68 3	23 3	0.0	3 2	2 9	1 5	0 6	347
26 00	42 8	24 7	32 5	45 9	29 3	24 9	2 26	11 0				65 4	25 6	0 6	1 9	3 2	2 2	0 6	312
27 00	43 0	26 4	30 5	47 2	28 7	24 1	2 32	10 6				65 2	28 2	0 0	2 7	2 1	1 5	0 0	333
28 00	44 4	25 5	30 1	47 4	29 0	23 6	2 40	10 9				66 7	26 1	0 6	3 6	1 2	0.9	0 9	330
32 00	42 0	27 1	30 8	45 9	29 8	24 3	2 52	11 1				68 0	24 5	0 3	4 0	3 2	0 0	0 0	347
33 50	43 5	25 5	31 0	46 4	29 0	24 5	2 84	11 1				69 1	23 5	0 0	3 1	3 4	0 3	0 3	353
34 00	47 9	21 6	30 4	51 6	24 4	24 1	3 12	11 1				63 3	28 3	0 2	2 6	4 1	0 9	0.2	417

T51

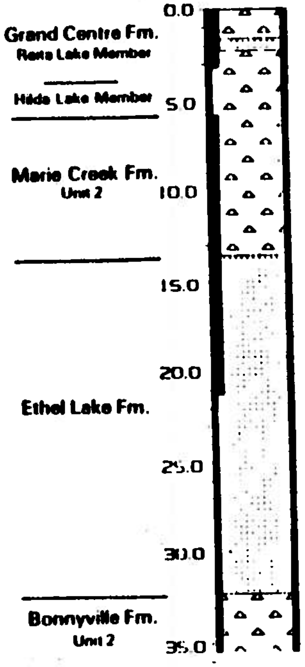
Alberta Geological Survey Testhole T 51
Location of LSD 1 Sec 17 Twp 59 Rng 7 W of 4 Mer , NTS 73L
Elevation 2105 Ft 642 M Source 1 50,000 NTS 73L/1
Date drilled 197609 02 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	COC	OTH	N
1 00								11 8											
2 00								10 6				71 2	17 3	0 0	2 7	6 1	2 3	0 5	825
3 00	27 9	37 6	34 6	31 8	40 5	27 7	2 15	9 5				59 6	10 7	0 0	2 9	25 0	1 1	0 7	280
4 00	35 4	30 9	33 7	39 5	32 9	27 7	2 54	11 0				73 8	14 2	0 7	1 3	7 9	2 0	0 0	302
5 00	36 2	29 5	34 3	39 9	32 2	27 9	2 58	9 9				66 1	16 5	0 6	2 0	10 8	2 0	0 3	351
6 00	33 8	32 7	33 5	37 6	34 7	27 7	2 39	9 9				62 7	22 8	0 0	1 7	11 3	0 7	0 7	302
7 00	36 0	30 0	34 0	39 8	32 7	27 4	2 71	9 8				69 2	19 5	0 0	3 0	6 5	0 9	0 9	338
8 00	33 5	31 6	34 8	37 6	34 8	27 6	2 27	10 1				68 0	19 0	0 0	2 0	9 2	1 4	0 3	294
9 00	38 8	28 2	33 0	42 7	30 6	26 7	3 18	9 5				66 2	18 8	0 5	4 1	9 2	0 7	0 3	393
10 00	38 7	29 3	32 0	42 8	31 9	25 3	3 38	10 6				67 1	25 5	0 2	1 7	4 7	0 7	0 0	404
11 00	33 8	31 0	35 1	37 6	35 1	27 3	2 18	10 1				60 3	24 3	0 3	2 2	11 4	1 3	0 0	317
12 00	35 8	30 2	34 0	39 8	32 8	27 4	3 24	10 8				65 8	20 9	0 0	3 4	8 8	0 7	0.2	407
13 00	26 4	29 7	43 9	29 7	36 3	34 0	1 79	11 3				72 6	18 5	0 0	2 6	5 7	0 0	0 4	227
14 00	34 9	28 0	37 0	38 7	31 3	30 0	2 45	10 5				67 6	21 7	0 0	3 1	6 9	0 6	0 0	318
15 00	33 6	30 6	35 8	37 2	34 6	28 3	2 53	10 2				63 9	27 2	0 3	2 4	5 2	0 6	0 0	327
16 00	33 7	28 0	38 4	37 3	31 5	31 1	2 37	10 5				70 0	18 2	0 3	3 7	6 7	0 7	0 3	297
17 00	32 7	30 2	37 1	36 3	33 7	30 0	2 21	10 7				66 8	21 1	0 7	3 1	6 9	1 0	0 0	289
18 00	34 1	28 0	37 9	38 0	30 9	31 1	2 19	6 1				61 6	23 5	0 3	2 9	9 5	2 2	0.0	315
19 00	30 5	29 8	39 7	34 0	34 3	31 7	2 15	6 3				68 9	16 1	0 0	2 4	10 8	1 7	0 0	286
20 00	33 8	28 5	37 7	37 6	32 1	30 3	2 15	5 3				64 2	26 4	0 7	2 0	6 4	0 3	0.0	299
21 00								19 3											
22 00								15 1											
23 00								15 4											
24 00								16 7											
25 00	8 8	27 0	64 2	10 3	37 1	52 7	0 54	15 1				74 6	21 1	0 0	1 4	2 8	0 0	0 0	71
26 00	10 0	27 4	62 6	11 7	36 5	51 8	0 59	13 3				72 9	20 0	0 0	1 2	4 7	1 2	0 0	85
27 00								16 3											
28 00								16 2											

T52

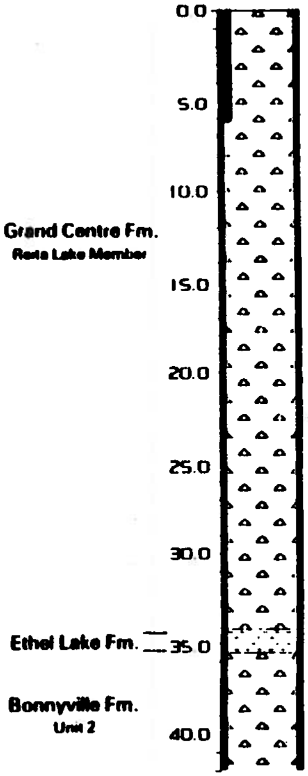
Alberta Geological Survey Testhole T 52
Location of LSD 3 Sec 5 Twp 60 Rng 4 W of 4 Mer , NTS 73L
Elevation 1970 Ft 601 M Source 1 50,000 NTS 73L/2
Date drilled 197609 03 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	41 4	18 7	39 9	44 3	20 1	35 7	1 78	10 8				73 8	26 2	0 9	0 0	0.0	0 0	0 0	214
2 00																			
3 00	36 8	26 5	36 7	42 5	26 8	30 7	1 58	12 1				68 7	26 4	1 9	1 0	1 4	0 5	0 0	208
4 00	35 4	26 8	37 8	38 3	29 7	32 0	1 29	12 8				68 4	25 9	0 6	1 7	2 3	1 1	0 0	174
5 50	15 7	30 1	54 2	17 9	35 7	46 4	0 72					67 3	29 7	0 0	3 0	0 0	0 0	0 0	101
6 00	41 0	29 9	29 1	43 9	32 1	24 0	3 43	10 4				52 1	25 3	0 0	6 9	13 4	0 0	0 0	418
7 00	40 2	31 3	28 6	44 5	31 7	23 8	2 99	11 3											
8 00	39 8	30 2	29 9	42 6	32 5	24 9	3 34	11 4				56 6	23 0	0 5	4 8	12 6	2 4	0 0	413
9 00	40 1	33 1	26 8	44 1	33 6	22 2	3 10	11 1											
10 00	41 6	30 8	27 5	43 9	33 0	22 1	3 29	11 5				56 7	28 7	0 2	3 1	9 7	1 5	0 0	390
11 00	38 4	33 9	27 7	42 6	35 5	22 0	2 80	11 3											
12 00	39 6	31 9	28 4	43 6	32 8	23 5	2 81	11 1				58 0	25 5	0 0	5 8	8 2	2 5	0 0	364
13 00	39 3	31 5	29 2	43 7	32 5	23 8	2 76	11 0											
32 00	50 6	24 9	24 5	53 7	27 8	18 5	2 85					57 4	35 4	0 0	2 5	2 7	1 9	0 0	364
33 50	45 9	28 5	25 6	49 8	30 9	19 4	2 50					60 5	34 9	0 0	2 6	1 1	0 9	0 0	347

T53

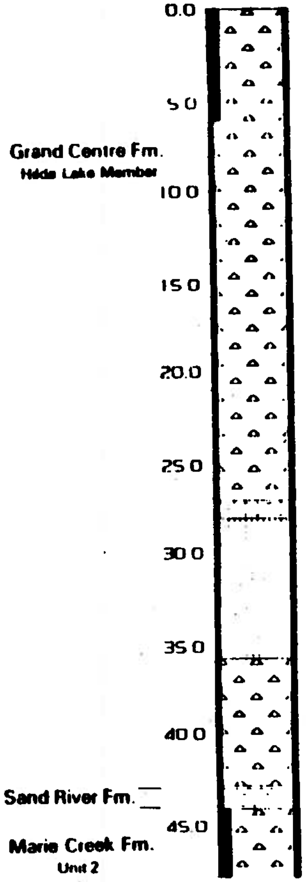
Alberta Geological Survey Testhole T 53
Location of LSD 4 Sec 21 Twp 61 Rng 4 W of 4 Mer , NTS 73L
Elevation 1830 Ft 558 M Source 1 50,000 NTS 73L/7
Date drilled 197609 04 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	CST	DST	LOC	OTH	N
1.00	36.5	26.2	37.3	41.0	28.1	30.9	1.49	12.8				67.6	27.4	0.5	0.5	2.9	1.0	0.0	204
2.00	37.8	27.7	34.5	42.4	29.7	27.8	1.53	13.0				66.0	26.4	0.5	2.0	4.6	0.5	0.0	197
3.00	38.0	26.3	35.7	42.7	27.9	29.4	1.64	15.1				65.8	25.7	1.0	2.0	4.4	1.0	0.0	202
4.00	38.3	28.6	33.1	43.2	29.6	27.3	1.80	13.2				62.3	30.7	0.9	2.2	3.1	0.9	0.0	228
5.00	38.3	27.9	33.8	43.2	29.2	27.7	1.87	13.8				70.8	23.3	0.0	0.4	2.7	2.8	0.0	219
6.00	38.6	30.7	30.7	41.5	32.3	24.2	1.67	10.7				54.2	35.5	0.0	4.0	8.9	1.3	0.0	225
7.00	37.2	26.4	36.4	41.8	26.5	31.7	1.31	11.1				59.5	33.1	0.5	2.2	3.8	0.5	0.0	183
8.00	36.1	32.6	31.3	41.4	34.7	23.9	1.52	10.9				72.2	23.9	0.0	1.9	1.9	0.0	0.0	205
9.00	39.8	26.5	33.7	44.1	29.3	26.6	2.35	10.4				71.5	24.3	0.6	0.6	2.4	0.3	0.3	334
10.00	41.9	29.8	28.3	46.3	33.7	19.9	2.57	9.7				75.1	22.0	0.6	1.3	0.6	0.0	0.3	313
11.00	39.6	29.0	31.3	44.7	30.3	25.0	1.87	9.6				71.8	23.5	0.4	2.1	1.3	0.8	0.0	238
12.00	39.8	30.3	29.9	44.5	32.9	22.6	2.13	9.9				72.5	22.5	0.4	2.3	2.3	0.0	0.0	262
13.00	37.1	27.8	35.1	41.2	31.1	27.6	1.36					64.7	31.0	0.5	0.0	2.2	1.0	0.5	184
14.00	36.0	30.2	33.8	40.9	31.2	27.9	1.54	10.5				67.5	29.0	1.0	1.5	0.5	0.5	0.0	200
15.00	39.5	27.6	32.9	44.1	30.8	25.1	1.73	10.0				66.7	26.1	0.5	1.9	3.9	0.5	0.0	207
16.00	35.7	30.5	33.8	40.7	34.9	24.4	1.42	10.0				74.9	20.3	1.1	0.5	2.1	1.0	0.0	187
17.00	31.7	32.3	36.0	35.6	36.4	28.0	1.40	11.0				67.4	30.5	0.5	0.0	1.6	0.0	0.0	187
18.00	43.1	26.6	30.4	47.6	27.6	24.8	1.76	9.4				75.2	21.7	0.0	0.9	1.7	0.0	0.4	230
19.00	36.5	29.6	33.9	41.6	31.4	27.1	1.50	10.4				71.0	24.5	0.5	2.5	1.5	0.0	0.0	200
20.00	33.5	29.2	37.3	37.6	32.3	30.1	1.21	11.5				77.1	19.8	0.6	1.2	0.6	0.6	0.0	166
21.00	36.5	29.7	33.7	41.3	31.0	25.8	1.67	10.5				68.9	26.5	1.4	0.4	2.7	0.0	0.0	219
22.00	36.5	29.6	33.9	41.1	31.8	27.0	1.61	10.9				68.7	28.0	1.4	1.4	0.9	0.0	0.0	214
23.00	36.3	30.9	32.8	41.1	31.7	27.2	1.32	10.9				75.5	21.7	0.0	1.1	1.1	0.5	0.0	180
24.00	35.2	28.7	36.1	39.7	29.9	30.4	1.46	11.0				67.3	28.4	0.5	1.0	1.0	1.0	0.5	197
25.00	31.0	36.0	32.9	36.1	38.2	25.6	1.25	11.2				71.8	19.2	0.0	0.6	6.4	1.3	0.6	156
26.00	36.7	28.5	34.8	41.3	30.3	28.4	1.39	11.0				74.6	23.7	0.6	1.1	0.0	0.0	0.0	173
27.00	34.7	28.4	36.9	39.5	31.1	29.4	1.60	11.4				72.4	24.0	0.0	1.0	2.5	0.0	0.0	196
28.00	36.3	27.4	36.2	40.8	29.3	29.9	1.49	10.5				75.5	18.9	0.5	2.2	2.8	0.0	0.0	180
29.00	34.7	28.0	37.3	39.0	31.6	29.6	1.45	11.6				73.6	19.9	1.5	1.0	4.0	0.0	0.0	201
30.00	34.9	30.6	34.4	39.9	31.9	28.2	1.55	11.3				77.0	20.6	0.0	0.5	1.5	0.5	0.0	204
31.00	35.1	30.7	34.1	40.3	32.5	27.2	1.65	11.1				68.8	26.6	0.0	1.4	2.3	0.0	0.9	218
32.00	35.5	30.2	34.3	40.5	31.2	28.3	1.83	11.2				69.9	27.8	0.4	0.4	1.3	0.0	0.0	223
33.50	29.3	37.0	33.7	34.0	38.8	27.2	1.11	12.7				76.0	20.7	2.0	0.0	1.3	0.0	0.0	150
34.00								17.7											
35.00	58.0	24.0	18.0	61.8	24.4	13.7	3.95	9.8				56.6	37.2	0.0	2.9	2.7	0.6	0.0	486
36.50	37.2	28.3	34.5	40.6	32.4	26.9	2.59	12.0				60.7	32.9	0.3	3.2	2.2	0.3	0.3	313
37.00	31.7	32.1	36.2	35.0	37.1	27.8	1.74	10.5				63.8	27.6	0.4	0.4	2.7	4.9	0.0	221
38.00	47.2	27.1	25.7	50.8	29.1	20.2	2.61	9.0				51.5	37.7	0.3	3.8	3.6	2.4	0.5	363
39.50	32.6	26.4	41.0	35.6	32.1	32.4	1.70	10.5				59.8	31.9	0.4	1.7	4.5	1.3	0.4	229
40.00	57.0	28.4	14.6	61.8	27.9	10.3	3.57					58.9	35.6	0.4	1.3	1.7	1.5	0.2	458

T54

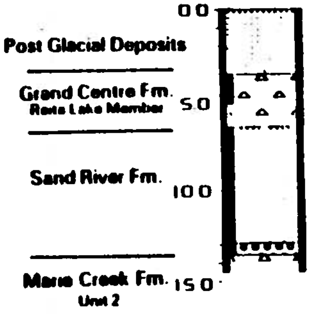
Alberta Geological Survey Testhole T 54
Location of LSD 3 Sec. 36 Twp 61 Rng 5 W of 4 Mer , NTS 73L
Elevation 1830 Ft 558 M Source 1 50,000 NTS 73L/7
Date drilled 197609 05 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT USS	LST	DST	LOC	OTH	N
1.00								12.4											
2.00	33.0	25.2	41.8	35.9	28.4	35.7	1.29	13.4				60.8	33.3	1.2	1.2	2.3	1.2	0.0	171
3.00	40.8	27.2	32.0	45.0	27.8	27.1	1.46	12.7				56.1	34.0	1.4	4.2	3.8	0.0	0.5	212
4.00	29.0	23.3	47.7	31.5	27.6	40.8	1.20	14.2				69.5	23.8	0.0	1.8	2.4	1.8	0.6	164
5.00	27.8	27.2	45.1	31.3	30.2	38.5	1.17	14.8				69.6	21.4	0.7	3.4	4.1	0.7	0.0	145
6.00	30.2	32.9	36.9	33.9	34.5	31.6	0.78	13.8				67.2	25.0	1.7	2.6	0.0	3.4	0.0	116
7.00	28.9	35.4	35.7	33.7	36.7	29.6	0.86	21.6				65.5	31.1	1.7	1.7	0.0	0.0	0.0	119
8.00	29.9	33.3	36.8	33.8	36.1	30.1	0.76	13.6				75.4	20.0	0.0	3.6	0.9	0.0	0.0	110
9.00								13.8											
10.00	28.6	34.9	36.5	33.4	36.9	29.7	0.62	14.2				77.9	22.1	0.0	0.0	0.0	0.0	0.0	77
11.00								13.9											
12.00	30.5	33.4	36.1	34.2	36.5	29.3	0.82	13.8				63.6	30.3	4.0	1.0	0.0	1.0	0.0	99
13.00								14.0											
14.00	30.8	32.7	36.5	34.6	35.7	29.8	1.01	13.7				76.5	15.9	2.3	3.0	1.5	0.0	0.7	132
15.00								13.6											
16.00	28.9	35.1	36.1	33.6	38.1	28.3	0.80	13.5				71.4	22.8	1.9	3.8	0.0	0.0	0.0	105
17.00								13.3											
18.00	28.0	34.2	37.7	32.4	35.3	32.2	0.62	13.8				62.6	31.9	1.1	1.1	2.3	1.1	0.0	91
19.00								13.8											
20.00	30.9	29.9	39.2	34.1	34.2	31.7	1.07	13.7				75.2	21.6	0.8	0.8	0.8	0.0	0.8	125
21.00								14.1											
22.00	30.5	27.4	42.1	34.4	31.1	34.5	0.98	14.0				67.6	28.3	2.1	0.7	0.7	0.7	0.0	145
23.00								14.3											
24.00	29.8	26.4	41.8	33.0	32.4	34.5	0.94	13.9				59.2	35.2	1.6	0.8	3.2	0.0	0.0	125
25.00	29.1	29.0	41.9	33.1	34.5	32.4	0.95	13.9				75.0	18.1	0.9	4.3	0.9	0.0	0.9	116
26.00	31.1	27.7	41.2	34.1	32.4	33.5	1.12	13.6				71.5	23.8	2.0	2.0	0.7	0.0	0.0	151
27.00								12.4											
36.50	28.5	27.4	44.1	32.4	31.9	35.7	0.77	12.4				72.1	24.3	0.9	0.0	1.8	0.9	0.0	111
37.00	28.3	27.4	44.3	31.3	30.9	37.8	0.92	12.9				78.5	17.7	2.8	0.0	0.9	0.0	0.0	107
38.00	28.9	28.8	42.3	32.9	31.1	36.0	0.96	12.9				68.2	27.3	0.7	1.5	0.7	0.0	1.5	132
39.50	29.3	28.4	42.2	32.4	31.6	36.0	0.73	12.9				71.0	23.0	1.0	2.0	3.0	0.0	0.0	100
40.00	28.5	27.9	43.6	32.3	30.7	37.0	0.96	12.7				73.1	22.4	0.0	2.6	1.7	0.0	0.0	116
41.00	31.9	27.1	41.0	34.8	30.0	35.2	0.82	12.8				73.7	22.8	1.7	0.0	1.7	0.0	0.0	114
42.50								14.9											
43.00								14.9											
44.00	42.0	25.7	32.2	45.4	28.2	26.3	3.76	10.3				59.7	22.3	0.0	2.5	14.0	1.4	0.0	479
45.00	39.1	29.4	31.4	42.5	31.1	26.4	2.60	10.2				54.8	23.5	0.0	3.7	16.7	0.9	0.3	323
46.00	36.0	30.5	33.5	40.3	31.8	27.9	2.17	11.5				57.0	19.9	0.0	3.4	18.2	1.3	0.0	291
47.00	35.3	30.0	34.7	38.6	32.8	28.6	2.31	11.5				53.2	22.5	0.0	5.4	17.2	1.6	0.0	297

T55

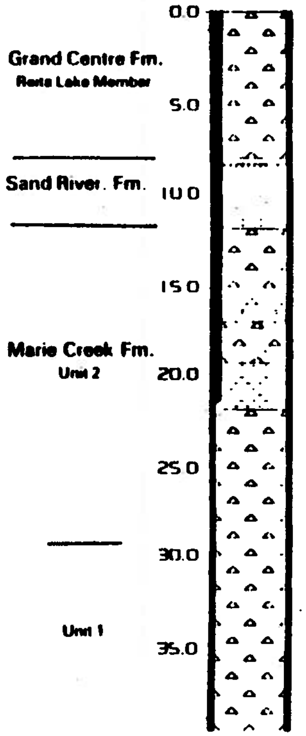
Alberta Geological Survey Testhole T 55
Location NE of LSD 1 Sec 26 Twp 61 Rng 4 W of 4 Mer , NTS 73L
Elevation 1800 Ft 549 M Source 1:50,000 NTS 73L/8
Date drilled 19760905 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT USS	LST	DST	LOC	OTH	N
4.00								17.8											
5.00								16.9											
6.00								15.0											
14.00								10.6											

T56

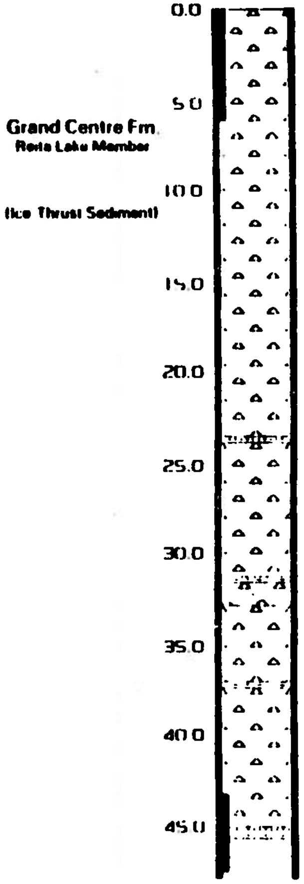
Alberta Geological Survey Testhole T 56
Location of LSD 14 Sec 6 Twp 61 Rng 4 W of 4 Mer , NTS 73L
Elevation 1800 Ft 549 M Source 1 50,000 NTS 73L/7
Date drilled 197609 06 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1.00	36.8	24.6	38.6	41.1	26.1	32.7	1.51	11.0				67.3	28.4	1.4	0.9	1.4	0.0	0.5	211
2.00	37.8	26.2	36.0	41.1	28.4	30.5	1.13	11.1				67.0	25.8	1.0	3.1	2.1	1.0	0.0	194
3.00	39.4	25.3	35.3	43.1	27.8	29.1	1.77	10.6				70.9	24.5	0.0	1.7	2.1	0.8	0.0	237
4.00	37.3	29.2	33.5	41.0	30.5	28.5	1.56	10.7				69.4	26.2	1.0	0.5	1.9	0.5	0.5	206
5.00	37.2	25.3	37.5	40.9	28.2	30.8	1.59	10.9				75.1	21.2	0.5	0.0	1.4	0.5	1.0	207
6.00	38.1	25.9	36.1	43.6	25.8	30.6	1.62	9.8				68.7	25.1	0.5	2.4	1.9	1.4	0.0	211
7.00	36.1	32.3	31.6	41.8	32.6	25.6	1.10	9.0				68.2	26.0	0.0	1.9	1.9	0.6	1.3	154
8.00	34.1	29.6	36.4	38.0	31.5	30.4	1.05	9.8				74.8	16.3	1.4	0.7	3.4	1.4	2.0	147
9.00																			
10.00																			
11.00																			
12.00	38.8	30.8	30.5	43.4	32.2	24.4	2.11	8.3				59.6	21.1	0.3	2.8	14.2	1.2	0.6	317
13.00	37.2	32.2	30.6	41.1	33.0	25.6	2.55	8.7				57.3	23.0	0.0	4.5	13.9	1.2	0.0	309
14.00	37.5	32.7	29.8	42.5	33.3	24.2	2.19	8.0				60.4	18.0	0.0	3.0	17.1	1.5	0.0	337
15.00	39.8	34.7	25.5	44.6	34.6	20.9	2.47					58.6	23.4	0.3	3.1	11.4	2.7	0.3	324
16.00	30.9	45.3	23.8	36.9	44.3	18.8	1.80					59.6	20.7	0.0	3.4	15.3	1.0	0.0	203
17.00	13.9	65.8	20.3	21.7	61.8	16.5	0.80	11.8				57.7	18.1	0.0	4.8	22.1	2.0	0.0	104
18.00	35.4	42.4	22.2	39.3	42.9	17.8	2.64	12.1				60.6	17.9	0.3	3.0	16.1	1.5	0.6	335
19.00								16.5											
20.00								15.1											
21.00								9.1											
22.00	40.0	36.5	23.5	44.4	36.5	19.1	2.95	10.3				58.3	23.1	0.0	4.3	12.2	1.5	0.2	393
23.00	44.1	31.4	24.5	48.8	32.6	18.7	3.40	9.8				58.7	21.7	0.0	3.8	14.8	0.7	0.3	424
24.00	50.0	28.2	21.8	53.7	29.0	17.3	3.51	8.6				59.9	24.8	0.0	2.9	10.8	1.3	0.2	452
25.00								8.9											
26.00	46.2	29.4	24.3	51.1	30.2	18.6	3.21	8.7				61.1	24.0	0.0	3.2	10.1	1.0	0.2	463
27.00								9.0											
28.00	44.5	29.6	25.9	48.3	31.1	20.6	2.61	9.4				60.1	23.7	0.3	3.5	11.8	0.6	0.0	346
29.00								9.1											
30.00	23.9	23.8	52.3	26.5	31.6	42.0	1.27	12.8				52.0	34.5	0.6	7.9	2.8	2.2	0.0	177
31.00								12.7											
32.00	24.3	24.7	51.0	26.6	31.7	41.7	1.26	12.6				61.4	29.0	0.0	1.7	5.1	2.9	0.0	176
33.50								9.4											
34.00	36.3	26.6	37.2	40.2	30.0	29.8	2.74	10.6				65.1	26.1	0.0	2.7	5.2	0.9	0.0	364
35.00								9.7											
36.50	37.8	25.8	36.4	40.8	29.6	29.6	3.11	9.4				64.4	26.7	0.2	1.8	4.3	2.6	0.0	393
37.00	36.0	26.4	37.7	39.8	29.9	30.3	2.56	9.9				65.7	25.3	0.3	4.1	4.4	0.3	0.0	344
38.00	36.8	25.3	37.9	39.8	30.0	30.3	3.23					61.9	26.1	0.2	2.9	3.9	1.9	0.0	410
39.50																			

T57

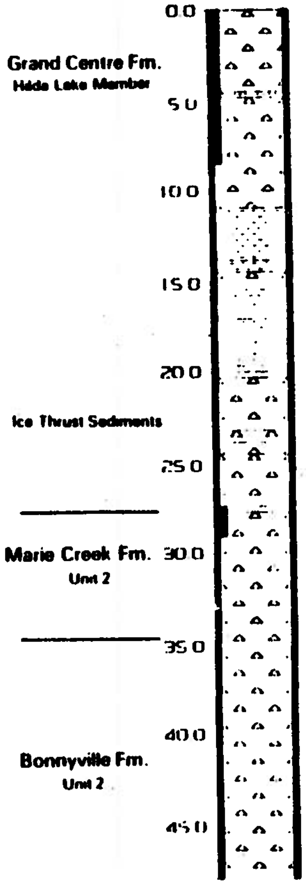
Alberta Geological Survey Testhole T 57
Location of LSD 16 Sec 8 Twp 60 Rng 5 W of 4 Mer . NTS 73L
Elevation 2050 Ft 625 M Source 1:50,000 NTS 73L/2
Date drilled 197610 19 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1.00	36.5	22.6	40.9	39.3	24.6	36.1	1.25	11.0											
2.00	34.0	26.0	40.0	37.9	28.4	33.7	1.58	10.7				63.9	27.8	1.0	2.1	4.4	0.5	0.0	205
3.00	37.1	25.1	37.7	39.9	28.1	32.1	1.52	12.2				69.4	21.7	0.9	0.7	3.9	0.8	0.4	435
4.00	37.7	26.7	35.6	41.9	28.1	30.0	1.36	12.6				74.0	20.7	0.8	1.4	2.5	0.5	0.0	631
5.00	39.3	25.1	35.6	42.5	27.2	30.4	1.79	11.7											
6.00	39.4	24.1	36.6	42.5	26.4	31.1	1.91	11.7				73.7	25.9	0.9	1.8	1.3	0.9	0.0	224
7.00	37.2	25.4	37.5	41.6	26.9	31.4	1.67	12.8											
8.00	36.3	25.8	37.8	39.6	28.6	31.8	1.72	11.1											
9.00	36.1	26.9	37.0	40.2	28.5	31.2	2.58	12.0				75.7	20.5	1.0	1.2	0.5	0.9	0.0	404
10.00	38.1	25.2	36.7	41.2	27.7	31.1	1.84	12.1				68.1	29.1	0.4	0.5	0.9	0.5	0.0	213
11.00	36.3	27.1	36.6	40.6	28.1	30.9	1.35	12.0											
12.00	37.5	25.0	37.5	40.4	27.6	31.9	1.23	12.2				66.2	28.6	1.9	1.2	1.9	0.0	0.0	154
13.00	36.4	25.5	38.1	40.6	27.0	32.3	1.29	11.7											
14.00	37.3	24.2	38.5	40.5	26.2	33.3	1.60	11.9											
15.00	38.7	26.6	34.7	42.7	28.0	29.3	1.74	11.0				69.7	24.3	0.4	1.6	1.6	0.8	1.6	505
16.00	41.0	24.0	35.0	44.0	26.5	29.5	1.85	11.4				72.2	20.8	0.7	1.2	2.1	1.3	1.4	418
17.00	40.8	24.4	34.8	44.0	27.3	28.6	1.81	11.4											
18.00	39.6	24.7	35.7	43.7	26.9	29.4	1.94	11.8				72.0	24.6	1.1	1.1	1.1	0.0	0.0	264
19.00	40.9	24.1	35.0	43.9	27.3	28.0	2.01	11.5				72.7	24.6	0.4	1.5	0.8	0.0	0.0	260
20.00	40.9	26.1	33.0	45.3	27.0	27.7	2.11	11.1											
21.00	28.7	28.9	42.3	31.5	34.2	33.2	1.58	12.8				77.9	18.4	0.8	1.0	0.8	0.5	0.0	38
22.00	34.2	28.9	36.9	38.4	32.2	29.4	1.86	12.1				74.8	20.7	1.3	1.3	1.3	0.4	0.0	448
23.00	28.0	28.8	43.3	30.9	34.3	34.8	1.11	12.1											
24.00	28.5	28.9	42.6	32.3	33.1	34.6	1.43	12.0											
25.00	27.9	28.1	44.0	30.6	33.3	36.2	1.45	12.4											
26.00	26.7	29.8	43.4	30.2	33.9	35.8	1.50	12.3				72.4	23.4	1.6	1.0	1.0	0.5	0.0	192
27.00	22.9	28.3	48.8	25.4	34.0	40.5	1.37	12.9				76.8	19.5	0.0	1.7	0.5	1.1	0.3	358
28.00	24.1	29.9	46.1	27.6	34.2	38.2	1.29	12.2				78.9	18.9	0.7	0.4	0.7	0.4	0.0	535
29.00	24.9	28.5	46.6	29.0	32.6	38.4	1.35	12.6											
30.00	25.5	46.1	28.5	28.9	58.3	12.8	1.45	11.0											
31.00								14.8											
32.00	38.1	28.4	33.5	41.1	32.3	26.5	1.51	11.9				72.3	21.2	1.1	2.8	0.0	0.6	0.0	177
33.50	41.1	28.0	30.9	45.4	29.6	25.0	1.77	11.0				70.7	27.1	0.4	0.4	1.3	0.0	0.0	229
34.00	44.7	26.3	29.0	48.3	27.8	23.9	1.65	10.8				70.8	27.3	0.0	0.9	0.5	0.5	0.0	216
35.00	44.9	27.3	27.7	49.8	27.6	22.6	1.82	10.3											
36.50	38.8	25.6	35.6	41.8	28.8	29.4	1.27	10.8				71.8	25.4	1.1	0.5	1.1	0.0	0.0	181
37.00	30.2	26.5	43.2	31.8	30.9	35.3	1.12	12.0				77.0	16.5	2.1	2.1	1.4	0.7	0.0	139
38.00	32.0	25.6	42.3	34.7	30.5	34.9	0.98	12.0											
39.50	28.5	26.8	44.7	31.7	31.4	36.9	1.51	11.5				71.6	22.1	1.9	2.5	1.5	0.0	0.0	201
40.00	26.0	23.6	50.4	28.0	30.7	41.3	0.84	13.7				71.3	24.3	2.6	0.9	0.9	0.0	0.0	115
41.00	28.6	22.1	49.3	31.3	27.5	41.2	1.50	13.4				74.9	23.0	0.5	0.0	1.0	0.5	0.0	191
42.50	14.2	20.8	65.0	15.4	29.7	54.9	0.43	13.6											
43.00	36.5	30.5	32.9	40.6	33.2	27.2	2.45	10.4											
44.00								10.6											
45.00								8.6				62.1	21.0	0.3	4.4	11.5	0.6	0.0	314
46.00								8.4											
47.00								11.5											

T58

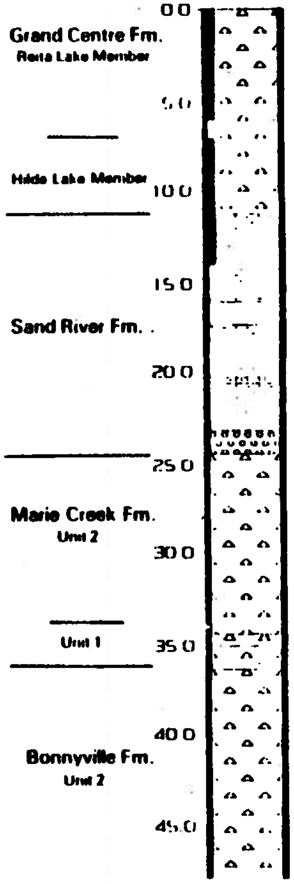
Alberta Geological Survey Testhole T 58
Location of LSD 16 Sec 11 Twp 61 Rng 2 W of 4 Mer . NTS 73L
Elevation 1850 Ft 564 M Source 1:50,000 NTS 73L/8
Date drilled 1976 10 20 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	46.7	30.0	23.2	50.7	30.2	19.1	3.05	9.2				60.2	30.9	0.2	4.2	2.1	2.0	0.0	475
2.00	47.2	29.0	23.8	51.2	29.5	19.4	3.23	9.2	29.1	12.2	0.26	66.4	24.8	0.7	3.7	2.5	1.7	0.0	408
3.00	48.4	27.4	24.1	52.3	27.8	19.8	3.48	8.7	32.0	13.4	0.36	64.4	26.1	0.4	3.1	3.4	2.6	0.0	716
4.00	47.5	27.1	25.4	51.3	27.2	21.4	3.01	9.6	31.8	13.4	0.34	61.4	29.9	0.5	3.5	3.3	1.3	0.0	599
5.00	53.4	25.3	21.4	57.1	25.2	17.7	3.46	8.7	21.1	10.2	0.42	56.8	35.1	1.3	4.3	1.5	0.9	0.0	461
6.00	50.3	25.4	24.3	53.8	26.0	20.2	1.55	8.9	33.0	13.8	0.32	63.0	29.1	0.4	3.4	1.9	2.1	0.0	467
7.00	52.5	25.4	22.1	56.1	26.0	17.9	4.29	8.9	33.5	14.1	0.41	64.4	28.2	0.7	3.7	1.6	1.4	0.0	564
8.00	59.5	20.1	20.3	62.3	21.6	16.1	7.41	9.1	35.2	14.8	0.36	64.0	30.8	0.4	2.4	1.1	0.2	0.0	458
9.00	27.4	36.7	35.9	30.5	43.1	26.3	1.96	12.4	30.2	12.7	0.34	55.1	21.9	0.8	9.6	3.7	6.7	0.0	490
10.00	27.3	35.0	37.6	30.5	41.0	28.4	1.98	12.2	29.8	12.5	0.37	53.8	26.7	0.0	10.8	4.8	4.1	0.0	519
11.00	25.7	36.5	37.8	28.9	42.0	29.0	1.19	12.4				54.9	25.8	0.3	6.3	3.8	8.3	0.0	364
12.00								16.1											
13.00								17.0											
14.00	29.2	35.8	35.0	32.3	39.7	28.1	1.62	13.5				47.9	36.6	0.4	3.5	5.5	6.2	0.0	549
15.00	33.1	28.4	38.6	36.4	31.6	32.0	2.22	12.3				43.5	37.0	0.2	4.9	5.4	8.7	0.0	448
16.00								14.3											
17.00								15.9											
18.00	1.4	38.8	59.9	3.2	48.9	47.9	0.12	15.4											
19.00								15.0											
20.00								15.6											
21.00	23.7	30.2	46.1	26.7	35.9	37.4	1.01	12.9	25.2	10.6	0.35	70.4	22.9	1.1	1.8	3.5	0.4	0.0	284
22.00	20.8	32.1	47.1	23.6	37.5	38.8	0.84	12.6	24.9	10.5	0.32	64.6	21.4	1.6	4.3	5.4	2.8	0.0	257
23.00	23.7	31.4	45.0	26.9	35.3	37.8	0.98	12.0	25.1	10.5	0.26	58.2	26.3	1.8	4.6	6.0	3.2	0.0	285
24.00	17.8	34.0	48.2	21.2	38.7	40.1	0.76	21.9	18.7	7.8	0.34	59.3	29.4	1.0	5.0	2.7	2.8	0.0	221
25.00	23.7	30.7	45.7	26.9	34.8	38.3	0.90	14.8	18.7	7.9	0.33	72.3	20.5	0.8	1.2	2.4	2.8	0.0	249
26.00	23.2	32.6	44.2	26.6	37.0	36.4	0.90	11.2	25.9	10.9	0.31	66.7	20.8	4.6	5.6	1.9	0.0	0.0	216
27.00								11.1	23.5	9.9	0.38								
27.50	46.1	26.3	27.6	50.1	27.5	22.4	3.31		27.7	11.6	0.29	61.8	26.8	0.8	3.9	2.0	1.7	0.0	611
29.00	46.0	26.3	27.8	49.7	29.3	21.0	2.98	7.8	38.3	16.0	0.19	62.8	22.6	1.9	2.7	9.3	0.5	0.0	376
30.00	45.0	29.5	25.4	48.8	33.3	17.9	1.02	8.4	33.0	13.8	0.31	60.9	25.7	1.0	5.3	4.7	2.3	0.0	471
31.00	45.1	29.4	25.4	48.8	32.5	18.7	2.88		31.6	13.3	0.36	64.9	22.6	1.1	6.5	4.0	1.1	0.0	402
32.00	45.6	28.7	25.8	49.3	32.3	18.4	3.56	8.4	32.2	13.6	0.39	64.7	22.8	1.3	4.8	3.2	2.9	0.0	377
33.50	43.6	28.7	27.7	47.2	31.4	21.4	3.60	8.6	32.7	11.8	0.41	62.6	25.9	0.2	4.6	1.9	4.1	0.0	522
34.00	44.1	30.7	25.2	47.7	31.5	20.7	3.28		32.2	11.6	0.35	63.4	26.7	1.1	3.1	3.5	2.2	0.0	606
35.00	48.6	34.9	16.5	52.3	31.1	16.6	3.21	7.2	30.6	12.9	0.36	63.2	26.8	0.0	4.2	2.7	2.8	0.0	451
36.50	51.9	26.3	21.7	55.4	28.9	15.7	3.16	7.0				57.9	32.0	0.3	5.0	3.0	1.6	0.0	397
37.00	51.8	29.0	19.3	55.1	30.1	14.9	3.05	7.1	32.5	13.6	0.34	55.8	32.9	0.0	4.1	4.1	2.8	0.0	414
38.00	60.8	21.3	17.9	63.7	21.9	14.4	1.35					56.0	34.3	0.8	3.2	3.2	1.6	0.0	373
39.50	54.5	21.8	23.7	57.5	22.9	19.6	2.97	8.4	30.1	12.7	0.37	59.0	31.3	0.3	4.2	2.4	2.6	0.0	668
40.00	50.9	23.9	25.2	54.0	25.0	21.0	2.82	6.7				61.7	28.9	0.3	5.8	1.4	1.9	0.0	360
41.00	50.1	27.3	22.5	53.7	29.7	16.7	3.45	7.7	30.0	12.7	0.41	62.4	27.2	0.0	4.4	2.9	3.1	0.0	412
42.50	51.0	25.4	23.6	54.2	27.9	17.9	2.81	7.7				60.9	27.7	0.0	5.0	3.2	2.7	0.0	340
43.00	53.0	25.2	21.9	56.4	26.9	16.7	4.01	9.1	34.2	14.4	0.36	60.0	29.8	0.9	3.2	3.6	2.5	0.0	560
44.00	51.2	26.4	22.4	54.5	28.8	16.7	3.02	7.6				57.1	32.0	0.9	3.7	3.2	3.2	0.0	438
45.00	49.2	26.9	23.8	52.7	29.8	17.4	3.15	7.6	32.6	13.7	0.38	55.6	34.4	1.0	4.1	3.3	1.6	0.0	390
46.00	50.4	25.7	23.9	53.7	27.7	18.5	2.85	10.0				60.1	24.9	0.5	6.0	4.9	3.0	0.0	449
47.00	52.6	24.7	22.7	56.1	26.5	17.4	2.49	8.9	33.8	14.3	0.43	61.1	29.1	0.6	4.1	3.3	1.8	0.0	659

T59

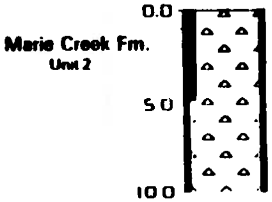
Alberta Geological Survey Testhole T 59
Location of LSD 1 Sec 21 Twp 63 Rng 3 W of 4 Mer , NTS 73L
Elevation 1790 ft 546 M Source 1:50,000 NTS 73L/8
Date drilled 1976 10 21 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET	QTZ	QTZT USS	LST	DST	LOC	OTH	N
1.00	31.0	22.0	47.0	33.0	26.0	41.0	1.61	11.9	11.1	5.5	0.40	76.3	19.6	2.1	0.5	0.9	0.5	0.0	219
2.00	36.0	24.0	39.0	40.0	26.0	34.0	1.96	10.7	32.2	13.5	0.32	70.8	23.0	2.3	0.4	3.1	0.1	0.0	257
3.00	22.0	29.0	49.0	24.0	33.0	43.0	1.33	14.1				63.9	25.6	0.6	5.0	4.4	0.6	0.0	180
4.00	19.0	22.0	59.0	22.0	38.0	40.0	1.47	16.7	18.7	7.9	0.49	64.1	26.5	1.2	1.2	5.3	1.8	0.0	170
5.00	38.0	23.0	39.0	42.0	25.0	33.0	2.10	12.7				73.8	22.2	0.0	0.4	1.8	0.7	0.0	275
6.00	32.0	29.0	39.0	36.0	31.0	33.0	1.17	11.1	28.3	11.9	0.19	67.0	23.6	2.2	2.2	5.0	0.0	0.0	182
7.00	28.0	39.0	33.0	34.0	37.0	29.0	0.88	11.9				69.8	16.0	0.0	4.7	8.5	0.9	0.0	106
8.00	29.0	38.0	33.0	34.0	39.0	27.0	0.96	10.1	28.2	11.8	0.18	61.5	20.5	0.0	4.3	12.8	0.9	0.0	117
9.00	28.0	40.0	32.0	34.0	39.0	28.0	0.88	11.2				66.0	25.5	0.9	0.9	5.7	0.9	0.0	106
10.00	29.0	38.0	33.0	33.0	38.0	29.0	0.94	10.6	27.7	11.6	0.28	64.1	20.2	0.8	2.5	10.9	1.2	0.0	119
11.00	28.0	39.0	33.0	33.0	38.0	29.0	0.98	10.7				61.8	20.4	1.8	0.9	14.6	0.9	0.0	110
12.00	41.0	38.0	22.0	46.0	36.0	18.0	2.17	10.4	29.5	12.4	0.24	79.2	16.4	1.1	0.4	1.1	0.7	0.0	274
13.00	35.0	43.0	22.0	39.0	43.0	18.0	1.18	9.8				77.6	13.9	3.0	1.8	3.0	0.6	0.0	165
14.00	29.0	44.0	27.0	33.0	45.0	21.0	0.97	11.6				77.0	14.8	3.0	0.7	1.5	3.0	0.0	135
15.00								8.6											
18.00								11.5											
19.00								9.1											
20.00								9.7											
21.00	26.0	49.0	25.0	30.0	51.0	19.0	0.92	9.8				75.0	21.1	6.7	1.0	3.9	0.0	0.0	104
22.00	28.0	50.0	21.0	34.0	49.0	18.0	0.90	12.9				71.4	21.8	2.4	0.8	1.6	0.0	0.0	124
23.00								10.4											
24.50	47.0	28.0	24.0	51.0	31.0	19.0	3.81		43.0	15.8	0.13	58.8	22.7	0.9	3.7	12.6	1.3	0.0	454
25.00	44.0	32.0	24.0	49.0	34.0	18.0	3.21	8.7				59.7	22.0	0.5	4.3	12.9	0.7	0.0	419
26.00	40.0	33.0	26.0	44.0	36.0	20.0	2.89	8.5	42.2	17.6	0.15	62.5	20.1	1.2	3.5	12.5	0.3	0.0	344
27.00	46.0	33.0	21.0	51.0	34.0	15.0	3.55	7.8				63.5	17.0	0.7	3.0	14.0	1.3	0.0	430
28.00	45.0	27.0	28.0	49.0	30.0	21.0	2.69	8.1	39.0	16.3	0.17	63.9	23.8	0.0	5.0	5.9	0.9	0.0	357
29.00	45.0	28.0	27.0	49.0	31.0	20.0	2.95	8.4				61.7	22.5	1.1	2.8	9.3	2.3	0.0	355
30.00	47.0	26.0	27.0	50.0	29.0	20.0	2.64	8.6	34.2	14.4	0.33	57.1	29.8	0.6	1.7	8.5	2.3	0.0	352
31.00	23.0	21.0	56.0	25.0	34.0	42.0	2.70	12.2				54.0	30.9	0.4	4.5	7.6	2.6	0.0	265
33.00	50.0	26.0	24.0	54.0	29.0	18.0	3.08	7.7	31.4	13.2	0.27	58.5	30.0	1.0	3.2	5.9	1.5	0.0	410
34.00	37.0	23.0	40.0	39.0	30.0	31.0	2.48	7.6	31.6	14.0	0.15	52.1	33.3	0.0	3.7	8.1	1.9	0.0	321
35.00	40.0	26.0	34.0	44.0	31.0	26.0	2.62					57.9	29.1	0.9	4.3	3.8	4.1	0.0	347
36.00	29.0	24.0	47.0	32.0	31.0	37.0	1.53	11.8				59.1	21.3	0.0	5.8	6.6	4.0	0.0	276
37.00	46.0	30.0	24.0	50.0	33.0	17.0	2.91	10.1	27.7	11.6	0.32	59.5	29.5	0.5	5.8	4.0	0.3	0.0	397
38.00	48.0	27.0	26.0	51.0	28.0	20.0	3.50		24.0	10.1	0.39	61.0	28.3	0.0	4.9	4.5	1.1	0.0	449
39.50	47.0	28.0	25.0	51.0	30.0	19.0	3.43					57.3	30.3	0.7	5.0	4.1	2.6	0.0	459
41.00	48.0	29.0	24.0	52.0	31.0	18.0	3.52	8.8	32.8	13.8	0.30	57.4	30.4	0.6	1.8	4.4	2.1	0.0	477
42.50	48.0	28.0	24.0	52.0	30.0	18.0	3.33	8.5				60.0	26.3	1.1	5.5	3.7	3.3	0.0	457
43.00	49.0	27.0	24.0	53.0	29.0	19.0	3.47		34.2	14.3	0.27	60.9	26.2	0.9	5.0	4.6	2.2	0.0	458
44.00	51.0	26.0	23.0	55.0	28.0	17.0	1.77					58.8	32.4	1.0	3.7	1.7	2.3	0.0	481
48.00	58.0	22.0	19.0	62.0	23.0	15.0	1.31		21.3	9.1	0.59	52.8	37.3	0.7	5.3	1.9	1.7	0.0	413

T61

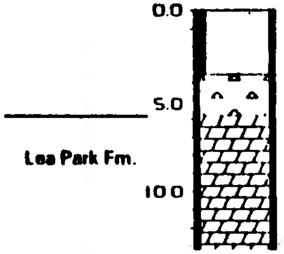
Alberta Geological Survey Testhole T 61
Location SW of LSD 4 Sec 29 Twp 58 Rng 6 W of 4 Mer , NTS 73L
Elevation 2160 Ft 659 M Source 1 50,000 NTS 73L/2
Date drilled 197610 20 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	COC	OTH	N
1 00								10 5											
2 00	31 0	38 3	30 6	34 9	38 6	26 5	2 15	9 4				55 5	15 5	0 0	7 3	21 2	0 4	0 0	245
3 00	37 5	31 9	30 6	41 3	32 7	26 1	2 72	9 2				58 6	23 4	0 6	4 7	12 4	0 3	0 0	338
4 00	36 8	32 2	31 0	40 7	32 7	26 6	2 81	9 3				56 5	24 4	0 0	3 8	13 6	1 6	0 0	368
5 00	36 7	32 4	31 0	40 2	33 6	26 2	2 86	9 1				61 2	21 9	0 0	4 8	11 2	1 1	0 0	374
6 00	36 6	32 0	31 3	40 5	33 5	26 0	2 72	8 6				57 1	24 3	0 3	4 2	11 8	2 1	0 0	329
7 00	37 2	32 6	30 2	40 7	34 0	25 4	3 01	9 2				58 5	25 6	1 0	3 6	10 1	1 0	0 2	386
8 00	37 5	31 2	31 3	41 3	36 1	22 6	2 85	8 5				57 3	24 9	0 5	3 8	12 7	0 8	0 0	370
9 00	38 6	29 6	31 8	42 4	30 8	26 8	2 71	8 6				54 6	28 6	0 9	4 0	11 1	0 6	0 0	350
10 00	39 7	29 4	30 9	43 2	31 2	25 6	2 96	9 5											

T62

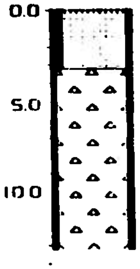
Alberta Geological Survey Testhole T 62
Location SE of LSD 4 Sec 6 Twp 60 Rng 6 W of 4 Mer , NTS 73L
Elevation 1825 Ft 556 M Source 1:50,000 NTS 73L/2
Date drilled 197610 20 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)					
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN META	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00								18.9											
3.00								14.4											
4.00								12.1											
5.00								12.0											
6.00								15.5											
7.00								16.0											
8.00								17.2											
9.00								16.5											
10.00								16.4											
11.00								15.4											
12.00								15.5											

T63

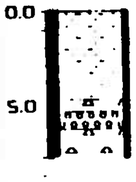
Alberta Geological Survey Testhole T 63
Location of LSD 16 Sec 15 Twp 63 Rng 7 W of 4 Mer . NTS 73L
Elevation 1850 ft 564 M Source 1:50,000 NTS 73L/7
Date drilled 19761021 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
2.00								9.3											
3.00								15.0											
4.00								3.4											
5.00								7.8											
6.00								4.7											
8.00								13.2											
11.00								4.1											
12.00								4.1											
13.00								7.3											

T64

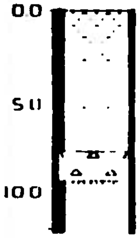
Alberta Geological Survey Testhole T 64
Location of LSD 7 Sec 15 Twp 63 Rng 7 W of 4 Mer . NTS 73L
Elevation 1850 Ft 564 M Source 1 50,000 NTS 73L/7
Date drilled 197610 21 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	COT (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	COC	OTH	N
2 50																			
4 00																			
5 00																			
6 00																			
7 00																			
8 00																			

T65

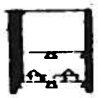
```
Alberta Geological Survey Testhole    T 65
Location      of LSD  4 Sec  1 Twp  61 Rng  7 W of 4 Mer     NTS  73L
Elevation   1850 Ft      564 M   Source  1 50,000 NTS 73L/7
Date drilled     1976 10 21  Logged by  M  FENTON

                  TEXTURE (%)                            MATRIX CARBONATE          COARSE SAND LITHOLOGY (%)
DEPTH  SAND SILT CLAY  SAND SILT CLAY VC SD   H2O    CO2  COT CA/DO    IGN   QTZ  QTZT  LST  DST  LOC  OTH    N
 (M) >62.5um      <4um  >50um      <2um 1 2mm  (%)   (cc)  (%)         METM        QSS

 7.00                                          15.6

 9.00                                           9.7
```



T66

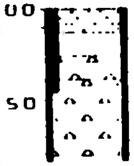
```
Alberta Geological Survey Testhole   T 66
Location      of LSD  5 Sec 22 Twp  62 Rng  6 W of 4 Mer .  NTS  73L
Elevation   1830 Ft     558 M   Source  1 50,000 NTS 73L/7
Date drilled    197610 21  Logged by  M  FENTON

                      TEXTURE (%)                          MATRIX CARBONATE         COARSE SAND LITHOLOGY (%)
 DEPTH  SAND SILT CLAY  SAND SILT CLAY VC SD   H2O   CO2  CO3 CA/DO    IGN   QTZ  QTZT  LST  DST  LOC  OTH    N
  (M) >62 5um     <4um  >50um     <2um 1 2mm   (%)   (cc)  (%)          METM        QSS

  1 00
  2 50
```

0.0



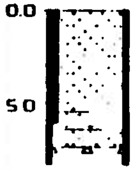
T67

```
Alberta Geological Survey Testhole    T 67
Location       of LSD  4 Sec  7 Twp  64 Rng  5 W of 4 Mer  .  NTS  73L
Elevation   1850 Ft      564 M   Source  1:50,000 NTS 73L/10
Date drilled    197610 21  Logged by  M  FENTON

                TEXTURE (%)                              MATRIX CARBONATE         COARSE SAND LITHOLOGY (%)
 DEPTH  SAND SILT CLAY  SAND SILT CLAY VC SD   H2O     CO2  CO3 CA/DO    IGN   QTZ  QTZT  LST  DST  LOC  OTH    N
  (M) >62.5um     <4um  >50um     <2um 1-2mm   (%)    (cc)  (%)          METM        OSS
```



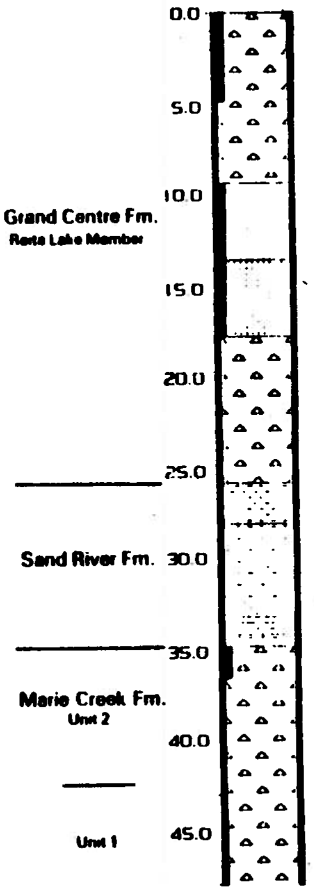
T68

```
Alberta Geological Survey Testhole   T 68
Location   NE of LSD  4 Sec 35 Twp  61 Rng  5 W of 4 Mer .  NTS  73L
Elevation   1850 Ft      564 M   Source  1 50,000 NTS 73L/7
Date drilled    1976 10 21  Logged by  M  FENTON

                      TEXTURE (%)                         MATRIX CARBONATE           COARSE SAND LITHOLOGY (%)
 DEPTH  SAND SILT CLAY  SAND SILT CLAY VC SD   H2O    CO2  CO3 CA/DO     IGN   QTZ  QTZT  LST  DST  LOC  OTH    N
  (M) >62.5um     <4um  >50um     <2um 1-2mm   (%)   (cc)  (%)           METM        QSS
```



T69

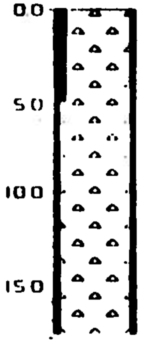
Alberta Geological Survey Testhole T 69
Location of LSD 12 Sec 29 Twp 63 Rng 6 W of 4 Mer , NTS 73L
Elevation 1875 Ft 572 M Source 1 50,000 NTS 73L/7
Date drilled 197610 23 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MEIM	QTZ	QTZT OSS	LST	DST	FOC	OTH	N
1 00								10 8											
2 00	37 1	25 4	37 3	40 8	27 2	32 0	2 26	11 0				64 0	27 1	1 2	1 6	4 8	1 2	0 0	247
3 00	35 4	30 8	33 8	39 6	32 3	28 2	1 70	10 1				68 6	25 6	2 2	0 9	1 3	0 9	0 0	223
4 00	36 5	29 0	34 5	40 4	30 5	29 1	1 71	10 1				65 9	26 5	0 9	2 2	3 1	1 3	0 0	226
5 00	39 0	26 9	34 1	43 3	27 5	29 1	1 74	10 2				77 1	19 1	1 7	2 6	0 4	0 0	0 0	230
6 00	39 6	26 9	33 5	43 6	27 6	28 8	1 93	10 8				76 6	19 3	0 0	1 4	1 1	1 4	0 0	274
7 00	37 9	26 7	35 4	41 9	28 2	29 9	2 11	11 7				67 8	27 0	0 0	2 1	2 8	0 3	0 0	289
8 00	42 5	25 3	32 2	46 5	26 4	27 1	2 49	10 6				70 4	21 6	0 9	1 6	3 5	0 0	0 0	314
9 00	39 1	26 7	34 2	43 2	27 8	29 0	1 53	10 5				68 5	26 0	0 0	2 5	2 5	1 0	0 0	200
18 00	35 8	28 0	36 2	39 7	32 2	28 1	1 44	9 7				69 5	24 0	1 5	2 0	2 5	0 0	0 0	200
19 00	34 4	30 4	35 2	38 3	33 6	28 2	1 50	9 8				69 9	26 5	0 5	0 5	2 5	0 0	0 0	196
20 00	35 9	27 0	37 1	40 1	30 0	29 9	1 66	9 3				70 8	25 0	1 3	0 8	1 7	0 0	0 4	236
21 00	35 8	27 3	36 9	39 5	31 8	28 7	1 44	9 5				69 6	25 1	1 6	1 0	1 6	1 0	0 0	191
22 00	36 0	26 8	37 2	40 0	31 4	28 6	1 58	9 7				73 6	23 1	0 5	0 5	2 3	0 0	0 0	212
23 00	37 0	26 2	36 8	40 7	31 4	27 8	1 39	10 1				74 1	22 3	0 0	2 0	1 0	0 5	0 0	197
24 00	27 3	38 4	34 3	32 9	40 9	26 2	0 72	9 6				66 0	27 0	0 0	5 0	2 0	0 0	1 0	101
25 00	25 1	41 4	33 6	30 3	43 6	26 1	0 47	10 2				70 5	22 9	0 0	1 6	4 9	0 0	0 0	61
26 00								14 0											
28 00								19 9											
29 00								20 1											
30 00								18 0											
31 00								15 8											
34 00								16 2											
35 00	33 5	32 5	34 0	37 5	36 0	26 5	2 00	12 7				55 8	23 1	0 3	3 8	15 8	1 0	0 0	285
36 50	38 1	33 2	28 6	42 0	36 4	21 6	2 55	9 3				61 2	19 9	1 9	2 9	13 3	0 3	0 3	307
37 00	38 5	33 2	28 3	42 7	36 9	20 4	2 77	8 7				60 7	19 4	0 5	3 0	15 5	0 5	0 3	361
38 00	40 9	31 7	27 4	44 8	35 2	20 0	3 11	9 6				59 3	21 5	0 2	4 8	13 4	0 7	0 0	396
39 50	38 7	38 5	22 8	43 0	39 4	17 7	2 66	8 1				52 0	27 2	1 1	3 6	14 9	1 1	0 0	356
40 00	48 2	32 9	18 9	53 0	31 9	15 1	3 21	8 3				57 7	23 7	0 8	3 3	13 6	0 8	0 0	388
41 00	60 5	26 4	13 1	64 9	24 0	11 1	4 81	8 4				59 6	26 4	0 3	2 9	9 8	0 6	0 3	307
42 50	36 9	29 0	34 1	40 3	31 2	28 5	2 68	8 5				59 4	28 8	0 3	3 3	7 5	0 6	0 0	331
43 00	30 9	27 7	41 4	34 1	31 8	34 2	2 11	9 6				59 9	29 6	0 3	2 4	5 6	1 7	0 0	287
44 00	32 0	29 0	39 0	35 1	33 1	31 9	2 20	9 2				62 4	29 4	0 3	0 7	5 1	2 0	0 0	293
45 00	30 2	27 3	42 5	33 4	31 8	34 8	2 00	10 1				64 4	25 5	0 4	2 6	6 4	0 7	0 0	267
46 00	32 5	24 2	43 2	35 4	29 2	35 4	2 64	9 7				65 0	25 8	0 6	2 1	5 2	1 2	0 0	329
47 00	31 7	28 7	39 6	35 1	32 6	32 3	2 22	8 7				61 8	28 5	1 1	1 0	5 8	1 3	0 3	309

T70

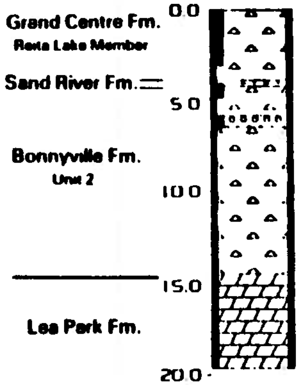
Alberta Geological Survey Testhole T70
Location of LSD 9 Sec 4 Twp 61 Rng 5 W of 4 Mer , NTS 73L
Elevation 1850 Ft 564 M Source 1:50,000 NTS 73L/2
Date drilled 1976 10 22 Logged by M FENTON



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	IGN METM	COARSE SAND LITHOLOGY (%) QTZ	QTZT QSS	FST	DST	LOC	OTH	N
1.00								11.4											
2.00								5.8											
3.00								6.1											
4.00								12.6											
5.00								11.9											
6.00								14.1											
10.00								5.5											
11.00								11.9											
12.00								6.9											
14.00								6.5											
15.00								11.1											
16.00								11.9											
17.00								12.1											

T71

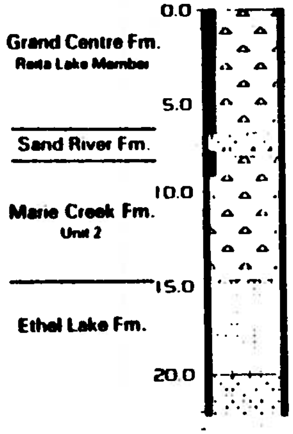
Alberta Geological Survey Testhole T 71
Location of LSD 9 Sec 25 Twp 59 Rng 6 W of 4 Mer , NTS 73L
Elevation 1825 Ft 556 M Source 1 50,000 NTS 73L/2
Date drilled 197610 22 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	35 1	25 3	39 5	39 0	25 7	35 3	1 50	17 5				62 7	26 5	1 0	4 1	3 1	1 0	1 5	196
2 00	37 4	27 1	35 5	40 4	28 1	31 6	1 64	14 2				70 0	26 0	0 5	2 5	1 0	0 0	0 0	200
3 00	28 6	24 1	47 3	31 3	26 7	42 0	1 30	15 6				73 7	20 5	0 6	3 8	0 6	0 6	0 0	156
4 00								20 3											
5 00	42 4	28 9	28 6	46 7	28 1	25 1	2 46	12 5				60 1	34 6	0 3	2 9	0 3	1 8	0 0	341
7 00	45 0	28 1	26 8	48 2	30 3	21 6	2 46					62 0	30 0	0 3	4 7	2 0	0 9	0 0	340
8 00	42 3	28 9	28 9	46 7	30 0	21 1	2 62	9 9				52 8	33 3	0 1	6 1	4 8	2 1	0 3	333
9 00	42 9	26 8	30 3	46 0	30 0	24 0	2 32	10 7				57 7	31 7	0 0	4 3	4 3	1 5	0 0	322
10 00	40 9	28 0	31 1	45 1	30 2	24 7	2 81	11 4				59 5	31 6	0 0	3 9	1 8	2 9	0 0	383
11 00	41 3	26 7	32 0	44 5	30 4	25 1	2 28	10 5				58 0	32 0	0 3	4 1	2 0	3 3	0 0	300
12 00	39 7	27 5	32 8	44 0	29 5	26 5	2 69	10 8				55 5	37 1	0 0	2 7	2 7	1 8	0 0	369
13 00	40 7	26 1	33 2	41 8	29 9	26 3	2 59	11 2				55 8	33 7	0 1	5 1	3 6	1 2	0 0	335
14 00	39 8	26 8	33 4	43 8	29 5	26 7	3 54	12 9				56 3	32 3	0 2	5 4	3 6	2 2	0 0	446
15 00								17 4											
16 00								16 9											
18 00								17 1											
19 00								[illegible] 4											

T72

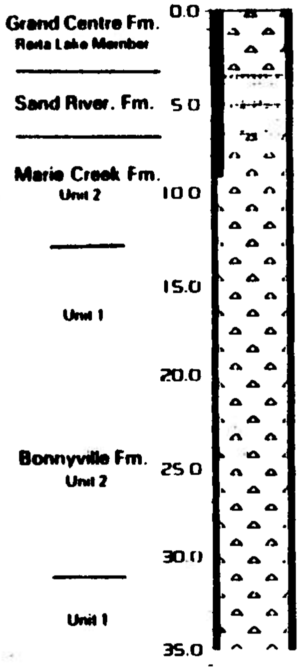
Alberta Geological Survey Testhole T 72
Location SE of LSD 8 Sec 1 Twp 60 Rng 1 W of 4 Mer , NTS 73L
Elevation 1900 Ft 579 M Source 1 50,000 NTS 73L/1
Date drilled 19761023 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE		COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 CA/DO (%)	IGN METM	QTZ	QTZT OSS	CST	DST	LOC	OTH	N
1 00	45 8	22 3	31 8	49 5	22 5	28 0	2 51	11 6			73 0	24 9	1 0	0 1	0 8	1 0	0 0	762
2 00	43 1	24 8	32 1	46 9	26 1	27 1	2 23	11 1			69 5	25 9	2 0	0 6	1 4	0 9	0 0	351
3 00	43 8	25 2	30 9	47 6	26 1	26 3	2 15	11 4			71 1	24 2	1 2	0 7	1 7	1 2	0 0	422
4 00	44 0	24 2	31 8	47 8	25 4	26 7	2 38	11 6			73 7	23 9	1 1	0 5	0 5	0 8	0 0	377
5 00	42 4	25 2	32 3	46 2	26 6	27 2	2 03	11 1			68 4	35 5	2 4	1 3	1 9	0 6	0 0	376
6 00	37 7	24 3	38 0	41 3	26 2	32 5	1 89	11 8			70 7	26 4	1 1	0 7	1 4	0 4	0 0	280
8 00	24 7	25 3	49 9	27 9	30 0	42 1	0 79	17 3			82 2	16 0	0 6	0 0	0 6	0 0	0 0	163
9 00	39 2	29 5	31 4	42 6	32 0	25 4	3 37	9 6			62 2	21 0	0 9	4 0	10 7	1 4	0 0	580
10 00	39 7	29 9	30 3	43 3	33 1	23 7	3 52	9 9			61 6	24 7	1 1	1 7	9 5	1 5	0 0	539
11 00	37 8	31 3	30 9	41 1	35 2	23 7	3 12	9 8			60 2	23 0	0 6	4 3	10 6	1 7	0 0	530
12 00	38 6	31 2	30 2	41 9	34 5	23 6	2 86	9 5			68 6	19 3	0 0	3 7	8 7	0 5	0 0	404
13 00	32 5	29 0	38 5	35 3	34 9	29 9	2 52	10 6			66 7	22 9	0 8	1 4	5 5	2 5	0 0	363
14 00	43 2	24 7	32 1	46 0	28 5	25 4	3 02	9 5			57 6	32 7	0 3	4 3	3 1	1 8	0 0	953

T73

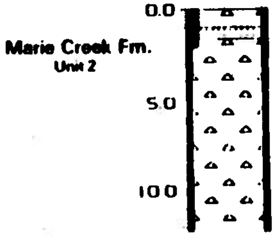
Alberta Geological Survey Testhole T 73
Location of LSD 9 Sec 6 Twp 65 Rng 7 W of 4 Mer NTS 73L
Elevation 2020 Ft 616 M Source 1 50,000 NTS 73L/11
Date drilled 197610 24 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT USS	LST	DST	LOC	OTH	N
1 00								9 7											
2 00	38 4	25 5	36 1	42 1	26 4	31 5	1 27	8 8				59 9	26 5	0 6	7 4	4 3	1 2	0 0	162
3 00	46 4	24 1	29 5	50 4	23 4	26 2	1 76	9 7				72 9	24 1	1 3	0 0	0 0	1 6	0 0	236
6 00								11 5											
7 00	40 9	36 7	22 4	46 1	35 7	18 2	2 64	11 9				64 2	22 0	0 6	3 5	8 9	0 9	0 0	346
8 00	40 1	37 7	22 1	45 2	37 6	17 2	2 95	11 3				61 5	23 2	0 3	4 5	9 6	0 9	0 0	353
9 00	41 0	35 7	23 3	45 7	36 9	17 4	2 66	10 2				57 7	26 6	0 3	3 7	10 0	1 8	0 0	350
10 00	40 7	38 0	21 3	45 4	39 3	15 2	2 50	9 6				61 2	21 7	0 0	2 9	11 2	0 6	0 0	313
11 00	42 5	35 0	22 5	47 0	36 6	16 4	2 93	9 9				64 7	24 2	0 3	1 9	8 0	0 8	0 0	360
12 00	44 2	36 1	19 7	48 6	36 4	14 9	2 97	9 5				59 7	28 6	0 0	3 5	7 3	0 6	0 0	395
13 00	33 5	28 9	37 6	37 3	32 6	30 2	2 10	11 4				61 1	31 4	0 0	1 6	2 3	1 6	0 0	255
14 00	29 8	32 8	37 4	33 5	37 5	29 0	1 89	12 0				53 3	36 7	0 0	3 3	4 6	2 1	0 0	240
15 00	20 9	36 2	42 9	23 8	42 5	33 7	1 06	12 4				60 0	33 3	0 0	3 0	1 5	2 2	0 0	135
16 00	21 2	37 7	41 1	24 3	41 3	32 4	1 17	12 4				60 4	29 9	0 0	5 8	1 9	1 3	0 6	154
17 00	23 5	32 1	44 4	26 6	37 7	35 7	1 28	12 6				59 7	28 0	0 0	3 0	7 3	2 4	0 0	165
18 00	11 3	34 0	54 7	12 5	47 2	40 2	0 64	15 7				65 9	30 6	0 0	2 3	1 2	0 0	0 0	85
19 00	24 1	34 3	41 6	26 5	41 4	32 1	1 58	12 4				57 4	33 0	0 0	5 6	2 5	1 0	0 0	197
20 00	28 5	34 9	36 5	31 7	40 5	27 8	2 02	12 9				59 8	33 1	0 0	2 8	3 2	0 4	0 4	251
21 00	38 5	28 5	33 0	42 4	32 4	25 2	2 29	10 8				66 2	26 8	0 3	2 6	3 6	0 0	0 3	307
22 00	36 6	30 0	33 4	40 4	33 8	24 9	1 94	10 9				67 8	25 1	1 8	4 2	0 3	0 7	0 0	283
23 00	36 7	28 9	34 4	40 5	33 9	25 7	1 95	10 7				60 6	31 7	0 8	2 7	2 3	2 0	0 0	259
24 00	41 4	29 1	29 4	45 3	33 5	21 2	2 45	9 7				59 7	30 7	0 3	5 7	1 8	1 5	0 3	315
25 00	41 8	27 7	30 5	45 8	31 9	22 3	2 31	4 1				54 7	37 0	0 0	3 3	3 3	1 2	0 0	305
26 00	41 7	26 9	31 4	46 0	32 1	22 0	2 13	4 6				65 1	27 8	0 0	3 4	2 4	1 3	0 0	295
27 00	39 8	25 9	34 3	43 9	30 0	26 0	2 19	4 9				62 6	30 4	0 0	1 4	2 8	2 7	0 0	289
28 00	38 3	29 1	32 6	41 9	34 4	23 7	2 71	9 8				64 7	28 1	0 6	3 0	2 2	1 4	0 0	366
29 00	38 4	25 9	35 7	42 0	31 4	26 6	2 46	9 5				65 8	28 1	0 6	2 6	1 3	1 6	0 0	310
30 00	37 7	27 4	34 9	41 3	33 2	25 5	2 87	10 0				68 7	27 4	0 3	0 8	2 2	0 5	0 0	368
31 00	32 8	24 2	43 0	36 5	30 9	32 6	2 28	10 6				68 1	24 5	0 0	3 7	2 0	1 6	0 0	298
32 00	32 0	26 6	41 4	35 2	34 3	30 5	2 03	10 8				62 3	31 5	0 4	2 9	1 8	0 8	0 0	273
33 50	35 2	23 9	41 0	38 4	30 5	31 0	2 61	10 1				64 7	28 8	0 0	2 7	2 7	1 2	0 0	337
34 00	37 0	26 7	36 3	40 5	33 3	26 2	2 15	8 8				60 3	32 7	0 0	2 7	3 4	0 6	0 0	290
35 00	36 1	24 1	39 8	39 6	30 0	30 4	2 12	11 7				66 7	27 5	0 4	2 5	0 7	1 4	0 7	276

T74

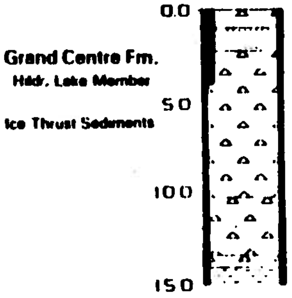
Alberta Geological Survey Testhole T 74
Location N of LSD 11 Sec 1 Twp 63 Rng 3 W of 4 Mer , NTS 73L
Elevation 1775 Ft 541 M Source 1 50,000 NTS 73L/8
Date drilled 197610 24 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	60 7	21 2	18 1	61 8	22 6	15 6	4 11					65 3	23 2	0 5	2 6	5 4	2 5	0 0	613
3 00	44 2	26 0	29 8	45 2	31 7	23 2	2 49	9 0				60 0	29 1	0 6	3 7	4 5	1 6	0 2	515
4 00	45 0	24 3	30 7	45 9	29 3	24 7	2 49					63 5	25 3	1 3	2 4	4 3	3 0	0 0	375
5 00	42 7	26 6	30 7	43 6	32 2	24 2	2 32					60 8	26 9	1 6	3 2	6 5	1 6	0 0	372
6 00	42 4	25 6	32 0	43 4	31 2	25 4	2 47	9 3				62 6	25 8	1 3	2 4	5 3	2 1	0 4	713
7 00	43 4	25 0	31 6	44 3	30 3	25 3	2 43	9 3				60 8	28 8	0 9	2 0	5 5	2 0	0 0	451
8 00	42 9	25 4	31 7	43 9	30 4	25 7	2 46	9 3				67 3	22 8	1 0	1 7	4 7	2 3	0 0	404
9 00	42 9	25 3	31 8	43 9	30 4	25 7	2 82	9 2				65 6	23 1	0 6	3 4	4 6	2 7	0 0	477
10 00	44 2	24 6	31 2	45 2	29 6	25 2	2 72					69 4	22 8	1 1	2 2	3 5	0 8	0 0	461
11 00	44 7	26 5	28 8	45 7	30 9	23 4	2 80	9 0				65 9	24 7	0 8	2 4	3 6	2 4	0 0	502
12 00	42 9	23 9	33 2	43 8	29 8	26 4	2 84	9 7				63 0	28 0	0 2	3 3	4 1	1 0	0 2	511

T75

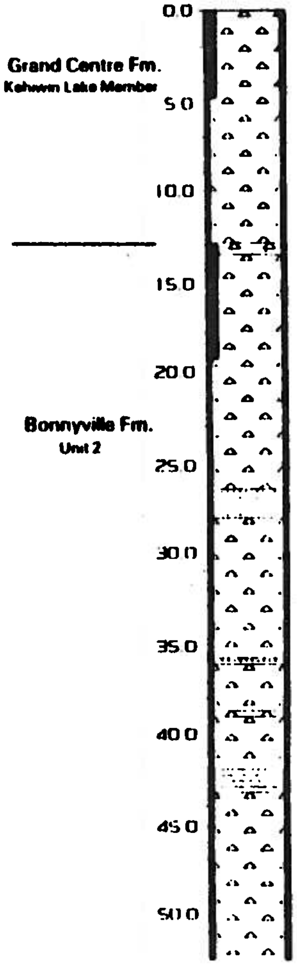
Alberta Geological Survey Testhole T 75
Location SW of LSD 6 Sec 26 Twp 62 Rng 2 W of 4 Mer . NTS 73L
Elevation 1875 ft 572 M Source 1 50,000 NTS 73L/8
Date drilled 197610 24 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	46 7	27 5	25 9	50 4	27 3	22 3	3 61	11 2				57 5	26 4	0 0	3 8	10 1	2 2	0 0	318
2 00	57 3	25 2	17 6	60 8	21 9	15 3	4 22					62 4	21 2	0 3	4 0	9 4	2 7	0 0	372
3 00	47 5	26 9	25 6	51 1	26 4	22 5	3 20	10 4				65 8	24 8	0 0	3 0	3 4	3 0	0 0	298
4 00	42 3	29 8	27 9	45 9	30 0	24 1	2 98	10 8				62 9	27 3	0 4	3 1	4 3	2 0	0 0	256
5 00	45 6	28 8	25 5	49 3	29 7	21 0	3 03	10 1				60 5	28 1	0 0	5 9	2 4	3 2	0 0	253
6 00	47 8	29 4	22 8	51 6	30 5	17 9	3 30	10 1				59 5	29 9	0 3	4 1	3 4	2 4	0 3	291
7 00	37 1	35 7	27 2	40 1	40 2	19 7	2 17	11 2				54 9	36 8	0 0	3 9	1 5	3 0	0 0	337
8 00	54 6	24 0	21 4	58 0	24 8	17 3	3 54	11 1				58 4	34 4	0 0	2 6	1 9	2 6	0 0	308
9 00	27 5	38 1	34 5	30 7	41 7	27 6	1 84	13 2				56 5	26 7	0 0	7 3	5 0	4 6	0 0	262
10 00	31 1	36 9	32 0	34 6	38 8	26 6	2 39	12 5				58 7	28 1	0 6	7 2	8 7	5 4	0 0	334
11 00								13 1											
12 00	40 1	29 7	30 1	42 8	33 1	24 1	2 04	11 9				55 4	20 4	0 0	6 5	6 0	11 7	0 0	397
13 00	62 4	19 8	17 9	65 1	20 0	14 9	6 75					66 5	18 7	0 0	7 2	4 3	3 2	0 0	278
14 00	51 5	26 5	22 0	54 9	27 0	18 2	4 22	11 2				56 1	22 1	0 0	10 1	5 3	6 2	0 0	417
14 60								18 0											

77 SR 1

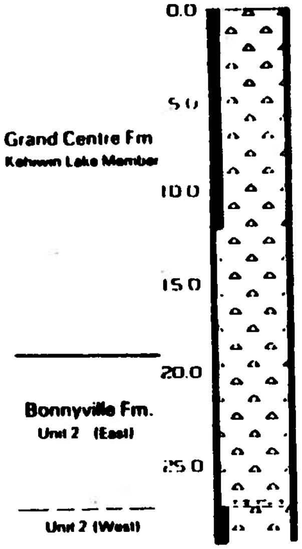
Alberta Geological Survey Testhole 77 SR 1
Location 01 LSD 1 Sec 28 Twp 58 Rng 8 W of 4 Mer . NTS 73L
Elevation 2100 FT 640 M Source 1 50,000 NTS 73L/7
Date drilled 1977/07 20 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	CST	OST	COL	OTH	N
1 00								11 6				65 9	22 9	1 7	0 9	6 1	2 3	0 0	341
2 00	38 0	43 2	18 8	40 7	44 8	14 5	1 36	12 2				66 9	23 8	1 0	3 6	3 3	1 1	0 0	390
3 00	40 1	40 8	19 0	43 1	40 6	16 3	1 52	10 7				65 9	26 0	0 8	4 0	2 4	0 8	0 0	496
4 00	38 9	42 4	18 7	41 8	43 9	14 4	1 82	10 8				67 8	23 8	0 6	4 0	2 9	0 8	0 0	478
5 00								10 7				62 1	29 9	0 6	3 0	2 8	1 3	0 2	531
6 00	41 3	40 6	18 1	44 3	42 2	13 5	2 47	10 6				65 3	26 8	0 2	4 6	2 0	0 8	0 2	459
7 00								11 1											
8 00	44 1	39 2	16 8	47 0	39 5	13 5	2 67	10 7											
9 00								10 5											
10 00	44 4	39 6	16 0	47 3	40 1	12 5	2 63	10 8				66 5	26 4	0 4	0 8	4 8	1 2	0 0	504
11 00								11 1				68 2	24 9	0 7	2 9	2 4	0 7	0 0	545
12 00	37 0	43 8	19 2	40 3	44 8	14 9	2 14	11 3											
13 00	29 0	47 8	23 1	31 5	48 3	20 3	1 35	12 1											
14 00	31 2	48 5	20 4	33 7	52 1	14 1	1 48	14 2				61 6	34 0	0 3	1 9	1 9	0 3	0 0	315
15 00								13 9											
16 00	28 7	49 4	21 9	31 6	51 0	17 4	1 21	14 3				54 7	36 2	0 6	3 7	1 9	2 8	0 0	320
17 00								14 3				57 3	37 3	0 3	2 3	1 0	1 3	0 0	300
18 00	33 4	46 7	19 9	36 0	48 0	16 0	1 66	13 7				54 1	38 8	0 8	1 8	0 8	3 7	0 0	508
19 00								13 9				58 6	32 7	1 2	2 5	1 2	2 5	0 0	324
20 00	31 6	47 9	20 5	34 5	50 5	15 0	1 35	11 7				46 8	46 0	0 0	3 2	2 1	1 6	0 3	374
21 00								11 2				58 9	33 6	0 6	2 9	2 5	1 3	0 2	518
22 00	34 4	47 0	18 6	37 0	50 6	12 3	1 75	12 8				57 4	36 1	0 5	3 6	1 5	0 8	0 0	390
23 00								12 8				62 6	30 5	0 3	2 3	3 9	0 3	0 0	305
24 00	36 0	46 3	17 7	38 9	49 6	11 5	1 96	12 8				60 9	34 5	0 6	1 5	1 2	0 9	0 3	333
25 00								11 9											
26 00	40 0	44 2	15 8	42 8	47 1	10 1	2 20	11 9											
27 00																			
28 00	38 5	44 0	17 4	41 5	47 2	11 3	1 69	12 3											
29 00	41 9	42 5	15 6	44 5	45 7	9 8	2 29	13 6				59 9	34 5	0 9	2 7	0 4	1 3	0 2	446
30 00								11 6											
31 00	41 8	41 2	16 9	44 7	44 5	10 7	2 00	11 2											
32 00								11 7											
33 50	42 2	40 9	16 9	44 8	44 5	10 7	1 69	10 7											
34 00								10 5											
35 00								10 1				61 9	27 2	0 7	4 7	2 2	1 0	0 2	405
36 00	48 9	38 0	13 1	51 7	39 0	9 3	3 73	10 7				59 7	32 5	0 4	1 5	3 7	0 9	1 3	539
37 00								9 8				64 0	29 1	0 8	2 4	1 3	1 6	0 5	375
38 00	44 2	39 6	16 2	47 0	41 9	11 1	1 86	10 8				59 8	29 9	0 7	3 9	2 0	3 6	0 0	438
39 50								10 5				62 3	32 5	0 6	2 1	1 2	1 2	0 0	329
40 00	41 5	41 6	16 8	45 0	43 0	12 0	1 58	11 8				59 3	30 7	0 2	4 6	2 3	2 6	0 2	388
41 00	27 3	51 9	20 7	31 6	53 2	15 2	0 72	12 5				62 5	30 1	0 7	4 0	1 8	0 7	0 0	272
42 50								25 4											
43 00								13 7				60 0	26 5	0 4	5 3	5 1	2 2	0 6	532
44 00	25 9	50 9	23 1	29 3	52 3	18 4	1 31	13 6											
46 00								14 0				57 8	29 7	0 0	3 0	6 4	2 7	0 3	296
47 00	26 2	50 5	23 4	29 6	53 0	17 5	1 15	11 6				60 2	27 9	0 0	4 4	5 0	1 9	0 6	480
48 00								11 6				57 2	25 8	0 4	6 7	4 5	5 2	0 2	554
49 00	32 0	45 1	21 0	31 8	47 6	17 6	1 38	13 0				56 9	29 2	0 7	3 3	6 2	3 7	0 0	568
50 00	33 9	44 2	21 9	36 7	47 0	16 3	2 14	12 5				61 3	27 1	0 9	3 5	3 2	0 9	0 0	379
51 00	35 9	43 4	20 7	39 0	45 6	15 4	1 58	11 1											
52 00	35 3	43 5	21 2	38 1	46 8	15 1	1 56	11 7				53 6	36 0	0 6	3 4	4 1	2 2	0 0	319
53 00	32 2	47 9	19 9	35 4	50 8	13 8	1 41	12 2				61 9	26 1	0 9	5 3	1 8	2 5	1 2	323

77 SR 2

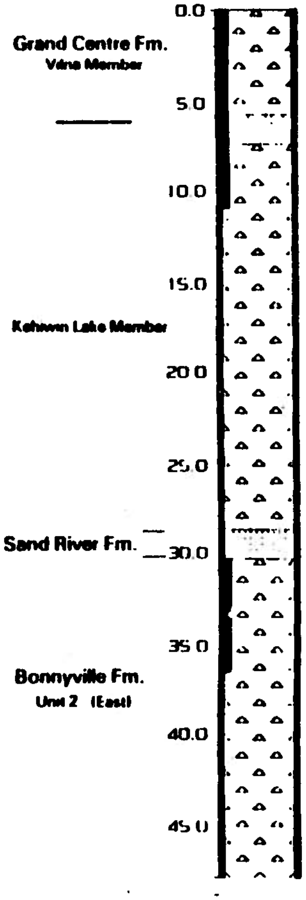
Alberta Geological Survey Testhole 77 SR 2
Location of LSD 4 Sec 17 Twp 58 Rng 7 W of 4 Mer , NTS 73L
Elevation 2175 ft 636 M Source 1 50,000 NTS 73L/3
Date drilled 197707 21 Logged by C LUTZAK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET M	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00								10 7	11 7	4 9	0 31	65 4	29 4	1 4	2 7	0 8	1 9	0 0	367
2 00	37 1	31 0	31 9	39 9	34 4	25 7	1 81	11 8	18 2	7 6	0 38	66 2	23 9	0 3	4 9	2 8	1 8	0 0	284
3 00	32 5	32 6	35 0	35 1	36 6	28 3	0 75	12 3	9 4	3 9	0 12	60 3	30 0	2 1	2 8	3 6	1 1	0 0	280
4 00	39 5	28 5	32 0	42 0	32 0	26 0	2 13	11 4	16 5	6 9	0 26	59 0	32 1	0 5	2 7	3 5	2 1	0 0	371
5 00	38 6	29 9	31 6	41 1	32 8	26 0	1 87	11 3	15 9	6 7	0 46	61 2	31 1	0 3	2 1	3 1	2 1	0 0	382
6 00	38 7	29 9	31 1	41 3	28 6	30 2	1 86	11 5	15 4	6 5	0 30	63 2	31 0	0 7	2 4	1 7	0 9	0 0	419
7 00	43 8	31 3	24 8	46 5	29 7	23 7	1 69	10 1	10 2	4 3	0 24	59 1	35 1	2 0	2 0	0 6	1 1	0 0	350
8 00								10 7	15 5	6 5	0 22	61 1	34 5	0 9	0 0	1 1	2 6	0 0	345
9 00	37 9	30 5	31 6	40 7	29 2	30 1	1 47	10 8	14 7	6 2	0 55	61 4	31 5	0 8	1 6	1 6	3 2	0 0	378
10 00								10 9	14 9	6 3	0 43	59 6	29 4	1 3	2 4	2 4	5 1	0 0	374
11 00	35 7	33 1	31 2	38 4	31 9	29 7	1 69	10 6	13 7	5 8	0 44	59 9	31 5	1 4	3 3	1 1	2 8	0 0	362
12 00								10 8	13 7	5 7	0 33	56 7	31 9	0 8	3 1	2 6	4 5	0 3	351
13 00	35 9	37 6	26 5	38 6	36 2	25 3	1 56	11 2	15 4	6 5	0 35	60 5	31 6	1 6	3 4	0 8	2 4	0 0	377
14 00	35 5	40 1	24 3	38 2	39 6	22 3	1 63	11 4	16 5	7 0	0 39	58 4	32 2	0 8	2 9	1 9	1 6	2 4	373
15 00								10 5	14 7	6 2	0 33	54 6	34 6	2 3	4 0	2 0	2 3	0 3	350
16 00	35 7	42 6	21 7	38 4	41 2	20 3	1 52	10 8	13 6	5 7	0 34	54 2	36 0	0 8	4 7	2 2	1 4	0 5	358
17 00								11 1	15 4	6 5	0 41	55 1	33 5	2 1	4 0	2 1	3 1	0 0	421
18 00	37 8	42 3	19 9	40 5	40 9	18 6	1 40	9 8	13 4	5 6	0 38	56 5	38 4	0 8	1 3	1 6	1 1	0 3	375
19 00								10 0	13 7	5 8	0 39	65 0	27 5	3 4	0 9	2 2	0 9	0 0	323
20 00	42 8	38 8	18 3	45 7	37 3	17 0	1 70	9 5	13 7	5 8	0 41	56 8	37 9	1 5	0 6	2 1	0 9	0 6	338
21 00								9 7	12 8	5 4	0 31	53 8	39 1	1 5	1 5	1 8	1 8	0 3	327
22 00	43 8	41 3	14 9	46 7	39 9	13 4	1 47	9 3	10 6	4 5	0 32	48 0	43 4	1 8	2 1	1 8	2 5	0 3	325
23 00	42 8	38 4	18 7	45 8	37 0	17 3	1 69	9 4	13 0	5 4	0 29	54 9	40 7	0 9	1 1	0 9	1 4	0 0	346
24 00	41 4	40 6	18 0	44 2	39 5	16 3	1 91	9 5	13 7	5 8	0 32	61 2	34 0	1 4	1 4	1 1	0 8	0 0	353
25 00	44 8	40 1	15 1	47 9	38 4	13 7	1 56	10 9	9 2	3 9	0 45	62 0	32 1	1 3	1 8	1 8	0 7	0 5	395
26 00	42 3	40 4	17 3	45 4	38 4	16 2	1 49	11 0	11 7	4 9	0 42	65 7	29 4	2 7	0 2	0 8	0 4	0 6	473
27 00	61 0	22 5	16 5	64 3	19 8	15 9	4 65	11 5	20 6	8 7	0 39	64 4	27 4	0 3	5 2	1 0	1 6	0 0	306
28 00	30 3	31 0	38 7	32 9	29 8	37 2	1 62	11 0				65 0	28 1	0 6	3 1	1 3	1 9	0 0	317
29 00	32 6	34 0	33 4	35 6	32 2	32 2	1 56	11 3	19 3	8 0	0 17	68 5	27 7	0 3	2 7	0 0	0 8	0 0	375

77 SR 3

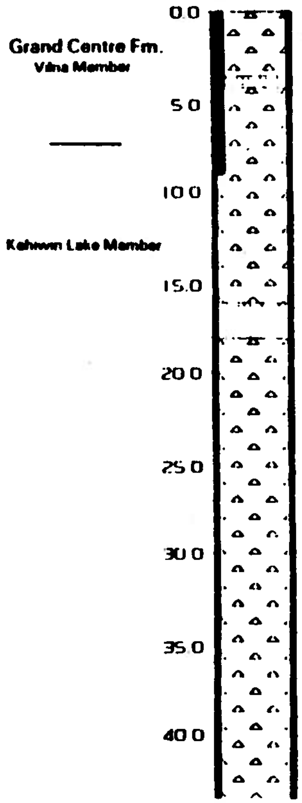
Alberta Geological Survey Testhole 77 SR 3
Location of LSD 16 Sec 10 Twp 58 Rng 10 W of 4 Mer . NTS 73L
Elevation 2130 Ft 649 M Source 1 50,000 NTS 73L/3
Date drilled 1977/07 22 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT USS	LST	DST	LOC	OTH	N
1 00								14 3	35 9	15 1	0 11	68 3	26 9	0 7	2 4	0 9	0 7	0 0	423
2 00	38 9	36.7	24 4	41 5	38 1	20 5	1 52	14 3	32 5	13 7	0 40	61 9	28 0	0 5	1 8	3 9	0 8	0 0	382
3 00	36 5	41 2	22 3	39 0	42 0	19 0	1 53	11 7	23 6	9 9	0 24	68 5	25 3	1 0	2 9	1 5	0 8	0 0	517
4 00	32 7	38 3	29 0	35 1	40 1	24 8	1 26	14 2	21 4	9 0	0 40	65 1	25 2	1 5	1 9	3 1	3 1	0 0	321
5 00	36 3	38 9	24 8	38 7	40 2	21 1	1 55	15 2	21 3	8 9	0 18	64 9	27 9	1 5	2 6	3 0	0 0	0 0	265
7 00								12 3	19 1	8 0	0 21	60 0	31 4	0 3	4 7	3 0	0 5	0 0	363
8 00	40 5	37 3	22 1	43 1	39 2	17 7	2 39	10 6	22 4	9 4	0 24	63 8	30 3	0 2	2 8	1 6	1 2	0 0	426
9 00	41 5	37 3	21 2	44 4	38 6	17 0	2 87	10 7	22 1	9 2	0 21	64 3	28 6	0 0	3 9	1 8	1 1	0 3	280
10 00								11 1	22 7	9 5	0 29	59 1	31 2	0 3	3 6	3 9	1 5	0 3	330
11 00	41 3	38 0	20 7	44 0	39 3	16 7	2 51	11 0	19 2	8 0	0 24	56 3	33 7	0 8	4 2	2 9	1 5	0 4	474
12 00								11 6	22 1	9 2	0 22	60 8	31 8	0 0	2 2	3 4	1 4	0 3	355
13 00	41 6	37 0	21 4	44 9	37 9	17 2	2 62	11 1	22 2	9 3	0 26	60 3	30 7	0 0	2 3	4 1	2 1	0 5	388
14 00								10 9	23 0	9 6	0 22	62 2	29 9	1 0	2 6	2 9	1 4	0 0	415
15 00	44 2	36 4	19 4	47 0	38 2	14 8	1 87	10 2	22 3	9 3	0 19	62 2	31 7	0 5	2 4	1 9	1 0	0 2	416
16 00								10 7	22 7	9 5	0 23	59 7	31 7	0 4	2 6	4 1	1 5	0 0	268
17 00	41 4	37 5	21 1	44 1	38 6	17 2	2 43	10 6	22 0	9 2	0 24	58 9	33 5	0 6	2 3	2 3	2 3	0 0	514
18 00								10 4	27 2	11 5	0 38	59 1	35 6	0 3	1 4	2 4	1 0	0 0	286
19 00	41 1	38 4	20 5	43 8	39 9	16 3	2 35	10 3	23 3	9 8	0 46	57 5	33 1	0 7	4 5	2 2	1 5	0 4	266
20 00								10 4	23 9	10 1	0 50	58 6	31 6	0 3	5 7	2 9	0 7	0 0	278
21 00	42 6	37 8	19 6	45 1	41 0	13 9	2 51	10 0	21 2	9 0	0 53	59 2	31 4	0 0	2 4	3 8	0 8	0 3	368
22 00								10 1	24 1	10 1	0 28	59 6	31 7	1 4	2 8	3 8	0 7	0 0	287
23 00	42 5	38 3	19 1	45 1	41 6	13 2	2 63	10 3	23 8	10 0	0 40	61 2	30 6	0 6	2 6	3 6	1 3	0 0	307
24 00								10 6	27 5	11 5	0 24	67 1	25 8	0 6	1 5	3 7	1 2	0 3	322
25 00	40 1	40 1	19 9	42 6	43 6	13 7	1 98	10 1	28 9	12 1	0 24	61 6	32 4	0 8	1 9	3 2	0 3	0 0	370
26 00								10 5	30 5	12 8	0 26	65 3	28 0	0 0	1 5	4 1	1 1	0 0	268
27 00	36 6	42 8	20 6	39 2	46 2	14 6	1 83	10 8	26 9	11.1	0 11	63 5	26 3	0 5	4 5	4 0	1 2	0 0	403
28 00	38 7	42 7	18 6	41 5	45 9	12 6	1 96	10 2	29 5	12 3	0 21	67 9	25.5	0 4	0 8	4 9	0 4	0 0	471
30 00	50 9	31 8	17 2	53 5	33 7	12 9	2 67	9 7	5 9	2 5	1 67	61 3	37 7	0 2	0 2	0 5	0 7	0 0	424
31 00	51 8	32 8	15 4	54 5	33 2	12 3	2 51	11 1	12 4	5 3	0 63	58 9	34 1	1 5	3 1	0 4	4 9	0 0	258
32 00	50 0	34 5	15 6	52 6	35 3	12 1	2 91	11 0	11 2	4 8	0 68	50 3	44 7	0 8	2 2	0 3	1 7	0 0	358
33 50								10 9	12 7	5 4	0 58	52 5	42 9	1 1	1 4	0 6	1 7	0 0	354
34 00	48 4	34 0	17 6	51 0	35 1	13 9	2 66	11 0	12 1	5 3	0 68	60 0	36 4	0 6	1 2	0 9	0 9	0 0	335
35 00								11 1	11 6	4 9	0 34	52 5	43 2	0 3	1 1	0 7	2 1	0 0	280
36 50	46 6	38 3	15 1	49 4	41 3	9 3	2 35	10 1	15 2	6 4	0 30	47 9	44 5	1 0	1 1	1 9	0.0	1 5	263
37 00								10 5	14 9	6 3	0 37	52 6	43 6	0 7	1 9	0 0	2 2	0 0	271
38 00	47 3	40 3	12 4	50 2	42 4	7 3	2 01	9 9	15 3	6 4	0 32	50 2	44 2	1 1	1 5	2 2	0 7	0 0	269
39 50								10 1	15 9	6 6	0 24	51 4	41 8	2 1	2 5	0 7	1 4	0 0	282
40 00	46 4	39 1	14 5	49 3	42 1	8 5	2 19		15 3	6 4	0 27	48 6	43 8	0 2	4 1	2 3	0 7	0 2	436
41 00								11 2	13 4	5 6	0 27	45 8	51 0	0 4	1 3	0 4	1 0	0 0	474
42 50	44 5	41 0	14 5	47 4	44 0	8 6	2 69	10 0	15 4	6 4	0 30	41 6	51 3	1 3	2 6	2 9	0 3	0 0	310
44 00								10 9	14 7	6 2	0 30	52 9	40 1	1 0	3 1	2 1	1 0	0 0	289
46 00	46 9	40 5	12 5	49 8	42 9	7 3	2 00	10 7	13 7	5 7	0 29								
47 00								10 2	16 1	6 7	0 29	50 7	42 1	1 7	2 0	2 0	1 1	0 0	345
48 00	47 4	38 6	14 0	50 3	41 5	8 2	2 08	10 5	16 1	6 8	0 21	51 8	36 6	1 4	7 5	1 9	0 5	0 2	413

77 SR 4

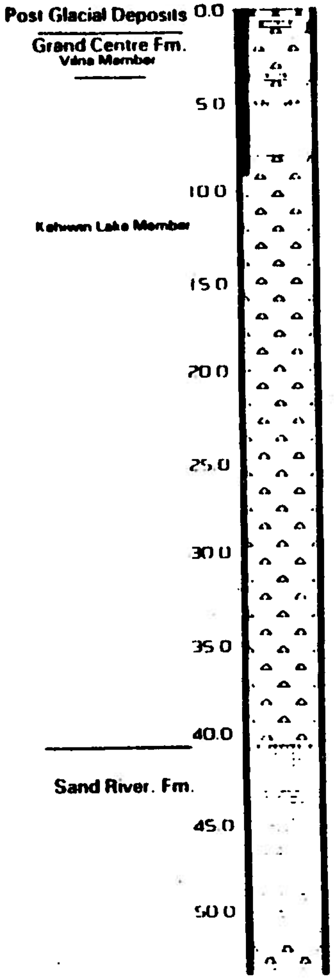
Alberta Geological Survey Testhole 77 SR 4
Location of LSD 13 Sec 14 Twp 58 Rng 11 W of 4 Mer . NTS 73L
Elevation 2095 Ft 639 M Source 1:50,000 NTS 73L/4
Date drilled 1977/07/21 Logged by C. FUTZAK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1.00								12.4				71.1	21.5	1.0	3.8	2.2	0.3	0.0	312
2.00	35.7	39.1	25.2	38.4	40.2	21.4	1.08	12.2				71.3	22.7	0.2	3.0	2.1	0.7	0.0	412
3.00	35.1	39.9	25.0	37.8	41.1	21.1	1.07	13.5				64.5	26.3	0.3	2.2	3.3	3.0	0.3	361
4.00	29.0	40.2	30.8	31.1	42.4	26.5	1.04	12.6				71.5	21.0	1.9	2.3	2.6	0.7	0.0	428
5.00								12.7				70.5	20.3	0.7	2.0	3.1	1.1	0.0	451
6.00	36.9	37.5	25.6	39.6	39.4	21.0	1.59	11.9				71.1	23.1	1.7	1.0	2.4	1.0	0.0	294
7.00								11.1				69.4	24.8	0.0	2.9	4.6	1.1	0.0	523
8.00	46.7	31.9	21.4	49.3	34.0	16.8	2.87	10.9				70.6	22.5	0.9	2.5	2.9	0.5	0.0	551
9.00	44.0	33.9	22.2	46.5	35.2	18.4	2.57	11.1				75.1	18.4	0.0	3.9	1.8	0.7	0.0	283
10.00								10.5				74.8	19.8	1.5	1.5	2.4	0.3	0.0	338
11.00	45.1	37.8	17.2	47.8	41.1	10.9	2.64	10.8				70.7	24.6	0.2	2.9	1.2	0.2	0.0	410
12.00								11.1				70.4	23.4	0.2	1.2	3.3	1.2	0.2	397
13.00	46.0	36.0	18.0	48.7	39.8	11.4	1.76	10.5				63.2	29.6	0.3	3.4	2.9	0.5	0.0	378
14.00								9.9				63.4	32.1	0.6	2.1	0.9	0.9	0.0	330
15.00	48.9	36.3	14.8	51.3	38.8	9.8	2.64	9.9				71.9	21.4	0.0	1.4	2.9	0.3	0.0	278
15.50								9.3				63.6	27.8	1.5	3.0	3.0	1.0	0.0	396
18.00	44.6	36.8	18.5	47.3	40.5	12.2	2.68	11.1				63.1	28.0	0.0	4.4	3.7	0.7	0.0	293
19.00								10.6				66.0	24.4	0.5	2.7	4.3	1.6	0.3	368
20.00	43.3	36.0	20.7	45.9	38.8	15.3	2.46	10.9				63.6	27.1	2.8	3.8	1.7	1.0	0.0	398
21.00								11.1				68.1	23.8	1.0	3.3	2.6	1.3	0.0	307
22.00	43.9	37.0	19.1	46.5	40.4	13.1	2.56	10.6				61.5	29.9	0.4	4.0	2.5	1.7	0.0	478
23.00								10.4				64.5	28.5	0.2	3.4	3.0	0.4	0.0	439
24.00	44.2	36.9	18.9	46.8	40.0	13.2	2.30	10.4				67.1	26.2	0.4	2.4	1.8	1.0	1.0	496
25.00								10.3				68.7	23.3	0.4	4.1	2.2	1.2	0.0	492
26.00	43.9	36.8	19.4	46.6	40.2	13.3	2.34	10.4				62.0	31.6	0.0	0.9	4.4	1.2	0.0	342
27.00								10.4				63.7	29.0	1.1	2.8	2.2	1.1	0.0	355
28.00	43.1	37.7	19.1	45.7	41.3	12.9	2.52	10.7				63.7	29.5	0.0	2.1	3.6	0.6	0.6	316
29.00								10.5				68.0	25.8	0.4	2.5	1.6	1.4	0.4	441
30.00	44.0	36.8	19.2	46.7	39.5	13.9	2.46	10.2				62.4	27.5	0.8	3.9	4.1	1.0	0.2	386
31.00								10.3				65.8	27.7	0.0	2.5	2.5	1.4	0.0	278
32.00	43.6	38.3	18.1	46.3	40.7	13.0	2.41	10.2				65.9	27.4	0.5	1.6	4.0	0.5	0.0	372
33.50								10.3				65.7	26.6	0.4	3.4	2.9	0.9	0.0	440
34.00	44.0	39.4	16.7	46.7	41.1	12.2	2.58	10.2				61.4	31.4	0.3	2.7	3.3	0.5	0.5	363
35.00								10.1				66.8	26.3	0.3	1.6	3.1	1.8	0.0	381
36.00	44.6	38.9	16.5	47.3	41.7	11.0	2.45	10.1				59.7	29.5	0.5	5.0	5.0	0.0	0.5	400
37.00								10.5				67.4	26.8	0.5	2.3	2.6	0.3	0.0	384
38.00								9.9				69.3	23.9	1.1	3.2	2.1	0.3	0.0	372
39.50								9.6				63.1	29.3	0.3	3.7	2.5	0.6	0.3	352
40.00								10.2				66.1	27.3	0.7	2.2	2.9	0.7	0.0	407
41.00								10.0				67.1	27.0	0.0	2.8	2.5	0.5	0.3	359
42.50								9.0				66.7	28.0	0.7	1.2	1.9	1.4	0.0	414
43.00								11.4				63.5	28.7	0.7	1.9	2.4	0.7	0.0	421

77 SR 5

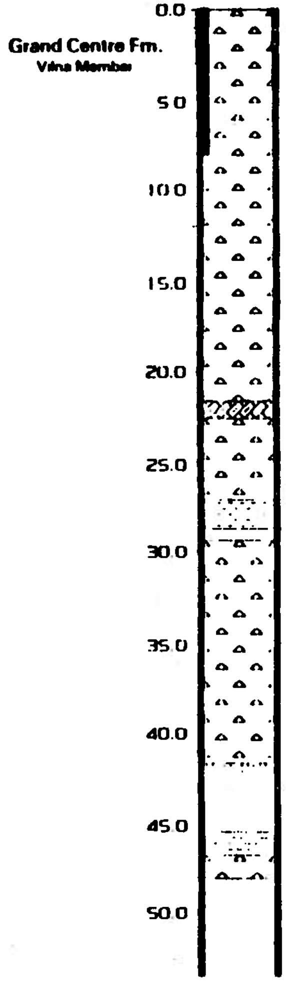
Alberta Geological Survey Testhole 77 SR 5
Location of LSD 3 Sec 26 Twp 59 Rng 13 W of 4 Mer . NTS 73L
Elevation 2100 FT 640 M Source 1 50,000 NTS 73L/4
Date drilled 1977/07 24 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
2 00	38 3	24 5	37 2	40 8	28 5	30 8	1 55	18 4				64 2	26 3	0 0	2 2	2 9	4 4	0 0	137
3 00	38 6	23 6	37 7	41 2	28 2	30 7	1 39	15 2				58 1	33 5	0 6	3 9	1 9	1 9	0 0	155
4 00	48 8	23 0	28 1	51 1	25 8	23 1	1 95	14 4				59 7	32 7	0 0	4 7	2 0	0 9	0 0	211
5 00	48 6	22 0	29 4	51 3	23 5	25 2	2 05	11 3				55 6	34 5	0 4	3 4	3 4	2 6	0 0	232
9 00	44 9	26 4	28 7	47 6	32 1	20 3	1 85					62 9	30 6	0 0	3 5	1 2	1 8	0 0	170
11 00	46 3	25 3	28 4	49 2	31 2	19 6	2 09					61 2	32 1	0 6	2 8	1 8	1 2	0 3	327
12 00								12 0											
13 00	45 3	26 0	28 7	47 9	32 7	19 4	2 06	12 6				53 1	37 4	1 7	2 1	3 8	1 4	0 0	289
14 00								11 9											
15 00	45 1	24 4	30 6	47 9	30 6	21 5	2 18	11 8				60 5	31 5	0 2	3 8	1 8	2 0	0 0	451
16 00								11 7											
17 00	46 3	24 2	29 5	48 9	30 5	20 5	2 19	11 4				56 6	35 5	0 4	2 8	2 6	1 9	0 4	468
18 00								10 8											
19 00	47 5	23 8	28 7	50 2	29 5	20 3	2 19	10 5				61 1	27 1	0 3	3 1	3 7	4 6	0 0	350
20 00								10 7											
21 00	46 2	26 4	27 5	48 8	31 6	19 7	2 12	10 4				62 7	27 9	0 6	2 0	3 4	2 8	0 2	501
22 00								11 2											
23 00	47 3	26 9	25 8	50 0	32 2	17 8	2 24	10 5				59 0	31 9	0 9	3 8	2 7	1 8	0 0	339
24 00								10 6											
25 00	46 1	28 3	25 6	49 1	33 3	17 6	2 39	10 4				66 7	25 1	0 0	4 3	2 8	1 2	0 0	327
26 00								10 5											
27 00	47 5	24 1	28 4	50 0	29 6	20 4	2 27	10 8				61 2	31 0	0 3	2 6	1 8	3 1	0 0	381
28 00								10 1											
29 00	50 4	23 6	26 0	53 3	28 2	18 5	2 10	10 2				56 4	31 1	0 0	4 1	4 4	3 7	0 3	296
30 00								9 9											
31 00	46 5	27 3	26 1	49 2	32 9	17 9	1 12	10 5				63 4	27 9	1 1	1 9	3 2	1 5	0 2	473
32 00								9 7											
33 50	44 7	24 9	30 4	47 2	31 8	21 0	2 28	10 4				63 0	29 6	0 0	2 5	2 5	2 9	0 0	513
34 00								10 8											
35 00	44 5	27 9	27 7	47 0	34 0	19 0	1 98	10 8				60 1	31 6	0 0	3 0	3 2	2 3	0 0	434
36 00								10 4											
37 00	43 9	26 2	29 9	47 0	31 0	22 0	1 82	10 5				61 2	29 9	1 1	3 1	3 6	0 8	0 0	384
38 00								10 7											
39 50	38 2	24 8	37 0	40 6	28 4	31 1	1 15	12 2				67 2	28 2	0 0	1 1	3 4	0 0	0 0	177
40 00								18 4											
43 00								16 4											
44 00								19 0											
46 00								19 4											
47 00								19 2											
48 00								20 0											
49 00								20 8											
50 00								19 5											
51 00								20 1											
52 00	5 9	23 9	70 2	6 8	35 3	57 9	0 21	17 5				55 1	18 1	4 1	2 1	0 0	0 0	0 0	47
53 00	1 4	41 6	57 0	1 9	59 2	38 9	0 00	20 0											
54 00	3 4	48 4	48 2	4 1	60 0	35 7	0 01	21 6											

77 SR 6

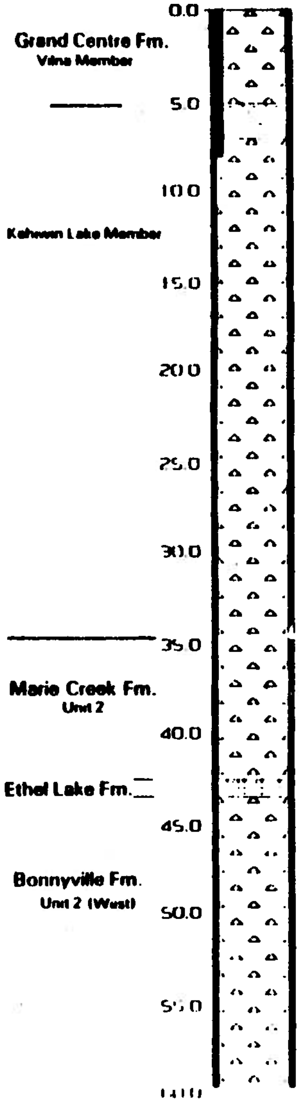
Alberta Geological Survey Testhole 77 SR 6
Location of LSD 9 Sec 23 Twp 58 Rng 11 W of 4 Mer . NTS 73L
Elevation 2130 ft 649 M Source 1 50,000 NTS 73L/4
Date drilled 1977/07/25 Logged by C FOTZAK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	COC	OTH	N
1 00								14 3											
2 00	28 2	44 2	27 6	31 1	46 0	22 9	0 82	14 7				66 0	18 9	1 4	6 6	2 8	1 9	1 0	106
3 00	35 0	41 1	23 9	37 6	42 7	19 7	1 03	12 7				78 4	12 3	0 9	5 3	0 9	1 8	0 0	114
4 00	36 5	38 5	25 0	39 4	40 0	20 7	1 10	16 1				62 9	22 9	1 9	4 8	5 7	1 9	0 0	105
5 00								16 6											
6 00	29 6	41 3	29 1	31 9	42 3	25 9	0 83	17 6				61 7	23 4	0 0	5 6	5 6	3 7	0 0	107
7 00								17 9											
8 00	36 3	39 5	24 1	39 9	41 8	18 4	1 80	15 1				70 6	20 9	1 4	1 4	4 3	1 4	0 0	211
9 00								16 7											
10 00	35 8	41 5	22 7	38 5	43 9	17 6	1 64	14 7				62 8	28 1	0 0	3 6	3 6	2 0	0 0	196
11 00								16 8											
12 00	31 4	41 0	27 6	33 6	45 7	20 7	2 10	14 0				75 7	17 6	0 0	1 8	4 8	0 0	0 0	227
13 00	34 6	42 1	23 4	37 4	44 6	18 0	1 34	14 0				71 7	25 4	0 6	1 7	0 0	2 3	0 0	173
14 00	38 1	41 1	20 5	41 3	42 7	15 9	1 54	12 8				75 6	19 2	0 0	1 0	2 6	1 6	0 0	193
15 00	37 5	39 6	22 8	40 4	41 8	17 8	1 68	10 9				74 5	18 4	1 5	3 6	2 0	0 0	0 0	196
16 00								11 0											
17 00	35 7	41 4	22 9	38 5	43 4	18 1	1 57	15 9				74 2	21 5	0 0	0 5	3 2	0 5	0 0	186
18 00								11 7											
19 00	37 9	39 6	22 4	40 8	41 2	18 0	2 00	10 8				78 1	17 3	0 0	1 3	3 4	0 0	0 0	237
20 00								12 0											
21 00								20 0											
22 00								18 8											
23 00								13 4											
24 00	31 1	41 9	27 0	33 3	44 7	22 1	1 29	14 5				65 8	23 9	0 6	3 2	6 5	0 0	0 0	155
25 00	29 7	41 8	28 4	31 9	45 4	22 7	1 30	14 7				68 8	20 4	0 0	5 1	4 5	0 6	0 6	157
26 00	29 3	41 9	28 9	31 4	45 7	22 9	1 29	14 5				62 6	22 6	3 2	5 2	4 5	1 3	0 6	155
27 00								16 0											
28 00								14 7											
29 00								15 1											
30 00								11 0											
31 00	27 8	46 6	25 6	30 6	51 5	17 9	0 74	12 8				56 8	31 6	1 1	1 1	9 5	0 0	0 0	95
32 00								10 2											
33 00	35 8	44 1	20 1	38 9	47 4	13 8	0 83	10 6				64 4	28 7	1 0	1 0	3 0	2 0	0 0	101
34 00								14 3											
35 00	14 9	55 4	29 7	17 4	61 1	21 1	0 29	13 6				84 4	13 3	0 0	2 2	0 0	0 0	0 0	45
36 00								14 7											
37 00	20 4	51 6	28 0	22 6	57 4	20 0	0 66	12 4				54 7	29 3	10 7	5 3	0 0	1 3	0 0	75
38 00								10 3											
39 00	33 7	42 3	24 0	36 1	47 7	16 3	0 97	10 1				69 7	25 2	1 7	0 8	0 0	2 5	0 8	119
40 00	41 1	40 4	18 5	41 8	46 3	11 8	3 70	10 0				78 0	17 9	1 6	0 0	1 6	0 8	0 0	123
41 00	24 2	45 0	30 8	26 5	52 4	21 1	0 39	12 9				71 4	22 4	4 1	0 0	2 0	0 0	0 0	49
46 00																			
47 00	35 7	43 5	20 8	38 1	49 0	12 9	0 94	11 8				66 1	24 0	0 0	5 0	2 5	2 5	0 0	121
48 00								15 5											
49 00								20 2											
50 00								21 9											
51 00								16 6											

77 SR 7

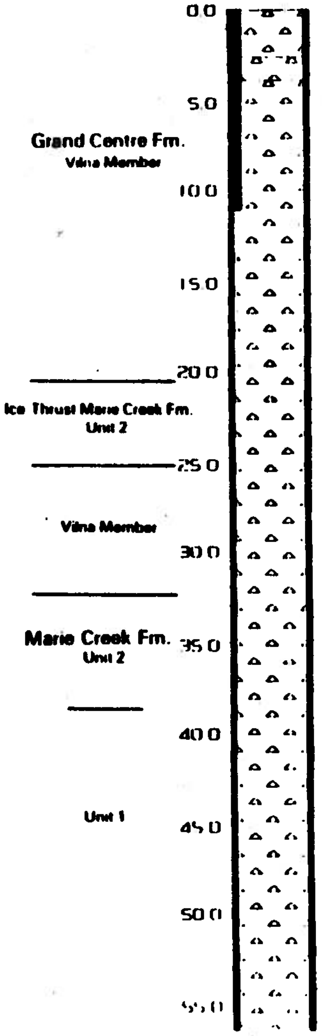
Alberta Geological Survey Testhole 77 SR 7
Location NE of LSD 16 Sec 29 Twp 59 Rng 11 W of 4 Mer NTS 73L
Elevation 2130 Ft 649 M Source 1 50,000 NTS 73L/4
Date drilled 1977/07 27 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/MG	IGN MEIM	QTZ	QTZI QSS	LST	DST	LOC	OTH	N
1 00								23 3				68 0	28 7	2 5	0 0	0 0	0 7	0 0	275
2 00	26 9	23 8	49 3	29 2	31 6	39 1	1 16	14 9				64 3	30 8	0 7	2 1	1 4	0 7	0 0	143
3 00	29 3	29 6	41 1	31 8	36 1	32 1	0 00	10 7				59 6	35 1	0 3	2 6	1 7	0 6	0 0	347
4 00	30 9	32 4	36 7	33 3	38 4	28 3	1 32	18 1				66 7	19 6	2 0	3 9	3 9	3 9	0 0	51
5 00	42 1	27 4	30 5	44 7	31 3	24 0	2 08	10 8				65 6	30 3	0 3	1 4	1 7	0 7	0 0	294
6 00								12 1				56 1	39 5	0 0	2 6	1 7	0 0	0 0	114
7 00	46 5	23 2	30 3	49 2	27 0	23 8	2 47	10 9				61 0	30 9	1 2	1 5	4 0	1 2	0 0	323
8 00	48 5	22 9	28 6	51 1	26 0	22 9	2 46	11 7				58 3	31 9	1 0	3 7	3 2	2 0	0 0	408
9 00	49 6	22 7	27 7	52 3	26 2	21 5	2 58	10 2				57 2	38 8	0 6	0 0	1 6	1 6	0 0	484
10 00								10 1				59 4	33 7	0 8	0 8	3 3	1 9	0 0	362
11 00	45 6	30 4	24 0	48 3	35 3	16 4	2 35	10 5				62 1	29 0	1 0	2 9	4 2	0 5	0 3	383
12 00								10 3				59 5	32 0	0 8	3 6	1 3	2 8	0 0	390
13 00	47 3	31 6	21 1	50 0	35 9	14 2	2 01	12 0				56 8	33 8	0 3	3 6	4 2	1 3	0 0	308
14 00								9 4				56 9	35 9	1 3	0 3	1 0	1 0	0 0	295
15 00	49 2	31 0	19 8	51 9	35 5	12 7	2 20	12 6				56 9	36 6	0 0	3 2	3 2	1 0	0 0	311
16 00								10 0				58 0	33 3	1 1	2 9	3 3	1 4	0 0	276
17 00	48 7	30 7	20 6	51 4	35 5	13 0	1 46	9 1				59 9	30 9	0 3	3 7	3 4	1 5	0 0	324
18 00								11 8				61 8	29 8	0 3	1 3	2 6	1 6	0 6	312
19 00	49 6	26 7	23 6	52 3	32 0	15 7	2 30	9 9				61 4	36 3	0 0	1 1	0 4	0 7	0 0	267
20 00								9 6				59 0	31 9	0 3	2 8	2 5	3 1	0 3	354
21 00	47 9	26 9	25 2	50 5	32 4	17 1	2 12	11 0				54 2	36 7	0 4	3 4	2 7	2 3	0 2	441
22 00								10 4				55 4	37 2	0 3	3 3	3 0	0 8	0 0	368
23 00	47 2	29 2	23 6	49 9	34 4	15 7	2 02	10 1				54 9	37 1	0 3	2 9	2 4	2 1	0 3	377
24 00								11 2				51 1	35 7	0 9	4 2	4 2	1 5	0 3	333
25 00	47 2	27 5	25 3	50 5	32 0	17 5	1 78	11 6				55 3	37 9	0 5	1 9	2 2	2 2	0 0	367
26 00								11 7				58 0	33 3	0 7	5 3	1 7	1 0	0 0	300
27 00	49 0	26 8	24 2	51 8	32 9	15 3	1 81	10 5				56 1	34 9	0 7	3 9	2 8	1 4	0 2	413
28 00								10 7				57 8	36 1	0 7	3 2	0 7	1 4	0 2	438
29 00	47 7	28 4	23 9	50 8	33 2	15 9	2 30	10 3				56 1	33 2	0 7	3 8	4 9	1 2	0 0	424
30 00								10 6				54 1	38 9	0 7	3 6	2 7	0 0	0 0	442
31 00	46 0	31 4	22 7	48 7	36 4	14 9	2 20	10 9				57 6	34 3	0 5	4 6	1 4	1 6	0 0	434
32 00								10 7				55 1	37 6	0 9	3 8	2 0	0 7	0 0	452
33 00	47 3	30 0	22 6	50 4	35 0	14 6	2 35	10 9				53 4	38 5	0 9	3 4	2 5	1 3	0 0	442
34 00								10 4				55 3	34 9	0 8	3 2	4 9	0 8	0 0	472
35 00	50 2	30 8	18 9	53 0	34 7	12 4	2 53	10 2				64 3	29 0	1 0	0 7	3 5	1 0	0 3	286
36 00								10 1				62 1	30 1	1 0	2 3	4 0	0 4	0 0	472
37 00	42 5	28 4	29 1	44 9	34 8	20 3	2 17	9 3				63 4	28 8	0 6	1 8	4 2	1 0	0 2	500
38 00								10 5				59 3	32 6	1 9	1 9	3 2	1 1	0 0	374
39 00	39 8	27 6	32 6	42 2	32 9	24 9	2 12	10 1				61 6	26 1	1 6	2 1	6 8	1 8	0 0	383
40 00								10 4				63 3	27 6	0 8	1 9	5 6	0 8	0 0	376
41 00	39 9	30 2	29 9	42 4	36 7	20 9	2 06	10 6				61 6	26 7	1 1	3 3	5 5	1 5	0 2	453
42 00								10 4				63 1	23 1	1 5	3 7	6 5	1 8	0 3	325
44 00	29 4	39 8	30 8	32 2	47 0	20 8	1 42	12 8				48 9	36 4	0 7	6 9	4 2	2 4	0 3	288
45 00								12 9				44 7	42 1	0 0	4 5	4 9	2 6	1 1	266
46 00	32 5	37 9	29 6	35 7	44 8	19 4	1 60	11 9				56 5	35 2	0 7	4 3	0 3	2 5	0 3	273
47 00								11 7				54 4	31 8	0 3	4 5	4 2	4 2	0 5	377
48 00	39 0	34 8	26 2	39 8	43 1	17 1	1 23	13 3				51 2	35 6	2 7	1 9	3 5	4 8	0 3	371
49 00								11 5				51 0	40 0	0 7	3 2	2 9	2 4	0 0	410
50 00	33 2	35 2	31 6	35 9	42 9	21 2	1 39	12 2				51 5	39 7	0 5	4 4	1 9	1 6	0 0	365
51 00								12 5				49 0	40 3	1 1	4 2	2 7	2 3	0 4	263
52 00	31 3	33 1	35 5	34 1	41 8	24 2	1 27	12 7				51 7	37 6	0 4	5 2	2 6	1 8	0 7	271
53 00								10 8				57 2	36 3	1 2	1 8	0 9	2 1	0 3	332
54 00	40 6	31 3	28 1	41 1	38 8	18 1	2 06	11 1				52 1	38 2	0 7	4 2	3 5	1 2	0 0	424
55 00								11 4											
56 00	39 1	29 4	31 5	41 9	37 2	20 9	1 53	10 8				56 0	35 6	1 6	3 1	2 3	1 3	0 0	382
57 00								11 6				52 1	35 5	0 6	6 0	2 0	3 4	0 0	352
58 00	38 1	38 2	23 7	40 6	44 2	15 1	1 59	11 9				56 4	36 9	0 5	1 7	2 5	1 9	0 0	358
59 00	38 5	32 0	29 5	41 1	39 1	19 6	1 52	11 5				61 1	32 1	1 2	2 2	1 5	1 2	0 3	324
60 00	36 1	39 1	24 8	38 8	45 9	15 1	1 35	10 9				59 7	32 8	0 9	2 8	1 8	1 8	0 0	323

77 SR 8

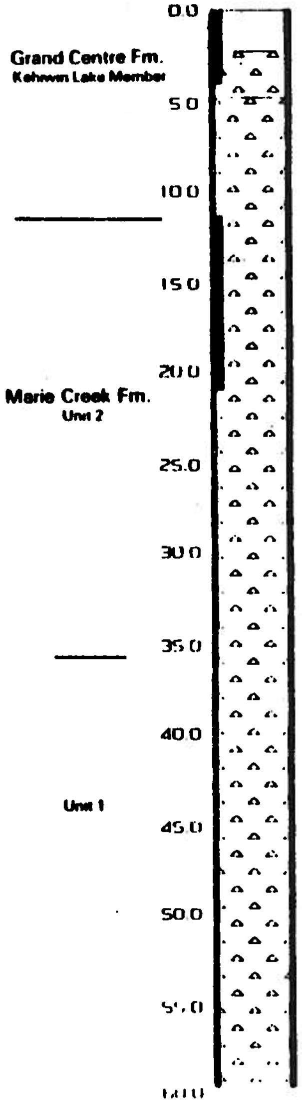
Alberta Geological Survey Institute 77 SR 8
Location SE of LSD 11 Sec 25 Twp 61 Rng 11 W of 4 Mer NTS 73L
Elevation 2150 Ft 656 M Source 1 50,000 NTS 73L/5
Date drilled 1977/07 28 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	26.1	35.1	38.8	28.8	38.5	32.7	0.90	14.1				69.3	27.4	0.8	0.8	1.3	0.2	0.2	521
2.00	34.9	30.7	34.4	37.2	35.1	27.7	1.20	16.5				54.0	31.5	2.7	6.3	2.7	1.8	0.0	111
3.00								12.8				59.6	26.1	2.7	4.8	5.9	0.8	0.0	371
4.00	32.9	25.1	42.1	35.3	29.3	35.3	0.86	13.7				61.0	28.7	2.1	1.2	5.5	1.2	0.2	421
5.00	32.4	28.6	39.1	34.9	32.1	33.0	1.07	14.0				59.2	29.9	1.5	4.0	3.7	1.5	0.0	321
6.00	35.3	27.6	37.1	37.8	30.9	31.3	1.10	12.8				54.9	35.4	0.9	3.7	2.3	1.7	1.0	570
7.00	36.3	27.6	36.0	38.9	29.9	31.2	1.12	11.3				51.6	35.7	1.7	3.6	4.4	1.0	0.0	412
8.00	37.0	28.7	34.3	39.5	31.6	28.9	1.10	11.7				58.4	34.2	2.2	1.9	1.5	1.8	0.0	322
9.00												56.5	31.4	0.5	4.3	5.8	1.4	0.0	414
10.00	33.7	27.8	38.5	36.2	33.4	30.3	1.23	12.0				59.2	31.2	0.6	2.0	5.9	0.9	0.0	304
11.00								11.6				60.0	30.3	0.8	3.5	3.8	0.7	0.3	597
12.00	30.4	26.1	43.6	32.6	33.0	34.5	1.59	12.1				59.5	26.7	1.3	5.8	5.1	1.4	0.0	583
13.00								11.9				59.7	30.6	1.0	3.6	4.2	0.4	0.2	497
14.00	36.9	29.3	33.7	39.5	22.8	37.8	1.14	13.3				56.8	35.3	1.4	3.5	2.1	0.7	0.0	433
15.00								13.6				62.8	29.1	0.4	3.4	2.8	0.8	0.2	463
16.00	27.7	30.2	42.1	29.8	23.0	47.2	1.08	12.5				61.2	28.4	0.6	2.0	4.5	2.6	0.0	510
17.00								12.9				63.3	29.0	1.5	2.5	3.1	0.6	0.0	325
18.00	32.0	33.4	34.6	47.2	13.5	39.3	0.88	11.2				61.4	32.2	2.0	1.7	2.0	0.6	0.0	298
19.00	27.3	36.3	36.4	30.0	29.1	40.9	0.82	12.4				59.4	29.8	0.9	3.2	3.2	3.2	0.3	315
20.00	29.9	33.1	37.0	32.7	26.6	40.7	0.80	10.8				50.3	37.8	0.6	6.2	4.7	0.3	0.0	320
21.00	31.0	32.0	37.0	33.2	25.7	41.1	2.11	11.0				61.4	26.6	0.2	1.8	8.3	1.5	0.0	443
22.00	31.2	39.9	28.9	33.5	32.6	33.9	1.82	10.5				51.8	27.0	1.1	3.6	12.1	1.5	0.0	356
23.00	30.7	38.7	30.6	33.0	31.3	35.7	1.83	10.1				57.3	24.6	0.3	2.1	13.0	2.1	0.3	337
24.00	31.5	37.5	31.1	33.8	30.4	35.8	2.04	9.8				56.0	28.1	0.7	3.5	10.8	0.9	0.0	427
25.00	33.3	35.0	31.8	36.3	27.9	35.7	0.75	8.8				57.0	34.0	1.5	3.1	1.5	1.8	0.0	323
26.00	29.0	33.6	37.4	31.6	26.7	41.8	0.60	11.5				56.7	32.3	1.8	5.5	0.9	2.4	0.5	217
27.00								10.8				68.3	24.6	2.0	0.7	2.4	1.6	0.2	407
28.00	22.6	39.2	38.3	24.5	32.4	43.0	0.59	12.0				50.0	26.8	2.0	4.0	5.0	11.6	0.0	298
29.00								12.5				68.8	22.4	0.4	2.7	5.6	0.0	0.0	478
30.00	9.8	57.0	33.2	12.4	50.3	37.3	0.88	12.2				61.9	28.6	0.6	3.0	4.9	0.9	0.0	328
31.00								12.1				58.7	31.3	3.0	2.1	3.3	0.9	0.6	329
32.00	26.8	39.1	34.0	29.4	32.1	38.5	0.89	11.2				68.9	23.9	0.0	1.4	5.3	0.5	0.0	360
33.00	34.3	39.7	26.0	36.8	33.8	29.4	2.19	9.8				66.5	15.2	0.6	3.9	13.0	0.9	0.0	361
34.00	30.7	40.4	28.8	32.7	34.1	33.2	1.94	10.3				71.8	22.1	0.2	1.0	4.6	0.2	0.0	411
35.00								8.6				55.8	16.2	0.2	5.1	18.9	3.0	0.2	428
36.00	38.3	36.9	24.8	41.3	30.8	27.9	2.61	8.9				47.7	17.4	0.0	7.0	23.9	3.7	0.3	356
37.00								8.4				52.1	14.1	0.2	6.3	19.0	7.8	0.0	411
38.00	12.1	61.8	26.1	14.9	55.4	29.7	2.12	9.6				50.1	20.7	0.0	6.9	18.2	3.6	0.0	363
39.00	28.2	33.8	37.9	30.0	26.8	43.2	1.88	12.1				57.4	29.5	2.4	3.0	6.2	1.5	0.0	336
40.00	26.3	35.4	38.3	28.1	28.8	43.1	1.67	13.2				57.4	27.7	0.4	4.4	8.9	0.8	0.0	472
41.00	34.3	34.1	31.6	36.4	27.4	36.2	1.69	11.7				61.7	27.1	0.0	2.4	8.2	0.5	0.0	376
42.00								11.7				59.8	27.6	0.3	2.5	8.1	1.1	0.0	358
43.00	28.6	36.0	35.4	30.4	29.7	39.9	1.59	12.9				66.4	24.3	0.6	2.2	5.4	0.9	0.0	313
44.00								10.4				62.1	22.1	0.9	3.7	9.8	0.6	0.0	327
45.00	17.3	51.8	30.8	19.6	46.0	34.4	1.87	10.5				68.0	22.7	1.0	3.1	4.7	0.4	0.0	488
46.00								10.7				61.9	26.3	0.0	2.5	8.8	0.6	0.0	365
47.00	34.6	35.7	29.7	37.0	28.9	34.1	2.03	10.7				64.9	21.2	0.9	1.8	10.5	0.6	0.0	325
48.00								10.4				68.9	21.7	0.3	1.4	6.4	1.3	0.0	360
49.00	34.2	33.8	32.1	36.4	27.7	36.0	2.12	10.6				63.1	24.9	0.2	3.3	7.4	0.7	0.0	429
50.00								10.0				67.5	23.8	0.5	1.6	5.2	1.0	0.0	382
51.00	37.8	33.1	29.1	40.1	26.7	33.2	2.63	9.8				66.1	25.4	0.0	1.0	6.4	1.0	0.0	511
52.00								10.1				66.5	25.6	0.2	1.7	5.5	0.4	0.0	457
53.00	36.0	35.4	28.6	38.3	29.1	32.5	2.32	9.2				69.9	21.8	0.7	1.1	6.4	0.0	0.0	416
54.00	41.8	32.7	25.1	44.2	26.7	29.2	2.75	9.5				68.6	22.1	0.2	1.7	6.4	0.7	0.0	574
55.00	29.4	35.8	34.8	31.5	29.3	39.1	1.10	11.4				67.5	23.0	0.0	1.9	4.5	2.9	0.0	308
56.00	31.8	38.9	30.1	37.0	28.9	34.1	2.29	10.0				59.2	29.3	0.8	2.5	6.1	2.0	0.0	358

77 SR 9

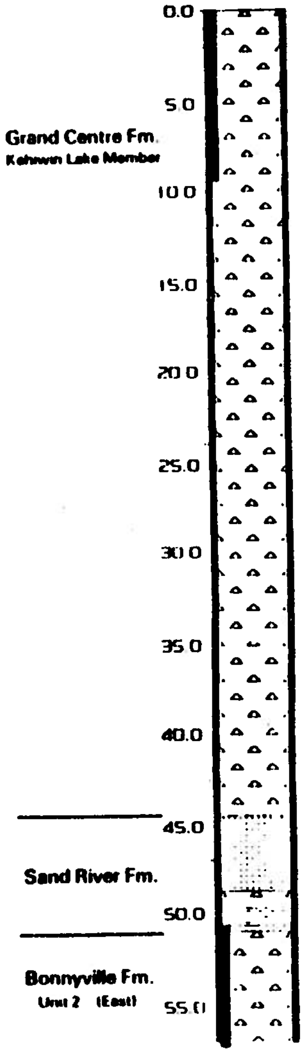
Alberta Geological Survey Testhole 77 SR 9
Location NE of LSD 16 Sec 7 Twp 60 Rng 8 W of 4 Mer NTS 73L
Elevation 2005 FT 611 M Source 1:50,000 NTS 73L/[illegible]
Date drilled 197708 01 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	COT (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
3.00	47.1	38.7	14.2	50.5	38.7	10.8	1.14	7.4				66.1	24.2	3.2	1.8	3.4	1.2	0.2	504
4.00																			
5.00	45.6	38.3	16.1	48.6	39.5	11.9	2.05	6.7				68.2	21.3	1.7	2.6	3.8	2.3	0.0	343
6.00	39.4	41.7	18.9	42.0	43.7	14.3	1.13	7.4											
7.00												59.3	23.9	3.3	6.1	4.5	1.9	0.7	423
8.00								7.8				66.2	24.0	1.2	3.6	3.8	1.2	0.0	337
9.00	38.2	42.3	19.4	40.8	44.5	14.7	1.07	8.1				58.8	25.7	2.2	3.8	4.4	4.9	0.4	452
10.00								8.6				63.4	19.8	3.6	6.3	4.7	1.9	0.3	363
11.00	34.9	43.2	22.0	37.5	44.6	17.9	1.22	10.9				69.5	17.3	0.5	3.7	8.1	0.8	0.0	381
12.00	35.0	30.9	34.1	37.4	33.0	29.6	2.18	7.7				69.6	18.5	0.2	2.8	7.2	1.3	0.0	388
13.00	34.9	31.8	33.3	37.4	34.4	28.1	1.99	7.2				72.0	15.8	0.2	3.4	6.9	1.6	0.0	436
14.00	36.4	31.9	31.6	39.0	34.5	26.5	2.28	7.2				62.2	20.3	2.1	12.7	2.1	0.5	0.0	418
15.00	36.2	31.3	32.5	38.7	33.8	27.4	2.39	7.8				66.0	17.7	0.3	3.0	12.5	0.8	0.0	368
16.00								8.3				66.1	20.6	0.0	2.5	9.3	1.2	0.2	431
17.00	35.0	32.3	32.7	37.6	35.4	27.0	2.03	7.7				69.2	15.7	0.3	3.9	10.2	0.8	0.0	383
18.00								8.6				68.4	19.2	0.2	2.9	7.3	2.0	0.0	452
19.00	35.8	31.4	32.8	38.3	34.1	27.5	2.10	8.0				70.1	16.0	0.0	3.7	9.0	1.0	0.2	401
20.00								7.9				69.2	16.5	0.7	3.2	9.7	0.0	0.5	400
21.00	36.7	28.8	34.5	39.2	32.0	28.8	2.20	8.6				71.8	14.6	0.6	3.7	8.5	0.9	0.0	458
22.00								8.6				69.5	16.8	0.4	2.7	10.2	0.4	0.2	482
23.00	35.1	29.6	35.3	37.6	33.0	29.4	2.31	8.7				68.1	17.5	1.4	2.9	9.0	1.2	0.0	411
24.00								7.9				65.7	20.3	0.2	3.8	10.4	0.0	0.0	394
25.00	34.5	30.5	35.0	37.0	33.5	29.5	2.18	8.7				67.7	22.3	0.2	2.2	6.5	1.0	0.0	412
26.00								8.1				64.2	22.8	0.6	3.2	8.0	0.9	0.2	464
27.00	33.9	29.0	37.1	36.3	32.9	30.8	2.24	8.3				69.4	15.4	0.5	3.1	10.7	0.5	0.3	382
28.00								8.6				71.1	19.7	0.0	2.2	6.7	0.0	0.2	401
29.00	32.5	28.9	38.6	34.8	32.9	32.3	2.11	8.5				71.5	18.3	0.3	3.4	6.3	0.3	0.0	382
30.00								6.7				66.9	20.5	0.0	2.2	10.1	0.5	0.0	366
31.00	33.2	28.8	38.0	35.6	32.2	32.2	2.34	8.9				68.6	16.1	0.0	2.0	10.9	2.5	0.0	404
32.00								8.2				65.8	19.4	1.2	3.9	8.1	1.5	0.0	406
33.00	33.8	28.4	37.8	36.2	32.0	31.8	2.08	8.5				67.1	20.2	0.0	2.0	10.2	0.5	0.0	401
34.00								8.9				71.1	17.2	0.5	2.7	6.5	1.9	0.0	367
35.00	31.7	27.7	40.6	34.0	32.5	33.5	2.43	7.0				64.8	24.6	0.0	1.9	7.5	0.8	0.0	358
36.00								7.8				64.3	20.2	0.5	3.1	9.6	1.7	0.5	415
37.00	33.0	28.7	38.2	35.4	32.3	32.3	2.20	8.0				64.6	19.8	0.0	1.7	12.3	1.5	0.0	398
38.00								8.3				64.6	21.2	0.3	2.3	8.7	0.9	0.0	345
39.00	32.6	27.9	39.5	34.9	31.3	33.8	1.94	8.5				65.0	21.7	0.0	2.9	6.6	1.7	0.0	409
40.00								8.9				64.3	18.8	0.6	3.4	10.6	2.3	0.0	350
41.00	29.2	27.6	43.2	31.4	32.1	36.4	1.80	9.3				71.2	18.9	0.1	2.0	6.7	0.9	0.0	314
42.00								9.1				72.7	16.9	0.6	3.2	6.4	0.3	0.0	344
43.00	32.5	25.6	42.0	34.8	29.9	35.4	2.01	9.2				66.5	19.5	0.2	2.8	10.4	0.5	0.0	394
44.00								8.5				66.5	21.9	0.0	3.6	6.7	0.9	0.3	328
45.00	30.5	26.6	42.9	32.8	30.7	36.6	2.06	8.7				61.6	24.6	0.0	1.8	6.2	1.1	0.0	370
46.00								8.4				69.8	17.4	0.6	2.2	8.0	1.9	0.0	311
47.00	27.8	27.8	44.4	30.3	32.5	37.1	1.71	9.0				68.7	17.7	0.3	3.1	7.6	2.4	0.3	288
48.00								8.6				69.9	18.8	0.0	1.4	9.0	0.8	0.0	366
49.00	30.3	28.6	41.2	32.7	32.8	34.6	1.95	8.6				67.0	23.1	0.0	2.7	6.3	0.8	0.0	364
50.00								8.6				61.2	21.9	0.0	4.2	9.1	1.5	0.0	329
51.00	31.1	26.9	42.1	33.5	31.4	35.1	1.88	8.3				67.4	20.7	0.6	3.6	7.0	0.6	0.0	328
52.00								8.5				52.4	30.7	0.9	4.4	10.2	1.3	0.0	225
53.00	29.6	27.3	43.1	31.7	31.8	36.5	2.00	8.6				61.7	20.2	0.6	1.4	10.9	0.9	0.3	322
54.00								14.4				65.4	21.4	1.0	3.7	7.6	0.8	0.0	379
55.00	33.9	29.4	36.7	36.5	32.9	30.6	2.24	10.2				67.5	19.8	0.0	2.9	8.0	1.8	0.3	339
56.00								8.1				61.2	24.0	0.7	2.1	10.6	1.4	0.0	411
57.00	31.4	26.1	42.5	33.6	30.7	35.7	2.10	8.7				64.2	21.7	0.5	3.8	6.6	1.1	0.0	361
58.00	31.6	27.0	41.4	33.9	31.1	35.0	2.06	8.2				67.1	21.4	0.3	1.5	8.7	0.6	0.0	322
59.00	[illegible]	[illegible]	[illegible]	42.1	27.8	29.8	1.11	6.6				66.7	21.6	1.1	2.5	7.5	0.3	0.0	357

77 SR 11

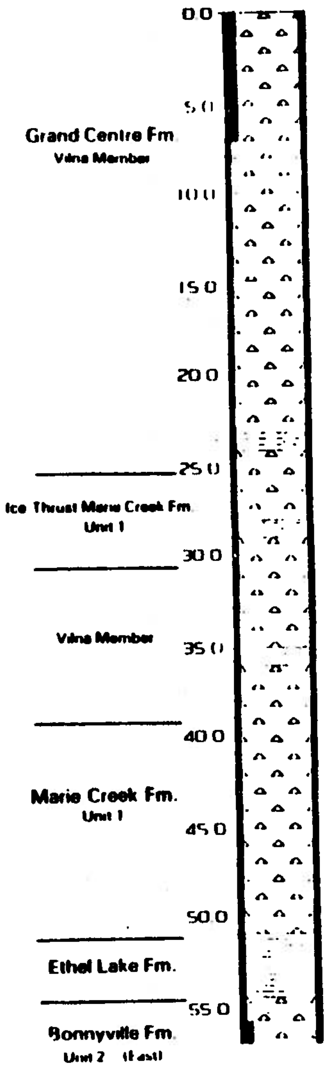
Alberta Geological Survey Testhole 77 SR 11
Location SE of LSD 1 Sec 8 Twp 59 Rng 10 W of 4 Mer , NTS 73L
Elevation 2130 ft 649 M Source 1 50,000 NTS 73L 3
Date drilled 197708 01 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
3 00	41 2	30 2	28 6	43 7	28 8	27 6	1 93	7 8											
4 00	42 1	30 6	27 2	45 1	29 0	25 9	2 34	8 3											
5 00	45 8	29 2	25 1	48 4	27 7	23 9	2 60	8 3											
6 00	45 7	30 7	23 6	48 4	29 3	22 3	2 70	9 1											
7 00	46 3	29 3	24 4	48 9	28 0	23 1	2 67	10 2											
8 00	43 6	30 9	25 5	46 4	29 2	24 4	2 22	9 3											
9 00	46 5	30 5	23 1	49 1	29 2	21 7	2 78	9 0											
10 00	46 0	30 0	23 9	48 8	30 6	20 6	2 41	9 1											
11 00	45 2	28 7	26 1	47 6	30 1	22 3	2 50	9 1											
12 00	42 8	34 2	23 0	45 3	36 4	18 3	2 18	9 5											
13 00	43 4	34 6	22 0	46 1	36 2	17 7	2 55	8 8					64 5	25 0	0 2	5 5	2 6	1 8	0 4	456
14 00	44 3	30 3	25 5	46 8	32 8	20 3	2 86	9 6					63 4	24 7	0 2	0 4	5 1	3 8	2 5	527
15 00								9 4					69 0	22 7	0 7	3 5	2 4	1 6	0 7	578
16 00	45 1	32 3	22 6	47 7	34 3	18 0	2 39	9 3					68 4	21 9	0 0	3 3	4 3	2 1	0 0	424
17 00								9 3					73 1	18 3	0 3	4 0	2 3	2 0	0 0	301
18 00	44 7	32 5	22 8	47 2	35 0	17 8	2 50	8 6					70 9	22 2	0 0	3 3	2 4	0 7	0 4	450
19 00	42 5	31 4	26 1	45 1	35 1	19 8	2 43	9 0					70 4	22 4	0 4	1 9	3 6	1 3	0 0	477
20 00								10 0					68 0	23 5	0 2	3 6	3 1	1 8	0 0	447
22 00	42 5	31 7	25 8	45 1	34 1	20 8	2 19	9 1					67 5	25 0	0 0	2 8	2 6	2 1	0 0	428
23 00								8 7					68 6	20 2	0 8	3 3	3 9	3 1	0 0	509
24 00	42 5	29 6	27 8	45 2	31 8	23 1	2 82												
25 00																			
26 00	42 2	31 7	26 1	44 8	35 5	19 7	2 37	10 2											
27 00								9 4											
28 00	42 1	32 1	25 8	44 6	35 2	20 2	2 54	12 1											
29 00								11 9											
30 00	42 8	33 5	23 7	45 4	36 9	17 7	2 20												
31 00								8 1											
32 00	44 2	29 9	25 9	46 9	33 1	20 0	2 39	8 0											
33 00								8 3											
34 00	43 3	32 3	24 4	45 7	36 5	17 7	2 47												
36 00	44 9	30 4	24 7	47 5	36 0	16 6	2 64	7 8					66 7	24 6	0 1	3 0	4 0	1 3	0 0	475
37 00								7 8					69 8	22 9	0 4	3 1	2 9	0 8	0 0	450
38 00	44 1	29 1	26 8	46 5	32 6	20 9	2 64	7 8					67 6	26 2	1 4	1 9	2 1	0 6	0 2	485
39 00								7 8					69 1	23 7	0 2	2 2	3 7	1 1	0 0	456
40 00	42 9	32 5	24 6	45 3	35 2	19 5	2 41	8 1					67 6	26 7	0 4	2 3	1 7	1 2	0 0	476
41 00								8 0					62 8	26 0	0 4	4 6	3 1	2 9	0 2	522
42 00	42 6	30 3	27 1	44 9	35 4	19 6	2 55	8 3					64 3	28 8	0 2	2 0	3 8	0 7	0 2	448
44 00	49 3	30 6	20 1	51 7	34 3	13 9	2 85	7 0					69 0	25 2	0 4	2 5	2 3	0 4	0 2	513
49 00								8 4					68 9	20 5	0 3	3 2	4 9	1 7	0 0	347
52 00	47 8	27 4	24 8	50 4	29 6	20 0	2 86	8 5					59 2	37 7	0 5	0 2	1 0	1 4	0 0	414
53 00	46 9	29 4	23 7	49 9	30 2	19 8	2 51	11 5					71 5	24 1	0 5	2 8	0 3	0 7	0 0	576
54 00	43 7	32 5	23 8	46 1	35 2	18 7	2 44	8 2					69 4	25 2	0 4	2 6	0 2	1 3	0 2	452
55 00	45 5	32 6	22 0	48 9	33 5	17 6	2 22	9 2					64 9	30 3	0 6	2 0	1 6	0 6	0 0	505
56 00	47 5	28 8	23 8	50 4	30 8	18 8	2 69	8 9					64 0	31 0	0 9	1 6	0 7	1 7	0 0	442

77 SR 12

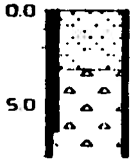
Alberta Geological Survey Testhole 77 SR 12
Location SW of LSD 1 Sec 15 Twp 60 Rng 10 W of 4 Mer NTS 73L
Elevation 2160 Ft 659 M Source 1 50,000 NTS 73L 1
Date drilled 197708 05 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	FST	DST	LOC	OTH	N
1 00								12 4				66 3	32 0	0 5	0 2	0 2	1 9	1 2	416
2 00	12 6	20 3	47 2	34 8	25 5	19 7	0 98	11 5				63 0	27 5	0 6	4 9	2 8	1 2	0 0	324
3 00	12 7	21 2	44 2	35 0	26 8	18 2	1 20	14 6				57 6	30 5	1 9	1 7	3 5	2 5	0 2	479
4 00	12 0	21 9	44 1	33 3	27 4	38 1	1 27	11 6				62 6	28 8	2 1	2 1	3 0	0 8	0 2	468
5 00	12 3	24 0	43 7	34 7	28 0	17 4	1 10	14 1				55 4	30 8	0 9	3 2	2 5	0 7	0 0	435
6 00	12 5	20 8	46 7	34 9	25 2	19 9	1 17	12 7				56 1	29 9	1 1	4 0	5 2	2 2	0 0	444
7 00								12 6				56 0	33 3	0 9	1 4	2 5	2 5	0 2	527
8 00	15 5	26 3	38 2	38 2	29 8	11 9	0 98	11 1				56 3	32 5	0 8	2 5	3 2	2 5	0 4	474
9 00								11 5				61 8	30 9	0 4	2 2	2 8	1 2	0 2	576
10 00	15 4	22 9	41 7	38 1	27 0	14 9	1 17	12 4				61 8	30 9	1 5	2 4	1 8	1 4	0 2	544
11 00								11 8				64 7	27 5	1 0	1 9	2 7	2 2	0 0	519
12 00	13 9	27 1	38 8	16 9	32 9	30 2	1 16												
14 00	39 7	27 8	32 5	42 7	31 5	25 8	1 41												
15 00								11 7				55 2	34 1	2 7	3 5	2 4	1 4	0 0	366
16 07	39 2	22 2	38 6	41 9	26 6	31 5	1 04	10 9				51 7	37 8	1 1	2 6	3 3	1 2	0 0	428
17 00								11 2				59 8	31 8	1 1	3 3	3 1	0 9	0 0	453
18 00	34 9	26 0	39 2	37 5	29 9	32 6	1 21	11 4				55 0	34 4	0 4	3 1	5 3	1 9	0 0	544
19 00								10 9				57 6	33 2	1 6	2 3	3 3	1 5	0 3	304
20 00	32 1	25 9	42 0	34 6	30 0	35 3	1 23	11 2				59 9	30 5	0 9	3 0	3 4	1 0	0 7	564
21 00								11 1				59 4	31 1	0 8	2 4	4 5	1 1	0 0	466
22 00	33 4	26 1	40 5	36 0	30 1	33 8	1 16	11 9				54 3	33 1	1 8	5 7	4 4	0 7	0 0	387
23 00								13 2				59 4	31 0	2 1	3 9	3 4	0 0	0 0	335
24 00	32 4	26 7	40 9	34 9	31 0	34 1	1 09	12 5				60 8	29 1	0 9	3 5	4 6	0 9	0 0	546
25 00	33 9	24 2	41 9	36 5	27 9	35 7	1 43	11 1				59 2	32 1	0 3	2 2	4 9	1 0	0 0	588
26 00	35 9	36 3	27 8	38 3	39 6	22 1	2 74	10 5				59 8	29 5	0 0	1 8	7 7	0 8	0 0	558
27 00	34 1	27 3	38 7	36 4	34 7	28 9	2 57	10 1				61 8	30 4	0 0	1 7	5 4	0 6	0 0	516
28 00								9 7				59 6	32 6	0 2	2 2	5 1	0 2	0 0	582
29 00	37 4	28 7	33 8	40 1	33 9	26 0	2 80	9 4				66 5	25 6	0 2	1 8	4 5	1 2	0 0	594
30 00	36 9	27 7	35 4	39 3	33 8	27 0	2 83	10 0				69 0	22 3	0 2	3 0	4 6	0 8	0 0	494
31 00								10 4				66 6	24 8	0 0	1 7	6 3	0 3	0 0	576
32 00								15 3				59 0	29 8	0 0	3 2	6 0	1 9	0 0	315
33 00	26 7	24 5	48 7	28 8	31 8	39 1	0 00	12 4				64 1	26 6	0 0	1 6	6 7	0 6	0 0	312
34 00	25 7	24 5	49 8	27 7	31 9	40 4	1 63	12 5				62 5	26 8	0 0	4 4	6 2	0 0	0 0	319
35 00								9 8				62 0	27 0	0 2	2 8	6 8	0 8	0 2	455
36 00	29 5	25 9	44 6	31 4	33 1	35 5	1 61	11 6				60 3	27 4	0 3	4 6	6 3	0 9	0 3	365
37 00	23 3	24 2	52 5	25 2	31 9	42 9	1 47	12 6				66 9	22 7	0 0	2 7	6 9	0 6	0 3	375
38 00								13 2				61 4	28 3	0 5	2 9	6 0	0 7	0 0	547
39 00	23 5	25 4	51 1	26 0	32 5	41 4	1 83	12 5				56 9	29 0	0 0	3 5	7 6	2 3	0 0	341
40 00								12 0				62 7	26 6	0 0	1 3	8 8	0 6	0 0	308
41 00	35 6	24 7	39 7	37 9	29 9	32 2	2 49	9 9				61 5	25 0	0 0	2 4	10 4	0 6	0 0	488
42 00								10 1				60 8	25 8	0 2	3 1	8 1	1 9	0 0	418
43 00	36 1	27 2	36 6	38 4	32 9	28 7	2 71	9 7				59 4	28 1	0 0	1 4	10 3	0 6	0 0	475
44 00								9 8				64 4	21 0	0 0	2 5	10 7	0 6	0 4	523
45 00	37 1	25 2	37 7	39 4	30 3	30 3	2 60	10 1				66 8	21 9	0 0	3 0	7 6	0 6	0 0	519
46 00								12 5				62 3	25 5	0 9	2 8	7 2	1 2	0 0	321
47 00	21 1	25 6	53 3	23 4	34 9	41 6	1 36	12 7				58 2	29 6	0 1	2 8	8 3	0 7	0 0	567
48 00								12 8				61 2	27 2	0 3	1 3	9 1	0 6	0 0	309
49 00	31 2	23 8	45 0	33 2	30 1	36 7	2 71	11 9				62 7	23 9	0 0	3 6	8 8	0 7	0 0	343
50 00								10 5				56 6	34 8	0 1	1 3	6 4	0 0	0 0	371
51 00								15 7											
52 00								16 8				55 5	38 9	0 0	2 8	2 8	0 0	0 0	36
53 00								16 8											
54 00								16 7											
55 00	45 5	23 9	30 6	48 0	27 4	24 6	2 08	9 5				50 1	42 0	0 0	4 2	2 9	0 6	0 0	447
56 00	54 7	22 5	22 8	57 3	21 8	17 9	2 37	9 2				51 7	42 2	0 0	3 0	1 9	1 0	0 0	524

77 SR 13

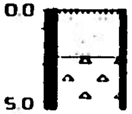
Alberta Geological Survey Testhole 77 SR 13
Location SE of LSD 16 Sec 33 Twp 60 Rng 13 W of 4 Mer , NTS 73L
Elevation 2125 Ft 648 M Source 1 50,000 NTS 73L/4
Date drilled 197708 06 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
4 00								10 1				74 2	21 6	0 4	1 0	1 8	1 0	0 0	508
5 00								10 5				66 2	19 8	1 9	4 5	5 5	1 3	0 3	308
6 00								10 4				73 6	21 9	0 5	1 3	1 1	1 6	0 0	379
7 00								10 5				74 9	20 6	0 0	2 0	1 5	1 0	0 0	403
8 00								12 9				59 4	31 0	0 3	1 6	4 1	1 3	0 0	318

77 SR 14

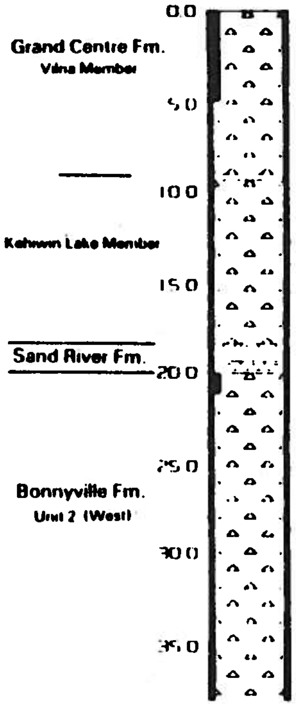
Alberta Geological Survey Testhole 77 SR 14
Location SE of LSD 8 Sec 15 Twp 61 Rng 11 W of 4 Mer NTS 73L
Elevation 2075 Ft 633 M Source 1 50,000 NTS 73L/5
Date drilled 1977/08/06 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET	QTZ	QTZT OSS	LST	DST	COC	OTH	N
3.00								12.7				69.4	26.5	0.7	0.2	0.7	0.5	0.0	599
4.00								11.0				75.6	22.8	0.5	0.5	0.2	0.5	0.0	426
5.00								11.1				73.7	20.6	0.4	0.7	3.6	1.1	0.0	281

77 SR 15

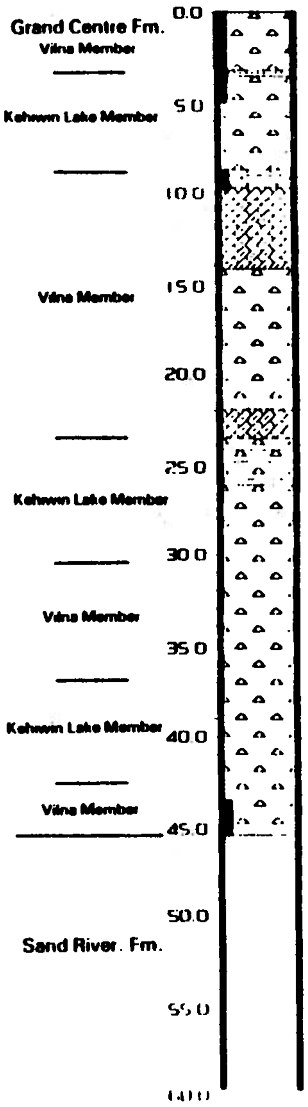
Alberta Geological Survey Testhole 77 SR 15
Location of LSD 9 Sec 15 Twp 61 Rng 11 W of 4 Mer , NTS 73L
Elevation 2065 Ft 630 M Source 1 50,000 NTS 73L/5
Date drilled 197708 06 Logged by M FENTON



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00								10.3				70.9	23.3	2.0	0.6	2.6	0.6	0.0	347
2.00	41.1	29.5	27.4	45.9	31.4	22.7	1.88	10.9				76.8	19.5	1.5	0.9	1.2	0.0	0.0	323
3.00	40.2	27.3	32.5	41.2	29.4	27.4	1.77	11.1				72.4	21.5	1.1	1.4	1.9	1.6	0.0	363
4.00	38.6	30.6	30.8	41.7	33.2	25.1	1.58	11.2				72.4	22.9	1.0	1.6	1.8	0.4	0.0	511
5.00	34.8	36.9	28.3	38.5	38.1	23.4	1.36	10.3				80.2	18.0	0.6	0.8	0.2	0.0	0.0	349
6.00	38.4	29.5	32.2	41.3	32.9	25.8	1.46	11.0				68.4	24.0	0.0	1.8	2.3	3.5	0.0	396
7.00	39.8	30.6	29.6	42.7	33.7	23.5	1.70	10.5				70.7	24.5	0.5	2.1	1.3	0.8	0.0	379
8.00	38.9	29.6	31.5	41.7	32.9	25.4	1.48	10.9				68.8	26.3	0.8	2.1	1.8	0.2	0.0	388
9.00	40.9	30.3	28.8	41.7	33.5	22.9	1.92	12.0				70.9	23.6	0.9	0.3	3.5	0.3	0.3	313
10.00	50.8	22.2	27.0	53.3	24.3	22.4	2.18	10.2				61.1	28.4	0.9	3.2	1.8	2.3	0.2	436
11.00	51.5	21.4	27.1	54.0	21.5	22.5	1.86	10.1				58.1	36.3	0.3	2.4	1.6	1.3	0.0	375
12.00	44.1	30.1	25.7	46.8	34.5	18.8	2.09	9.6				58.7	30.4	0.9	4.0	3.7	1.9	0.3	322
13.00	41.2	30.6	28.2	44.0	34.9	21.1	1.62	10.8				59.8	33.8	0.8	3.1	1.4	1.1	0.0	358
14.00	40.4	30.9	28.6	43.2	34.9	21.9	1.60	10.7				62.7	27.1	0.6	3.9	3.9	1.6	0.0	306
15.00	44.0	26.1	29.9	46.6	30.0	23.5	1.99	9.2				63.1	30.3	0.2	1.5	3.3	1.3	0.2	396
16.00								9.4				67.6	21.1	0.8	2.2	6.0	0.3	0.0	364
17.00	42.8	30.0	27.2	45.3	34.5	20.2	2.02	9.1				60.6	32.1	1.2	2.1	3.3	0.6	0.0	330
18.00	44.6	28.2	27.2	47.3	32.7	20.0	1.96	9.1				65.5	26.6	0.5	3.8	2.8	0.5	0.2	394
20.00								12.9											
21.00	35.5	31.9	32.6	37.9	37.0	25.1	1.92	10.5				57.5	32.8	0.0	3.7	4.5	1.2	0.2	402
22.00	35.8	32.6	31.6	38.3	38.3	23.1	2.15	9.4				61.0	29.5	0.0	3.4	4.6	0.7	0.7	410
23.00	33.1	32.1	34.6	35.9	38.2	25.8	1.78	10.6				58.2	30.7	0.3	4.8	2.6	3.4	0.0	378
24.00	35.1	30.1	34.8	37.9	35.0	27.1	1.46	9.7				67.7	26.7	0.9	0.9	1.2	2.6	0.0	344
25.00								9.7				61.6	30.1	0.6	2.3	2.0	3.1	0.3	349
26.00	34.8	29.8	35.4	37.5	35.0	27.5	1.36	9.2				55.1	35.6	1.4	2.6	3.2	1.7	0.3	345
27.00								10.0				62.2	27.2	0.3	4.7	3.3	2.2	0.0	360
28.00	34.7	28.0	37.3	37.2	34.3	28.4	1.50	9.1				60.2	33.1	0.1	2.1	2.1	1.9	0.3	372
29.00								8.6				61.2	31.9	0.9	3.5	0.9	1.2	0.3	338
30.00	36.0	33.2	30.8	38.9	38.0	23.2	1.49	9.7				58.4	34.4	0.6	3.8	1.8	0.6	0.3	337
31.00								10.0				55.0	40.9	0.6	0.6	1.6	0.6	0.3	320
32.00	36.3	31.6	32.1	39.1	36.9	24.0	1.30	10.1				64.7	27.3	2.7	1.3	1.0	3.0	0.0	300
33.00								10.5				61.8	31.2	0.7	2.4	0.7	2.4	0.3	288
34.00	36.5	29.5	34.0	39.1	34.3	26.5	1.52	9.6				59.7	29.4	0.3	5.1	2.4	2.7	0.3	333
35.00	37.0	30.8	32.2	39.7	37.6	22.7	1.52	9.8				59.3	34.0	2.0	1.4	1.7	0.9	0.6	344
36.00	37.4	33.4	29.1	40.1	39.2	20.7	1.55	9.6				59.8	33.2	2.0	2.3	1.8	0.5	0.2	391
37.00	37.0	32.2	30.8	39.6	38.1	22.3	1.57	9.4				59.7	33.1	2.6	2.8	1.3	0.2	0.2	390
38.00	37.4	31.2	31.4	40.0	37.7	22.3	1.59	9.3				58.2	35.8	1.4	3.1	1.0	0.6	0.0	514

77 SR 16

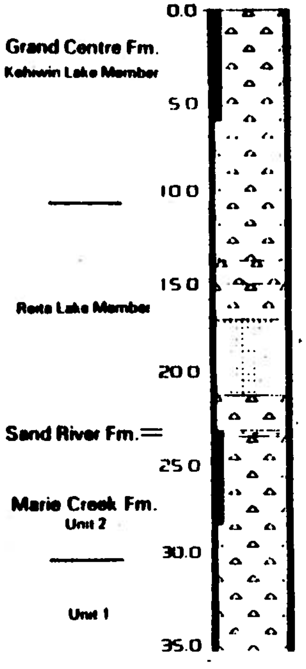
Alberta Geological Survey Testhole 77 SR 16
Location SE of LSD 9 Sec. 18 Twp 61 Rng 9 W of 4 Mer. NTS 73L
Elevation 2065 Ft 630 M Source 1 50,000 NTS 73L/6
Date drilled 1977 08 07 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00	26 9	35 7	37 4	29 2	39 8	31 0	1 16	11 3				61 1	33 1	1 1	1 3	3 2	0 0	0 0	314
2 00	24 8	36 4	38 8	27 0	41 0	32 0	0 88	12 5				62 8	28 7	2 1	2 1	4 2	0 0	0 0	282
3 00																			
4 00	43 0	24 8	32 2	45 7	26 9	27 4	2 19	7 8				62 8	30 5	0 2	2 3	3 1	1 0	0 0	514
5 00	39 9	25 4	34 7	42 4	29 2	28 4	2 05	6 7				69 4	27 3	0 0	1 1	1 8	0 4	0 0	447
6 00	39 5	29 6	31 0	41 9	33 0	25 1	1 95	7 8				67 3	26 5	0 2	1 5	4 3	0 0	0 0	392
7 00	41 6	25 8	32 6	44 3	28 9	26 8	2 42	6 8				64 9	30 0	0 6	1 7	2 3	0 4	0 0	473
8 00	40 9	28 4	30 6	43 4	32 4	24 2	2 16	8 5				67 9	25 9	0 2	1 0	4 2	0 6	0 0	474
10 00								17 7											
11 00								17 4				22 6	6 4	0 0	6 4	0 0	6 4	51 6	31
12 00								17 5				10 5	7 9	0 0	7 9	0 0	2 6	61 0	38
13 00								17 6				0 0	4 0	0 0	18 0	0 0	2 0	76 0	50
14 00								18 1				36 4	22 7	4 5	2 3	0 0	0 0	34 1	44
15 00	28 6	28 7	42 7	30 9	34 2	34 9	1 21	10 3				67 9	24 2	0 7	3 3	3 3	0 3	0 0	302
16 00	31 1	30 8	38 1	33 6	35 4	31 1	1 17	9 8				75 2	26 3	0 9	2 0	2 0	0 2	0 0	448
17 00								14 7				70 1	24 2	0 7	3 4	1 5	0 0	0 0	264
18 00	28 3	30 6	41 0	30 8	34 7	34 5	0 99	11 1				67 6	28 1	1 2	1 2	1 6	0 2	0 0	491
19 00	30 5	31 7	37 9	33 1	36 0	30 9	1 18	11 1				62 9	29 7	0 6	4 7	1 8	0 3	0 0	337
20 00								10 2				62 5	23 3	0 5	2 7	2 8	8 0	0 0	563
21 00	31 1	29 4	39 5	33 6	33 2	33 2	1 32	9 9				64 8	27 2	0 6	3 7	3 3	0 2	0 0	489
22 00	8 3	14 3	77 4	9 2	26 5	64 3	0 35	17 4											
23 00								18 4											
24 00	47 8	23 8	28 4	50 3	26 5	23 2	1 42	9 5											
25 00	35 4	29 5	35 1	37 4	34 8	27 8	1 45	10 5				72 7	24 0	1 3	0 3	1 6	0 0	0 0	370
26 00	46 2	27 2	26 6	48 8	30 3	20 9	2 07	9 0				70 5	24 5	2 6	0 7	1 2	0 4	0 0	417
27 00	40 6	27 4	32 0	43 2	31 3	25 6	1 28	9 8				72 2	19 3	1 8	2 4	3 7	0 6	0 0	327
28 00	40 1	29 5	30 4	42 8	32 7	24 5	1 24	9 3				70 8	22 1	0 6	2 9	3 2	0 3	0 0	308
29 00	39 3	31 5	29 2	42 2	34 5	23 3	1 02	9 7				66 5	29 3	0 7	0 5	2 7	0 2	0 0	562
30 00								8 7				72 8	22 0	1 4	1 1	2 5	0 0	0 0	437
31 00	30 3	34 1	35 6	33 2	38 5	28 3	0 96	8 8				72 6	24 1	0 9	0 9	1 4	0 0	0 0	431
32 00								12 6				78 7	19 3	0 8	0 8	0 4	0 0	0 0	254
33 00	27 1	26 9	46 0	29 1	33 4	37 5	1 08	10 3				71 0	23 4	1 3	0 4	1 5	0 2	0 0	462
34 00								12 0				76 3	19 8	1 6	0 6	1 6	0 0	0 0	308
35 00	26 7	29 7	43 5	28 6	37 6	33 7	1 21	11 8				71 0	24 4	1 8	0 9	1 5	0 0	0 0	324
36 00								11 3				70 9	25 6	1 2	0 2	1 6	0 4	0 0	488
37 00	41 4	25 6	33 0	44 0	29 5	26 5	1 36	0 4				71 5	21 4	2 0	1 8	3 1	0 2	0 0	607
38 00								9 7				76 9	19 3	0 5	1 0	2 0	0 2	0 0	399
39 00	41 1	26 5	32 4	43 6	30 8	25 6	1 62	8 9				70 4	24 4	0 6	0 8	3 7	0 2	0 0	517
40 00	40 0	27 6	32 3	42 7	33 3	24 0	1 15	9 0				70 6	25 1	1 3	0 7	2 2	0 0	0 0	541
41 00	40 3	29 1	30 6	42 7	33 9	23 4	1 38	8 7				71 7	22 7	1 3	1 5	2 6	0 2	0 0	541
42 00	34 7	34 6	30 7	37 7	39 0	23 3	1 17	7 6				68 9	26 3	1 1	0 8	2 0	0 6	0 0	498
43 00	28 3	36 3	35 3	31 1	41 4	27 5	0 86	9 0				73 6	24 3	0 5	0 5	0 7	0 4	0 0	432
43 50	32 7	37 9	29 4	35 0	42 5	22 4	1 20	7 4				59 4	35 1	0 8	1 5	2 0	1 2	0 0	603
44 00	35 4	38 1	26 5	37 6	42 7	19 7	1 17	11 8				65 9	25 4	2 2	2 2	2 8	1 5	0 0	723

77 SR 17

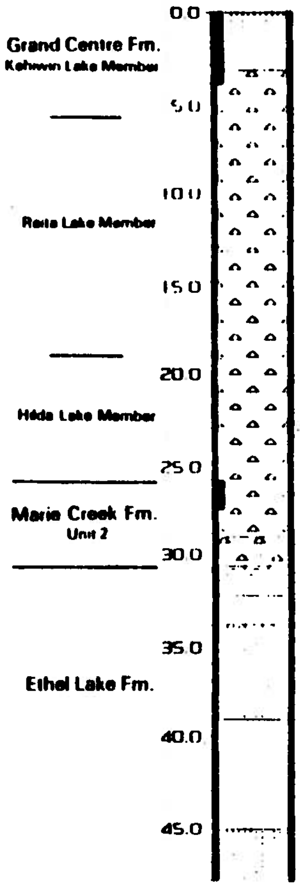
Alberta Geological Survey Testhole 77 SR 17
Location NE of LSD 15 Sec 9 Twp 61 Rng 8 W of 4 Mer . NTS 73L
Elevation 1900 Ft 579 M Source 1:50,000 NTS 73L/6
Date drilled 197708 OR Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00								7 6				69 8	22 2	6 6	0 0	0 5	0 8	0 0	364
2 00	44 0	26 2	29 8	46 5	29 2	24 3	1 05	12 7				57 7	27 2	5 7	6 3	6 1	0 8	0 0	521
3 00	45 5	26 0	28 6	48 1	27 5	24 4	1 08	11 5				55 0	24 8	5 0	7 0	6 8	1 4	0 0	560
4 00	46 2	25 5	28 2	49 0	26 8	24 2	1 30	11 0				57 0	25 0	4 5	5 9	5 7	1 7	0 0	420
5 00	45 7	25 5	28 9	48 5	26 7	24 8	1 18	10 1				57 7	26 3	5 1	5 3	4 1	1 4	0 0	414
6 00	40 0	26 5	33 5	42 7	28 6	28 7	1 07	9 7				55 5	26 5	1 4	4 0	3 4	1 5	5 5	476
7 00	37 3	26 5	36 2	39 9	29 1	31 0	1 27	9 6				64 8	25 2	2 3	3 6	1 0	2 5	0 5	392
8 00	37 9	26 2	35 9	40 4	29 0	30 6	2 25	10 4				55 2	21 0	2 4	2 1	4 5	0 9	10 8	333
9 00	41 6	26 9	31 5	44 4	29 2	26 4	1 80	8 4				46 2	20 5	1 6	2 4	5 3	1 6	0 0	148
10 00	40 9	26 7	32 4	43 6	28 6	27 8	1 65	8 7				56 0	22 0	1 6	0 4	2 5	0 9	16 5	441
11 00								11 3				76 1	16 8	2 2	0 9	2 2	1 3	0 4	226
12 00	37 4	22 5	40 1	40 0	26 8	33 3	1 47	11 5				66 8	24 0	1 1	2 5	3 0	1 1	1 3	525
13 00								11 6				70 4	21 5	1 6	1 9	2 8	1 4	0 3	362
14 00	32 5	33 9	33 6	35 3	37 8	26 9	1 75	8 1				61 8	19 2	0 7	1 7	16 0	0 5	0 0	411
15 00								8 2				67 1	24 5	2 0	1 6	4 1	0 4	0 0	441
16 00	31 5	28 9	39 5	34 0	33 9	32 2	1 39	8 6				65 2	24 2	2 0	2 8	5 4	0 3	0 0	351
22 00	38 8	24 7	36 5	42 0	27 0	31 0	1 65	9 0				62 6	25 7	1 1	4 2	5 8	0 3	0 0	377
23 00	35 2	27 4	37 4	38 0	29 8	32 2	0 87	8 5				72 8	25 3	0 4	0 4	0 8	0 2	0 0	470
24 00								18 5											
25 00								10 3				57 3	14 8	0 1	4 1	20 9	2 3	0 0	344
26 00	33 2	24 1	42 8	35 6	29 1	35 3	2 12	9 5				64 8	18 5	0 6	1 8	12 4	1 8	0 0	498
27 00	36 2	26 8	37 0	39 3	29 9	30 8	2 56	8 9				64 8	18 0	0 8	3 5	11 1	0 8	1 0	515
28 00	37 1	30 1	32 8	40 3	32 2	27 5	2 51	8 3				58 9	18 9	0 6	4 1	16 7	0 7	0 0	538
29 00	38 6	30 3	31 1	41 5	32 9	25 6	2 40	7 7				60 0	15 5	0 4	2 7	18 6	1 3	1 3	515
30 00	39 5	31 8	28 7	42 4	34 5	23 0	2 18	7 7				47 0	23 8	0 1	2 4	12 0	1 8	12 6	337
31 00	35 7	22 0	42 3	38 1	27 3	34 6	1 75	8 6				60 3	28 5	0 2	3 1	4 2	1 1	2 6	453
32 00	34 9	20 8	44 3	37 3	26 6	36 1	1 76	8 9				61 2	25 9	0 2	2 8	7 7	1 9	0 2	428

77 SR 18

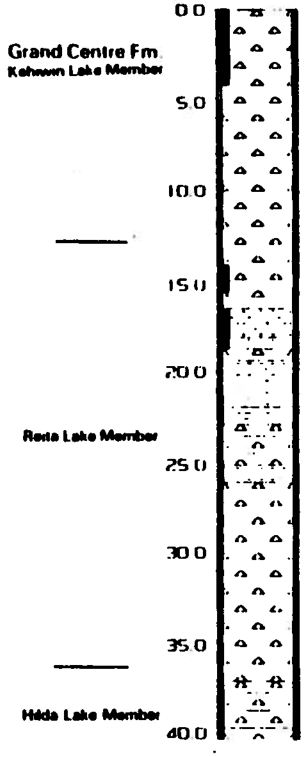
Alberta Geological Survey Testhole 77 SR 18
Location NE of LSD 9 Sec 2 Twp 63 Rng 9 W of 4 Mer , NTS 73L
Elevation 1940 Ft 591 M Source 1:50,000 NTS 73L/6
Date drilled 1977 08 09 Logged by K JOHNSON



	TEXTURE (%)								MATRIX CARBONATE				COARSE SAND LITHOLOGY (%)						
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
3.00	41.9	27.0	31.1	44.9	29.9	25.3	1.65	10.6				61.4	34.1	0.2	2.2	1.2	0.7	0.0	404
4.00	41.3	27.6	31.1	44.6	30.4	25.0	2.04	9.2				64.6	26.7	0.9	2.6	3.3	1.7	0.0	427
5.00	37.9	24.8	37.4	41.0	28.4	30.5	1.48	9.2				63.9	29.9	0.2	1.5	3.6	0.4	0.2	468
6.00	30.6	23.0	46.4	33.2	28.0	38.8	1.12	12.1				65.0	26.6	0.9	2.8	3.1	1.2	0.3	320
7.00	26.5	24.6	48.9	29.1	29.6	41.3	1.00	11.1				63.8	26.9	1.2	3.1	2.6	1.4	0.7	421
8.00	24.4	24.6	50.9	26.4	31.2	42.4	1.11	14.0				64.0	27.4	0.5	2.4	3.1	1.2	1.4	421
9.00								8.8				65.0	30.2	1.0	1.5	1.8	0.2	0.0	394
10.00	19.7	24.2	56.1	22.3	30.4	47.3	1.31	12.0				65.9	26.7	1.1	1.2	3.4	1.0	0.4	505
11.00								9.8				62.3	27.3	0.3	3.0	5.8	1.2	0.0	329
12.00	33.3	22.0	44.7	35.8	25.8	38.4	1.53	11.6				65.6	27.7	0.5	1.5	3.9	0.5	0.0	584
13.00								11.7				64.9	29.9	0.3	1.3	1.9	1.6	0.0	308
14.00	38.7	22.2	39.1	41.5	26.9	31.6	1.18	10.1				66.5	27.2	1.9	1.6	1.9	0.5	0.3	367
15.00								10.9				69.9	24.2	1.4	0.0	3.9	0.3	0.0	359
16.00	31.9	27.2	40.9	34.5	32.0	33.4	1.11	11.5				63.4	30.2	1.1	0.5	4.2	0.3	0.3	358
17.00								10.6				65.6	27.4	1.5	1.1	4.2	0.2	0.0	456
18.00	39.1	23.0	37.8	41.8	27.1	31.1	2.17	11.0				68.2	26.3	0.7	1.7	2.5	0.2	0.2	399
19.00								11.9				73.4	22.9	0.7	0.7	2.3	0.0	0.0	301
20.00	30.7	28.1	41.2	33.1	33.4	33.3	1.10	12.4				60.7	29.4	1.1	1.9	3.7	2.9	0.3	623
21.00								12.9				57.3	29.6	1.7	3.4	3.9	2.8	0.2	408
22.00	31.2	23.7	45.1	33.7	30.1	36.1	1.04	12.3				61.8	28.5	1.7	3.6	3.4	0.6	0.2	466
23.00								12.6				61.4	26.9	2.1	2.4	4.8	2.1	0.0	371
24.00	31.1	22.4	46.5	33.3	30.1	36.6	0.96	12.9				51.8	34.9	1.3	2.2	5.4	0.6	0.0	458
25.00	29.0	20.8	50.2	31.0	28.2	40.8	0.90	12.6				57.2	29.7	2.3	4.0	5.3	1.2	0.2	397
26.00	35.5	25.0	39.5	38.1	28.6	33.3	2.08	8.6				54.7	22.6	0.0	3.5	18.0	1.1	0.0	561
27.50	44.3	22.3	33.4	46.6	26.3	27.1	2.10	9.7				58.3	22.7	1.0	3.2	13.4	1.0	0.0	379
28.00	41.1	31.2	27.7	44.1	35.4	20.5	1.89	9.5				56.6	28.7	0.3	2.1	11.0	1.1	0.0	380
30.00	36.7	38.4	24.9	39.6	42.1	18.3	1.99	9.8				59.0	24.3	0.0	1.9	11.8	0.2	0.2	415
31.00								17.0											
32.00								17.8											

77 SR 19

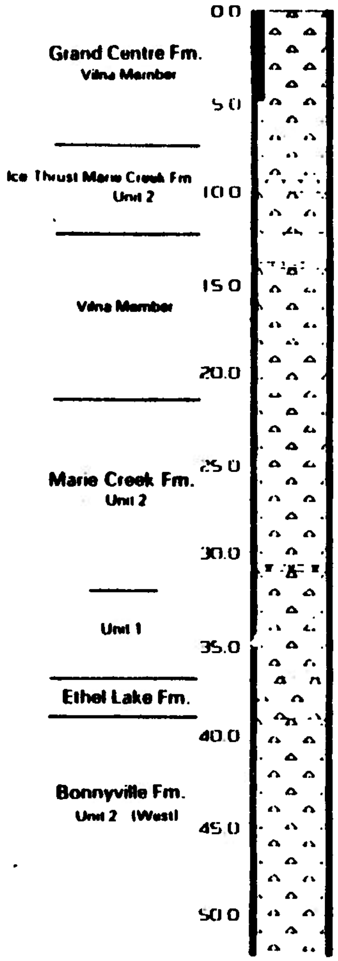
Alberta Geological Survey Testhole 77 SR 19
Location SE of LSD 9 Sec 11 Twp 61 Rng 9 W of 4 Mer NTS 73L
Elevation 1925 ft 587 M Source 1:50,000 NTS 73L/11
Date drilled 197708 14 Logged by ANDRIASHEK



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	IGN METM	COARSE SAND LITHOLOGY (%) QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00								9 1				66 5	32 1	0 2	0 0	0 4	0 6	0 0	454
2 00	46 7	19 5	33 8	49 5	22 3	28 2	2 60	8 8				66 8	27 3	1 1	0 9	1 6	0 3	0 0	565
3 00	43 3	24 4	32 3	46 8	26 0	27 2	1 50	8 0				61 1	30 8	0 4	3 9	2 8	1 0	0 0	532
4 00	43 5	20 4	36 1	46 2	26 4	27 4	2 39	7 0				61 5	30 9	0 2	3 0	3 9	0 5	0 0	542
5 00	43 6	19 4	37 0	46 3	24 2	29 5	2 20	6 7				61 9	29 8	0 3	2 0	2 8	2 6	0 6	352
6 00	44 1	21 0	35 0	46 8	25 0	28 3	2 47	9 5				65 9	25 9	0 0	2 9	4 9	0 3	0 0	309
7 00	43 5	21 9	34 6	46 3	27 4	26 3	2 19	6 4				63 5	28 6	0 3	2 7	4 5	0 3	0 0	559
8 00								7 1				68 1	24 1	0 3	2 5	3 7	1 0	0 2	560
9 00	44 3	20 8	34 9	46 9	27 2	25 9	2 11	7 3				66 8	24 0	0 6	1 9	5 7	0 9	0 0	317
10 00								6 7				66 3	27 1	0 4	2 8	3 0	0 4	0 0	528
11 00	47 4	20 9	31 7	50 2	25 2	24 5	2 69	6 4				68 0	25 9	0 4	2 2	3 2	0 4	0 0	506
12 00								6 9				67 8	27 1	0 8	1 3	2 8	0 2	0 0	388
13 00								7 8				67 9	24 2	0 6	2 7	4 1	0 4	0 0	508
14 00	38 5	18 7	42 8	41 0	23 5	35 5	2 25	8 4				66 1	28 0	0 6	1 3	3 0	0 6	0 3	304
15 00	38 8	24 4	36 8	41 6	27 1	31 3	1 68	7 6				53 0	43 1	2 4	0 3	0 0	1 2	0 0	332
19 00	47 2	20 9	31 9	49 9	24 7	25 3	3 15												
20 00								14 5											
21 00								11 9											
22 00								13 6				51 0	26 5	0 0	11 2	4 1	6 1	1 0	98
23 00	33 0	18 8	48 2	35 6	22 7	41 7	1 44	10 0				68 2	28 8	0 3	0 9	1 8	0 0	0 0	333
24 00	26 3	25 8	47 9	29 0	31 0	40 0	1 33	9 5				57 6	35 7	0 9	0 9	3 8	0 9	0 0	314
25 00								10 5											
26 00	37 3	19 4	43 3	40 0	24 4	35 6	1 91	10 3				68 7	27 6	0 6	0 6	1 7	0 9	0 0	355
27 00	36 7	18 7	44 6	39 2	24 0	36 7	1 66	9 0				72 4	24 7	0 4	0 7	1 8	0 0	0 0	450
28 00	38 4	18 5	43 0	41 3	23 6	35 2	2 03	8 2				72 6	23 7	0 7	1 1	0 9	0 9	0 0	435
30 00								7 9				67 9	28 4	1 2	0 4	1 6	0 4	0 0	496
31 00	33 8	24 3	41 9	36 5	28 8	34 7	1 42	9 0				68 6	27 6	1 3	1 6	0 9	0 0	0 0	315
32 00								8 8				68 7	27 6	0 3	1 2	1 5	0 3	0 0	326
33 00	31 1	20 1	48 4	33 5	26 6	39 9	1 64	9 4				66 8	29 3	0 1	1 4	1 9	0 3	0 0	362
34 00								7 7				72 6	24 5	0 8	0 8	0 8	0 4	0 0	391
35 00	35 6	21 9	42 5	38 1	26 7	35 2	1 61	8 9				70 7	26 1	0 3	1 1	1 4	0 3	0 0	352
36 00								7 6				69 8	25 1	2 1	1 8	0 5	0 4	0 0	434
37 00	17 7	23 6	58 7	19 5	29 9	50 7	0 64	11 3				68 5	25 3	1 1	1 7	3 1	0 0	0 0	292
38 00	19 4	23 6	56 9	21 3	29 1	49 6	1 04	10 9				66 9	29 9	1 0	0 5	1 4	0 2	0 0	578
39 00	26 5	19 9	53 6	28 4	25 2	46 4	1 14	7 9				65 1	29 3	2 5	0 6	2 5	0 0	0 0	321
40 00	36 8	21 9	41 3	38 9	26 6	34 5	1 52	7 2				70 8	26 9	0 3	1 2	0 6	0 3	0 0	342

77 SR 20

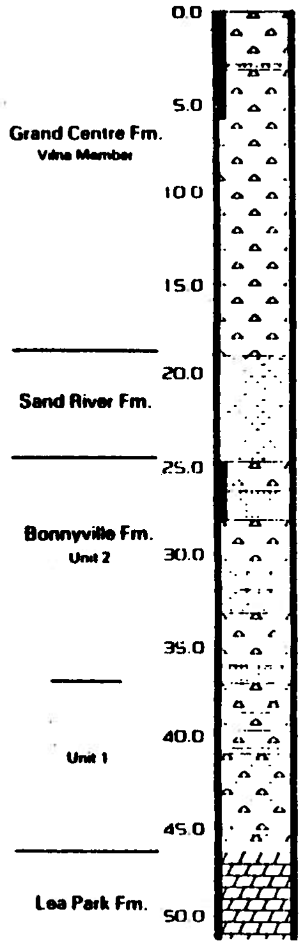
Alberta Geological Survey Testhole 77 SR 20
Location of LSD 1 Sec 25 Twp 61 Rng 11 W of 4 Mer., NTS 73L
Elevation 1955 ft 596 M Source 1:50 000 NTS 73L/5
Date drilled 1977/08/16 Logged by C LOTZAK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	CO2 (cc)	COT (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1.00								22.5				59.7	32.6	2.7	1.1	1.9	0.5	0.0	181
2.00	22.8	32.9	44.1	24.9	37.1	37.8	0.80	23.8				58.5	31.2	1.3	2.1	4.3	2.6	0.0	234
3.00	27.9	30.8	41.3	30.8	34.1	35.0	0.78	22.0				56.7	37.4	1.1	0.8	2.0	0.8	0.0	254
4.00	30.5	26.9	42.6	33.1	29.9	37.0	0.94	21.8				52.4	29.7	2.0	1.4	1.7	1.7	11.2	357
5.00	28.9	29.7	41.3	31.5	33.0	35.4	0.86	21.7				50.1	28.2	2.7	3.0	1.6	2.7	9.8	337
6.00	30.2	27.8	42.0	32.8	30.9	36.3	0.80	4.0				56.8	31.1	1.9	6.0	2.8	0.6	0.6	315
7.00								22.4				54.3	32.9	2.8	3.7	5.6	0.3	0.3	322
8.00	35.0	29.2	35.8	37.7	32.1	30.2	1.15	10.1				51.8	36.2	2.6	5.8	3.2	0.3	0.0	309
9.00								8.7				54.2	26.8	2.6	7.2	6.9	2.6	0.0	153
10.00	62.7	20.0	17.3	64.9	22.0	13.1	2.04	9.3				65.5	25.3	4.6	2.9	1.2	0.2	0.2	478
11.00	57.4	25.5	17.1	59.9	28.4	11.7	1.53	17.1				45.9	30.7	7.0	8.5	6.3	9.9	0.6	316
12.00	47.1	24.9	28.0	50.0	27.1	22.9	1.11	8.7				54.6	30.7	4.2	3.4	6.3	0.8	0.0	238
14.00								2.2											
15.00	34.6	30.3	35.1	36.9	34.8	28.3	1.05	9.5				70.3	24.7	1.4	1.1	2.0	0.4	0.0	441
16.00	32.6	32.1	35.2	35.2	35.9	28.9	0.96	8.3				62.8	29.9	1.9	3.3	1.6	0.3	0.3	368
17.00	31.5	34.8	33.7	34.1	38.2	27.7	1.15	9.5				62.9	29.0	0.9	2.2	4.3	0.7	0.0	445
18.00								8.8				60.7	30.7	1.0	3.3	3.7	0.7	0.0	300
19.00	30.8	32.5	36.7	33.2	36.9	29.9	1.19	8.9				66.4	25.3	1.5	1.8	3.5	1.5	0.2	451
20.00								9.2				60.3	31.5	1.6	1.6	3.7	1.2	0.0	489
21.00	29.1	30.2	40.7	31.2	35.1	33.7	1.39	10.1				64.9	26.7	1.4	1.8	3.9	1.2	0.0	431
22.00								9.4				53.5	34.2	2.0	4.1	3.6	1.6	0.9	439
23.00	34.4	33.1	32.5	37.1	36.2	26.7	1.09	8.8				49.5	33.6	3.2	5.7	5.9	1.4	0.7	440
24.00								9.1				53.5	32.0	2.6	6.6	3.8	1.2	0.2	422
25.00	38.3	30.3	31.1	40.6	33.2	26.2	1.53	9.9				52.2	34.8	2.3	2.7	6.7	1.3	0.0	299
26.00								10.4				50.3	32.4	4.3	6.5	3.7	2.3	0.6	352
27.00	20.7	32.1	47.2	22.6	37.3	40.0	0.72	11.9				60.8	31.3	2.5	1.1	3.1	1.4	0.0	355
28.00								12.1				53.8	28.9	4.4	3.3	6.6	2.9	0.0	273
29.00	33.1	29.7	37.2	35.2	35.3	29.5	1.20	10.8				49.5	35.3	1.8	6.7	5.1	1.5	0.0	388
30.00	34.0	31.4	34.6	36.4	35.9	27.8	0.92	10.2				47.4	34.1	4.3	5.9	4.9	2.9	0.4	487
31.00	34.3	28.4	37.3	36.6	33.9	29.6	1.07	10.6				46.3	36.1	4.2	6.2	4.4	2.0	0.7	404
32.00	28.8	30.3	40.9	30.9	35.3	33.8	0.90	11.0				53.1	32.3	2.7	6.5	3.0	1.7	0.5	399
33.00								12.9				64.0	25.9	3.3	1.2	4.0	1.5	0.0	397
34.00	21.8	29.1	49.0	23.6	35.6	40.8	0.64	12.1				61.8	28.3	2.5	2.8	3.3	1.0	0.2	395
35.00								12.2				57.6	30.4	2.7	2.7	4.5	1.8	0.2	444
36.00	23.2	31.5	45.3	25.0	38.5	36.5	0.86	11.7				52.7	33.8	4.4	3.6	3.6	1.3	0.5	385
37.00								8.4				59.2	36.5	0.0	1.8	2.5	0.0	0.0	277
38.00	23.4	38.4	38.2	26.1	42.7	31.2	0.80	10.5				62.0	30.9	1.2	2.1	3.6	0.0	0.2	418
39.00								9.1				55.2	37.7	0.6	2.9	3.2	0.3	0.0	316
41.00	41.5	33.5	25.0	44.2	24.9	30.9	1.61	6.1				43.9	49.5	0.9	3.9	1.2	0.6	0.0	335
42.00	39.3	23.4	37.3	40.6	27.9	31.6	6.79	9.7				50.3	42.9	2.9	1.3	1.3	0.6	0.6	310
43.00	37.7	30.3	32.0	40.5	34.1	25.4	1.11	9.1				49.8	42.0	3.3	0.0	1.5	3.0	0.4	269
44.00								9.1				46.6	45.8	3.1	1.3	1.8	1.3	0.0	386
45.00	35.2	32.1	32.7	38.0	36.2	25.8	1.23	8.8				44.5	48.7	3.7	0.9	0.9	1.3	0.0	458
46.00	36.6	30.8	32.6	39.5	34.9	25.7	1.26	11.2				50.1	41.5	2.4	0.9	0.9	0.9	0.9	326
47.00	36.7	31.6	31.8	39.3	34.9	25.8	1.09	10.1				48.8	43.3	3.9	1.1	1.0	1.6	0.0	305
48.00	24.1	31.9	44.0	25.9	39.6	34.1	0.98	11.6				64.4	29.2	2.8	1.1	0.7	1.1	0.3	281
49.00	33.1	28.3	38.1	36.2	31.6	32.2	0.81	10.8				49.4	42.3	1.9	1.5	2.6	1.9	0.4	265
50.00	32.7	28.0	39.3	35.4	33.4	31.2	0.96	9.9				46.2	45.5	1.1	2.9	1.3	2.0	0.7	118
51.00	35.3	29.3	35.5	38.0	32.0	30.0	1.07	9.6				50.7	39.7	2.6	5.2	0.7	1.4	0.2	426
52.00	36.7	29.1	34.2	39.3	32.2	28.5	1.16	9.5				48.9	46.4	2.8	1.1	0.1	0.0	0.3	280

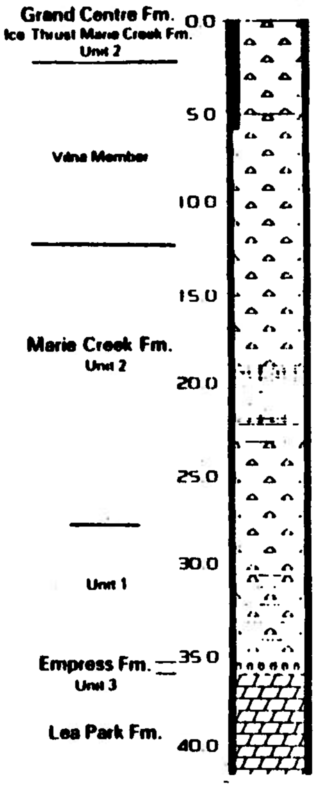
77 SR 21

Alberta Geological Survey Testhole 77 SR 21
Location N of LSD 10 Sec 18 Twp 63 Rng 12 W of 4 Mer , NTS 73L
Elevation 1990 Ft 607 M Source 1 50,000 NTS 73L/5
Date drilled 197708 17 Logged by ANDRIASHEK



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1.2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT QSS	LST	DST	COC	OTH	N
1.00								15.1				56.7	38.9	1.7	0.6	0.4	1.5	0.0	455
2.00	36.2	26.4	37.4	38.8	29.1	32.1	1.37	12.8				60.3	29.6	1.3	4.3	3.7	0.8	0.0	375
3.00	32.9	29.2	37.9	35.4	31.5	33.1	1.11	13.7				67.0	24.8	1.5	3.8	1.5	1.3	0.0	524
4.00	30.1	30.4	39.5	32.5	33.7	33.8	1.15	15.5				61.5	26.8	2.1	4.8	2.1	0.7	0.0	291
5.00	34.7	26.3	39.0	37.3	28.7	34.0	1.31	13.7				64.3	26.2	1.4	3.3	3.9	1.8	0.0	614
6.00	34.6	30.5	34.9	37.3	33.4	29.3	1.22	15.1				58.1	31.5	1.6	2.9	3.7	2.2	0.0	375
7.00	26.9	30.0	43.1	29.2	35.5	35.3	0.96	15.7				60.9	27.9	1.4	3.6	4.5	1.7	0.0	358
8.00								16.7				65.9	24.6	0.7	2.7	3.7	2.1	0.0	402
9.00	35.2	30.9	33.8	37.8	34.4	27.8	1.36	14.5				56.0	31.2	2.7	4.0	2.5	3.5	0.0	593
10.00								15.2				62.2	27.1	1.9	4.6	2.2	1.6	0.3	370
11.00	32.7	30.2	37.1	35.2	34.8	29.9	1.10	14.7				60.8	30.3	1.9	2.7	1.9	1.9	0.5	373
12.00								15.6				62.6	27.7	1.2	2.6	3.3	2.4	0.0	490
13.00	31.7	30.5	37.8	34.0	34.4	31.6	1.06	15.9				65.6	23.4	2.9	2.7	3.4	1.3	0.6	445
14.00								15.0				63.7	30.3	1.0	1.6	2.3	0.8	0.2	485
15.00	35.4	28.3	36.3	37.9	31.1	31.1	1.00	15.3				61.7	30.4	1.3	1.3	2.0	3.0	0.2	394
16.00								15.0				66.0	25.6	0.8	1.3	3.3	2.8	0.2	391
17.00	38.2	27.6	34.2	41.0	30.9	28.0	1.73	13.1				53.1	40.1	1.4	2.5	2.0	0.6	0.3	354
18.00								15.5				56.1	30.5	0.3	4.2	5.0	2.1	1.9	383
19.00	31.5	33.9	34.6	35.1	36.2	28.8	0.90	12.1				56.0	30.8	0.0	5.6	2.6	5.0	0.0	302
20.00								17.5											
21.00								19.6											
22.00								18.5											
25.00	39.5	30.9	29.7	42.6	32.9	24.5	1.53	12.0				56.1	36.8	0.7	2.1	1.4	1.2	1.4	423
26.00	39.1	31.4	29.5	42.3	33.0	24.7	1.28												
28.00	33.6	31.9	34.4	36.5	34.4	29.0	1.41	10.9				66.8	26.6	0.8	3.4	2.0	0.0	0.3	353
29.00	33.1	33.0	33.9	36.0	35.0	29.1	1.25	12.6				66.7	26.1	0.3	3.6	2.0	0.7	0.7	303
30.00	32.1	36.2	31.7	34.7	38.6	26.7	1.77	10.8				61.9	29.2	0.4	3.3	1.9	1.2	0.0	480
31.00								13.2				62.6	29.9	0.9	3.4	1.5	1.2	0.3	324
32.00								12.3				68.1	24.7	0.8	3.4	1.5	0.8	0.8	263
33.00								17.5				59.4	23.2	0.0	2.9	5.8	8.7	0.0	69
34.00	34.9	29.8	35.3	37.5	32.9	29.5	1.19	11.8				64.4	26.0	0.2	4.9	2.6	1.9	0.0	531
35.00	30.0	33.7	36.4	32.6	37.1	30.1	1.47	13.4				60.3	28.9	0.9	4.1	3.2	2.2	0.2	443
36.00	34.0	33.4	32.6	36.7	36.8	26.5	1.03												
37.00	33.2	31.7	35.1	35.8	35.6	28.6	1.22	12.6				56.6	29.1	1.3	5.2	1.2	2.7	0.8	519
38.00	26.5	35.0	38.5	28.7	40.3	31.0	1.06												
39.00								14.3				59.5	32.2	0.2	5.1	1.8	1.0	0.2	494
40.00	20.1	30.4	49.5	21.6	38.2	40.2	1.04	13.5				61.6	29.5	0.7	1.7	1.2	1.4	0.0	431
41.00	18.3	31.5	50.2	47.9	10.9	41.2	0.00	13.3				71.6	22.5	0.8	2.2	2.5	0.3	0.0	356
42.00	21.8	33.4	44.8	23.3	42.1	34.7	1.08	13.2				64.3	30.1	0.0	3.4	1.3	0.9	0.0	535
43.00	20.6	31.1	48.3	22.2	39.4	38.4	1.16	13.0				65.8	26.2	0.1	5.0	1.7	1.0	0.0	301
44.00	18.5	33.1	48.5	19.8	40.7	39.4	0.98	13.4				64.9	25.8	0.8	2.4	2.7	3.3	0.0	488
45.00								13.8				66.4	26.2	1.3	1.7	3.5	0.9	0.0	461
46.00	41.0	34.9	21.1	43.5	38.2	18.4	2.06	10.6				58.8	32.9	0.0	4.0	2.8	1.1	0.3	352
47.00								14.6											
48.00								15.2											
49.00								15.4											
50.00								15.4											

77 SR 22



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Alberta Geological Survey Testhole    77 SR 22
Location   5  of LSD  3 Sec 31 Twp  64 Rng 13 W of 4 Mer  .  NTS  73L
Elevation    1920 Ft      585 M   Source  1 50,000 NTS 73L/12
Date drilled     197708 20  Logged by  C  LUTZAK

                        TEXTURE (%)                              MATRIX CARBONATE              COARSE SAND LITHOLOGY (%)
 DEPTH  SAND SILT CLAY   SAND SILT CLAY  VC SD   H2O     CO2  CO3 CA/DO     IGN   QTZ  QTZT  LST  DST  LOC  OTH     N
  (M) >62 5um     <4um  >50um     <2um   1 2mm   (%)     (cc)  (%)          METM       QSS

  1 00                                           13 5                       42 2  26 9  5 7  9 3 14 8  1 1  0 0   547
  2 00  42 6 31 4 27 0  44 4 33 8 21 8   1 62    14 5                       44 4  23 4  6 8 11 2 13 6  0 5  0 0   205
  3 00  36 8 31 5 31 7  39 6 33 8 26 6   1 51    13 7                       62 4  26 1  3 4  3 0  4 0  1 0  0 0   594
  4 00  33 2 33 5 33 4  35 7 36 4 27 8   1 25    13 9                       61 2  29 5  3 2  2 9  1 3  1 9  0 0   312
  5 00  33 5 31 8 34 7  36 3 34 6 29 1   1 08    12 6                       63 2  26 9  2 2  2 7  3 6  1 3  0 0   446
  6 00  34 8 30 8 34 4  37 4 34 5 28 2   1 59    12 6                       63 8  24 4  1 9  2 6  5 2  1 9  0 0   307
  7 00  31 6 34 1 34 3  34 2 38 0 27 8   1 11    12 5                       65 4  24 4  1 1  2 4  4 1  2 2  0 4   541
  8 00  32 8 32 6 34 6  35 6 35 4 29 1   1 08    11 2                       62 1  28 9  1 7  1 7  3 4  1 9  0 0   464
  9 00                                           12 2                       67 6  21 1  2 9  1 1  5 5  1 5  0 2   451
 10 00  33 4 32 8 33 9  36 1 36 7 27 1   1 27    11 6                       67 8  23 1  1 8  2 4  2 8  1 6  0 4   494
 11 00                                           11 9                       68 5  24 6  0 2  1 2  2 6  2 4  0 0   419
 12 00  28 4 33 5 38 1  30 8 38 6 30 6   0 90    14 4                       68 6  24 2  0 0  3 3  2 6  1 0  0 2   389
 13 00                                           11 9                       61 0  25 2  1 6  6 6  4 2  1 1  0 3   377
 14 00  34 6 30 7 34 7  37 4 35 2 27 4   0 92    13 5                       61 9  22 7  1 7  7 0  4 7  2 0  0 0   299

 17 00  34 8 31 0 34 3  37 5 34 4 28 1   1 12
 18 00  37 7 37 0 25 3  40 6 34 2 25 3   1 11    11 2                       59 7  21 3  3 2  6 7  6 0  2 5  0 6   315


 23 00  37 2 30 8 32 0  40 2 34 4 25 5   1 14    12 5
 24 00  37 3 31 4 31 3  40 1 35 5 24 4   1 10    10 9                       59 5  24 0  2 0  4 9  6 9  2 2  0 4   491
 25 00  30 3 31 3 38 5  32 7 35 1 32 2   0 90    11 9                       58 3  27 5  2 9  5 9  4 4  0 8  0 2   477
 26 00  31 8 30 3 37 9  34 1 35 4 30 5   0 91    11 8                       54 0  30 7  0 5  5 7  4 6  3 9  0 5   387
 27 00                                           12 1                       57 5  29 5  1 2  4 2  6 0  1 5  0 0   400
 28 00  30 3 31 8 37 9  32 4 36 8 30 8   1 23    11 7                       61 9  27 3  0 3  3 7  2 7  3 7  0 3   373
 29 00                                           13 3                       65 9  25 3  1 4  3 0  2 2  1 4  0 8   502
 30 00  28 0 29 6 42 4  29 9 35 0 35 1   0 72    12 6                       65 9  25 2  2 4  2 4  2 2  1 1  0 7   449
 31 00                                           13 2                       69 1  22 5  1 2  3 0  3 0  0 9  0 2   431
 32 00  29 9 32 4 37 7  32 0 39 0 29 0   1 15    13 2                       65 4  27 2  1 0  3 6  2 3  0 5  0 0   390
 33 00  26 3 35 7 38 0  28 1 42 4 29 5   0 82    12 6                       59 4  32 8  1 5  4 6  1 5  0 0  0 0   259
 34 00  30 0 33 1 36 9  32 4 39 7 28 0   0 90    12 2                       66 7  21 6  2 8  4 7  3 6  0 5  0 0   361
 35 00  16 8 44 3 39 0  19 0 44 2 36 8   0 64    14 2                       61 6  28 0  0 6  4 3  4 3  1 2  0 0   164

 37 00                                           14 9

 39 00                                           13 5
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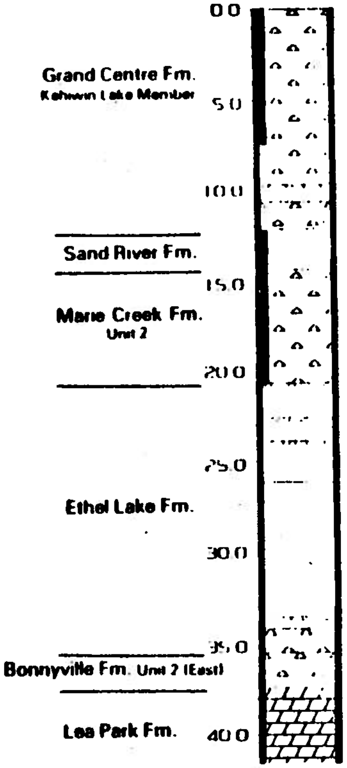
77 SR 23

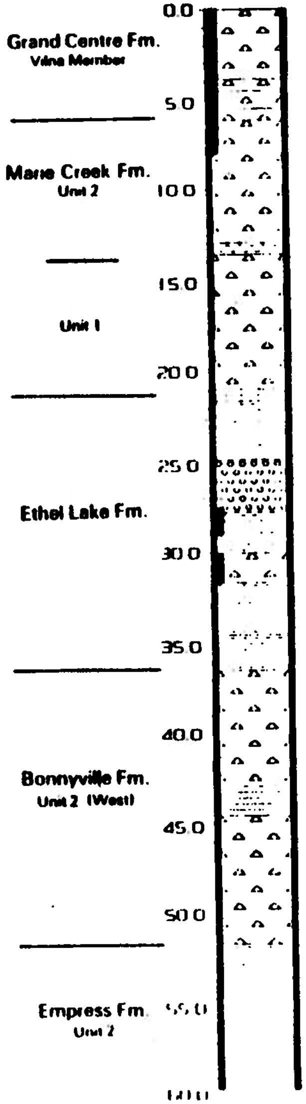
Alberta Geological Survey Testhole 77 SR 23
Location NE of LSD 6 Sec 31 Twp 65 Rng 10 W of 4 Mer . NTS 73L
Elevation 2030 Ft 619 M Source 1:50,000 NTS 73L/11
Date drilled 1977/08/21 Logged by C. LUTZAK



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1.00	46.3	33.9	19.8	49.1	29.1	21.9	2.26												
2.00	43.5	13.4	43.2	45.3	6.5	48.2	0.04	20.0											
3.00	45.9	26.4	27.7	48.4	21.3	30.3	1.88	9.5				68.5	24.7	0.5	2.8	2.1	1.3	0.0	388
4.00	46.5	29.7	23.8	49.1	24.6	26.1	2.61	9.8				63.9	21.2	0.6	3.4	3.8	1.2	5.8	499
5.00	46.1	27.8	25.9	49.0	22.7	28.3	2.49	9.5				63.5	21.5	0.6	4.1	3.4	1.7	5.5	293
6.00	44.0	29.5	26.5	46.5	24.6	28.9	2.40	9.5				66.5	23.5	0.7	4.0	3.6	0.7	0.9	421
7.00	46.4	35.5	18.1	49.0	30.1	20.8	2.24	9.1				65.2	21.1	0.5	4.2	5.8	1.6	1.4	431
8.00	16.5	48.6	34.9	18.6	41.9	39.6	1.01	11.7				55.7	26.1	0.0	3.7	6.2	6.0	2.3	352
9.00	28.2	38.8	33.0	30.9	32.3	36.8	1.02	12.1				58.9	28.9	0.4	5.4	4.8	1.2	0.2	480
10.00																			
11.00	15.8	47.0	37.2	18.1	40.0	41.9	0.94												
12.00	23.1	48.5	28.4	25.3	42.9	31.8	0.55	12.8											
13.00																			
14.00																			
15.00	37.2	43.8	19.0	40.2	38.4	21.4	2.28	9.5				61.2	24.7	0.4	3.2	5.7	1.8	0.0	441
16.00	36.4	38.8	24.8	39.6	41.6	18.8	2.21	12.0				65.5	23.7	0.2	2.9	7.3	0.4	0.0	481
17.00	39.1	33.4	27.5	42.0	36.5	21.5	2.46	7.1				66.5	23.4	0.2	3.2	4.9	1.8	0.0	492
18.00	41.3	30.3	28.4	44.1	33.6	22.3	2.58	9.5				64.4	22.9	0.8	1.9	8.2	1.5	0.2	514
19.00	38.9	31.3	29.8	41.6	34.9	23.5	2.44	10.1				67.7	23.3	0.2	1.8	5.2	1.8	0.0	498
20.00	41.5	31.0	27.5	43.9	34.7	21.4	2.01												
23.00												57.2	27.4	3.8	6.2	3.8	0.9	0.6	339
33.50																			
34.00								9.7				65.9	26.3	0.3	2.3	3.2	1.6	0.3	308
36.00	45.9	28.4	25.6	48.5	32.1	19.2	2.14	8.9				55.2	37.8	0.6	5.4	0.9	0.0	0.0	460
37.00	44.8	29.0	26.1	47.3	32.1	20.6	2.29	8.9				61.5	30.9	0.0	3.8	3.2	0.6	0.0	314
38.00								17.1											
39.00								16.5											
40.00								16.1											
41.00								16.6											

77 SR 24

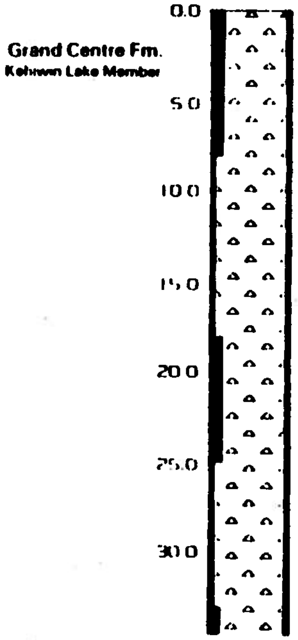
Alberta Geological Survey Testhole 77 SR 24
Location SE of LSD 9 Sec 19 Twp 65 Rng 12 W of 4 Mer NTS 73L
Elevation 1920 Ft 585 M Source 1:50 000 NTS 73L/12
Date drilled 197708 22 Logged by ANDRIASHEK



DEPTH (M)	TEXTURE (%) SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT USS	LST	DST	LOC	OTH	N
1.00								9.1				62.2	35.9	0.8	0.0	0.0	1.0	0.0	384
2.00	31.8	35.0	33.2	34.3	34.4	31.3	0.68	13.1				56.1	31.7	2.7	3.5	4.6	1.3	0.0	369
3.00	25.1	39.3	35.6	27.4	38.7	33.9	0.64	14.8				57.0	30.0	1.8	1.5	6.7	3.0	0.0	330
4.00	26.8	35.7	37.5	30.0	34.7	35.3	0.51	14.5				61.8	31.7	2.1	1.3	3.0	0.0	0.0	233
5.00	9.8	39.0	51.2	11.0	40.4	48.6	0.12	17.9				70.8	20.3	3.5	4.4	0.0	0.9	0.0	113
6.00																			
7.00	38.5	36.9	24.6	41.8	35.3	22.9	1.19	9.8				63.9	29.9	1.4	2.4	1.4	1.0	0.0	294
8.00								11.0				57.9	25.7	3.6	6.4	5.7	0.7	0.0	440
9.00	37.2	35.4	27.4	40.2	34.2	25.6	1.64	9.8				67.1	24.1	2.1	2.3	2.7	1.6	0.0	560
10.00								10.4				65.9	27.0	0.2	1.9	4.5	0.5	0.0	425
11.00	40.2	34.6	25.2	42.7	33.9	23.4	2.35	10.3				64.2	29.6	0.0	3.0	3.2	0.0	0.0	402
12.00	38.2	35.8	26.0	40.8	35.1	24.0	1.76	11.5				63.8	29.3	0.4	3.1	3.1	0.2	0.0	450
13.00								10.6				54.4	36.6	0.6	3.7	4.4	0.3	0.0	320
14.00	30.3	37.0	32.7	32.7	36.7	30.6	1.06												
15.00								11.2				59.3	28.6	1.2	2.7	5.4	2.7	0.0	332
16.00	29.7	40.8	29.5	32.3	40.0	27.7	0.96	12.1				59.6	28.8	1.7	5.0	4.5	0.2	0.0	399
17.00								12.5				56.7	28.2	3.0	4.2	5.1	2.4	0.4	504
18.00	28.5	39.8	31.7	31.4	38.9	29.7	0.72	11.8				66.0	25.9	1.5	2.5	2.8	1.2	0.0	324
19.00								11.3				55.5	30.8	1.7	6.2	3.8	1.7	0.2	468
20.00	36.2	36.8	27.0	39.0	35.5	25.5	1.11	11.4				57.3	31.3	3.1	4.1	2.3	1.6	0.2	483
21.00								14.9				78.7	16.2	0.0	2.5	0.0	2.4	0.0	80
22.00								20.8											
23.00								16.3											
24.00								17.6				74.2	16.1	3.2	3.2	3.2	0.0	0.0	31
25.00												56.2	36.2	0.0	5.0	2.5	0.0	0.0	80
26.00																			
27.00																			
27.50								14.7				69.6	25.0	0.0	4.3	1.0	0.0	0.0	92
29.00																			
30.00	19.3	55.7	25.0	21.6	55.5	22.8	0.53												
34.00								15.0											
35.00								19.4											
36.00								18.0											
37.00	36.2	38.6	25.2	39.3	37.5	23.2	1.42	10.7				59.0	38.5	0.6	0.6	0.6	0.3	0.3	322
38.00	22.1	44.8	33.1	24.1	45.5	30.5	0.60	17.3				62.9	22.9	0.6	6.4	5.6	0.4	1.1	467
39.00	40.0	35.1	24.9	42.7	34.1	23.2	1.45	9.7				57.2	38.3	1.4	1.2	1.5	0.4	0.0	514
40.00	41.5	32.8	25.8	44.2	31.6	24.2	2.05	9.5				54.7	36.0	0.7	1.7	6.5	0.2	0.0	400
41.00	40.3	35.1	24.5	42.9	34.1	23.0	2.00	9.6				66.6	27.8	0.0	2.1	0.2	1.2	0.2	485
42.00	34.5	41.8	23.7	37.3	40.7	22.0	1.27	10.8				65.7	29.1	1.8	1.2	0.6	1.5	0.3	326
44.00								17.1				68.6	25.4	2.6	0.2	0.2	2.8	0.2	465
45.00	33.9	39.2	26.9	36.2	39.1	24.7	0.98					45.2	41.9	3.2	0.0	9.7	0.0	0.0	31
46.00	30.9	39.6	29.4	33.4	39.1	27.5	0.86												
47.00	25.8	38.9	35.3	28.0	38.6	33.3	0.68					55.1	37.1	1.9	1.2	2.3	2.1	0.0	477
48.00	29.7	37.3	33.0	32.2	37.2	30.6	0.76	12.8				63.1	24.9	1.8	1.8	0.9	1.8	0.3	374
49.00	26.8	41.0	32.2	29.3	40.7	30.1	0.84	12.5				57.3	31.4	1.7	6.8	1.4	1.4	0.0	427
50.00	28.6	37.8	33.6	31.0	37.9	31.1	0.72	12.1				56.0	37.8	1.9	0.7	1.9	1.3	0.8	373
51.00	34.2	32.9	32.8	36.8	32.7	30.5	0.62	11.0				61.4	24.6	1.8	3.5	1.8	7.0	0.0	57
52.00								11.5											
53.00								11.9				63.6	32.0	0.1	3.6	0.4	0.0	0.0	250
54.00								14.2											
55.00								16.2											
56.00								17.8											
57.00								22.6											
58.00								16.2											
59.00								16.0											

77 SR 25

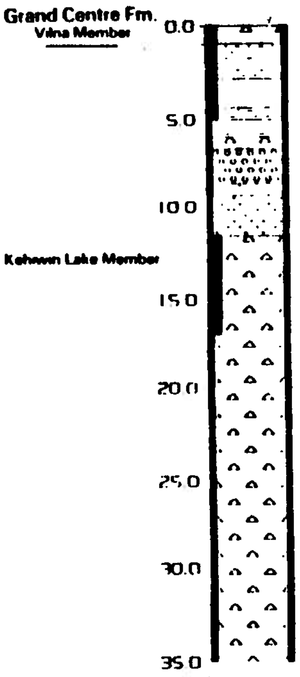
Alberta Geological Survey Testhole 77 SR 25
Location 5 of LSD 6 Sec 29 Twp 68 Rng 9 W of 4 Mer . NTS 73L
Elevation 1815 Ft 553 M Source 1 50,000 NTS 73L/14
Date drilled 197708 24 Logged by C FUTZAK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN META	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00								14 8				70 6	25 1	1 7	0 3	0 0	2 3	0 0	299
2 00	20 4	44 0	35 6	21 7	18 4	39 8	0 57	17 9				63 5	20 3	3 4	5 4	6 7	0 7	0 0	148
3 00	0 8	52 4	46 8	0 9	45 5	53 6	0 00	21 6											
4 00	28 6	38 0	33 4	30 6	31 4	38 0	0 96	14 0				55 9	25 6	2 8	7 8	7 8	0 0	0 0	281
5 00	38 0	33 3	28 7	40 4	27 6	31 9	2 34	12 7				75 1	19 6	0 5	2 4	1 6	0 8	0 0	377
6 00	36 9	32 7	30 4	39 3	26 6	34 1	2 03	17 0				66 1	26 7	1 7	0 9	2 9	1 7	0 0	419
7 00	39 5	29 0	31 4	42 0	22 8	35 2	2 07	12 2				73 2	23 1	0 4	1 1	1 4	0 2	0 2	437
8 00	24 5	42 7	32 8	26 1	36 9	37 0	1 12	14 9				61 9	25 9	2 4	2 7	3 2	2 7	1 3	375
9 00	17 8	35 9	46 3	20 2	29 6	50 2	0 47	23 8				66 3	14 8	1 7	1 7	1 7	13 7	0 0	175
10 00	24 3	33 4	42 3	26 5	27 4	46 1	0 68	15 6				69 4	24 5	0 7	1 1	3 2	1 1	0 0	281
11 00	37 4	31 5	31 1	40 1	25 4	34 5	1 55	16 1				63 4	24 3	1 6	1 6	1 7	7 9	0 0	445
12 00	45 6	30 8	23 7	48 0	24 9	27 1	0 84	13 0				68 7	19 4	1 9	1 1	2 8	6 0	0 0	464
13 00	48 2	25 6	26 1	50 4	20 0	29 6	1 10	12 0				67 7	23 7	1 0	1 9	2 7	2 9	0 0	511
14 00	46 9	28 2	24 9	49 0	23 0	28 0	0 84	11 1				67 7	23 2	1 8	0 4	1 4	5 4	0 0	276
15 00	48 2	29 9	21 9	50 6	24 5	24 9	1 10	12 3											
16 00	38 9	31 4	29 7	41 3	24 6	34 1	1 51												
17 00	54 3	24 1	21 6	56 3	19 5	24 2	3 29												
18 00	26 0	43 6	30 4	29 4	36 7	33 9	0 84					60 6	23 0	9 7	0 0	0 0	6 7	0 0	165
19 00	26 0	37 8	36 2	29 4	30 6	40 0	0 69	12 3				54 2	28 3	9 0	0 0	0 6	7 7	0 0	155
20 00	27 6	51 4	21 0	31 9	44 0	24 1	0 74					54 7	27 0	16 2	0 0	0 0	2 0	0 0	148
21 00	49 1	36 6	14 3	52 6	30 4	17 0	8 03	15 4											
22 00	50 1	26 9	23 0	53 1	21 2	25 7	2 19					66 9	29 8	0 2	0 3	0 0	2 8	0 0	571
23 00	36 2	33 8	30 1	38 3	27 1	34 6	0 94	15 2				61 7	34 1	3 3	0 0	0 0	0 8	0 0	489
24 00	25 0	46 8	28 2	28 6	40 0	31 4	1 23	12 9											
25 00	13 4	62 7	23 9	16 3	56 5	27 2	0 87												
26 00	28 5	43 4	28 2	31 6	37 6	30 8	1 02												
27 00	37 0	37 8	25 2	39 5	32 2	28 3	1 59												
28 00	15 9	53 4	30 7	18 1	47 4	34 5	0 60												
29 00	23 0	47 5	29 5	26 1	41 0	32 9	0 90												
30 00	11 2	59 6	29 3	14 8	52 8	32 1	0 27					49 3	12 3	27 4	0 0	0 0	10 9	0 0	73
31 00	18 6	54 5	26 9	22 2	47 8	30 0	0 43	13 3											
32 .00	18 5	53 9	27 6	22 1	47 2	30 8	0 37												

77 SR 26

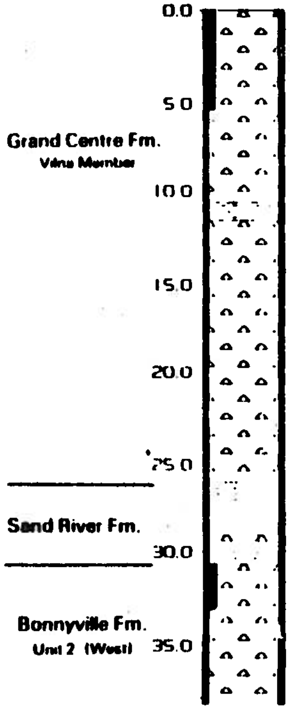
Alberta Geological Survey Testhole 77 SR 26
Location: of LSD 2 Sec 8 Twp 68 Rng 10 W of 4 Mer . NTS 73L
Elevation 2345 Ft 715 M Source 1 50,000 NTS 73L/14
Date drilled 19770829 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00								18 5				78 7	18 0	0 4	1 7	2 7	0 4	0 0	478
5 00								21 6											
6 00								15 2				77 0	19 2	0 3	0 7	2 7	0 0	0 0	291
12 00	32 7	35 3	32 0	35 2	34 2	30 6	1 48	14 8				76 4	18 5	1 1	1 1	2 9	0 0	0 0	275
13 00	37 3	31 2	31 5	39 8	30 1	30 2	2 12	14 0				72 0	23 2	0 2	0 9	3 5	0 2	0 0	453
14 00	42 4	30 0	27 6	45 1	28 5	26 4	2 29	14 0				71 2	21 6	1 0	2 4	2 8	1 0.	0 0	496
15 00	42 7	30 8	26 5	45 5	29 0	25 4	2 40	13 3				71 9	21 2	0 0	1 4	2 9	2 5	0 0	278
16 00	43 3	30 6	26 1	46 1	29 0	24 9	2 50	13 4				69 4	23 9	0 2	2 2	3 6	0 4	0 0	448
17 00	42 8	32 2	25 0	45 5	30 9	23 6	2 58	12 9				64 3	28 7	0 5	1 6	4 0	0 8	0 0	373
18 00								12 6				67 6	23 9	1 0	2 5	3 2	1 4	0 3	284
19 00	42 6	33 5	24 0	45 3	32 0	22 6	2 47	12 7				72 9	20 9	0 0	1 8	3 7	0 4	0 4	273
20 00								11 9				65 9	24 1	1 5	3 0	3 7	0 7	0 0	268
21 00	42 3	34 0	23 7	45 0	32 8	22 3	2 53	12 7				69 7	24 0	0 4	1 7	3 3	0 9	0 0	521
22 00								12 0				73 6	21 0	0 8	1 6	2 2	0 8	0 0	367
23 00	40 6	37 5	21 9	43 6	36 0	20 5	2 37	12 8				70 3	23 7	0 3	3 1	0 8	1 3	0 5	380
24 00								12 0				66 5	25 6	1 5	1 9	1 9	2 2	0 4	266
25 00	41 0	33 7	25 3	43 9	32 5	23 6	2 31	12 7				68 8	26 8	0 2	2 2	1 2	0 2	0 5	414
26 00								12 4				65 7	26 0	0 9	1 1	3 4	2 5	0 2	434
27 00	42 6	33 8	23 6	45 3	32 6	22 1	2 29					71 8	23 4	0 5	1 9	1 9	0 5	0 0	372
28 00								12 2				62 8	30 1	1 1	2 6	3 3	0 0	0 0	269
29 00	41 9	33 5	24 6	44 9	31 9	23 2	2 17	12 6				66 2	27 9	0 0	1 3	3 5	1 1	0 0	459
30 00								12 4				68 8	23 2	0 8	2 5	2 5	1 4	0 7	439
31 00	40 1	32 2	27 6	43 0	30 8	26 1	2 09	11 8				70 4	25 4	1 1	1 1	0 8	0 4	0 8	260
32 00	40 8	33 3	26 0	43 6	31 9	26 4	2 14	12 2				67 0	27 0	0 2	2 1	2 8	0 8	0 0	385
33 00	40 8	33 8	25 3	43 7	32 5	23 8	2 22	11 8				72 4	22 4	0 4	1 5	2 2	0 7	0 4	272
34 00	37 2	38 1	24 7	40 3	36 8	22 9	1 83	12 3				63 1	31 4	0 5	1 7	2 2	0 7	0 2	404
35 00	42 2	33 0	24 8	45 1	31 6	23 4	2 41	11 4				62 7	30 0	0 8	1 5	4 2	0 4	0 4	263

77 SR 27

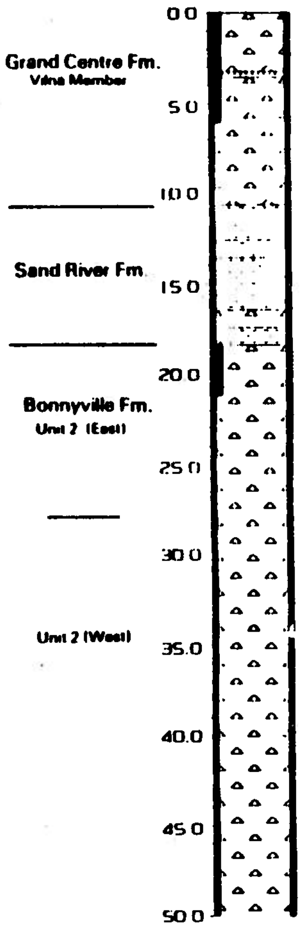
Alberta Geological Survey Testhole 77 SR 27
Location NE of LSD 2 Sec 16 Twp 67 Rng 12 W of 4 Mer . NTS 73L
Elevation 2055 Ft 627 M Source 1 50,000 NTS 73L/13
Date drilled 197708 13 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O * (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	LOC	OTH	N
1 00								14 7				69 8	25 2	2 3	0 0	0 4	1 7	0 4	242
2 00	23 3	39 7	37 0	25 5	39 4	35 1	0 51	14 9				69 6	21 2	2 4	4 8	1 2	0 8	0 0	250
3 00	16 1	46 0	37 9	18 0	46 1	35 9	0 11	16 8				71 8	18 8	1 9	2 3	0 5	0 5	0 0	213
4 00	20 2	41 8	38 0	22 4	41 2	36 5	0 68	16 3				61 7	31 1	3 0	3 0	0 9	1 3	0 0	235
5 00	16 4	44 0	39 5	18 0	44 9	37 1	0 35	16 9				73 7	17 5	2 9	2 2	2 2	1 5	0 0	137
6 00	19 8	41 8	38 4	21 7	42 1	36 2	0 50	14 0				67 2	18 9	3 0	4 0	3 3	3 0	0 0	302
7 00								13 1				64 4	26 3	2 2	2 2	2 7	1 4	0 0	407
8 00	25 6	37 0	37 4	27 9	36 5	35 6	0 72	13 7				64 0	24 5	2 4	2 4	2 1	4 5	0 0	331
9 00								13 8				65 8	26 6	1 4	2 2	3 2	0 0	0 7	278
10 00	20 6	38 8	40 6	22 6	38 9	38 5	0 60	12 9				71 3	19 5	4 2	2 9	1 0	2 6	0 7	307
11 00								15 2											
12 00								9 9				66 7	28 0	2 2	0 6	1 9	0 6	0 3	323
13 00	29 8	40 9	29 3	32 7	39 5	27 9	1 21	12 0				68 0	23 7	1 2	2 7	2 7	1 5	0 3	337
14 00	21 3	43 2	35 5	23 6	41 0	35 4	0 58	11 7				65 2	21 6	2 5	3 9	1 1	5 0	0 0	282
15 00								12 4				55 4	29 1	2 8	6 3	4 2	1 7	0 4	285
16 00								13 2				61 1	25 5	3 2	3 2	4 6	2 1	0 0	411
17 00	28 3	39 1	32 6	30 3	39 0	30 8	0 84	14 0				60 0	23 5	4 0	4 4	3 7	3 7	0 7	430
18 00								14 4				68 8	17 4	2 1	4 9	3 4	3 1	0 3	384
19 00	33 8	36 1	30 1	36 2	35 5	28 3	1 25	11 4				68 3	15 0	2 0	6 7	5 3	1 6	1 0	505
20 00								12 2				62 9	21 5	2 6	6 6	3 0	3 3	0 0	302
21 00	31 4	38 4	30 2	33 7	37 9	28 4	0 88	14 0				62 2	26 9	1 1	4 3	4 3	0 5	0 0	368
22 00								14 0				68 1	21 0	1 5	2 8	3 9	2 4	0 3	386
23 00	31 4	33 7	34 9	33 7	32 9	33 4	1 04	12 1				61 1	26 1	1 3	4 4	5 0	2 1	0 0	383
24 00	28 5	36 7	34 8	30 5	36 0	33 5	1 04	11 8				66 8	21 0	1 6	3 8	4 1	2 8	0 0	319
25 00								19 4				72 5	22 5	3 0	1 0	0 0	1 0	0 0	102
26 00								22 0											
27 00								19 7											
28 00								21 6											
29 00								21 7											
30 00								18 5											
31 00	44 9	29 2	25 9	47 3	27 6	25 2	2 98	11 8				65 7	30 1	0 0	1 0	2 6	0 6	0 0	312
32 00	40 3	32 8	26 9	42 8	31 4	25 8	2 61	12 5				67 8	20 5	0 5	2 9	3 1	5 3	0 0	419
33 00	39 0	33 1	27 9	41 5	27 5	31 1	2 67	12 2				70 4	21 2	0 0	2 6	3 8	2 0	0 0	345
34 00	36 2	35 5	28 3	38 6	30 0	31 4	2 45	11 7				63 8	26 5	0 7	3 4	3 0	2 7	0 0	298
35 00	34 7	36 9	28 4	37 2	31 4	31 4	2 01	11 1				55 2	32 4	0 2	3 7	5 6	2 4	0 4	460
36 00	34 1	37 2	28 7	36 5	31 4	32 0	1 84	12 0				61 1	28 1	0 2	4 2	4 2	1 5	0 7	455
37 00	33 9	37 7	28 4	36 4	32 2	31 4	1 92	12 1				69 9	20 8	0 7	3 6	2 9	1 9	0 7	418

77 SR 28

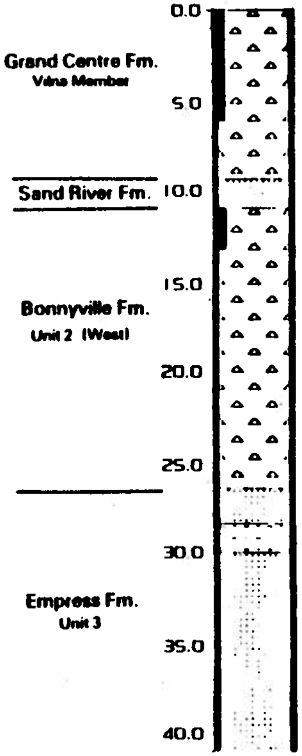
Alberta Geological Survey Testhole 77 SR 28
Location of LSD 10 Sec 22 Twp 69 Rng 11 W of 4 Mer NTS 73L
Elevation 2070 Ft 631 M Source 1:50,000 NTS 73L/11
Date drilled 1977/10 27 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC/SD 1-2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN MET	QTZ	QTZT OSS	LST	DST	LUC	OTH	N
1.00	20.5	28.6	50.9	22.3	34.3	43.3	0.64												
2.00	21.5	34.0	44.5	24.1	38.3	37.6	0.86	8.0				70.1	25.3	0.4	2.3	1.1	0.8	0.0	261
3.00	22.9	28.4	48.8	25.0	32.8	42.2	0.99					68.2	25.0	1.6	2.4	2.4	0.4	0.0	252
4.00	35.0	31.7	33.4	38.6	32.8	28.6	0.88					68.8	26.5	1.1	1.4	1.4	0.9	0.0	362
5.00	19.5	38.2	42.3	22.4	41.3	36.3	0.79					60.1	31.0	1.5	4.4	2.6	0.4	0.0	271
6.00	22.8	38.7	38.4	25.7	42.4	31.9	0.72					62.9	26.7	2.7	3.0	3.0	1.5	0.0	329
7.00	22.2	29.1	48.7	24.4	38.3	37.3	0.84					60.9	29.1	1.4	3.1	2.1	2.3	1.0	289
8.00	21.6	28.3	50.1	24.1	37.2	38.7	0.68												
9.00	21.2	29.1	49.7	23.3	37.6	39.1	0.80	7.1				61.2	28.2	1.7	3.6	1.9	3.3	0.0	358
10.00	20.7	31.2	48.0	22.7	42.0	35.3	0.69					60.9	31.6	0.7	2.7	1.7	2.1	0.3	297
17.00	22.1	37.4	40.5	25.1	41.5	33.4	0.59					64.0	26.6	1.0	2.6	2.3	3.1	0.0	391
19.00	47.6	21.6	30.8	50.4	23.2	26.4	2.47	9.7				63.8	29.4	0.0	2.0	3.6	1.2	0.0	500
20.00	46.8	22.1	31.0	49.5	24.4	26.0	2.56	9.6				64.7	28.7	0.5	2.0	3.9	0.2	0.0	558
21.00	46.6	25.3	28.1	49.3	27.6	23.1	1.94	9.1				62.1	31.8	0.2	2.6	2.6	0.4	0.2	493
22.00	50.0	23.4	26.6	53.0	25.8	21.2	2.82	9.8				65.4	27.1	0.4	2.6	3.2	1.2	0.0	495
23.00								9.3				61.6	30.9	0.8	3.0	2.5	0.8	0.2	469
24.00	43.5	26.5	30.0	46.1	31.1	22.8	0.29	9.6				65.6	25.4	0.4	2.9	4.7	0.6	0.2	445
25.00								9.2				66.3	28.2	0.0	2.0	3.0	0.6	0.0	504
26.00	44.5	26.6	28.9	47.1	31.5	21.4	1.97	9.8				59.9	32.8	0.5	1.4	4.2	0.9	0.2	549
27.00								10.6				65.4	29.3	0.2	2.3	2.1	0.8	0.0	529
28.00	38.2	25.0	36.8	41.1	31.2	27.7	2.01	10.9				66.6	29.3	0.3	0.5	1.6	1.6	0.0	368
29.00								11.0				68.4	27.5	0.0	1.7	1.7	0.6	0.0	342
30.00	33.2	25.9	41.0	35.9	32.3	31.8	1.66	11.3				63.2	28.9	0.3	2.1	3.7	0.9	0.0	356
31.00								10.5				58.8	34.1	0.8	2.3	2.8	1.1	0.0	352
32.00	36.1	26.3	37.6	39.0	30.9	30.1	1.78	11.4				56.2	38.0	0.3	2.0	1.4	2.0	0.0	347
33.00								11.3				56.9	32.9	2.1	3.0	2.7	2.1	0.3	371
34.00	34.7	26.0	39.3	37.5	32.3	30.2	1.24	11.5				56.8	35.5	1.7	3.0	1.9	1.0	0.0	470
35.00								13.0				56.8	33.7	0.8	2.8	2.8	1.8	1.1	359
36.00	36.8	28.6	34.5	39.4	34.8	25.8	1.88	10.9				58.8	35.8	0.2	2.5	2.0	0.4	0.2	405
37.00								11.1				62.4	28.9	0.3	5.4	2.7	0.3	0.0	370
38.00	36.3	28.8	34.8	39.0	35.5	25.6	1.52	10.2				65.0	30.3	0.3	2.3	1.4	0.6	0.0	352
39.00								10.6				61.0	29.0	0.0	4.1	2.3	0.9	0.6	341
40.00	37.3	24.9	37.8	40.0	29.8	30.1	1.69	9.7				59.7	31.3	0.3	2.1	2.7	0.9	0.1	747
41.00								10.0				61.5	33.7	1.0	1.4	1.2	1.0	0.0	637
42.00	34.5	29.5	36.0	37.3	34.1	28.6	1.57	11.7				60.6	32.5	0.8	2.2	2.2	1.8	0.0	508
43.00								10.7				64.7	29.2	0.7	2.3	1.8	1.3	0.0	603
44.00	36.3	29.2	34.5	39.0	34.1	26.7	1.86	10.6				64.2	26.9	0.5	3.1	4.0	1.0	0.2	573
45.00												64.6	27.4	0.0	1.1	2.8	1.8	0.3	325
46.00	41.1	27.8	31.1	43.6	31.8	24.6	2.51					65.9	27.2	0.0	1.5	4.5	0.9	0.0	463
47.00	39.3	23.9	36.8	41.8	30.6	27.6	1.89					61.6	32.4	0.0	2.1	3.4	0.4	0.0	386
48.00	39.7	23.3	37.0	42.2	28.9	28.9	1.90					61.5	29.3	0.6	2.5	4.9	1.2	0.0	525
49.00	40.6	23.9	35.5	43.3	29.1	27.6	2.53					61.1	33.3	0.3	1.8	3.2	0.3	0.0	319
50.00	41.0	25.6	33.4	43.4	30.8	25.8	1.85					67.0	23.6	0.9	2.9	4.5	0.9	0.2	555

77 SR 29

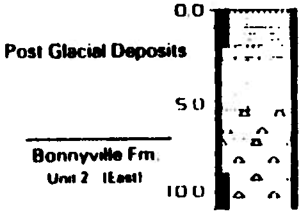
Alberta Geological Survey Testhole 77 SR 29
Location of LSD 8 Sec 2 Twp 69 Rng 13 W of 4 Mer , NTS 73L
Elevation 1920 Ft 585 M Source 1 50,000 NTS 73L/13
Date drilled 197710 28 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT USS	LST	DST	LOC	OTH	N
1 00	35 6	27 0	37 5	38 2	30 7	31 1	1 67	11 9				68 6	23 0	0 3	3 3	2 5	1 5	0 0	395
2 00	36 7	27 1	36 2	39 2	30 9	30 0	1 97	11 9				69 4	24 1	0 5	1 6	1 6	2 7	0 0	373
3 00	34 7	35 6	29 7	37 3	38 9	23 9	2 50	11 5				72 8	20 8	0 0	2 1	1 9	2 5	0 0	481
4 00	38 5	28 7	32 8	41 0	31 4	27 6	2 33	10 7				74 6	18 2	0 3	2 3	3 3	1 0	0 0	307
5 00	37 9	50 8	11 3	40 5	51 0	8 5	2 15	10 9				68 7	24 4	0 0	2 8	1 6	2 4	0 0	499
6 00	31 7	38 1	30 2	34 1	44 9	21 0	1 45	11 1				72 2	19 4	0 3	2 9	1 9	3 2	0 0	309
7 00	34 4	39 7	26 0	36 9	45 8	17 3	1 87	11 1				64 6	24 2	0 4	3 8	1 7	4 6	0 8	240
8 00	20 0	46 5	33 5	22 3	54 2	23 5	0 53	12 1				65 9	27 5	2 4	2 4	1 2	11 8	1 2	85
9 00	33 9	45 0	21 1	36 3	49 8	13 9	1 25	9 9				68 1	24 8	0 6	2 1	2 8	1 2	0 2	467
10 00								10 1				61 8	30 9	0 5	3 8	2 4	0 5	0 0	372
11 00	39 3	26 5	34 2	41 8	30 0	28 3	2 04	10 1				64 8	30 1	0 4	1 8	2 0	0 9	0 0	551
12 00	38 6	30 7	30 7	41 2	34 4	24 4	2 79	9 6				64 5	27 2	0 2	3 7	2 4	1 0	0 0	493
13 00	39 9	39 5	20 6	42 4	45 0	12 6	2 21	9 3				65 7	28 0	0 2	2 4	3 0	0 7	0 0	539
14 00	39 3	36 8	23 9	42 1	42 5	15 4	2 17	9 8				61 2	29 1	0 6	3 4	2 4	2 8	0 2	467
15 00								9 8				58 9	33 8	0 6	3 8	1 6	0 8	0 0	506
16 00	40 1	36 9	23 0	42 6	42 6	14 8	2 27	10 1				54 9	36 1	1 3	1 3	4 0	1 5	0 0	399
17 00								10 2				60 6	30 6	0 7	3 4	4 0	0 7	0 7	297
18 00	38 0	37 1	24 8	40 5	43 2	16 3	2 00	11 1				58 1	34 6	0 3	1 6	4 4	1 0	0 0	384
19 00								11 1				59 7	31 8	0 5	3 4	3 6	1 0	0 0	412
20 00	35 2	32 3	32 6	37 7	36 5	25 7	1 88	10 8				59 8	31 8	0 2	3 3	5 1	1 4	0 0	428
21 00								9 3				58 2	36 7	0 2	2 7	1 2	1 0	0 2	411
22 00	37 0	32 5	30 5	39 4	38 8	21 7	1 64	9 3				59 4	35 2	0 5	1 5	2 2	1 0	0 2	401
23 00	36 7	36 0	27 3	39 2	41 8	18 9	1 68	10 1				58 5	31 8	0 9	5 1	3 0	1 5	0 3	334
24 00	39 8	31 4	28 7	42 2	38 1	19 7	1 88	14 7				61 1	32 4	0 5	0 8	4.5	0 8	0 0	398
25 00	41 0	36 8	22 3	43 3	42 3	14 3	2 02	9 8				68 3	26 5	0 4	1 7	1 9	1 5	0 2	479
26 00	42 2	32 8	25 0	44 6	38 2	17 1	2 49	9 4				66 0	28 5	0 5	1 6	3.0	0 7	0 0	438
29 00								13 1				58 0	37 9	1 8	0 9	0 5	0 9	0 0	219

77 SR 30

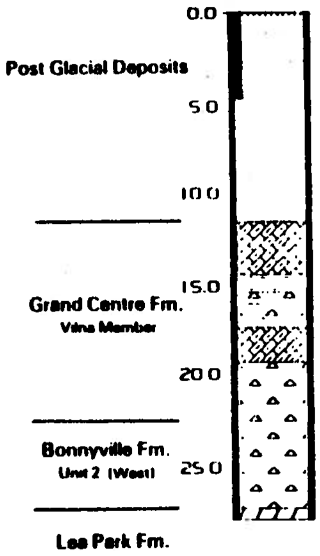
Alberta Geological Survey Testhole 77 SR 30
Location SW of LSD 14 Sec 22 Twp 69 Rng 12 W of 4 Mer NTS 73L
Elevation 1920 Ft 585 M Source 1 50,000 NTS 73L/13
Date drilled 1977 10 30 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT USS	LST	DST	LOC	OTH	N
1 00								16 6				65 6	28 1	1 6	0 8	2 3	1 6	0 0	128
3 00								17 5				65 7	28 0	0 0	1 2	2 8	2 2	0 3	324
4 00								19 4				81 8	18 2	0 0	0 0	0 0	0 0	0 0	22
5 00								17 8				81 3	17 8	0 0	0 0	0 9	0 0	0 0	107
7 00	42 5	19 5	18 0	46 8	41 4	11 8	1 29	9 9				66 6	24 7	0 0	1 5	5 7	1 2	0 0	332
8 00	49 0	29 0	22 0	51 8	33 3	14 9	2 12	10 4				61 9	30 0	0 8	1 6	3 7	1 2	0 0	491
9 00	41 5	28 0	28 5	46 1	32 1	21 6	1 73	10 7				60 9	32 8	0 6	1 1	1 7	2 3	0 3	348
10 00	45 4	27 2	27 5	48 1	30 8	21 1	1 73	10 1				57 9	36 8	1 1	0 5	1 3	2 4	0 0	378
11 00	46 5	34 4	19 1	49 1	38 1	12 8	1 75	9 9				63 3	30 1	1 6	0 5	1 6	2 5	0 2	436

77 SR 31

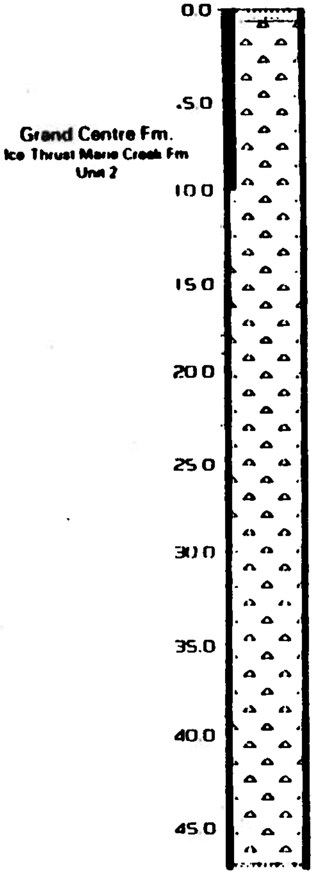
Alberta Geological Survey Testhole 77 SR 31
Location SW of LSD 2 Sec 31 Twp 69 Rng 13 W of 4 Mer . NTS 73L
Elevation 1860 Ft 567 M Source 1 50,000 NTS 73L/13
Date drilled 1977 10 30 Logged by M FENTON



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	LST	DST	COC	OTH	N
2 00								5 7											
3 00								9 7											
4 00								18 5											
5 00								19 3											
6 00								21 9											
7 00								20 7											
8 00								18 3											
9 00								20 8											
10 00								19 0				40 4	40 4	2 0	0 0	0 0	17 2	0 0	151
11 00								19 1				51 5	43 8	2 1	0 0	1 3	0 8	0 4	235
12 00	14 3	39 1	46 5	16 2	50 8	33 0	0 22	20 7				66 2	28 2	0 0	0 0	5 6	0 0	0 0	71
13 00								18 4				62 6	25 7	0 5	4 8	2 4	3 4	0 0	206
14 00								17 3				51 8	24 7	0 0	9 9	9 9	3 7	0 0	81
16 00	5 8	57 1	37 1	7 6	67 6	24 8	0 12	17 4				66 0	26 0	0 0	4 0	0 0	2 0	0 0	50
17 00								16 1				57 1	28 6	4 8	9 5	0 0	0 0	0 0	21
18 00								12 1				58 6	29 8	3 7	2 1	4 2	1 6	0 0	191
19 00								16 1				40 9	47 3	2 1	5 4	2 1	2 1	0 0	93
20 00	46 3	19 1	34 6	48 2	24 9	26 9	2 11	10 3				61 1	30 4	0 6	2 0	5 5	0 3	0 0	342
21 00	29 4	33 7	37 0	31 9	41 3	26 8	1 52	11 5				61 2	32 8	0 7	1 9	2 6	0 5	0 0	415
22 00	28 9	36 6	34 5	32 1	42 7	25 2	1 33	11 0				59 8	33 0	0 7	2 6	2 8	0 7	0 0	575
23 00	40 1	32 0	27 9	42 7	37 1	20 3	2 65	15 8				60 5	31 6	1 3	2 6	2 3	0 9	0 6	307
24 00	39 8	31 8	28 4	42 4	37 6	20 0	2 39	9 0				61 7	31 6	0 6	3 2	2 0	0 9	0 0	342
25 00	38 4	32 7	29 0	41 0	38 7	20 3	2 59	9 5				58 2	35 8	0 2	2 7	2 4	0 7	0 0	589
26 00	34 8	33 0	32 2	37 4	39 2	23 4	1 67	11 4				51 6	39 7	0 8	3 4	3 4	0 7	0 0	589
27 00	24 7	38 0	37 3	27 2	45 3	27 5	0 78												
28 00								15 7											
29 00								17 6											

77 SR 33

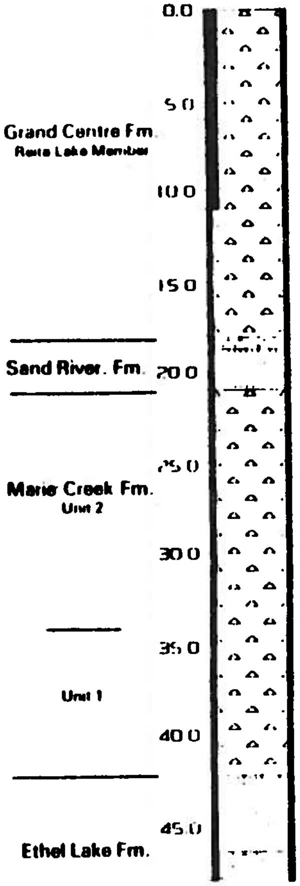
Alberta Geological Survey Testhole 77 SR 33
Location of LSD 4 Sec 27 Twp 65 Rng 7 W of 4 Mer . NTS 73L
Elevation 2455 Ft 748 M Source 1 50,000 NTS 73L/10
Date drilled 197807 14 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
1 00	47 2	17 8	35 0	49 7	20 7	29 7	1 25	12 4				73 3	21 7	1 6	0 0	0 0	0 4	0 0	255
2 00	51 0	22 3	26 7	53 4	25 4	21 2	3 53	11 8				67 7	25 0	0 0	1 7	4 4	1 1	0 0	523
5 00	46 7	25 9	27 4	49 4	28 6	22 0	2 85	10 1				60 5	27 6	0 3	2 7	6 6	1 7	0 0	301
6 00								11 4				67 8	21 1	0 0	3 4	5 7	2 0	0 0	351
7 00	46 4	24 6	29 0	49 0	28 0	23 0	2 80	11 2				64 7	21 5	0 3	2 0	10 2	1 4	0 0	391
8 00								10 6				60 1	26 2	0 0	4 7	7 9	0 9	0 0	466
9 00	45 7	25 9	28 4	48 4	28 7	22 8	2 48	10 8				62 5	26 5	0 0	2 5	7 1	1 7	0 0	408
10 00								10 6				63 4	21 1	0 6	3 7	10 4	0 8	0 0	355
11 00	43 6	28 0	28 4	46 4	32 6	21 0	2 93	10 6				62 1	22 4	0 0	3 0	11 4	1 1	0 0	464
12 00								11 3				64 0	12 9	0 3	3 5	17 0	2 3	0 0	311
13 00	39 3	30 0	30 7	42 5	35 3	22 2	2 06	10 6				66 4	18 4	0 5	2 5	11 1	1 0	0 0	396
14 00								10 7				61 6	15 9	0 3	4 0	16 9	1 3	0 0	372
15 00	39 0	28 0	32 9	41 8	34 9	23 2	2 85	10 4				68 0	26 3	0 2	1 4	1 8	1 0	0 0	438
16 00								9 8				61 6	28 9	0 0	2 6	3 9	2 1	0 5	380
17 00	44 7	26 7	28 6	47 4	32 1	20 5	2 65	10 5				64 5	24 1	0 3	2 6	5 7	2 9	0 0	349
18 00								10 2				64 3	28 3	0 0	3 1	3 9	0 4	0 4	258
19 00	43 5	27 7	28 8	46 0	34 3	19 7	2 75	10 4				56 5	28 8	0 0	3 5	8 8	1 9	0 4	260
20 00	45 9	25 4	28 7	48 7	31 6	19 7	2 92	9 9				61 2	26 2	0 0	2 8	7 6	2 2	0 0	317
22 00	41 9	24 4	33 6	46 5	30 7	22 8	2 71	10 0				67 3	22 3	0 0	2 4	5 6	2 2	0 5	413
23 00	44 8	26 4	28 8	47 6	32 4	20 0	2 93	10 1				59 9	28 6	0 0	2 4	7 6	1 2	0 3	329
24 00								10 1				67 0	22 1	0 0	2 7	5 2	2 7	0 3	367
25 00	44 6	28 1	27 3	47 3	33 1	19 7	2 53	9 4				62 3	26 5	0 0	2 2	7 3	1 3	0 3	313
26 00								9 9				67 0	20 8	0 0	2 5	7 5	1 8	0 7	279
27 00	44 4	26 5	29 2	46 9	32 2	20 8	2 64	9 8				66 0	25 1	0 0	2 1	5 8	1 0	0 0	382
28 00								9 5				63 9	23 9	0 0	3 1	8 2	0 8	0 0	255
29 00	42 7	26 2	31 1	45 3	32 0	22 7	2 56	8 9				64 4	23 2	0 0	4 8	6 3	1 0	0 0	315
30 00								9 3				67 1	17 8	0 2	5 8	6 3	2 9	0 0	416
31 00	44 3	27 2	28 5	46 8	31 5	21 7	2 84	8 9				62 5	26 0	0 0	1 3	8 6	1 6	0 0	304
32 00								9 8				63 8	25 5	0 3	2 1	7 4	0 9	0 0	337
33 00	45 2	25 3	29 4	47 8	29 1	23 2	2 39	12 8				65 2	21 1	0 5	4 3	8 2	0 5	0 5	417
34 00								9 6				62 4	26 5	0 0	1 7	7 8	1 7	0 0	351
35 00	44 6	26 5	28 8	47 5	31 0	21 5	2 81	8 6				66 1	23 9	0 0	3 2	5 6	0 8	0 0	251
36 00								9 2				61 1	24 5	0 3	1 8	11 6	0 8	0 0	388
37 00	43 0	31 1	25 8	46 4	34 5	19 1	3 03	9 6				62 8	24 0	0 3	2 5	9 3	1 1	0 0	366
38 00								10 0				60 9	19 2	0 0	4 7	13 4	1 8	0 0	276
39 00	40 5	29 6	29 9	43 2	34 9	21 8	2 58	9 9				63 0	17 3	0 0	1 4	16 6	0 7	0 0	289
40 00								9 8				61 3	23 5	0 8	4 6	7 5	2 3	0 0	388
41 00	42 7	29 7	27 7	45 3	34 5	20 2	0 00	10 0				63 7	22 9	0 3	2 1	9 5	1 5	0 0	336
42 50	52 7	23 0	24 3	55 4	27 0	17 5	4 69					62 5	23 5	0 0	1 9	10 5	1 6	0 0	315
44 00	50 7	28 4	20 9	54 2	29 8	16 0	3 01												
45 00								9 7											

77 SR 34

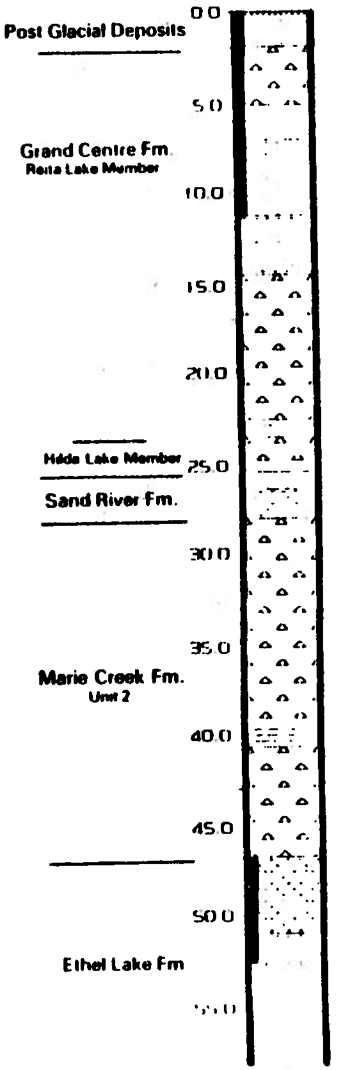
Alberta Geological Survey Testhole 77 SR 34
Location of LSD 16 Sec 20 Twp 66 Rng 5 W of 4 Mer . NTS 73L
Elevation 2115 Ft 645 M Source 1 50,000 NTS 73L/10
Date drilled 197807 14 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT OSS	CST	DST	LOC	OTH	N
1 00	44 3	21 7	33 9	46 8	22 8	30 4	1 80	10 9				76 5	16 0	1 1	2 2	3 4	0 8	0 0	268
2 00								9 2				74 2	20 7	0 4	2 0	2 0	0 8	0 0	256
3 00	45 3	20 1	34 6	47 9	20 0	32 1	1 86	11 2				67 2	22 0	2 0	2 9	4 4	1 3	0 0	454
4 00								11 4				66 8	25 8	1 2	1 7	2 8	1 9	0 0	422
5 00	23 3	26 3	50 4	25 1	28 7	46 1	1 14	12 8				68 6	21 5	0 7	3 5	2 0	2 0	0 0	456
6 00								12 5				72 1	17 2	1 7	2 3	5 9	1 1	0 0	355
7 00	19 9	42 0	38 2	22 1	42 4	35 5	2 54	11 6				71 4	21 0	1 4	1 1	3 4	1 1	0 0	357
8 00								11 8				72 0	18 9	0 2	1 5	5 7	1 5	0 2	460
9 00	44 0	21 2	34 8	46 4	21 2	32 5	2 71	10 7				69 6	22 0	1 1	2 7	3 8	0 5	0 0	368
10 00	37 5	24 6	38 0	39 6	24 4	35 9	1 97	10 7				68 8	23 1	0 3	0 9	4 7	2 2	0 0	321
11 00	45 0	22 3	32 7	47 4	21 8	30 7	3 05	10 7				73 5	19 4	0 0	3 0	2 8	0 2	0 7	427
12 00	47 3	25 4	27 3	50 0	25 1	25 0	3 17	9 5				70 0	24 4	0 0	2 6	2 6	0 3	0 0	307
13 00	46 8	22 3	30 9	49 3	23 1	27 7	3 80	10 3											
14 00								9 5				72 2	22 2	0 4	1 5	1 9	1 5	0 4	266
15 00	53 3	22 9	23 8	56 2	21 9	22 0	4 80	10 1				68 4	27 0	0 0	0 4	2 0	0 0	0 0	256
16 00								6 1				70 0	22 1	0 5	2 4	2 1	3 1	0 0	420
17 00	42 5	26 4	31 1	45 2	26 9	27 9	4 08	12 8				67 4	25 9	0 0	1 7	1 0	3 7	0 3	301
18 00								18 1				69 9	23 9	0 3	1 2	1 8	3 0	0 0	335
19 00																			
22 00	36 1	31 4	32 5	38 5	33 2	28 2	2 38	12 6				63 7	26 7	0 2	1 8	4 0	3 6	0 0	446
23 00	49 1	25 1	25 8	51 8	25 6	22 6	2 65	10 2				67 2	22 9	0 0	3 1	5 0	2 3	0 0	262
24 00								10 7				58 6	25 4	0 0	4 1	11 3	0 9	0 0	319
25 00	52 4	23 4	24 2	55 3	22 2	22 5	4 52	10 6				73 1	19 6	0 0	1 2	5 0	1 2	0 0	260
26 00								10 6				59 5	32 1	0 0	3 8	2 3	2 3	0 0	262
27 00	47 9	23 4	28 7	51 0	23 1	25 9	2 70	10 3				59 0	29 5	0 3	3 1	4 9	2 8	0 3	390
28 00								9 9				59 0	29 7	0 0	3 5	4 5	2 6	0 5	424
29 00	48 8	25 8	25 4	52 2	24 7	23 1	3 04	11 1				58 0	31 7	0 0	2 9	5 1	1 9	0 3	312
30 00								9 8				62 3	27 9	0 3	2 7	5 3	1 2	0 3	337
31 00	47 6	25 3	27 1	50 5	25 0	24 5	2 68	10 3				59 6	28 2	0 3	4 9	4 5	1 7	0 3	287
32 00								10 3				61 0	26 9	0 0	5 1	3 7	3 3	0 0	510
33 00	46 9	23 7	29 4	49 6	23 4	27 0	2 81	10 5				67 5	22 2	0 0	2 2	3 9	4 2	0 0	360
34 00								11 7				73 0	18 6	0 4	3 6	2 2	2 2	0 0	274
35 00	32 8	14 1	53 1	35 8	33 9	30 2	1 51	12 4				68 2	23 0	1 9	1 1	4 2	1 1	0 4	261
36 00								11 5				61 8	27 8	1 0	2 2	3 1	1 9	0 2	414
37 00	42 4	22 2	35 4	45 1	22 2	32 7	2 10	12 6				65 5	25 2	1 5	2 7	3 6	0 9	0 3	330
38 00								11 3				60 7	29 0	0 4	3 1	3 4	3 4	0 4	262
39 00	40 4	24 6	35 0	43 2	24 5	32 2	1 90	15 8				64 2	29 4	0 0	1 0	3 2	1 3	1 0	310
40 00								11 4				70 7	18 8	0 8	3 4	6 0	0 4	0 0	266
41 00	40 9	25 7	33 5	41 8	25 1	33 1	2 06	14 8				65 3	27 2	0 3	1 9	3 4	1 9	0 0	323
42 00	43 0	23 4	33 6	45 7	23 2	31 1	3 43	11 7				62 3	27 5	0 0	1 4	4 3	0 7	0 0	276

77 SR 35

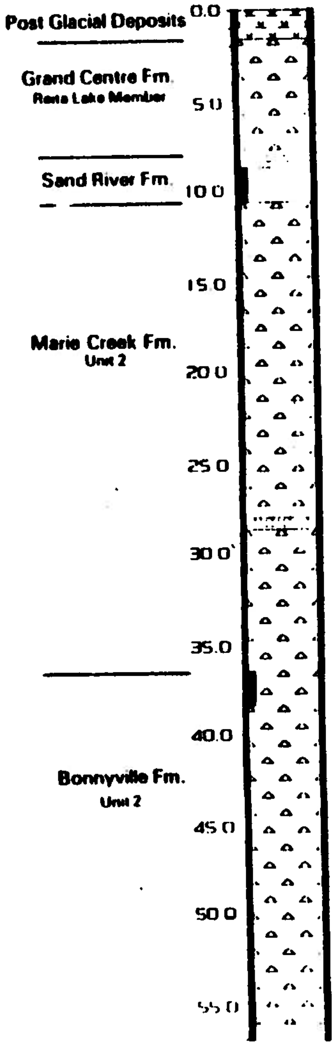
Alberta Geological Survey Testhole 77 SR 35
Location of LSD 2 Sec 6 Twp 66 Rng 1 W of 4 Mer , NTS 73L
Elevation 2000 FT 610 M Source 1 50,000 NTS 73L/10
Date drilled 197802 20 Logged by ANDRIASHEK



DEPTH (M)	TEXTURE (%) SAND 62.5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1-2mm	H2O (%)	MATRIX CARBONATE CO2 (cc)	CO3 (%)	CA/DO	COARSE SAND LITHOLOGY (%) IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
2.50	41.0	20.8	38.2	43.8	24.0	32.2	1.42	10.2	3.8	1.6	0.77	68.4	29.2	2.4	0.0	0.0	0.3	0.0	804
3.00	41.8	22.5	35.7	45.5	23.6	30.9	1.61	11.0	3.5	1.5	1.21	69.0	27.6	3.1	0.0	0.0	0.4	0.0	673
4.00	38.6	26.7	34.7	42.2	28.8	29.0	1.48	11.8	20.2	8.4	0.25	68.4	27.5	1.4	0.6	1.6	0.5	0.0	702
5.00	42.3	22.3	35.4	45.9	24.0	30.1	1.64	11.9				67.3	27.8	2.4	0.4	1.3	0.7	0.0	745
6.00								12.4											
7.00								17.5											
8.00								16.3											
11.00								21.7											
12.00								21.5											
13.00								19.9											
14.00								14.1				74.5	21.7	1.2	1.7	0.7	0.2	0.0	419
15.00	42.1	25.1	32.8	45.6	27.4	27.1	1.81	11.3	24.1	10.1	0.26	71.6	22.9	2.1	1.1	2.0	0.2	0.0	933
16.00	40.7	26.0	33.3	44.5	28.1	27.4	1.77	11.6	24.1	10.1	0.21	67.0	26.3	2.1	1.2	2.5	0.6	0.0	1072
17.00	43.3	24.9	31.8	46.9	26.2	26.9	1.93	11.3	24.7	10.1	0.18	65.7	29.5	1.4	2.2	1.1	0.0	0.0	271
20.00	36.8	27.1	36.1	40.6	30.1	29.3	1.65	12.9	23.4	9.8	0.17	68.6	25.8	1.5	1.8	2.0	0.3	0.0	850
21.00	37.2	27.2	35.6	40.8	29.1	29.8	1.86	12.8	25.0	10.4	0.15	72.5	23.1	0.8	2.0	1.6	0.0	0.0	247
22.00	36.7	27.5	35.8	40.6	29.6	29.8	1.74	12.2	24.4	10.1	0.16	67.1	28.6	1.7	0.6	2.8	0.4	0.0	821
23.00																			
24.00	23.9	28.6	47.4	27.1	33.8	39.1	0.88	11.1	24.2	10.0	0.08	66.1	26.8	1.6	1.5	4.0	0.4	0.0	684
25.00	30.8	28.7	40.5	34.6	31.8	33.6	1.24	15.8	24.5	10.2	0.14	68.2	18.8	0.5	1.9	10.2	0.4	0.0	431
27.00								18.0											
28.00	43.4	26.7	29.9	46.8	28.3	24.9	3.56	9.9	37.2	15.4	0.14	70.8	25.3	0.6	1.3	2.6	1.2	0.0	154
29.00	42.2	27.8	30.0	46.0	29.5	24.5	3.27	11.7	34.4	14.3	0.14	65.9	22.8	0.8	3.3	8.5	1.3	0.0	399
30.00	43.4	25.6	30.9	46.9	28.6	24.5	2.91	9.8	37.9	15.9	0.26	64.0	21.0	0.8	3.5	10.0	1.1	0.0	400
31.00	41.6	29.1	29.3	45.0	32.5	22.5	3.07	9.8				65.8	16.8	0.5	2.8	12.3	1.8	0.0	398
32.00	41.5	28.0	30.5	45.1	30.9	24.0	2.82	10.2	36.3	15.1	0.16	62.0	22.3	1.3	1.3	11.8	1.6	0.0	382
33.50	41.6	28.4	30.0	45.1	31.3	23.7	2.83	10.1	35.2	14.7	0.20	65.1	17.0	1.1	2.7	12.1	1.3	0.0	364
34.00	41.2	28.2	30.6	44.8	30.8	24.4	2.51	9.4	39.9	16.6	0.16	63.0	19.0	1.5	3.6	12.3	0.6	0.0	332
35.00	42.4	27.7	29.9	45.9	30.4	23.7	2.94	10.5	35.8	14.9	0.21	59.6	18.5	1.6	2.6	16.5	1.3	0.0	389
36.00	41.8	29.7	28.5	45.7	31.9	22.5	2.79	10.2	38.8	16.2	0.24	60.6	25.7	2.0	1.7	8.9	0.8	0.0	358
37.00	39.4	27.9	32.7	43.1	31.0	25.9	2.93	10.7	28.1	11.8	0.28	60.3	27.4	1.5	4.7	3.9	1.9	0.0	383
38.00	37.2	27.9	34.9	40.3	32.3	27.4	2.61	9.8	35.7	14.9	0.23	57.6	33.6	0.6	3.2	3.2	1.2	0.0	342
39.50	36.7	26.2	37.0	39.8	32.1	28.1	2.67		27.7	11.6	0.36	56.9	29.6	2.0	6.3	3.7	1.7	0.0	348
41.00	48.8	24.0	27.2	52.4	28.0	19.7	3.47	8.6	29.6	12.4	0.27	66.3	23.8	1.4	4.4	3.5	1.1	0.0	433
41.50	48.0	25.2	26.7	51.8	27.0	21.2	4.24		31.5	13.2	0.36	77.9	16.7	0.4	3.3	1.5	0.2	0.0	538
43.00	48.5	24.0	27.5	52.0	26.3	21.7	2.71	8.5	23.0	9.7	0.41	61.8	26.7	0.9	4.2	2.8	1.7	0.0	356
44.00	47.8	24.6	27.6	51.6	27.4	21.0	2.31		22.3	9.4	0.28	68.6	24.5	1.0	2.0	3.9	0.0	0.0	306
46.00	44.7	25.1	30.1	48.3	29.4	22.3	2.59	8.8	24.9	10.5	0.45	57.1	33.7	0.9	2.3	2.9	3.2	0.0	350
52.00	40.1	29.2	30.6	43.9	33.2	22.9	2.56					59.1	27.6	0.9	3.9	5.8	2.5	0.0	362

77 SR 36

Alberta Geological Survey Testhole 77 SR 36
Location of LSD 9 Sec 21 Twp 66 Rng 4 W of 4 Mer NTS 73L
Elevation 2090 Ft 637 M Source 1:50,000 NTS 73L/9
Date drilled 197802 21 Logged by ANDRIASHEK



	TEXTURE (%)								MATRIX CARBONATE			COARSE SAND LITHOLOGY (%)							
DEPTH (M)	SAND >62 5um	SILT	CLAY <4um	SAND >50um	SILT	CLAY <2um	VC SD 1 2mm	H2O (%)	CO2 (cc)	CO3 (%)	CA/DO	IGN METM	QTZ	QTZT QSS	LST	DST	LOC	OTH	N
2 00	43 4	24 9	31 8	46 6	26 0	27 4	1 46		28 4	12 0	0 37	64 2	21 6	0 5	2 6	4 2	1 0	0 0	190
3 00	41 5	27 5	31 0	45 2	27 5	27 3	1 15		26 3	11 0	0 30	57 8	27 1	3 0	6 0	6 0	0 0	0 0	166
4 00	41 7	26 5	31 8	45 0	27 7	27 3	1 10	12 7	24 9	10 4	0 31	62 3	24 6	4 2	3 9	4 4	0 7	0 0	594
5 00	41 7	25 6	32 7	45 1	26 7	28 2	1 26	12 2	25 7	10 7	0 19	62 0	23 2	4 0	4 6	5 1	1 0	0 0	648
6 00	40 6	25 1	34 3	43 8	26 7	29 6	1 91	12 2	27 4	11 4	0 21	68 5	24 4	3 8	0 9	2 1	0 2	0 0	422
7 00	42 4	24 5	33 0	45 9	25 6	28 5	1 86	12 3	24 8	10 3	0 17	67 4	24 7	3 3	1 6	2 3	0 6	0 0	430
8 00	40 5	24 9	34 7	43 5	26 4	30 1	2 15	13 3	23 6	9 8	0 14	66 6	25 5	2 0	2 3	2 5	0 8	0 0	608
8 50								20 6											
10 00																			
11 00	40 7	29 9	29 4	44 4	30 3	25 3	2 89	11 4	35 1	14 6	0 13	63 1	18 3	1 1	1 4	12 8	0 3	0 0	360
12 00	42 2	29 1	28 7	45 9	29 4	24 7	3 41	11 2	38 5	16 1	0 23	60 4	19 8	0 2	2 5	15 8	0 9	0 0	404
13 00	44 7	29 6	25 6	48 5	30 5	21 0	3 01	9 8	35 1	14 6	0 17	65 6	19 2	1 0	3 3	9 2	1 3	0 0	390
14 00	45 1	28 7	26 2	48 8	29 4	21 9	2 55	10 5	35 5	14 9	0 30	65 3	21 0	1 2	4 0	6 8	1 5	0 0	352
15 00	51 8	25 1	23 1	55 7	25 5	18 9	4 42	10 0	31 4	13 2	0 32	63 6	24 7	0 6	3 1	6 8	1 3	0 0	353
16 00	46 7	26 2	27 1	50 3	28 2	21 5	2 93	8 9	30 7	12 9	0 33	67 3	22 0	0 8	3 5	4 0	2 1	0 0	373
17 00	47 0	27 5	25 4	50 9	29 0	20 2	3 99	9 9	33 8	14 1	0 17	68 7	20 9	0 2	4 1	4 7	1 4	0 0	492
18 00	46 1	27 6	26 3	49 9	28 5	21 6	3 18	9 6	29 6	12 4	0 33	60 0	27 5	1 7	4 7	3 7	1 9	0 0	407
19 00	46 0	26 8	27 2	49 9	30 7	19 4	3 16	10 0	29 4	12 3	0 29	69 1	20 2	1 5	1 9	4 6	2 6	0 0	411
20 00	46 3	27 2	26 5	49 9	30 4	19 7	3 28	10 0	30 2	12 7	0 40	66 0	21 7	1 2	4 3	3 4	2 3	0 0	415
21 00	45 4	27 5	27 1	49 3	31 2	19 5	3 01	10 3	29 1	12 2	0 31	66 4	20 7	1 1	4 2	5 8	1 6	0 0	381
22 00	45 3	26 6	28 0	49 0	31 3	19 7	2 90	10 0	28 8	12 1	0 30	65 5	21 5	0 6	5 4	4 8	2 0	0 0	354
23 00	44 2	26 8	28 9	48 1	31 1	20 8	3 00	10 8	28 4	11 9	0 31	72 9	17 5	0 6	1 9	4 7	2 1	0 0	365
24 00	42 8	27 0	30 2	46 3	30 9	22 8	2 50	11 0	29 4	12 3	0 37	64 2	24 1	0 9	5 4	3 0	2 1	0 0	332
25 00	42 2	27 6	30 2	46 0	31 7	22 2	2 88	10 7	28 0	11 7	0 25	69 8	19 4	0 6	5 4	3 8	0 5	0 0	371
26 00	41 9	27 7	30 4	45 7	31 7	22 7	2 63	10 9	29 4	12 4	0 31	63 5	26 7	0 9	2 0	2 9	3 5	0 0	348
27 00	40 7	29 9	29 5	44 6	33 7	21 7	2 49	11 2	29 5	12 4	0 26	64 6	24 6	0 9	4 4	4 4	1 2	0 0	342
29 00	50 1	28 4	21 5	54 6	30 0	15 4	2 94	10 2	31 2	12 1	0 35	69 6	18 5	1 4	2 7	4 8	2 5	0 0	372
31 00	49 2	28 1	22 6	53 8	29 7	16 6	3 21	10 1	29 4	12 3	0 31	68 1	21 3	0 5	4 2	4 2	1 1	0 0	427
32 00	50 2	27 6	22 2	54 7	29 4	16 0	3 48	10 0	31 6	13 3	0 41	66 7	21 8	0 2	4 3	5 0	1 9	0.0	417
33 50	48 6	29 1	22 3	53 2	31 1	15 7	3 23	9 5	28 1	11 8	0 42	67 0	17 7	1 4	5 7	5 9	1 4	0 0	406
34 00	50 2	28 0	21 8	54 6	30 0	15 4	3 29	10 7	38 9	16 2	0 24	63 6	25 7	0 0	7 2	6 0	2 4	0 0	401
35 00	51 9	27 9	20 1	56 7	28 7	14 6	3 60	10 5	37 2	15 5	0 21	65 3	22 1	1 1	5 1	4 2	1 8	0 0	452
36 00	39 6	27 9	32 5	43 2	27 6	29 2	2 42	10 7	11 0	4 7	0 81	58 1	34 7	1 9	3 1	0 9	0 6	0 0	320
37 00	42 0	27 6	30 4	45 5	27 5	27 0	2 16	9 9	11 6	4 9	0 71	62 2	32 4	0 6	3 7	0 3	0 3	0 0	296
38 00	41 4	28 8	29 8	45 0	31 0	24 0	2 22	9 6	14 0	5 9	0 58	63 2	30 0	1 6	2 6	1 0	1 3	0 0	313
39 50	44 1	28 2	27 8	47 6	30 3	22 1	2 26	9 6	12 1	5 1	0 67	62 9	31 6	0 3	1 3	1 3	2 6	0 0	310
41 00	44 5	30 1	25 4	48 4	31 9	19 7	2 25	10 3	13 7	5 8	0 73	64 7	28 2	1 8	1 8	2 1	0 9	0 0	326
41 50	44 3	26 2	29 6	47 8	28 9	23 3	2 21	10 0	13 4	5 7	0 75	63 5	33 4	2 0	0 7	0 0	0 3	0 0	293
43 00	47 8	29 4	22 8	51 5	31 2	17 3	2 46	10 8	12 0	5 1	0 50	58 1	34 4	1 2	1 7	3 4	1 2	0 0	349
44 00	49 4	25 1	25 5	53 2	27 0	19 8	2 75	10 1	12 0	5 1	0 34	59 4	33 0	1 8	1 5	1 8	2 4	0.0	342
46 00	46 6	27 6	25 8	50 3	28 8	21 0	2 28	10 7	11 3	4 8	0 56	59 3	34 8	2 3	1 3	1 0	0 9	0 0	302
47 00	46 7	29 5	23 8	50 6	30 8	18 6	2 28	10 6	11 5	5 8	0 49	60 9	33 6	1 5	2 1	1 5	0 3	0 0	327
48 00	47 4	28 3	24 3	51 0	30 5	18 5	3 15	10 5	14 9	6 3	0 54	63 5	29 7	3 8	1 0	0 5	1 3	0 0	394
50 00	45 1	30 1	24 9	49 4	31 0	19 6	1 48	10 6	10 7	4 5	0 42	54 5	34 2	3 0	3 0	1 0	3 0	0 0	202
51 00	45 2	29 7	25 1	49 2	31 2	19 6	1 25	10 9	10 6	4 5	0 44	55 1	38 8	3 3	0 6	0 6	0 6	0 0	178
52 00	45 9	29 6	24 5	50 1	31 6	18 3	1 56		11 8	5 0	0 46	47 5	44 4	2 2	0 4	1 3	3 1	0 0	223
53 00	45 7	29 5	24 8	49 6	31 6	18 8	1 52	11 2	10 6	4 5	0 58	54 3	38 0	1 9	1 4	1 0	3 4	0 0	208
54 00	48 9	29 3	21 8	53 1	30 5	16 4	1 39	10 7	9 6	4 1	0 39	46 7	46 2	3 5	0 5	0 0	2 5	0 0	199
55 00	46 4	28 5	25 1	50 2	30 3	19 8	1 47		11 0	4 6	0 48	51 8	39 6	3 5	1 5	1 5	2 0	0 0	197
57 00	48 2	30 1	21 7	52 5	30 9	16 6	1 36					46 5	45 5	3 2	1 1	1 1	2 2	0 0	187

Table P-c-1
CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS,
QUATERNARY, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
LSD	SEC	TP	R	M	(m)											
7	17	55	4	4	558.7	30	21	28	4		212	38	2	0.20	1.20	241
7	18	55	4	4	558.7	30	21	28	4		212	38	2	0.20	1.20	241
1	21	55	7	4	609.0	6	<1	330	1	36	798	184	5	0.19	0.10	959
16	20	55	9	4	590.5	112	36	36	2		531	65	1	0.14	1.93	514
1	4	55	12	4	605.0	3	1	337	2	32	565	224	14	0.38	0.67	891
16	9	55	12	4	538.9	4	1	408	1	19	673	263	14	0.30	0.70	1072
9	27	55	13	4	559.2	53	24	84	3		465	35	1	0.12	0.30	437
4	5	56	3	4	538.7	107	56	156	4		571	252	20	0.21	3.67	877
16	12	56	7	4	567.2	69	52	396	5		638	596	84	0.24	7.00	1516
16	22	56	11	4	588.3	93	36	116	3		620	131	3	0.12	2.38	689
16	33	56	11	4	585.5	103	29	18	6		471	10	1	0.20	1.60	387
4	34	56	11	4	602.2	64	20	9	5		309	25	1	0.13	0.41	277
4	34	56	11	4	576.7	116	17	99	36		516	183	2	0.05	1.70	940
4	35	56	11	4	611.1	69	35	21	5		396	33	6	0.28	0.10	367
4	25	56	12	4	577.0	62	40	158	12	5	625	122	1	0.17	3.68	720
1	14	56	14	4	553.4	12	4	298	1		734	89	2	0.20	3.20	826
13	31	57	1	4	621.8	16	45	71	5		321	114	2	0.06	0.20	415
4	5	57	2	4	563.3	37	38	16	5	32	207	37	1	0.25	0.20	299
1	6	57	2	4	573.6	183	58	30	3		701	116	5	0.38	0.70	748
1	9	57	2	4	568.3	84	66	46	5		706	10	44	0.25	1.60	608
13	9	57	2	4	548.8	80	57	143	4		526	184	23	0.28	4.10	751
13	12	57	2	4	595.9	99	42	16	6		479	65	1	0.35	0.50	464
4	15	57	2	4	578.2	117	46	93	4		562	200	18	0.21	4.20	758
16	16	57	2	4	576.1	120	61	57	4		704	113	7	0.33	19.50	733
4	17	57	2	4	578.5	127	69	46	4		703	64	2	0.31	14.10	678
4	17	57	2	4	567.4	178	24	25	2		624	37	2	0.31	3.50	585

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS, QUATERNARY, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
LSD	SEC	TP	R	M	(m)											
14	19	57	2	4	568.6	77	52	12	7		512	17	2	0.31	3.00	427
4	30	57	2	4	629.1	109	53	9	4		500	26	38	0.29	1.60	491
16	20	57	5	4	582.0	107	38	18	2		520	29	6	0.36	5.00	457
13	26	57	5	4	635.1	147	58	24	6		573	32	30	0.28	0.10	719
13	18	57	8	4	543.7	32	41	30	4	4	268	116	2	0.10	3.00	400
13	23	57	9	4	586.4	83	35	223	4		688	280	4	0.22	0.08	968
5	34	57	9	4	623.0	165	78	100	7		730	170	2	0.32	0.50	882
4	7	57	10	4	591.6	152	55	259	4		707	607	12	0.21	1.82	1437
4	14	57	10	4	584.3	184	73	70			695	321	4	0.29	4.11	1092
4	25	57	10	4	594.8	132	62	128	5		793	193	2	0.21	0.31	912
1	29	57	10	4	585.5	80	37	271	4	5	673	411	22	0.25	0.23	1161
12	26	57	11	4	620.3	136	71	60			267	304	2	0.30	7.14	854
1	2	57	12	4	602.0	91	34	13	4		427	90	1	0.14	2.98	444
13	6	57	12	4	624.8	94	36	8	4		507	15	1	0.32	0.70	408
16	32	57	16	4	582.6	290	84	313	7		584	1192	20	0.06		2404
4	6	58	8	4	633.4	368	132	131	9		695	1097	1	0.18	2.41	2081
4	7	58	8	4	589.9	196	80	110	7	40	463	750	2	0.20	3.15	1413
16	7	58	8	4	604.7	177	77	131	8		421	677	1	0.33	0.30	1281
13	20	58	8	4	612.3	250	94	212	8		722	935	4	1.23	3.17	1860
4	6	58	9	4	531.0	18	7	406	1	9	654	106	236	0.42	1.10	1106
13	6	58	9	4	615.3	490	118	155	4		705	1225	4	0.32	6.20	2323
4	15	58	9	4	567.3	29	14	352	3		804	206	63	0.38	1.00	1062
16	21	58	9	4	634.9	414	244	93	13		1151	1144	4	0.25	13.40	2497
13	24	58	9	4	583.2	197	73	202	5		465	793	21	0.14	3.82	1521
4	25	58	9	4	590.5	173	94	245	7		644	897	13	0.16	10.50	1747
13	26	58	9	4	583.5	61	83	354	2		644	676	7	0.10	0.31	1502

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS,
QUATERNARY, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
LSD	SEC	TP	R	M	(m)											
16	32	58	9	4	596.0	108	71	122	4		322	430	4	0.25	0.02	898
4	8	58	10	4	620.1	48	50	50	4	5	337	182	1	0.18	2.44	503
16	15	58	10	4	612.8	312	117	129	5		745	851	2	0.19	5.06	1784
13	25	58	10	4	600.1	173	55	175	5		615	459	5	0.33	1.00	1180
13	36	58	10	4	598.2	74	128	169	7		398	784	2	0.15	3.18	1362
4	2	58	11	4	614.5	133	63	32	4		675	108	4	0.30	2.80	677
1	14	58	11	4	607.2	7	49	106	7	58	203	190	5	0.20	0.04	522
16	14	58	11	4	593.6	191	75	120	5		727	527	1	0.20	1.36	1277
16	22	58	11	4	567.7	43	15	288	2		592	187	39	0.25	0.54	846
1	28	58	11	4	610.2	74	50	14	3		432	38	11	0.71	0.22	425
13	32	58	11	4	540.0	243	83	13	5		581	484	4	0.22	0.70	1124
16	32	58	14	4	635.1	84	34	9	2		401	13	1	0.36	0.07	344
4	33	58	14	4	630.9	75	25	20	3	5	420	25	1	0.25	0.02	359
8	15	58	17	4	557.0	78	27	33	6		368	17	2	0.20	0.02	306
4	3	59	9	4	644.8	486	14	78	7		868	652	1	0.11	0.25	1660
16	6	59	9	4	623.8	121	48	16	4		504	98	2	0.25	0.18	544
16	7	59	9	4	617.2	128	53	36	7		588	148	1	0.20	0.22	664
3	17	59	9	4	500.5	92	65	210	6		576	484	20	0.20		1048
13	23	59	9	4	542.8	195	69	110	4		672	410	29	0.22	2.34	1150
4	27	59	9	4	627.9	133	73	47	6		922	113	10	0.21	3.45	843
1	29	59	9	4	579.3	165	59	105	5		661	328	4	0.25	1.89	991
1	32	59	9	4	586.1	141	59	111	6		627	308	7	0.17	4.70	949
16	33	59	9	4	626.2	93	40	37	4		479	72	16	0.35	0.05	499
1	35	59	9	4	536.8	147	60	117	5		523	491	6	0.19	5.13	1083
1	2	59	10	4	593.0	24	8	625	6	38	911	771	45	0.43	0.80	1967
1	9	59	10	4	538.0	105	67	211	3		713	481	22	0.19	16.10	1241

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS,
QUATERNARY, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
LSD	SEC	TP	R	M	(m)											
12	11	59	10	4	597.7	68	33	25	3		449	21	1	0.26	1.89	373
13	11	59	10	4	564.8	167	64	148	5		617	519	3	0.18	1.81	1210
1	3	59	11	4	585.2	89	54	36	4		468	104	1	0.27	0.47	519
13	15	59	11	4	614.2	50	86	48	7		518	164	1	0.28	9.30	625
16	26	59	11	4	602.4	230	100	96	6		787	586	1	0.29	0.63	1407
16	31	59	11	4	614.6	479	17	77	7		607	857	9	0.31	0.40	1750
9	9	59	12	4	615.7	112	63	87	10		700	175	2	0.31	3.00	795
13	20	59	12	4	597.5	216	42	139	8		700	425	6	0.17	2.50	1187
13	32	59	12	4	644.3	104	35	11	2		465	21	2	22.00	0.46	408
1	1	59	13	4	604.9	16	13	228	1	5	596	134	1	0.21	0.42	690
1	22	59	13	4	596.6	103	53	159	5		1092	13	2	0.21	1.66	873
12	29	59	13	4	606.1	120	44	27	4		520	89	1	0.36	2.98	541
13	34	59	13	4	596.2	76	35	76			530	55	5	0.20	0.82	624
4	26	59	14	4	612.3	70	29	34	3		454	35	2	0.23	4.63	397
4	25	59	15	4	617.2	82	31	8	2		388	5	1	0.44	1.50	321
13	26	59	15	4	616.6	18	36	10	5	9	196	31	1	0.21	2.76	208
16	34	59	15	4	632.6	113	39	20	4		541	10	1	0.21	4.38	443
14	16	60	1	4	568.3	116	46	29	5		612	12	2	0.40	0.40	517
16	16	60	1	4	560.1	102	0	9	4		489	5	10	0.35	0.20	414
13	17	60	1	4	574.5	77	59	27	6		660	13	6	0.39	0.30	512
4	19	60	1	4	505.3	118	47	71	5		665	61	8	0.26	29.00	668
13	19	60	1	4	562.1	89	53	12	4		522	0	2	0.22	0.30	460
16	21	60	1	4	532.6	100	50	39	5		612	18	8	0.25	2.40	523
16	22	60	1	4	518.2	88	53	42	5		617	38	5	0.30	0.30	541
16	23	60	1	4	543.6	56	37	28	4		417	5	10	0.35	0.70	346
16	24	60	1	4	552.8	98	42	8	3		522	11	2	0.36	2.10	388

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS,
QUATERNARY, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
LSD	SEC	TP	R	M	(m)											
1	25	60	1	4	546.7	69	59	42	9		593	24	7	0.35	1.00	508
4	25	60	1	4	525.9	270	146	3	9		429	1437	51	0.30	0.70	2443
1	27	60	1	4	521.5	137	53	35	6		718	35	5	0.31	3.30	633
1	28	60	1	4	525.3	118	49	31	5		610	15	3	0.28	1.60	529
5	28	60	1	4	543.6	81	44	8	5		528	28	13	0.90	0.10	447
10	28	60	1	4	530.9	72	47	28	4		577	32	6	0.42	4.20	474
13	28	60	1	4	486.5	114	30	200	4		768	100	81	0.26	1.20	912
16	28	60	1	4	535.3	117	44	22	5		600	19	1	0.23	0.30	513
1	29	60	1	4	550.5	172	79	14	5		720	44	17	0.40	0.70	778
16	29	60	1	4	532.5	160	42	19	4		663	32	1	0.20	1.60	589
4	33	60	1	4	536.6	75	48	71	7		662	113	7	0.54	0.40	649
4	34	60	1	4	522.0	128	45	150	6		672	160	22	0.18	0.50	843
9	25	60	3	4	525.0	64	21	229	4	20	691	120	30	0.26	7.78	832
13	6	60	4	4	534.9	39	23	500	4	9	769	241	341	0.29	0.49	1536
1	19	60	4	4	539.2	65	35	5	4	10	395	19	2	0.20	0.09	341
13	27	60	4	4	521.2	93	47	196	5		796	120	56	0.24	0.32	939
1	26	60	6	4	579.7	198	73	146	3		893	333	2	0.23	0.55	1196
4	26	60	6	4	536.8	59	38	139	4		720	87	15	0.21	2.30	697
4	31	60	6	4	523.5	96	36	13	3		511	15	1	0.32	0.31	416
1	32	60	6	4	537.5	46	51	147	4		796	125	14	0.15	3.80	779
16	34	60	6	4	523.3	86	24	419	4	12	1029	348	103	0.20	0.05	1502
4	1	60	8	4	547.3	86	33	55	5		494	86	3	0.17	3.42	511
4	3	60	9	4	577.7	2	1	540	1		725	640	25	0.22	0.16	1566
1	6	60	9	4	585.5	171	62	114	5		697	370	10	0.17	5.72	1076
1	8	60	9	4	576.1	205	81	170	8		656	698	10	0.18	4.20	1494
13	28	60	9	4	592.1	178	95	277	4		351	983	30	0.20	7.31	1740

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS, QUATERNARY, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
LSD	SEC	TP	R	M	(m)											
13	30	60	9	4	541.5	26	5	515	1		684	200	369	0.32	0.40	1459
16	23	60	10	4	558.5	97	33	379	4		645	613	46	0.28	1.30	1496
4	24	60	10	4	614.8	98	40	64	6		512	145	1	0.29	3.56	606
4	36	60	10	4	545.3	31	10	542	3	36	751	76	454	0.25	0.37	1523
4	8	60	11	4	636.6	143	80	21	5		605	75	51	0.38	0.10	711
9	9	60	11	4	621.0	228	115	65	9		812	489	55	0.30	0.57	1367
13	12	60	14	4	629.1	195	74	78	5		771	378	1	0.43	1.57	1111
1	31	60	16	4	656.8	122	44	7	4		643	20	32	0.11	1.04	563
1	7	60	17	4	595.9	42	18	220	2		601	154	3	0.12	0.46	735
1	17	61	4	4	523.6	89	43	207	4		654	212	122	0.34	0.25	999
13	26	61	4	4	529.1	128	48	210	8		674	346	85	0.22	2.77	1158
13	18	61	5	4	534.0	120	64	50	5		608	141	4	0.34	0.05	695
1	23	61	5	4	530.5	257	108	260	7		619	947	115	0.24	2.00	2000
4	4	61	6	4	511.1	30	48	392	5		903	562	34	0.18	0.43	1517
13	27	61	6	4	503.5	121	40	124	5		722	200	1	0.15	3.68	847
1	28	61	6	4	505.7	168	59	99	5		751	275	1	0.16	3.20	977
4	10	61	8	4	558.7	21	60	145	3	6	452	288	4	0.25	3.11	751
13	25	61	8	4	518.5	65	21	944	5		685	1396	267	0.19	0.86	3035
13	28	61	8	4	557.8	159	65	98	0		597	450	14	0.26	3.36	1085
16	3	61	9	4	574.2	211	69	221	4		863	420	105	0.20	2.50	1455
16	4	61	9	4	580.2	185	91	185	7		922	458	45	0.31	1.40	1432
16	6	61	9	4	623.8	19	63	28	3		381	124	1	0.50	0.47	427
4	17	61	9	4	577.5	140	55	107	3		674	244	6	0.17	3.80	896
16	9	61	10	4	549.9	45	20	394	3		659	323	115	0.30	4.19	1225
5	11	61	10	4	540.7	33	13	531	4		729	206	312	0.23	1.88	1458
16	29	61	10	4	592.1	126	57	49	3		345	272	57	0.16	3.85	735

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS, QUATERNARY, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
LSD	SEC	TP	R	M	(m)											
4	13	61	12	4	595.7	115	61	38	9		634	174	4	0.29	0.27	713
4	3	61	17	4	634.6	146	42	21	4		662	<10	<1	0.24	0.10	556
13	30	62	1	4	524.3	146	64	16	4		568	<122	<1	0.27	1.91	634
13	13	62	2	4	518.2	78	51	23	3		429	<94	<2	0.20	2.60	478
16	13	62	2	4	509.6	114	47	49	5		587	<102	<1	0.18	1.20	608
4	27	62	2	4	510.8	84	26	544	4	21	590	676	148	0.10	3.10	1852
15	3	62	5	4	532.3	113	55	33	5		713	30	1	0.30	0.35	589
12	27	62	6	4	494.4	106	42	60	5		616	36	4	0.12	1.27	557
5	33	62	6	4	513.4	281	89	411	6		520	597	654	0.22	0.10	2294
1	21	62	7	4	553.7	113	38	10	2		504	15	1	0.23	5.25	428
16	21	62	7	4	543.0	53	27	12	2	13	303	15	1	0.20	3.81	272
13	7	62	8	4	496.5	143	59	148	3		705	366	23	0.11	6.30	1089
4	28	62	8	4	502.5	99	47	14	2		534	50	3	0.31	2.29	478
4	1	62	9	4	537.4	184	65	640	5		613	960	400		1.70	2550
1	8	62	9	4	605.8	57	24	18	3		190	125	1	0.32	5.54	322
16	4	62	10	4	548.3	100	54	397	4		671	203	474	0.19	1.01	1563
1	19	62	10	4	569.5	283	105	267	5		592	1000	93	0.25	1.56	2045
13	12	62	12	4	632.6	148	60	81	4		705	241	30	0.31	0.03	912
1	14	62	12	4	617.4	132	53	143	6		752	320	7	0.26	0.02	1040
13	34	62	14	4	570.1	124	49	95	4		706	130	3	0.32	2.08	754
4	7	63	1	4	486.9	85	28	203	7		551	281	64	0.23	1.00	939
16	15	63	1	4	453.2	20	7	246	3	7	556	60	67	0.20	0.06	687
2	19	63	1	4	467.4	72	28	489	5		567	5	586	0.30	1.72	1444
3	19	63	1	4	452.6	16		276	1		576	58	85	0.21	0.40	1015
4	19	63	1	4	466.6	9	5	261	2		543	54	77	0.32	0.33	695
5	20	63	1	4	459.3	16		269	2		593	38	78	0.23	7.00	1000

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS, QUATERNARY, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
13	20	63	1	4	466.3	55	19	215	4		528	135	92	0.26	1.17	781
13	20	63	1	4	499.6	126		276	5		720	336	42	0.13	5.40	1510
13	20	63	1	4	499.6	58		223	4		492	120	103	0.21	16.50	1020
14	20	63	1	4	468.9	48	18	226	4		620	78	87	0.18	1.54	768
16	20	63	1	4	474.7	57	19	193	4		680	105	55	0.23	0.29	720
1	29	63	1	4	504.1	93		225	5		472	91	69	0.22	5.90	960
1	29	63	1	4	502.5	52	18	212	5		473	200	62	0.28	1.46	800
1	3	63	2	4	504.1	36	23	293	4		547	322	2	0.30		902
1	20	63	2	4	488.3	339	124	417	8		655	1385	109	0.20	7.60	2705
13	8	63	3	4	499.9	27	31	604	6	<5	663	846	134	0.20		1978
4	4	63	4	4	535.8	34	41	12	3	13	263	<5	<1		1.48	238
4	19	63	4	4	520.0	131	49	60	7		646	118	13	0.24	16.10	702
13	32	63	4	4	499.9	114	38	212	5		632	3	106	0.35	4.00	1158
16	32	63	4	4	509.9	62	22	117	4	8	582	<5	42	0.18		548
13	2	63	5	4	539.5	108	47	12	3		483	<21	3	0.23	0.15	433
15	3	63	5	4	531.6	119	54	14	5		606	<49	2	0.27	0.09	542
13	9	63	5	4	533.4	87	39	13	11		515	<4	2	0.42	2.00	411
4	16	63	5	4	533.4	92	45	13	9		521	<16	3	0.43	12.21	435
4	33	63	5	4	531.9	135	45	29	5		706	<25	1	0.26	0.38	588
1	7	63	6	4	537.4	7	2	270	3	9	597	<72	4	0.24		662
13	8	63	6	4	534.3	1	1	458	9		741	<375	20	0.19		1248
16	13	63	6	4	534.2	5	1	282	3		663	<104	13	0.27	0.70	735
16	15	63	6	4	559.0	98	50	15	4		547	<52	1	0.20	0.63	490
1	29	63	6	4	514.5	26	10	286	2		579	<100	98	0.26	0.60	811
16	12	63	7	4	559.5	77	90	21	4		592	31	28	0.64	0.10	667
4	16	63	7	4	505.1	104	34	113	6		699	98	2	0.18	7.80	700

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS, QUATERNARY, COLD LAKE STUDY AREA

LOCATION					ELEVATION	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
LSD	SEC	TP	R	M	(m)											
3	26	63	7	4	506.3	106	34	97	6		658	87	6	0.18	3.29	661
6	26	63	7	4	544.8	118	43	60	3		653	74	2	0.31	0.51	622
16	26	63	7	4	509.8	9	17	314	2	28	493	303	14	0.20	1.10	980
1	31	63	7	4	542.5	113	33	81	2		648	95	2	0.21	6.99	646
4	13	63	8	4	470.5	109	42	28	5	12	635	5	1	0.18		515
1	3	63	9	4	532.8	74	32	315	4	<5	506	140	323	0.21	0.34	1138
13	19	63	10	4	537.4	64	25	396	3		417	232	392	0.21	0.28	1318
4	31	63	10	4	537.5	7	35	143	4	21	451	27	26	0.20	2.90	464
16	14	63	11	4	519.7	119	33	274			690	5	325	0.24	0.71	1170
16	33	63	11	4	548.0	188	68	219			635	656	16	0.11	6.50	1514
16	36	63	11	4	515.3	83	45	21	5		503	45	4	0.20	9.00	454
16	36	63	11	4	515.3	146	40	175	3		976	23	37	0.20	3.21	905
13	4	63	14	4	562.2	102	82	61	4	12	366	332	18	0.23	1.14	812
4	19	63	14	4	548.2	50	28	12	4		233	20	29	0.18	0.40	261
4	14	63	15	4	567.4	88	58	31	4		643	10	1		0.20	506
13	15	63	15	4	572.7	83	70	30	4	23	508	38	45	0.71	0.20	551
1	23	63	15	4	569.5	102	49	11	6		591	30	5	0.10	0.10	499
4	17	64	5	4	540.3	121	39	105	5		806	46	4	0.17	4.50	718
13	15	64	7	4	566.0	96	42	15	3		534	15	2	0.21	0.96	437
16	32	64	7	4	566.0	61	24	384	4	<5	744	300	152	0.22	1.98	1293
4	17	64	10	4	513.3	62	27	183	5		510	107	85	0.19	20.70	744
1	19	64	10	4	514.5	82	45	112	5		698	104	6	0.20	2.71	699
4	28	64	14	4	610.7	126	36	10	2		467	80	14	0.38	0.11	498

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS,
QUATERNARY, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
13	32	64	15	4	568.8	92	33	46	5		480	72	4	0.33	0.70	493
16	19	64	16	4	600.6	95	45	164	6		628	221	31	0.17	2.80	879
1	30	64	16	4	591.0	68	46	338	5		549	450	145	0.28	1.90	1328
13	30	64	16	4	576.1	216	69	313	6		637	742	73	0.19	1.10	1735
13	30	64	16	4	595.4	39	59	299	6		570	336	129	0.25	5.70	1158
16	30	64	16	4	593.9	115	47	342	5		495	300	160	0.30	1.50	1605
4	32	64	16	4	584.3	195	70	192	5		772	578	53	0.35	2.10	1480
13	22	64	17	4	580.5	33	63	212	4		414	443	8	0.17	1.00	973
13	22	64	17	4	578.1	96	71	233	5		615	416	11	0.28	4.50	1143
16	22	64	17	4	574.4	71	118	191	4		723	450	19	0.23	7.20	1220
1	25	64	17	4	592.8	112	48	141	9		519	329	22	0.21	1.80	923
16	25	64	17	4	603.2	106	57	57	5		669	105	2	0.23	12.00	677
13	26	64	17	4	595.6	123	78	169	5		642	449	14	0.25	6.70	1158
16	26	64	17	4	601.5	115	48	76	4		594	197	6	0.26	0.10	743
16	26	64	17	4	601.2	128	56	53	7		598	222	8	0.29	1.20	775
16	26	64	17	4	596.8	19	5	12	20		114	24	16	0.22	0.40	154
13	27	64	17	4	585.4	2	133	114	6		702	290	12	0.17	2.90	910
16	27	64	17	4	598.5	93	38	11	2		492	0	8	0.37	1.80	404
16	27	64	17	4	574.2	219	29	200	4		727	388	8	0.17	3.00	1212
16	27	64	17	4	594.1	34	61	104	8		482	188	2	0.18	23.02	635
1	28	64	17	4	615.1	164	79	92	5		642	383	7	0.28	3.00	1055
1	33	64	17	4	603.5	31	13	8	2		168	13	1	0.27	0.50	154
1	34	64	17	4	588.3	13	42	94	4		370	93	11	0.19	0.50	443
4	34	64	17	4	593.8	137	58	106	5		681	130	43	0.31	3.30	822
16	34	64	17	4	600.2	34	42	15	3		343	17	1	0.12	0.50	285
1	35	64	17	4	588.9	140	57	107	4		639	253	9	0.28	7.90	897

CHEMICAL COMPOSITION (mg/L) OF FORMATION WATERS,
QUATERNARY, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	ELEVATION (m)	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Fl	Fe	TDS
16	35	64	17	4	576.1	140	61	154	4		721	320	13	0.26	5.40	1060
16	35	64	17	4	581.2	68	44	82	4		413	182	6	0.16	2.00	596
4	36	64	17	4	579.9	66	46	71	3		483	108	5	0.19	2.60	544
13	36	64	17	4	558.1	107	64	259	4		645	483	23	0.26	6.70	1269
11	34	65	7	4	577.6	47	43	80	6		471	58	6	0.20		442
16	17	65	11	4	537.2	187	80	130	5		734	558	2	0.16	5.46	1323
16	5	65	12	4	526.8	187	90	165	3		783	731	14	0.15	11.55	1576
4	7	65	12	4	556.3	295	91	128	6		625	808	8	0.18	7.60	1645
4	7	65	16	4	578.4	56	65	241	5		855	193	69	0.33	0.75	1052
4	8	65	16	4	572.4	71	83	259	5		1077	191	40	0.27	0.48	1180
1	18	65	16	4	586.1	117	70	248	5		637	500	124	0.16	1.46	1379
16	19	65	16	4	610.8	84	106	48	6		675	185	3	0.27	1.30	764
13	33	66	15	4	525.9	60	24	325	3		659	244	124	0.10	1.30	1028
1	35	66	16	4	535.8	136	50	340	4		706	563	52	0.17	0.24	1493
13	19	67	16	4	551.1	78	45	96	4		478	227	14	0.20	6.67	699
13	20	67	16	4	499.6	34	12	245	3		538	181	58	0.31	9.70	798
13	23	67	16	4	539.6	133	7	406	3		611	267	536	0.24	0.50	1681
4	35	67	16	4	536.9	42	18	448	2		723	310	173	0.25	2.58	1349
13	24	67	17	4	559.3	123	39	302			598	467	105	0.30	1.10	1473
13	24	67	17	4	543.2	83	36	260			688	294	36	0.19	1.50	1141

Note: Only 277 chemical analyses (aquifer intervals of the wells are known) are listed in this table, although 320 were used to produce the main hydrochemical map. (Atlas maps P-c-1 to P-c-3).

Table P-h-1
HYDRAULIC HEADS IN THE EMPRESS FORMATION (UNIT 1) AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	32	55	12	4	585.2	558.7	562.4	560.8	577.6
14	35	56	3	4	494.1	492.3	493.8	492.3	519.7
12	26	56	5	4	518.2	504.4	506.0	504.4	518.2
16	27	56	5	4	519.7	517.2	518.8	517.2	522.4
13	34	56	5	4	522.7	520.6	522.1	520.6	529.7
13	34	56	12	4	567.5	545.6	549.6	545.6	587.0
13	36	58	12	4	527.9	526.7	527.9	526.7	607.5
4	15	58	17	4	578.5	551.7	554.1	552.9	568.8
14	19	58	17	4	587.7	566.6	567.8	566.6	571.5
3	24	58	17	4	578.5	556.0	559.3	558.1	563.9
13	35	58	17	4	566.6	564.5	565.7	564.5	575.2
13	36	58	17	4	566.6	559.9	565.4	563.9	573.3
1	30	59	8	4	534.3	527.0	529.4	528.2	572.1
3	17	59	9	4	504.4	496.5	499.3	495.9	584.6
1	9	59	10	4	547.1	532.5	535.5	532.8	594.1
4	21	59	15	4	535.2	521.5	525.5	523.6	553.8
4	32	60	6	4	506.3	500.5	503.2	500.5	527.3
16	17	60	7	4	518.2	513.0	515.4	514.2	529.7
16	26	60	7	4	505.4	496.8	498.7	496.8	530.7
15	30	60	7	4	504.7	493.8	498.0	496.5	534.6
9	2	60	8	4	518.8	502.6	511.5	509.9	538.0
4	18	60	8	4	519.4	512.7	513.9	512.7	566.9
1	26	60	8	4	494.8	489.9	489.7	488.2	543.1
1	26	60	8	4	506.9	491.2	494.6	493.4	544.1
1	26	60	8	4	508.8	483.6	485.3	483.8	543.7
4	4	61	6	4	512.7	509.6	512.7	509.6	539.5
16	5	61	6	4	506.6	504.7	506.3	505.1	530.4
16	6	61	6	4	488.0	485.9	487.7	486.2	538.6
4	7	61	6	4	502.6	493.8	495.9	494.7	539.5
13	7	61	6	4	497.7	495.3	496.5	495.3	522.7
16	7	61	6	4	503.2	499.3	502.0	500.8	534.0
2	8	61	6	4	503.2	500.2	502.3	501.1	533.7
3	9	61	6	4	483.7	474.6	475.8	474.6	527.3
5	10	61	6	4	509.6	507.8	509.6	508.4	530.0
1	15	61	6	4	509.6	505.7	506.9	505.7	539.5
4	16	61	6	4	506.6	499.9	501.1	499.9	531.6
4	17	61	6	4	502.9	480.4	485.2	484.0	542.5
9	26	61	7	4	494.7	492.6	493.8	492.6	544.1
1	27	61	8	4	483.1	464.5	469.1	467.9	543.2
16	4	62	5	4	495.3	490.1	494.1	493.2	528.5

HYDRAULIC HEADS IN THE EMPRESS FORMATION (UNIT 1) AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	19	62	5	4	487.1	461.8	474.3	472.7	526.7
5	19	62	5	4	485.5	461.8	474.3	469.7	526.7
6	19	62	5	4	485.2	466.3	472.7	471.5	526.7
6	19	62	5	4	488.0	470.9	475.2	471.5	526.4
13	29	62	5	4	482.8	466.0	467.3	465.7	523.3
4	28	62	8	4	504.4	500.5	502.0	500.5	515.7
16	33	62	14	4	517.2	514.2	515.4	514.2	545.0
1	11	63	5	4	488.3	485.2	486.5	485.5	538.3
6	4	63	8	4	570.0	570.0	480.1	476.7	531.6
6	13	63	8	4	471.2	466.3	470.9	467.9	542.5
6	13	63	8	4	472.1	468.8	471.8	468.8	543.5
13	17	63	14	4	484.6	481.6	484.0	482.8	568.5
1	2	64	7	4	525.8	495.9	499.0	497.7	550.8
12	24	65	2	4	461.8	453.8	456.3	453.5	562.7
4	26	65	4	4	617.2	617.2	456.0	451.4	588.9
4	26	65	4	4	451.4	440.4	449.9	444.4	596.2
8	34	66	14	4	492.3	489.5	491.3	490.1	537.4
14	35	66	14	4	477.3	476.4	477.6	476.4	550.8
13	4	67	12	4	490.7	489.5	490.7	489.5	559.3
4	5	67	12	4	523.0	514.8	516.6	515.1	550.5
16	7	67	12	4	487.7	481.6	486.5	485.2	515.1
6	15	67	13	4	478.8	474.9	476.7	475.5	550.8

Table P-h-2
HYDRAULIC HEADS IN THE EMPRESS FORMATION (UNIT 3) AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
1	17	58	8	4	584.3	577.3	578.8	577.6	641.9
3	6	58	9	4	531.6	530.4	531.3	530.4	623.9
5	7	58	9	4	548.0	547.4	548.0	547.4	623.6
12	7	58	9	4	540.1	532.2	537.7	536.4	612.6
16	7	58	9	4	552.0	548.0	551.4	550.2	622.7
5	8	58	9	4	544.1	542.5	543.8	542.5	623.9
8	12	58	9	4	577.6	576.1	577.3	576.1	639.5
4	15	58	9	4	568.1	566.6	567.8	566.6	628.2
9	18	58	9	4	566.0	559.3	561.7	559.3	623.0
13	24	58	9	4	583.7	582.8	583.7	583.1	620.9
3	25	58	9	4	601.1	581.9	581.6	580.3	619.7
1	12	58	10	4	541.0	533.7	536.4	535.2	625.8
4	25	58	10	4	566.6	562.1	566.6	564.2	633.7
16	23	58	11	4	567.5	566.3	567.8	566.3	626.7
4	23	59	9	4	545.3	540.4	544.4	541.3	590.1
6	32	60	6	4	520.0	515.7	517.9	516.3	523.0
16	33	60	6	4	520.0	517.9	519.1	517.9	530.4
16	33	60	6	4	515.7	513.6	515.4	514.2	528.8
15	34	60	6	4	524.3	522.4	523.6	522.4	553.5
4	27	61	4	4	497.4	480.7	482.2	480.7	544.4
3	28	61	4	4	473.4	465.4	470.6	466.0	530.7
3	28	61	4	4	470.6	461.5	469.4	461.8	526.4
3	28	61	4	4	473.4	464.8	467.0	465.7	530.7
9	29	61	4	4	475.2	470.9	472.1	470.9	533.1
8	32	61	5	4	498.9	482.5	498.9	494.1	539.7
3	13	61	6	4	512.1	493.5	495.0	493.5	549.6
3	3	62	4	4	512.1	509.0	510.8	509.3	551.7
9	21	62	5	4	508.4	498.0	500.8	499.6	509.0
13	25	63	3	4	443.5	437.4	443.5	437.4	531.9
8	36	63	3	4	515.7	507.8	509.9	509.0	541.3
5	33	63	4	4	477.6	474.6	475.5	474.6	542.2
13	7	63	5	4	488.6	487.1	488.0	487.1	560.8
4	26	63	5	4	482.8	471.8	480.1	478.5	572.7
16	26	63	7	4	500.8	492.3	497.7	496.5	559.3
4	17	64	5	4	534.6	531.9	533.1	531.9	563.6
12	19	65	1	4	505.7	491.3	523.3	485.2	537.1
13	19	65	1	4	512.4	489.2	530.7	477.0	543.5
8	3	65	2	4	515.7	504.7	506.9	505.4	533.4
16	6	65	2	4	511.1	508.4	510.5	509.3	552.3
16	16	65	2	4	483.4	468.5	475.5	474.3	534.0

HYDRAULIC HEADS IN THE EMPRESS FORMATION (UNIT 3) AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	23	65	2	4	499.6	489.5	495.6	487.7	541.6
10	24	65	2	4	510.2	489.8	491.0	489.8	543.2
10	24	65	2	4	503.8	489.5	498.3	489.2	545.6
10	24	65	2	4	508.1	488.3	500.5	488.9	543.8
10	24	65	2	4	510.2	489.8	491.0	489.8	543.8
10	24	65	2	4	508.1	488.3	500.8	488.9	543.8
10	24	65	2	4	508.1	488.3	500.5	488.9	543.8
13	9	65	13	4	527.3	525.2	526.4	525.2	566.9
16	15	65	13	4	532.2	525.8	527.0	525.8	558.7
1	16	65	13	4	519.1	512.7	513.9	512.7	577.9
16	30	67	14	4	477.9	470.0	473.0	471.5	536.1
4	23	68	13	4	541.6	536.4	539.2	538.0	559.9

Table P-h-3
HYDRAULIC HEADS IN THE BRONSON LAKE (UNIT 2) FORMATION AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
11	33	56	2	4	559.0	548.6	555.0	553.2	595.3
4	4	56	3	4	537.1	531.3	534.0	531.3	567.8
4	4	56	3	4	538.0	533.1	535.5	534.3	571.2
4	5	56	3	4	541.0	536.4	538.9	537.7	563.6
13	23	56	4	4	527.9	526.1	527.9	524.9	576.1
13	23	56	4	4	524.9	523.0	524.9	521.8	573.0
4	25	56	12	4	582.2	571.8	574.5	573.0	591.0
1	26	56	12	4	578.5	570.6	573.0	571.5	590.1
12	23	57	9	4	589.8	583.1	586.7	583.7	646.5
1	29	57	10	4	586.7	584.3	585.5	584.3	631.2
10	23	57	12	4	549.9	546.8	548.9	547.4	592.5
13	31	57	12	4	583.7	558.7	581.6	580.0	638.3
13	21	58	8	4	573.3	565.7	568.1	566.9	638.3
13	21	58	8	4	573.0	565.7	568.1	566.9	639.5
13	28	58	8	4	559.6	553.5	555.0	553.5	606.9
1	31	58	9	4	562.4	555.0	556.9	555.7	597.7
5	12	58	10	4	562.4	556.3	559.3	556.3	632.2
1	7	58	11	4	570.9	564.2	566.9	565.4	593.4
14	32	58	11	4	542.5	537.4	539.8	538.6	601.4
4	27	59	12	4	550.5	539.2	540.7	539.2	615.7
4	1	60	8	4	543.5	542.5	545.9	545.0	553.5
4	30	60	9	4	552.9	549.2	550.5	549.2	595.9
12	16	60	17	4	641.3	639.8	641.3	640.1	648.6
13	20	61	5	4	515.7	513.9	515.1	513.9	527.3
4	17	61	6	4	520.6	517.9	519.7	518.5	535.5
5	24	62	5	4	499.6	495.9	498.0	496.5	522.7
4	25	62	5	4	499.9	496.2	497.4	496.2	511.8
13	2	62	6	4	499.9	497.7	499.3	497.7	538.0
13	8	62	6	4	511.5	510.2	511.5	510.2	548.6
1	18	62	6	4	517.2	514.2	516.6	515.4	538.0
5	33	62	6	4	514.5	512.4	513.9	512.7	540.1
13	33	62	6	4	535.2	529.1	531.3	529.7	548.6
13	7	62	8	4	497.4	495.6	497.1	495.6	518.2
9	30	62	8	4	524.0	521.5	523.0	521.5	527.9
4	31	62	8	4	503.8	492.3	495.3	493.8	526.7
16	17	63	1	4	462.1	444.4	452.6	451.1	524.3
2	19	63	1	4	469.4	468.2	468.2	466.6	524.6
13	20	63	1	4	470.9	461.8	470.9	461.8	514.8
9	13	63	6	4	518.2	506.0	511.1	509.9	530.4
1	29	63	6	4	516.0	513.0	514.2	513.0	562.4

HYDRAULIC HEADS IN THE BRONSON LAKE (UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	16	63	7	4	509.9	500.2	505.4	503.8	553.2
5	26	63	7	4	509.6	502.9	507.2	505.7	563.3
7	5	63	8	4	499.9	491.6	494.1	492.6	513.6
16	32	63	8	4	502.9	499.9	501.7	500.2	544.1
16	14	63	11	4	520.6	518.8	520.0	518.8	553.2
9	36	63	11	4	516.3	514.2	515.7	514.2	568.5
4	1	64	7	4	513.9	510.8	513.3	511.8	550.5
13	5	65	3	4	515.7	503.5	513.6	509.9	595.9
16	7	65	11	4	516.6	513.9	515.4	513.9	574.5

Table P-h-4
HYDRAULIC HEADS IN THE MURIEL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	28	55	3	4	528.8	516.9	520.9	519.4	570.9
5	16	56	3	4	545.6	541.0	543.5	541.9	567.5
16	15	56	4	4	544.4	538.6	544.1	538.6	571.5
9	23	56	9	4	569.4	563.3	565.1	563.9	582.8
13	32	56	11	4	587.0	577.6	586.1	584.6	605.9
9	15	56	12	4	577.9	559.0	561.7	560.2	579.7
3	30	57	2	4	582.2	580.6	581.6	580.4	590.4
13	4	57	3	4	563.9	554.1	557.5	556.0	592.2
13	3	57	9	4	624.5	615.7	617.2	615.7	633.4
12	5	57	9	4	616.3	614.8	616.3	614.8	627.9
4	10	57	9	4	613.3	610.2	613.0	611.4	619.0
4	10	57	9	4	609.3	606.6	608.1	606.6	611.1
16	16	57	9	4	606.6	595.0	596.5	595.0	637.0
4	5	57	10	4	596.5	596.2	596.5	595.0	624.8
4	12	58	11	4	580.0	578.2	579.1	578.2	630.9
10	17	59	4	4	559.6	548.6	553.8	551.7	627.6
10	32	59	4	4	533.1	527.3	529.4	527.9	583.4
16	24	59	5	4	545.6	542.5	543.8	542.2	573.0
1	36	59	5	4	523.6	520.9	524.0	520.9	582.2
5	21	59	6	4	574.9	573.0	574.5	571.5	575.5
16	34	59	7	4	556.3	547.1	548.6	547.1	585.2
13	4	59	8	4	552.6	549.9	551.4	550.2	598.3
4	28	59	8	4	539.8	533.4	534.9	533.4	577.0
4	14	59	9	4	567.5	563.3	564.8	563.3	585.8
8	35	59	9	4	542.2	531.3	533.1	531.9	579.4
1	5	59	10	4	568.1	565.4	566.9	565.4	583.7
16	23	60	1	4	502.6	489.2	491.9	490.7	546.5
12	25	60	1	4	512.4	508.4	509.6	508.4	554.4
11	26	60	1	4	499.0	492.3	494.7	493.5	513.6
10	28	60	1	4	510.5	506.0	510.2	507.8	556.6
12	28	60	1	4	516.6	513.6	515.1	513.9	547.1
12	31	60	1	4	507.5	501.4	506.3	505.1	537.4
6	28	60	3	4	514.8	507.8	509.0	507.8	562.7
11	6	60	4	4	535.8	533.4	534.6	533.4	563.9
8	19	60	4	4	542.5	535.8	538.0	536.4	563.3
14	19	60	4	4	538.9	535.8	537.4	536.1	561.4
5	20	60	4	4	544.7	533.4	537.1	535.8	562.7
13	27	60	4	4	522.7	519.7	522.4	520.9	566.9
11	34	60	4	4	527.9	526.1	527.9	526.4	562.7
8	20	60	5	4	544.4	536.4	540.7	539.2	562.1

HYDRAULIC HEADS IN THE MURIEL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
7	21	60	5	4	546.8	545.6	546.8	545.6	572.4
13	21	60	5	4	549.9	545.3	547.7	546.5	570.0
16	22	60	5	4	546.5	544.1	545.6	544.1	554.7
1	26	60	5	4	495.6	492.6	493.8	492.6	531.3
12	28	60	5	4	537.7	533.7	537.1	535.8	560.5
15	33	60	5	4	528.5	521.8	525.5	524.0	562.4
12	9	60	6	4	546.5	543.8	545.9	544.7	557.5
1	13	60	6	4	540.1	538.3	540.1	538.9	561.4
1	13	60	6	4	540.7	530.0	532.2	531.0	562.1
16	18	60	6	4	538.9	531.0	533.1	531.6	560.8
4	26	60	6	4	537.4	536.4	537.1	536.4	563.9
5	26	60	6	4	535.5	534.6	535.5	534.9	562.4
12	29	60	6	4	517.6	516.3	517.6	516.3	528.5
4	31	60	6	4	525.2	521.8	525.8	521.8	529.4
16	10	60	7	4	544.1	542.2	543.2	541.9	577.6
1	13	60	7	4	542.2	538.6	540.1	538.9	574.5
4	16	60	7	4	538.6	534.3	535.8	534.6	557.5
1	17	60	7	4	536.4	530.4	531.9	530.7	555.7
16	17	60	7	4	525.5	516.6	517.9	516.6	535.8
4	7	60	8	4	545.3	538.6	543.5	542.2	576.4
5	7	60	8	4	546.5	530.7	536.8	535.5	577.0
4	8	60	8	4	541.6	537.4	539.5	538.3	567.5
13	8	60	8	4	541.3	532.2	540.4	538.9	571.2
13	8	60	8	4	541.0	534.9	538.0	536.4	570.6
13	16	60	8	4	548.6	526.4	540.7	539.5	570.9
4	17	60	8	4	541.3	538.0	541.3	538.0	571.5
16	20	60	8	4	536.1	530.7	535.5	532.5	571.5
1	26	60	8	4	548.2	543.9	545.6	544.1	567.6
1	26	60	8	4	529.7	520.2	526.9	524.2	563.2
1	27	60	8	4	535.5	520.6	525.8	524.6	563.9
13	28	60	8	4	559.3	556.3	557.8	556.3	594.1
3	1	60	9	4	556.3	538.0	552.3	551.1	577.9
9	1	60	9	4	557.5	544.1	549.9	548.3	580.3
4	2	60	9	4	548.3	534.6	539.8	537.1	592.8
9	3	60	9	4	555.7	530.7	550.2	548.9	588.3
9	4	60	9	4	550.5	535.8	548.6	547.4	588.0
12	10	60	9	4	547.7	525.8	527.6	526.1	587.7
1	12	60	9	4	554.1	538.0	541.0	539.8	580.9
1	12	60	9	4	563.0	531.0	537.7	536.1	576.1
1	20	60	9	4	545.0	542.8	544.4	543.2	589.8

HYDRAULIC HEADS IN THE MURIEL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
13	24	60	9	4	543.2	538.6	541.6	540.4	567.8
4	21	60	17	4	648.3	641.6	647.4	645.9	653.2
14	15	61	1	4	493.8	481.6	483.7	482.2	493.8
8	23	61	1	4	495.3	482.8	485.2	483.7	516.6
5	11	61	2	4	514.2	509.6	511.1	509.9	548.6
3	28	61	4	4	514.8	485.5	489.2	486.5	544.1
4	28	61	4	4	508.7	503.5	509.0	506.0	546.5
4	28	61	4	4	509.9	486.2	509.9	506.9	548.6
13	30	61	4	4	506.6	490.7	503.2	502.0	538.3
13	30	61	4	4	509.9	508.1	509.3	508.1	538.0
13	30	61	4	4	509.9	508.1	509.3	508.1	538.0
8	32	61	4	4	505.1	489.2	501.1	499.9	546.2
2	1	61	5	4	552.3	546.5	548.0	546.5	554.1
16	9	61	5	4	533.4	529.4	530.7	529.1	551.1
13	18	61	5	4	534.6	531.6	534.6	533.4	549.9
13	20	61	5	4	519.7	513.9	517.6	516.3	543.8
8	23	61	5	4	531.3	529.7	531.0	529.7	548.0
2	24	61	5	4	501.1	498.0	501.1	498.0	530.4
16	25	61	5	4	510.2	508.1	510.2	508.7	539.2
8	27	61	5	4	526.4	525.2	526.7	525.2	547.4
12	31	61	5	4	516.0	509.0	516.3	513.3	544.7
3	35	61	5	4	506.6	504.7	506.0	504.7	529.1
8	35	61	5	4	504.7	501.1	503.8	501.4	531.0
4	36	61	5	4	509.6	506.0	507.5	506.0	527.3
1	3	61	6	4	531.0	529.7	531.0	529.7	560.5
1	5	61	6	4	521.2	518.2	520.9	519.4	533.7
1	5	61	6	4	514.5	511.8	514.2	513.0	538.9
7	5	61	6	4	522.1	519.4	521.8	520.3	540.7
13	5	61	6	4	510.2	505.1	508.1	506.6	530.0
13	5	61	6	4	507.8	504.7	507.8	506.3	524.3
16	5	61	6	4	510.8	508.7	510.5	509.3	529.1
16	5	61	6	4	521.5	518.2	520.3	519.1	539.5
3	7	61	6	4	516.6	510.8	513.0	510.8	536.4
14	7	61	6	4	520.9	518.2	520.6	519.1	530.4
14	7	61	6	4	511.5	510.8	512.1	510.5	530.7
14	7	61	6	4	486.2	475.2	477.0	445.0	522.7
2	9	61	6	4	519.7	513.0	516.0	514.5	533.4
3	10	61	6	4	518.8	506.0	518.5	506.0	537.4
3	19	61	6	4	517.9	512.7	514.2	513.0	539.5
5	19	61	6	4	519.1	511.8	513.0	511.8	544.1

HYDRAULIC HEADS IN THE MURIEL LAKE FORMATION AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
8	19	61	6	4	512.1	504.4	508.7	507.5	540.7
7	21	61	6	4	517.6	513.3	514.5	513.3	541.9
13	27	61	6	4	506.9	500.2	504.7	503.2	534.9
1	28	61	6	4	507.5	504.1	507.5	506.0	541.0
4	13	61	7	4	522.4	519.7	521.5	520.3	532.2
2	3	61	8	4	535.2	524.9	528.5	527.0	563.6
12	25	61	8	4	520.0	516.9	518.5	516.9	545.0
13	27	61	9	4	512.4	496.8	499.9	498.3	568.5
13	6	61	10	4	573.6	573.3	573.6	573.0	621.2
16	21	61	10	4	560.8	550.5	552.0	550.5	585.2
4	28	61	10	4	543.2	540.7	542.5	541.3	612.0
7	1	62	1	4	504.4	502.6	503.8	502.6	519.7
13	7	62	1	4	513.3	511.5	513.0	511.5	525.2
9	10	62	1	4	490.4	483.1	484.3	483.1	529.4
4	14	62	1	4	498.3	494.1	496.8	495.6	516.6
12	20	62	1	4	484.9	478.2	480.4	479.1	525.8
7	23	62	1	4	477.3	473.0	475.2	474.0	530.0
7	26	62	1	4	459.3	455.7	458.7	457.5	515.7
3	36	62	1	4	495.6	477.3	495.0	492.6	512.7
2	11	62	2	4	493.8	487.7	490.7	489.5	496.8
1	16	62	2	4	500.2	491.3	496.2	490.7	505.1
1	16	62	2	4	495.9	491.3	494.7	489.2	505.1
1	16	62	2	4	494.1	490.1	492.9	487.4	504.7
1	16	62	2	4	496.5	490.1	495.6	490.1	504.4
3	26	62	2	4	534.9	522.7	524.0	522.7	534.9
2	33	62	3	4	477.0	470.0	475.8	472.7	524.0
2	25	62	4	4	511.1	503.2	510.5	509.3	533.1
12	30	62	4	4	518.2	510.5	512.1	510.5	521.2
14	3	62	5	4	516.6	515.1	517.2	516.0	531.0
13	20	62	5	4	507.5	498.3	502.6	501.4	507.5
1	20	62	6	4	523.0	514.5	518.8	517.6	540.4
12	27	62	6	4	497.4	487.1	493.8	492.3	527.3
5	31	62	6	4	533.4	530.4	532.8	531.3	542.5
13	8	62	8	4	528.8	520.3	522.4	520.9	558.1
12	17	62	8	4	540.1	536.4	538.0	536.4	558.1
4	28	62	8	4	531.9	503.2	504.7	503.2	520.0
4	28	62	8	4	531.9	495.3	503.2	501.7	518.2
4	1	62	9	4	538.3	536.4	538.0	536.4	566.9
13	35	62	9	4	522.7	521.5	522.7	521.5	529.7
1	13	62	10	4	544.4	542.8	544.4	543.2	566.3

HYDRAULIC HEADS IN THE MURIEL LAKE FORMATION AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
7	7	63	1	4	488.0	481.3	483.7	482.5	534.6
14	20	63	1	4	477.0	466.3	470.0	467.0	520.3
16	20	63	1	4	480.1	467.9	475.5	474.0	522.7
9	7	63	2	4	501.7	500.5	501.7	500.5	521.2
7	16	63	2	4	480.1	471.8	479.1	474.6	531.0
7	16	63	2	4	480.7	474.6	477.6	474.6	531.9
1	20	63	2	4	488.9	487.7	488.9	487.7	537.7
11	21	63	2	4	498.0	492.9	496.2	493.2	540.7
13	8	63	3	4	502.0	497.7	502.0	501.4	521.5
16	32	63	4	4	513.3	506.6	507.8	506.6	561.7
14	24	63	6	4	510.8	509.3	510.5	509.3	547.7
12	8	63	7	4	516.6	510.5	512.1	510.5	551.1
13	14	63	7	4	517.6	516.3	517.9	516.3	551.7
16	26	63	7	4	515.1	504.4	507.2	505.7	569.7
16	34	63	7	4	513.0	504.4	506.6	505.1	561.7
6	4	63	8	4	570.0	570.0	514.2	509.6	530.4
7	4	63	8	4	517.9	508.1	512.7	508.1	529.4
16	32	63	8	4	518.2	507.5	509.0	507.8	538.0
8	14	63	9	4	517.6	507.2	508.7	507.2	518.2
1	6	63	10	4	542.8	541.3	542.8	541.3	548.9
13	19	63	10	4	541.9	532.8	538.6	537.4	556.9
5	30	63	10	4	538.6	537.1	538.3	537.1	545.3
4	31	63	10	4	545.3	529.7	531.3	530.0	568.5
13	13	63	11	4	531.9	530.4	531.9	530.4	558.7
4	24	63	11	4	543.5	540.7	542.8	541.6	552.9
9	36	63	11	4	531.9	528.2	529.4	528.2	570.0
4	28	64	2	4	526.7	522.7	526.1	524.6	538.0
13	30	64	3	4	527.0	504.1	526.7	521.5	596.8
8	31	64	3	4	520.6	504.4	511.5	506.9	597.7
1	5	64	4	4	526.7	507.5	526.7	507.5	553.2
5	6	64	5	4	496.5	493.5	497.4	495.9	562.4
15	8	64	5	4	527.9	524.3	526.1	524.9	543.2
16	32	64	8	4	547.1	536.4	538.0	536.8	566.9
5	5	64	10	4	531.3	520.3	525.5	524.3	589.8
4	17	64	10	4	524.9	501.7	505.1	503.8	582.2
8	19	64	10	4	523.6	505.4	516.6	515.4	559.6
7	22	64	11	4	527.9	514.5	520.3	518.8	559.9
4	27	64	11	4	516.6	504.7	515.7	509.6	560.5
13	27	64	11	4	519.7	502.6	505.7	504.4	557.5
8	3	65	2	4	520.3	509.3	511.5	509.9	537.7

HYDRAULIC HEADS IN THE MURIEL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	9	65	2	4	532.2	524.9	529.4	524.9	549.6
10	24	65	2	4	539.8	516.3	521.5	520.3	543.2
13	5	65	3	4	531.0	514.5	524.6	520.9	606.9
10	6	65	3	4	547.7	514.8	524.9	515.1	598.9
9	1	65	4	4	518.2	487.7	516.3	511.1	596.5
4	26	65	4	4	526.4	507.5	525.2	522.1	595.9
15	8	65	11	4	554.7	548.6	550.2	548.6	562.4
14	17	65	11	4	538.6	531.6	533.1	531.6	563.3
6	10	66	5	4	555.4	532.3	548.1	532.3	632.7
12	10	66	5	4	543.6	525.3	540.4	528.2	633.4
4	28	66	5	4	531.3	521.5	526.1	521.5	637.0
13	33	66	15	4	526.7	525.2	526.7	525.2	566.0
3	2	67	14	4	541.3	529.7	531.6	530.4	563.9
	23	67	14	4	527.3	518.2	524.3	518.2	550.2
1	30	67	14	4	517.6	508.4	510.5	509.3	540.7
2	31	67	14	4	512.7	509.0	511.5	510.2	538.9
2	4	67	15	4	532.2	530.7	531.9	530.7	569.4
9	19	67	15	4	529.1	527.0	528.2	527.0	550.5
16	21	67	15	4	513.6	507.5	511.1	509.6	544.1
1	25	67	15	4	521.2	519.7	521.2	519.7	546.5
12	27	67	15	4	515.1	510.5	512.7	511.1	545.3
13	34	67	15	4	517.9	515.1	516.9	515.4	552.3
14	20	67	16	4	502.3	499.9	500.8	499.9	547.1
13	34	67	16	4	538.9	518.2	520.6	519.4	552.9
4	35	67	16	4	539.2	534.6	535.2	534.6	564.2
12	3	68	16	4	530.4	524.3	528.8	525.8	548.6

Table P-h-5
HYDRAULIC HEADS IN THE BONNYVILLE (UNIT 1 AND UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
13	4	55	4	4	562.4	558.4	561.4	558.4	575.5
3	5	55	4	4	563.6	555.3	559.0	557.8	571.5
4	5	55	4	4	556.0	554.7	615.7	615.7	565.7
3	6	55	4	4	565.4	562.4	614.2	614.2	573.3
4	9	55	4	4	551.7	547.1	549.2	548.0	570.9
8	9	55	4	4	573.6	559.3	573.6	561.4	573.6
5	10	55	4	4	599.8	542.2	566.0	564.8	598.6
12	14	55	4	4	574.5	557.8	563.3	562.1	569.7
3	17	55	4	4	582.2	559.0	563.6	562.4	574.9
1	18	55	4	4	588.9	556.3	562.4	561.1	576.1
7	18	55	4	4	585.8	553.2	559.3	558.1	573.0
12	35	55	4	4	562.1	556.3	563.6	560.5	586.7
4	17	56	3	4	576.7	572.7	575.8	574.2	577.9
1	18	56	3	4	557.8	552.3	556.6	555.0	600.5
4	19	56	3	4	566.0	558.4	561.4	560.2	603.5
13	19	56	3	4	562.1	552.9	557.8	556.6	573.9
16	19	56	3	4	566.3	555.3	560.2	559.3	582.5
15	20	56	3	4	572.4	564.8	573.0	568.5	589.8
14	22	56	3	4	568.1	558.4	562.7	561.1	589.5
13	25	56	3	4	556.3	552.6	556.0	554.7	583.4
1	28	56	3	4	554.7	548.6	554.1	552.9	572.7
4	28	56	3	4	551.7	539.8	543.8	542.2	593.8
13	28	56	3	4	581.3	562.4	564.2	562.7	582.8
13	28	56	3	4	569.1	564.2	566.3	564.8	578.2
5	31	56	3	4	579.1	570.0	572.7	571.5	608.1
1	15	56	4	4	560.8	547.1	549.6	548.3	606.6
1	18	56	6	4	571.8	569.4	570.6	569.4	577.0
4	22	56	6	4	555.7	554.1	555.7	554.1	576.1
1	36	56	6	4	575.5	570.6	572.1	570.9	592.5
9	12	56	7	4	568.5	566.0	567.2	566.0	578.8
5	15	56	11	4	583.7	577.0	581.6	580.3	607.8
10	22	56	11	4	579.1	570.0	571.2	570.0	606.2
16	22	56	11	4	591.3	585.2	588.6	587.3	620.3
1	34	56	11	4	574.5	567.8	573.9	572.7	612.3
9	16	57	2	4	566.9	562.7	563.6	562.1	586.1
15	16	57	2	4	576.7	575.5	576.7	575.5	593.8
2	17	57	2	4	560.2	541.3	544.1	542.5	580.0
3	17	57	2	4	580.3	578.8	580.3	578.8	595.9
3	17	57	2	4	572.7	562.1	571.5	570.3	596.5
3	17	57	2	4	572.7	561.4	570.9	569.7	598.0

HYDRAULIC HEADS IN THE BONNYVILLE (UNIT 1 AND UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
3	17	57	2	4	581.3	575.2	577.3	576.1	601.1
6	17	57	2	4	588.9	586.4	588.3	586.7	598.6
11	17	57	2	4	589.8	575.8	589.2	587.7	599.5
14	19	57	2	4	572.7	564.5	569.4	568.1	594.4
3	20	57	2	4	586.4	584.0	586.1	585.2	595.3
9	4	57	3	4	570.0	558.7	564.2	562.7	598.0
1	6	57	3	4	581.6	577.6	581.3	579.7	593.1
6	9	57	3	4	575.5	565.4	574.2	572.7	599.8
6	16	57	3	4	585.5	575.8	579.4	577.9	595.3
9	16	57	3	4	577.9	566.9	575.2	573.6	596.5
13	16	57	3	4	578.8	573.6	576.1	574.5	598.0
6	12	57	4	4	570.0	562.4	567.5	566.0	613.6
4	32	57	5	4	611.1	608.1	611.1	608.1	631.9
1	33	57	5	4	612.6	603.2	606.6	605.3	631.2
11	2	57	7	4	609.6	606.2	607.8	606.6	618.7
14	23	57	7	4	649.2	642.5	647.4	646.2	657.8
5	24	57	7	4	648.3	647.1	648.6	647.1	656.2
13	6	57	8	4	614.5	612.3	613.9	612.3	624.8
3	22	57	8	4	635.5	628.5	630.6	629.4	646.8
15	32	57	8	4	596.5	594.4	595.9	594.7	637.0
13	34	57	8	4	623.0	622.7	623.3	622.7	644.0
8	16	57	9	4	620.6	594.4	605.9	604.7	638.9
13	20	57	9	4	594.4	592.8	594.1	592.8	628.8
4	7	57	10	4	592.8	590.4	591.9	590.4	613.6
4	16	57	10	4	607.5	606.2	607.5	606.2	624.2
9	17	57	10	4	603.5	602.0	603.5	602.0	633.7
9	17	57	10	4	604.4	596.8	598.6	597.1	630.6
8	19	57	10	4	615.7	612.6	615.1	613.9	630.6
6	25	57	10	4	595.9	593.8	595.9	592.8	634.6
13	25	57	10	4	594.1	588.0	589.5	588.0	638.9
5	2	57	11	4	607.8	604.1	605.3	604.1	623.0
9	2	57	11	4	613.0	602.3	604.7	603.5	624.5
14	18	57	11	4	602.9	600.5	602.6	601.4	613.0
4	20	57	11	4	602.6	601.1	602.9	601.4	617.8
15	20	57	11	4	603.5	599.2	601.1	599.5	618.4
4	27	57	11	4	601.4	596.5	598.3	596.8	626.1
1	2	57	12	4	607.8	584.6	585.8	584.6	612.3
4	35	57	12	4	576.1	567.2	570.0	566.9	604.7
16	35	57	12	4	579.1	576.4	578.8	577.3	614.5
4	34	57	13	4	644.7	642.2	644.0	642.8	647.7

HYDRAULIC HEADS IN THE BONNYVILLE (UNIT 1 AND UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
13	35	57	13	4	629.7	624.8	628.2	626.7	636.4
16	32	57	16	4	584.9	580.3	582.2	580.9	589.8
5	7	58	8	4	590.7	589.2	590.4	589.2	626.1
9	7	58	8	4	605.9	603.5	605.3	603.8	643.1
13	20	58	8	4	613.6	611.1	612.6	611.1	632.8
1	22	58	8	4	598.0	595.9	597.4	595.9	625.1
13	36	58	8	4	605.0	595.9	597.4	596.2	608.1
13	26	58	9	4	584.6	582.5	584.0	582.5	624.8
1	27	58	9	4	586.7	583.7	586.7	583.7	623.3
3	27	58	9	4	620.3	617.2	620.3	617.2	635.5
13	29	58	9	4	604.4	602.6	603.8	602.6	637.3
4	32	58	9	4	602.6	597.7	602.0	598.9	632.5
15	32	58	9	4	597.4	594.7	596.2	594.7	637.3
4	7	58	10	4	588.3	584.6	585.8	584.6	617.8
4	12	58	10	4	579.1	576.1	579.1	576.7	636.4
16	18	58	10	4	603.2	602.0	602.6	602.0	642.8
13	36	58	10	4	598.9	597.4	598.9	597.4	623.3
13	1	58	11	4	592.2	590.1	591.6	590.1	622.7
16	22	58	11	4	570.0	565.4	568.5	565.4	615.1
3	10	58	12	4	574.5	560.8	565.7	564.2	600.5
11	11	58	12	4	580.3	577.0	578.2	577.0	612.0
13	22	58	12	4	572.1	558.1	566.9	565.4	624.5
13	24	58	12	4	575.2	568.5	570.6	569.1	617.8
4	27	58	12	4	580.6	572.4	580.0	578.8	613.3
16	32	58	12	4	585.8	583.7	585.2	583.7	619.4
12	20	58	13	4	638.6	637.6	638.9	637.6	655.0
4	33	58	14	4	641.6	620.3	621.8	620.3	655.6
16	24	59	5	4	573.9	571.5	574.5	573.0	594.4
12	20	59	6	4	571.8	570.3	571.8	570.3	575.5
4	20	59	7	4	574.9	566.3	567.8	566.3	615.7
6	35	59	7	4	553.5	550.5	552.6	551.1	588.3
4	23	59	8	4	595.3	592.8	594.4	592.8	603.8
12	23	59	8	4	589.8	588.6	589.8	588.3	600.8
5	31	59	8	4	577.6	576.1	577.6	576.1	589.8
15	8	59	9	4	581.6	578.5	580.6	579.1	606.6
15	10	59	9	4	570.6	563.9	565.4	564.2	600.5
12	11	59	9	4	577.6	574.9	577.6	576.1	589.5
14	12	59	9	4	573.9	563.6	564.8	563.3	565.1
1	3	59	11	4	586.7	583.7	586.7	583.7	594.4
16	19	59	11	4	585.8	583.4	585.2	583.7	621.2

HYDRAULIC HEADS IN THE BONNYVILLE (UNIT 1 AND UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
12	25	59	11	4	594.4	589.5	590.7	589.5	611.1
3	28	59	11	4	583.1	581.9	583.1	581.9	616.9
8	35	59	11	4	594.4	592.8	595.9	592.8	605.0
3	4	59	12	4	587.3	579.1	580.6	579.1	613.6
11	5	59	12	4	590.4	587.7	589.2	587.7	623.9
4	4	59	13	4	595.9	592.8	595.3	594.1	631.2
4	27	59	14	4	603.5	586.7	588.9	587.3	617.5
16	2	59	17	4	576.1	569.4	571.2	570.0	577.0
1	22	59	17	4	573.0	571.5	573.3	572.1	585.5
8	35	59	17	4	569.4	567.5	569.4	567.5	597.4
5	28	60	1	4	533.1	529.7	531.3	529.7	558.1
6	34	60	1	4	523.6	520.3	523.6	522.1	536.4
14	33	60	3	4	525.8	524.3	525.8	524.3	554.7
12	8	60	9	4	567.8	559.3	560.8	559.6	591.0
8	19	60	9	4	559.3	550.5	555.0	552.0	595.6
16	23	60	10	4	560.2	556.9	558.7	557.2	591.9
3	25	60	10	4	550.5	548.9	550.8	549.2	595.0
4	25	60	10	4	555.3	548.6	554.1	551.7	593.8
9	26	60	10	4	553.5	551.1	553.2	552.6	596.8
13	1	60	11	4	611.1	609.9	611.1	609.6	616.6
13	1	60	11	4	601.7	599.8	601.7	600.2	614.2
13	36	60	12	4	571.5	570.0	571.5	570.0	602.0
4	1	60	13	4	597.4	592.8	594.4	592.8	637.6
4	30	60	13	4	627.9	625.4	627.3	625.8	661.4
12	24	60	14	4	616.6	602.0	609.0	602.0	669.6
13	16	60	16	4	600.8	597.1	598.3	597.1	616.3
4	5	60	17	4	591.0	585.8	587.3	586.1	600.2
4	27	60	17	4	655.9	645.6	652.3	646.2	655.9
4	25	61	3	4	506.9	506.3	508.1	506.6	545.0
14	15	61	4	4	519.4	513.6	516.6	515.1	542.5
1	17	61	4	4	524.3	523.0	524.3	523.0	548.3
4	36	61	9	4	545.6	543.2	544.7	543.2	563.0
5	5	62	3	4	507.5	506.3	507.5	506.3	537.4
4	16	62	6	4	513.6	511.1	513.6	512.1	542.5
1	21	62	9	4	556.6	553.2	554.7	553.2	560.5
16	4	62	10	4	549.9	546.8	549.9	546.8	589.2
4	26	62	13	4	584.3	579.1	580.9	579.4	584.3
1	29	63	1	4	510.5	501.4	504.1	502.6	534.9
1	20	63	2	4	512.1	507.5	512.1	507.5	537.1
16	28	63	2	4	521.2	514.5	517.6	516.0	541.3

HYDRAULIC HEADS IN THE BONNYVILLE (UNIT 1 AND UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
1	19	63	4	4	524.0	516.0	518.5	517.2	532.5
12	19	63	5	4	526.4	522.1	524.0	522.7	539.5
9	13	63	6	4	522.7	510.5	515.7	514.5	534.9
2	3	63	9	4	533.7	531.9	533.4	531.9	544.1
9	23	63	11	4	542.2	534.9	541.6	540.4	552.3
9	23	63	11	4	542.2	534.9	541.6	540.4	552.3
4	24	63	11	4	543.5	540.7	542.8	541.6	552.9
16	33	63	11	4	553.2	542.8	549.6	548.3	586.7
13	4	63	14	4	563.3	561.1	564.2	561.1	565.7
1	5	63	14	4	564.8	563.0	567.2	563.0	564.5
16	5	63	14	4	539.2	534.6	536.8	535.5	570.0
16	5	63	14	4	538.0	530.4	535.8	534.6	570.0
16	5	63	14	4	537.4	534.0	535.8	534.6	570.0
13	10	63	14	4	580.9	579.4	580.9	577.0	580.3
16	11	63	14	4	569.4	568.5	568.5	568.1	570.0
1	18	63	14	4	548.9	543.8	551.7	543.8	558.4
4	19	63	14	4	552.0	544.4	551.7	544.4	552.0
16	19	63	14	4	542.5	541.0	544.1	541.0	559.6
11	21	63	14	4	541.0	539.2	539.5	539.2	544.1
8	22	63	14	4	580.9	580.6	580.6	580.3	584.3
9	22	63	14	4	577.3	575.5	577.0	570.0	577.6
6	27	63	14	4	592.5	590.1	590.7	590.4	593.4
11	28	63	14	4	597.4	595.6	596.8	596.5	597.7
1	35	63	14	4	587.0	585.8	586.4	586.1	595.0
1	13	63	15	4	546.8	544.1	546.8	546.5	548.6
14	14	63	15	4	578.8	576.4	577.9	577.6	577.9
16	15	63	15	4	573.6	571.8	573.6	571.8	577.9
4	1	64	4	4	523.6	522.7	523.6	522.4	548.6
4	17	64	5	4	541.0	539.5	541.0	539.5	564.8
16	8	64	7	4	551.7	547.1	548.6	547.1	565.4
16	16	64	7	4	573.6	570.0	571.5	570.0	592.8
9	32	64	7	4	566.9	565.1	566.3	565.1	600.5
4	24	64	14	4	566.0	562.1	566.0	564.2	620.0
13	30	64	16	4	578.2	573.9	575.5	573.9	601.4
4	32	64	16	4	588.0	585.5	587.0	585.5	599.5
14	21	64	17	4	579.1	571.8	573.9	572.4	616.6
1	27	64	17	4	571.2	562.4	566.9	565.4	610.5
9	27	64	17	4	572.4	569.7	572.4	569.7	573.6
13	27	64	17	4	582.8	578.2	580.3	578.8	615.7
16	30	64	17	4	606.6	595.9	600.8	599.2	611.4

HYDRAULIC HEADS IN THE BONNYVILLE (UNIT 1 AND UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
10	36	64	17	4	570.6	569.1	570.6	569.1	600.8
9	1	65	4	4	560.5	546.5	551.7	546.5	595.9
4	33	65	5	4	580.6	579.1	580.6	579.4	595.9
1	2	65	11	4	571.5	566.9	569.4	567.8	581.6
16	17	65	11	4	537.7	536.8	537.7	536.8	554.7
13	5	65	12	4	554.1	544.1	546.2	545.0	560.8
16	5	65	12	4	527.3	526.4	527.3	526.1	568.8
1	30	65	13	4	549.2	548.6	549.9	548.3	566.9
1	7	65	16	4	577.6	575.2	576.7	575.2	605.6
4	7	65	16	4	578.8	577.9	579.4	577.9	605.3
4	8	65	16	4	578.2	572.1	573.6	572.1	602.0
4	8	65	16	4	574.9	570.0	571.5	570.0	601.4
4	19	65	16	4	610.8	605.3	607.2	605.6	612.3
16	19	65	16	4	611.1	610.5	611.1	610.5	614.2
13	2	66	9	4	599.2	595.6	597.4	596.2	616.0
4	4	66	13	4	545.0	542.8	545.6	542.5	557.8
5	5	66	13	4	523.3	516.6	522.1	520.6	569.4
1	32	66	13	4	526.1	524.9	526.4	524.9	543.8
16	33	66	13	4	505.7	502.9	504.4	502.9	562.1
16	33	66	13	4	508.7	506.0	507.5	506.0	565.1
10	8	66	14	4	546.2	541.3	544.1	542.5	564.8
4	9	66	14	4	551.7	550.2	551.7	550.2	583.7
4	20	66	14	4	533.1	530.0	531.6	530.0	563.0
13	27	66	14	4	531.6	527.0	529.4	528.2	552.6
13	34	66	14	4	519.7	518.2	519.1	517.9	557.8
14	34	66	14	4	520.0	517.9	520.0	518.5	532.2
14	35	66	14	4	531.3	530.0	531.3	530.4	548.6
1	26	66	15	4	527.0	522.7	525.8	522.7	560.2
14	34	67	15	4	536.1	533.4	536.1	533.7	564.2
9	26	67	17	4	556.3	551.7	554.4	553.2	584.6
12	14	68	13	4	557.8	547.1	555.7	554.1	566.3
6	26	69	12	4	547.1	541.9	546.8	545.3	575.8

Table P-h-6

HYDRAULIC HEADS IN THE ETHEL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
13	31	55	3	4	577.9	576.1	577.6	576.4	584.0
8	8	56	3	4	565.1	543.8	547.1	545.9	559.9
1	16	56	3	4	562.1	555.0	557.2	556.0	573.6
4	16	56	3	4	570.0	566.3	568.8	567.2	573.3
16	16	56	3	4	576.7	568.8	573.6	572.1	580.0
13	21	56	3	4	576.7	567.5	570.9	569.7	579.7
13	21	56	3	4	583.7	574.2	578.8	577.3	588.6
6	28	56	3	4	580.6	574.2	576.1	574.5	595.3
7	28	56	3	4	581.9	572.1	577.0	575.5	592.5
15	28	56	3	4	585.2	568.5	582.2	580.3	601.1
5	29	56	3	4	586.1	572.7	581.6	580.0	586.7
9	31	56	3	4	595.0	585.2	592.2	590.7	604.7
6	33	56	3	4	606.6	580.6	584.3	582.8	592.5
14	4	56	4	4	575.8	573.6	577.0	573.6	577.9
2	11	56	4	4	582.2	567.5	569.7	568.1	575.2
5	11	56	4	4	590.7	572.7	574.5	573.0	581.3
16	11	56	4	4	589.8	580.0	582.2	580.6	587.7
3	5	57	2	4	586.4	575.2	577.3	576.1	579.7
1	6	57	2	4	576.7	570.6	576.7	575.5	585.2
15	8	57	2	4	588.0	580.6	583.4	582.2	592.2
7	9	57	2	4	582.8	553.8	564.5	563.0	577.9
3	15	57	2	4	591.0	566.0	587.7	586.1	597.1
3	15	57	2	4	591.6	566.6	588.3	586.7	597.4
8	17	57	2	4	591.3	578.5	589.8	588.3	597.1
10	17	57	2	4	596.8	591.3	595.9	594.7	602.0
14	20	57	2	4	600.5	598.0	599.2	597.7	636.7
4	4	57	3	4	591.9	568.8	581.6	580.3	596.8
16	4	57	3	4	594.4	584.0	593.8	592.2	621.8
1	5	57	3	4	588.0	582.5	584.9	583.1	599.2
4	6	57	3	4	596.8	594.7	596.2	594.7	605.3
13	8	57	3	4	605.3	599.8	602.6	601.1	607.5
4	9	57	3	4	598.9	593.8	597.1	595.9	608.1
11	6	57	4	4	645.3	643.4	645.0	643.7	653.2
1	1	58	2	4	605.6	583.7	591.0	589.8	642.2
16	18	58	6	4	608.4	605.9	612.6	605.9	647.7
12	20	58	6	4	614.2	610.8	612.0	610.5	637.6
16	24	59	6	4	583.7	573.3	577.6	574.5	578.5
2	25	59	8	4	592.2	574.2	577.3	574.2	598.9
5	9	59	9	4	592.2	590.4	591.6	590.4	605.0
16	17	59	9	4	599.8	592.2	595.3	592.2	613.0

HYDRAULIC HEADS IN THE ETHEL LAKE FORMATION AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
1	28	59	9	4	566.9	565.4	566.9	565.7	586.1
1	29	59	9	4	580.6	577.9	579.4	577.9	589.8
16	31	59	9	4	591.9	579.7	584.9	583.7	593.4
8	32	59	9	4	591.0	581.3	583.1	581.6	591.9
14	33	59	9	4	582.8	574.5	576.4	575.2	589.5
4	1	59	10	4	598.9	593.8	594.7	593.8	628.8
1	2	59	10	4	594.4	591.6	593.1	591.9	623.0
7	25	59	10	4	584.0	570.0	578.5	577.3	593.1
1	36	59	10	4	577.9	573.6	575.5	574.2	598.6
5	9	59	11	4	581.9	578.8	581.6	578.5	610.2
16	27	59	15	4	631.9	627.6	629.1	627.6	647.7
15	1	60	1	4	551.7	548.9	550.5	549.2	567.8
2	11	60	1	4	559.9	557.8	559.6	558.4	575.5
10	11	60	1	4	556.9	541.0	544.7	543.5	557.2
12	15	60	1	4	546.2	541.9	544.7	543.5	575.5
1	16	60	1	4	558.4	547.4	550.5	549.2	585.8
6	21	60	1	4	533.4	531.9	533.4	531.9	561.1
12	21	60	1	4	553.2	538.0	539.5	538.3	571.5
16	22	60	1	4	521.8	515.1	518.2	516.6	550.8
10	23	60	1	4	544.4	543.2	544.4	542.8	563.0
1	25	60	1	4	547.7	545.6	547.4	545.9	564.2
5	28	60	1	4	545.6	541.6	543.5	541.9	555.7
7	28	60	1	4	526.7	524.0	526.1	524.6	563.9
12	28	60	1	4	526.7	522.7	526.1	524.6	564.8
5	29	60	1	4	533.1	531.9	533.1	531.9	541.3
6	33	60	1	4	541.0	535.2	536.8	535.2	546.5
16	13	60	6	4	564.8	563.6	564.8	563.6	573.0
10	16	60	6	4	556.6	552.0	553.5	552.3	560.8
13	16	60	6	4	552.0	550.5	552.0	550.5	557.8
16	16	60	6	4	553.8	549.2	552.3	549.2	558.4
16	16	60	6	4	554.7	549.9	551.7	550.2	559.3
9	17	60	6	4	558.4	556.6	558.4	556.9	563.6
16	18	60	6	4	541.9	536.1	538.0	536.4	561.7
5	19	60	6	4	541.3	539.8	541.0	539.8	572.7
5	21	60	6	4	555.3	553.2	554.7	553.5	559.9
4	22	60	6	4	550.2	545.0	547.1	545.9	561.7
7	32	60	6	4	539.2	535.8	538.9	535.8	546.2
8	8	60	7	4	567.2	564.2	565.7	564.2	590.4
4	33	60	8	4	545.0	541.9	543.5	541.9	570.0
1	5	60	9	4	585.2	573.9	576.1	574.9	588.6

HYDRAULIC HEADS IN THE ETHEL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
1	6	60	9	4	591.6	579.4	581.3	580.0	591.6
16	6	60	9	4	591.9	588.0	588.9	587.7	603.2
1	7	60	9	4	585.2	578.5	579.7	578.5	594.7
1	8	60	9	4	577.9	574.2	575.8	574.5	589.8
13	8	60	9	4	580.9	572.7	574.2	572.7	585.5
14	21	60	9	4	592.8	592.2	592.8	591.3	607.2
2	1	60	10	4	593.1	588.9	591.0	588.3	593.8
3	14	60	10	4	590.4	584.3	586.1	584.6	597.4
16	22	60	10	4	604.7	602.3	603.2	602.0	624.2
16	32	60	10	4	604.4	592.8	594.4	592.8	594.4
15	1	60	11	4	599.2	598.0	598.9	597.7	612.6
6	2	60	11	4	620.0	604.7	605.0	603.5	617.5
13	5	61	2	4	527.6	524.6	525.8	524.6	544.1
8	14	61	4	4	529.4	528.8	530.4	528.8	542.2
13	26	61	4	4	529.7	528.5	529.7	528.5	542.2
3	28	61	4	4	520.9	517.6	520.6	519.4	545.9
1	5	61	6	4	530.0	527.3	528.8	527.3	535.8
14	7	61	6	4	522.1	520.6	522.1	520.6	527.6
5	21	61	6	4	532.8	521.8	528.5	527.3	544.7
16	11	61	7	4	531.0	529.7	531.0	529.7	535.5
4	13	61	7	4	525.2	520.6	524.6	523.3	532.2
2	23	61	7	4	530.4	529.1	530.4	529.1	538.3
13	28	61	8	4	529.7	527.0	529.7	527.3	561.4
9	4	61	9	4	583.7	576.7	580.6	579.1	606.2
13	4	61	9	4	584.3	570.6	578.2	577.0	602.6
4	7	61	9	4	580.6	574.5	579.4	577.9	608.1
4	9	61	9	4	584.9	570.0	571.5	570.0	604.4
12	16	61	9	4	577.9	569.1	571.5	570.3	603.2
3	17	61	9	4	582.2	572.7	581.6	580.0	606.6
9	29	61	10	4	598.0	586.1	587.7	586.1	591.3
8	32	61	10	4	588.9	573.0	585.8	584.6	595.9
4	27	62	2	4	512.4	509.3	510.5	509.3	515.1
9	34	62	2	4	534.3	526.7	527.6	527.0	533.4
7	3	62	3	4	527.3	525.2	526.7	526.1	529.7
16	10	62	3	4	498.0	493.8	496.2	494.7	534.9
5	1	62	4	4	528.5	499.0	522.7	504.4	550.5
13	6	62	4	4	522.7	515.1	517.9	516.6	536.1
12	19	62	4	4	514.8	502.9	506.6	502.9	523.6
15	3	62	5	4	533.7	531.0	532.5	531.0	538.3
10	4	62	5	4	527.0	526.7	527.6	526.1	544.1

HYDRAULIC HEADS IN THE ETHEL LAKE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION LSD	SEC	TP	R	M	AQUIFER ELEVATIONS (m amsl) TOP	BOTTOM	COMPLETED INTERVAL ELEVATIONS (m amsl) TOP	BOTTOM	HYDRAULIC HEAD (m amsl)
9	4	62	9	4	549.2	547.7	549.2	547.7	559.9
1	19	62	10	4	578.2	560.8	562.7	561.4	589.5
4	18	63	5	4	536.1	534.0	535.5	534.0	546.8
8	32	63	5	4	537.1	533.4	534.6	533.4	551.7
4	33	63	5	4	533.1	530.7	533.1	531.6	551.7
9	13	63	6	4	536.1	531.9	533.4	532.2	548.6
1	31	63	7	4	533.7	533.1	533.4	533.1	550.2
13	33	63	11	4	562.4	560.2	562.4	560.8	571.5
1	5	64	11	4	577.6	570.0	571.8	570.6	587.3
1	5	64	11	4	577.6	567.5	572.1	567.8	589.8
1	26	64	12	4	564.2	560.2	562.1	560.8	568.8
10	30	64	16	4	592.2	589.8	591.3	589.8	599.5
8	32	64	16	4	587.0	581.6	585.8	584.3	598.3
12	22	64	17	4	583.1	576.1	579.7	578.2	614.2
15	22	64	17	4	583.4	577.6	581.3	579.7	615.7
15	22	64	17	4	578.2	573.3	575.2	573.6	610.5
9	27	64	17	4	575.5	573.0	574.2	572.7	605.3
12	27	64	17	4	591.9	587.7	591.0	589.5	606.2
1	33	64	17	4	589.8	587.7	589.5	588.0	604.4
1	34	64	17	4	588.9	584.3	586.1	584.6	598.6
9	35	64	17	4	577.6	574.5	577.0	575.8	602.6
5	36	64	17	4	582.8	577.0	582.5	580.9	589.5
13	3	65	13	4	549.6	548.3	549.6	548.3	569.7
1	18	65	13	4	553.2	549.9	551.4	549.9	573.6
14	33	66	13	4	541.0	539.8	541.0	539.8	558.1
14	33	66	13	4	544.1	540.4	541.6	540.4	558.1
15	17	66	14	4	551.7	536.1	538.6	537.4	558.1
13	34	66	14	4	521.5	519.4	521.5	520.0	559.3
13	4	66	15	4	548.3	541.9	543.2	541.9	563.0
1	17	66	15	4	542.5	536.4	538.0	536.4	563.0
1	18	66	15	4	543.5	536.4	538.0	536.4	564.2
11	25	66	15	4	538.0	525.2	529.4	528.2	558.7
9	31	66	15	4	550.5	544.1	549.6	548.6	568.5
16	27	66	16	4	544.1	531.9	534.3	533.1	565.7
2	35	66	16	4	539.5	532.2	533.7	532.5	557.8
13	31	66	17	4	554.1	552.9	554.4	552.9	598.6
4	15	67	13	4	536.8	532.5	536.8	535.5	537.4
4	14	67	16	4	567.5	552.9	555.3	553.8	598.9
13	19	67	16	4	554.4	547.7	549.9	548.6	583.1
14	22	67	16	4	558.1	552.0	552.9	552.0	583.7

HYDRAULIC HEADS IN THE ETHEL LAKE FORMATION AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	23	67	16	4	573.9	569.4	571.5	570.0	594.1
13	23	67	16	4	550.2	535.2	543.2	541.9	570.3
15	24	67	16	4	550.2	546.5	548.6	547.4	565.4
2	13	67	17	4	553.5	550.5	551.7	550.5	583.7
16	22	67	17	4	552.9	545.9	546.5	545.9	582.5
5	24	67	17	4	554.1	542.5	546.2	545.0	584.3
8	24	67	17	4	552.6	544.4	547.4	545.0	584.0
13	24	67	17	4	544.4	541.9	543.8	542.5	574.9
13	17	68	14	4	560.5	559.0	560.2	559.0	566.0
13	17	68	14	4	554.1	551.7	553.5	548.6	566.0
12	3	68	16	4	550.8	549.2	550.8	549.2	561.4

Table P-h-7
HYDRAULIC HEADS IN THE MARIE CREEK (UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	20	56	3	4	585.8	580.0	585.2	583.7	595.3
13	28	56	3	4	606.6	603.5	605.0	603.5	608.7
11	31	57	1	4	624.8	620.0	623.6	622.4	630.0
2	7	59	5	4	612.6	605.0	606.2	605.0	637.0
13	19	59	7	4	606.6	599.5	601.1	599.5	613.0
16	7	59	9	4	608.1	601.7	605.0	602.0	625.8
16	34	59	15	4	637.0	634.3	635.5	634.3	652.3
4	21	60	6	4	561.4	559.6	560.8	559.6	566.0
16	26	60	6	4	556.3	555.0	556.3	555.0	570.9
13	21	60	8	4	577.9	565.4	566.9	565.7	601.7
1	22	60	8	4	577.6	576.1	577.6	576.1	600.5
8	4	60	9	4	580.3	577.0	578.2	577.0	592.8
12	13	60	10	4	604.7	599.2	600.5	598.6	637.0
16	15	61	2	4	533.1	530.0	531.3	529.7	546.5
16	32	61	2	4	530.0	527.9	530.0	528.5	534.0
3	2	61	6	4	543.2	540.1	541.3	540.1	548.6
1	3	61	9	4	578.2	568.5	577.9	574.9	603.5
1	5	61	9	4	598.3	596.8	598.3	596.8	611.4
12	30	62	1	4	527.3	521.2	522.4	521.2	530.4
3	3	62	2	4	529.1	523.0	526.1	524.9	542.2
13	13	62	2	4	519.4	516.9	518.2	516.9	524.3
16	13	62	2	4	518.8	500.5	503.5	500.5	524.3
1	16	62	2	4	496.5	490.4	495.9	490.4	504.4
8	20	62	2	4	520.0	515.4	518.2	515.1	531.0
15	24	62	2	4	530.7	528.8	530.4	528.8	538.6
4	26	62	2	4	529.4	521.5	522.7	521.5	558.4
1	33	62	4	4	531.9	530.0	531.3	530.0	539.8
4	19	62	5	4	529.4	527.3	528.8	527.6	538.0
6	19	62	5	4	528.2	526.1	527.6	526.4	536.8
16	21	62	7	4	544.1	541.9	543.5	541.9	556.6
9	11	63	1	4	512.7	509.0	510.5	509.0	534.0
4	22	63	2	4	527.3	524.6	525.8	524.6	527.6
9	18	63	3	4	518.5	515.7	518.5	516.9	523.0
9	18	63	3	4	519.4	515.1	516.6	515.1	521.5
9	15	63	4	4	529.4	525.8	527.3	525.8	534.3
15	27	63	4	4	527.6	526.1	527.6	526.1	547.1
13	3	63	5	4	534.3	528.8	531.6	530.4	531.9
16	8	63	5	4	535.5	526.4	527.6	526.4	538.0
4	16	63	5	4	534.9	531.9	533.4	531.9	545.6
4	4	63	6	4	534.9	531.9	534.9	533.4	543.8

HYDRAULIC HEADS IN THE MARIE CREEK (UNIT 2) FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
13	5	63	6	4	541.0	526.4	531.0	529.7	539.5
12	8	63	6	4	541.3	527.3	530.4	528.8	541.3
11	9	63	6	4	541.3	520.3	531.6	530.4	541.3
13	12	63	6	4	536.4	530.4	531.6	530.4	540.1
4	16	63	6	4	546.8	530.4	533.1	531.9	548.6
1	17	63	6	4	539.5	533.1	534.3	532.8	547.4
9	17	63	6	4	538.9	531.9	533.4	532.2	541.0
4	18	63	6	4	542.8	531.0	533.1	531.9	540.1
13	31	63	6	4	538.9	537.4	538.9	537.4	560.8
13	31	63	6	4	537.7	536.4	537.7	536.4	551.7
13	33	63	6	4	527.9	520.9	522.1	520.9	547.1
11	10	63	7	4	543.2	537.1	539.2	538.0	543.2
14	13	63	7	4	536.4	530.7	532.2	531.0	538.0
4	32	63	7	4	542.5	541.9	542.5	541.9	561.4
4	36	63	7	4	544.7	542.5	544.1	542.5	564.2
3	36	63	10	4	588.9	587.7	588.9	587.7	606.6
13	36	63	12	4	570.0	566.9	570.0	568.5	579.1
7	19	64	16	4	602.0	599.2	600.8	599.5	606.2
12	26	64	17	4	593.8	589.5	591.6	590.1	597.1
14	26	64	17	4	596.8	594.4	596.5	594.7	604.1
10	27	64	17	4	597.4	593.1	595.0	593.4	607.2
12	27	64	17	4	587.3	583.4	586.1	584.6	599.8
3	34	64	17	4	594.7	592.8	594.1	592.5	592.5
8	34	64	17	4	593.4	591.9	593.4	591.9	600.8
8	34	64	17	4	590.4	586.1	590.4	588.9	597.7
8	34	64	17	4	592.5	589.2	592.2	590.7	601.4
1	21	65	2	4	572.7	571.5	574.2	573.0	576.7
13	13	65	17	4	572.4	569.7	571.5	570.0	594.4
13	14	65	17	4	584.0	581.3	582.8	581.3	600.5
13	31	66	13	4	549.2	542.5	544.1	542.5	553.2
9	30	66	14	4	542.5	527.3	535.2	534.0	556.6
13	30	66	14	4	548.0	510.2	516.0	509.9	548.3
12	14	67	16	4	589.8	587.7	588.6	587.7	600.5
13	24	67	17	4	561.4	557.8	560.5	558.1	591.3
13	25	67	17	4	572.7	571.5	572.7	571.5	580.6

Table P-h-8
HYDRAULIC HEADS IN THE SAND RIVER FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
13	22	57	9	4	624.2	619.7	621.2	619.7	639.8
14	27	57	12	4	602.3	601.1	602.6	601.1	613.0
16	29	57	12	4	603.8	600.2	602.0	600.5	619.7
4	35	57	12	4	603.2	602.0	603.5	602.0	611.1
12	19	57	13	4	634.9	619.7	621.5	620.3	635.5
14	2	58	9	4	613.6	608.1	611.4	610.5	641.6
13	6	58	9	4	616.6	613.9	615.7	614.5	639.2
15	6	58	9	4	619.7	618.1	619.7	618.4	639.2
3	10	58	9	4	623.0	620.0	622.1	620.9	637.6
8	31	58	9	4	609.3	605.9	609.0	605.9	641.6
13	31	58	9	4	615.7	609.6	614.2	612.6	649.2
1	2	58	10	4	607.2	603.8	605.0	603.5	636.4
1	8	58	10	4	609.0	599.8	605.9	604.7	638.3
12	9	58	10	4	606.2	597.4	599.2	598.0	637.0
16	14	58	10	4	599.8	598.0	599.2	598.0	640.1
9	15	58	10	4	615.4	610.2	615.4	614.2	640.7
16	19	58	10	4	611.7	610.8	611.7	611.1	646.2
5	2	58	11	4	616.3	612.6	613.9	612.6	631.5
4	6	58	11	4	592.2	583.7	585.8	584.3	625.4
16	14	58	11	4	594.4	592.8	594.7	593.1	618.7
4	27	58	11	4	602.9	599.8	601.7	600.5	611.7
16	30	58	11	4	598.6	596.8	598.0	596.8	625.4
1	1	58	12	4	596.5	586.7	590.1	588.6	615.4
2	1	58	12	4	600.5	594.4	596.5	595.0	616.3
10	15	58	12	4	580.0	577.9	579.1	577.6	616.0
8	28	58	12	4	605.0	598.9	602.6	601.1	604.4
16	20	58	13	4	656.8	656.8	610.2	609.0	643.7
4	27	58	13	4	602.9	601.4	602.9	601.7	637.6
9	25	58	14	4	619.0	609.9	616.0	614.8	645.3
11	35	58	14	4	628.5	625.1	627.3	625.8	663.9
13	18	59	9	4	573.0	557.8	562.4	560.8	612.6
6	20	59	9	4	610.8	602.9	605.0	603.5	606.6
16	33	59	9	4	589.5	583.7	585.2	583.7	625.1
13	34	59	9	4	584.9	577.6	579.1	577.6	592.2
13	22	59	10	4	615.7	613.9	615.4	613.9	626.1
16	9	59	11	4	603.2	594.4	601.1	599.8	621.8
12	14	59	11	4	597.7	594.7	597.7	594.7	617.8
16	14	59	11	4	598.0	596.2	598.0	596.8	646.5
14	22	59	11	4	598.9	586.1	591.0	590.4	615.4
7	26	59	11	4	602.9	602.0	602.9	601.4	609.9

HYDRAULIC HEADS IN THE SAND RIVER FORMATION AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
	29	59	11	4	608.4	607.2	608.4	607.5	635.8
16	31	59	11	4	621.8	609.6	614.2	611.7	629.4
1	3	59	12	4	602.9	598.9	600.5	598.9	615.1
4	4	59	12	4	608.7	607.5	609.0	607.5	625.8
5	4	59	12	4	602.0	592.5	595.3	593.8	623.0
14	16	59	12	4	597.4	595.3	597.7	596.2	627.0
1	1	59	13	4	608.7	601.1	603.5	602.3	633.7
11	1	59	13	4	599.8	598.9	600.2	598.6	627.9
4	12	59	13	4	604.7	602.0	603.8	602.3	634.3
4	19	59	13	4	603.5	602.0	603.5	602.0	638.6
13	22	59	13	4	605.9	594.4	598.0	596.5	633.4
12	25	59	13	4	595.3	590.4	593.4	590.4	639.5
9	27	59	13	4	600.2	593.8	598.6	597.1	635.8
12	29	59	13	4	607.2	602.0	607.2	605.9	644.7
9	7	59	14	4	659.9	637.9	641.3	640.1	659.3
13	22	59	14	4	641.3	634.9	637.3	636.1	673.9
13	4	60	1	4	553.2	548.6	551.1	549.9	575.5
1	9	60	1	4	570.9	565.1	566.6	565.4	575.8
4	16	60	1	4	573.9	565.1	568.1	566.9	573.3
14	16	60	1	4	575.8	560.8	570.3	568.8	580.6
5	17	60	1	4	576.7	570.9	573.6	572.1	582.2
16	17	60	1	4	564.2	555.0	559.3	557.8	587.3
7	19	60	1	4	563.3	561.4	563.0	561.4	565.1
13	19	60	1	4	565.1	559.0	559.9	558.4	567.5
7	20	60	1	4	567.8	564.2	566.6	565.4	576.4
5	33	60	3	4	554.7	548.3	549.9	548.3	575.5
11	23	60	5	4	559.9	556.3	559.9	555.0	561.7
1	26	60	6	4	580.6	578.8	580.3	578.8	590.4
12	27	60	6	4	557.5	553.8	556.6	555.0	563.9
15	35	60	6	4	551.1	549.6	550.8	549.6	556.6
8	19	60	8	4	587.3	586.1	587.3	586.1	607.8
13	35	60	8	4	563.6	557.8	559.3	557.8	548.6
4	3	60	9	4	583.4	576.7	577.9	576.7	591.6
5	3	60	9	4	583.7	577.0	577.9	576.7	591.9
3	4	60	9	4	581.9	578.2	580.6	579.4	592.8
1	6	60	9	4	591.6	579.4	581.3	580.0	591.6
16	27	60	9	4	590.7	585.2	588.3	585.2	594.1
12	28	60	9	4	593.8	590.7	592.2	590.7	605.0
12	28	60	9	4	593.4	590.7	592.2	590.7	605.0
5	10	60	11	4	623.6	620.6	621.2	620.6	626.7

HYDRAULIC HEADS IN THE SAND RIVER FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
12	22	60	11	4	619.4	616.0	618.7	617.2	625.4
4	29	60	11	4	601.7	600.5	602.0	600.5	603.5
2	30	60	11	4	585.5	584.6	585.5	584.3	603.5
4	9	60	12	4	602.3	601.4	603.5	599.5	646.2
5	23	60	12	4	602.9	601.7	612.6	612.6	604.4
16	5	61	3	4	550.2	540.4	541.6	540.4	574.5
9	7	61	3	4	542.8	539.5	541.9	540.4	557.8
12	18	61	3	4	539.8	539.2	540.7	539.2	557.2
1	32	61	5	4	546.5	543.2	545.6	543.2	554.1
4	29	61	6	4	541.0	538.3	539.8	538.6	545.0
4	16	61	7	4	544.1	541.0	542.5	541.0	545.0
13	5	61	8	4	571.2	565.7	567.5	566.3	579.7
4	10	61	8	4	559.9	557.5	559.0	557.5	566.0
16	17	61	8	4	561.7	554.7	556.3	554.7	567.5
13	28	61	8	4	559.3	556.3	559.3	556.3	561.7
12	3	61	9	4	585.5	580.0	581.6	580.0	605.0
13	20	61	9	4	583.4	570.9	573.9	570.9	615.7
16	21	61	9	4	566.6	560.8	562.4	561.1	599.8
1	23	61	9	4	559.9	556.3	557.8	556.6	580.6
1	24	61	9	4	558.7	553.8	555.7	553.2	565.4
4	21	61	10	4	603.2	597.7	599.2	598.0	611.7
4	5	61	15	4	659.3	625.4	628.5	625.4	661.4
4	3	61	17	4	635.2	634.0	635.5	634.0	647.7
4	34	62	1	4	532.5	529.7	530.4	529.1	545.0
13	35	62	1	4	522.1	519.1	520.3	519.1	544.1
16	5	62	2	4	523.0	520.9	523.3	521.8	533.4
16	23	62	2	4	542.5	539.5	541.0	539.5	548.0
1	27	62	2	4	537.7	529.7	532.5	531.6	535.8
9	34	62	2	4	531.0	529.1	530.7	529.1	534.6
13	18	62	4	4	538.0	534.6	536.4	534.9	548.0
12	5	62	5	4	558.7	553.8	555.0	553.8	557.2
8	13	62	5	4	540.4	537.7	539.2	538.0	551.1
8	25	62	5	4	540.1	537.1	538.9	537.7	548.3
2	31	62	5	4	536.4	530.4	532.2	530.7	538.0
5	32	62	5	4	536.1	528.2	529.7	528.5	539.2
7	7	62	6	4	541.0	538.0	539.5	538.0	547.4
13	27	62	8	4	557.2	554.7	556.3	554.7	569.4
4	3	62	9	4	559.9	557.8	559.3	557.8	568.5
16	23	62	11	4	591.9	589.2	590.1	589.5	591.9
3	2	63	2	4	534.3	523.3	528.5	527.0	539.5

HYDRAULIC HEADS IN THE SAND RIVER FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
6	2	63	2	4	531.9	523.0	524.9	523.0	535.8
6	2	63	2	4	535.5	527.3	529.1	527.6	539.8
5	16	63	2	4	540.1	529.4	530.7	529.4	539.5
11	21	63	2	4	538.9	533.4	535.8	534.6	541.3
6	23	63	2	4	546.2	535.8	537.7	535.8	550.8
4	28	63	2	4	536.4	533.7	535.2	533.7	540.7
4	9	63	3	4	538.0	527.9	529.4	527.9	531.9
1	20	63	3	4	533.7	527.3	529.4	527.9	539.8
4	4	63	4	4	537.7	534.0	535.5	534.3	547.1
12	13	63	4	4	534.9	525.2	528.2	526.7	531.3
13	2	63	5	4	540.7	538.3	539.5	538.3	541.9
16	3	63	5	4	542.5	531.9	533.7	532.5	547.1
13	9	63	5	4	538.9	527.9	529.1	527.9	541.0
9	14	63	5	4	537.1	534.6	536.8	535.2	541.6
4	18	63	5	4	541.9	534.6	536.1	534.6	543.5
4	4	63	6	4	539.5	527.3	536.4	534.9	545.6
3	5	63	6	4	547.7	532.2	533.4	532.2	540.7
1	7	63	6	4	542.5	532.2	533.7	532.2	539.5
4	7	63	6	4	544.1	527.3	528.5	527.3	540.4
14	10	63	6	4	541.9	526.4	527.9	526.7	538.6
16	12	63	6	4	549.2	535.8	537.1	535.8	542.8
3	18	63	6	4	547.4	529.4	534.9	533.7	540.4
4	18	63	6	4	552.3	532.5	534.6	533.4	541.6
4	18	63	6	4	544.1	534.3	536.1	534.9	544.1
7	27	63	6	4	543.5	541.3	543.5	542.2	560.8
6	15	63	7	4	542.2	537.1	538.3	537.1	557.8
6	26	63	7	4	546.5	543.2	544.7	543.2	560.2
16	34	63	7	4	560.2	558.4	560.5	558.4	570.0
14	35	63	7	4	546.5	541.9	543.8	542.5	566.9
6	13	63	8	4	546.2	543.8	546.2	545.0	550.5
13	8	63	14	4	570.3	566.9	570.0	566.9	573.9
12	4	64	7	4	564.5	560.8	562.1	560.8	569.1
9	13	64	7	4	553.5	551.7	553.2	551.7	563.3
13	15	64	7	4	568.5	563.6	564.8	563.6	589.8
13	21	64	7	4	593.4	583.1	586.1	584.9	593.4
16	34	64	13	4	569.1	567.8	569.1	567.8	586.7
10	30	64	16	4	596.8	591.0	592.5	591.3	603.5
12	30	64	16	4	597.7	593.4	595.9	594.4	601.7
7	25	64	17	4	595.6	591.6	594.4	592.8	602.9
16	9	65	11	4	592.5	590.7	592.5	591.0	608.1

Table P-h-9
HYDRAULIC HEADS IN THE GRAND CENTRE FORMATION AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
10	22	55	4	4	597.4	581.9	583.4	581.9	590.4
1	14	56	9	4	653.8	647.7	675.1	675.1	653.8
9	26	56	9	4	618.4	616.0	617.5	616.0	631.9
4	13	57	2	4	607.2	594.4	595.9	594.7	603.2
10	14	57	2	4	618.4	615.1	618.1	616.6	629.7
15	19	57	4	4	646.5	631.2	634.6	633.7	643.7
16	20	57	5	4	583.7	580.3	581.9	580.3	585.2
12	2	57	6	4	598.9	589.8	597.4	589.8	600.5
1	25	57	6	4	590.7	587.7	589.8	588.3	609.6
13	31	57	6	4	598.6	592.8	594.4	592.8	597.4
13	32	57	7	4	668.7	663.5	665.1	663.9	670.0
5	10	57	8	4	641.9	640.1	641.6	640.1	643.1
15	18	57	9	4	625.4	613.9	617.8	616.6	638.6
4	32	57	10	4	626.7	624.5	626.1	624.8	633.4
5	32	57	10	4	625.1	623.0	623.6	623.3	631.9
12	26	57	11	4	610.2	603.5	605.6	604.1	627.3
13	6	57	12	4	633.1	618.1	625.8	619.4	634.0
15	32	57	12	4	614.2	608.1	610.2	608.7	631.9
8	34	57	12	4	613.3	609.3	612.0	610.5	616.3
15	34	57	12	4	649.2	640.1	641.6	640.1	643.1
1	6	58	2	4	634.0	629.4	632.5	631.2	647.7
12	1	58	7	4	643.1	641.9	643.4	641.9	653.8
2	4	58	7	4	674.2	668.7	670.9	669.6	685.2
2	15	58	7	4	661.1	658.4	661.4	658.4	674.5
12	21	58	7	4	637.3	630.0	631.5	630.0	649.2
4	10	58	8	4	643.1	635.5	637.0	635.5	646.2
1	1	58	9	4	646.5	645.3	669.0	669.0	658.4
4	17	58	9	4	628.5	622.4	625.4	622.4	640.7
13	18	58	9	4	646.8	643.7	646.8	643.7	649.8
16	21	58	9	4	635.8	634.0	635.5	634.0	650.1
16	21	58	9	4	649.8	646.5	648.0	646.5	650.1
1	5	58	10	4	630.0	627.6	655.3	655.3	642.5
14	7	58	10	4	623.3	621.8	623.0	621.8	642.5
4	8	58	10	4	620.3	619.7	620.3	619.7	641.3
16	19	58	10	4	615.1	613.9	615.1	613.9	646.2
3	34	58	10	4	636.1	630.6	632.2	630.6	643.7
1	14	58	11	4	607.8	605.6	608.1	606.6	634.9
16	24	58	11	4	611.1	606.6	608.1	606.6	646.2
1	28	58	11	4	613.9	606.6	608.1	606.6	612.3
10	34	58	11	4	625.4	621.2	624.2	621.2	627.9

HYDRAULIC HEADS IN THE GRAND CENTRE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
1	6	58	12	4	619.0	617.5	619.0	617.5	637.0
14	10	58	12	4	605.9	601.4	603.5	602.0	636.4
6	28	58	12	4	622.1	611.1	613.3	612.0	618.4
5	33	58	12	4	619.7	611.1	613.6	612.0	618.4
16	29	58	13	4	629.7	626.4	628.2	627.0	645.3
9	25	58	14	4	634.3	625.1	631.2	630.0	660.5
3	2	58	16	4	599.8	588.9	601.1	588.3	613.3
10	17	59	4	4	645.0	641.3	642.5	641.3	652.3
8	36	59	6	4	578.5	577.0	578.5	577.0	592.2
4	3	59	9	4	647.7	641.9	644.0	642.8	659.6
3	16	59	9	4	621.5	618.7	621.5	620.0	649.2
4	27	59	9	4	628.8	627.0	628.5	627.0	633.1
4	17	59	10	4	614.2	612.6	613.9	612.6	621.8
13	15	59	11	4	615.4	613.0	614.5	613.3	624.8
9	23	59	11	4	622.7	620.6	621.8	620.6	626.1
5	28	59	11	4	623.3	619.7	621.2	619.7	631.9
16	30	59	11	4	634.3	617.2	621.5	620.3	632.8
8	9	59	12	4	616.3	615.1	616.6	615.1	631.5
16	15	59	12	4	627.9	623.0	624.2	623.0	630.3
9	16	59	12	4	617.5	616.9	618.4	616.9	628.5
1	17	59	12	4	641.9	641.0	642.5	641.0	647.4
4	21	59	12	4	638.3	636.7	638.3	636.7	642.2
12	23	59	12	4	625.1	623.6	625.1	623.6	627.9
8	32	59	12	4	625.4	623.3	624.8	623.3	638.6
13	32	59	12	4	645.3	643.4	644.7	644.0	645.3
1	33	59	12	4	619.7	616.6	617.5	616.9	621.8
4	17	59	13	4	611.4	606.6	609.6	608.4	635.5
4	19	59	13	4	621.2	619.7	622.1	619.4	638.3
1	23	59	13	4	634.6	633.1	634.6	633.1	638.3
13	3	59	14	4	659.6	649.8	650.4	648.9	676.0
5	20	59	14	4	671.2	655.0	656.5	655.3	662.0
13	1	59	15	4	638.6	629.4	630.6	629.1	646.2
16	34	59	16	4	605.3	603.2	604.7	603.2	609.6
16	24	60	1	4	558.7	550.2	552.3	551.1	560.2
11	11	60	1	4	616.3	615.7	616.6	615.1	617.2
1	6	60	2	4	602.9	601.4	602.9	601.4	615.7
14	22	60	3	4	575.8	573.9	575.5	574.2	585.2
6	36	60	5	4	554.7	553.5	554.1	553.5	557.2
9	23	60	7	4	557.5	550.8	552.3	550.8	582.2
4	29	60	8	4	593.4	590.1	591.6	590.4	609.0

HYDRAULIC HEADS IN THE GRAND CENTRE FORMATION AQUIFER,
COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
4	2	60	9	4	631.2	630.3	630.9	629.7	631.2
13	1	60	11	4	620.9	613.6	614.2	612.3	614.5
4	8	60	11	4	639.2	634.0	638.3	635.2	641.3
9	9	60	11	4	621.5	620.6	621.2	620.6	620.3
13	34	60	12	4	617.2	608.1	609.6	608.4	617.2
13	22	60	14	4	675.7	673.0	676.7	674.2	677.6
8	35	60	14	4	670.0	668.4	666.9	665.4	670.6
8	5	60	15	4	669.3	666.0	667.5	666.0	673.6
5	17	60	15	4	673.6	671.5	673.6	671.5	683.7
1	31	60	16	4	664.5	653.8	655.3	653.8	658.4
13	20	60	17	4	629.4	618.4	620.0	618.4	622.7
2	18	61	1	4	532.8	530.0	531.9	530.4	540.4
4	19	61	8	4	580.6	576.4	577.6	576.4	582.8
16	6	61	9	4	627.6	620.0	623.0	621.8	637.6
13	7	61	9	4	602.0	600.2	600.5	600.2	623.3
16	14	61	9	4	597.4	576.7	582.2	576.7	597.4
12	19	61	11	4	625.1	623.0	624.5	623.0	626.4
8	9	61	12	4	604.7	602.0	603.5	602.0	609.0
16	33	61	14	4	623.6	622.1	623.6	622.1	649.2
12	9	61	17	4	670.3	667.8	670.3	667.8	669.6
3	12	62	1	4	543.2	539.8	542.8	539.8	554.7
13	36	62	2	4	548.6	543.2	545.6	544.1	557.5
1	21	62	7	4	558.7	548.6	553.2	552.0	571.5
2	8	62	9	4	606.9	604.7	605.9	604.7	610.2
13	9	62	14	4	687.0	685.5	686.4	686.1	688.5
1	16	62	14	4	646.8	645.3	646.5	646.2	652.3
1	21	63	6	4	541.9	537.7	541.0	539.8	545.6
13	23	63	6	4	554.7	549.6	551.7	550.2	566.9
8	2	63	7	4	561.7	550.2	552.9	551.4	557.5
16	12	63	7	4	561.7	557.2	558.4	557.2	560.8
3	6	63	9	4	601.4	596.5	598.0	596.5	604.1
4	14	63	15	4	567.8	561.1	567.8	565.4	567.8
3	33	63	15	4	624.5	623.6	624.2	623.9	624.5
13	13	63	17	4	632.8	631.2	632.8	631.2	658.4
9	21	64	7	4	619.4	588.0	589.8	583.6	602.0
4	28	64	14	4	615.7	605.6	607.5	607.2	617.2
13	32	64	15	4	570.6	566.9	570.0	566.9	574.5
16	19	64	16	4	561.4	554.1	556.9	555.3	567.5
13	11	64	17	4	614.8	613.3	614.2	613.3	627.9
3	13	64	17	4	606.9	604.1	606.2	605.9	615.1

HYDRAULIC HEADS IN THE GRAND CENTRE FORMATION AQUIFER, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		HYDRAULIC HEAD (m amsl)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM	
16	16	64	17	4	605.3	600.8	603.8	602.3	609.6
10	25	64	17	4	608.4	598.0	600.8	599.2	607.5
10	26	64	17	4	605.3	597.1	599.8	598.3	604.1
15	26	64	17	4	604.1	598.9	600.5	598.9	603.8
10	27	64	17	4	605.0	601.4	602.9	601.4	607.5
12	36	64	17	4	601.7	554.7	558.4	556.9	602.6
14	7	65	11	4	593.1	590.7	594.1	591.3	597.1
9	18	65	13	4	580.6	573.3	576.1	574.5	581.9
1	24	65	14	4	569.1	566.3	567.2	566.9	571.5
5	30	65	14	4	584.6	571.5	580.0	572.4	579.7
12	8	65	16	4	581.6	580.0	581.6	580.0	599.2
13	8	65	16	4	566.9	565.4	566.9	565.4	594.7
2	18	65	16	4	588.6	583.7	585.2	583.7	608.1
4	36	65	16	4	566.3	564.5	566.0	564.5	591.3
1	7	65	17	4	621.5	605.9	608.1	606.6	626.1
8	21	65	17	4	615.1	609.6	610.2	609.9	617.8
1	35	66	14	4	550.2	525.8	528.2	525.8	540.4
15	8	66	15	4	549.2	545.0	546.5	545.0	570.9
1	26	66	15	4	561.1	559.9	560.2	559.9	568.5
12	34	66	17	4	602.6	598.6	600.2	598.6	613.6
16	17	67	17	4	585.2	574.5	576.1	574.5	594.4
9	3	68	10	4	622.1	619.0	621.8	620.3	629.4
11	17	68	14	4	560.8	559.0	560.8	559.6	570.0
13	24	68	17	4	585.2	576.1	579.1	576.1	588.9

Table P-h-11

INTERPRETED HYDRAULIC PARAMETERS FOR WELL TEST AND AQUIFER TEST DATA
MURIEL LAKE FORMATION, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		OBSERVATION WELL DISTANCE (m)	HYDRAULIC CONDUCTIVITY (m/s)	TRANSMISSIVITY (m**2/s)	STORATIVITY	20 YEAR SAFE YIELD (m**3/s)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM					
16	15	56	4	4	538.3	533.7				0.910E-05	0.420E-04		
16	15	56	4	4	541.0	535.8				0.390E-05	0.200E-04		
16	28	60	1	4	521.8	516.6	522.1	518.2		0.970E-03	0.500E-02		0.50E-02
1	26	60	8	4	531.7	522.1	528.9	529.3		0.730E-02	0.700E-02		
5	36	61	3	4			507.2	505.7			0.310E-04		
1	32	61	4	4	499.0	482.5	499.0	494.1	30.5	0.280E-03	0.400E-02	0.370E-03	0.51E-01
16	5	61	6	4	519.8	518.0	519.7	518.4		0.890E-04	0.160E-03		0.83E-03
4	19	61	6	4	514.5	507.2	508.4	507.2		0.560E-04	0.410E-03		0.56E-02
12	21	62	1	4	484.9	479.1	480.4	479.1		0.120E-04	0.740E-04		0.54E-02
16	10	62	1	4	490.4	483.1	484.3	483.1		0.300E-04	0.220E-03		0.41E-02
13	20	62	3	4	514.8	511.8	514.8	511.8		0.310E-03	0.290E-02	0.330E-03	0.15E-02
2	33	62	3	4			475.8	472.7			0.150E-01		0.15E-01
9	36	63	11	4			515.7	514.2			0.130E-03		0.21E-02
9	1	65	4	4	518.1	509.0	518.6	507.1		0.140E-04	0.130E-03		0.62E-01
8	7	66	5	4	531.0	523.1	531.3	523.7		0.140E-03	0.160E-02	0.390E-03	0.29E-01
6	10	66	5	4	565.5	532.3	548.1	532.3	106.1	0.770E-04	0.180E-02	0.140E-04	
6	10	66	5	4					125.0	0.180E-03	0.410E-02	0.260E-03	
6	10	66	5	4					150.0	0.200E-03	0.460E-02	0.420E-03	
6	10	66	5	4					2924.0	0.950E-04	0.220E-02	0.550E-03	
6	10	66	5	4					3829.0	0.160E-03	0.370E-02	0.160E-02	
6	10	66	5	4					4950.0	0.120E-03	0.270E-02	0.440E-04	
5	15	67	13	4	508.5	502.9	507.8	506.6		0.420E-06	0.230E-05		0.30E-04
3	28	67	17	4	527.9	515.7				0.370E-03	0.450E-02		

Table P-h-12

INTERPRETED HYDRAULIC PARAMETERS FOR WELL TEST AND AQUIFER TEST DATA
BONNYVILLE FORMATION, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		OBSERVATION WELL DISTANCE (m)	HYDRAULIC CONDUCTIVITY (m/s)	TRANSMISSIVITY (m**2/s)	STORATIVITY	20 YEAR SAFE YIELD (m**3/s)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM					
7	18	55	4	4	585.8	553.2					0.330E-02		
9	22	56	11	4	580.6	571.5				0.670E-05	0.610E-04		
6	26	56	11	4	570.3	560.8				0.260E-04	0.240E-03		
15	7	57	2	4	576.1	574.5				0.190E-04	0.290E-04		
8	8	57	2	4	566.0	562.0				0.100E-05	0.400E-05		
3	17	57	2	4	585.5	583.4				0.190E-03	0.420E-03		
5	35	57	12	4	595.0	573.0				0.390E-05	0.850E-04		
3	2	58	16	4	601.4	590.4				0.240E-04	0.270E-03		
1	35	59	11	4	594.4	589.5	592.5	590.1		0.190E-04	0.910E-04		0.72E-03
13	34	59	13	4	606.5	598.9	601.4	600.2		0.220E-03	0.170E-02		0.30E-02
4	24	63	11	4	546.5	543.8	545.9	544.7		0.130E-03	0.340E-05		0.17E-02
16	33	63	11	4			549.6	548.3			0.500E-03		
9	3	68	10	4	622.1	619.0	621.8	620.8		0.980E-04	0.300E-03		0.12E-02

Table P-h-13

INTERPRETED HYDRAULIC PARAMETERS FOR WELL TEST AND AQUIFER TEST DATA
ETHEL LAKE FORMATION, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		OBSERVATION WELL DISTANCE (m)	HYDRAULIC CONDUCTIVITY (m/s)	TRANSMISSIVITY (m**2/s)	STORATIVITY	20 YEAR SAFE YIELD (m**3/s)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM					
15	8	57	2	4	590.7	581.3				0.120E-04	0.110E-03		
15	20	59	6	4	585.2	584.0	585.3	584.1		0.130E-04	0.160E-04		0.38E-04
5	9	59	11	4			581.6	578.5			0.190E-04		
16	21	60	1	4	533.4	531.9	534.9	530.3		0.270E-02	0.410E-02		0.17E-01
1	26	60	8	4	550.2	545.9	547.7	546.2		0.150E-02	0.650E-02		
4	17	61	6	4			535.8	531.3			0.320E-04		0.15E-03
4	27	62	2	4			510.5	509.3			0.340E-03		
9	10	62	3	4			496.2	494.7			0.880E-03		0.83E-01
4	34	66	15	4							0.140E-04		
10	5	67	4	4	602.0	615.9	612.7	609.7		0.370E-01	0.260E-02		0.37E-01
14	17	68	14	4	555.0	551.7				0.100E-03	0.340E-03		0.15E-02

Table P-h-14

INTERPRETED HYDRAULIC PARAMETERS FOR WELL TEST AND AQUIFER TEST DATA
SAND RIVER FORMATION, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		OBSERVATION WELL DISTANCE (m)	HYDRAULIC CONDUCTIVITY (m/s)	TRANSMISSIVITY (m**2/s)	STORATIVITY	20 YEAR SAFE YIELD (m**3/s)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM					
16	26	56	9	4	618.4	616.0				0.150E-03	0.370E-03		
1	17	60	1	4							0.970E-02		0.65E-02
13	16	60	16	4							0.110E-04		
15	32	61	2	4			630.0	528.5			0.340E-02		
5	24	67	17	4	552.6	541.0				0.510E-03	0.590E-02		
9	24	67	17	4	552.6	544.4				0.840E-04	0.690E-03		
13	24	67	17	4	552.3	549.8				0.980E-04	0.240E-03		

Table P-h-15

INTERPRETED HYDRAULIC PARAMETERS FOR WELL TEST AND AQUIFER TEST DATA
GRAND CENTRE FORMATION, COLD LAKE STUDY AREA

LOCATION					AQUIFER ELEVATIONS (m amsl)		COMPLETED INTERVAL ELEVATIONS (m amsl)		OBSERVATION WELL DISTANCE (m)	HYDRAULIC CONDUCTIVITY (m/s)	TRANSMISSIVITY (m**2/s)	STORATIVITY	20 YEAR SAFE YIELD (m**3/s)
LSD	SEC	TP	R	M	TOP	BOTTOM	TOP	BOTTOM					
5	23	60	12	4							0.150E-04		

Table P-h-16
INTERPRETED HYDRAULIC PARAMETERS FOR THE BRONSON LAKE AQUITARD, COLD LAKE STUDY AREA

LOCATION					AQUITARD ELEVATION (m) (m)		VERTICAL HYDRAULIC CONDUCTIVITY (m/s)	LEAKAGE FACTOR (m)	DISTANCE FROM PUMPING WELL (m)
LSD	SEC	TP	R	M	Top	Bottom			
1	26	60	8	4	519.51	507.02	9.29E-09	2670.0	80.0
1	26	60	8	4	519.51	507.02	6.76E-09	1995.0	798.0
1	26	60	8	4	519.51	507.02	1.29E-08	1650.0	990.6
4	28	61	4	4	486.46	475.18	3.32E-07	396.2	59.4
4	28	61	4	4	486.46	475.18	1.46E-07	548.6	1371.6
4	19	62	5	4	501.90	485.55	2.30E-09	6400.0	190.0
4	4	63	8	4			2.70E-08	406.4	30.5
6	3	63	8	4	479.41	471.79	1.33E-09	2225.0	22.2
12	24	65	2	4	511.88	508.23	1.59E-07	640.1	6.4
12	24	65	2	4	511.88	508.23	7.05E-08		28.3
12	24	65	2	4	511.88	508.23	7.61E-08	809.0	60.6
9	7	66	5	4	550.10	545.84	1.75E-08		17.7
9	7	66	5	4	550.10	545.84	1.79E-08		78.7

Table P-h-17
INTERPRETED HYDRAULIC PARAMETERS IN THE BONNYVILLE (unit 1) AQUITARD, COLD LAKE STUDY AREA

LOCATION					AQUITARD ELEVATION (m) (m)		VERTICAL HYDRAULIC CONDUCTIVITY	LEAKAGE FACTOR (m)	DISTANCE FROM PUMPING WELL (m)
LSD	SEC	TP	R	M	Top	Bottom	(m/s)		
8	32	61	4	4	513.59	498.95	5.90E-08		30.5
6	10	66	5	4	565.51	555.45	1.68E-08	1061.0	106.0
6	10	66	5	4	565.51	555.45	7.0E-09	2500.0	125.0
6	10	66	5	4	565.51	555.45	5.4E-09	3000.0	150.0
6	10	66	5	4	565.51	555.45	1.7E-08	1170.0	2924.0
6	10	66	5	4	565.51	555.45	1.7E-08	1532.0	3829.0
6	10	66	5	4	565.51	555.45	8.2E-11	4950.0	4950.0

HYDROGEOLOGY OF THE COLD LAKE STUDY AREA ALBERTA, CANADA

Data Base: Section 3 - Instrumentation for Hydrogeological Investigations

Open File Report 1996 - 1j

Prepared by
Basin Analysis Group
Alberta Geological Survey
Alberta Research Council
(Project Manager: Dr. Brian Hitchon)

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1985-01-31

ALBERTA
RESEARCH
COUNCIL

DATA BASE

Section 3: Instrumentation for Hydrogeological Investigations

Dr. D.M. Borneuf

PREFACE

This Data Base forms an integral part of the study "Hydrogeology of the Cold Lake Study Area, Alberta, Canada" carried out from 1982-04-01 to 1985-01-31, and jointly funded by the Alberta Research Council and Alberta Environment. It is a reference document most of the information from which is presented in synthesized form in the accompanying Report and Atlas. It effectively represents a hard copy form of new and selected interpreted information present into GWDB as part of this study; as such, both A and B level information is implicitely included. Other than location identification no data is repeated from the ERCB well data file. The information is organized in three sections, as follows:

Section 1: Phanerozoic Data

This includes new stratigraphic picks by ARC staff, the chemical composition and physical properties of formation waters, and the interpreted hydraulic parameters from drillstem tests and cores, all organized by hydrostratigraphic units.

Section 2: Quaternary Data

This includes the logs of shallow boreholes, the chemical composition of shallow groundwater, and the interpreted hydraulic parameters from well tests and aquifer tests, most organized by stratigraphic units.

Section 3: Instrumentation for Hydrogeological Investigations

The first part is an annotated catalogue of manufacturers and the type of equipment they provide; the second is a reference list of papers on methods for measuring and using some relevant hydrogeological parameters.

For Sections 1 and 2 it is important that readers refer to the written Report for information on the techniques used to cull out erroneous data from the vast amount of hydrochemical and hydraulic data originally entered into GWDB; it is the resulting selected and intepreted data which is contained in Sections 1 and 2.

TABLE OF CONTENTS

INTRODUCTION

The aim of this section of the Data Base is to obtain a general idea of which components are available on the market to measure or record specific hydrogeological parameters in the field. Of necessity a literature search had to be initiated as far as methods and techniques are concerned. The work has involved: 1) the gathering of data on instrumentation, 2) contacting instrumentation companies and discussing particular points with them, 3) viewing some equipment in a field situation, and 4) attending seminars about some aspects of instrumentation such as pressure transducers, data acquisition systems.

This section is in two parts: the first part is a catalogue of manufacturers and the type of equipment they provide; it is divided into sections from data acquisition systems to water level sensors. A number of comments on particular products are made throughout the catalogue. The second part is a reference list of papers on methods for measurement and use of some of these parameters.

CATALOGUE OF MANUFACTURERS

Using a very general classification, names of companies, addresses and products offered are listed. The list was compiled using only companies for which some technical documentation on a particular product was available. In some particular cases a large amount of information has been gathered and is available. The data collected often includes a price list dated either from late 1982 or through 1983 or later. In some instances discussion with the manufacturer has taken place.

The general classification used is as follows:

Data acquisition systems
Geophysics
Groundwater and surface water flow measurements
Meteorological instruments
Power
Temperature
Water sampling and special piezometer systems
Water level sensors
General catalogues of products

DATA ACQUISTION SYSTEMS

HANDAR, 1380 Borregas Avenue, Sunnyvale, California, 94086
Representative in Canada - GENEQ Inc., 7878 Est, Rue Jarry,
Ville d'Anjou, Quebec, H1J 1H5
Phone: (514) 354-2511.

Products

Multiple Access Data acquisition systems 540/545A for remote locations:

Wind, wind speed, dew point, solar radiation, barometric pressure, precipitation, temperature.

Data storage: cassette type, modem, transmitters.

IN SITU, 209 Grand Avenue, Laramie, Wyoming, 82070
Phone: (307) 742-8213

Products

S.E. 200 Hydrologic Analysis and Monitoring systems:

Previous teething problems seem to have been solved. This system is a very good candidate for use in aquifer testing programs, it has a printer and screen, and allows field plotting of drawdown or recovery curves for field evaluation. Data can be downloaded into a larger computer system. Basic cost of the system as of end of May 1984, including SE200, HP85 computer, software package, 4 pressure transducers and 1000 feet of cable is $12810 (US). Additional accessories allow extension to 16 channels, expansion memory modules up to 128 K.

S.E. 1000 stand-alone water level data acquisition system:

This system appears to be a very good candidate as a stand-alone data acquisition system and should be evaluated. The basic cost of the SE 1000 data logger is $1995 (US); RS 232 interface, data transfer package, etc. are also available. A series of software packages from Bestpump to Ellsamp, including publicly available software such as Prickett-Lonnquist aquifer simulation, etc. are also available.

SEA DATA CORPORATION through GENEQ (see above)

Products

Data logger model 1250 (salt water environment):

ANALOG DEVICES, P.O. Box 280, Norwood, Massachussetts, 02062

Products

Computer-based measurement and control, made easy
MACSYM 2 Computer (not specialized for groundwater studies)
Signal conditioning

CAMPBELL SCIENTIFIC CANADA CORPORATION, 10429 - 87 Avenue,
Edmonton, Alberta, T6E 2P4
Phone: (403) 439-2771

Products

CR 21 Micrologger; Printer; Sensors: Thermistors, wind speed, pyranometer, soil moisture blocks, tilting bucket raingauges, wetness sensing grid, some potential use for groundwater.

The Cr 21 is used by the Atmospheric Sciences and Terrain Sciences Departments of the Alberta Research Council. A report on the performance of this type of data acquisition system is to appear in the Newsletter of the Computing Department of ARC in the near future. This equipment appears to be of good quality and is quite sophisticated.

CR 5 Digital recorder; Sampling modules; Data transfer and processing
CR 7

CANADIAN APPLIED TECHNOLOGY, Buttonville Airport, 16th Avenue,
Buttonville, Ontario, L3P 3J9
Phone: (416) 297-4681.

Products

Stream flow
Water levels Series 2200 data acquisition: This is an expensive type

of equipment.

ENVIROLABS INC., 626 Sonora Avenue, Glendale, California, 91201
Phone: (213) 240-2666

Products

Data systems and peripheral equipment for environmental sciences:
Data logger with printer Model DL 120 MCP
Environmental data logger Model DL 110
Pressure transducer Model PT 105 V
Analog data converter AC 116
Stage transmitter
Pressure monitor
Flow and water level detector
Temperature logging systems

SINCO, 3668 Albion Place North, Seattle, Washington, 98103
Phone: (206) 633-3073

Products

Electrical piezometer system, 564 series:
Continuous monitoring
Pump test monitoring measurements by remote sensing

MOW-TECH, 10704 - 181 Street, Edmonton, Alberta
Phone: (403) 484-6356
This equipment is not really designed for sale.

Products

Water well monitoring equipment:
Aquifer testing: data acquisition system, microcomputer based, pressure transducers +$3000 (CDN).

This equipment was designed only for the needs of Hydrogeological Consultants Ltd. for aquifer testing. It is composed of a microcomputer which is used as a controller to start the pump, to take the transducer readings, print them on a printer, etc. There is no memory available; the only memory function for data acquisition is the printed data. Steps are being taken to add some kind of memory in the future (1984).

The pressure transducers used in this system are very expensive; in the order of $3000 each. Signal conditioning has been added to the original pressure transducer and repackaged in a rugged stainless steel case. The whole system can run on its own.

LAKEWOOD ENGINEERING LTD., 9119 - 39 Avenue, Edmonton, Alberta

Products

Data acquisition system: composed of a stand alone unit, a smart SHARP micro computer with memory blocks. Literature and prices are available. The equipment is manufactured in Edmonton.

The system comprises:

1. A SHARP 1500 microcomputer, modified to increase the internal memory up to 16K bytes;
2. An in-situ data collecting unit with up to 8 input lines with various internal memory configurations, from 8 to 32K bytes of RAM memory;
3. Memory pods, from 8 to 32K bytes of memory with their own internal power supply;
4. Interface to dump data from memory pod to host computer with RS 232.

The data is accumulated in the in-situ unit. The data can be recoverd when the in-situ unit is connected to the SHARP microcomputer, and a data pod whose memory capability has to match that of the in-situ unit (at least the same but not smaller) is plugged into it. Using commands on the microcomputer, the data from the in situ unit is dumped in the data pod. The in-situ unit can continue data logging in the meanwhile. The data pod can then be removed and carried to where data can be dumped in the main computer. To do so, an interface and the data pod are connected to the host computer; data recorded on the data pod are then dumped in the host computer.

This type of equipment is ideally suited to aquifer testing; it also has applications for short or long term data acquisition. One added advantage of this equipment is that it is available in Edmonton, thus reducing downtime.

One important drawback of this system is the lack of groundwater related software; it would be more difficult to use than the In Situ SE 200. A lot of software may need to be developed before the system is fully usable.

Other options include radio-transmission modules, modems, etc.

The Surface Water group (ARC) has purchased several of these units for their 1984 field work period.

OMNIDATA INTERNATIONAL, P.O. Box 3489, Logan, Utah, 84321
Phone: (801) 753-7760

Products

Model 516 polycorder, electronic notebook and data logger:
Datapod (miniature data logger).

Following is a short write up which appeared in the ARC Computing Newsletter in August 1983.

> " The Polycorder - An Electronic Notebook for Field and Lab Studies.
>
> The Soils Department is currently experimenting with a relatively new research tool designed to facilitate data collection and entry into computer systems. The Polycorder is described as being a portable data collection system that accepts keyboard entry of visually observed data and scans voltages and digital signals for a variety of scientific instruments. Featuring a 21 key alphanumeric keyboard and an environmentally sealed case, the Polycorder is a durable and flexible field tool. It can function as a remote data logger, can be used for keying in of data, or real-time data collection in the laboratory. An internal programming language is used to facilitate calculations and data manipulation prior to computer entry. Interface with the computer is accomplished through the RS 232 serial I/O port at rates from 300 to 19200 baud. Several models are available

> based on the size of the memory which ranges from 4K to 16K bytes.
>
> Applications being studied by the department are the collection of soil survey data in the field, data collection in the laboratory and interfacing the Polycorder with data base management systems available at ARC and the University of Alberta. Preliminary work with the instrument indicates that operation is simple and straightforward. Staff are able to become familiar with formatting and operating the Polycorder in one working day. Data transfer has been shown to be quick and clean using normal terminal setups or an acoustic coupler from remote locations. Real savings in man hours spent coding and keypunching data are expected to be realized. The time from data collection to manipulation can be reduced from months to days making the researcher more effective and cost efficient..."

NOTE: This equipment has 10 single ended or 5 differential inputs; it may not have enough internal memory for some applications. It can be used as a stand alone data acquisition system at a remote site. The maximum memory available is 16K bytes.

This company also offers one or two channel recorders called the DATAPODS, for events, rain gauges, temperature/voltage, stream gauge, soil moisture/solar radiation, etc. One problem with this type of equipment is that memory is in UV erasable chip which can be physically removed for data retrieval. In cold weather environments this does not seem to be very practical in regard to chip contacts that can be bent out of shape very easily!

PETUR USA, INSTRUMENT COMPANY, INC., 19023 - 36 Avenue,
W. Lynnwood, Washington, 98036
Phone: (206) 774-9191.

<u>Products</u>

Groundwater monitoring system:
Totally automated, pneumatic or electric sensors, accuracy to 0.1%, range 67 m water standard, other ranges available, real time clock; 5 second to 24 hour readings, thermal printer standard, RS 232 hookup.

GENEQ INC. - see address above

Products

A complete source for environmental instrumentation, from meteorological instrumentation to hydrological, hydrogeological instrumentation, including automatic and remote data acquisition systems.

WEIR-JONES ENGINEERING CONSULTANTS LTD.,
107 - 2003 McKnight Boulevard N.E., Calgary, Alberta, T2E 6L2
Phone: (403) 276-5044

TERRASCIENCE SYSTEMS LIMITED, same address

Products

Monitoring programs and data collection:

System 800 Data Acquisition System, Intelligent Field Data Acquisition System, low power, CMOS technology, up to 32 sensors of varied types, serial communication port RS 232, data cassette digital tape recorder (optional), provides signal conditioning, wide operating range -40 to +70 D.C. local calculation of engineering units, real-time clock. On board storage of up to 48K bytes and a data cassette recorder are also available.

Tiltmeters in various configurations

Pressure transducers

Thermistor string assemblies in any configuration

Cables, designed for hostile environments, from light to heavy duty.

METEOR COMMUNICATIONS (CANADA) CORPORATION, 830B Pembroke Street,
Victoria, British Columbia, V8T 1H9

Products

Meteor burst communication system:

A basic meteor burst communication system consists of a master and a number of remote data acquisition and/or communication terminals.

The system is completely self-supporting and contains all the necessary communications and computer equipment to provide reliable, error free operation on a continuous basis.

"It is based on the predictable reflection of radio waves by the billions of meteors entering the Earth's atmosphere every day. The maximum length of a single-hop link is about 2000 km, a distance determined by the height of the meteor burn-up region and the curvature of the earth. The quality of transmission is not affected by atmospheric disturbances. Operating costs are significantly lower than for a commercial satellite system. Transmissions over the system cannot be intercepted or jammed due to the unique transmission path used by each individual transmission."

Meteor Burst Communication Network Ltd. provides a radio common-service based in Victoria, which covers the four western provinces with a radius of 2000 km from Victoria.

Remote terminals prices range from $6000 to $10,000 (CDN).

APPLIED INSTRUMENTATION CORP., 10451 Shellbridge Way,
Richmond, B.C., V6X 2W8
Phone: (640) 270-4174

Products

The "SCOUT" compact, battery powered, computer suitable for unattended measurement, recording and control at remote sites. Very low power consumption of the Scout permits 3 months of stand alone, continuous monitoring of multiple sensors.

Capabilities with compatible sensors include measurement of pressure, temperature, displacement, strain, flow, precipitation, and other common hydrological, geotechnical and meteorological variables. Internal memory of up to 64K bytes is available. The system can run various application programs. It has a built-in RS 232 communication interface.

SARASOTA AUTOMATION INC., 1500 N. Washington Boulevard,

Sarasota, Florida, 33577
Phone: (813) 366-8770
This equipment is manufactured in England by DVW Microelectronics Ltd.

Products

HUSKY: Portable computer for outdoor use, interfaces with electronic instruments, measuring devices.

This machine is available with 16, 32, 48, 64, 96, 144K bytes of internal memory. The price, in US funds, ranges from $2845 for the 16K machine to $6515 for the 144K machine. Software is available from the manufacturer; it also has bar code facilities.

RADIO SHACK

Products

Stand alone TRS80 microcomputer:

This can be used for data acquisition in the field for observations that are repetitive. With 32K of memory, the computer costs $1000 (CDN). It has a built-in modem which allows transfer of data onto a larger computer via telephone lines. It is powerful enough to do some data manipulation with appropriate programs; a data cassette recorder is also available; it is slower than most recorders. It is not as rugged as the Polycorder for example; however, it has other advantages such as a full size keyboard, and it can be used as a remote terminal. A word-processor is also available. It is not sealed like the Polycorder, and hence can suffer in rain.

TAURUS COMPUTER PRODUCTS, 89 Queensway West, Suite #330,
Mississauga, Ontario, L5B 2V2
Phone: (416) 273-5242

Products

Used in conjunction with a P.C. permits the conversion of P.C. into data acquisition and control systems. It comes with 16K bytes system eprom 2K bytes system RAM, and 32K bytes of user expansion space.

GEOPHYSICS

BISON INSTRUMENTS INC., 5708 W. 36th Street,
Minneapolis, Minnesota, 55416
Phone: (612) 926-1846

Products

Six channel signal enhancement seismograph, Model 1580:
Signal enhancement earth resistivity system, Model 2390:
Earth resistivity meter, Model 2350B:
Twelve channel signal processing seismograph, GeoPro 8012:
Signal enhancement seismograph, Model 1570C:
Logging systems (McPhar): Multilog 3:

JOHNSON-KECK GEOPHYSICAL INSTRUMENTS

Products

Electric logger, Model DR74:
Digital temperature logger, DTM 75-D:
Hole caliper system, HC-70:

SINCO, 3668 Albion Place North, Seattle, Washington, 98103
Phone: (206) 633-3073

Products

Digitilt Tiltmeters (horizontal or vertical tilt)
Digitilt (LCD) indicators
Digitilt Inclinometers
Digitilt Mag-tape
Digitilt Recorder processor printer

GROUNDWATER AND SURFACE WATER FLOW MEASUREMENT

BESTOBELL CANADA LTD., 15619 - 112 Avenue, Edmonton, Alberta, T5M 2V8
Phone (403) 452-3941

Products

A500 ultrasonic flowmeter.

BLUE WHITE INDUSTRIES, 14931 Chestnut Street,
Westminster, California, 92683
Phone: (714) 839-8529

Products

Flowmeters: Pitot type, maximum discharge $7.4 \times 10^{-2} m^3/s$; flow through type meters, discharge measurement up to $1.2 \times 10^{-3} m^3/s$

DELAVAL TURBINE CANADA LTD., 6845 Rexwood Road, Unit #1,
Mississauga, Ontario, L4V 1R2

Products

Flow transducers: measuring up to $6.31 \times 10^{-3} m^3/s$, linearity is + or -1% of full scale output, accuracy is + or -1.5% of full scale output, hysteresis less than 0.5%.

FISHER AND POTER, Warmington, Pennsylvania, 18974

Products

Rotameters:
Magnetic flowmeters:
Turbine flowmeters:
Flowtubes and open channel flow sensors, stilling wells:
Parshall flumes:

HALLIBURTON SERVICES, SPECIAL PRODUCTS DIVISION, Duncan, Oklahoma
Represented in Edmonton by Simark Controls Ltd.
Phone: (403) 465-6158

Products

Turbine flowmeters: diameter from 19 mm to 203 mm, and discharge measured from 1.9 x 10^{-3} to 2.5 x $10^{-1} m^3/s$, accuracy is + or-1%, repeatability is + or -0.05%, and temperature range is from -73°C to 100°C.

K-V ASSOCIATES INC., P.O. Box 574, Main Street,
Falmouth, Massachusetts, 02540
Phone: (617) 540-0561
Products
Direct groundwater flow measurement, for shallow applications

GENEQ INC., 7878 Est, Rue Jarry, Ville d'Anjou, Quebec, H1J 1H5
Phone: (514) 354-2511. From Montedoro-Whitney Company
Products
Pipe line and open flow channel flow monitors:
Recorders:
Velocity monitors:

ISCO, P.O. Box 82531, Lincoln, Nebraska, 68501
Represented in Alberta by LEE INSTRUMENT & SUPPLY CO. LTD.,
6923 Farrell Road S.E., Calgary, Alberta, T2H OT3
Phone: (403) 252-4222.
Products
Open channel measuring and monitoring

MONTEDORO-WHITNEY, 2741E McMillan Road, San Luis Obispo, California, 93401
Represented in Edmonton by Canadian Forestry Equipment Ltd.,
17212 - 106 Avenue, Edmonton, Alberta
Phone: (403) 484-6687
Products
Portable water velocity monitor: digital electronic instrument with electromagnetic probe and cable.

METEOROLOGICAL INSTRUMENTS

GENEQ INC., 7878 Est, Rue Jarry, Ville d'Anjou, Quebec, H1J 1H5
Phone: (514) 354-2511

Products

Precipitation gauges

Belfort instrumentation; wind transmitters, wind indicators, recorders, wind vector transmitters, anemometers, event recorders, chart drives, microbarographs, barometers, evaporation stations, evaporation recorders, psychrometers, instrument shelters, hydrothermographs, thermographs, air and dew point, temperature systems, pyranographs, liquid level recorders, rain and snow transmitters

AANDERAA INSTRUMENTS LTD., 560 Alpha Street, Victoria, B.C., V8Z 1B2
Phone: (604) 386-7783

Products

Data collecting instruments for land, sea and air:

Automatic weather stations:

SIERRA-MISCO, INC., 1825 Eastshore Highway,
Berkeley, California, 94710-1998
Phone: (415) 843-1282

Products

Various meteorological sensors

POWER

LENBROOK INDUSTRIES LIMITED, 1145 Bellamy Road,
Scarborough, Ontario, M1H 1H5
Phone: (416) 438-4610
202 - 7003 - 5th Street S.E. Calgary, Alberta
Phone: (403) 253-7433

Products

Most SOLAREX products: photovoltaic panels and associated products:

The Terrain Sciences Department (ARC) owns 3 SX 110 Solarex panels; they provide 17 volts at 6 amps/hr., a regulator is needed before the panel is connected to a battery to avoid overcharging; a diode is also needed to avoid current flow from the battery to the panel in no-light conditions. Two of these panels are connected to two six-volt golf cart batteries (deep discharge type); only two panels keep these batteries permanently charged (this has been going on for a period of six months), while operating a set of instruments with fairly high power requirements.

THE SOLAR POWER CORPORATION
Represented in Alberta by ACCUBUILD INDUSTRIES, 12924 - 146 Street,
Edmonton, Alberta, T5L 2H7 and by
MECHRON ENERGY LTD., 2437 Kaladar Avenue, Ottawa, Ontario, K1V 8B9
Phone: (613) 733-3855

Products

Photovoltaic modules:
Voltage regulators:

WESTRONIC ENGINEERING SALES LIMITED, 7056A Farrell Road, S.E.,
Calgary, Alberta, T2H 0T2
Phone: (403) 253-5585

Products

Most ARCO solar panels and special batteries for photovoltaic applications:

Some of these panels have been installed in Fort McMurray (SWERP); the ones used do not need regulators since they produce 14 volts at 9 amps.

GENEQ INC., 7978 Est, Rue Jarry, Ville d'Anjou, Quebec, H1J 1H5
Phone: (514) 354-2511

Product

"THERMO" Oil Battery, a 30H group Thermo oil battery will retain about 75% of its power at -20C.

NIFE JUNGNER LTD., 80 Barbados Blvd Unit 1, Scarborough, Ontario, M1J 1K9
Phone: (416) 264-3451
4032 Cote Vertu, Montreal, Quebec, H4R 1V4
Phone: (514) 334-9500

Products

Special batteries for photovoltaic applications:

TEMPERATURE

YELLOW SPRING INSTRUMENT INTERNATIONAL INC.,
Box 279, Yellow Springs, Ohio, 45387
Phone: (513) 767-7242

Products

YSI Scientific temperature instruments, thermistor temperature probes, electronic thermometers.

ENVIRO LABS INC., 626 Sonora Avenue, Glendale, California, 91201
Phone: (213) 240-2666

Products

Temperature logging systems:
Digital thermometers:

JOHNSON (see address above)

Products

Temperature logging systems:

RYAN INSTRUMENTS, INC., a Peabody Company,
P.O. Box 599, Kirkland, Washington, 98033
Represented in Edmonton by CANADIAN FORESTRY EQUIPMENT LTD.,
17212 - 106 Avenue, Edmonton, Alberta
Phone: (403) 484-6687

Products

RYAN Model J Portable Waterproof Thermograph: For unattended operation for up to 180 days, for water or ambient air temperature.

Accuracy: Time: The greater of + or -0.5% elapsed time or + or -1 hour.

Temperature: + or -2% full scale

Operation is with one C cell battery, sprocket drive of chart geared to a miniature stepping motor powered by CMOS IC, and timed by a quartz crystal oscillator.

TERRASCIENCE SYSTEMS LTD., #107, 2003 McKnight Boulevard N.E.,
Calgary, Alberta, T2E 6L2
Phone: (403) 276-5044

Products

Thermistor strings in various configurations:
Data acquisition systems: see Weir-Jones Engineering

WATER SAMPLING AND SPECIAL PIEZOMETER SYSTEMS

ATLANTIC SCREEN INC., Road 5, Box 70, Georgetown, Delaware, 19947
Phone: (302) 856-2126

Products

Plastic well screens and strainers, monitoring well products:

GEOENGINEERING INC., 390 Morris Avenue, Denville, New Jersey, 07834
Phone: (201) 625-0700

Products

Water samplers:
Piezometers:
Sampling pump:

GEOTECH ENVIRONMENTAL EQUIPMENT INC., 1441 West 46 Avenue, Unit #10,
Denver, Colorado, 80211
Phone: (303) 433-7101, 433-9278

Products

Small diameter well pump:
Peristaltic pumps:
Sample splitter:
Bailers:

ISCO, P.O. Box 82531, Lincoln, Nebraska, 68501
Phone: (800) 228-4373 - sales; (800) 228-4374 - service
Represented in Alberta by LEE INSTRUMENTS AND SUPPLY CO LTD,
Process Instrumentation specialists, 6923 Farrell Road S.E.,
Calgary, Alberta, T2H 0T3
Phone: (403) 252-4222

Products

High speed samplers: up to 28 samples collected over a period from 1 to 999 minutes.

Surface Water Group (ARC) own one of these samplers.

Water well sampler: small enough to fit a 50 mm well, powerful enough to purge a 46 m well. Ideal to sample wells for groundwater contamination. A compressed gas bottle or a compressor activates a bladder-type pump. The bladder is manufactured of silicone rubber. Samples contact only polycarbonates, medical-grade silicone rubber, teflon, etc. Flow rates are up to $1.3 \times 10^{-5} m^3/s$. For shallow well application (up to 8 m deep) the company (ISCO) also offers a battery operated portable pump.

SLOPE INDICATOR COMPANY, Seattle, Washington, 98103
Phone: (206) 633-3073

Products

Piezometer systems (packer piezometer system):
Pneumatic water sampler:

FULTZ ENTERPRISES, R.D. 2, Box 381, Lewiston, Pennsylvania, 17044
Phone: (717) 248-2300

Products

Portable groundwater sampling pump. Model SP-201: Lift is from $1.1 \times 10^{-4} m^3/s$ (US) at 6 m to $1.5 \times 10^{-5} m^3/s$ at 53 m. It is available in a back-pack arrangement, and includes the pump, discharge hose, power pack hose reel. It comes with 30.5 m hose, the power supply allows 4 hrs of pumping. The pump materials are stainless steel and teflon. The diameter of the pump is 63 mm.

INDUSTRIAL & ENVIRONMENTAL ANALYSTS INC., P.O. Box 626,
Essex Junction, Vermont, 05452
Phone: (802) 878-5138

Products

Sampling pumps: Lift capacity of up to 76 m; 4.4×10^{-5} to $9.5 \times 10^{-5} m^3/s$, small diameter pump.
Syringe samplers: Stainless steel/teflon construction eliminates totally the contact with air, tubing or other organic material.

Allows discrete sample to be taken at any desired depth in water column. Outside diameter is 44 mm, the sample volume is 0.85 L. The price is $1100 (US). Other pumps are also available from this company; they range in price from $500 to $2100 (US) depending on the materials used in the manufacturing of the pump and in the maximum lift that the pump can offer.

WESTBAY INSTRUMENTS, 265 - 25th Street, West Vancouver, B.C., V7V 4H9
Phone: (604) 926-8541 - office; (604) 926-5667 - residence.

Products

Piezometer systems: head measurements
Piezometer systems: ground water sampling
Piezometric permeability profiler:
MP system is all the above: it is also available in stainless steel when pvc is not good enough for sampling purposes.
Modular monitoring system:

This is a beautifully made instrument; it is, however, delicate and is expensive to purchase; ancillary equipment such as pressure transducers, readers, etc. are also quite expensive.

Another piezometer system not marketed, but which can be built from relatively unexpensive materials, is described in a paper by J. Cherry and P.E. Johnson (1982): A multilevel device for monitoring in fractured rocks in Groundwater Monitoring review, summer 1982. This system can be built relatively easily from material available almost anywhere; it also appears simple and it has been used in Canada at AECL testing sites.

JOHNSON-KECK, P.O. Box 43118, St. Paul, Minnesota, 55164
Phone: (612) 636-3900

Products

Submersible sampling pump for 50 mm piezometers: Self contained, with its own power (battery pack). One of these pumps is used in a Terrain Sciences Department project.

GENEQ INC., 7878 Est, Rue Jarry, Ville d'Anjou, Quebec H1J 1H5
Phone: (514) 354-2511

Products

The Barclad multi-level groundwater sampling system:
Portable water quality monitor (from Montedoro-Whitney Company):
Conductivity meters:
Dissolved oxygen meters:
Solar illuminance meters:
pH meters:
Thermometers:
Turbidity meters:
Complete water quality monitoring systems:

Q.E.D. ENVIRONMENTAL SYSTEMS, INC., 1254 N. Main Street, P.O. Box 7209,
Ann Arbor, Michigan, 48107
Phone: (313) 995-2547

Products

Groundwater sampling: WELL WIZARD: compressed air bladder-type pump, made of pvc or teflon, very few moving parts, lockable tamper proof cap. Maximum flow rate of the pump is $3.8 \times 10^{-5} m^3/s$ at 75 m; maximum lift is 70 m. This system uses compressed air from bottles or compressor to actuate the bladder pump.

A well field can be converted to the state-of-the-art dedicated monitoring system for $375 (US) per well.

Driver-controller:
Static head indicator:

MARTEK INSTRUMENTS, INC., P.O. Box 16487, 17302 Daimler Street,
Irvine, California, 92713
Phone: (714) 540-4435

Products

Process water quality monitoring systems:
Water quality monitor Mark 10, Mark 6, Mark XIV Borehole water quality monitor, in situ measurements of temperature, pH, dissolved oxygen, conductivity, temperature-corrected conductivity or salinity, in fresh or sea water bodies: 114 mm in diameter, some sensors are 50 mm in diameter. Mark VI is $10,900 (US), Mark X is $3570 (US), Mark XIV is $5715 (US).
Water quality Analyser Mark 5:
Water quality Data Logger Mark 8:
Conductivity-Temperature Analyzer:

MONTEDORO-WHITNEY, 2741E McMillan Road, San Luis Obispo, California, 93401
Represented in Edmonton by Canadian Forestry Equipment, Ltd.,
17212 - 106 Avenue, Edmonton, Alberta
Phone: (403) 484-6687

Products

Portable water quality analyzers with programmable Digital data logger: Measurement of six parameters such as: dissolved oxygen, pH, temperature, depth, conductivity, and specific ion.
Other water quality meters: conductivity, salinity, dissolved oxygen, temperature.

OIL RECOVERY SYSTEMS, INC., Mill Street, Greenville, New Hampshire, 03048
Phone: (603) 449-5222

Products

Sampling equipment to extract a liquid cut from the surface or within the liquid from monitoring wells, at settling ponds, tanks, sewers, pumps, etc. Sampling is possible to a depth of up to 100 m.

SOILMOISTURE EQUIPMENT CORPORATION, 801 S. Kellog Avenue,
Geoleta, California, 93117

Phone: (805) 964-3525

Products

Suction lysimeters: Three models available, which can sample moisture in the vadose zone.

Model 1900 series of samplers:

Tensiometer systems:

AUTOMATIC LIQUID SAMPLERS LIMITED, Unit 15, The Maltings, Turk Street,
Alton, Hampshire, GU34 1AN, U.K.
Phone: Alton (0420) 87040

Products

Automatic samplers for surface water; may be adaptable to sampling wells.

WATER LEVEL SENSORS

STEVENS WATER RESOURCES PRODUCTS, LEUPOLD & STEVENS, INC., P.O. Box 688,
Dept. M-43, Beaverton, Oregon, 97075
Phone: (503) 646-9171

Products

Water level recorders for variable periods of time, day, week, monthly, six months.

A. OTT GMBH, P.O. Box 2120, Jager str. 4-12 D-8960 KEMPEN
Federal Replubic of Germany
Phone: (0831) 20 59-0

Products

Data acquisition systems for hydrology, meteorology, pollution control

METRITAPE, represented in Alberta by C.D. NOVA INSTRUMENTS LTD.,
#3, 227 - 14 Street N.W., Calgary, Alberta
Phone: (403) 283-2813

Products

Sensors, readers, meters:
Metritube:
Digilevel readouts:
This equipment is bulky; it is probably good for a permanent installation, in a tank for example. It is also relatively expensive.

DRUCK LIMITED, Fir Tree Lane Groby, Leicestershire LE6 0FH, England

Products

Precision transducer systems: relatively inexpensive.
PDCR 10/D: Downhole pressure/level measurement:

Good quality pressure transducers with good resolution, repeatability, low hysteresis, no creep. This company manufacturers pressure transducers specially designed for water-level monitoring.

Terrain Sciences Department has three pressure transducers from this company: PDCR 22 (2) for tensiometer application and PDCR 10/D for water-level monitoring with a maximum water level fluctuation of 10 m.

Another new product has appeared; it is a small bore pressure transmitter, PTX 160/D, the characteristics of the pressure transducer are the same as the PDCR 10, it is only 17.5 mm in diameter and 220 mm in length.

A PDCR 10/D is also available and of the same diameter as the previously mentioned transmitter.

These pressure transducers are encapsulated in titanium, are electron-beam welded, and are for use with liquids that are compatible with titanium and quartz.

Right now these products are available through HOSKIN SCIENTIFIC (WESTERN) LTD., 239 East 6th Avenue, Vancouver, B.C., V5T 1J7
Phone: (604) 872-7894

Operating temperature range is -20 to +30C.

AMETEK CONTROLS DIVISION, represented in Edmonton by:
BRIAN ENGINEERING LTD. INSTRUMENTS, 9259 - 48 Street, Edmonton, Alberta
Phone: (403) 468-2123

Products

Continuous fluid level measurement systems:

Pressure transducers and digital readouts:

ARC owns one of these systems; it is used to measure recoveries in a slug-test set up; a strip chart recorder allows the production of the recovery curve which then can be analyzed.

SENSO METRICS INC., 7775 Kester Avenue, Van Nuys, California, 91405
Phone: (213) 988-6070, represented in Canada by:
JEROME & FRANCIS CO. LTD., 1015 Prospect Avenue,
North Vancouver, B.C., V7R 2M5
Phone: (604) 986-1286

Products

Pressure transducers:

FLUID DATA SYSTEMS, 7370 "S" Opportunity Road, San Diego, California, 92111
Phone: (714) 560-8541

Products

FLUIDGAGE (based on the force balance principle):

This is a very sensitive instrument; it is also quite expensive. For example, for a fluctuation of up to 30 m, the cost is nearly $6000; a water-level recorder can be connected to this sensor to record the data.

SINCO, 3668 Albion Place North, Seattle, Washington
Phone: (206) 633-3073

Products

Water level indicator, model 51453:

BELL & HOWELL, Lennox Road, Basingstoke, Hampshire, RG22, 4AW, England
Phone: Basingstoke (0256) 20244 Research Centre
Represented in Alberta by CANADIAN DYNAMICS NOVA LTD., #3,
227 - 14 Street, N.W., Calgary, Alberta, T2N 1Z6
Phone: (403) 283-8106
and in British Columbia by CD NOVA, 217B East Street 16th Avenue, ???
Vancouver, B.C., V5T 2T5
Phone: (604) 872-8106

Products

Various types of pressure transducers, special applications for groundwater, barometric pressure. The company branch in England is studying a data acquisition system using their sensors; they are talking about using up to 30 sensors at the same time, and mainly for groundwater applications.

An excellent seminar was presented in early 1983 by B&H, with representatives from the U.K. branch and the U.S. branch. A review of pressure transducer technology and principles was presented, then presentation of the company's various pressure transducers was made.

It appeared after this seminar that pressure transducers with very good overall characteristics can be purchased relatively cheaply.

DREXELBROOK ENGINEERING COMPANY, 205 Keith Valley Road,
Horsham, Pennsylvania, 19044
Phone: (215) 674-1234
Represented in Edmonton by SPARTAN CONTROLS LTD., 8525 Davies Road,
Edmonton, Alberta, T6E 4N3

Products

Deep well monitor: Uses a low voltage radio frequency oscillator through a sensing element lowered in the well.

VALIDYNE ENGINEERING CORPORATION, 8626 Wilbur Avenue,
Northridge, California
Phone: (213) 886-2057

Products

Pressure transducers and ancillary equipment:
Thermocouples:

WEIR-JONES ENGINEERING CONSULTANTS LTD., 107, 2003 McKnight Boulevard
N.E.,
Calgary, Alberta, T2E 6L2

Products

Thermistor string assembly:

SIERRA-MISCO INC., Environmental products, 1825 Eastshore Highway,
Berkeley, California, 94710
Phone: (415) 843-1282

Products

Sensors and data acquisition systems, telemetry instruments:

Event-reporting systems: precipitation, liquid level, level sensor, pressure transducers, water level recorders, data transmitters, repeaters, receivers, terminals, printers, barometric pressure sensors, relative humidity sensors, soil-moisture sensors, dew point, solar radiation sensor, rain gauge, snow pillow, antennae.

GENERAL CATALOGUES OF PRODUCTS

1903-1984 HORIZON ENVIRONMENTAL, 7435 North Oak Park Avenue,
Chicago, Illinois, 60648
Phone: (312) 647-7644
Represented in Canada by COMEAU TECHNIQUE LTD., Ltee, Section 3600,
01260 Rue Richmond, Montreal, Quebec, H3K 2H2

1983 MARKSON SCIENCE CATALOGUE

FISHER CATALOGUE

In the 1983 summer issue of GROUNDWATER MONITORING REVIEW a guide to buying monitoring products appeared. It gives a short description of the products offered by each company and their address.

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II DISPERSION AND GROUNDWATER FLOW

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