WOODLANDS COUNTY

PART OF THE ATHABASCA RIVER BASIN
INCLUDES PART OR ALL OF TP. 056 TO 065, RG. 04 TO 13, W5M

REGIONAL GROUNDWATER ASSESSMENT

Prepared for:

In conjunction with:

Prairie Farm Rehabilitation Administration

Administration du rétablissement agricole des Prairies

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES

PAGE

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF APPENDICES

1.0 EXECUTIVE SUMMARY

This report provides an overview of a regional study of the groundwater resources within the southeastern portion of Woodlands County. This study includes an identification of the aquifers within Woodlands County, including the determined extent of each aquifer and a description of the quality and quantity of groundwater available from each aquifer, a review of the hydraulic relationship between aquifers and an evaluation of the risk of groundwater contamination.

This study was completed by creating a database for Woodlands County modified from the Alberta Environment Groundwater water well database. Information from geophysical well logs, licensed well information, digital elevation data and improved well locations from air photos provided by PFRA was used to update and improve the database. Using a GIS program this database was used to produce maps and cross-sections, which portray hydrogeological characteristics of Woodlands County. Additional information from previous geological and hydrogeological mapping studies covering Woodlands County were an integral part of the mapping component.

Woodlands County contains approximately 2592 water wells of record, which are mostly used for stock or domestic purposes. The completion aquifer was identified for nearly ninety percent of these wells. Water wells completed in surficial deposits account for 465 of these wells and are located primarily along the Athabasca and McLeod Rivers and in the northern portion of the County. Upper bedrock aquifers are found in the Paskapoo Formation, Scollard Formation, Edmonton Group, Bearpaw Formation and the Belly River Group.

Chemistry data is available from 913 water well records within the County. Groundwater from surficial and bedrock aquifers are generally of the sodium bicarbonate type and iron rich. Total dissolved solids (TDS) concentrations are typical for Alberta. Fluoride and nitrate concentrations exceed the maximum allowable concentrations recommended by Health Canada for drinking water in some areas of the County and should be monitored in these areas for health reasons. High iron and TDS concentrations may reduce the aesthetic qualities of the groundwater.

There are currently 60 licensed wells in Woodlands County which use a maximum of 4552 m^3/day from surficial and bedrock aquifers. Estimates of groundwater flow available from each aquifer and the unlicensed well consumption indicate that usage from the Upper Scollard and Bearpaw formations may exceed the available resources from these aquifers and mining of these aquifers may be occurring. In addition, usage from the Lower Scollard and Upper and Lower Horseshoe Canyon aquifers is estimated to be at least seventy percent of the available resources in these aquifers. These estimates should only be used as a guideline, but they highlight the necessity of obtaining more accurate information to provide better estimates of the groundwater resources available.

Overall the information available to complete this study is limited and of largely questionable quality. The database could be significantly improved by Woodlands County through the completion of a field verification project and the initiation of a groundwater monitoring program.

The field verification project should obtain the location (latitude and longitude), elevation, depth (mBGL), water level (mBGL) and the casing height (mAGL or mBGL) for all water wells currently listed in the database. For the groundwater monitoring program a minimum of twenty-five wells should be selected to monitor the aquifers within Woodlands County for a period of at least two years prior to proceeding with an update of the groundwater budget included herein. This groundwater monitoring program should be continued for a minimum period of five years. It is recommended that Woodlands County proceed with these efforts prior to any attempt to update the interpretation of this report and the accompanying maps.

2.0 PROJECT OVERVIEW

Regional groundwater studies covering Woodlands County were completed by the Alberta Research Council between 1962 and 1977. Since these studies were completed, over twenty years ago, substantial new data, e.g. from more recent water wells and consultants reports, have been produced for this area. Woodlands County and the Prairie Farm Rehabilitation Administration (PFRA) have recognized the value of reassessing the groundwater resources within this area to incorporate this new information and to make use of new technologies that will render this data significantly more useful for planning, development and management purposes within Woodlands County.

2.1 REPORT CONTENTS

This report provides an overview of this study assessing the groundwater resources within Woodlands County. This report also describes the methodology used in the completion of this study. Page-sized copies of all maps and figures included in this report are provided in Appendix A.

Additional information is provided on the CD-ROM, which accompanies the final version of this report. The CD-ROM contains the geo-referenced and updated groundwater database, all maps and tables prepared during this study and the groundwater query program to facilitate use of the groundwater database. A listing of all the maps and figures included on the CD-ROM can be found in Appendix B. Poster-sized drawings, which visually summarize the findings of this study, will also accompany the final report. These maps are listed in Appendix C.

2.2 PROJECT SCOPE

This project is a regional study of the groundwater resources within Woodlands County. The information contained herein is intended to be used as a guide for planning, management and development purposes. The hydrogeological conditions at specific locations will require field verification.

This regional groundwater assessment includes the following:

- identification of aquifers within the surficial deposits and upper bedrock;
- determination of the spatial extent of each aquifer;
- description of the quantity and quality of groundwater within each aquifer;
- review of the hydraulic relationship between aquifers; and
- evaluation of the risk of groundwater contamination.

3.0 INTRODUCTION

3.1 SETTING

Woodlands County is located in central Alberta within the Athabasca River basin. Only the southeastern portion of Woodlands County was covered in this study (Figure 1). This portion of the County follows mainly the township lines, but also the Athabasca and McLeod Rivers in part. The study area covers part or all of townships 56 to 65 and ranges 4 to 13, west of the fifth meridian. For simplicity, the study area will be referred to as Woodlands County (County) throughout this report.

Land surface elevations within the study area vary from 620 to 1030 meters above mean sea level (AMSL). The elevation generally decreases towards the Athabasca River and towards the northeast end of the study area.

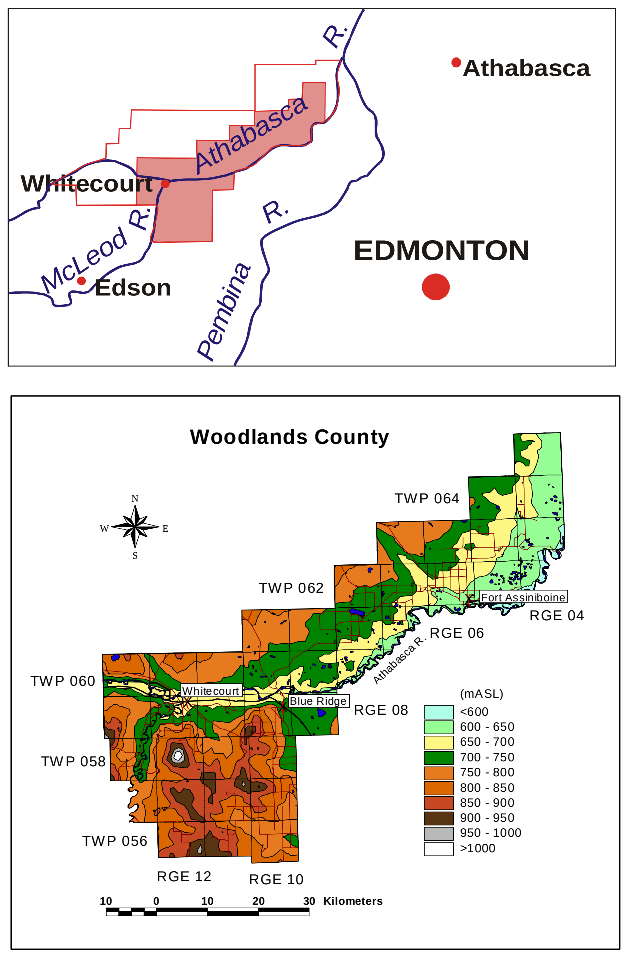


Figure 1. Location Map

3.2 CLIMATE

Based on the Alberta Region Land Classification System, both the Boreal Forest and Foothills Regions are found within the study area. The Foothills region covers much of the western portion of the study area, while the river valley and eastern portion are part of the Boreal Forest region.

The climate of the Boreal Forest region is subhumid, continental with short cool summers and long cold winters. The mean summer (May to September) temperature is around 12^{o}C and there are typically 85 frost-free days a year. The Foothills region also has a continental climatic regime with slightly cooler summers, but warmer winters than the Boreal Forest region, due to less influence by cold Artic air masses.

Precipitation is generally slightly greater in the Foothills region and tends to coincide with the growing season in all areas.

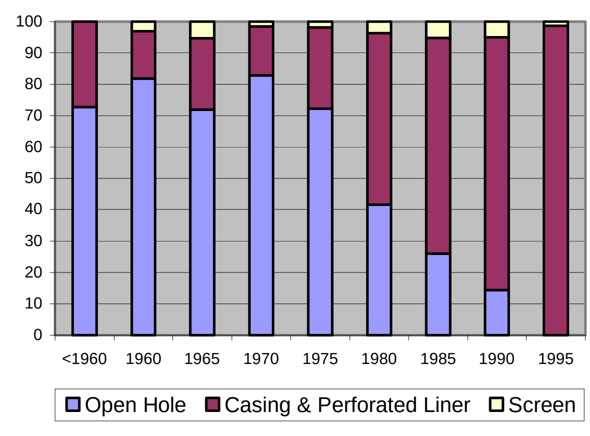
The mean annual precipitation is 514 millimetres based on data from three meterological stations within Woodlands County with data from 1994 to 2000.

3.3 BACKGROUND INFORMATION

There are approximately 2592 water wells in the groundwater database for Woodlands County. Of these, 1788 are used for either domestic and or stock. The remaining 804 wells are used for a variety of uses, such as municipal, industrial and environmental purposes. However the purpose is not reported or else unknown for 185 of these remaining wells. The domestic and stock wells range in depth from 2 to 180 m. Lithological information is available in the database for 1521 water wells.

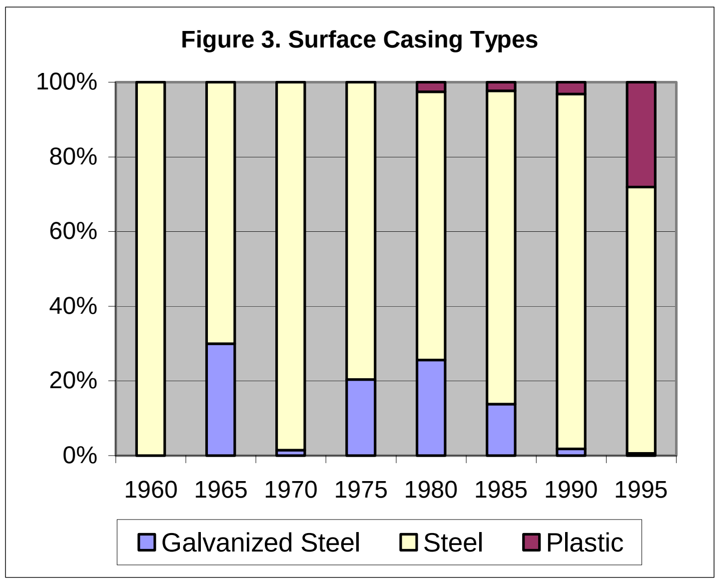
Prior to 1980 most water wells in Woodlands County were completed as open hole over the production zone and surface casing. Since that time the majority of wells have been completed using either perforated casing or a perforated liner over the production zone. This shift has occurred gradually over time as clearly shown in Figure 2. The third major type of well completion is to screen the production zone. This type of completion has shown only small historical and current use in Woodlands County.

Figure 2. Well Completion Description

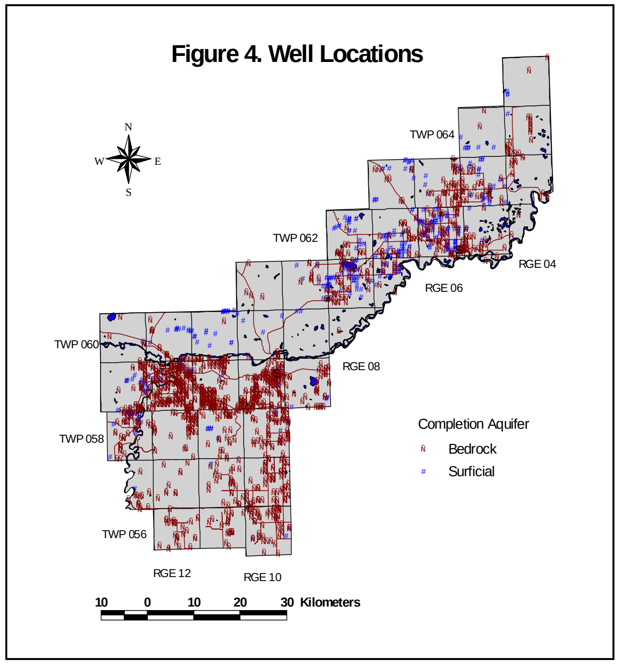


Casing diameter information is only available for 1273 water wells. Of these, 58 water wells have casing diameters greater than 450 mm. These wells are all bored or dug wells, whereas the remaining wells are mainly drilled wells. The actual number of large diameter wells is likely to be considerably higher, since many dug wells are unlikely to have been reported to AE.

A wide range of surface casing materials have been used in water wells in Woodlands County including concrete, wood, fiberglass and stainless steel. The most common types of materials used are galvanized steel, steel and plastic. These three casing types account for more than ninety percent of the total casing usage reported. Steel casing has been, and remains, the most commonly used surface casing in the area throughout the period from 1950 to present (Figure 3). Galvanized steel began to be used in 1966 and typically accounted for 15 to 30 % of surface casing use until 1990. Galvanized steel has been used in only five wells on record since 1990. Plastic surface casing was first used in 1983 and has slowly become more commonly used over time. Between 1995 and 1999, plastic surface casing accounted for nearly thirty percent of surface casing use.

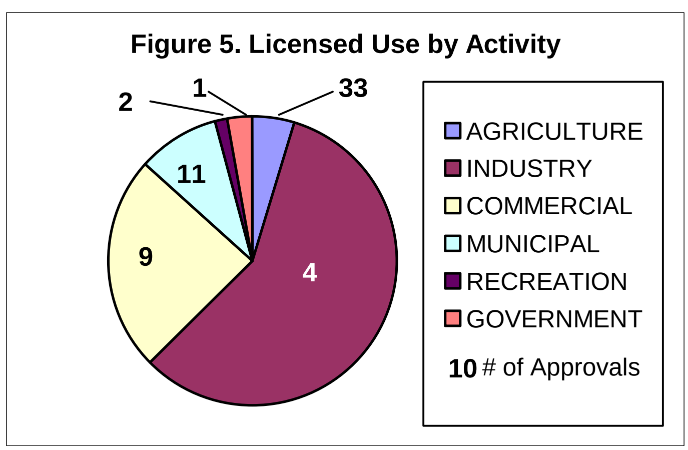


The completion aquifer was identified from information in the water well records for 2317 wells within the study area. Of these, 465 wells are completed within surficial deposits above the bedrock (Figure 4). Most of the wells completed in surficial deposits are located along the Athabasca and McLeod Rivers and in the northern portion of the County.



At present there are only 60 licensed wells within Woodlands County (B-16). The total maximum licensed groundwater diversion amounts to 4552 m^3/day. Industrial use, primarily by the Power Resource Development Corporation, accounts for 58 % of this diversion amount (Figure 5).

Chemistry data is available from 913 water well records, of which 24% are from wells completed in surficial deposits and the remainder from wells completed in bedrock aquifers. Groundwater from both surficial and bedrock aquifers is typically of the sodium bicarbonate type (B-24 and B-32) and iron rich (1.5 mg/L average). Most other parameters, such as fluoride, chloride, sulphate and TDS concentrations, are slightly higher for bedrock than surficial aquifers. TDS concentrations are typically below 850 mg/L for bedrock aquifers and below 650 mg/L for surficial aquifers. Groundwater from surficial aquifers is generally chemically very hard, while groundwater from bedrock aquifers is generally chemically hard. These values are slightly lower than typical values for Alberta.



The chemical groundwater parameters for upper bedrock aquifers are summarized in Table 1 and compared to criteria listed in the Guidelines for Canadian Drinking Water Quality (GCDWQ) (Federal-Provincial Subcommittee on Drinking Water 1999). The GCDWQ criteria listed in Table 1 indicate the aesthetic levels for most of these parameters, i.e. the levels above which the taste, hardness or corrosiveness of the water may become more noticeable. Unlike the others, the criteria listed for fluoride and nitrate indicate the maximum allowable concentration established by Health Canada for health reasons.

Table 1. Upper Bedrock Groundwater Quality in Woodlands County Wells

Parameter	GCDWQ	Minimum	Maximum	% Exceeding GCDWQ
	(mg/L)			
TDS	500	73	3458	66
Sulphate	500	0.07	25	1
Nitrate (as N)	10	0.09	28	1
Chloride	250	0.03	377	1
Fluoride	1.5	0.03	3.5	13
Iron	0.3	0.04	46.8	49

These data indicate that for most upper bedrock groundwaters these parameters generally meet the GCDWQ criteria. The exception to this statement, TDS concentrations were found to exceed the GCDWQ aesthetic criterion in two thirds of the water wells within the County. TDS concentrations in Alberta are expected to range between 195 to 1100 mg/L as a result of the rock types found in the upper bedrock (Federal-Provincial Subcommittee on Drinking Water 1995). Only a few water wells within the County exceed the upper limit of this more realistic range. TDS concentrations above the GCDWQ criterion may not be as palatable or may result in mineral encrustation of plumbing and household appliances.

Iron concentrations exceed the GCDWQ aesthetic criteria in almost half of the water wells in the County. Groundwater with iron concentrations above 0.3 mg/L may be noticeable in taste or iron colouring of the water, which may discolour laundry or plumbing.

Both nitrate (NO_3) and nitrite (NO_2) (not shown in Table 3) are found to exceed the GCDWQ criteria in only a couple of wells completed in upper bedrock aquifers across Woodlands County ($\leq$ 1% of wells) and are not considered to pose a health concern.

Thirteen percent of water wells in the County had groundwater with a fluoride concentration that exceeded the GCDWQ criteria. This is not unusual within Alberta where concentrations as high as 4.4 mg/L have been recorded in drinking water, however, areas with high concentrations should be monitored for health reasons. Areas of concern are mainly east of Whitecourt and also near Fort Assiniboine (B-30). Health Canada indicates a reference concentration of 3.7 mg/L as a guideline for addressing possible health concerns. No upper bedrock groundwaters within Woodlands County were found to exceed this reference concentration.

Water level data is useful for groundwater management purposes. Within Woodlands County there are currently no observation wells operated by Alberta Environment. Some data can be obtained from the monitoring of licensed water wells. However, this is expected to supply very little data relative to the size of the County. Water levels are available from drillers reports for water wells at the time of completion. It is suggested that at the present time this is likely to provide the best readily available water level data for the County.

4.0 METHODOLOGY

4.1 DATA COLLECTION AND SYNTHESIS

The main source of data for this study is the Alberta Environment (AE) groundwater database. This database contains information such as chemistry and drillers reports for some water wells. The latter may include aquifer tests and lithological information.

For this project a square area was selected from the AE groundwater database covering townships 55 to 66 and ranges 03 to 14. All data collection procedures, data quality checking and updating actions described here were applied to records contained in this database. This final database produced as part of this study covers this square area and is included on the CD-ROM accompanying this report. All mapping procedures used this database to develop maps (described below) and, once finalized, the maps were trimmed to reflect the Woodlands County borders. This larger area was selected to minimize edge effects and to incorporate information from adjacent areas, particularly to supplement mapping and interpretations of aquifers with sparse data within the County.

The greatest difficulty with the AE database is the lack of quality control during data collection. Unfortunately very little can be done to correct for this in the current database. Data checking procedures consisted of reviewing the entire database for inconsistencies. For example, where casing depths were recorded as greater than the total depth of the hole, the casing depth was adjusted. This procedure was able to remove these inconsistencies from the database, however there is no mechanism to check the accuracy of data recorded in the database.

The AE database uses the legal land description location for identifying the location of water wells, with only sporadic records containing a ground elevation. In the absence of other locating information, water well records are assigned a location equal to the center of the quarter section or LSD (as available). In the AE groundwater database, well locations defined to the center of the smallest legal land description subdivision can result in the positioning of multiple wells at the same location. This reduces the ability to use the data in the database to its full capacity and requires a correction to avoid this problem. PFRA provided improved locations for water wells in Woodlands County through the re-positioning of water wells based on aerial photographs and subdivision plans. With this improved location information no two wells were recorded as having the same geographical location for Woodlands County and no further corrections were required.

Ground elevations were determined based on digital elevation model data at a scale of 1:250,000 obtained from the Canadian Center for Topographic Information. These data have horizontal spacings of 93 m (N-S) by 65-35 m (E-W). These data spacings are closer than are typically found in smaller scale digital elevation data, e.g. 1:20 000 with 100 m spacing from AltaLis, although the accuracy is not as good. The 1:250,000 scale data sets have an accuracy of 10 m in urban areas and 25 m in rural areas as compared to +/- 5 m for x+y, +/- 3m for z in the 1:20,000 scale data sets. For the purposes of this study, the accuracy of this data set is adequate. For further discussion and details of the elevation data set used, the reader is referred to publications by Geomatics Canada (1996 and 2000).

Once spatial locations have been assigned for each record, additional determinations are made for each record where sufficient information is available. Accordingly the following information is added to the database, where possible:

- depth to bedrock;
- thickness of sand and gravel;
- thickness of saturated sand and gravel;
- presence of sand and gravel within 1 m of surface; and
- top and bottom of completion interval.

The following parameters were calculated and added to the database for well records containing sufficient information:

- apparent transmissivity;
- apparent hydraulic conductivity;
- apparent yield; and
- apparent storativity (approximate only).

The apparent transmissivity was determined from pump test data (where available). The hydraulic conductivity is estimated by dividing the apparent transmissivity by the completion interval. The apparent yield is obtained from the apparent transmissivity and the depth of saturated material above the top of the completion zone.

A table was created containing the tops of geological formations picked from geophysical well logs from oil and gas wells. Geographic locations were assigned to each well and this information was used to obtain geological control across the study area.

All distance measurements in the database were stored as meters and all chemical parameters were converted to mg/L.

4.2 SPATIAL DISTRIBUTION OF AQUIFERS

The stratigraphy used for this study was modified from the geological map of Alberta (Hamilton et al. 1998) and is summarized in Figure 6. This map shows the Bearpaw Formation to pinch out southeast of the study area. Where the Bearpaw Formation is absent, the entire interval of strata of the Edmonton Group plus the Belly River Group is termed the Wapiti Formation. However, for this study, strata within the Wapiti Formation were subdivided into lateral equivalents of formations recognized to the southeast on the basis of correlations from geophysical well logs. This subdivision permits better correlation with adjacent study area, such as the Lac Ste Anne County to the south, provides a more detailed assessment of groundwater resources within the County and will enable more targeted resource management efforts by the County.

Figure 6. Geological Column for Woodlands County

	Group and Formation		Member		Zone	
Lithologic Description	Thickness	Designation	Thickness	Designation	Thickness	Designation
sand, gravel, till, clay, silt	<80	Surficial Deposits	<40	Upper	<30	First Sand and Gravel
			<60	Lower		
sandstone, shale, coal	<800	Paskapoo Formation				
shale, sandstone, coal	60-150	Scollard Formation	40-100	Upper	<2	Upper Ardley Coal Zone
					<20	Ardley Coal Zone (main seam)
					<1	Nevis Coal Seam
			20-60	Lower		
shale, clay, tuff	<25	Wapiti Formation / Edmonton Group (equivalent) / Battle Formation (equivalent)	<0.3	Kneehills Member		
shale, siltstone, sandstone	5-10	Wapiti Formation / Edmonton Group (equivalent) / Whitemud Formation (equivalent)				
shale, sandstone, coal, bentonite, limestone, ironstone	300-380	Wapiti Formation / Edmonton Group (equivalent) / Horseshoe Canyon Formation (equivalent)	<100	Upper		
			<100	Middle		
			<170	Lower		
shale, sandstone, siltstone	60-120	Wapiti Formation / Bearpaw Formation (equivalent)				
sandstone, shale, siltstone, coal	120-330	Wapiti Formation / Belly R. Group (equiv.) / Oldman Formation (equivalent)				
sandstone, shale, coal	70-170	Wapiti Formation / Belly R. Group (equiv.) / Foremost Formation (equivalent)				
shale, silt		Lea Park Formation				

Depth (m): 0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200

A table containing the oil and gas geophysical log information defines the top of each formation at discrete locations. This point data is used to interpolate each surface, i.e. the top of each formation and the elevation of this interpolated surface is stored at regular intervals in a grid file.

4.3 HYDROGEOLOGICAL PARAMETERS

The surfaces which have been created for the top of each geological unit can be used to compare with the completion interval at each well location and identify the aquifer in which each well is completed. For wells which are lacking completion information, but contained casing details the completion interval of the well was assumed to cover the interval from the bottom of the casing to the bottom of the well. If no casing information was supplied for a well, the completion interval was assumed to be equal to one quarter of the depth of the well. It was statistically determined that for most wells the completion interval corresponds to one quarter of the well depth.

In wells where the completion interval spanned more than one aquifer the completion aquifer was designated as the aquifer in which the well was predominantly completed. Thus, the aquifer characteristics determined from this well could be assumed to be reasonably representative of that aquifer. In instances where two aquifers were almost equally contributing to the groundwater production for a given well, the completion aquifer was not defined as the aquifer characteristics would not be representative of either aquifer.

The aquifer parameters and chemical information from all wells completed in a particular aquifer can now be combined and used to create maps illustrating the spatial distribution of these parameters for each aquifer. Information is interpolated, as in the creation of geological surfaces, and grids are created representing the spatial distribution of each parameter in each aquifer.

4.3.1 Risk Criteria

Table 2. Groundwater Contamination Risk Criteria

Presence of Sand or Gravel within 1 m of Ground Surface	Surface Permeability	Groundwater Contamination Risk
No	Low	Low
No	Moderate	Moderate
No	High	High
Yes	Low	Very High
Yes	Moderate	Very High
Yes	High	Very High

The risk of groundwater contamination is dependant in part on the porosity and permeability of materials near the ground surface, which control the ability of contaminants to move through the surface and into the groundwater system. Surface materials, which are high in porosity, such as sands and gravels, and are permeable are at high risk to allow groundwater contamination. The risk of groundwater contamination is determined based on two factors: the presence or absence of sand or gravel within 1 m of the surface and the surface permeability determined from surficial geology mapping. These two parameters are combined as shown in Table 2 to determine the spatial distribution of groundwater contamination risk levels.

4.4 MAPS AND CROSS-SECTIONS

Grids which represent particular surfaces can be contoured to create maps, e.g. contouring the grid containing the elevation of the top of the Paskapoo Formation will produce a structure map of the Paskapoo Formation. Different maps can be created by combining grids, e.g. subtracting the grid with the elevation of the Paskapoo Formation from the ground surface elevation grid will produce a grid which can be contoured to create a map showing the depth to the top of the Paskapoo Formation.

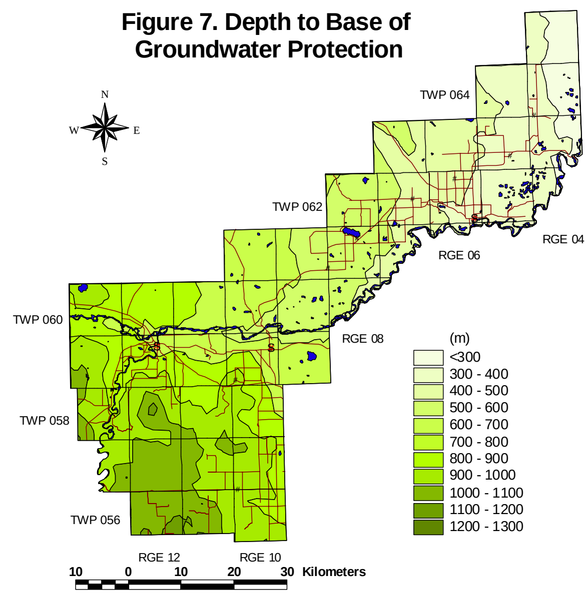
Data from drillers' reports used to calculate hydrogeological parameters is only available for bedrock units at depths of less than 200 m. Consequently data for each aquifer tends to be concentrated in areas where the bedrock unit is found down to this depth and may not always provide good coverage over the entire thickness or extent of the aquifer. The maps produced in this study show contours over the entire extent of each bedrock unit and in some instances this data may have been interpolated over significant distances. For these maps the data density is displayed and information in areas of low data density should be considered poorly constrained and interpreted as a guideline only. For some aquifers the density data was sufficiently low overall to prevent the production of a reasonable map (e.g. yield maps for the Foremost and Oldman aquifers).

Cross-sections were prepared by selecting appropriate lines of section across the map area. The first and last points of each line were selected in Surfer. The ‘Slice’ function in Surfer was then used to create a table containing the x, y and z position of points that describe the position of a discrete surface along the cross-section line. These data were obtained for each hydrogeologic surface and stored in one table for each cross-section line. These tables were then imported into ArcView where the x-z data could be displayed and then formatted to form the cross-sections.

4.5 BASE OF GROUNDWATER PROTECTION

Within Woodlands County the base of groundwater protection was defined by depth intervals obtained from the Alberta Energy and Utilities Board (EUB) at the eastern portion of the County as the top of the Lea Park Formation. Data from the EUB did not contain any information defining the depth to the base of groundwater protection within the western portion of Woodlands County. Information from an Alberta Research Council Report (Tokarsky 1977), which reviewed the hydrogeology of this area and defined the base of groundwater protection as the depth at which the TDS exceeds 4000 mg/L, was used to provide more data points across this area and extrapolating across large distances. The resulting base of groundwater protection surface is shown in Figure 7. No water wells were found to be completed below the base of groundwater protection within Woodlands County.

Figure 7. Depth to Base of Groundwater Protection



4.6 LICENSED WELL REVIEW

A table containing currently licensed wells within Woodlands County was obtained from Alberta Environment. Comparison of well locations, completion intervals and well owner/applicant name between the groundwater database and licensed well table enabled 40 of the 60 licensed wells in the County to be assigned a well id and this information can now be linked to the groundwater database. The assigned diversions represent slightly more than fifty percent of the total licensed diversions.

4.7 SOFTWARE

The files on the CD-ROM have been generated using the following software:

- Microsoft Office 2000
- Surfer 6.02
- Adobe Acrobat Reader 4.0
- ArcView 3.2 with Spatial Analyst 2.0
- CorelDraw 9.0

5.0 AQUIFERS

5.1 BACKGROUND

Aquifers occur in geological materials that are porous, permeable and saturated. Aquifers in which the water level is below the top of the geological unit are named water table aquifers. Aquifers in which the water level is above the top of the geological unit are called artesian aquifers. Aquifers occur in two types of geological materials; in the sediments above the bedrock surface or surficial deposits and in the upper bedrock. The geological nature, the projected quantity and quality of groundwater found in these two types of geological materials are reviewed below.

5.1.1 Surficial Aquifers

Surficial deposits are discontinuous across Woodlands County. They are found in small patches across the County area and more continuously along the north side of the County. These deposits are a maximum 30 m thick (Figure 8) and are generally composed of glacial sediments. Aquifers in these sediments are found in saturated sand and gravel deposits.

Casing diameter information is available for 113 of the 465 water wells completed in surficial deposits. Nearly one third of the surficial wells have casing diameters greater than 450 mm and are bored or dug wells. Half of the surficial water wells with smaller diameter casing are completed as open hole, the remainder mostly use a perforated liner/casing or screen.

Water quality from surficial aquifers in Woodlands County is suitable for use as drinking water, although in some areas iron concentrations exceed the GCDWQ aesthetic criteria. Residents who use groundwater for domestic purposes may desire treatment to reduce iron concentrations before consumption.

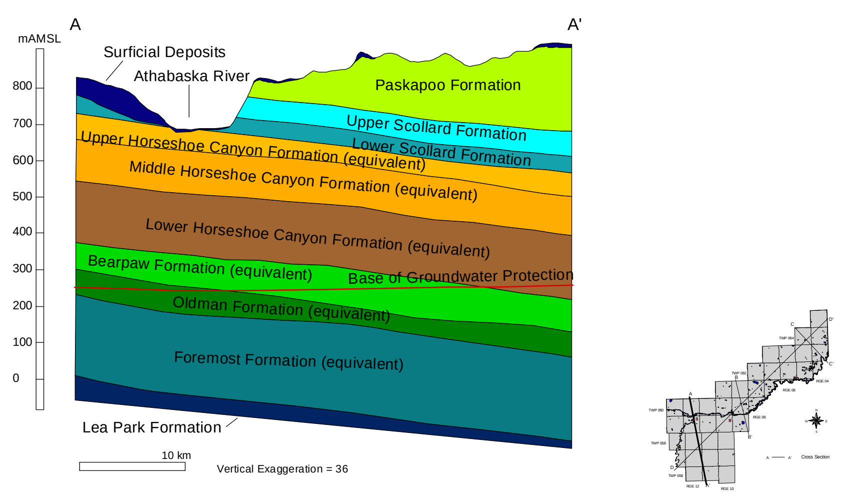


Figure 8. Hydrogeological Cross Section A-A'

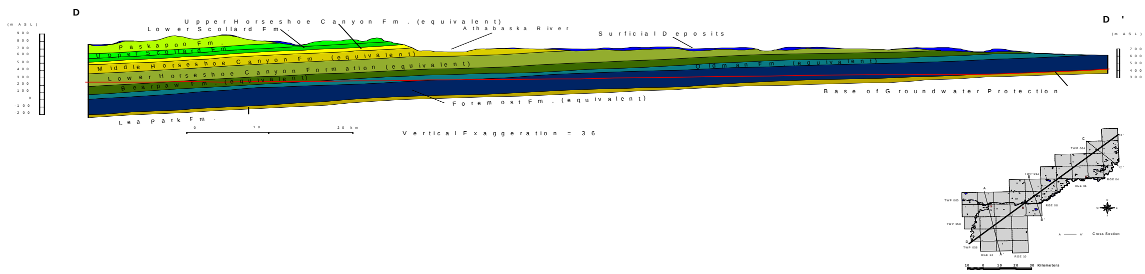
5.1.2 Bedrock Aquifers

Upper bedrock aquifers are found in porous, permeable and saturated rock layers within 200 m of the surface. Water wells completed in bedrock aquifers are found throughout the County. Bedrock aquifers include strata within the Paskapoo Formation, Scollard Formation, and equivalents of the Edmonton Group (Horseshoe Canyon Formation), Bearpaw Formation and the Belly River Group (Oldman and Foremost Formations).

These bedrock strata were deposited in a basin, which was deepest at the eastern edge of the Rocky Mountains and became shallower towards eastern Alberta. Bedrock strata were deposited in layers, which were thicker towards the west, at the deepest part of the basin. Periods of erosion followed this deposition, most recently by ice sheets during the ice ages and by subaerial erosion at the present time. Bedrock strata, which underlie surficial deposits, i.e. subcrop, were exposed during these events and were eroded as the ground was somewhat leveled. This had the result of thinning the northeast edge of each bedrock formation where it subcrops. Each bedrock unit is tilted down to the southwest and has a flat, even tabular form where it underlies other rock units but thins to a wedge where it subcrops. This can be clearly seen in Figure 9, e.g. the Lower Horseshoe Canyon Formation.

This geometry means that formations, which are shallow at the west end of the County, become eroded to the east and are not preserved across the entire County. Bedrock strata at greater depths are found over greater portions of or even the entire County. Some formations are too deep in the western portion of the County to be considered upper bedrock aquifers, however they become progressively shallower towards the northeastern end of the County where they can form upper bedrock aquifers (Figure 9).

Figure 9. Hydrogeological Cross-section D-D'



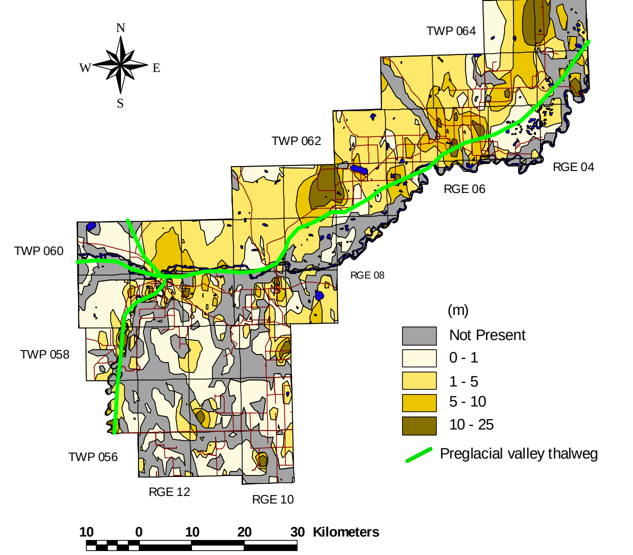
More than 98% of water wells completed in bedrock have casing diameters of less than 450 mm. These wells are mostly drilled and are mainly completed with casing and perforated liner or casing and open hole completion.

Groundwater from upper bedrock aquifers within Woodlands County has a water quality, which is generally suitable for drinking, however TDS, fluoride and iron concentrations sometimes exceed the GCDWQ criteria.

5.2 SURFICIAL AQUIFER

Surficial deposits form a thin (<30 m thick), discontinuous layer above bedrock within Woodlands County (B-17). Aquifers within these deposits are formed from saturated sands and gravels. Surficial deposits within Woodlands County are composed mainly of glacial sediments. These are generally glacial lacustrine or moraine deposits and range from silt and clay to sand and gravel. Gravel is common in alluvial terrace deposits along the major rivers and sand in aeolian dune fields.

Figure 10. Thickness of Sand and Gravel Aquifer



The thalwegs of preglacial valleys are shown in Figure 10. The Athabasca River over part of its length follows the pathway of the major preglacial High Prairie valley. Similarly, modern rivers, such as the McLeod River, follow in part the pathway of tributary preglacial valleys. As a result of erosion associated with these modern rivers, significant sand and gravel deposits associated with these preglacial valleys have been removed. The High Prairie valley was a broad valley. Sand and gravel deposits associated with this valley are preserved particularly along the northern side of this valley. The widespread distribution of sand and gravel deposits in this area and generally thin nature of these deposits makes it difficult to distinguish deposits related to the preglacial valleys from others on a regional scale based on drillers' reports alone. Consequently, these sand and gravel deposits have been mapped as one aquifer across the County and may include both preglacial and younger deposits.

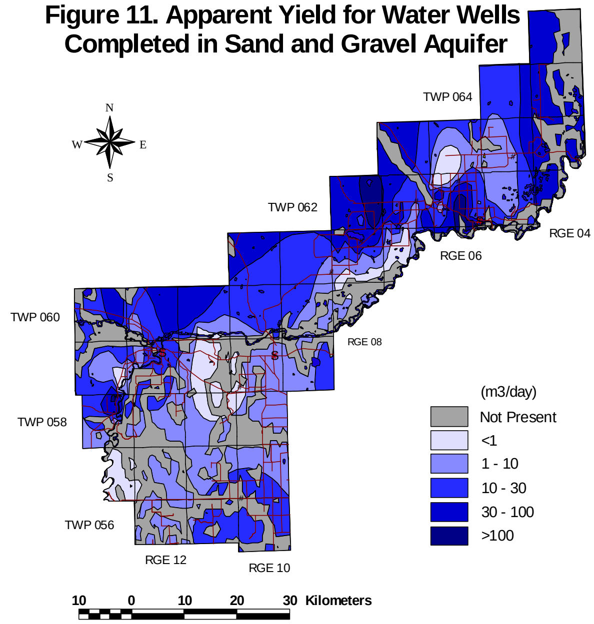
5.2.1 Aquifer Thickness

Sand and gravel can be found up to 30 m thick within the County. The surficial aquifer, however, is only formed of saturated sand and gravel, i.e. those found below the water table. Within Woodlands County the sand and gravel aquifer is generally 2 to 5 m thick with some thicker areas up to 25 m in thickness (Figure 10).

5.2.2 Apparent Yield

Calculated long term yields from the surficial aquifer indicate many areas can expect yields between 6 and 30 m^3/day and locally these yields may be as high as 100 m^3/day (Figure 11).

Figure 11. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer



5.2.3 Chemical Quality of Groundwater

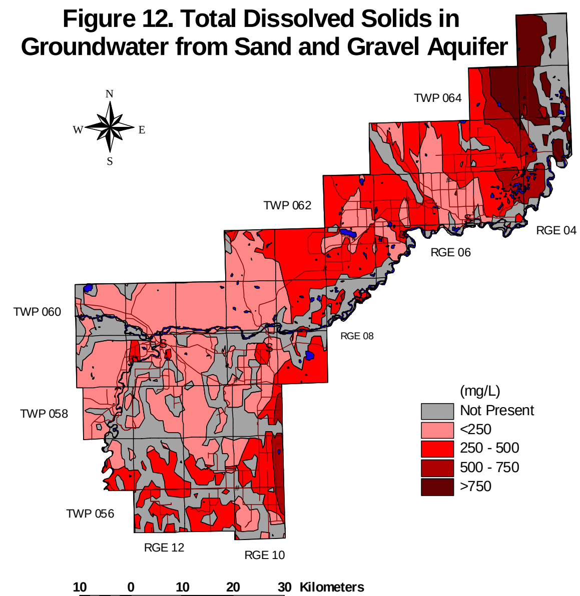
Groundwaters from surficial aquifers generally have TDS concentrations of 300 to 700 mg/L, which is within the expected range of TDS values for Alberta (Figure 12). Chloride, sulphate and fluoride (B-22) concentrations are generally low, however iron concentrations are high in some areas (B-21). 44% of water wells completed in surficial deposits have iron concentrations above the GCDWQ criteria. Groundwater quality from surficial aquifers is summarized in Table 3.

Nitrate was reported at concentrations that exceed the GCDWQ criteria in eighteen percent of water wells completed in surficial deposits. By contrast, nitrite concentrations (not shown in Table 3) were not found to exceed the GCDWQ criteria in any of these wells. Areas of nitrate concern are mostly west of Whitecourt and a small area west of Fort Assiniboine (B-23). Nitrate concentrations should be monitored for health reasons.

Table 3. Groundwater Quality from Surficial Aquifers

Parameter	Minimum	Maximum	% Exceeding GCDWQ	GCDWQ
	(mg/L)			
TDS	138	1638	37	500
Sulphate	0.10	7.31	0	500
Nitrate	0.1	315	18	10
Chloride	0.01	6.77	0	250
Fluoride	0.03	1.16	0	1.5
Iron	0.03	25.8	44	0.3

Figure 12. Total Dissolved Solids in Groundwater from Sand and Gravel Aquifer



5.3 BEDROCK AQUIFERS

5.3.1 Geological Characteristics

The upper bedrock within Woodlands County consists of the Paskapoo Formation, the Scollard Formation, the Edmonton Group (Horseshoe Canyon Formation), the Bearpaw Formation and the Belly River Group (Oldman and Foremost Formations). Figure 13 shows the bedrock formations that subcrop in the County. Progressively younger formations form the subcrop from the northeast of the County toward the southwest, starting with the Foremost (equivalent) Formation of Late Cretaceous age in the northeast to the Paskapoo Formation of Tertiary age in the southwest.

The geological map of Alberta (Alberta Geological Survey 1999) shows the Bearpaw Formation to thin in a northwest direction from its maximum thickness in southeast Alberta and to pinch out southeast of the study area. Where the Bearpaw Formation is absent, it becomes difficult to differentiate the overlying Edmonton Group strata from the underlying Belly River Group, and the entire interval of strata of the Edmonton Group plus the Belly River Group is termed the Wapiti Formation (Hamilton et al. 1998). For this study, strata within the Wapiti Formation were subdivided into lateral equivalents of formations recognized to the southeast on the basis of correlations from geophysical well logs.

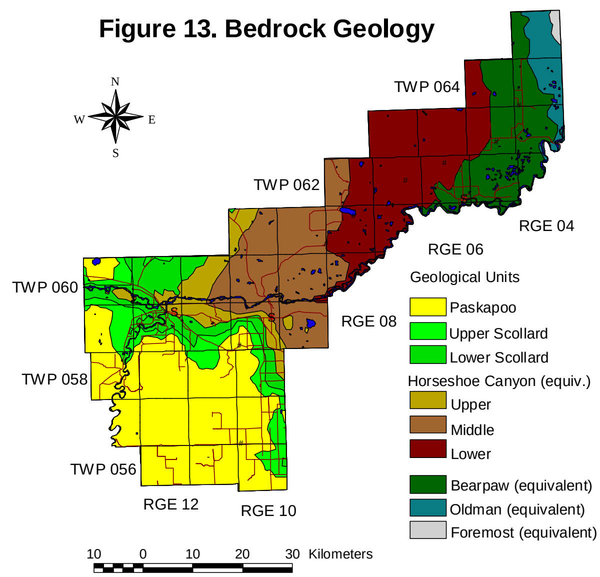


Figure 13. Bedrock Geology

The Paskapoo Formation is the upper bedrock and subcrops only in the southwestern portion of Woodlands County. The Paskapoo Formation consists of sequences of thick tabular sandstones overlain by interbedded siltstone and mudstone (Dawson et al. 1998). The Paskapoo Formation can reach a maximum thickness of 800m, however, within Woodlands County the Paskapoo Formation has a maximum thickness of 285 m.

The Scollard Formation underlies the Paskapoo Formation and underlies only the southwestern portion of Woodlands County. The Scollard Formation is subdivided into the Upper and Lower Scollard. The Scollard Formation consists of thick, gray to buff sandstone and siltstone units interbedded with thin, olive green mudstone beds and coal (Dawson et al. 1998). The Upper Scollard contains thick, widespread and economically significant coal seams, named the Ardley and Nevis coal seams, whereas the Lower Scollard generally contains no coal. Within

Woodlands County the Upper Scollard has a maximum thickness of 75 m and the Lower Scollard has a maximum thickness of 70 m.

The Edmonton Group underlies the Scollard Formation. The Edmonton Group consists of the thin Battle and Whitemud Formations and a thick Horseshoe Canyon Formations. The thickness of the Edmonton Group varies from 300 to 500 meters.

The two formations underlying the Scollard Formation, the Battle and Whitemud Formation, have a combined thickness of 20 m. The Whitemud Formation consists of a white kaolinitic siltstone. The Battle Formation consists of dark grey shale and contains tuffaceous units, one of which is named the Kneehills Tuff (Dawson et al. 1998). The widespread nature and distinct character of these formations has made these units significant geological markers, however, the presence of clay minerals in these units makes them aquitards. These formations will not be considered further in this report.

Beneath the Battle and Whitemud Formations is the Horseshoe Canyon Formation. The Horseshoe Canyon Formation consists of interbedded sandstone, mudstone, siltstone and coal (Dawson et al. 1960). The Horseshoe Canyon Formation (equivalent) has a thickness of greater than 350 m. The Horseshoe Canyon Formation (equivalent) is subdivided into the Lower, Middle and Upper portions. Both the Upper and Lower Horseshoe Canyon consist primarily of sand and coal, whereas the Middle Horseshoe Canyon consists predominantly of shale with bentonite and little sandstone or coal. The Upper Horseshoe Canyon (equivalent) has a maximum thickness of 80 m within the study area and underlies the southwestern portion of Woodlands County. The Middle Horseshoe Canyon (equivalent) has a maximum thickness of 175 m within Woodlands County and underlies the southwestern half of the map area. The Lower Horseshoe Canyon (equivalent) has a maximum thickness of 180 m within Woodlands County and underlies the southwestern two thirds of the County.

The Lower Horseshoe Canyon (equivalent) is underlain by the Bearpaw Formation. The Bearpaw Formation consists of shale and siltstone with sandstone lenses and kaolinitic claystone (Dawson et al. 1998). The Bearpaw Formation can reach a thickness of greater then 200 m within Alberta. Within Woodlands County the Bearpaw Formation (equivalent) reaches a maximum thickness of 115 m. The Bearpaw Formation (equivalent) underlies most of Woodlands County, except for eastern parts of townships 63 to 65 in range 4.

The Belly River Group (equivalent) underlies the Lower Horseshoe Canyon (equivalent). These formations consist of fluvial sandstone and siltstone with minor mudstone and coal. The Belly River Group (equivalent) is subdivided into the upper Oldman Formation (equivalent) and the stratigraphicaly lower Foremost Formation (equivalent). The Oldman Formation (equivalent) underlies the Lower Horseshoe Canyon Formation (equivalent) throughout all of Woodlands County except for the northeastern corner of township 65 range 4. The upper portion of the Oldman Formation consists of carbonaceous sandstone, shale and coal seams, whereas the lower portion consists of fresh water sandstone, shale and minor siltstone. The Foremost Formation (equivalent) underlies the Oldman Formation (equivalent) beneath the entire area of

Woodlands County. The Foremost Formation consists of coal seams and carbonaceous shales in the upper part and sandstones, shales and carbonaceous shales in the main portion. The Foremost and Oldman Formations are included in the hydrogeological mapping in this study, however, sparse information available for these units prevents a complete investigation of their hydrogeological characteristics.

The Foremost Formation (equivalent) is underlain by the Lea Park Formation. The Lea Park Formation underlies the entire County area. The Lea Park Formation is typically composed of shale with minor amounts of silt. The Lea Park Formation forms an aquitard and the hydrogeological characteristics of this formation will not be considered further in this report.

5.3.2 Aquifers

1852 water wells within Woodlands County were completed within bedrock aquifers. More wells are completed within the Paskapoo Formation than any other aquifer (Table 4). This formation also has the smallest extent within the County, indicating the highest overall well density is within the Paskapoo Formation. The majority of the remaining wells are completed within the Scollard Formation and the Horseshoe Canyon Formation (equivalent).

Table 4. Completion Aquifer

Geological Unit	No. of Water Wells
Surficial	465
Paskapoo	382
Upper Scollard	265
Lower Scollard	277
Upper Horseshoe Canyon	208
Middle Horseshoe Canyon	248
Lower Horseshoe Canyon	185
Bearpaw Formation	198
Oldman Formation	40
Foremost Formation	19
Other	495
TOTAL	2317

Apparent yield values were determined for 918 bedrock water wells, which is approximately half of all bedrock water wells. The apparent yields within the upper bedrock aquifers are generally less than 50 m^3/day (Figure 14). Areas with higher apparent transmissivities are generally located north of the Athabasca River in the central portion of Woodlands County.

An apparent yield value was determined for a specific aquifer in 908 wells. Less than half of the wells have an apparent yield greater than 10 m^3/day (Table 5).

Figure 14. Apparent Yield for Upper Bedrock Aquifers

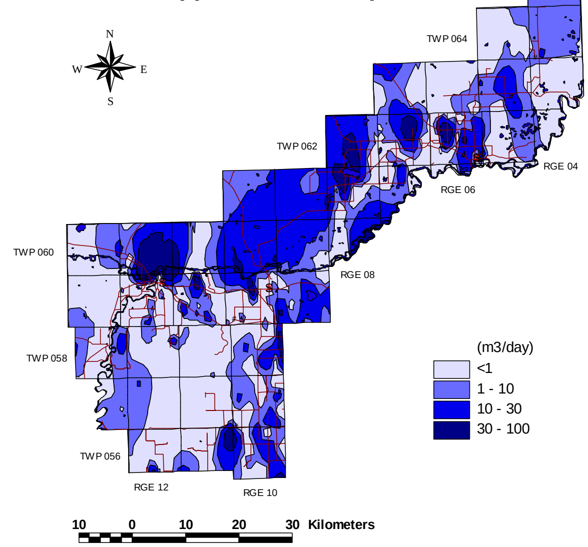


Table 5. Apparent Yield for Bedrock Aquifers

Aquifer	No. of water wells with apparent yield values	Number of Water Wells with Apparent Yields (m^3/day)		
		<10	10 to 50	>50
Paskapoo	186	133	40	13
Upper Scollard	144	90	39	15
Lower Scollard	163	98	51	14
Upper Horseshoe Canyon	105	68	26	11
Middle Horseshoe Canyon	106	54	38	14
Lower Horseshoe Canyon	92	50	29	13
Bearpaw Formation	92	60	17	15
Oldman Formation	14	10	4	0
Foremost Formation	6	3	2	1
Total	908	566	246	96

5.3.3 Chemical Quality of Groundwater

TDS concentrations within upper bedrock aquifers in Woodlands County are generally between 500 and 1000 mg/L (Figure 15).

Chloride and sulphate concentrations are generally less than 150 and 125 mg/L, respectively (B-28). Iron concentrations are frequently elevated in the upper bedrock aquifers above the GCDWQ (0.3 mg/L) (B-29). Fluoride concentrations exceed the GCDWQ criteria in areas near Whitecourt and Fort Assiniboine (B-30). Nitrate concentrations were found to exceed GCDWQ criteria in central and eastern parts of the County (B-31). Fluoride and nitrate concentrations should be monitored for health reasons.

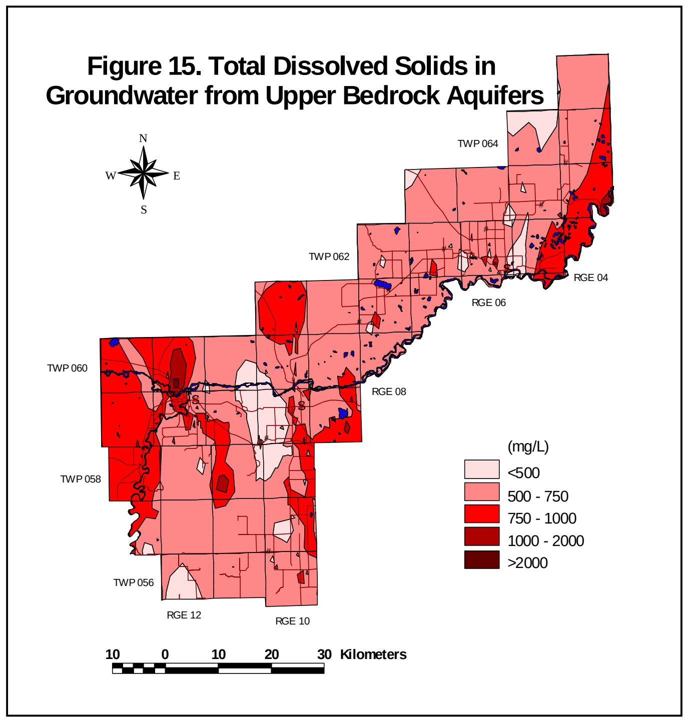


Figure 15. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifers

5.3.4 Paskapoo Aquifer

The Paskapoo Aquifer is composed of the porous and permeable intervals of the Paskapoo Formation. The Paskapoo Formation subcrops under part or all of townships 56 to 59 ranges 10 to 13 W5M and township 60 range 13, W5M. The Paskapoo Formation is eroded throughout most of the County. The Paskapoo Formation has a maximum thickness of 285 m at the southwestern edge of the County and thins to the northeast (B-34).

5.3.4.1 Depth to Top

The bottom surface of the Paskapoo Formation is fairly flat, but dips gently down to the southwest. By contrast, the top surface is quite irregular due to variations in topography, which are primarily the result of erosion by rivers, streams and surface water runoff. The Paskapoo Formation is covered by surficial deposits, which vary in thickness, but are generally less than 20 m deep (B-33).

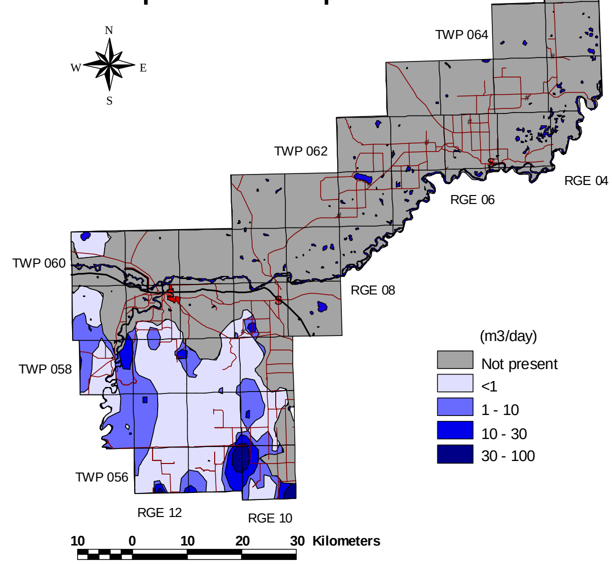
5.3.4.2 Apparent Yield

The projected long term yield for most water wells completed in the Paskapoo Aquifer is generally less than 10 m^3/day (Figure 16). Wells within approximately one third of the subcrop area of the Paskapoo Formation indicate a greater projected long term yield of 10 to 100 m^3/day.

5.3.4.3 Quality

TDS concentrations in groundwater from the Paskapoo Aquifer are generally between 300 and 700 mg/L (B-37). Chloride, sulphate and fluoride concentrations for these groundwaters are generally less than 20, 250 and 1.0 mg/L, respectively. However, most chemical records indicate high iron concentrations, in exceedance of the GCDWQ criteria (0.3 mg/L).

Figure 16. Apparent Yield for Water Wells Completed in Paskapoo Formation



5.3.5 Upper Scollard Aquifer

The Upper Scollard Aquifer is composed of the porous and permeable portion of the Upper Scollard Formation. The Upper Scollard Formation subcrops beneath the southwestern portion of Woodlands County, with only a slightly greater extent than the Paskapoo Formation. The Upper Scollard has a fairly uniform thickness of 75 m within Woodlands County (B-40). It is eroded throughout most of the County.

5.3.5.1 Depth to Top

The Upper Scollard Formation has a reasonably flat upper surface, is of generally uniform thickness and dips down to the southwest. Where it is present, the depth to the top of the Upper Scollard Formation generally varies between 30 and 200 m below the ground surface (B-39), but can be at a depth of over 250 meters beneath some of the Wyles Hills. These depth variations are primarily the result of changes in the topography in the southwest portion of the County.

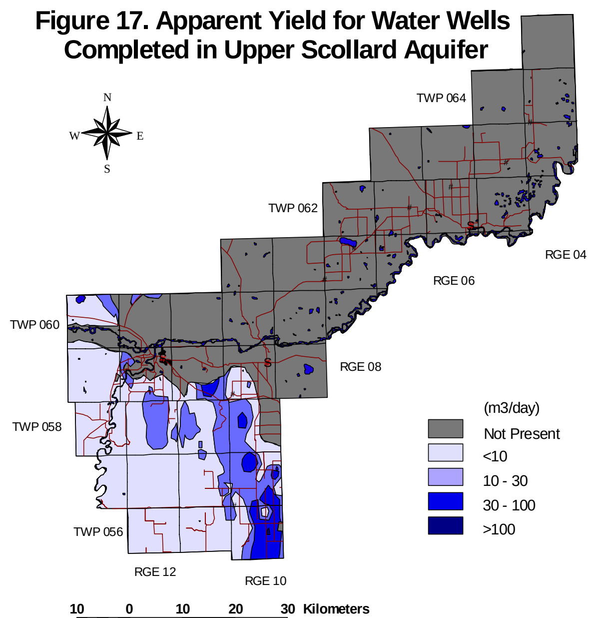
5.3.5.2 Apparent Yield

The calculated long term projected yields from water wells completed within the Upper Scollard Formation are generally less than 10 m^3/day (Figure 17). An area of higher yields exists in the southeast corner of the County with apparent yields between 10 m^3/day to greater than 100 m^3/day.

5.3.5.3 Quality

TDS concentrations in groundwater from the Upper Scollard Aquifer are generally between 400 and 800 mg/L (B-43). Chloride and sulphate concentrations are generally low in groundwater from the Upper Scollard Aquifer. Approximately half of the wells completed in this aquifer have iron concentrations that are above the GCDWQ criteria (0.3 mg/L).

Figure 17. Apparent Yield for Water Wells Completed in Upper Scollard Aquifer



5.3.6 Lower Scollard Aquifer

The Lower Scollard Aquifer is composed of the porous and permeable sections of the Lower Scollard Formation. The Lower Scollard Formation is generally 45 to 70 m thick and underlies part of the County area in townships 56 to 60 in ranges 10 to 13 W5M (B-46).

5.3.6.1 Depth to Top

The Lower Scollard Formation has a relatively flat upper surface and is generally of uniform thickness. It is deepest in the southwest corner of the County and shallows to the northeast. The top of the Lower Scollard Formation is generally 300 m beneath the ground surface at the southwest end of the County and shallows to generally 50 m beneath the surface towards the northeast (B-45).

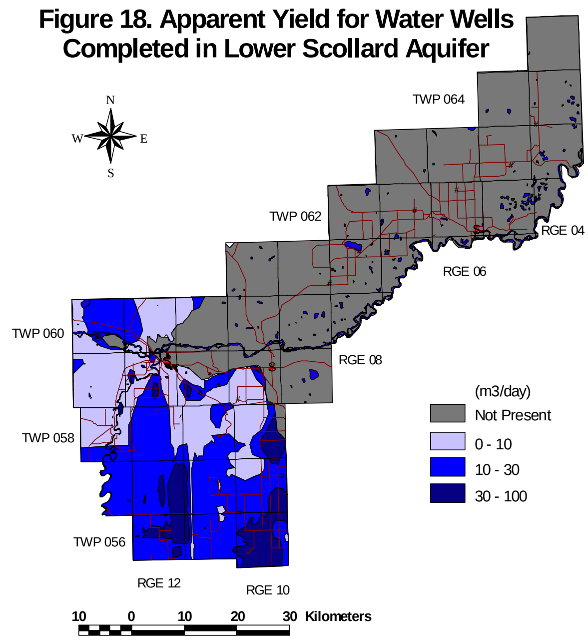
5.3.6.2 Apparent Yield

Mapping of the long term projected yields from water wells completed in the Lower Scollard Formation indicates approximately half of the subcrop area of the aquifer has apparent yields of 10 to 30 m^3/day (Figure 18). A few areas have higher projected apparent yields of 30 to 100 m^3/day, but most other areas have projected long term yields of less than 10 m^3/day. The areas of higher yields are located in the southernmost part of Woodlands County.

5.3.6.3 Quality

The chemistry of groundwater from the Lower Scollard Aquifer is very similar to that from the Upper Scollard Aquifer. TDS concentrations generally range from 400 to 800 mg/L (B-49). Chloride and sulphate concentrations are generally low. More than half of the wells completed in this aquifer have iron concentrations that are above the GCDWQ criteria (0.3 mg/L).

Figure 18. Apparent Yield for Water Wells Completed in Lower Scollard Aquifer



5.3.7 Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer is composed of the porous and permeable portions of the Upper Horseshoe Canyon Formation (equivalent). The Upper Horseshoe Canyon Formation (equivalent) is between 30 and 80 m thick (B-52), with the thickest sections located in township 60 ranges 11 to 13 W5M. The Upper Horseshoe Canyon Formation (equivalent) underlies the southwestern portion of Woodlands County in all or parts of townships 56 to 61 ranges 10 to 13 W5M.

5.3.7.1 Depth to Top

The Upper Horseshoe Canyon Formation (equivalent) is of fairly uniform thickness and dips down to the southwest. The Upper Horseshoe Canyon Formation (equivalent) is greater than 400 m below ground surface at the southwest end of the County and shallows to less than 50 m below ground surface towards the northwest edge of it's extent (B-51).

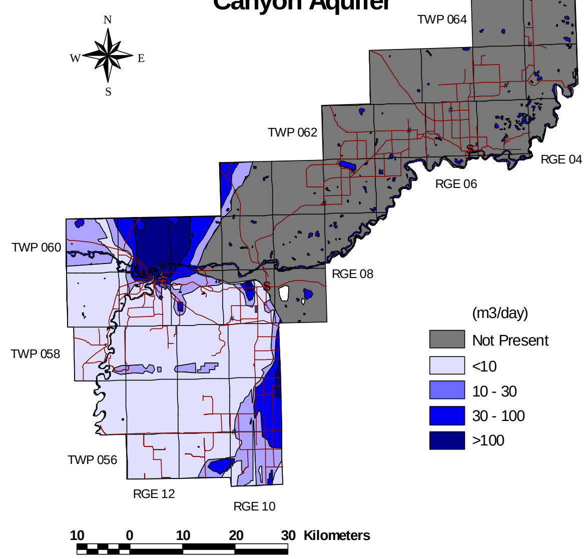
5.3.7.2 Apparent Yield

The Upper Horseshoe Canyon Formation (equivalent) is generally a poor aquifer with projected long term apparent yields of less than 10 m^3/day (Figure 19). However, locally this aquifer may have yields in excess of 100 m^3/day. Within Woodlands County these areas are north of the town of Whitecourt and along the southeastern margin of the County.

5.3.7.3 Quality

Chemistry records from water wells completed within the Upper Horseshoe Canyon Aquifer indicate TDS concentrations of generally 500 to 850 mg/L in groundwater from this aquifer (B-55). Groundwater from this aquifer generally has low chloride and sulphate concentrations. Fluoride concentrations in approximately one quarter of wells completed in this aquifer and iron concentrations in more than half of water wells completed in the Upper Horseshoe Canyon Aquifer exceed the GCDWQ criteria for these parameters (1.5 and 0.3 mg/L, respectively).

Figure 19. Apparent Yield for Water Wells Completed in Upper Horseshoe Canyon Aquifer



5.3.8 Middle Horseshoe Canyon Aquifer

The Middle Horseshoe Canyon Aquifer is composed of the porous and permeable intervals of the Middle Horseshoe Canyon Formation (equivalent). The Middle Horseshoe Canyon Formation (equivalent) underlies the southwestern half of Woodlands County and is eroded in the remaining portion of the County. The Middle Horseshoe Canyon Formation (equivalent) is generally between 110 and 120 m thick where preserved within Woodlands County (B-58).

5.3.8.1 Depth to Top

The depth from the ground surface to the top of the Middle Horseshoe Canyon Formation (equivalent) varies from greater than 450 m at the southwest corner of Woodlands County to less than 50 m near the center of the County (B-57). The Middle Horseshoe Canyon Formation (equivalent) is of fairly uniform thickness and has a relatively flat upper surface.

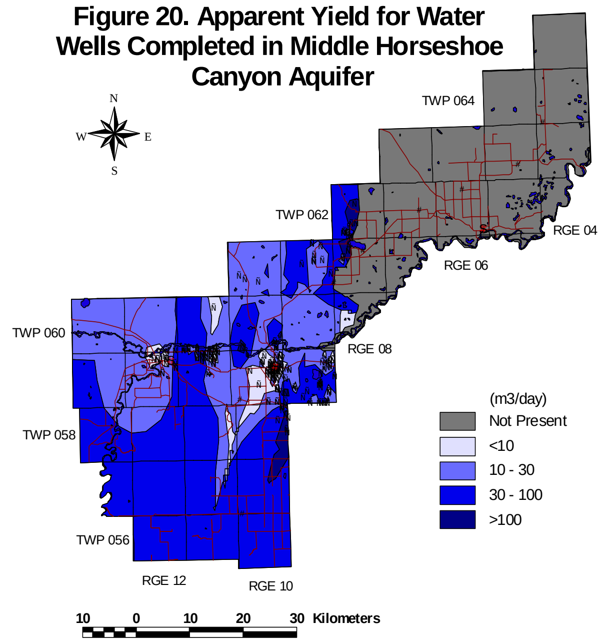
5.3.8.2 Apparent Yield

Projected long-term apparent yields of 10 to 100 m3/day are indicated over approximately one half of the preserved extent of the Middle Horseshoe Canyon Aquifer within Woodlands County. Locally yields in excess of 100 m3/day are possible (Figure 20).

5.3.8.3 Quality

Groundwater quality from the Middle Horseshoe Canyon Aquifer appears to be similar to the Upper Horseshoe Canyon Aquifer. TDS concentrations are generally between 550 and 800 mg/L (B-61), chloride and sulphate concentrations are generally low and fluoride and iron concentrations exceed the GCDWQ criteria in approximately one quarter and a third of the water wells, respectively.

Figure 20. Apparent Yield for Water Wells Completed in Middle Horseshoe Canyon Aquifer



5.3.9 Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Formation (equivalent) underlies most of Woodlands County except for part or all of townships 62 to 65 in ranges 4 and 5 W5M. The Lower Horseshoe Canyon Aquifer is composed of the porous and permeable sections of the Lower Horseshoe Canyon Formation (equivalent). The Lower Horseshoe Canyon Formation (equivalent) is of generally uniform thickness, between 160 and 180 m, within Woodlands County (B-64).

5.3.9.1 Depth to Top

The Lower Horseshoe Canyon Formation (equivalent) has a relatively flat upper surface and dips down to the southwest. The Lower Horseshoe Canyon Formation (equivalent) is covered by covered by a wedge of surficial deposits and bedrock which has a thickness of greater than 550 m at the southwestern edge of Woodlands County and thins to less than 50 m towards the northeastern corner of the County (B-63).

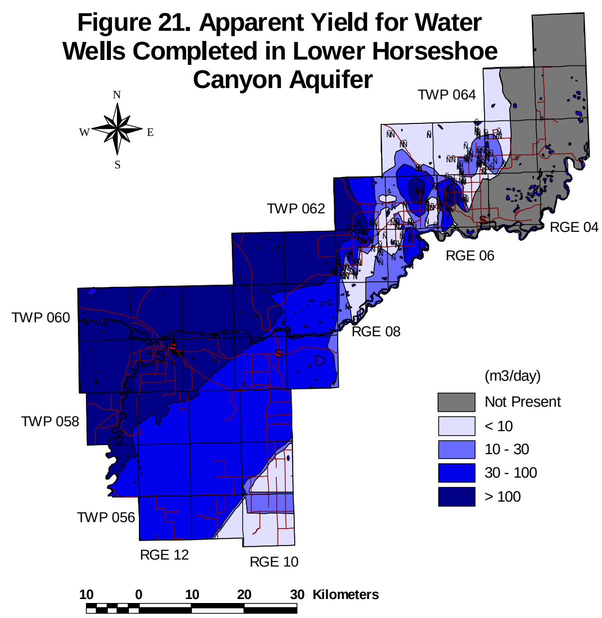
5.3.9.2 Apparent Yield

Projected long-term yields for the Lower Horseshoe Canyon Aquifer indicate yields of 10 to 100 m^3/day in general. Yields greater than 100 m^3/day may be obtained locally within the area along the northwestern edge of the County (Figure 21).

5.3.9.3 Quality

Groundwater quality from the Lower Horseshoe Canyon Aquifer appears to be similar to the Upper and Middle Horseshoe Canyon Aquifers. TDS concentrations are generally between 450 and 900 mg/L (B-67), chloride and sulphate concentrations are generally low and iron concentrations exceed the GCDWQ criteria in approximately one half of the water wells completed within this aquifer. Fluoride concentrations are almost entirely below the GCDWQ criteria in groundwater from this aquifer.

Figure 21. Apparent Yield for Water Wells Completed in Lower Horseshoe Canyon Aquifer



5.3.10 Bearpaw Aquifer

The Bearpaw Aquifer is composed of the porous and permeable sections of the Bearpaw Formation (equivalent). The Bearpaw Formation (equivalent) underlies the entire County except for portions of townships 62 to 65 in range 4 W5M. The Bearpaw Formation (equivalent) ranges in thickness from 80 to 110 m throughout most of its preserved extent (B-70).

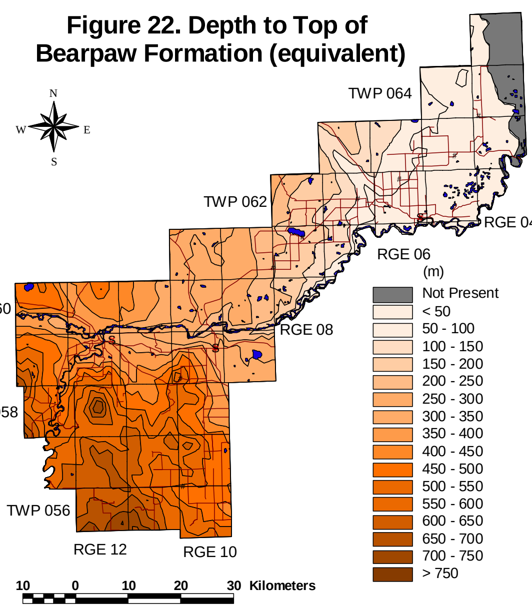
5.3.10.1 Depth to Top

The Bearpaw Formation (equivalent) has a relatively flat upper surface and is fairly uniform in thickness. The top of the Bearpaw Formation (equivalent) is 745 m deep at the southwestern end of Woodlands County and shallows gradually towards the northeast to less than 50 m below the ground surface (Figure 22). The Bearpaw Formation (equivalent) is eroded in the northeast end of the County.

5.3.10.2 Quality

TDS concentrations in groundwater from the Bearpaw Aquifer are generally between 350 and 900 mg/L (B-72). Chloride and sulphate concentrations are generally low in groundwater from this aquifer. Iron concentrations exceed the GCDWQ criteria in approximately half of the water wells completed in this aquifer.

Figure 22. Depth to Top of Bearpaw Formation (equivalent)



5.3.11 Oldman Aquifer

The Oldman Aquifer is composed of the permeable and porous sections of the Oldman Formation (equivalent). The Oldman Formation (equivalent) underlies the entire County except for part of township 65 range 4 W5M. The Oldman Formation (equivalent) ranges between a thickness of 60 and 100 m (B-75).

5.3.11.1 Depth to Top

The Oldman Formation (equivalent) is fairly uniform in thickness and dips down to the southwest. The depth to the top of this formation ranges from a maximum of 800 m in the southern end of the County and becomes more shallow towards the northeast end of Woodlands County where it is less than 100 m below the ground surface (Figure 23).

5.3.11.2 Quality

Only a few chemical records are available for groundwater from the Oldman Aquifer. These indicate TDS concentrations in the Oldman Aquifer ranges from 750 to 1150 mg/L. Chloride and sulphate concentrations appear generally low. Approximately half of the fluoride concentrations and one quarter of the iron concentrations in groundwater from the Oldman Aquifer exceed the GCDWQ criteria. This chemistry is based on only a few data records and should be considered a rough guide only.

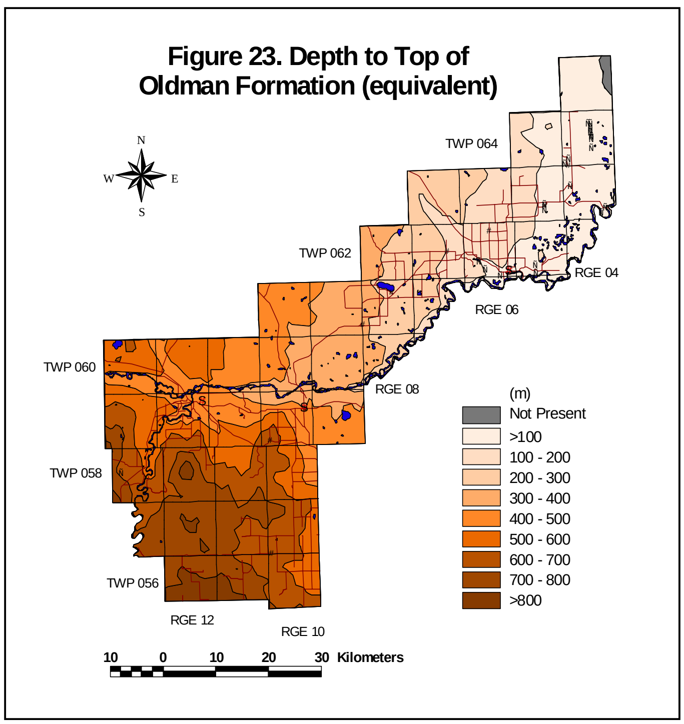


Figure 23. Depth to Top of Oldman Formation (equivalent)

5.3.12 Foremost Aquifer

The Foremost Aquifer is formed from the porous and permeable sections of the Foremost Formation (equivalent). The Foremost Formation (equivalent) underlies the entire County area and ranges in thickness from 150 to 200 m (B-78).

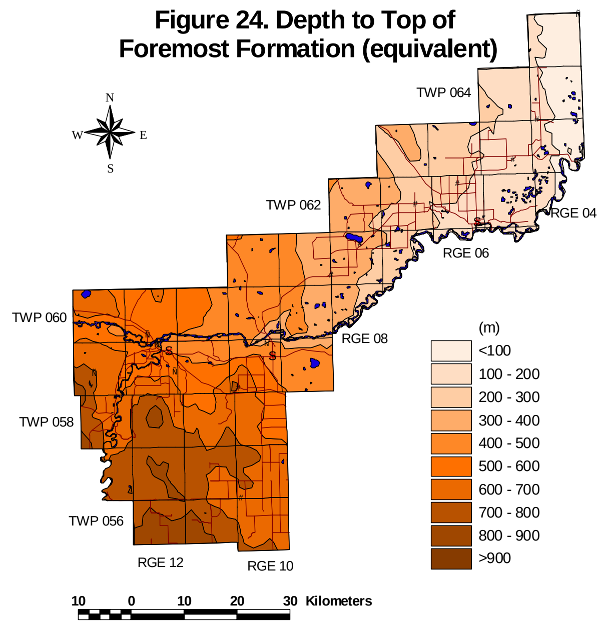
5.3.12.1 Depth to Top

The top of the Foremost Formation (equivalent) ranges from a maximum depth of 900 m at the southern end of the County and becomes progressively shallower towards the northeast where it is less than 100 m below the ground surface (Figure 24). The Bearpaw Formation (equivalent) is reasonably uniform in thickness and has a relatively flat upper surface.

5.3.12.2 Quality

Only a couple of chemical records are available for groundwater from the Foremost Aquifer. These indicate very high TDS concentrations of greater than 2500 mg/L in groundwater from this aquifer. Sulphate and chloride concentrations are substantially higher than from other bedrock aquifers in the area. Sulphate concentrations are generally below 240 mg/L, however all chloride concentrations analyzed exceed the GCDWQ (250 mg/L).

Figure 24. Depth to Top of Foremost Formation (equivalent)



6.0 GROUNDWATER BUDGET

6.1 HYDROGRAPHS

There are no observation water wells operated by AE within Woodlands County. Two observation wells outside the County boundaries but nearby are completed in a lower sand and gravel aquifer, which is not found in Woodlands County and therefore can not be used to provide information regarding changes in the groundwater supply.

Water level information provides important information for groundwater management. This information can be used to identify changes in the groundwater supply due to variations in water use and recharge. Woodlands County may want to consider identifying landowners who would be willing to participate in a groundwater monitoring program and selecting several key wells to begin monitoring water levels in the main groundwater aquifers within the County.

6.2 GROUNDWATER FLOW

An indirect estimate of the groundwater recharge within Woodlands County is possible by calculating the amount of water flowing through each aquifer. If the aquifer is being recharged at the same rate as its discharge then the amount of water flowing through the aquifer over a particular time period should be equal to the recharge. This calculation is also based on the assumption that groundwater flow is predominantly in the horizontal direction, through the aquifer, and not laterally between aquifers.

The amount of water flowing through an aquifer is calculated from an average transmissivity, the average hydraulic gradient and average estimated width of the aquifer. The average transmissivity was obtained from well completion information from wells completed in each aquifer. The average hydraulic gradient was obtained from the non-pumping water level surfaces. The width of the aquifer was estimated as the average effective width of the aquifer.

An estimate of the groundwater flow was not be made for the surficial deposits aquifer due to their discontinuous nature. The estimation of groundwater flow direction and hydraulic gradient in many of these limited areas of surficial deposits was not possible from the available information.

Maps of the non-pumping water level within the bedrock aquifers show that the direction of groundwater flow in the upper bedrock units, Paskapoo to Horseshoe Canyon (equivalent) Formations, is predominantly towards the Athabasca and MacLeod Rivers (B-35, B-41, B-47 and B-53). This indicates that these aquifers are likely discharging into these rivers. This flow direction is only weakly evident in the Middle and Horseshoe Canyon Formations and not evident in the Bearpaw (equivalent) and deeper formations.

Table 6. Groundwater Flow Budget

Aquifer	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Licensed Diversion (m3/day)	Estimated Unlicensed Diversion (m^3/day)
Surficial						**172**	**669**
Paskapoo	4	0.03	10	Southeast	1200		
	4	0.02	20	Northwest	1600		
	4	0.02	25	Southeast	2000		
				Total	**4800**	**147**	**1907**
Upper Scollard	5	0.008	10	South	400		
	5	0.005	25	West	625		
				Total	**1025**	**36**	**1323**
Lower Scollard	4	0.010	20	South	800		
	4	0.008	35	West	1120		
				Total	**1920**	**36**	**1383**
Upper Horseshoe Canyon	10	0.004	25	South	1000		
	10	0.006	35	West	2100		
				Total	**3100**	**1310**	**1038**
Middle Horseshoe Canyon	10	0.006	55	Southeast	**3300**	**372**	**1238**
Lower Horseshoe Canyon	5	0.003	80	Southeast	**1200**	**10**	**923**
Bearpaw	6	0.002	90	Southeast	**1080**	**228**	**988**

Table 6 shows the estimated quantity of groundwater available in each aquifer and the licensed diversion for each aquifer. An estimate of the unlicensed diversion for each aquifer was made based on the number of wells completed in each aquifer (Table 4). Based on information from the database, the well use is identified as 64 % domestic, 21 % domestic and stock and 11% stock. A corresponding number of the wells completed in each aquifer was multiplied by assumed usage rates of 3.4 m^3/day for domestic wells and 6.5 m^3/day for stock wells.

These groundwater flow estimates indicate that there is more water available in each of the aquifers than is currently licensed for diversion, but when unlicensed diversions are included there may be some shortfalls. These estimates suggest that current usage of both the Upper Scollard and Bearpaw aquifers may exceed the available resources of these aquifers and mining of these aquifers may be occurring. These estimates also indicate that more than half of the estimated resources from the Lower Scollard, Upper and Lower Horseshoe Canyon aquifers may already be in use. These estimates are only approximate and should be taken only as a general indication of the quantity of groundwater flow. They do highlight the necessity of obtaining more accurate and precise data to refine these estimates in order to more accurately evaluate the available groundwater resources within Woodlands County and enable the County to manage their groundwater resources effectively.

6.2.1 Quantity of Groundwater

The quantity of groundwater stored in the surficial deposits is estimated as between 0.8 and 1.4 km^3. The surficial aquifer is discontinuous across the County and is preserved across approximately 40 % of the County area or roughly 1330 km^2. The average thickness of the saturated sands and gravels is roughly 3 m. Porosity of sand and gravel is typically between 20 and 35 % (Fetter 1994), which provides a range of the total estimated volume of groundwater stored in surficial deposits.

6.2.2 Recharge/Discharge

Areas of recharge and discharge were mapped by comparing the non-pumping water levels in the surficial and bedrock aquifers. In areas where the water level is higher in the surficial deposits then in the underlying bedrock, the hydraulic gradient is towards the bedrock aquifers and water will move into the bedrock aquifers from the surficial deposits. This direction of groundwater flow would be considered a recharge to the bedrock aquifers. In areas where the water levels are higher in the bedrock aquifers, discharge from the bedrock aquifers would occur and water would flow into the surficial deposits and potentially into surface water bodies, lakes, rivers, etc.

The areas on the map have been determined by subtracting the non-pumping water level surface determined from water wells completed in the surficial deposits from the non-pumping water level surface determined from water wells completed in the upper bedrock aquifers. The areas are classified as recharge when the water level in the surficial deposits is more than five meters above the water level of the upper bedrock aquifer and discharge when the water level in the surficial deposits is more than five meters below the water level of the upper bedrock aquifer. Areas that fall between these definitions are classified as intermediate.

Bedrock aquifers within Woodlands County are recharged by water flowing through each aquifer both from within and outside the County and by water that infiltrates through overlying deposits. Over 60 % of the County area is classified as recharge to the bedrock aquifers (Figure 25). Given the low permeability, in general, of the surficial deposits, it is expected that the majority of recharge to the bedrock aquifers within Woodlands County is occurring from water flowing through the aquifers. However, surficial deposits are thin and much of the surficial material is quite sandy. There could be considerable local recharge.

Discharge areas are located mainly along the Athabasca, McLeod and Freeman Rivers. In these areas the bedrock aquifers are discharging either directly or indirectly into the Athabasca River, which flows to the northeast, out of the County. Within the southwest portion of

Woodlands County, surficial deposits are thin and discontinuous forming a mixed pattern of discharge and recharge areas.

It is important to recognize areas of recharge as these areas are more susceptible to groundwater contamination as the result of surface activities. In areas of discharge the hydraulic gradient is upwards and it is unlikely that contaminants will migrate downwards into the aquifer(s). Soils and surface waters, however, are more subject to contamination in groundwater discharge areas.

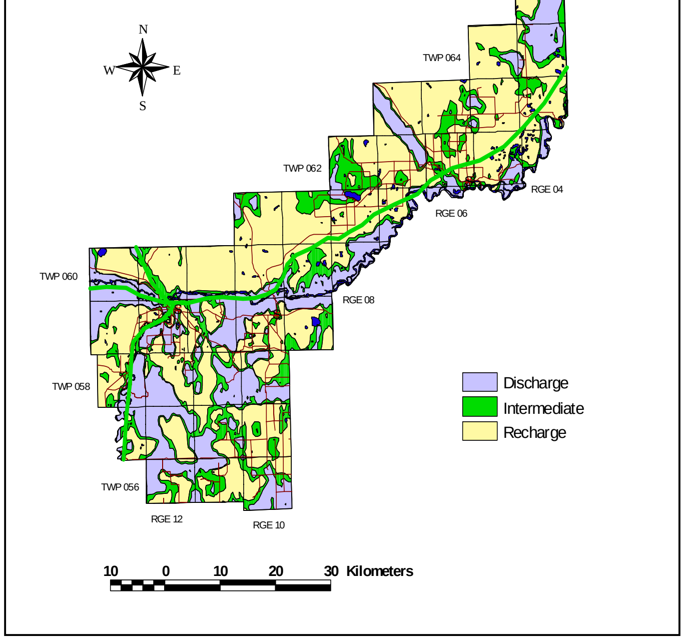


Figure 25. Areas of Bedrock Recharge and Discharge

7.0 POTENTIAL FOR GROUNDWATER CONTAMINATION

Activities at the ground surface are the primary source of groundwater contamination. Leakage from landfills, storage tanks, lagoons or septic systems can infiltrate the ground surface and travel into groundwater aquifers. Contaminants such as pesticides, fertilizers and manure can also be produced by agricultural activities.

Identifying the relative contamination risk of areas enables the appropriate locating of industries that have the potential to produce contaminants in areas of lower risk, where possible, and the proper management of these industries in areas of greater potential risk to reduce the possibility of groundwater contamination.

The risk of groundwater contamination is dependant on several factors. In areas where the groundwater is discharging, i.e. flowing towards the surface, the likelihood of contaminants migrating downwards is low. In areas where the hydraulic gradient is downwards towards the groundwater aquifers, the ease with which contaminants can migrate down towards the aquifers is controlled by the permeability of the surface materials. Geological materials such as clay or till have a low permeability and contaminants will migrate more slowly through these materials than through sand or gravel. If sand or gravel are present within the first meter of the ground surface this will enable the contaminants to migrate more quickly into the subsurface.

The permeability of surface materials was defined on the basis of geological material type using a surficial geology map for the area (Shetsen 1990) as shown in Table 7.

Table 7. Permeability Classification

Permeability	Materials
High	Gravel & sand and sand & silt
Medium	Silt & clay, sand & silt and peat
Low	Till and bedrock

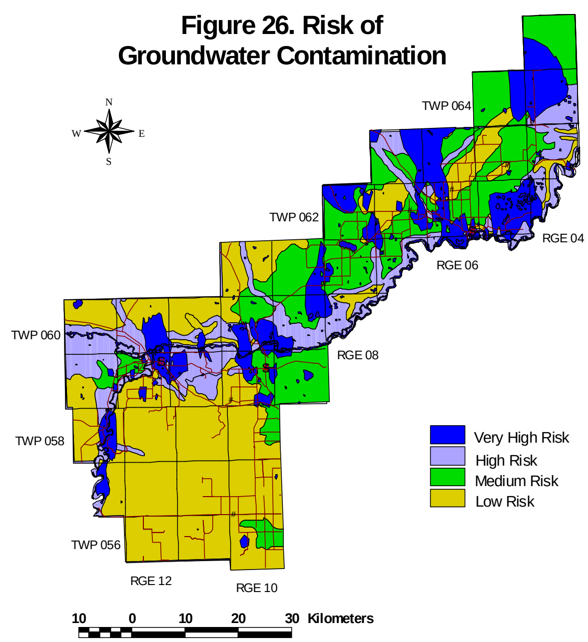
The presence of sand and gravel was mapped using the lithological information in the groundwater database. The risk of groundwater contamination was determined by combining the relative permeability of surface materials with the mapped presence of sand and gravel surface, as outlined in Table 8.

Table 8. Groundwater Contamination Risk Criteria

Presence or Sand or Gravel within 1 m of Ground Surface	Surface Permeability	Groundwater Contamination Risk
No	Low	Low
No	Moderate	Moderate
No	High	High
Yes	Low	Very High
Yes	Moderate	Very High
Yes	High	Very High

Less than 30% of the area within Woodlands County has a high or very high risk of groundwater contamination (Figure 26). Some of these areas are located along the river valleys within the County. These same areas were also generally mapped as discharge areas (see Figure 25), indicating that the actual risk of groundwater contamination to bedrock aquifers is lower than these high risk designations. Areas of very high risk are found near Whitecourt and Fort Assiniboine and locally in the northern portion of the County. All of these designations are made based on regional mapping. Site specific studies should be taken in order to investigate the site specific contamination risks.

Figure 26. Risk of Groundwater Contamination



8.0 RECOMMENDATIONS

One of the issues highlighted in this report is the data quality of the groundwater database. Specific issues are the accuracy and completeness of the data. Information collected for the database is submitted by numerous people with varying amounts of knowledge. Information submitted for the database often includes only sporadic data, missing key pieces of information such as the well elevation and completion information. To remedy these issues in full is simply not possible. The well location corrections provided by PFRA and the corrections made in this study to the database are a significant step to improving the data quality. Significant further improvements could be made by field verification of the location (latitude, longitude and elevation), depth in meters below ground level (mBGL), water level (mBGL) and the casing height (mAGL or mBGL). Given the number of wells within the County currently listed in the database such a project, including updating the database, could be completed by one individual during a 4 month period. This information would substantially improve the accuracy of the database, provide valuable, accurate water level information and enable new maps to be created which would be a significant improvement to the current hydrogeological maps. It is recommended that a field verification program, as outlined above, should be undertaken before attempting to upgrade the mapping and interpretations included in this report.

Given the significant quantities of water used by the licensed wells, these wells should be included in the field verification program. Accurate locations for these wells are necessary in order to assign these wells to an aquifer. This information is necessary in order to improve the assessment of current groundwater usage. These sixty wells should be made a priority in any field verification project.

Available information indicates that the current use of the main aquifers within Woodlands County is generally less than the available resources, but some exceedances are suggested by the current estimates. This information is particularly sparse within Woodlands County and efforts must be made to obtain more information to permit a more accurate assessment of the groundwater budget and enable better planning for the future. Specifically, groundwater level information should be obtained for the main aquifers within Woodlands County. We suggest that Woodlands County consider obtaining the assistance of water well owners in this regard. The M.D. of Rocky View is providing water well owners with a tax credit if they accurately measure the water level in their well once a week. A pilot project indicated that records should be collected over a five year period in order to obtain a useful set of data. The cost of such a program is expected to be cheaper than installing observation wells and could result in a greater quantity of data available for analysis. A minimum of four wells in the Surficial aquifer, three wells from each of the Upper and Lower Scollard, Upper Horseshoe Canyon, Lower Horseshoe Canyon and Bearpaw aquifers should be selected in addition to a minimum of two wells from each of the remaining aquifers. Thus, a minimum of twenty-seven wells should be selected for use as groundwater level monitors.

These wells should be selected on the basis of their representativeness of the aquifer they are intended to monitor (i.e. should be completed over the largest possible interval of the aquifer to be monitored and not completed over any other aquifer) and all of these wells together should provide good areal coverage of the aquifer across the primary areas of usage. It is recommended that under such a program, two years (minimum) data should be collected prior to updating the groundwater budget provided in this report. In addition, the existing data along with the updated data could be used to create a hydrogeological model of Woodlands County. This model can be used to determine a groundwater budget for Woodlands County.

9.0 REFERENCES

Dawson, F.M., Evans, C.G., Marsh, R. and Richardson, R. Uppermost Cretaceous and Tertiary Strata of the Western Canada Sedimentary Basin. In Geological Atlas of the Western Canada Sedimentary Basin. G.D. Mossop and I. Shetsen (comps.). On-line version: http://www.ags.gov.ab.ca/AGS_PUB/ATLAS_WWW/A_CH30/CH_30.HTM (1998,01,20)

Federal-Provincial Subcommittee on Drinking Water. 1995. Guidelines for Canadian Drinking Water Quality. Health Canada.

Federal-Provincial Subcommittee on Drinking Water. April 1999. Summary of Guidelines for Canadian Drinking Water Quality. Health Canada.

Fetter, C.W. 1994. Applied Hydrogeology. Prentice Hall, Inc. New Jersey. 691 p.

Glass, D. (ed) 1997. Lexicon of Canadian Stratigraphy, Volume 4, Western Canada, Including Eastern British Columbia, Alberta, Saskatchewan and Southern Manitoba. Society of the Petroleum Geologists.

Geomatics Canada. 1996. Standards and Specifications of the National Topographic Data Base. Edition 3.1. Natural Resources Canada. 32 p.
On-line version: http://www.cits.rncan.gc.ca/ext/html/english/products/ntdb/stdntdb3.html

Geomatics Canada. 2000. Canadian Digital Elevation Data Standards and Specifications. 15 p. Natural Resources Canada.
On-line version: http://www.cits.rncan.gc.ca/ext/html/english/products/cded/stdcded.html

Hamilton, W.H, W. Langenberg, M.C. Price, D.K. Chao 1998. Geological map of Alberta.

Jones, J.F. 1962. Reconnaissance groundwater study Swan Hills and adjacent areas, Alberta. Research Council of Alberta. Preliminary Report 62-5.

Ozoray, G.F. 1972. Hydrogeology of the Wabamun Lake area, Alberta. Alberta Research Council. Report 72-8.

Shetsen, I. 1990. Quaternary Geology, Central Alberta. Alberta Research Council. Map 213.

Tokarsky, O. 1977. Hydrogeology of the Whitecourt area, Alberta. Alberta Research Council. Report 76-3.

10.0 ABBREVIATIONS

AE	Alberta Environment
AMSL	above mean sea level
GCDWQ	Guidelines for Canadian Drinking Water Quality
m	meters
m^3/day	cubic meters per day
mAGL	meters above ground level
mBGL	meters below ground level
mg/L	milligrams per litre
mm	millimeters
PFRA	Prairie Farm Rehabilitation Administration
TDS	Total Dissolved Solids

11.0 GLOSSARY

Apparent yield	The rate a water well could be pumped at from an aquifer
Aquifer	Rock or sediment in a part of a formation, formation or group of formations that is saturated and able to transmit economic quantities of water
Aquitard	A unit of low permeability that stores groundwater and transmits groundwater slowly from one aquifer to another
Hydraulic Conductivity	A coefficient of proportionality that describes the rate at which water will flow through a unit area at a hydraulic gradient of one. Units: length/time
Hydraulic Gradient	The change in hydraulic head over a unit distance in the direction of maximum change in hydraulic head. Units: length/length (dimensionless)
Outcrop	The total area over which a particular rock unit occurs at the land surface.
Permeability	Ability of a geological material to transmit water, described by hydraulic conductivity
Subcrop	The total area over which a particular bedrock unit (formation or group) directly underlies (i.e. is in direct contact with) overlying surficial materials.
Surficial Deposits	Sediments above the bedrock surface
Transmissivity	The rate at which water can be transmitted through a unit width of an aquifer under a unit hydraulic gradient. Units: $length^2$/time

APPENDIX A

MAPS AND FIGURES INCLUDED IN REPORT

APPENDIX B

LIST OF MAPS AND FIGURES INCLUDED ON CD-ROM

1. GENERAL

2. SURFICIAL

3. BEDROCK

3.1 General

3.2 Paskapoo Aquifer

3.3 Upper Scollard Aquifer

3.4 Lower Scollard Aquifer

3.5 Upper Horseshoe Canyon Aquifer

APPENDIX C

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

Bedrock Topography
Apparent Yield in Sand and Gravel Aquifer
Total Dissolved Solids in Groundwater from Sand and Gravel Aquifer
Apparent Yield from Water Wells Completed in Upper Bedrock Aquifers
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifers
Risk of Groundwater Contamination
Cross-Section A-A’
Cross-Section B-B’
Cross-Section C-C’
Cross-Section D-D’
Areas of Bedrock Recharge and Discharge