5. Aquifers

5.1 Background

An aquifer is a permeable rock that is saturated. In this context, rock refers to subsurface materials, such as sand, gravel, sandstone and coal. If the non-pumping water level is above the top of the rock unit, this type of aquifer is an artesian aquifer. If the rock unit is not entirely saturated and the water level is below the top of the rock unit, this type of aquifer is a water-table aquifer. These types of aquifers occur in one of two general geological settings in the M.D. The first geological setting includes the sediments that overlie the bedrock surface. In this report, these sediments are referred to as the surficial deposits. The second geological setting includes aquifers in the upper bedrock. The geological settings, the nature of the deposits making up the aquifers within each setting, the expected yield of water wells completed in aquifer(s) within different geologic units, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

5.1.1 Surficial Aquifers

Surficial deposits in the M.D. are mainly less than 100 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 150 metres. The Buried Helena and Beverly valleys are the main linear bedrock lows in the M.D (see Figure 11). Other linear bedrock lows include the Buried Sinclair, St. Paul and Vermilion valleys, and the Moore Lake, Big Meadow, Bronson Lake and Holyoke channels. The west-east cross-section E-E', Figure 9 shown below, passes across both the Buried Helena and Beverly valleys and shows the surficial deposits being in the order of 200 metres thick across the Buried Helena Valley.

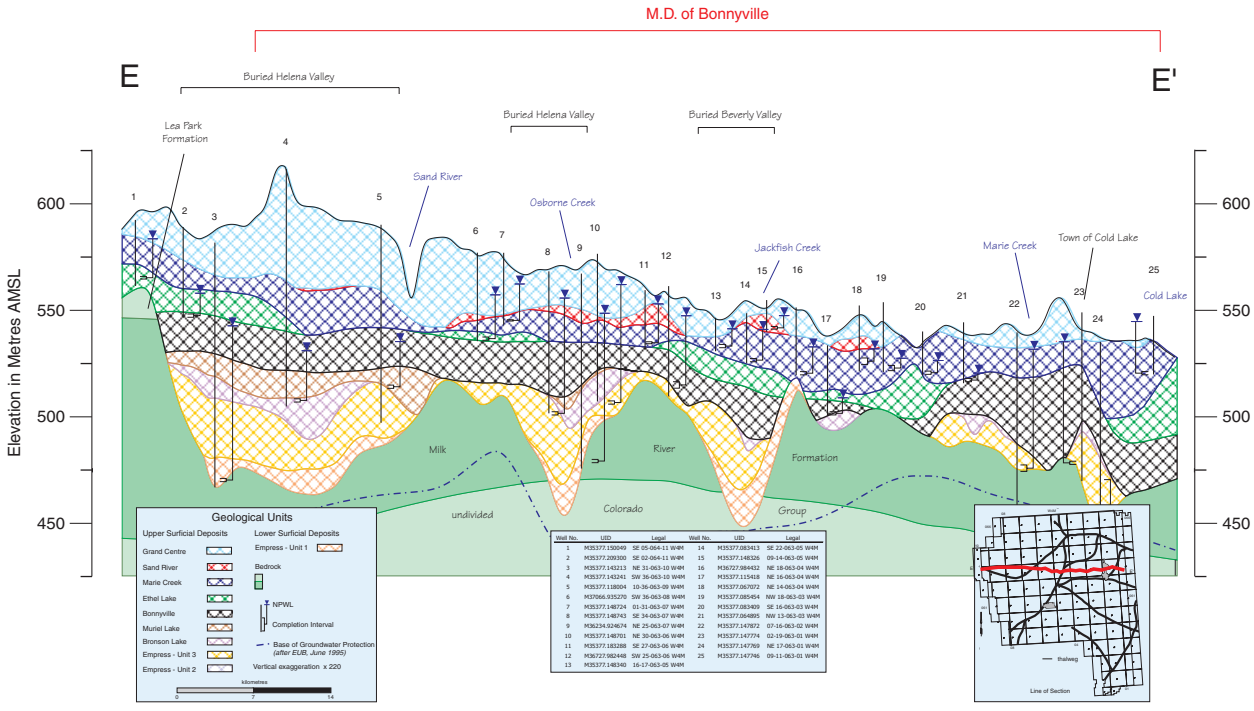

Figure 9. Cross-Section E - E'

In the M.D., the Base of Groundwater Protection extends below the bedrock surface but can extend into the Empress Formation, as shown on Figure 10 on the following page. A map showing the depth to the Base of Groundwater Protection is given on Page 7 of this report, in Appendix A, and on the CD-ROM.

The south-north cross-section B-B', Figure 10 shown below, passes across the Buried Beverly, Helena and Sinclair valleys and shows the surficial deposits being mainly less than 100 metres thick but in the order of 200 metres thick across the Buried Helena Valley.

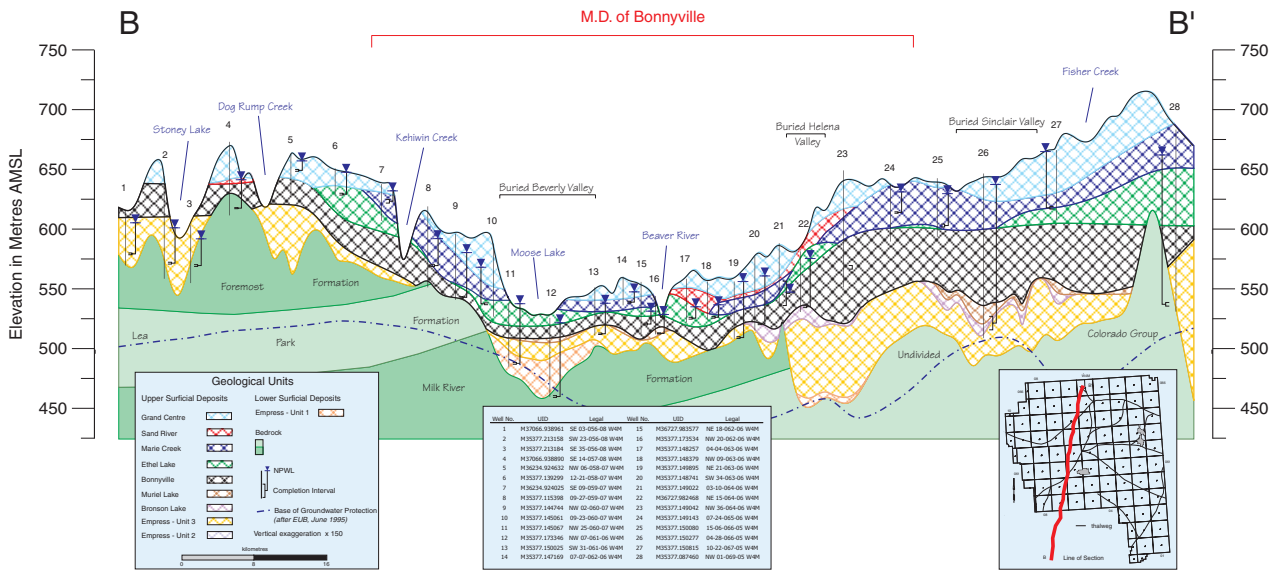

Figure 10. Cross-Section B - B'

The main aquifers in the surficial materials are sand and gravel deposits. In order for a sand and gravel deposit to be an aquifer, it must be saturated; if not saturated, a sand and gravel deposit is not an aquifer. The top of the surficial aquifers has been determined from the non-pumping water level in water wells that are less than 20 metres deep. The base of the surficial deposits is the bedrock surface.

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the M.D., casing-diameter information is available for 2,361 of the 2,425 water wells completed in the surficial deposits; 269 (11%) of the 2,361 water wells have a casing diameter of more than 275 millimetres, and are assumed to be bored or dug water wells.

5.1.2 Bedrock Aquifers

In the M.D., the upper bedrock includes the Foremost, Lea Park and Milk River formations, and the *undivided* Colorado Group, as shown above in Figure 10. Some of this bedrock contains saturated rocks that are permeable enough to transmit groundwater for a specific need. In the M.D., the upper bedrock aquifer(s) are of minor importance and there are only a few water wells completed in the upper bedrock.

5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. These include pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly as a result of glaciation. The *lower surficial deposits* include pre-glacial fluvial[10] and lacustrine[11] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[12], meltwater deposits, and ice contact deposits. Pre-glacial materials are expected to be mainly present in association with the buried bedrock valleys.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeologic unit, they consist of three hydraulic parts. The first unit is the sand and gravel deposits of the lower surficial deposits, when present. These deposits are mainly saturated. The second and third hydraulic units are associated with the sand and gravel deposits in the upper surficial deposits. The sand and gravel deposits in the upper surficial deposits occur mainly as pockets. The second hydraulic unit is the saturated part of these sand and gravel deposits; the third hydraulic unit is the unsaturated part of these deposits. For a graphical depiction of the above description, please refer to Figure 6, Page 7. While the unsaturated deposits are not technically an aquifer, they are significant as they provide a pathway for liquid contaminants to move downward into the groundwater.

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on the adjacent map. There are numerous linear bedrock lows shown on the bedrock topography map. The lowest elevation of the linear bedrock low is the thalweg; the thalwegs for the linear bedrock lows in the present report are named as per Gold, Andriashek and Fenton, 1983.

Over the majority of the M.D., the surficial deposits are less than 100 metres thick (Page A-19). The exceptions are mainly in association with areas where buried bedrock valleys are present, where the deposits can have a maximum thickness of more than 200 metres. The main linear bedrock lows in the M.D. are southwest-northeast-trending, are designated as the Buried Helena Valley and the Buried Beverly Valley. The bedrock surface is at its lowest elevation of less than 440 metres AMSL within the Buried Helena Valley near Cold Lake. The lowest elevation of the bedrock surface within the Buried Beverly Valley is less than 460 metres AMSL.

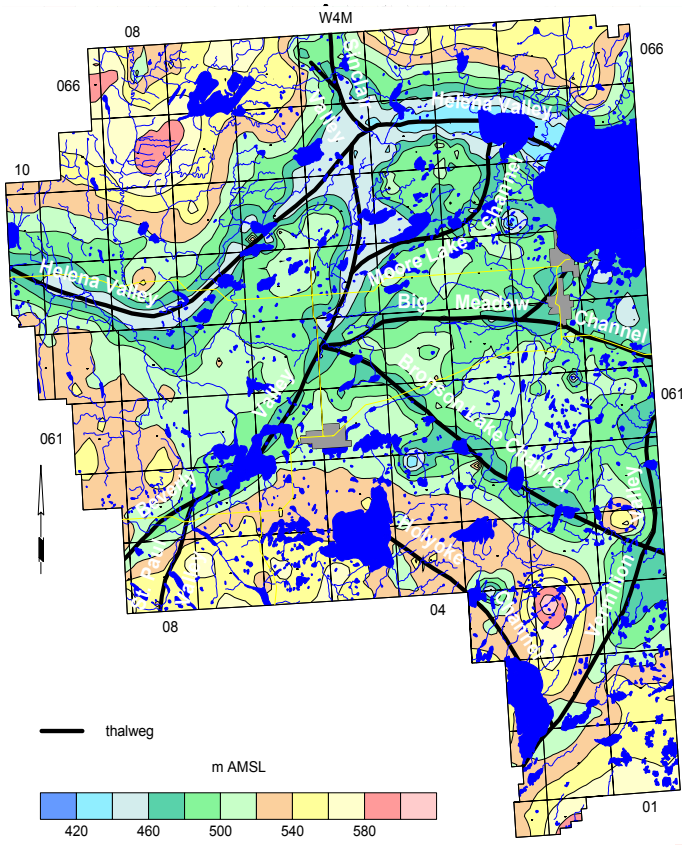

Figure 11. Bedrock Topography

[10] See glossary
[11] See glossary
[12] See glossary

The Buried Helena Valley is the deepest and widest buried bedrock valley in the M.D. and is present in the north-central part of the M.D. The Valley is eight to twelve kilometres wide within the M.D., with local bedrock relief being up to 70 metres. Sand and gravel deposits can be expected in association with this bedrock low, with the sand and gravel deposits expected to be mainly less than 30 metres thick.

There are three buried bedrock valleys that are tributaries to the Buried Helena Valley: the Sinclair, Vermilion, and Imperial Mills valleys. The Buried Sinclair Valley, present in the northern part of the M.D. in townships 065 and 066, range 05, W4M, is eight to ten kilometres wide, with local bedrock relief being up to 80 metres. Sand and gravel deposits can be expected in association with this bedrock low, and can be more than 50 metres thick where the Buried Sinclair Valley joins the Buried Helena Valley.

The Buried Vermilion Valley, present in the southeastern part of the M.D., joins the Buried Helena Valley east of Cold Lake in Saskatchewan. The Buried Vermilion Valley is three to five kilometres wide, with local bedrock relief being up to 40 metres. In the County of Vermilion, where the Buried Vermilion Valley is more clearly defined, the Valley is eight to 15 kilometres wide, with bedrock relief being up to 100 metres. Sand and gravel deposits associated with this bedrock low are expected to be mainly less than ten metres thick.

The Buried Imperial Mills Valley is present in Lakeland County (see Appendix F). The Buried Kikino Valley present in Lakeland County connects two major buried valleys, the Beverly and Helena valleys (Andriashek and Fenton, 1989). The Buried Imperial Mills Valley joins the Buried Helena Valley in township 065, range 11, W4M. The Buried Kikino Valley, not well defined in Lakeland County, joins the Buried Helena Valley near Lac La Biche (Yoon, 1974).

The Buried Beverly Valley enters the M.D. in township 059, range 09, W4M and joins the Buried Helena Valley in township 065, range 05, W4M. The Buried Beverly Valley is five to eight kilometres wide within the M.D., with local bedrock relief being up to 60 metres. Sand and gravel deposits can be expected in association with this bedrock low, with the sand and gravel deposits expected to be mainly less than 20 metres thick.

There are three buried bedrock valleys that are tributaries to the Buried Beverly Valley: the Buried St. Paul, Kikino (Lakeland County) and Vegreville (County of St. Paul) valleys. The Buried Kikino Valley joins the Buried Beverly Valley in the County of Smoky Lake (Andriashek and Fenton, 1989). The Buried Vegreville Valley joins the Buried Beverly Valley in the County of St. Paul.

The Buried St. Paul Valley is the only tributary to the Buried Beverly Valley present within the M.D. The Buried St. Paul Valley, located in the southwestern part of the M.D., joins the Buried Beverly Valley in township 060, range 08, W4M. The Buried St. Paul Valley is not well defined in the M.D., but is expected to be one to two kilometres wide, with local bedrock relief being up to 30 metres. Sand and gravel deposits associated with this bedrock low are mainly less than ten metres thick.

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. In the Sand River area (73L), the preglacial sediments have been defined by Andriashek and Fenton (1989) to include primarily preglacial sand and gravel deposits, and in this report have not been differentiated between fluvial and lacustrine deposits. The lower sand and gravels are referred to by Andriashek and Fenton as the Empress Formation - Unit 1. The Empress Formation – Unit 1 occurs in the Buried Helena, Beverly and Sinclair valleys, and in parts of the Buried Vermilion Valley. The extent of the Empress Formation – Unit 1 has been defined and documented in the Sand River area (73L) by Yoon (1974), and by Andriashek and Fenton (1989). The total thickness of the Empress Formation – Unit 1 in the Buried Imperial Mills Valley is mainly less than 15 metres.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with generally minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. Because the meltwater channels are mainly an erosional feature, the sand and gravel deposits associated with these features are considered not to be significant aquifers. The Formations that comprise the upper surficial deposits have been defined by Andriashek and Fenton (1989) and are described in Section 5.3 of this report. The thickness of the upper surficial deposits is mainly less than 100 metres, but can be more than 150 metres in the northwestern and southwestern parts of the M.D.

The major meltwater channels in the M.D. have been outlined by Andriashek and Fenton (1989). In the M.D., there are four major meltwater channels: the Moore Lake, Big Meadow, Bronson Lake and Holyoke channels as shown previously on Figure 11. These meltwater channels mainly overlie linear bedrock lows. Because sediments associated with the lower sand and gravel deposits are indicated as being present in many of these linear bedrock lows, it is possible that the bedrock lows were originally tributaries to the buried bedrock valleys (Andriashek and Fenton, 1989).

Sand and gravel deposits occur throughout the M.D. (Figure 12). The sand and gravel deposits of more than ten metres thick occur mainly in association with linear bedrock lows. Thicknesses of more than 50 metres are expected at the junction of the Buried Helena and Sinclair valleys and in association with parts of the Holyoke Channel.

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 70% of the M.D. where sand and gravel deposits are present, the sand and gravel deposits are between 10 and 30% of the total thickness of the surficial deposits (Page A-21). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly in the areas associated with linear bedrock lows.

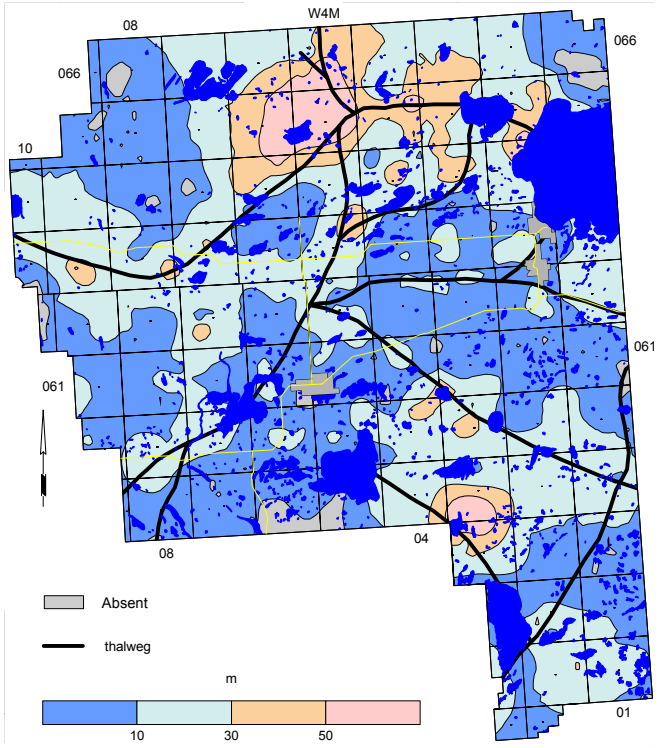

Figure 12. Thickness of Sand and Gravel Deposits

5.3 Surficial Deposits

5.3.1 Quaternary Stratigraphy

There are eight glacial formations and one preglacial formation present in the surficial deposits in the M.D. The eight glacial formations, from youngest to oldest, are: the Grand Centre, Sand River, Marie Creek, Ethel Lake, Bonnyville, Muriel Lake, Bronson Lake formations, and the upper two units (Units 2 and 3) of the Empress Formation. The preglacial formation is the lower unit (Unit 1) of the Empress Formation. A generalized geologic column, showing the eight formations, is illustrated on Figure 7, in Appendix A and on the CD-ROM. The following descriptions of the nine formations are modified from Andriashek and Fenton (1989):

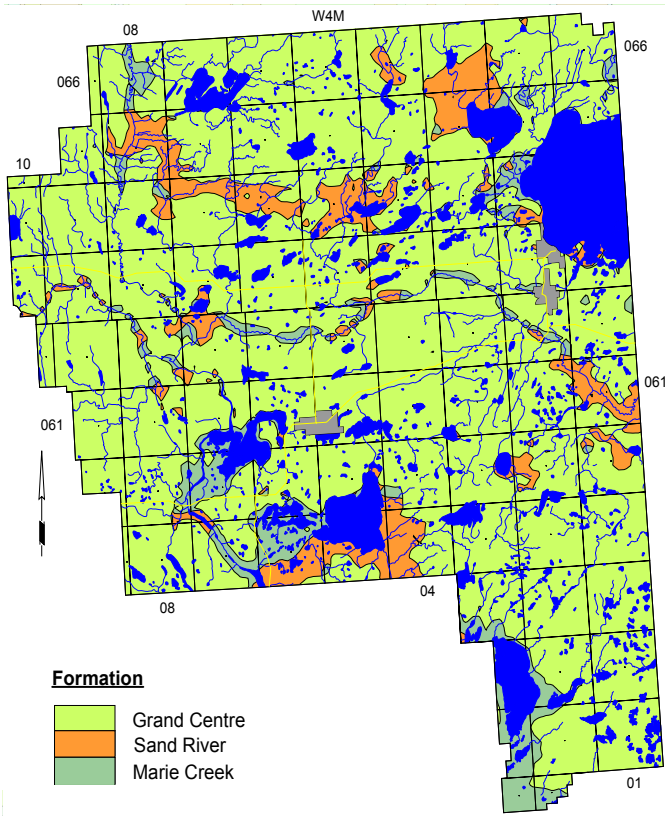

Figure 13. Surficial Geology Map

"The Empress Formation is the oldest, and is divided into three units on the basis of lithology; Unit 1, preglacial sand and gravel; Unit 2, silt and clay; and Unit 3, glacial sand and gravel." The thickness of the Empress Formation is in the order of 70 metres. The Empress Formation – Unit 1, where present, rests on the top of the Lea Park and Milk River formations and the *undivided* Colorado Group.

In the M.D., the sand and gravel deposits of the Empress Formation – Unit 1 are found on the floors of the Buried Helena and Beverly valleys and the southern portion of the Buried Sinclair Valley. "Unit 1 generally consists of thin (< 5 metres) basal gravel overlain by sand or gravelly sand ranging in thickness from 5 to 10 metres".

In the M.D., the silt and silty clay deposits of the Empress Formation – Unit 2 "is confined almost entirely to the bottoms of the valleys and channels", specifically segments of the Buried Helena, Beverly and Sinclair valleys, and a segment of the Moore Lake Channel. "The Unit is generally thick near the confluence of the Buried Helena and Beverly valleys", where the Unit can be up to 40 metres thick. There will be no direct review of the Empress Formation - Unit 2 because there are no water wells in the M.D. that are completed in the Unit; the only maps associated with the Empress Formation – Unit 2 to be included on the CD-ROM will be structure-contour maps.

In the M.D., the Empress Formation – Unit 3 is the lowest stratigraphic unit, all of whose sediments are of glacial origin. The sediments consist primarily of sand and gravel deposits. The determination of the areal extent and thickness of the Empress Formation – Unit 3 is the only Formation designation that differs from Andriashek and Fenton. The Empress Formation - Unit 3 directly overlies the bedrock surface in areas of bedrock highs. For this regional study, the determination of the areal extent and thickness of the Empress Formation – Unit 3 is calculated by subtracting the total thickness of the Bonnvyille, Muriel Lake and Bronson Lake formations from the top of the Bonnyville Formation.