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Groundwater Resources of the Lake Saint-Martin Area, Manitoba

Sheet 3 of 6

Potentiometric Surface Bedrock Aquifers

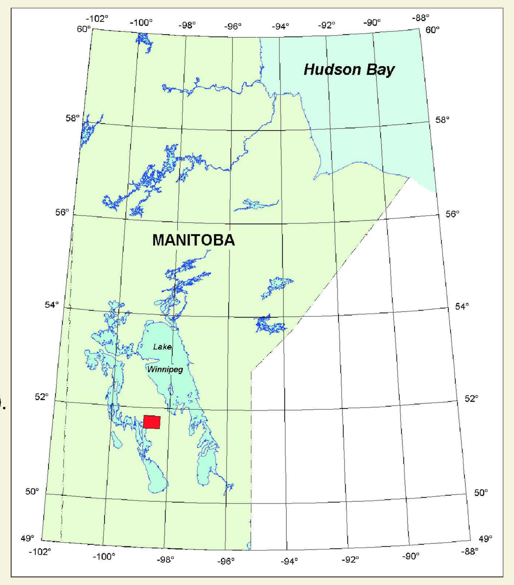

Figure 1: Location of study area

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Map Notes

Introduction

The potentiometric surface of bedrock aquifers in the Lake Saint-Martin area (Figure 1) was mapped previously by Betcher (1987) at a scale of 1:250 000. As part of its hydrogeological investigations in the area, the Geological Survey of Canada has prepared these more detailed maps of groundwater head (see Map Production Notes). In Figure 2, the potentiometric surface is displayed in terms of its elevation above sea level. In Figure 3, it is displayed in terms of its depth below ground level. For reference, the regional topography (Matile and Keller, 1999) and bedrock geology (McCabe and Bannatyne, 1970) are shown in Figures 4 and 5, respectively.

The potentiometric maps are based primarily on observations taken in June of 2001, at the time of year when groundwater levels are normally highest. During the period of field investigations, from 1998 to 2001, groundwater levels in upland areas fluctuated over more than 5m throughout the year whereas in low-lying areas the range of fluctuations was closer to 1m.

Hydrogeological Setting

The bedrock geology in the study area has been described in detail by McCabe and Bannatyne (1970). A simplified geological map based on that of Bannatyne and McCabe (1984) is shown in Figure 5. The main feature of this map is the 220 ma Lake Saint-Martin Impact Structure which disrupts the normal Interlake stratigraphic succession of gently dipping Ordovician and Silurian carbonates. The 24km diameter complex crater exhibits a central uplifted core of Precambrian basement rocks surrounded by a shallow concentric sedimentary basin. The crater-fill sediments consist of impacted-related carbonate breccias, granitic microbreccias and meltrock of the Permian St-Martin Complex overlain by coarse to fine-grained Jurassic red beds, dolomitic mudstones and evaporites (gypsum and anhydrite).

Outside the impact structure, the bedrock aquifer is hosted by Ordovician and Silurian dolomites and it forms part of the extensive Carbonate-Evaporite Unit of the Western Glaciated Plains Region (Betcher et al., 1995). The permeability of the carbonate aquifer can be quite high due to dissolution features and, locally, due to intense impact-related fracturing and faulting surrounding the crater rim. Within the impact structure, the main bedrock aquifer is hosted by highly permeable brecciated carbonates and granitic microbreccias of the St-Martin Complex. However, because of the high permeabilities in both the carbonate and breccia aquifers, their heads are continuous across the crater rim and, as a result, they are viewed here as a single aquifer system. In the central portion of the impact structure, the breccia aquifer is confined by red beds that form a leaky aquitard containing coarse lenses of higher permeability. In turn, this aquitard is overlain by a shallow phreatic aquifer hosted by karstic evaporites. Except in upland regions, the bedrock aquifers are confined by tills and glacio-lacustrine clays of varying thickness.

Potentiometric surface elevation

Figure 2 shows a map of the potentiometric surface in the bedrock aquifer system where heads are expressed in metres above sea level. Because the bedrock aquifers are confined throughout most of the region, the potentiometric surface elevation is usually different from the water table elevation. Groundwater flows from areas of high head, usually in uplands, to areas of lower head, usually in swamps, streams, rivers and lakes. Areas of highest groundwater head are known as recharge zones because that is where precipitation replenishes the aquifer system. In these areas, the water table elevation is higher than the potentiometric surface elevation measured in a deep well because flow is downward. Conversely, areas of lowest head are known as discharge zones because that is where groundwater leaves the aquifer system. In these areas, the potentiometric surface elevation measured in a deep well is higher than the water table elevation because flow is directed upward.

The map of groundwater heads shows several recharge zones for the bedrock aquifer. The most significant of these lies in the northwest corner of the study area. It represents the southern tip of a bedrock ridge overlain by permeable glacial sands and gravels which can be seen in Figure 4. Groundwater recharged here flows southwest toward Lake Manitoba and southeast toward Lake Pineimuta. The bedrock ridge between Lakes Manitoba and Pineimuta forms a local recharge zone where precipitation enters the highly fractured carbonate aquifer directly, through a thin, discontinuous layer of till. Groundwater then flows radially, outward, toward adjacent lakes and wetlands. The low north-south ridge, underlying the village of Gypsumville, represents another local recharge zone. Here, groundwater enters the bedrock aquifer as leakage through the overlying Jurassic Red Beds from the unconfined evaporite karst aquifer. This groundwater flows toward Lake Pineimuta and Lake Saint-Martin. North of Gypsumville, there is a poorly-defined groundwater divide beyond which flow is to the north, toward Gypsum Lake and the Warpath River drainage system.

Potentiometric surface depth

Figure 3 shows a map of potentiometric surface in terms of its depth below the ground surface. This kind of map is useful because it directly provides the depth to the static water level that is measured in a well although this water level should not be confused with the level of the water table. In general, depths to water are greatest in upland areas, particularly if the aquifer material is quite permeable. Here, on the ridges of highly permeable, fractured Paleozoic carbonates the depth to water may exceed 10m. Figure 3 also clearly shows areas where artesian, or flowing wells, may be expected. These conditions are found where the potentiometric surface elevation is greater than the ground elevation, usually in low-lying areas where groundwater is discharging from a confined aquifer to evaporate in swamps or to feed the surface drainage system. Here, artesian conditions are found over much of the shallow basin extending northward from Lake Pineimuta. Wells in this area flow freely throughout most of the year and the land is usually waterlogged despite the two major drains excavated in order to alleviate this problem.

Map Production Notes

The potentiometric surface represented in Figures 2 and 3 has been compiled from water level measurements performed during the first week of June 2001 in wells completed at various depths within the bedrock aquifers. Additional data sources used in the preparation of these maps include selected water level measurements from provincial water well records, elevations of known flowing wells and elevations of groundwater seeps. Depth to water measurements are referenced to topographic elevations of the Digital Elevation Model (DEM) shown in Figure 4. This DEM, with a 100m resolution, has been modified from that of Matile and Keller (1999) to remove artifacts of digital image processing.

The potentiometric surface was interpolated from measurement locations using the geostatistical method known as kriging with an "external drift" or deterministic spatial trend, described in Desbarats et al. (2002). The spatial trend in the potentiometric surface is modeled by the topographic elevation given by the DEM. The trend residual, to be estimated, is the depth to water. This kriging method takes advantage of fine-resolution topographic information in the DEM to improve the estimation of potentiometric levels in areas of sparse well control.

The uncertainty in depth to water level is less than 1 m in the central portion of the study area, where well control is fairly tight. However, the uncertainty is higher in peripheral areas. Because water level measurements are referenced to the topographic surface, the uncertainty in potentiometric surface includes that in the Digital Elevation Model. The uncertainty in the DEM is reported to average 3m over southern Manitoba although this figure is likely quite conservative for the study area.

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POTENTIOMETRIC SURFACE

Figure 2

Potentiometric Surface Elevation

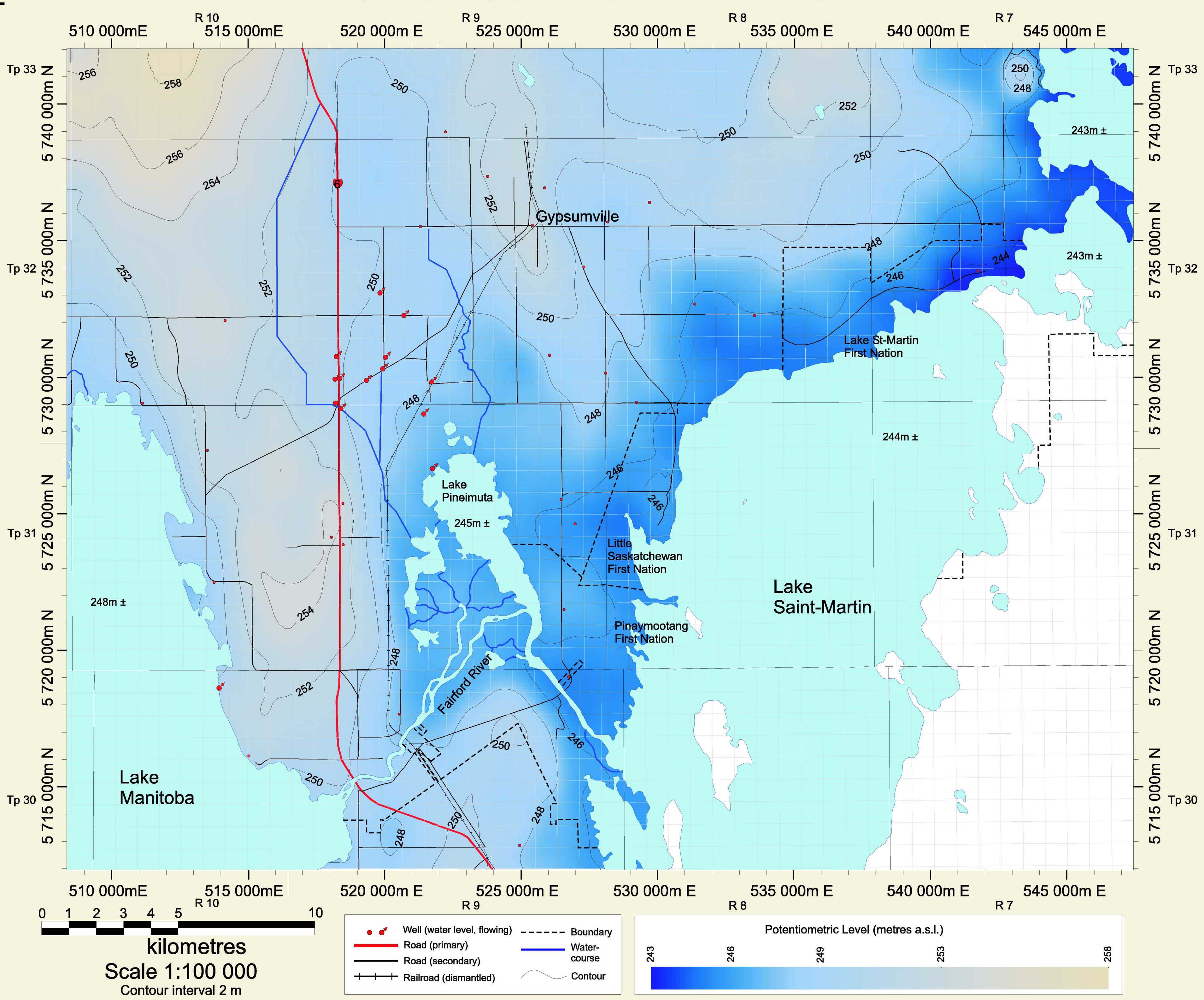

Figure 3

Potentiometric Surface Depth

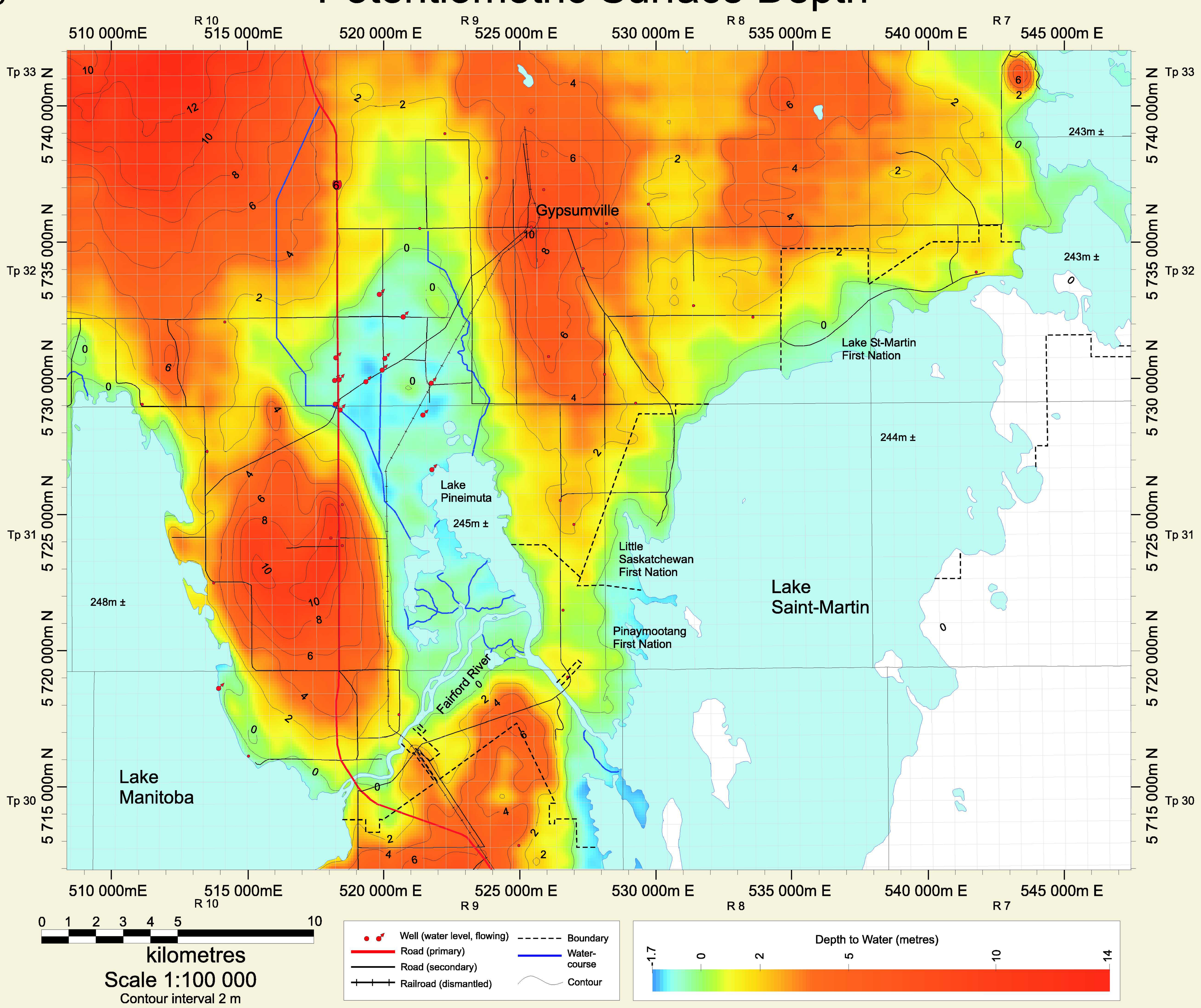

Figure 4

Digital Elevation Model

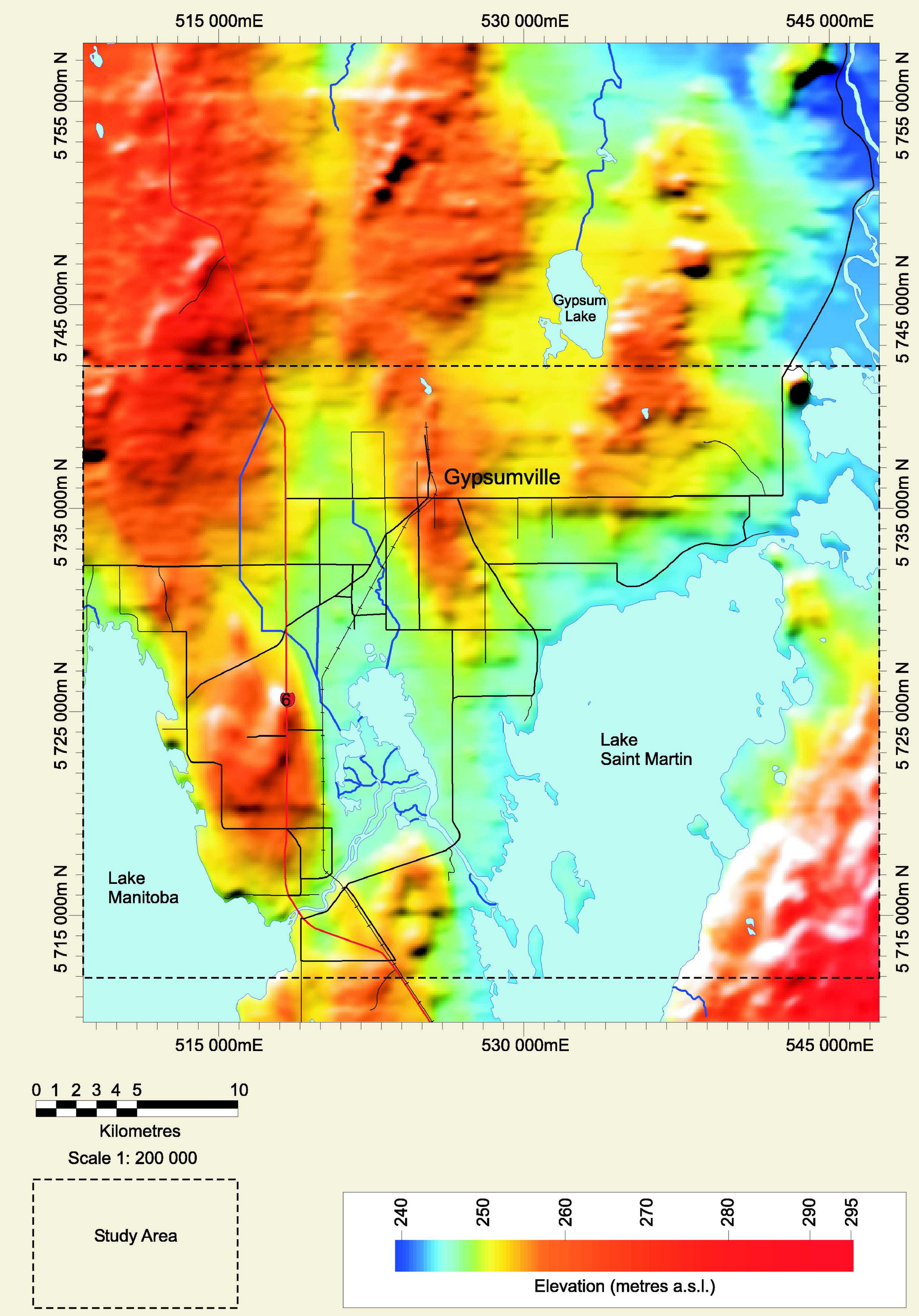

Figure 5

Bedrock Geology