YES VIRGINIA, THERE ARE BURIED VALLEY AQUIFERS IN MANITOBA

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ABSTRACT
Buried valley aquifers form important sources of groundwater supply in the Prairie provinces of Canada, particularly through parts of Saskatchewan and Alberta where permeable sand and gravel deposits within glacial or pre-glacial valleys eroded into Cretaceous bedrock may form the only significant local aquifers. In Manitoba there has historically been less exploration carried out to define and evaluate these features, in part due to the relatively greater abundance of shallow sand and gravel or bedrock aquifers in the province.

Based on a review of existing literature and re-interpretation of water well and test hole logs, a revised map has been developed showing the locations of buried valleys underlain by Mesozoic and Cenozoic bedrock in south-western and west-central Manitoba. In most cases, these valleys are extensions of known buried valleys in Saskatchewan and North Dakota. The groundwater supply potential of some of these features is also discussed.

RÉSUMÉ
Les aquifères des vallées enfouies constituent d'importantes sources d'eaux souterraines dans les Provinces des Prairies et peuvent former les seules aquifères locales importantes, particulièrement dans certaines régions de la Saskatchewan et de l'Alberta où des dépôts de sable et de gravier perméables dans les vallées glaciaires ou préglaciaires se sont érodés en sous-sols rocheux crétacés. Au Manitoba, il y a eu historiquement moins d'exploration pour définir et évaluer ces reliefs, en partie en raison de l'abondance relativement plus importante d'aquifères peu profondes de sable et gravier ou de substratum rocheux dans la province.

En se fondant sur la documentation actuelle et la réinterprétation des registres des puits d'eau et des forages d'essai, on a dressé une carte révisée montrant les endroits des vallées enfouies qui reposent sur du substratum rocheux mésozoïque et cénozoïque dans les régions du sud-ouest et du centre-ouest du Manitoba. Dans la plupart des cas, ces vallées sont le prolongement de vallées enfouies connues de la Saskatchewan et du Dakota du Nord. Le potentiel en approvisionnement en eau souterraine de certains de ces reliefs est également abordé.

1. INTRODUCTION

Groundwater forms an important source of water supply in the Prairie provinces of Canada, providing water for about 30% of the population as a whole and up to 90% of the population within rural areas (Rutherford, 2004). In Saskatchewan and Alberta, sand and gravel deposits found within buried valleys cut into Cretaceous bedrock form important local aquifers (Lennox et al., 1988). While a number of major buried valley features mapped in Saskatchewan and North Dakota are known to extend into western Manitoba, there has been less exploration carried out in this province to determine the presence of aquifers within the valley deposits or the water supply potential from these aquifers.

With increasing demands for secure groundwater supplies in Manitoba for municipal, rural residential, pipeline and agricultural needs, attention has recently returned to evaluating aquifers within buried valleys as possible sources of groundwater supply, specifically in south-western Manitoba which is considered drought prone. While some of these features have been shown on older maps and reports, many additional water well and test hole logs are now available in provincial government files which may be useful in re-defining the trends of some features or the occurrence of buried sand and gravel.

In this paper we present a new compilation of buried valleys in south-western and west-central Manitoba based on a review of previous published and non-published reports and the current provincial database of water supply wells and test holes.

2. BURIED VALLEYS

Buried valleys are a common feature in glacial terranes, particularly where the underlying bedrock consists of relatively soft and easily eroded sediments such as shale (see Lennox et al., 1988 for an excellent introduction). In the Western Glaciated Plains numerous valleys were cut into Cretaceous and Tertiary bedrock units prior to the initiation of continental glaciation. Alluvial deposits, in particular Tertiary sands and gravels are generally thought to have been transported from the Rocky Mountains to the west and rest on the underlying bedrock in parts of many of these valleys.

During the Pleistocene, considerable modification occurred to many of the older valleys and new valleys were formed by meltwater erosion during glacial retreats and channelling of drainage waters during inter-glacial stages. By the end of the Pleistocene many of the valleys had been partially or completely infilled with glacial sediment. Modern drainage networks in many cases may follow the path of older partially infilled valleys but where infilling has been complete there may be no current surface topography or drainage associated with the buried features.

Sand and gravel associated with the Tertiary alluvial deposits and sorted glacial infill materials in buried valleys form significant aquifers in parts of the glaciated plains. These aquifers are generally highly confined and, while they may be quite transmissive, the long term yield is limited by recharge waters having to migrate through significant thickness of low-permeability tills.

3. BURIED VALLEYS OF SOUTH-WESTERN MANITOBA

Most of south-western Manitoba is underlain by soft Cretaceous shales which, in parts of the area, are overlain by a hard siliceous member of the Upper Cretaceous Pierre Shale. A relatively small part of the area is underlain by Tertiary and Upper Cretaceous sandstones, siltstones and shales which form the Turtle Mountain upland and by Lower Cretaceous sandstones and shales of the Swan River Formation underlying the Swan River Plain between the Duck Mountains and the Porcupine Hills.

During the Tertiary this area was subject to erosion from north flowing rivers originating in the northern United States and easterly flowing rivers from Saskatchewan which developed a number of deeply incised broad to narrow valleys. Drainage in southern Manitoba was likely dominated by the ancestral Missouri River which is believed to have flowed northward into southern Saskatchewan then eastward through Manitoba before turning to the north (Klassen and Wyder, 1970; Meneley et al, 1957; Laird, 1967; Kupsch, 1964). Valleys developed during the Tertiary were significantly modified during the Pleistocene with many valleys being deepened and widened and most being partially or completely infilled by glacial deposits. New valleys were also formed during the Pleistocene in response to massive flows of meltwater from receding glaciers and failures of pro-glacial lakes which released catastrophic floods of water. A summary discussion on buried valleys in southwestern Manitoba was presented by Klassen and Wyder (1970) and a bedrock surface compilation which also showed the presence of buried valleys was given by Teller et al., 1976.

Sand and gravel aquifers have been intercepted in a number of these features although to date the amount of exploration for groundwater has generally been on a reconnaissance scale.

Each of the major buried valleys will be discussed briefly (in a clockwise manner) below in terms of their location and extent as well as the potential for groundwater development.

3.1 Spiritwood Aquifer System

The Spiritwood aquifer system consists of a complex network of glacially deposited sand and gravel bodies interbedded with till and clay, infilling a broad north-south trending Tertiary valley formed by northward flowing drainage from North Dakota (Randich and Kuzniar, 1984; Bluemle, 1984). In North Dakota the valley is up to 15-20 km wide and 100-150 m deep. The buried valley runs north north-westward across the state before it crosses into Manitoba just east of Turtle Mountain in Tp 1 Rge 14 W1. From there it has been traced northward for about 60 km (Figure 1). Klassen et al. (1970) indicate that the valley turns to the north-east about 20 km into Manitoba but more recent information may indicate that the feature orients to the north-west at this point.

No detailed drilling of this feature has taken place in Manitoba although a number of private wells have intersected aquifers within the system. The wells for the Village of Cartwright appear to draw from sand and gravel infill of the Spiritwood. The total dissolved solids of a limited number of samples from wells completed in the aquifer are typically in the range of 1000-1200 mg/L. Given the importance of this aquifer in North Dakota, its water supply potential may be significant in Manitoba and additional investigation of the aquifer complex would appear warranted.

3.2 Turtle Mountain Valleys

Test drilling as part of a regional groundwater study identified one or two buried valleys in the Turtle Mountain upland (Western Ground-water Consultants Ltd., 1982). Based on limited information, the main valley enters Manitoba from the south in Tp 1 Rge 22W1 (Figure 1) and may be joined by a tributary channel about 8 km north of the border. There is little information on the trend of these features from the point where they leave the Turtle Mountain upland just south of Whitewater Lake. The main valley cuts more than 100 m into the underlying Turtle Mountain and Boissevaine Formations and appears to be infilled primarily with till. The water supply potential is unknown.

3.3 Medora-Waskada Channel

The Medora-Waskada Channel is a very narrow feature, in places less than 1 km wide, yet the base of the channel lies as much as 90 m beneath the surrounding bedrock surface (Pierre Shale). The channel appears to enter Manitoba from the south (Figure 1) in Tp 1 Rge 26W1 (Betcher, 1983) although it is not identifiable with a bedrock channel feature mapped in North Dakota. Recent test drilling in this area by the Manitoba Water Branch (unpublished) failed to identify the southern extension of the feature. It is believed to be oriented to the north north-east and is traceable to the Village of Medora (a distance of about 30 km). One could speculate, based on the orientation of the channel, that it is the same narrow buried valley that has been intersected at Souris, a further 50 km to the north-east.

Test holes into the Medora-Waskada Channel have identified infill materials as consisting of 10-40 m of glacial till overlying an interlayered sequence of clay and sand or gravel. Till has been reported beneath the clay/sand sequence in at least one test hole which also indicated the possible presence of a basal sand/gravel resting on bedrock. The nature of the basal sand/gravel was not identified.

Locally sand/gravel intervals in the clay/sand sequence have been found to be sufficiently thick and permeable to form significant aquifers. The water supply for the Town of Waskada as well as water for a regional pipeline and loading station are obtained from coarse-grained channel sediments intersected between 50 and 100 m. Short-term pumping rates up to 17 L/s have been reported, although the long-term sustainable yield from these aquifers has not been investigated in detail. A monitoring well located about 16 m from the Town of Waskada well has shown continuing water level declines since it was installed in the late 1980's with water level declines now approaching 7 m. Groundwater quality is good to marginal with a TDS between approximately 800 and 1200 mg/L.

3.4 Pierson Valley

The Pierson Valley is a broad, generally low-relief feature that appears to enter Manitoba from North Dakota or possibly Saskatchewan in Tp. 1 Rge. 29W1 (Figure 1). This valley follows a northerly course for about 35 km then traverse north-eastward to Brandon where it merges with the Assiniboine River valley (Klassen and Wyder, 1970). The extent of the valley south of the Town of Pierson has been confirmed by recent test drilling carried out by WaterMark Consulting Ltd. (2004). The valley has not been recognized in North Dakota. It was speculated by WaterMark Consulting Ltd. that the southern portion of the Pierson Valley may be a tributary to the Estevan Valley which has not been recognized to extend into Manitoba.

The basal sediments in the Pierson valley consist of stratified sand, silt and clay which may fine along the north-east extension of the valley from south of Pierson to Broomhill (WaterMark, 2004). Based on limited testing, these sediments may yield 2-8 L/s to individual wells over a 20 year period (WaterMark, 2004). Water quality is marginal with TDS from about 1100-1900 mg/L.

3.5 Qu'Appelle/Assiniboine River Valleys

A detailed study of the geology of these valleys was undertaken by Klassen (1975), including test drilling in the valley bottoms. Klassen suggested that the valleys of both the Qu'Appelle and Assiniboine rivers developed about the same time, early in the Wisconsinan and served as spillways during the final recession of the ice sheets. The current river valleys were shown to be generally co-incident with the ancestral valleys.

Through detailed test drilling across the valleys, Klassen (1975) was able to identify two major sedimentary infill units beneath the current base of the Assiniboine and Qu'Appelle valleys. The lower unit he termed the Virden fill while the overlying unit was named the Assiniboine alluvium. The Virden fill was described as beds of clay, silt, sand and a smaller proportion of gravel and was generally 18-30 m thick. The Assiniboine alluvium consists of clay, silt and fine sand and is considered to be overbank deposits dating from approximately 12,000 years to present.

The upper and lower units, particularly the lower Virden fill unit, seem to offer significant groundwater development potential along parts of the valleys. At Brandon, a supplementary or reserve groundwater for the City has been developed from confined sand and gravel aquifers beneath the river channel. A number of industries to the east of Brandon along the Assiniboine River have also developed groundwater supplies from similar aquifer units or associated sands and gravels.

3.6 Hatfield-Rocanville Aquifer System

The Hatfield Valley aquifer system has been well studied in Saskatchewan (Maathuis, in preparation). The valley is thought to have developed during the Tertiary and has been traced across the full width of Saskatchewan, entering Manitoba in Tp. 23 (Figure 1) between the Riding and Duck Mountains (Judd-Henrey et al., 2004). Just to the west of Manitoba the Hatfield Valley splits into a northern and a southern channel with the southern channel referred to as the Rocanville Valley. This buried valley enters Manitoba in Tp. 16 (Figure 1). In Saskatchewan coarse sediments in the lower part of the Hatfield Valley and overflow sediments on the sides of the main channel form a significant aquifer up to 30 km wide and 30-50 m thick. The aquifer is overlain by up to 90 m of glacial deposits, mainly tills (Maathuis, in preparation).

In Manitoba the Hatfield valley has been traced for about 80 km in a north-easterly then easterly direction until drill hole evidence for the valley is lost to the west of Dauphin Lake (Klassen et al., 1970; Little and Sie, 1976). However, this easterly extension and the width of the valley are somewhat speculative as very little detailed geological test drilling has been carried out and reliance has been placed on occasional deep water well logs. The Hatfield valley is bisected where it is crossed by the Assiniboine River in Manitoba, with groundwater discharge taking place into the river from the aquifer (Schreiner and Maathuis, 1982).

Klassen et al. (1970) have shown the Rocanville buried valley entering Manitoba in Tp. 16 then abruptly trending to the south, lying to the west of but paralleling the Assiniboine River until merging with the Pierson Valley near Oak Lake. The southern part of the Rocanville

Valley was termed the Virden Valley by Klassen and Wyder (1970).

No significant groundwater development has taken place in either the Hatfield or Rocanville valleys in Manitoba although the limited information which is available indicates good water supply potential from sands and gravels Interbedded with tills and clays in both features. Only a few analyses of water samples collected from wells completed into these valley aquifers are available, however the limited information indicates a mixed-cation-sulfate type groundwater with a TDS less than 2000 mg/L.

3.7 Swan River Valley

The Swan River Valley forms a buried valley system in Manitoba but does not appear to have been recognized in Saskatchewan (Judd-Henrey et al., 2004). The valley enters Manitoba as a broad north-east trending topographic low, termed the Swan River Plain, separating the Duck Mountains on the south from the Porcupine Hills on the north (Figure 1).

The valley is well defined to about 35 km north-east of the Saskatchewan border where is has cut as much as 90 m into the underlying Swan River Formation (Little, 1973). The valley then appears to broaden and shallow as it approaches Devonian carbonate bedrock farther to the north-east where its distinctive signature is lost. There is some evidence of transverse valleys having been cut into the bedrock, possibly representing drainage from the highlands to the north and south into the Swan River valley as it developed and deepened.

Test drilling has generally shown the lower part of the valley to be infilled with tills with local, generally thin, sand and gravel layers or lenses. Tertiary sands and gravels have not been reported in drill hole logs although Nielsen (1988) reports Tertiary material has been incorporated into the till deposits. The till is overlain by clay, silt and sand representing glacio-lacustrine, deltaic and beach deposits at the end of the last glaciation.

Groundwater development from sand and gravel aquifers within the Swan River Valley infill materials has generally been limited to domestic supplies. However, near and to the south of the Town of Swan River up to 30 m of sand and gravel has been intersected, overlain by thin clays and resting on till. This aquifer has been developed as a source of water supply for the Town. Whether this deposit should be considered part of the buried valley system or not is questionable; in places it may be unconfined.

3.8 Other Buried Valleys

A number of other buried valleys have been intersected by water wells and test holes in south-western Manitoba but have often been defined by only one or two holes (Unpublished files, Groundwater Management Section, Manitoba Water Stewardship; Klassen and Wyder, 1970; Klassen et al., 1970). The sparse rural population in this area and the lack of detailed test drilling have not allowed these locally identified channels to be traced for any distance with confidence. However it is obvious that a complex network of interconnecting river valleys existed during the Tertiary, with modification to these valleys taking place during the Pleistocene.

4. DISCUSSION/RECOMMENDATIONS

Numerous buried valleys have been partially mapped in south-western Manitoba, many being partially infilled with sand and gravel aquifers having potentially significant groundwater development potential. As groundwater will likely play an increasingly important role in providing secure water supplies to the region in the future, additional work needs to be carried out to establish the framework of these aquifers, their water quality and long-term yield. As part of such future studies it would be appropriate for Manitoba to adopt the Tertiary/Quaternary geological/hydrogeological model and nomenclature that has been in use in Saskatchewan for several decades. This would not only help to integrate hydrogeological studies in the two provinces but would provide clearly identified target horizons or units that would be identifiable by the drilling and groundwater industries in the province.

5. ACKNOWLEDGEMENTS

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6. AUTHOR'S NOTE

A detailed map showing buried valleys in south-western Manitoba has been prepared to accompany this paper, however it is not suitable for publication in these conference proceedings. A copy may be obtained by contacting the principal author.

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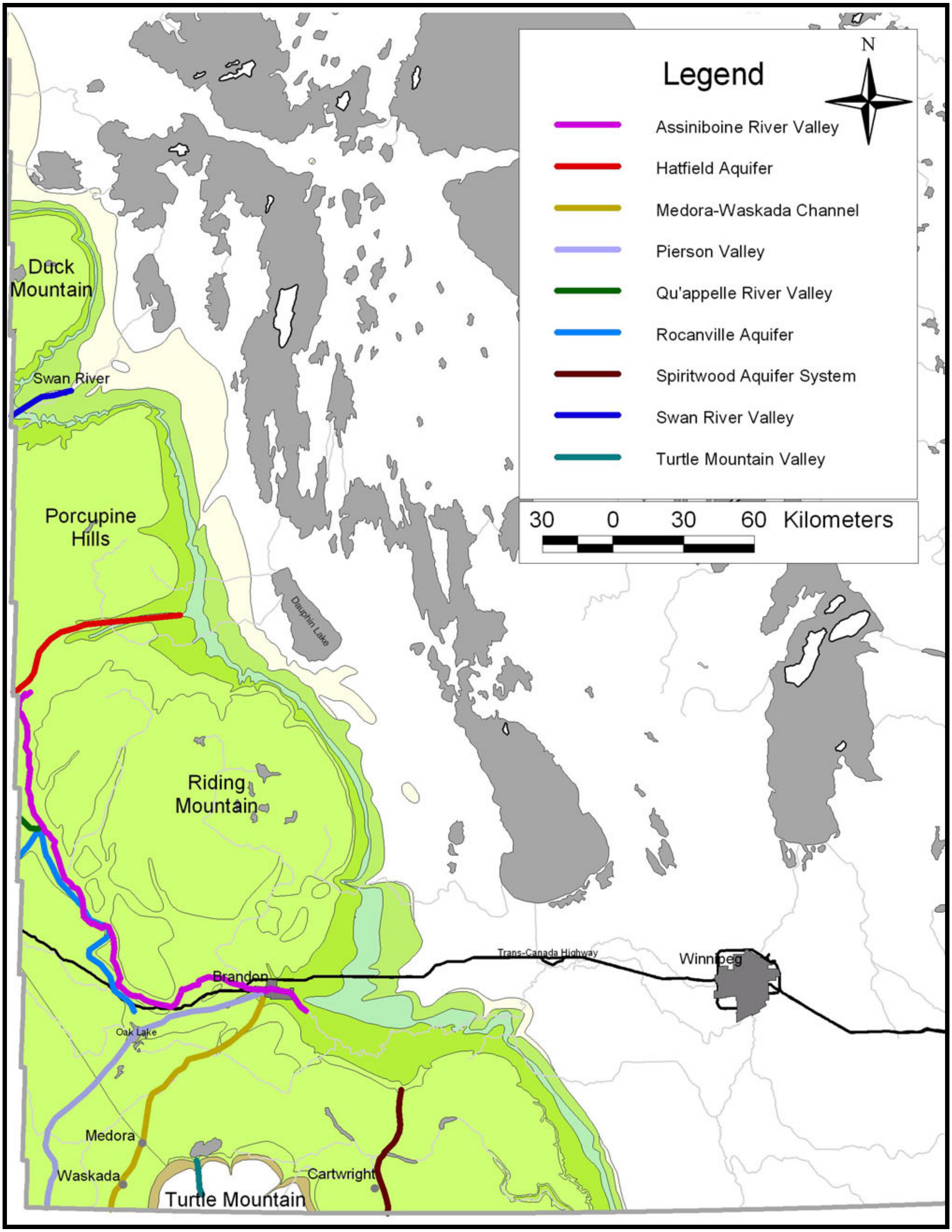

Figure 1: Buried valleys of south-western Manitoba.