# 4.0 Assessment of Results

As part of the requirements to obtain a Water Rights License from MB Water Stewardship, three basic questions need to be addressed. These include:

1. Can a well or wells of sufficient capacity be developed to provide the required water supply?
2. Will the withdrawal of groundwater for this project result in negative impacts to other groundwater users or the environment in the area in either the short or long term?
3. Can the aquifer sustain the required supply without depleting the groundwater resource over the long term?

The following sections provide an assessment of the results of this investigation relative to the above questions.

## 4.1 Well Capacity

The measured static water level in pumping well PW-1 at the start of the 72 hour pumping test was 23.6 metres (77.5 feet) below the top of the well casing. After 72 hours of pumping at 107 litres per second (1,700 USgpm), the measured water level was 47.3 metres (155.25 feet) and the total measured drawdown was 23.7 metres (77.8 feet). The specific capacity of this well, based on these test results, is approximately 4.5 litres per second per metre of drawdown (21.9 USgpm/ft). The indicated well efficiency is a low 40%. The well was developed prior to the start of the pumping test and the low efficiency may be a function of the hydraulics of the formation in the immediate area of the well (ie: flow within a layered sequence where movement is primarily horizontal and very little vertical movement is possible).

At the time of the pumping test, the height of standing water above the well screen in the pumping well was 37.4 metres (128 feet). Review of the hydrograph for the long term provincial monitoring well screened in the Lower Sand Unit (Figure 09) indicates that the water levels have fluctuated over the long term by approximately 3 metres and are currently near the upper end of the range. Extrapolating this to the pumping well and assuming that only 2/3 of the standing water above the screen can be used (conservative), the available drawdown is estimated to be 22.7 metres (74.5 feet). The indicated well capacity is therefore approximately 100 litres per second (1,600 USgpm), double the current project requirement of 50 litres per second (800 USgpm).

## 4.2 Estimated Drawdown Effects at a Distance

Extrapolation of the pumping test distance-drawdown results at the end of the 107 litres per second (1,700 USgpm) pumping test (Figure 17) indicates that the theoretical zero drawdown point was at a distance of 2,250 metres from the pumping well. Review of the time drawdown plots in Appendix G indicates that well TH-5A was approaching an equilibrium water level (the rate of change in water level over time was approaching zero). The drawdown at the distal monitoring wells was still developing but the rate of change was declining.

Utilizing the observed distance drawdown relationship shown on Figure 17, the distance drawdown effects of pumping at the proposed project rate of 50 litres per second (800 USgpm) over longer periods of time can be estimated using the Theis Non-Equilibrium Well Equation (Driscoll, 1995). The results of this analysis are shown on Figure 18. As indicated, at a distance of 6000 metres, the predicted drawdown after 5 years of continuous pumping is 0.2 metres, 0.4 metres after 10 years of continuous pumping, and

0.6 metres after 20 years of continuous pumping. This analysis is conservative and actual drawdowns that will occur will be less for the following reasons:

- The analysis assumes that all groundwater is withdrawn from storage and that no recharge of the aquifer occurs. While it is possible that during drought conditions little to no recharge may occur over successive years, it is unlikely that this condition would continue for 10 or 20 years.

- The analysis assumes that the drawdown cone is roughly circular in shape and that the water table is relatively flat (negligible hydraulic gradient). At this site (Figure 14), a relatively steep east to west hydraulic gradient of 0.005 exists. The drawdown cone in this case would preferentially develop towards the undeveloped area towards the east (ie: water would be preferentially drawn from the direction of higher groundwater pressure to the east).

## 4.3 Potential Third Party or Environmental Impacts

### 4.3.1 Existing Groundwater Users

The existing groundwater users in the area are shown on Figure 03 and representative drill logs are provided in Appendix A. Also provided in Appendix A is a summary per section of the well depths, type of well (screen vs open hole) and the formation from which water is withdrawn. In general based on the available information, 6% of the existing wells in the area consist of screened wells installed in the shallow, unconfined sands and gravels, 59% consist of screened wells installed in a deeper confined sand and gravel layer, and 35% are open holes in either the Red River Formation limestones or Winnipeg Formation sandstones.

As shown on Figure 03, the majority of the existing users are located on the lowlands to the west of Bedford Ridge with all wells greater than a distance of 6 kilometres from the pumping well. The eastern most wells in this area that are installed in a deeper confined aquifer are generally under flowing artesian heads (0.3 to 1.5 metres of head above grade). These flowing artesian conditions decrease to the west away from the Bedford Ridge. Other wells in the area include a number of screened sand and gravel wells near the Village of Sandilands 8 kilometres to the south and a number of screened sand and gravel wells near the Village of Kerry 14 kilometres to the east. The only existing groundwater well within 6 kilometres of the pumping well is a well located at the forestry station on Highway 210, approximately 4 kilometres north of the pumping well. Review of the well log for this site (Appendix A, 35-5-9E, Owner: Dept of RRTS) indicates that it is a screened well installed in a confined sand and gravel zone at a depth of 51.8 metres (170 feet) to 55.3 metres (181.4 feet) below grade. The available drawdown is at least 30 metres (100 feet) and the indicated well capacity is at least 6.3 litres per second (100 USgpm).

Based on the predicted long term drawdown effects provided in Section 4.2, the known existing groundwater user conditions in the area and the large distance between the pumping well and existing users, potential impacts to existing groundwater users are considered to be very unlikely. Some minor fluctuations in groundwater levels over and above the natural seasonal fluctuation of <1 metres may occur within the existing wells but this will not adversely affect the existing wells.

### 4.3.2 Potential Environmental Impacts

The existing environmental setting within the study area is documented in detail in a report prepared by North-South Consultants Inc. (2005). The following summary is extracted from that report:

> The groundwater well site is located within the southwest corner of the Lake of the Woods ecoregion within Canada's Boreal Shield ecozone. At a coarse scale, the ecoregion is underlain by massive, crystalline, Archean bedrock which has formed hummocky, broadly sloping uplands

and lowlands. The areas soils are classified as Eluviated Brunisols and Gray Luvisols developed on sandy to loamy textured materials, and Dark Gray Chernozems or Luvisols developed on clayey lacustrine sediments. The poorly drained sites associated with these soils are classified as Humic Gleysols and peaty phases of Gleysolic soils. Organic soils developed on forest, sphagnum or fen peat are dominant in the low-lying terrain surrounding the Bedford Hills.

Land use consists primarily of forestry, except where other primary uses or legislative protection has been designated. Merchantable forest on well- to poorly-drained mineral soils and on many of the organic soils is utilized by the forestry industry. These areas also provide habitat for wildlife and are extensively used for recreational purposes. Land use for agriculture, especially east of the Bedford Ridge, is minimal. The majority of soils have moderately severe to very severe limitations for arable agriculture. The sandy soils require careful management to protect against the risk of wind erosion and to maintain productivity, and soils with extremely stony and cobbly surface conditions require stone clearing to permit annual cultivation. There are also areas of low relief dominated by organic soils with imperfectly- to poorly-drained soils whose seasonally high water tables are subject to surface ponding in the spring or following heavy rains.

Terrestrial vegetation is typically a wooded succession of trembling aspen, paper birch, jack pine to white spruce, black spruce and balsam fir. Cooler and wetter sites support a white cedar, black spruce and tamarack succession state. The region is interspersed with numerous wetlands, most of which are peat accumulating forms such as bogs and fens. Characteristic wildlife includes moose, black bear, wolf, lynx, snowshoe hare and woodchuck. Bird species include ruffed grouse, hooded merganser, pileated woodpecker, bald eagle, turkey vulture, herring gull and waterfowl.

The existing environment in the area could be affected by the proposed groundwater withdrawal in one of two ways: the lowering of the water table below the root zone within the drawdown cone area; or significantly affecting the water balance in the surface water bodies outside the drawdown area.

Relative to any shallow water table that may interact with the surface environment and in particular plant roots, the results of this study have shown that, within the majority of the drawdown cone area, the shallow water table is at considerable depth (ie: 7.5 metres below grade at the well site, increasing to 38.5 metres to the south). The identified vegetation species in the area have broad shallow root systems that could not tap into this deep water table and instead rely on soil moisture accumulated by direct infiltration at the plant site. In addition, this study has shown that the water will be withdrawn from a deeper confined aquifer that has only a very limited hydraulic connection with the shallow unconfined aquifer, and the withdrawal of water from the deeper aquifer will not adversely affect the water balance in the shallow unconfined water table. Therefore, within the drawdown cone area, two levels of protection of the surface environment are present. Firstly, the water table is too deep to be considered a water source for plants, and secondly, the pumping of water will be from a deeper confined aquifer and the shallow water table balance will not be affected.

Relative to the water balance in the surface water bodies in the area, the only significant surface or shallow water is contained in the wetlands at the west toe of the Bedford Ridge. The results of this study have shown that this shallow water is primarily derived from drainage of infiltrating water on the Bedford Ridge through the Upper Sand Unit and discharging at the west toe of the Bedford Ridge. The withdrawal of groundwater from the deeper confined aquifer will not significantly affect the water balance in the shallow Upper Sand Unit and therefore the water balance in the wetlands to the west will not be affected. Also, due to the excess water in this lowland area, artificial drains, such as the Davidson Ditch, have been constructed to enhance the drainage of the shallow unconfined water table. Even if the pumping could affect the shallow unconfined water table, the net effect would be to reduce the volume of water entering these artificial drains.

### 4.4 Aquifer Sustainability

The philosophical concept of "sustainable yield" or "safe yield" has been used in the hydrogeologic industry for many years to try to estimate the maximum quantity of groundwater that can be extracted from an aquifer. Lee (1915) first defined "safe yield" as: "*The limit to the quantity of water which can be withdrawn regularly and permanently without dangerous depletion of the storage reserve*". Since then researchers and practitioners have found the definition to be ambiguous and that "safe yield" has no unique or constant value as it is dependant on how an aquifer is developed (spacing/number of wells and pumping rates) and how this affects the complex interaction of groundwater with other elements of the hydrologic cycle (Domenico and Schwartz, 1990). Maathuis and van der Kamp (2003) document a case history in Saskatchewan that shows that groundwater resources in complex aquifer settings can only be evaluated when the system is stressed by pumping for long periods of time and long term monitoring records are available to document how the system responds to the stress of pumping. Given that this aquifer system is essentially undeveloped and very little information is available on the response of the aquifer to pumping, the estimation of a safe or sustainable yield is considered unwarranted and imprudent at this time. Therefore, **for the purposes of this evaluation of aquifer sustainability**, the approach taken is to demonstrate that the requested supply rate of 50 litres per second (800 USgpm) will not result in the depletion of groundwater in storage. Future proponents for further groundwater development from this aquifer system would be required to similarly demonstrate that that their proposed withdrawal is sustainable in conjunction with all previously approved withdrawals.

One method of determining if the proposed withdrawal will result in the depletion of groundwater in storage is to estimate the current groundwater flow rate through the aquifer (ie: if the natural rate of recharge and discharge from the aquifer is much less than the proposed pumping rate then groundwater will not be withdrawn from storage). The studies completed at this site have shown that the target Lower Sand Unit has a high bulk transmissivity of approximately 0.01 $m^2$/sec (75,000 USgpd/ft), and a high hydraulic gradient under the current natural pre-development conditions of 0.005. These results are indicative of an aquifer system that has a high natural flow rate. This interpretation is supported by the measured high quality of the groundwater which suggests that the residence time in the ground is low. Therefore, as a first order scoping level approximation of how much water might be available from this aquifer, an alternate form of Darcy's Law was used to obtain a preliminary estimate of the groundwater flow. The alternate form of Darcy's Law used is as follows (Freeze and Cherry, 1979):

$$Q = KiA$$

Where: Q = The volume of water per unit of time

K = The hydraulic conductivity of the aquifer

i = The hydraulic gradient

A = The cross-sectional area of the aquifer through which the water moves

In completing this scoping level assessment, the following information and assumptions were made:

- Only groundwater flowing through the roughly north-south cross-section of the Lower Sand Unit extending from test well SILA #1 to GSC 99-02 (Section C on Figure 12) was assumed. Groundwater is also known to be flowing from east to west within the Upper Sand Unit, the Sandstone Unit and smaller intertill sand and gravel aquifers but these were neglected as a conservative measure. As indicated on Figure 12, at this location the interpreted lateral extent of the aquifer is 8,000 m. If an average thickness of 20 metres is assumed, the cross-sectional area (A) is 160,000 $m^2$.

- The results of the 72 hour pumping test indicate that the bulk transmissivity of the aquifer at this location of 0.01 $m^2$/sec (75,000 USgpd/ft) which equates to a hydraulic conductivity of 5 x $10^{-4}$ m/s. Based on published information (Freeze and Cherry, 1979), this is consistent with the expected hydraulic conductivity for the observed soils within this aquifer.

- A measured hydraulic gradient of 0.005 was used.

Using the above information in the alternate form of Darcy's Law, the estimated groundwater flow within the Lower Sand Unit beneath the Bedford Ridge is approximately 400 L/s or 12,600 $dam^3$/annum, or almost an order of magnitude greater than the required groundwater flow rate for this project of 50 litres per second or 1,500 $dam^3$/annum. Therefore, the proposed withdrawal rate is well below the natural predevelopment recharge/discharge rate for the target aquifer. It is also important to note that this estimate is considered conservative as it is based on the current, static, non-pumping conditions. Pumping would artificially increase the gradient and therefore the flow of groundwater. For example, the existing hydraulic gradient from test well TH-4 to TH-5A is 0.006 ((369.2 m – 342.3 m)/4800 m, Figure 14). The predicted drawdown at TH-5A after 20 years of pumping is 7 metres and negligible at TH-4. Therefore, the predicted hydraulic gradient under pumping conditions would increase to 0.007 (an increase of 17%). A 17% increase in the natural flow rate of 400 L/s is equal to 68 L/s or roughly equivalent to the proposed pumping rate of 50 L/s (within the margin of error of these first order calculations).

Assuming the groundwater within the Lower Sand Unit is derived from recharge in the area between the pumping well and the indicated groundwater flow divide near test hole TH-10 (Figure 14), a distance of approximately 10 kilometres, and the recharge zone is 8 kilometres wide (as per the interpreted lateral cross-sectional area on Figure 12), then the indicated recharge rate is approximately 150 mm (6 inches) per annum. This is consistent with the estimated recharge rate in Cherry (2000) of 174 mm (6.9 inches) per annum based on environmental isotopes. However, this study has shown that, within that assumed recharge area, the vertical flow of groundwater is significantly restricted by the confining Upper Silt Unit and therefore it is unlikely that a recharge rate of 150 mm (6 inches) per annum could be achieved. This suggests that the recharge area for the Lower Sand Unit must extend much further east and probably southeast. Review of the regional stratigraphy (Little, 1980 and Betcher, 1986, Figures 06 and 07, respectively) suggest that to the east the Lower Sand Unit may extend to surface where it would be in direct hydraulic connection with the extensive water resources within the St. Labre Bog, Whitemouth Lake and adjoining wetlands. If so, the potential available water supply increases dramatically. Given that the proposed pumping rate of 50 litres per second for this project is almost an order of magnitude less than the indicated groundwater flow rate, the proposed withdrawal is considered sustainable and that significantly more groundwater could likely be withdrawn without adversely affecting the groundwater resources in the area.