Groundwater Supply at Gull Lake

Gull Lake Area
Tp 041 and 042, R 28, W4M and Tp 041 and 042, R 01 and 02, W5M

Prepared for
Ponoka County

Prepared by
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Executive Summary

The County of Ponoka retained the services of HCL to determine if sufficient groundwater is available for a proposed development in 22 square kilometres of land east of Gull Lake. The proposed development will include up to 1,700 residential lots. The present review considered groundwater supply, aquifers present and possible impact on Gull Lake.

From the perspective of groundwater supply, consideration is given to water balance as a percentage of the entire Gull Lake Basin. The Basin has an area of 270 square kilometres including the Lake (AAFC, Mar-2008). The water-balance estimates indicated that groundwater discharge to the Lake from the Basin is in the order of 24,000 m³/day and that total groundwater recharge in the Basin is 54,000 m³/day. The balance included estimates for annual precipitation to the Lake and the land within the Basin, evaporation from the Lake, evapotranspiration from the land area, an estimate of current groundwater use, and groundwater flow into and out of the Gull Lake Basin.

Groundwater availability for the area of proposed development is being considered in the context of the entire Gull Lake Basin. The area of proposed development represents slightly less than 8% of the entire Basin; for this area, the groundwater recharge is estimated to be 4,300 m³/day, with 44% of the groundwater expected to discharge to Gull Lake and 56% of the groundwater to be used or lost to evapotranspiration.

In the area of proposed development, the only aquifers that have been identified are in the bedrock. Groundwaters associated with Geounit 3 discharge directly toward Gull Lake; groundwaters in aquifers associated with Geounit 1 pass under the Lake; and groundwaters in aquifers associated with two other geounits (Geounits 3 and 4) may discharge indirectly into the Lake. Flow through each geounit has been estimated based on the generally available aquifer parameters and estimated hydraulic gradients within the geounits. For the geounit discharging directly to the Lake, the estimated flow is 7,000 m³/day while the geounit passing under the Lake has an estimated flow of 800 m³/day. The two geounits that discharge above Lake level have a combined flow of 350 m³/day.

The proposed development on the east side of Gull Lake is expected to include 1,700 lots. The amount of water required for the lots depends on the utilization of the lots. If they are to be full-time residences, the water requirement would be expected to be in the order of 2,400 m³/day[1] to as little as 100 m³/day[2], if the lots were all parking spots for recreational vehicles. While the *Water Act* protects up to 3.4 m³/day per lot, the amount far exceeds any normal use of water for domestic needs; all other needs must be licensed.

The present data indicate that an adequate groundwater supply would be available for the proposed development. At least two geounits are present under the lands proposed for development. The depth to the base of the 20-metre-thick geounit that flows under Gull Lake varies from 50 to 100 metres below ground. Development of this aquifer to its full potential would be preferred because diversion of groundwater from this geounit is expected to have little or no impact on the water level in Gull Lake; the downside to the development of the deeper geounit is that poorly completed water wells could drain shallower aquifers.

1 Alberta Environment indicates average daily water consumption is 343 litres per day per person; for a household of four, this would be about 1.4 m³/day. http://www3.gov.ab.ca/env/water/Conservation/residential.cfm

2 Alberta Environment guidelines indicate that the expected volume of sewage for an RV park is 180 litres per day per lot. Based on this information, if an RV lot were used for 3 months per year, 16.2 m³, or about 0.05 m³/day of groundwater, would be used.

1. Introduction

1.1. Purpose

The first multiple-lot subdivision at Gull Lake in Ponoka County (County) was Parkland Beach in 1975, located on the northwestern side of Gull Lake. Since that time, approximately 630 cottage and acreage lots have been created, and landowners have expressed interest in further development. The County has identified areas on the east side of Gull Lake where further development will be considered, and these areas are shown on Figure 1. The County anticipates that between 1,600 and 1,700 lots could be created. The main purpose of this study as defined by the County is to determine that a sufficient quantity of groundwater is available for future development on the east side of Gull Lake.

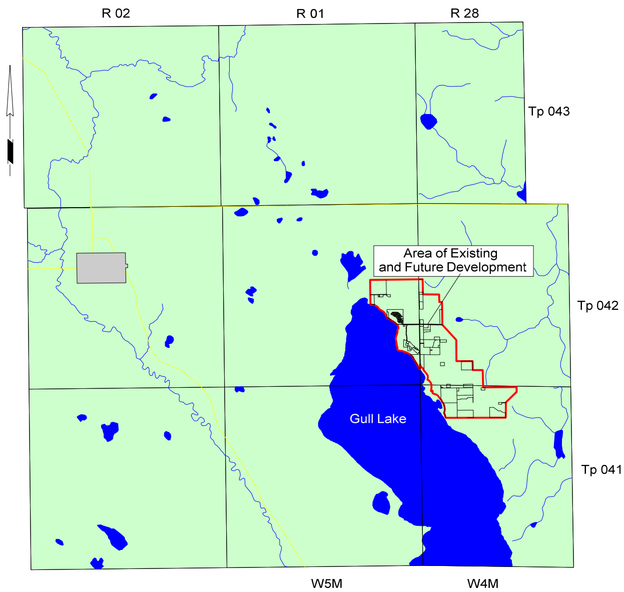

Figure 1. Area of Existing and Future Development

A total supply of 1,250 cubic metres per year (3.4 cubic metres per day) of groundwater is protected for each lot under section 23(3) of the *Water Act* (Province of Alberta, 2000). While this quantity of water, 2,125,000 m³/year for the proposed 1,700 lots (5,820 m³/day), is protected under the *Water Act* for household use, a typical permanent residence with four people would use approximately 1.4 m³/day[1], 2,400 m³/day for 1,700 permanent residences, or as low as 0.05 m³/day[2] if all lots were parking spots for RVs.

1.2. Scope

Hydrogeological Consultants Ltd. (HCL) were retained by the County to use the readily available hydrogeological data to answer the following questions, and to include the information in a covering report:

a) How much groundwater is available on a sustainable basis, to supply residential development in the study area, without depleting the supply to existing households, licensees, and traditional agricultural users?

b) Will the extraction of this much groundwater affect natural systems such as the state of wetlands, and the quality and quantity of overflows to the lake?

c) Will the change from agricultural to residential use affect the infiltration rates, either positively or negatively, and is it possible or desirable to increase infiltration through surface engineering measures, or by control of land cover?

HCL has defined the area of study (AOS) of the present program as a 3x3 township area around township 042, range 01, W5M, and the area of interest (AOI) as the area of future development on the east side of Gull Lake, as shown above in Figure 1.

[1] Alberta Environment indicates average daily water consumption is 343 litres per day per person; for a household of four, this would be about 1.4 m³/day. http://www3.gov.ab.ca/env/water/Conservation/residential.cfm

[2] Alberta Environment guidelines indicate that the expected volume of sewage for an RV park is 180 litres per day per lot. Based on this information, if an RV lot were used for 3 months per year, 16.2 m³, or about 0.05 m³/day of groundwater, would be used.

2. Background

2.1. Gull Lake Drainage Basin

For the present report, the Gull Lake Drainage Basin is a sub-basin of the Red Deer River Drainage Basin. The sub-basin (AAFC, Mar-2008) is that part of the Red Deer Drainage Basin that is above the Aspen Beach gauging station.

2.2. General Hydrogeology

The upper bedrock in the AOS is the Dalehurst Member of the Paskapoo Formation (HCL, 2003). The Paskapoo Formation is comprised primarily of non-marine sandstone and shale deposits. The Paskapoo Formation is subdivided into three Members; from youngest to oldest they are: the Dalehurst, Lacombe and Haynes members; the Lacombe Member is often divided into the upper and lower parts by HCL. The total thickness of the Paskapoo Formation underlying the AOI is in the order of 250 metres.

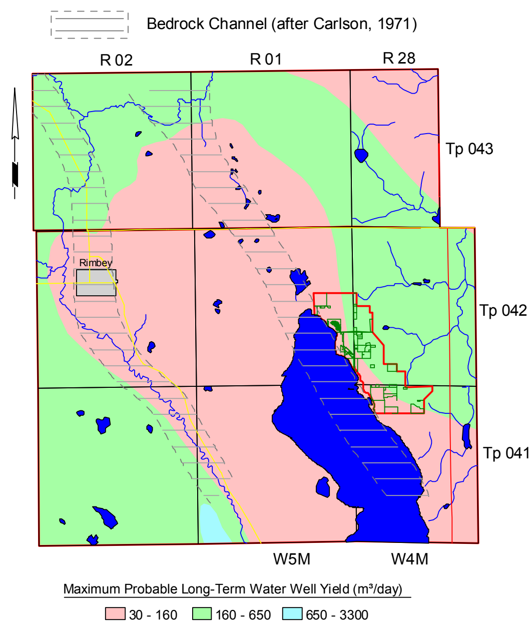

Figure 2. Combined Hydrogeological Map (after Tokarsky, 1971 and LeBreton, 1971)

The regional hydrogeological maps prepared by the Alberta Geological Survey (Tokarsky, 1971; LeBreton, 1971) indicate that water wells completed in aquifers within 300 metres of surface in the AOS are expected to mainly have long-term yields that are between 30 and 650 cubic metres per day (m^3/day), as shown in Figure 2. In the western part of the AOI, water wells are expected to have long-term yields that are between 30 and 160 m^3/day, and in the eastern part of the AOI, long-term yields are expected to be between 160 and 650 m^3/day. The Gull Lake Bedrock Channel, a linear bedrock low, trends northwest to southeast beneath Gull Lake. Associated with the linear bedrock low are sand and gravel deposits that are expected to be mainly less than five metres thick (HCL, 2003).

Groundwater from upper bedrock aquifer(s) in the AOI would be expected to be sodium-bicarbonate-type waters with a total dissolved solids (TDS) content of less than 1,000 milligrams per litre (mg/L) (HCL, 2003).

Ponoka County

SW 13-042-01 W5M

General Results Depth(s)	Top metre	Yield m^3/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L	Fluid Expected
gwQuery Determined Minimum	20	513[2]	7	426	26	--	--
gwQuery Determined Maximum	25	513[2]	7	426	26	--	--

Detailed Results Geologic Unit Encountered	Top metre	Yield* m^3/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L	Fluid Expected
Lower Surficial Deposits	0	19[2]	--	482	31	6	--
Bedrock Surface	12						
Dalehurst Member	12	513[2]	7	426	26	--	--
Upper Lacombe Member	82	66[2]	18	887	188	18	--
Lower Lacombe Member	137	228[2]	9	917	247	3	--

Parameter	metre
Base of Groundwater Protection (Depth) [4]	356
Ground Elevation (AMSL)	901

Legend/Notes

'--' indicates information not available.

Base of Groundwater Protection (BGP; TDS > 4,000 mg/L).

* Yield based on the 'Fluid Encountered' being water.

[2] Results are based on a regional groundwater study by hydrogeological consultants ltd. (HCL)

[3] Results are based on a summary of Drill Stem Test (DST) results.

[4] https://www3.eub.gov.ab.ca/Eub/

The information calculated with the MOW-TECH LTD. gwQuery is meant only as a guide. Actual drilling conditions may vary. MOW-TECH LTD. is not liable for drilling or groundwater problems as a result of using this data.

Table 1. Groundwater Query

2.3. Groundwater Query

The Groundwater Query for Ponoka County is based on the regional groundwater assessment (HCL, 2003). The results of the Query for the development in SW 13-042-01 W5M are provided in Table 1. The geological information in the table indicates that the upper bedrock below the proposed development is the Dalehurst Member of the Paskapoo Formation. The Query shows that the Dalehurst Member forms the bedrock surface in the area of proposed development; the base of the Dalehurst Member is at a depth of 82 metres below ground level (BGL), an elevation of 819 metres above mean sea level (AMSL). Beneath the Dalehurst Member is the Upper Lacombe Member in the depth interval from 82 to 137 metres BGL, approximately 819 to 764 metres AMSL.

The groundwater component of the Groundwater Query indicates that the expected approximate yields from water wells completed in the Dalehurst Member are 500 m^3/day. The table also shows that water wells completed in the Upper Lacombe Member have expected yields that are in the order of 70 m^3/day.

Groundwaters from the Dalehurst Member are expected to have a TDS concentration of approximately 425 milligrams per litre mg/L. Groundwaters from the upper part of the Lacombe Member are expected to have a TDS concentration that is approximately 890 mg/L.

The base of groundwater protection is at a depth of 356 metres. This is the depth below which groundwater is expected to have a TDS concentration of more than 4,000 mg/L.

Because the Groundwater Query is based on regional data, local conditions may vary.

3. Present Program

3.1. Maps

The proposed development is within the 1:50,000 National Topographic Series (NTS) 83A12 and 83B9 map sheets. Digital topographic control has been obtained from the 1:20,000 digital elevation model (DEM) prepared by AltaLIS Ltd.

3.2. Groundwater Database – Area of Study

The groundwater database, maintained by the Groundwater Centre, is an enhanced version of the Alberta Environment (AENV) groundwater database and shows that, in the AOS, there are 3,311 groundwater records. Of these 3,311 records, 2,413 are classified as being records that are for water wells. The adjacent table provides a breakdown of the "type of work" making up the database records. Water wells included in the "new well" category, although new at the time the information was filed with AENV, may now be many years old.

The information in the groundwater database has been used in the preparation of cross-sections and thematic maps, and to determine aquifer parameters.

Spatial information on groundwater records may be limited to the quarter section. Unless more detailed information is available, the coordinates assigned to groundwater records are the centres of their legal location.

Type of Work	No. of Records
Chemistry	365
Deepened	24
Federal Well Survey	151
New Well	1780
Old Well - Test	1
Reconditioned	3
Reconstructed	2
Test Hole	1
Water Test Hole	25
Well Inventory	61
Cathodic Protection	2
Coal Test Hole	3
Core Hole	2
Drill Stem Test Hole	1
Dry Hole - Abandoned	2
Flowing Shot Hole	528
New Well - Abandoned	45
Old Well - Abandoned	12
Spring	28
Structure Test Hole	235
Test Hole - Abandoned	3
Water Test Hole - Abandoned	29
Well - Abandoned	8
Total Water Well Records	***2413***
Groundwater-Related Records	***898***
Total	*3311*

Table 2. Groundwater Database Records – Area of Study

3.3. Groundwater Database – Area of Interest

In the AOI, there are 104 groundwater records. Of these 104 records, 88 are classified as being records that are for water wells.

Type of Work	No. of Records
Chemistry	7
Deepened	1
Federal Well Survey	2
New Well	75
Reconditioned	1
Well Inventory	2
Flowing Shot Hole	4
Structure Test Hole	7
Water Test Hole - Abandoned	5
Total Water Well Records	***88***
Groundwater-Related Records	***16***
Total	*104*

Table 3. Groundwater Database Records – Area of Interest

3.4. Existing Lots and Licences

There are approximately 500 existing lots located in the AOI[3]. Currently, there are 22 authorized groundwater diversions in the AOI, for a total annual diversion of 136,363 cubic metres (m^3). Of the 22 authorizations, two are for commercial purposes (15,273 m^3/year), two are for municipal purposes (82,000 m^3/year), five are for agriculture purposes (17,422 m^3/year), and 13 are registrations (21,668 m^3/year).

[3] http://alta.registries.gov.ab.ca/spinii/logon.aspx

3.5. Gull Lake Level Data

Precipitation data were obtained for the Dakota West meteorological station from 1963 to 2009; these data were obtained from Environment Canada[4].

3.6. Existing Reports

A list of sources provided in the Bibliography section of this report provides data that pertain to the work completed for this project. The soils maps were reviewed to identify possible wetlands areas.

3.7. Data Processing

Transmissivity values from the aquifer test data from pumped water wells have been calculated using the following approximation of the Theis non-equilibrium equation:

$$T = \frac{2.3 \cdot Q}{4 \cdot \pi \cdot \Delta s}$$

Where:

T = Transmissivity
Q = Discharge
Δs = Drawdown per log cycle

Transmissivity from specific capacity is calculated based on the following equation:

$$\frac{Q}{s} = \frac{4 \cdot \pi \cdot T}{2.3 \cdot \log_{10}\left(\frac{2.25 \cdot T \cdot t}{S \cdot r^2}\right)}$$

Where:

S = Storativity and is assumed to be 0.0001
t = time since discharge started
r = effective radius of the water well

Drawdowns at various times and distances from the groundwater discharge point are calculated from the following equation:

$$s = \frac{Q \cdot W(u)}{4 \cdot \pi \cdot T}$$

Where:

W(u) is the well function of u

And

$$u = \frac{r^2 \cdot S}{4 \cdot T \cdot t}$$

When multiple groundwater discharge points are involved, the principle of superposition is used. The multiple discharge points can be at various locations or at one location.

Drawdowns at various times and distances are calculated based on approximations of W(u). For values of u greater than 0 and less than one, the following approximation is used:

4 http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html

$$W(u) = -\ln u + (-0.57721556) + (0.99999193)*u + (-0.24991055)*u^2 + (0.05519968)*u^3 + (-0.000976004)*u^4 + (0.00107857)*u^5$$

Where:

ln = natural logarithm

For values of 1 < u < infinity, the following approximation is used:

$$W(u) = (1/(u*e^u))*(((0.250621)+(2.334733*u)+u^2))/((1.681534)+(3.330657*u)+u^2))$$

Theoretical long-term yield is calculated from the Moell Method[5], using the following equation:

$$Q_{20} = \frac{Q(H_A)}{s_{100} + 5\Delta s} \times 0.7$$

Where

H_A	= available drawdown
S_{100}	= the drawdown after 100 minutes of pumping
Q	= pumping rate during the aquifer tests
Q20	= sustainable yield for 20 years
Δs	= drawdown per log cycle
0.7	= safety factor

All gridding uses the Kriging method with a linear variogram model as provided in Golden software Surfer V9.

[5] Groundwater Evaluation Guideline, 05 December 2002. Alberta Environment.

4. Results

4.1. Pigeon Lake Hydrology

A water-balance model for Pigeon Lake was recently developed by Sameng Inc. (May-2009). The model was developed, in part, to determine the effects that pumping a defined amount of groundwater would have on the Pigeon Lake water level. The water-balance model used surface-water runoff and precipitation as inputs, and evaporation and lake discharges as outputs. Groundwater estimates were used to calibrate the water-balance model to the recorded Lake levels. The results of the model indicated that a daily groundwater inflow of 0.55 m^3/sec (47,520 m^3/day) is required to simulate the measured Pigeon Lake water levels.

The groundwater recharge of 47,520 m^3/day represents a recharge rate that is equivalent to 19% of the annual precipitation received by the Pigeon Lake Drainage Basin.

Physical Characteristics

	Gull Lake [(1)]	Pigeon Lake [(2)]
Elevation[(3)] (m AMSL)	899.23	849.48
Surface Area of Lake (km²)	80.6	97
Surface Land Area of Drainage Basin (km²)	206	186
Drainage Basin Area including Lake (km²)	286.6	283
Average Groundwater Inflow (m³/yr)		17,300,000
Average Precipitation on Pigeon Lake (mm)		500.0
Groundwater Recharge (mm/m²)		93.0
Percentage of Precipitation Infiltrating Pigeon Lake (%)		19

(1) AENV, 2003
(2) Sameng Inc. May 2009
(3) on date of sounding in 1961

Table 4. Gull Lake/Pigeon Lake Hydrology

4.2. Gull Lake Hydrology

A Gull Lake study conducted in 2003 by AENV (2003) referenced an internal AENV memo by S. Douglas (Douglas, 2001). Douglas concluded that a daily water inflow of 43,836 m^3 is required in order to maintain Gull Lake water levels; the 43,836 m^3/day includes both groundwater- and surface-water flow and there was no breakdown as to the quantity of surface water or groundwater.

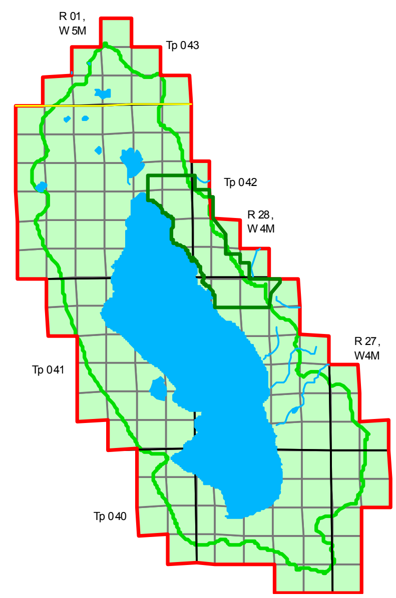

Figure 3. Gull Lake Basin

Both Gull Lake and Pigeon Lake are relatively large compared to their drainage areas, as shown in the table above. The large area of the lakes, compared to the contributing drainage area, suggests that both Gull Lake and Pigeon Lake have a significant groundwater component.

4.2.1. Gull Lake Water Balance

The hydrology of a basin is a sum of all of the precipitation minus all of the evaporation from surface-water bodies, all of the evapotranspiration (sublimation is included in evapotranspiration), and all of the water that is consumed. In the Gull Lake Basin (Figure 3), the land area is 190 km^2[6] and the Lake occupies 80.6 km^2; the average daily precipitation in the Basin amounts to a total water volume of 401,426 cubic metres in the entire Gull Lake Drainage Basin. Thirty percent (119,465 m^3/day) of the precipitation falls directly on the Lake and 70% (281,961 m^3/day) falls on the land. Of the precipitation that falls on the land, a percentage runs off as surface water, a percentage is lost to evapotranspiration and a percentage infiltrates; because there is no net accumulation of water in the soil, the infiltrating water that does not enter the groundwater system is assumed to be lost to evapotranspiration.

6 AAFC – PFRA, Mar-2008

A net water balance for the Gull Lake Basin has been obtained from the data available; a summary is provided in the adjacent table. The value for groundwater flow into the Lake has been obtained by determining the volume of water entering the Lake (137,706 m³/day) and the amount of water lost from the Lake (evaporation -161,200 m³/day + surface-water consumption -198 m³/day), with groundwater making up the difference (23,692 m³/day). One source of water that has entered the Lake during periods of Lake-level decline is surface water from the Blindman River. Alberta Environment (May-2003) indicates that diversion has occurred in 13 years since 1976, and that when pumping from the Blindman River operates, the diversion inflow represents only 1% of the Lake volume. For the purpose of determining the Gull Lake Water Balance, diversion from the Blindman River has been set to zero.

	m³/day
Sources	
Direct Precipitation	119,465
Runoff	18,241
Blindman Diversion	0
Total Water Input	**137,706**
Losses	
Evaporation	161,200
Surface water consumption	198
Groundwater consumption*	3,195
AENV's Approvals - groundwater	1,369
Total Water Withdrawal	**165,962**
* Domestic/Stock Water Wells	
Groundwater Reaching Lake	23,692
Groundwater Not Reaching Lake	30,404
Groundwater Recharge to Basin	54,096
Evapotranspiration	234,674

Table 5. Gull Lake Basin Water Balance

The groundwater consumption has been determined by taking into consideration all known water wells within the Gull Lake Drainage Basin. In this area, there are 116 licensed and registered water wells, 1,154 domestic water wells, 75 stock water wells, and 113 domestic and stock water wells. In 2007, the total protected non-household groundwater use in the sub-basin was 1,369 m³/day. To determine the groundwater use from domestic water wells, diversion is set to 0.4 m³/day[7]; for stock-only use, a diversion of 14.3 m³/day is used[8]; and for domestic and stock use, a diversion of 14.7 m³/day is used.

For calculating evapotranspiration, it is assumed that approximately 19% of the precipitation that falls on the land will infiltrate to become groundwater. Of the precipitation infiltrating the land surface, approximately 44% will discharge in to Gull Lake, leaving approximately 56% not reaching Gull Lake; this 56% plus the precipitation to the land surface that does not become run-off, is the evapotranspiration for the Gull Lake Drainage Basin. The combined run-off plus groundwater reaching (discharging to) Gull Lake is 41,933 m³/day, which is slightly less than the AENV total of 43,836 m³/day being contributed from both sources. The value for evapotranspiration (234,675 m³/day [450 mm/year]) has been determined by subtracting the groundwater recharge to the Basin (54,096 m³/day) plus surface run-off (18,241 m³/day) plus groundwater use (4,564 m³/day) plus groundwater leaving the Basin (789 m³/day – see Geounit 1 in Table 9) from the precipitation that falls on the land (281,961 m³/day) plus the groundwater not reaching Gull Lake (30,404 m³/day). This value for evapotranspiration is approximately 93% of the calculated potential evapotranspiration.

4.2.1.1. Groundwater Recharge Entering Gull Lake from Area of Proposed Development

The area of proposed development, outlined by the red line on Figure 1, represents slightly less than 8% of the Gull Lake Basin. For this area, the groundwater recharge is estimated to be 4,328 m³/day, with 56% (2,432 m³/day) of the groundwater expected to discharge to Gull Lake, as shown on the adjacent table.

Gull Lake Basin Area (km²)	270
Area of Interest Land Area (km²)	22
Percentage of Gull Lake Basin Area	8%
Precipitation onto AOI (m³/day)	31,998
Groundwater Entering Gull Lake from AOI (m³/day) (8% of Gull Lake Basin volume)	1,895
Groundwater Not Entering Gull Lake from AOI (m³/day) (8% of Gull Lake Basin volume)	2,432
Total Groundwater Recharge from AOI (m³/day)	**4,328**

Table 6. Groundwater Recharge Entering Gull Lake from AOI

7 HCL, September 2003
8 Ibid

4.2.2. Groundwater Inflow to Gull Lake Based on Winter Precipitation Data

Figure 4 shows the recorded water levels for Gull Lake measured near Aspen Beach and a three-year running average of the annual precipitation measured at the Dakota West meteorological station. From the graph, it can be seen that generally the water level in Gull Lake is affected by the precipitation. However, from 1976 to 1982, the Lake level is unexpectedly low; similar conditions occur again in 1988 and 1989, and from 1995 to 1998.

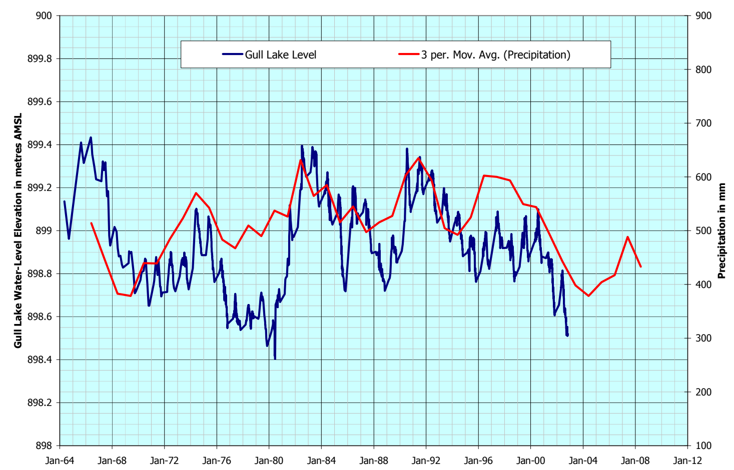

Figure 4. Comparison of Gull Lake Water Levels to Monthly Precipitation

Figure 4 also shows that the Gull Lake water levels rise from November of one year to August of the following year and then decline from August to November. There are very few water levels measured between November and April of most years; there is no natural stream flow into Gull Lake and there has been no stream flow from Gull Lake for decades (Alberta Lake Management Society, 2006).

There are 33 years when there is a reading for Lake level in late October or early November and late February or early March of the following year. In 29 of the 33 years, the water level in February/March is higher than the water level in October/November; in one year (October/November 1974 to February/March 1975), there is no change and three years when there was a slight decline in water level from October/November to February/March. In the years when there was a rise in water level, the minimum rise was 0.001 metres, the maximum was 0.275 metres and the average was 0.0531 metres. The average number of days over which the change in water level was measured was 122.

By taking the change in water level between October/November and February/March and dividing it by the number of days over which the change was measured, it is possible to obtain an average daily change in water level. Because the area of Gull Lake is known, it is possible to calculate the daily volume of water represented by the change in water levels. For the 33 years, the average daily change in Lake water levels represents 30,615 m³/day. Since this change is occurring in the winter months when there is no surface-water flow, the result indicates that the average daily inflow of groundwater into Gull Lake is 30,615 cubic metres. Because the AOI represents approximately 8% of the Gull Lake Basin, the daily groundwater inflow from the AOI would be expected to be 2,450 m³/day. The average daily groundwater flow into Gull Lake from the AOI between 1966 and 2002 is shown in Figure 5.

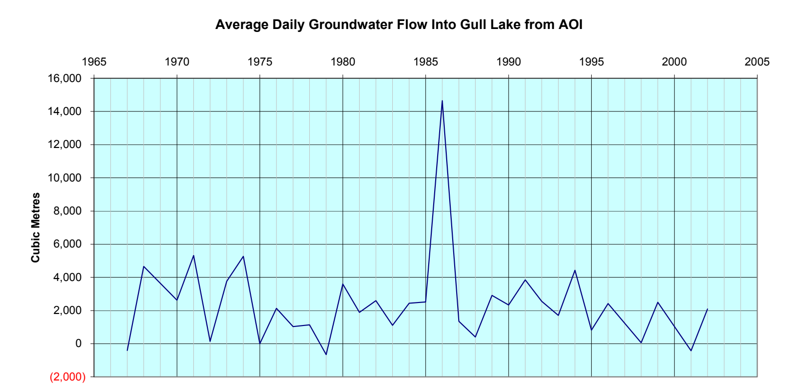

Figure 5. Average Daily Groundwater Flow Into Gull Lake from AOI

For this analysis, the snow falling on the ice and the effects caused by the freezing of Lake water to a depth of 0.6 metres have been assumed to have no net impact on the water level in Gull Lake.

4.3. Wetlands

For regulatory purposes under the Clean Water Act in the USA, the term “wetlands” means "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas." There is no record of wetlands having been identified in the AOI. None of the soils maps that were reviewed showed any evidence of wetlands areas away from Gull Lake.

4.4. Infiltration Rates

The amount of water that infiltrates into the groundwater flow system is dependent on many variables such as soil moisture, type of soil and slope of the land surface. Soils such as clay and silt will encourage runoff and minimize recharge while larger-grained soils such as sorted sand or gravel will encourage infiltration[9]. On the surface, the type of land use is also important. When considering agriculture, it is necessary to consider whether land use will be for livestock or crops. As many crops are planted in rows, this can create channels in the soil that will increase surface runoff during heavy rainfall events. If the land will be developed for domestic use, the area that is used for house, garage and driveways will prevent infiltration into the soil. With industrial developments, the building and parking lot will prevent infiltration. To increase infiltration in domestic and industrial areas, gardens can be created and green space should be maximized. Homeowners and businesses should be encouraged to plant trees and flowers, as the root systems and trunks/stems will increase the likelihood that infiltration will occur. In the case of confined feedlot operations, direct groundwater recharge is unlikely and undesirable. The spreading of mammal wastes will not adversely affect groundwater recharge rates.

4.5. Water Well Summary

In the AOI, there are 77 water wells completed in the Dalehurst Member of the Paskapoo and 11 water wells for which there were insufficient data to determine the geologic unit of water well completion, as shown in the table below; no water wells have been completed in the surficial deposits. The upper bedrock in the AOI is the Dalehurst Member; water wells completed in the Dalehurst Member are expected to have average apparent long-term yields that are in the order of 180 m^3/day, and the groundwaters from these water wells are expected to have TDS concentrations of less than 500 mg/L.

Geologic Unit	No. Water Wells Completed	Average Elevation Depth of Water Wells (m AMSL)	Average Elevation of NPWL (m AMSL)	Average Apparent Yield (m^3/day)	Average TDS (mg/L)
Dalehurst Member	77	885	906	181	483
[unknown]	11	946	896	--	442

Table 7. Summary of Water Wells in the Area of Interest

9 http://ga.water.usgs.gov/edu/watercycleinfiltration.html

In the AOI, there are 80 values for the elevation of non-pumping water level (NPWL) from 72 water wells, and these values are shown on the adjacent figure. The graph indicates four distinct data groupings that can be associated with groundwater flow: NPWL elevations below 898 metres AMSL (lowest recorded water-level elevation for Gull Lake); NPWL elevations ranging between 898 and 910 metres AMSL; NPWL elevations ranging between 910 and 930 metres AMSL; and NPWL elevations of greater than 930 metres AMSL.

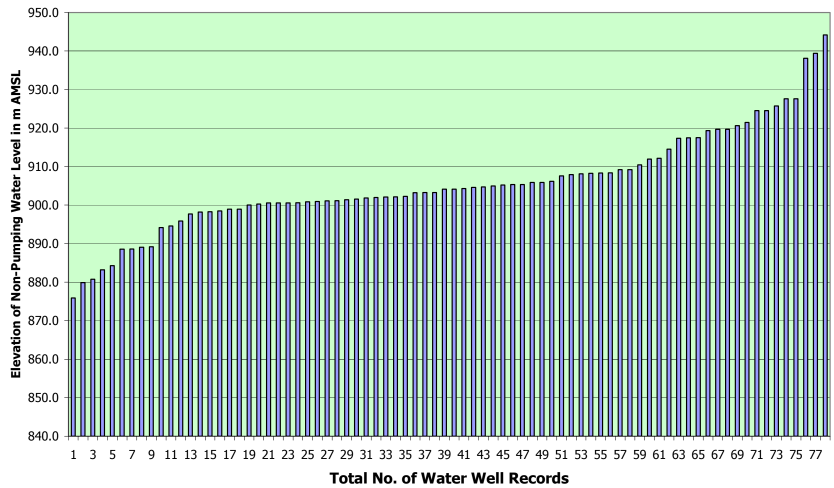

Figure 6. Histogram of Water Wells with Non-Pumping Water-Level Elevations within the Area of Interest

4.6. Groundwater Quality

A total of eight chemical analyses are available in the Groundwater Centre database associated with groundwater samples collected from six water wells in the AOI. In addition to the eight groundwater analyses, there is one sample that was collected from Gull Lake at SW 13-042-01 W5M, at a location near the boat launch within the AOI.

The adjacent Piper tri-linear diagram is used to illustrate the chemical make-up of the dissolved solids in the groundwaters. Where a particular groundwater plots on the graph depends on the percentage of major anions and major cations.

The Piper diagram shows that, chemically, the groundwaters from the five bedrock water wells are classified as sodium-calcium-magnesium-bicarbonate-type waters, and are similar in chemical composition to the Gull Lake water sample, a sodium-magnesium-bicarbonate-carbonate-type sample. The remaining two bedrock water wells are classified as sodium-bicarbonate-type waters.

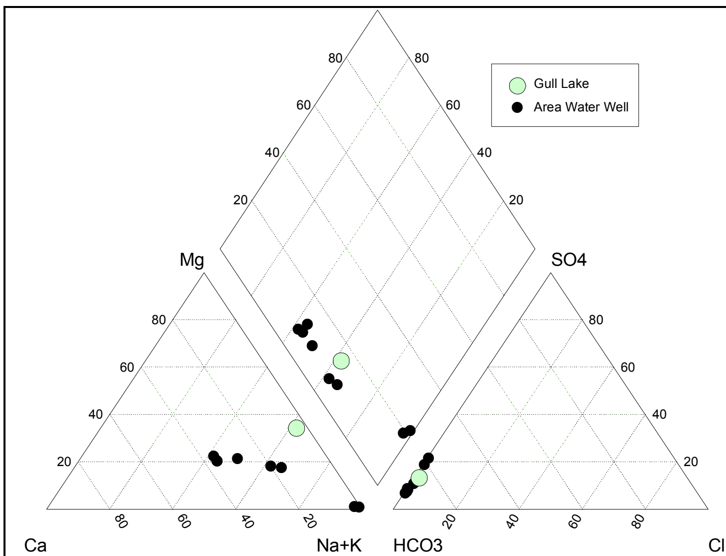

Figure 7. Piper Tri-Linear Diagram

5. Interpretation

5.1. Gull Lake Water Balance

There are too few data to establish a water balance for the AOI, the area of proposed development in Ponoka County east of Gull Lake. The approach that has been taken is to consider the water balance for the entire Basin and then use a ratio of the AOI to the entire Gull Lake Drainage Basin. Even the process of determining the water balance for the entire Basin is at best an estimate. The first large assumption is that the groundwater recharge rate of 19% of total precipitation for the Pigeon Lake Basin is the same for the Gull Lake Drainage Basin. Based on this assumption and the results of the AENV (2003) report showing that the total water inflow to Gull Lake was 43,836 m³/day, calculations were made to determine a groundwater recharge of 4,320 m³/day for the AOI, with 2,432 m³/day reaching Gull Lake.

A value of groundwater recharge to Gull Lake was also calculated using the water-level changes between late fall and late winter. During this time of the year, the change in Lake water level is assumed to be the result of groundwater discharge to the Lake. Based on this calculation, the groundwater inflow into Gull Lake would be 2,450 m³/day.

Because of the similarity of the results from the two methods of calculating the quantity of groundwater entering Gull Lake, the expectation is that slightly more than 2,000 m³/day of groundwater would be reaching Gull Lake.

5.2. Geometry of Aquifers

In the AOI, the elevations of the non-pumping water levels in water wells range from a low 879.9 metres AMSL to a high of 944.2 metres AMSL. The water wells that have non-pumping water-level elevations that are below 898 metres AMSL are completed in aquifers where the groundwater cannot discharge into Gull Lake[10].

The water wells that have non-pumping water-level elevations between 898 and 910 metres AMSL are completed in aquifers where the groundwater could be expected to directly discharge into Gull Lake.

Water wells that have non-pumping water levels that are above an elevation of 910 metres AMSL are completed in aquifers where the groundwater discharge is expected to be on the land surface at elevations above Gull Lake.

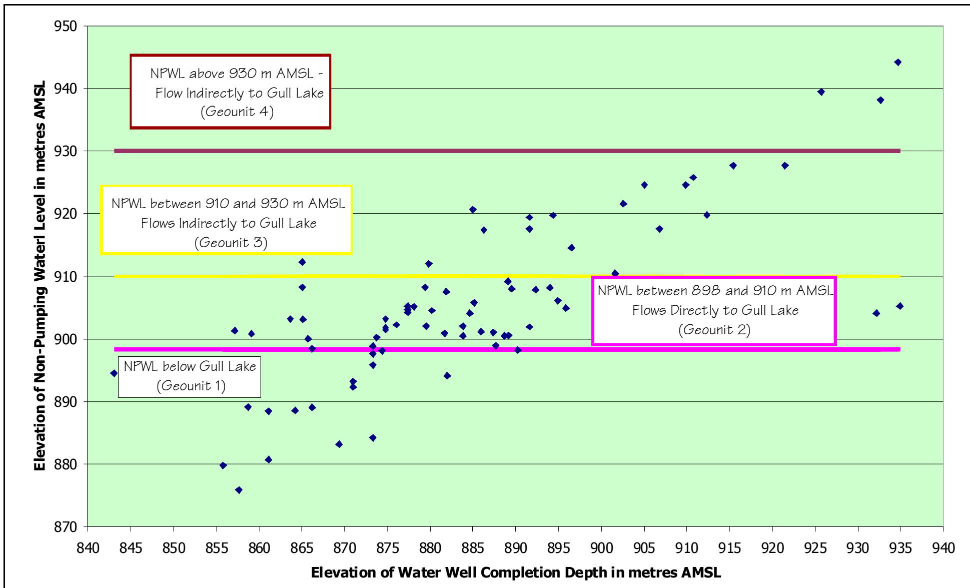

Figure 8. Depth of Completed Elevation vs NPWL Elevation for Water Wells in the Area of Interest

[10] Lowest recorded Lake level is 898 metres AMSL.

The elevation of depth completed is compared to the four groundwater flow scenarios for water wells completed in the AOI, and is shown in Figure 8 on the previous page. In general, groundwater from water wells completed at elevations that are between 898 and 873 metres AMSL will flow directly to Gull Lake; groundwater from water wells completed above an elevation of 899 metres AMSL will flow indirectly to Gull Lake, and groundwater from water wells completed at elevations below 873 metres AMSL will flow below Gull Lake.

From an analysis of the elevation of non-pumping water levels, it has been determined that there are four separate geologic units (geounits). The trend of each geounit is based on the trend of the top of the Lacombe Member. The lowest geounit passes under Gull Lake and is referred to as Geounit 1; the top of Geounit 1 is 58 metres above the top of the Upper Lacombe Member and is shown on the cross-section below. The geounit overlying Geounit 1 contains aquifers that discharge directly into Gull Lake and is referred to as Geounit 2. Geounits 3 and 4 are at elevations above Geounit 2 and the groundwater from aquifers associated with these geounits will discharge on to the ground surface, and therefore, indirectly to Gull Lake.

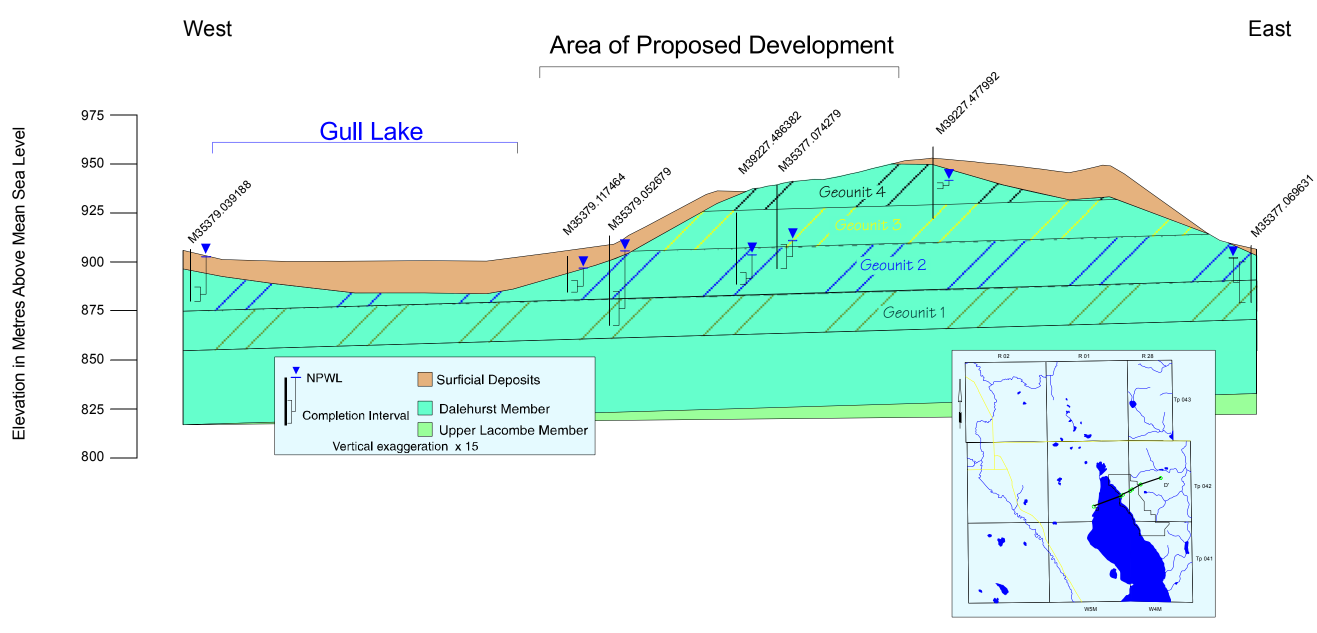

Figure 9. Southwest - Northeast Cross-Section

Of the 77 water wells completed in the Dalehurst Member, 75 have sufficient data to further delineate into four aquifers, as shown in Table 8. Fifty-three percent of the water wells in the AOI are completed in Geounit 2.

Aquifer	No. Water Wells Completed	Average Elevation Top of Completion (m AMSL)	Average Elevation Completed Depth of Water Well (m AMSL)
Geounit 4	4	939	934
Geounit 3	17	910	896
Geounit 2	40	892	882
Geounit 1	14	874	861

Table 8. Geounits - Average Elevation of Completion Intervals

5.3. Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the AOI. One indirect method of measuring recharge is through water balance, reviewed earlier in this report; a second approach is to estimate the quantity of groundwater flowing laterally through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow through an aquifer must be averaged and estimated. To determine the flow requires a value for the average transmissivity of the aquifer, an average hydraulic gradient and an estimate for the width of the aquifer. For the present program, the flow has been estimated for the AOI.

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer; flow through the aquifers takes into consideration hydrogeological conditions outside the AOI. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 9.

Aquifer/Area of Interest	Trans (m^2/day)	Gradient (m/m)	Width (m)	Flow (m^3/day)	Aquifer Flow (m^3/day)
Geounit 4					29
northwest	4.9	0.001	9,600	29	
Geounit 3					323
southwest	8.4	0.004	9,600	323	
Geounit 2					7,078
southwest	158	0.005	9,600	7,078	
Geounit 1					789
southeast	13.5	0.009	4,800	567	
northeast	3.7	0.006	9,600	222	
Total Aquifer Flow					7,867

Table 9. Groundwater Flow

Table 9 indicates that the current and proposed groundwater diversion of 2,400 m³/day represents 30% of the estimated aquifer flow of 7,867 m³/day in the four bedrock aquifer(s). However, even though the proposed use is less than the calculated aquifer flow, there can still be local impacts on water levels. The calculations of flow through individual aquifers as presented in Table 9 are very approximate and are intended only as a guide; more detailed investigations are needed to better understand the groundwater flow.

The results of this analysis show a total groundwater recharge that is approximately twice the groundwater recharge calculated from the water-balance approach. This may be related to the geometry of the Gull Lake Drainage Basin. In the AOI, the land surface slope is steeper than in other parts of the Basin, particularly to the northwest. Because of the geometry, a ratio approach may not provide the best answer. If the total groundwater recharge in the AOI is twice the value obtained from the water balance, the contribution of groundwater to Gull Lake could be equally higher. From the water balance, groundwater flow within the AOI was determined to be 2,432 m³/day; double this amount would be less than 5,000 m³/day. From the flow through the aquifer analysis, the volume of flow would be sufficient to provide this volume of water and still not require all of the groundwater to enter the Lake.

5.4. Wetlands

There are no data readily available for wetlands in the AOI away from the immediate area of Gull Lake. Of the 75 water wells in the AOI with sufficient information to determine the elevation of the bottom of the water well, only six are completed above Geounit 2. If there are wetlands away from Gull Lake above an elevation of 903 metres AMSL, it is these water wells, completed in Geounits 3 and 4, that could be expected to have an impact on wetlands away from Gull Lake.

Because wetlands away from Gull Lake would be maintained by discharge from Geounits 3 or 4 and because historically there has not been significant development of the aquifers in these geounits, the expectation is that future development will not include these aquifers. Without development of these aquifers, the wetlands away from the Lake will not be impacted; wetlands near the Lake would not be expected to be affected by groundwater use.

5.5. Infiltration Rates

There are very little quantitative data available with respect to land-use changes. However, the proposed changes in land use would not be expected to have a significant impact on groundwater infiltration rates.

5.6. Groundwater Quality

A total of eight chemical analyses are available in the groundwater database associated with groundwater samples collected from six water wells in the AOI. Of the eight chemical analyses, six are associated with four water wells that are completed in Geounit 2, one is associated with a water well that is completed in Geounit 3, and one analysis is associated with a water well that is completed in Geounit 1; there are no chemical analyses associated with water wells that are completed in the uppermost Indirect Flow Aquifer (Geounit 4). In addition to the eight groundwater analyses, there is one sample that was collected by Mow-Tech Ltd. in November 2007 from Gull Lake.

When the analyses results are plotted on the Piper tri-linear diagram, there are two main groupings of chemical quality, as shown in Figure 10.

The diagram shows that, chemically, the groundwaters from Geounit 2, classified as sodium-calcium-magnesium-bicarbonate-type waters, are similar in chemical composition to the Gull Lake water sample, a sodium-magnesium-bicarbonate-carbonate-type sample. The groundwaters from GeoUnit 1, the deepest aquifer, and GeoUnit 3, a shallower aquifer, are sodium-bicarbonate-type groundwaters.

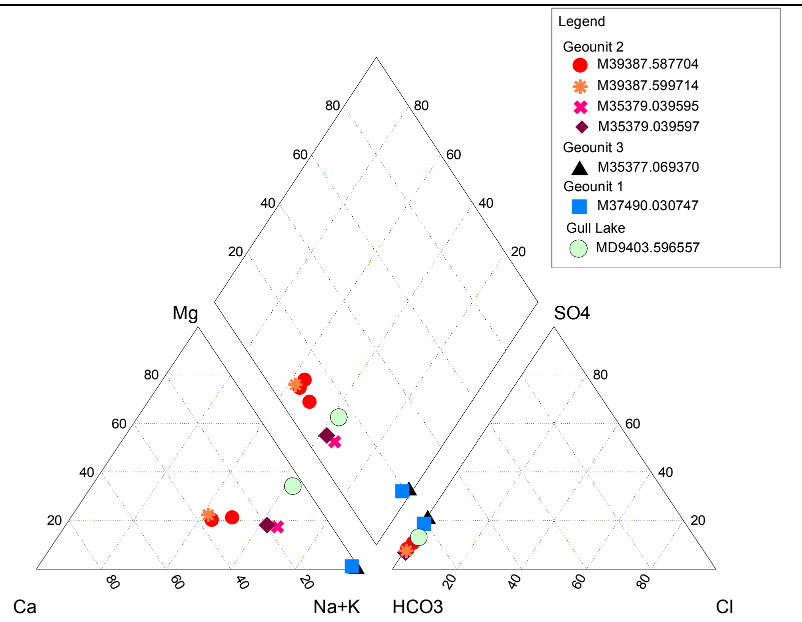

Figure 10. Piper Tri-Linear Diagram

6. Conclusions

The proposed development of 1,700 lots on 22 square kilometres of land east of Gull Lake will require water supplies in the range of 100 to 2,400 m³/day. The aquifers present in the area of interest are expected to be able to provide groundwater supplies to satisfy the water need; the groundwater development should focus on the deepest of the four geounits in the AOI to minimize the effects on water levels in Gull Lake. However, even the development of all groundwater supplies from the second deepest geounit would have minimal effect on the water level in Gull Lake.

It has been estimated that the volume of groundwater entering Gull Lake is in the order of 1,900 m³/day. This volume of water represents approximately 27% of the groundwater flowing through the geounit that discharges directly into Gull Lake. Presumably, the remaining 73% of the groundwater not discharging into Gull Lake is available for water supplies without having a negative impact on water levels in Gull Lake.

Two of the four geounits are present beneath most of the 22 square kilometres that are to be developed. Groundwater in the deepest geounit is flowing out of the Gull Lake Basin under Gull Lake. The volume of groundwater estimated to be flowing through this geounit is 800 m³/day. Groundwater flowing through the geounit overlying the deepest geounit (Geounit 2) is expected to be discharging into Gull Lake. The quantity of groundwater flowing through this geounit is estimated to be 7,000 m³/day.

Because groundwater flowing through Geounit 1 is leaving the Gull Lake Basin, development of groundwater from this geounit would have little or no effect on the water level in Gull Lake. The depth to the bottom of this geologic unit varies from 50 to 100 metres below ground level. The groundwater from this geounit is expected to be a sodium-bicarbonate-type water with total dissolved solids of less than 500 mg/L.

The remaining two geounits, Geounits 3 and 4, are only present in the topographically higher areas away from Gull Lake. The total groundwater flow in these two geounits is estimated to be 350 m³/day. The groundwater in these geologic units would reach Gull Lake only after the groundwater has been discharged to the land surface. Because wetlands away from Gull Lake would be maintained by discharge from Geounits 3 or 4 and because there has not been significant development of aquifers in these geounits, the expectation is that future development will not include aquifers within Geounits 3 and 4. Without development of these aquifers, the wetlands away from the Lake will not be impacted; wetlands near the Lake would not be expected to be affected by groundwater use.

There are very little quantitative data available with respect to land-use changes. However, the proposed changes in land use would not be expected to have a significant impact on groundwater infiltration rates in the AOI.

7. Recommendations

Because local hydrogeological conditions may vary significantly within the AOI, it is recommended that background information be collected. One type of background data that is required is the spatial position of area water wells. The second type of data includes the frequent measuring of water levels in selected water wells. Therefore, it is recommended that the following work be undertaken:

(1) A field-verified water well survey in the area of the proposed development. The horizontal coordinates of the water wells should be determined within ten metres; a consumer-grade GPS is adequate for this purpose.

(2) The County has indicated that they have municipal reserve in several quarter sections within the AOI. The County may wish to consider approaching the water well owners of the existing water wells within the municipal reserve to initiate a groundwater-monitoring program.

Legal Location	Water Well Owner	GCID	Date Completed	Aquifer
NE 04-042-28 W4M	Street, Marty	M35377.069370	14-Jun-83	Geounit 3
SE 12-042-01 W5M	In Shore Dev Ltd	M39859.702386	16-Jan-08	Geounit 2
SW 13-042-01- W5M	Raymond Shores Ltd.	M39387.599714	26-Apr-04	Geounit 2
NE 08-042-28 W4M	Harty, Edward	M35377.069379	26-Sep-88	Geounit 2
NW 17-042-28 W4M	Chalmers, Craig	M39227.478659	01-Oct-04	Geounit 2
SE 08-042-28 W4M	Renaud, Daryl	M38808.580724	21-Jul-00	Geounit 1

Table 10. Existing Water Wells Recommended to be Used as Observation Water Wells in the AOI

The table and figure shown provide a summary of these water wells.

HCL would be pleased to assist the County in establishing a program to collect the baseline information.

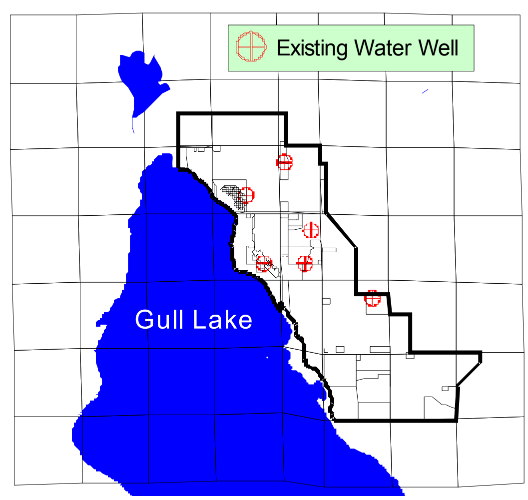

Figure 11. Existing Water Wells Recommended to be Used as Observation Water Wells

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Hydrogeologist

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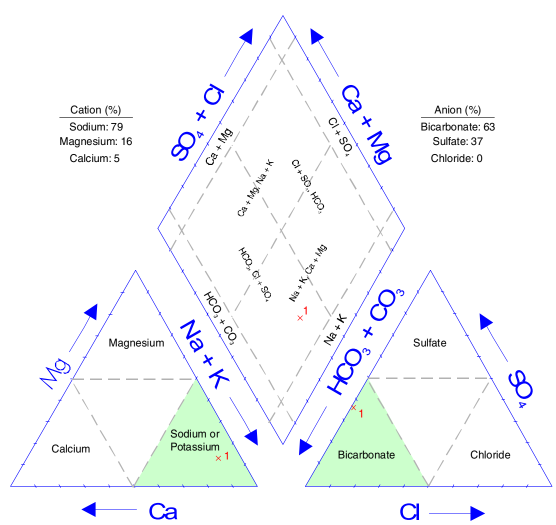
9. Glossary

AENV	Alberta Environment
AMSL	above mean sea level
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer and water level within five metres of the top of the aquifer.
BGL	Below Ground Level
DEM	Digital Elevation Model
km	kilometre
mm	millimetres
m²/day	metres squared per day
m³	cubic metres
m³/day	cubic metres per day
mg/L	milligrams per litre
NPWL	non-pumping water level
Piper tri-linear diagram	a method that permits the major cation and anion compositions of single or multiple samples to be represented on a single graph. This presentation allows groupings or trends in the data to be identified. From the Piper tri-linear diagram, it can be seen that the groundwater from this sample water well is a sodium-bicarbonate-type. The chemical type has been determined by graphically calculating the dominant cation and anion. For a more detailed explanation, please refer to Freeze and Cherry, 1979



Piper Tri-Linear Diagram

Surficial Deposits	includes all sediments above the bedrock
TDS	Total Dissolved Solids

Transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer
	Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings
	Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test
	Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer
WSW	Water Source Well or Water Supply Well
VE	Vertical Exaggeration
Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer
	Apparent Yield: based mainly on apparent transmissivity
	Long-Term Yield: based on effective transmissivity

Stratigraphy of the "Undisturbed" Geology of Alberta as used by Hydrogeological Consultants Ltd.

- upper surficial
- lower surficial
- Cypress Hills Fm
- Dalehurst Member
- upper part of Lacombe Member
- lower part of Lacombe Member
- Haynes Member
- upper part of Scollard Fm
- lower part of Scollard Fm
- Battle/Whitemud Fms
- upper part of Horseshoe Canyon Fm
- middle part of Horseshoe Canyon Fm
- lower part of Horseshoe Canyon Fm
- Bearpaw Fm
- Oldman Fm
- Foremost Fm
- Lea Park Fm
- Milk River Fm
- Colorado shale
- Cardium Fm
- Kaskapau Fm
- Dunvegan Fm
- Shaftesbury Fm
- Viking Fm
- Joli Fou Fm
- upper part of Mannville Grp
- middle part of Mannville Grp
- lower part of Mannville Grp
- Jurrassic
- Triassic
- upper part of Paleozoic
- Banff Fm
- Wabamun Group
- Winterburn Group
- Woodbend Group
- Beaverhill Lake Group
- Elk Point Group
- Precambrian

10. Conversions

Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inches	25.400 000	millimetres
miles	1.609 344	kilometres
kilometre	0.621 370	miles (statute)
square feet (ft²)	0.092 903	metres (m²)
metres (m²)	10.763 910	square feet (ft²)
metres (m²)	0.000 001	kilometres (km²)
Concentration		
grains/gallon (UK)	14.270 050	ppm
ppm	0.998 859	mg/L
mg/L	1.001 142	ppm
Volume (capacity)		
acre feet	1233.481 838	cubic metres
cubic feet	0.028 317	cubic metres
cubic metres	35.314 667	cubic feet
cubic metres	219.969 248	gallons (UK)
cubic metres	264.172 050	gallons (US liquid)
cubic metres	1000.000 000	litres
gallons (UK)	0.004 546	cubic metres
imperial gallons	4.546 000	litres
Rate		
litres per minute	0.219 974	ipgm
litres per minute	1.440 000	cubic metres/day (m³/day)
igpm	6.546 300	cubic metres/day (m³/day)
cubic metres/day (m³/day)	0.152 759	igpm
Pressure		
psi	6.894 757	kpa
kpa	0.145 038	psi
Miscellaneous		
Celsius	F° = 9/5 (C° + 32)	Fahrenheit
Fahrenheit	C° = (F°- 32) * 5/9	Celsius
degrees	0.017 453	radians