Groundwater Resources
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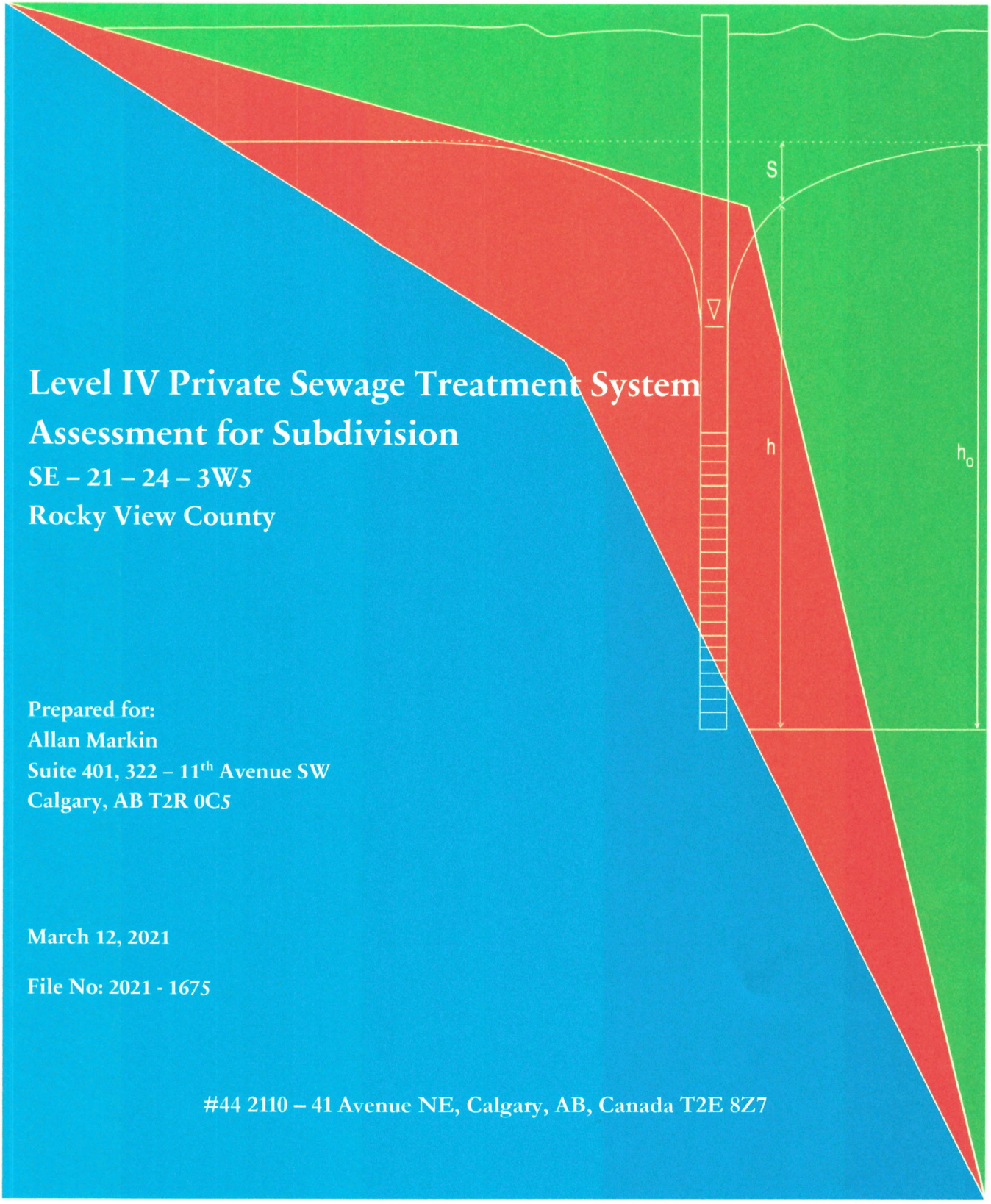

Level IV Private Sewage Treatment System Assessment for Subdivision

SE – 21 – 24 – 3W5

Rocky View County

Prepared for:
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March 12, 2021

File No: 2021 - 1675

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Disclaimer

Groundwater Resources Information Technologies Ltd. (GRIT Ltd.) has performed the work as described below and made the findings and conclusions set out in the report in a manner consistent with the level of care and skill normally exercised by members of the geological science profession practicing under similar conditions at the time the work was performed. This report presents a reasonable review of information available to GRIT Ltd. Within the established scope, work schedule and budgetary constraints, GRIT Ltd. accepts no responsibility for any deficiency, misstatement or inaccuracy in this report resulting from misinformation from any individuals that provided information as part of this report. GRIT Ltd. appreciates the opportunity to present these finding on behalf of the Client. If you have any questions regarding the above report, please do not hesitate to contact the above signed.

Executive Summary

Groundwater Resources Information Technologies Ltd. (GRIT) was retained by Allan Markin to complete a Level IV Private Sewage Treatment System (PSTS) assessment for a subdivision on land for country residential use located within the SE ¼ – 21 – 24 –3W5M in Rocky View County, Alberta (the "Site"). The PSTS assessment was completed following the *2015 Alberta Private Sewage Systems Standard of Practice (SOP)* and the *Model Process for Subdivision Approval (Alberta Association of Municipal District and Counties (2011)*.

The Site is located on a relatively flat portion of land which is mostly covered by grasses, trees and shrubs. Springbank Creek flows through the northwest portion of the site along a localized topographic low. The parcel is located within an area with high development density, with the surrounding area comprising a mixture of farmland and residential acreages. There are 22 developed residential properties within the Site quarter section. Quarter sections adjacent to the site in all directions except the southeast, have been developed with residential acreages.

Two test pits were dug on each proposed lot to log the soil, collect soil samples for grain size analysis, and determine if a shallow water table is present. The soil types identified at the site were silty clay and clay textures. These soil types will support primary or secondary treated effluent disposal. There were indications of shallow water table conditions across the site which indicates that a mounded system will likely be required for new septic systems. The low infiltration rates of the clay also show a mounded system would perform better than a conventional septic systems with direct discharge into the soil.

To allow for the design of the parcel size for the future acreage, total septic field areas have been provided based on the soil texture, grade and effluent type. Calculations assume that each parcel would be developed with a three bedroom house, which has a corresponding peak wastewater volume of 1,530 L/day. Calculations assume that the mounded treatment field is composed of a sand layer contained in a mound overlying the native in situ treatment field. The below calculations follow the process outlined in the 2015 SOP (Safety Codes Council) for mounded treatment fields.

Nearby landowners reported failed conventional below grade septic fields with mounded systems installed that were performing satisfactorily.

Calculated Parameter	Grain Size	
	Silty Clay	Clay
Primary Treated Infiltration Loading Rate (L/day/m^2)	6.9	6.9
Hydraulic Linear Loading Rate (L/day/m^2)	44.7	44.7
Area Required for Sand Layer (m^2)	38.3	38.3
Required Soil Infiltration Area (m^2)	221.7	221.7
Length of Sand Treatment Layer (m)	34.2	34.2
Width of Sand Treatment Layer (m)	1.1	1.1
Width of Required Soil Infiltration Area (m)	6.5	6.5
Upslope Mound Length (m)*	2.7	2.7
Downslope Mound Length (m)*	3.0	3.0
In-situ Soil Infiltration Width (m)	4.1	4.1
Toe to Toe Width of Mound (m)	6.8	6.8
Final Mound Area (m^2)	232.6	232.6

Final siting of the PSTSs should maintain the required setback distances from the treatment field to property lines, water wells, water courses, buildings and septic tanks as outlined in the SOP.

A drilling investigation was undertaken as part of the detailed Level IV septic field assessment which includes a cumulative impact assessment for all the septic fields on thea area, an evaluation of risk to underlying aquifers, and evaluation on whether septic effluent migration would have adverse affects to Springbank Creek. The site is underlain by approximately 10 m of clay interpreted to be a lake bed deposit which was tested to have low permeability.

The cumulative impact assessment which shows low nitrate and nutrient concentrations in the shallow silty clay layer and even lower nitrate concentration in the underlying sandstone bedrock aquifer. Higher nitrate concentrations in the silty clay layer are attributed to existing septic fields in the area and natural sources (ex. manure and degradation of organic material on surface). Both the silty shale overburden and bedrock aquifer show acceptable amounts of nitrates and downward migration of excessive nitrates to drinking use aquifers is not occurring at the site. With development, given the lot size and average groundwater recharge, sufficient precipitation should occur which would dilute the nitrogen loading to acceptable levels.

Testing of the silty clay overburden shows sufficiently low permeability to form an effective barrier to septic field effluent and risks of contamination of the underlying aquifers is at a sufficiently low risk. Horizontal groundwater flow velocities are also low (0.004 m/year) and

results in very slow migration of septic effluent in the subsurface. As such the risk of untreated septic effluent entering nearby Sprinkbank Creek is negligible.

Mounding calculations show a risk with breakthrough of septic field effluent to the surface in sites underlain by shallow water table if a mounded treatment system is not installed. Thus, a mound system is recommended for all new lots developed on the site.

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[1.0] Introduction

Groundwater Resources Information Technologies Ltd. (GRIT) was retained by Allan Markin to complete a Level IV Private Sewage Treatment System (PSTS) assessment for a 13 – lot residential subdivision within SE – 21 – 24 – 3W5 in Rocky View County, Alberta (hereinafter referred to as the Site). The purpose of the investigation was to establish the soil texture and structure across the Site to establish the feasibility of future PSTS installations on the residential lots. A site map of the proposed development is provided in **Appendix A.**

The PSTS assessment was completed according to the *Alberta Private Sewage Systems Standard of Practice* (Safety Codes Council, 2015) or *SOP*. General reporting has been completed following *The Model Process for Subdivision Approval and Private Sewage* (2011).

[2.0] Background

[2.1] Site Description

The Site is located on a relatively flat portion of land which is mostly covered by grasses, trees and shrubs. Springbank Creek flows through the northwest portion of the site along a localized topographic low. There is an access road within the Site boundaries, and the property can be accessed from the east via Range Road 33.

The parcel is located within an area with high development density, with the surrounding area comprising a mixture of farmland and residential acreages. There are 22 developed residential properties within the Site quarter section. Quarter sections adjacent to the site in all directions except the southeast, have been developed with residential acreages. The quarter section to the southeast remains undeveloped cropland.

As per our understanding, the Site will be developed into 13 residential lots as outlined in **Appendix A, Plate No. 1**. The lots are sized appropriately to allow for an alternate area for septic fields and to meet applicable setback distances from structures, water wells and property boundaries as outlined in the SOP and summarized in **Table 9, Section 7.0**.

[2.2] Local Topography

The Site topography ranges from 1,159 meters asl (above sea level) near the eastern property boundary along Springbank Creek to 1,168 meters asl along the western property boundary. The closest water body is Springbank Creek located within the northwest portion of the site. An air photo showing topographic contours of the Site is shown in **Appendix A, Plate No. 2.**

[3.3] Regional Geology

According to the Alberta Research Council map entitled "Surface Materials of the Calgary Urban Area: Calgary Sheet" (S.R Moran, 1986) the area underlain by lacustrine-offshore sediment composed of silt and clay.

According to the Water Well Drillers Reports from wells installed within the Site quarter section the upper 14 – 22 meters of material is described as a mixture of mostly lacustrine clay, and gravel. The presence of clay within surficial sediments is favorable in preventing contamination from surface sources (such as septic field effluent) from entering lower aquifers.

Test holes drilled on the site show the lake bed clay is approximately 10 m thick with some intervening thin till units, also composed largely of clay or clay / silt.

The bedrock geology of the area consists of upper/late Cretaceous non-marine strata of the Paskapoo Formation containing mostly interbedded fluvial sandstone and shale/mudstone.

The sandstone aquifers are interpreted to consist of river channel deposits. Typical thickness of these sandstone bodies is approximately 5 m, but river channels may be stacked to form extensive, thick aquifers. Bedrock near the Site is located approximately 0 – 18 meters below ground surface based off Water Well Drilling Reports in the area. The large range in bedrock depth is due to the large topographic range across the site.

[3.4] Surface Soil Conditions

The Alberta Soils Information Viewer indicates that the soils underlying the site is part of soil polygon 11978 and is composed of well drained Orthic Black Chernozem overlying fine textured clay, silty clay and sandy clay deposits. Soils belong to the Fish Creek soil series and are derived from fine textured lacustrine sediments.

[3.5] Water Wells and Groundwater Under the Direct Influence of Surface Water (GWUDI)

According to the Alberta Environment and Parks (AEP) water well database, there are no records for a water supply well on the Site. The AEP water well database lists 1 water well within ~150 meters of the Site boundary. An aerial photo showing well locations as listed on the AEP database relative to the Site is provided in **Appendix A**, **Plate No. 3**.

The Water Well Drilling Report for the well located within 150 meters of the Site is from 1991. The supply well is completed within a bedrock sandstone aquifer.

Soil strata overlying the well completed within a bedrock sandstone aquifer includes 10 meters of lacustrine clay and at least 4 meters of mudstone bedrock overlying the production zone. The clay and bedrock will serve as barriers to the migration of septic field effluent to the underlying aquifers. Water well drilling reports for the wells within 150 m of the Site do not indicate the presence of domestic use groundwater that could be under the direct influence of surface water.

[3.6] Previous Geotechnical Investigation

No previous geotechnical reports were available for the Site. A geotechnical assessment is currently underway for the site.

[4.0] Field Assessment and Shallow Groundwater Conditions

On February 18, 19, 23 and 24, 2021, 24 test holes (TH – 1 & TH – 24) were excavated within the Site boundaries to give a general assessment of soil types throughout the property. Two test holes were excavated on each new proposed subdivision lot. The test holes were located in areas with slopes suitable for a septic field and where there was reasonable access for excavation equipment.

Soils were logged by personnel from GRIT on February 18, 19, and 24, 2021. Soils were logged according to the Canadian System of Soils Classification (1998). A summary of the test hole profiles, field observations and field tests are provided in **Table 1**. Test hole locations are illustrated in **Appendix A**, **Plate No. 4**. GPS location of the test holes were measured using a cellphone.

Table 1: Soil Profile and Observations

Horizon	Texture	Depth (m)	Colour	Gleying	Mottling	Structure	Grade	Consistency	Moisture	% Coarse	Lab Analysis	Notes
	TH-1 – GPS Location: 51.0580059° N -114.3526762° E											
A	Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silt Loam	0.30 – 0.50	Dark Yellowish Brown 10YR 3/4	No	No	Blocky	Strong	Firm	Dry	0	No	-
C_1	Silty Clay	0.50 – 2.75	Olive Brown 2.5Y 4/4	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-2 – GPS Location: 51.0582382° N -114.3530899° E											
A	Loam	0.0 – 0.40	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silt Loam	0.40 – 0.45	Brown 10YR 4/3	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Silty Clay	0.45 – 1.20	Dark Yellowish Brown 10YR 4/4	No	No	Blocky	Strong	Loose	Dry	0	No	-
C_2	Clay	1.20 – 2.75	Dark Yellowish Brown 10YR 4/4	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-3 – GPS Location: 51.0584308° N -114.3544853° E											
A	Silt Loam	0.0 – 0.40	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	Rooted
B	Silt Loam	0.40 – 0.50	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Firm	Dry	0	No	-
C_1	Clay	0.50 – 2.80	Olive Brown 2.5Y 4/4	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-4 – GPS Location: 51.0583770° N -114.3546325° E											
A	Silt Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	Rooted
B	Silt Loam	0.30 – 0.40	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Clay	0.40 – 2.80	Olive Brown 2.5Y 4/3	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-5 – GPS Location: 51.0579977° N -114.3549876° E											
A	Silt Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-

B	Silt Loam	0.30 – 0.35	Dark Brown 10YR 3/3	No	No	Blocky	Strong	Firm	Dry	0	No	-
C_1	Clay	0.35 – 2.80	Olive Brown 2.5Y 4/3	Yes	No	Blocky	Strong	Firm/ Slight Plastic	Moist	0	Yes	-
	TH-6 – GPS Location: 51.0579406° N -114.3554221° E											
A	Silty Clay	0.0 – 0.35	Black 10YR 2/1	No	No	Blocky	Moderate	Plastic	Moist	0	No	-
C_1	Clay	0.35 – 2.50	Olive Brown 2.5Y 4/4	Yes	Yes	Blocky	Strong	Slight Plastic	Moist	0	Yes	-
	TH-7 – GPS Location: 51.0586287° N -114.3564682° E											
A	Clay	0.0 – 0.50	Black 10YR 2/1	No	No	Blocky	Moderate	Plastic	Moist	0	No	-
B	Clay	0.50 – 0.55	Very Dark Brown 10YR 2/2	No	No	Blocky	Moderate	Plastic	Moist	0	Yes	-
C_1	Clay	0.55 – 2.80	Olive Brown 2.5Y 4/3	Yes	Yes	Blocky	Strong	Slight Plastic	Moist	0	Yes	-
	TH-8 – GPS Location: 51.0580121° N -114.3572091° E											
A	Silt Clay Loam	0.0 – 0.20	Black 10YR 2/1	No	No	Blocky	Strong	Frozen/ Firm	Moist	0	No	Rooted
B	Silt Clay Loam	0.20 – 0.30	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Firm	Moist	0	No	-
C_1	Silty Clay	0.30 – 2.80	Dark Olive Brown 2.5Y 3/3	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-9 – GPS Location: 51.0579815° N -114.3586994° E											
A	Silt Clay Loam	0.0 – 0.25	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silt Clay Loam	0.25 – 0.40	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Slight Plastic	Dry	0	No	-
C_1	Clay	0.40 – 2.80	Olive Brown 2.5Y 4/3	No	No	Blocky	Strong	Slight Plastic	Dry	0	Yes	-
	TH-10 – GPS Location: 51.0581954° N -114.3591205° E											
A	Silt Loam	0.0 – 0.25	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silt Loam	0.25 – 0.30	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Silty Clay	0.30 – 2.50	Dark Yellowish Brown 10YR 3/4	No	No	Blocky	Strong	Firm	Dry	0	Yes	Backhoe refusal at depth
	TH-11 – GPS Location: 51.0582300° N -114.3599812° E											
A	Loam	0.0 – 0.40	Black 10YR 2/1	No	No	Blocky	Strong	Firm	Dry	0	No	Rooted

B	Silt Loam	0.40 – 0.45	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Firm	Dry	0	No	-
C_1	Clay	0.45 – 1.20	Light Olive Brown 2.5Y 5/4	No	No	Blocky	Strong	Hard	Dry	0	Yes	-
C_2	Clay	1.20 – 2.75	Olive Brown 2.5Y 4/3	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-12 – GPS Location: 51.0583319° N -114.3604331° E											
A	Silt Loam	0.0 – 0.65	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Loose	Dry	0	No	Rooted
C_1	Clay	0.65 – 2.80	Olive Brown 2.5Y 4/3	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-13 – GPS Location: 51.0586548° N -114.3608211° E											
A	Silt Clay Loam	0.0 – 0.20	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silt Clay Loam	0.20 – 0.35	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Clay	0.35 – 2.80	Dark Yellowish Brown 10YR 3/4	Yes	No	Blocky	Strong	Firm/ Slight Plastic	Moist	0	Yes	Gleying starts at 1.0 m
	TH-14 – GPS Location: 51.0586647° N -114.3601871° E											
A	Silt Loam	0.0 – 0.20	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silty Clay	0.20 – 0.30	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Clay	0.30 – 2.80	Dark Brown 10YR 3/3	No	No	Blocky	Strong	Hard	Moist	0	Yes	Calcareous precipitates
	TH-15 – GPS Location: 51.059043° N -114.3577302° E											
A	Silt Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silt Clay Loam	0.30 – 0.35	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Clay	0.35 – 2.80	Olive Brown 2.5Y 4/4	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-16 – GPS Location: 51.0592594° N -114.3578384° E											
A	Silt Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	Rooted
B	Silt Loam	0.30 – 0.50	Dark Grayish Brown 2.5Y 4/2	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Clay	0.50 – 0.70	Very Dark Grayish Brown 10YR 3/2	No	No	Blocky	Moderate	Hard	Dry	0	Yes	-

C_2	Silty Clay	0.70 – 2.80	Olive Brown 2.5Y 4/3	Yes	Yes	Blocky	Strong	Loose	Moist	0	Yes	-
	TH-17 – GPS Location: 51.0588173° N -114.3534916° E											
A	Silt Loam	0.0 – 0.25	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silt Clay Loam	0.25 – 0.30	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Silty Clay	0.30 – 2.80	Dark Olive Brown 2.5Y 3/3	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-18 – GPS Location: 51.0590722° N -114.3534507° E											
A	Silt Clay Loam	0.0 – 0.25	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
B	Silt Clay Loam	0.25 – 0.30	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Frozen	Frozen	0	No	-
C_1	Silty Clay	0.30 – 2.80	Olive Brown 2.5Y 4/4	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-19 – GPS Location: 51.0593533° N -114.3545876° E											
A	Silt Loam	0.0 – 0.50	Black 10YR 2/1	No	No	Blocky	Strong	Loose	Dry	0	No	-
C_1	Loam	0.50 – 1.05	Olive Brown 2.5Y 4/3	No	No	Blocky	Strong	Loose	Dry	0	No	-
C_2	Clay	1.05 – 2.80	Olive Brown 2.5Y 4/4	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-20 – GPS Location: 51.0594674° N -114.3548233° E											
A	Silt Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Loose	Moist	0	No	Rooted
B	Loam	0.30 – 0.40	Dark Grayish Brown 2.5Y 4/2	No	No	Blocky	Strong	Loose	Dry	0	No	-
C_1	Silty Clay	0.40 – 1.30	Light Olive Brown 2.5Y 5/3	No	No	Blocky	Strong	Loose	Dry	0	No	-
C_2	Clay	1.30 – 2.80	Light Olive Brown 2.5Y 5/4	Yes	Yes	Blocky	Strong	Firm	Moist	0	Yes	-
	TH-21 – GPS Location: 51.0592762° N -114.3559834° E											
A	Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	Rooted
B	Silt Loam	0.30 – 0.55	Very Dark Brown 10YR 2/2	No	No	Blocky	Strong	Loose	Moist	0	No	-
C_1	Silty Clay	0.55 – 2.80	Dark Grayish Brown 2.5Y 4/2	No	No	Blocky	Strong	Firm	Dry	0	Yes	-
	TH-22 – GPS Location: 51.0591677° N -114.3561983° E											

A	Silt Clay Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	Rooted
B	Silt Clay Loam	0.30 – 0.45	Very Dark Grayish Brown 2.5Y 3/2	No	No	Blocky	Strong	Loose	Moist	0	No	Iron oxide inclusions
C_1	Silty Clay	0.45 – 1.40	Light Olive Brown 2.5Y 5/3	No	No	Blocky	Strong	Loose	Moist	0	No	-
C_2	Clay	1.40 – 2.80	Grayish Brown 2.5Y 5/2	No	No	Blocky	Strong	Firm	Moist	0	Yes	-
	TH-23 – GPS Location: 51.0593243° N -114.3572393° E											
A	Silt Clay Loam	0.0 – 0.30	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	Rooted
C_1	Clay	0.30 – 2.80	Grayish Brown 2.5Y 5/2	No	No	Blocky	Strong	Loose	Dry	0	Yes	-
	TH-24 – GPS Location: 51.0592107° N -114.3570499° E											
A	Silt Clay Loam	0.0 – 0.25	Black 10YR 2/1	No	No	Blocky	Strong	Frozen	Frozen	0	No	Rooted
C_1	Clay	0.25 – 2.80	Grayish Brown 2.5Y 5/2	No	No	Blocky	Strong	Loose	Dry	0	Yes	-

Soil at the Site is characterized by a developed A horizon up to 65 cm thick with a loam, silt loam or silt clay loam soil texture and strong blocky structure. The B horizon is relatively thin in most locations and composed of a silt loam or silt clay loam soil. The C horizon consist mainly of silty clay or clay soil textures.

There were visual indications of a shallow water table present in 6 of the 24 test pits excavated (TH-5, TH-6, TH-7, TH-13, TH-16, and TH-20) in the form of gleying or mottling. No impervious soil conditions or bedrock were encountered.

[4.1] Grain Size Analysis

Soil samples were collected by personnel from GRIT during the excavation of soil pits on February 18, 19 and 24, 2021 for determination of grain size. Sample depth, grain size distribution and texture are summarized in **Table 2**. Structure of the soil was determined during test hole logging by personnel from GRIT. Grain size analysis results are attached in **Appendix B**.

Table 2: Laboratory Determination of Grain Size

Sample ID	Sample Depth (m)	% Sand	% Silt	% Clay	Texture	Grade/Structure
TH-1	1.0	4.2	46.2	49.6	Silty Clay	Strong/Blocky
TH-2	1.5	7.2	38.2	54.6	Clay	Strong/Blocky
TH-3	1.0	8.2	36.6	55.2	Clay	Strong/Blocky
TH-4	1.0	6.2	39.2	54.6	Clay	Strong/Blocky
TH-5	1.0	2.0	38.1	59.9	Clay	Strong/Blocky
TH-6	1.0	11.6	35.7	52.7	Clay	Strong/Blocky
TH-7	1.0	12.2	39.6	48.2	Clay	Strong/Blocky
TH-8	1.0	4.6	45.8	49.6	Silty Clay	Strong/Blocky
TH-9	1.0	4.0	38.1	57.9	Clay	Strong/Blocky
TH-10	1.0	4.6	46.9	48.6	Silty Clay	Strong/Blocky
TH-11	1.0	12.4	36.8	50.8	Clay	Strong/Blocky
TH-12	1.0	8.6	40.2	51.2	Clay	Strong/Blocky
TH-13	1.0	8.2	30.0	61.8	Clay	Strong/Blocky
TH-14	0.8	6.2	37.6	56.2	Clay	Strong/Blocky
TH-15	1.0	16.0	38.9	45.1	Clay	Strong/Blocky
TH-16	0.6	31.2	27.9	40.9	Clay	Strong/Blocky
TH-16	1.0	10.4	44.9	44.7	Silty Clay	Strong/Blocky
TH-17	1.0	4.2	41.0	54.8	Silty Clay	Strong/Blocky
TH-18	1.0	7.6	41.4	51.0	Silty Clay	Strong/Blocky
TH-19	1.2	8.2	25.0	66.8	Clay	Strong/Blocky
TH-20	1.5	8.4	35.4	56.2	Clay	Strong/Blocky
TH-21	1.0	2.4	44.7	52.9	Silty Clay	Strong/Blocky
TH-22	1.5	14.6	37.2	48.2	Clay	Strong/Blocky
TH-23	1.2	12.2	34.9	52.9	Clay	Strong/Blocky
TH-24	1.0	14.0	34.7	51.3	Clay	Strong/Blocky

Soil texture at 0.6 – 1.50 meters depth, near the typical installation depth for lateral trenches (0.9 m), indicate a clay or silty clay texture with strong blocky structure.

The infiltration loading rates acceptable for the soil texture for primary (five day Biochemical Oxygen Demand [BOD] 30 – 150 mg/L) and secondary treated (BOD of less than 30 mg/L) effluent for the areas sampled are summarized in **Table 3**.

Table 3: Laboratory Determination of Grain Size and Corresponding Infiltration Loading Rates

Sample ID	Grain Size	Structure/Grade	Infiltration Loading Rate (L/day/m²)	
			Primary Treated	Secondary Treated
TH-1	Silty Clay	Strong/Blocky	6.9	9.8
TH-2	Clay	Strong/Blocky	6.9	9.8
TH-3	Clay	Strong/Blocky	6.9	9.8
TH-4	Clay	Strong/Blocky	6.9	9.8
TH-5	Clay	Strong/Blocky	6.9	9.8
TH-6	Clay	Strong/Blocky	6.9	9.8
TH-7	Clay	Strong/Blocky	6.9	9.8
TH-8	Silty Clay	Strong/Blocky	6.9	9.8
TH-9	Clay	Strong/Blocky	6.9	9.8
TH-10	Silty Clay	Strong/Blocky	6.9	9.8
TH-11	Clay	Strong/Blocky	6.9	9.8
TH-12	Clay	Strong/Blocky	6.9	9.8
TH-13	Clay	Strong/Blocky	6.9	9.8
TH-14	Clay	Strong/Blocky	6.9	9.8
TH-15	Clay	Strong/Blocky	6.9	9.8
TH-16	Clay	Strong/Blocky	6.9	9.8
TH-16	Silty Clay	Strong/Blocky	6.9	9.8
TH-17	Silty Clay	Strong/Blocky	6.9	9.8
TH-18	Silty Clay	Strong/Blocky	6.9	9.8
TH-19	Clay	Strong/Blocky	6.9	9.8
TH-20	Clay	Strong/Blocky	6.9	9.8
TH-21	Silty Clay	Strong/Blocky	6.9	9.8
TH-22	Clay	Strong/Blocky	6.9	9.8
TH-23	Clay	Strong/Blocky	6.9	9.8
TH-24	Clay	Strong/Blocky	6.9	9.8

[4.2] Shallow Groundwater Conditions

The water level in the standpipes installed during excavation work were measured on March 4, 2021 and March 11, 2021. Due to the high clay content in the soils water levels in the wells would likely take longer than a week to recover so a second water level measurement was made. Depths to shallow groundwater, as measured on March 11, 2021, are summarized in **Table 4.**

Table 4: Depth to Shallow Groundwater

Standpipe ID	Depth to Shallow Groundwater (m BGS)
TH-2	Dry to 2.75
TH-5	Wet at 2.15
TH-6	Dry to 2.80
TH-8	Dry to 2.80
TH-9	Dry to 2.80
TH-12	Dry to 2.80
TH-14	Dry to 2.80
TH-16	Dry to 2.80
TH-18	Dry to 2.80
TH-20	Dry to 2.80
TH-22	Dry to 2.80
TH-24	Dry to 2.80

All the standpipes were dry, except for TH-5 which indicated a water table at 2.15 meters below ground surface. The high clay content (low permeability) and large foot print of each excavation can result in it taking several months for sufficient water to infiltrate and fill in the pits and standpipe to the natural static level. TH 5 was located in a relatively low topographic position on the site.

Based off drilling investigations, existing wetland mapping, indications of mottling and gleying in test pits and the water level in TH-5, the water table underneath the site likely sits at 2 – 3 meters below ground surface. There would also be seasonal variability in the groundwater table and variability from year to year depending on the amount of precipitation received. Due to these factors a shallow water table will likely be a concern when installing septic field systems on the site. Since a shallow water table exists a mounded treatment field would be required to meet the applicable separation distance between the treatment field and the water table.

[5.0] Parcel suitability

Soil texture and structure within the areas investigated indicate that the Site is acceptable for mounded septic fields with primary or secondary treated effluent. No impervious bedrock that would limit infiltration capacity were identified during the site assessment. Shallow groundwater that would limit vertical separation was encountered, resulting in mounded treatment fields being required on all new lots.

To aid in designing the final lot sizes for future residential development, approximate PSTS field areas have been calculated and are provided in **Table 5**. Total field areas have been provided based on the soil textures and structures reported for the locations sampled. Infiltration areas are based on a three-bedroom residence with a calculated peak effluent volume of 1,530 L/day. Calculations assume that the mounded treatment field is composed of a sand layer contained in a mound overlying the native in situ treatment field. The below calculations follow the process outlined in the 2015 SOP (Safety Codes Council) for mounded treatment fields.

Table 5: Infiltration Area, Treatment Area and Total Mound Area Based on Soil Texture and Primary Effluent Type

Calculated Parameter	Grain Size	
	Silty Clay	Clay
Primary Treated Infiltration Loading Rate (L/day/m^2)	6.9	6.9
Hydraulic Linear Loading Rate (L/day/m^2)	44.7	44.7
Area Required for Sand Layer (m^2)	38.3	38.3
Required Soil Infiltration Area (m^2)	221.7	221.7
Length of Sand Treatment Layer (m)	34.2	34.2
Width of Sand Treatment Layer (m)	1.1	1.1
Width of Required Soil Infiltration Area (m)	6.5	6.5
Upslope Mound Length (m)*	2.7	2.7
Downslope Mound Length (m)*	3.0	3.0
In-situ Soil Infiltration Width (m)	4.1	4.1
Toe to Toe Width of Mound (m)	6.8	6.8
Final Mound Area (m^2)	232.6	232.6

* Assumes land slope of 2%

Final siting of the treatment fields should take into consideration the setback distances for a treatment field, as measured from the toe of the treatment mound, as outlined in **Table 9**. Parcels are of sufficient size to allow for a secondary area for installation of a PSTS.

[6.0] Cumulative Impact Assessment

[6.1] Drilling Investigation

Four boreholes were drilled on the site on February 18, 2021 to describe the soil to depths of 16.5 meters. The holes were completed with the aid of an auger rig supplied by All Service Drilling Ltd. of Airdrie. Monitoring wells were installed in all four holes to determine depth to the water table, allow for in-situ hydraulic conductivity tests, and allow for collection of groundwater samples for chemical analysis.

Test hole logs showing strata encountered, monitoring well design and depth to water table are included in Appendix C.

Silty clay deposits, of the same origin as encountered in the test pits, were encountered to a depth of 14.0 m. Sandstone bedrock was encountered from 14.0 – 16.5 meters below surface.

Water levels as measured in the four wells can be used to illustrate the decreasing level of water with depth and the downward groundwater flow directions as follows:

Table 6: Depth to Groundwater

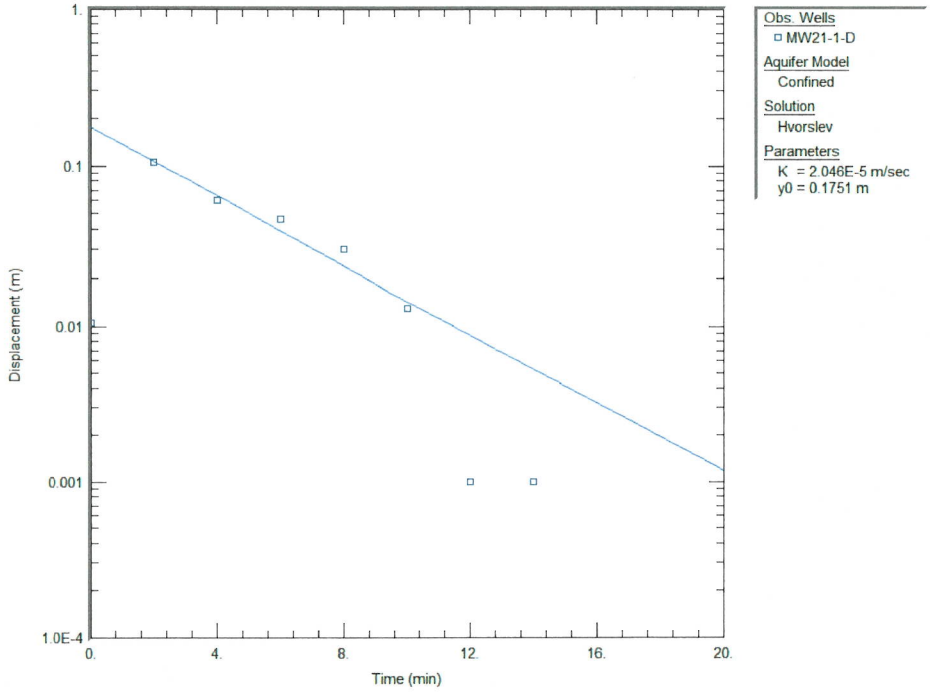
Well	Mid-point of Screen (m BGS[1])	Depth to Groundwater (m, BGS)	Ground Elevation (masl[2])	Groundwater Elevation (masl)
MW21-1-S	6.0	Dry	1167.0	-
MW21-1-D	15.75	7.05	1167.0	1159.95
MW21-2	6.0	2.94	1169.2	1166.80
MW21-3	6.0	3.78	1168.0	1164.22

[1]Below Ground Surface, [2]meters above sea level

[6.2] Hydraulic Conductivity – Slug Tests

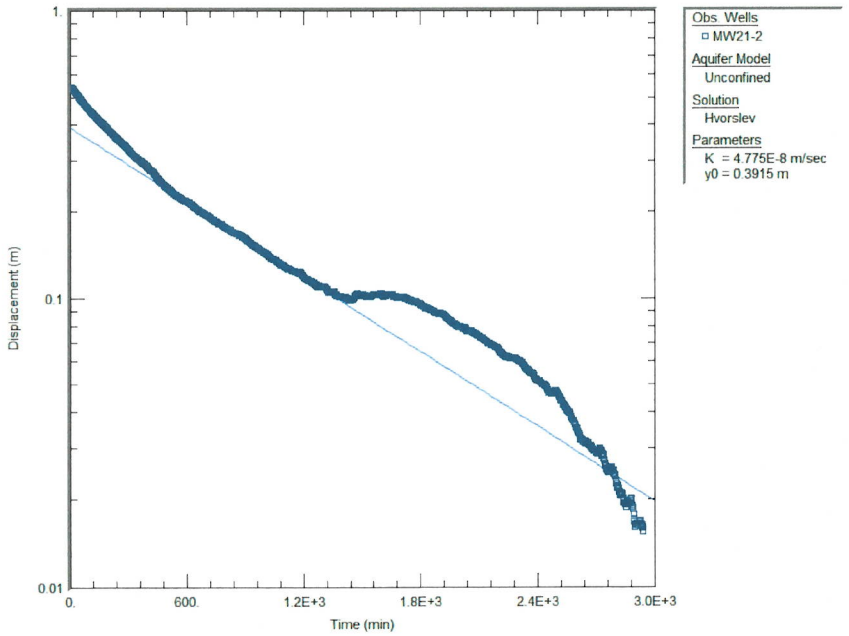
On March 2, 2021 slug tests were conducted on the three groundwater monitoring wells which contained water (MW21-1-D, MW21-2 and MW21-3). The slug tests were interpreted with the AQTESOLV software developed by HydroSoft, using the Hvorslev solution. The results of the slug tests are shown in the figures below:

Figure 1. Hvorslev solution fit to slug test data from MW21-1-D



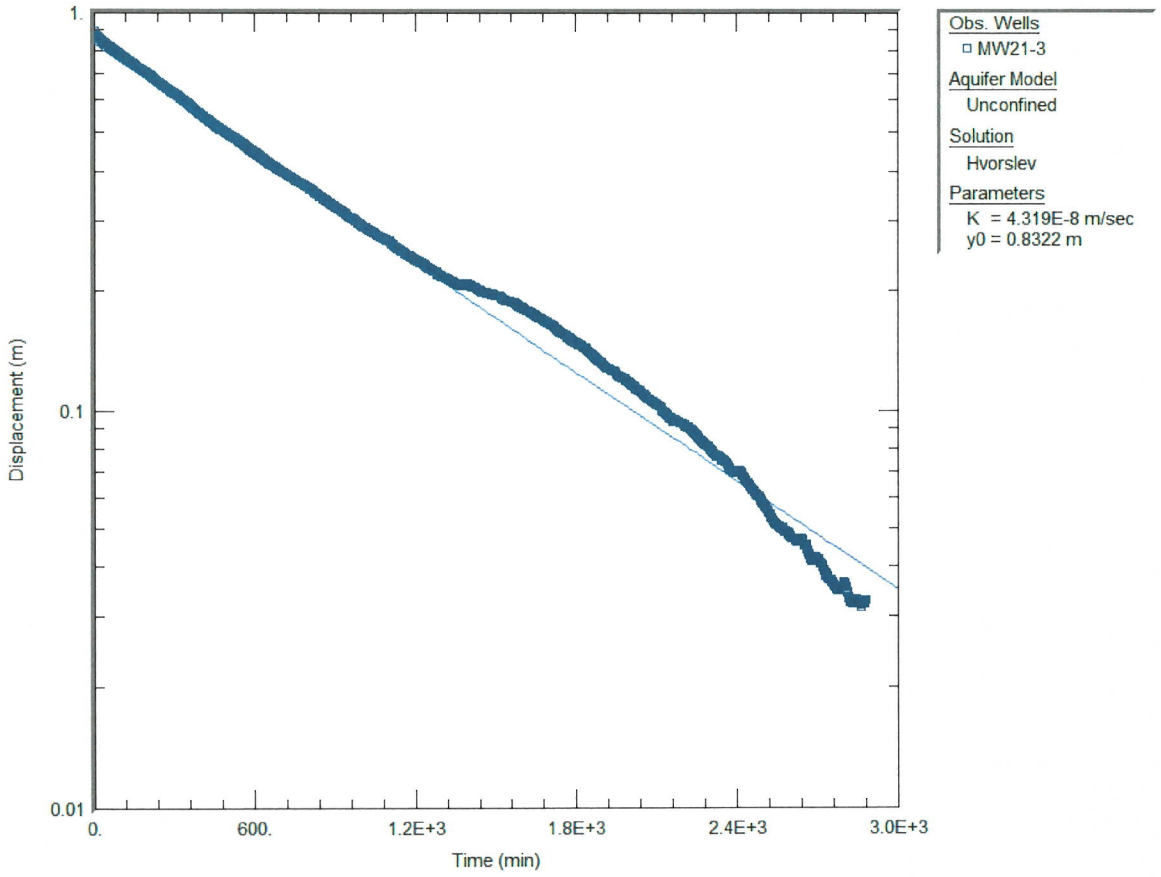
The hydraulic conductivity in MW21-1-2, completed within bedrock sandstone, is 2.0×10^{-5} m/s. This is within the expected range for a shallow confined sandstone aquifer.

Figure 2. Hvorslev solution fit to slug test data from MW21-2



The hydraulic conductivity in MW21-2, completed within silty clay deposits, is 4.8×10^{-8} m/s. This is within the expected range for a silt clay deposits.

Figure 3. Hvorslev solution fit to slug test data from MW21-3



The hydraulic conductivity in MW21-3, completed within silty clay deposits, is 4.3×10^{-8} m/s. This is within the expected range for a silt clay deposits.

The slug test results from the two wells completed in silty clay deposits (MW21-2 and MW21-3) show very similar hydraulic conductivity values. The silty clay deposits they are completed in are likely part of the same geological unit which spreads across the site from near surface to approximately 14.0 meters deep. As the permeability of these units are so low they will act as an effective barrier between the septic field systems on surface and the underlying bedrock sandstone aquifer, located below 14.0 meters. According to Alberta Tier 2 Soil and Groundwater Remediation Guidelines (2019) a layer exceeding 5 meters in thickness with a permeability less than 10^{-7}m/s constitutes a barrier layer. The silty clay layer

will also limit groundwater flow from the new septic systems into the nearby surface water body (Springbank Creek) due to the units limited hydraulic capabilities.

[6.4] Groundwater Flow Velocity

Horizontal groundwater flow velocity through the silty clay layer was determined using the change in ground elevation and average hydraulic conductivity in MW21-2 and MW21-3 as follows:

$$v = Ki$$

Where:
v = horizontal groundwater flow velocity
K = average hydraulic conductivity
i = hydraulic gradient (change in water level/distance between wells)

$$v = \left(4.6 \times 10^{-8} \frac{m}{s}\right)\left(\frac{1.20\ m}{472.7\ m}\right) = 1.2 \times 10^{-10} \frac{m}{s} = 0.004\ m/year$$

The average horizontal groundwater flow velocity through the silty clay layer is 0.004 meters per year. The groundwater flow velocity is extremely low and results in very slow migration of septic effluent in the subsurface. As such the risk of untreated septic effluent entering nearby Sprinkbank Creek is negligible.

[6.5] Groundwater Chemistry

Two water samples were collected from the site, one from the silt clay deposits (MW21-3) and one from the bedrock sandstone (MW21-1-D). A water sample could not be collected from Springbank Creek as even after augering to the base of the frozen Creek no liquid water was available to sample.

The sampled waters were analyzed for routine dissolved salts, total coliforms, e.coli and nutrients (including nitrates). The samples were analyzed by ALS Labs of Calgary and the lab report from ALS Labs is attached in Appendix D.

A summary of the results of the relevant septic field effluent parameters is as follows:

Table 7: Water Quality Parameters

Parameter	MW21-1-D (Sandstone Bedrock)	MW21-3 (Silty Clay)
Ammonia	0.106	0.113
Nitrate	0.21	1.20
Nitrite	0.053	0.094
Total Phosphorus	0.050	0.207
Sulfate	149	228
Total Dissolved Solids	675	1360
Sodium	62.7	83.2
E. Coli	<1	<1
Total Coliforms	<1	110
All values in mg/L except coliforms in MPN		

The lab results show higher nutrient and bacteria concentrations in the low permeability silty clay layer compared to the lower concentrations seen in the underlying bedrock aquifer. The nitrate concentration in both the sandstone bedrock and silty clay overburden are well below the drinking water guideline limit of 10 mg/L. The different chemistry between the two waters indicates the silty clay layer acts as an effective barrier to the migration of existing septic field effluent (from upgradient developments) and natural sources of nitrates (ex. horse manure) from entering into the underlying drinking use aquifer. The presence of the upper most silty clay has prevented these organic and bacterial constituents from migrating to drinking use aquifer depths.

[6.6] Nitrate Loading to Groundwater and Surface Water

Effects of the septic field effluent on the nitrate concentration can be determined from the baseline water quality characteristics and recharge of the septic field effluent and rainwater.

Baseline nitrate levels in the shallow silty clay layer are 1.20 mg/L. Each septic field has a nitrate loading volume of 40 grams/day/lot gives total nitrate loading. According to maps published in the Alberta Geological Survey Report 91 (Regional Geological and Hydrogeological Characterization of the Calgary – Lethbridge Corridor in the South Saskatchewan Regional Planning Area, 2017) the area has an average annual

evaportranspiration of 405 mm and precipitation of 500 mm, for an expected net groundwater recharge of 95 mm.

Most of the residential lots have an area of 2 acres (0.81 ha), with one lot with an area of 3.1 acres (1.25 ha) and another with an area of 2.9 acres (1.18 ha). The total area of the site including any environmental or municipal reserves is 35.42 acres. The total groundwater recharge volume across the entire site would be 13,617 m^3 per year (with no nitrate concentration). With the effluent from each of the new residential lots providing 365 m^3/year at a concentration of 40 mg/L nitrate the resulting concentration of nitrate loading to the subsurface, due to dilution from infiltrating precipitation, would be 9.7 mg/L. The additional nitrate concentration of 9.7 mg/L to the existing 1.2 mg/L in the overburden silty clay layer exceeds the 10 mg/L nitrate concentration for drinking water. However, the nitrate concentration in the underlying sandstone aquifer is only 0.21 mg/L, so the additional nitrate loading to the aquifer would still be less than the maximum nitrate concentration of 10 mg/L and shows that the site can accommodate the additional nitrate loading.

[6.7] Groundwater Mounding

Theoretical development of a mound underneath a septic field was modelled utilizing the Zlotnik Method and the MOUNDSOLV program developed by HydroSoft. Parameters used as input into the model include an infiltration rate of 1.5 m^3/day, mound size of 6.8 m x 34.2 m and hydraulic conductivity values as determined from the field hydraulic conductivity tests. A storativity value of 0.2 was used for an unconfined aquifer (water table).

Model times of 1 month, 1 year, 5 years, 10 years and 20 years was calculated. The model assumes that the homes are occupied 365 days per year.

Printouts of the mound rise from the MOUNDSOLV program are attached in Appendix F. A summary of the rise at the end of each period is as follows:

Table 8: Water Table Rise with Time Under Septic Field

Time	Maximum Water Table Rise (m)
1 month	0.49
1 Year	1.51
5 Years	2.32
10 Years	2.65
20 Years	3.02

The results show a groundwater mound of 3.02 m will occur after 20 years. As the water table is on the order of 2 to 3 m a risk of breakthrough of septic field effluent could occur with conventional septic fields, and as was previously recommended, the sites should use a mounded system.

[7.0] Summary

The site is suitable for soil treatment of septic effluent, with mounded septic fields. The limiting factor in treatment is the shallow water table and the low permeability of the clay found across the site.

Further siting considerations for a septic field are included in the following table:

Table 9: Minimum Recommended Setback Requirements for Treatment Field

Minimum Setback Distance (in meters)	Setback From
15	Water Source or Water Well
100	Licensed Municipal Water Well
15	Water Course
1.5	Property Line
10	Basement, Cellar or Crawl Space
1	Building without Permanent Foundation
5	Building with Permanent Foundation but no Basement
5	Septic Tank or Packaged Sewage Treatment Plant

A summary of the overall parcel suitability and limiting characteristics for the site can be described as follows:

Table 10: Parcel Suitability for Private Sewage Treatment System

Site Variable	Suitability	Description
Soil texture and structure	Low - Moderate	Good structure but low permeability limits a a traditional field with primary or secondary treated effluent. Silty clay or clay soil textures result in larger fields and lower loading rates
Depth of Suitable Soil	Moderate	Silty clay/ clay soil extends to a depth of at least 3.0 m. No impermeable bedrock was encountered.
Hydraulic Capability	Low - Moderate	Evidence of seasonal wetting (gleying/mottling) in some test pits
Soil Horizons	Very	No bedrock was encountered
Depth to Water Table	Low - Moderate	Shallow groundwater was encountered and development will occur next to wetland areas
Topography	Very	Site is hummocky with most slopes less than 5%
Flooding	Moderate	Issues with flooding are possibly based on the presence of wetlands across the site and the low range in topographic elevation across the property.
Density	Moderate	Moderate development density
Encumbrances	Very	Parcel is of sufficient size for an alternate PSTS location.
Parcel Size	Very	Parcel is of sufficient size for alternate PSTS location.
Surface Water	Moderate	Springbank Creek runs through the northwest portion of the property but proper set backs are maintained and sections are part of an environmental reserve
Overall Suitability	Moderate	Good parcel size, shallow slopes, low permeability soil types, shallow groundwater table.
Recommendations	Suitable for mounded treatment field with primary and secondary treated effluent	

[8.0] References

Alberta Association of Municipal Districts and Counties. 2011. *The Model Process for Subdivision Approval and Private Sewage.*

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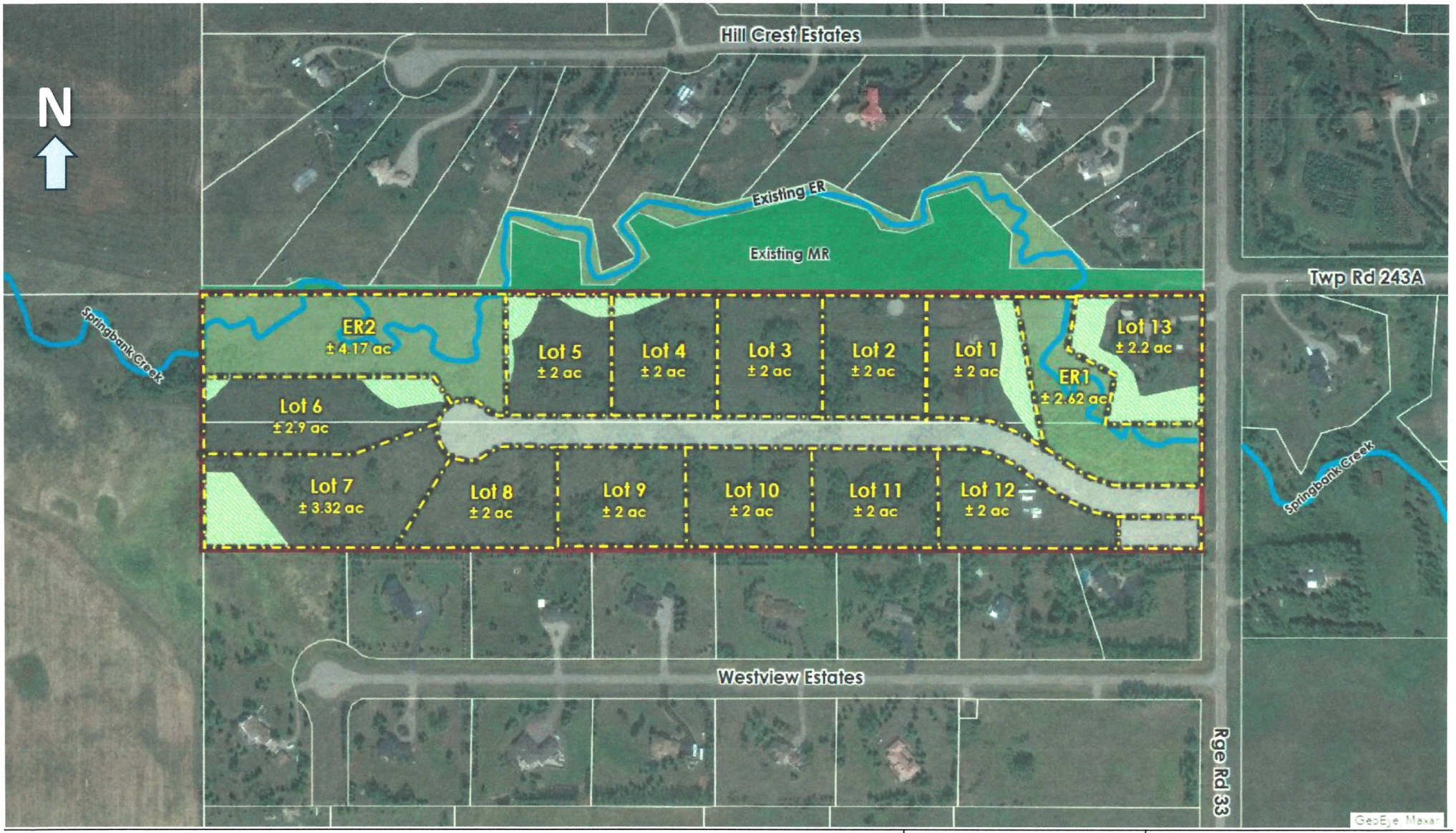
Appendix A: Site Maps



LEGEND

Site Boundaries

Lot Boundaries

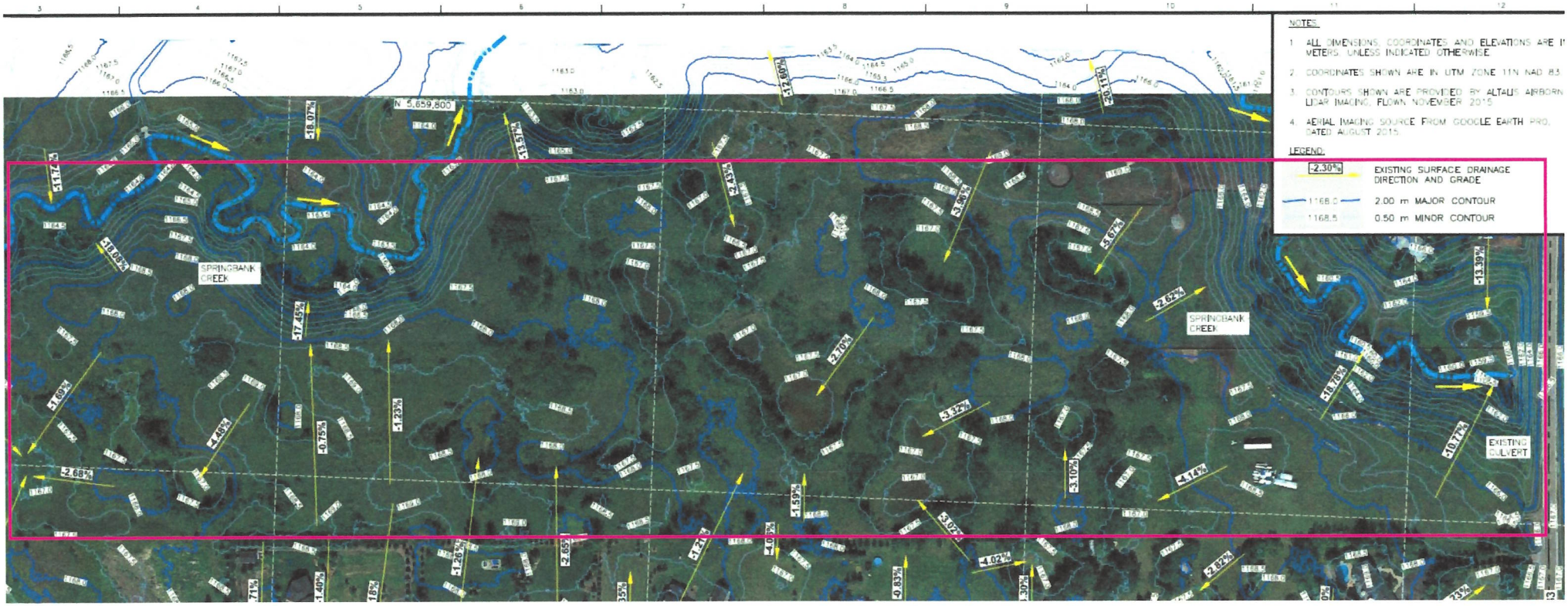
Allan Markin

Groundwater Resources
Information Technologies Ltd.

Subdivision Boundaries
SE – 21 – 24 – 3W5
Rocky View County

Date: March 2021	Project: 2021-1675	Plate No. 1

N



LEGEND

Site Boundary

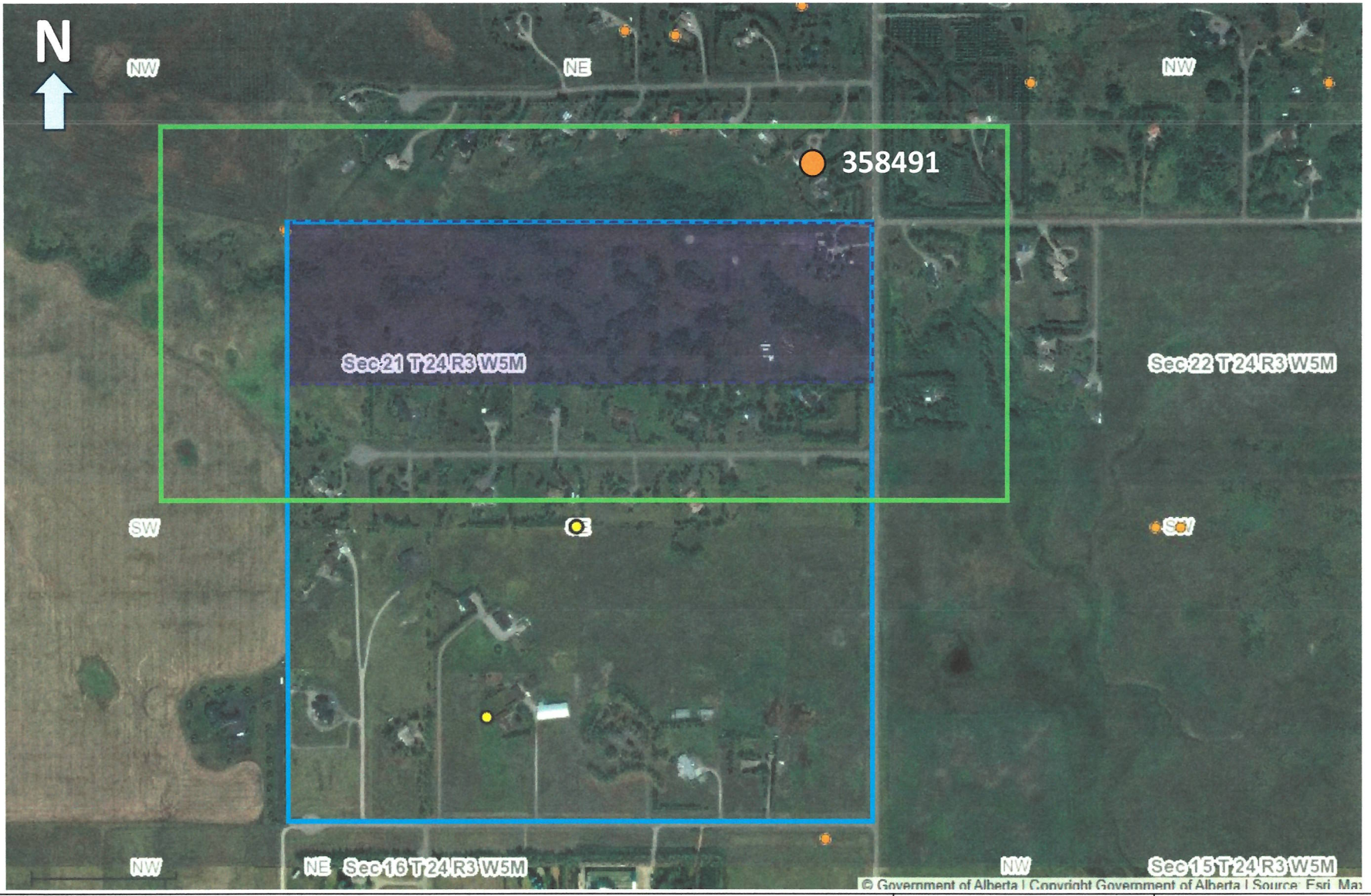
Surface Topography Contour (Contour Interval = 0.5 m)

Alan Markin

Groundwater Resources
Information Technologies Ltd.

Topographic Map
SE – 21 – 24 – 3W5
Rocky View County

Date: March 2021	Project: 2021-1675	Plate No. 2



LEGEND

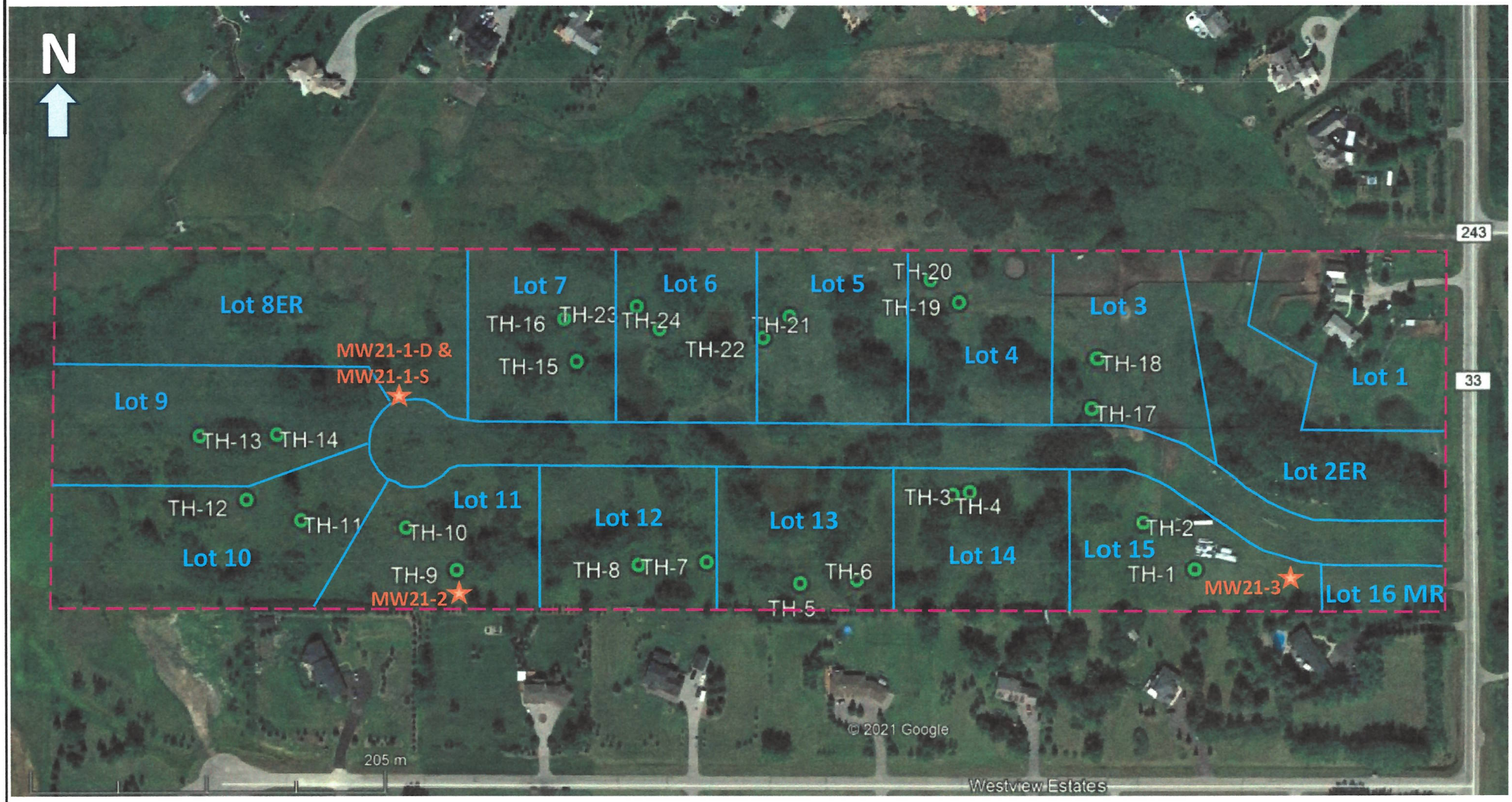
- Quarter Section Boundary
- Site Boundary
- ~ 150m radius
- Water Well Location (with listed well ID)

Allan Markin

Groundwater Resources
Information Technologies Ltd.

Water Wells within 150 m
SE – 21 – 24 – 3W5
Rocky View County

Date: March 2021	Project: 2021-1675	Plate No. 3



LEGEND

- Test Hole Location
- Monitoring Well Location
- Lot Boundaries
- Site Boundary

Allan Markin

Groundwater Resources
Information Technologies Ltd.

Test Hole and Monitoring Well Locations
SE – 21 – 24 – 3W5
Rocky View County

Date: March 2021	Project: 2021-1675	Plate No. 4

Appendix B: Grain Size Analysis

Groundwater Information Technologies
(GRIT) LTD.
ATTN: ALANNA FELSKE
#44, 2110 - 41 Avenue NE
Calgary AB T2E 8Z7

Date Received: 24-FEB-21
Report Date: 07-MAR-21 14:33 (MT)
Version: FINAL

Client Phone: 403-470-1237

Certificate of Analysis

Lab Work Order #: L2561414
Project P.O. #: NOT SUBMITTED
Job Reference: 2021-1675
C of C Numbers: 17-768215, 17-768217, 17-768218
Legal Site Desc:

Inayat Dhaliwal
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2561414-1 TH-1 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	4.2		1.0	%		07-MAR-21	R5397648
% Silt	46.2		1.0	%		07-MAR-21	R5397648
% Clay	49.6		1.0	%		07-MAR-21	R5397648
Texture	Silty clay					07-MAR-21	R5397648
L2561414-2 TH-2 @ 1.5M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	7.2		1.0	%		07-MAR-21	R5397648
% Silt	38.2		1.0	%		07-MAR-21	R5397648
% Clay	54.6		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-3 TH-3 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	8.2		1.0	%		07-MAR-21	R5397648
% Silt	36.6		1.0	%		07-MAR-21	R5397648
% Clay	55.2		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-4 TH-4 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	6.2		1.0	%		07-MAR-21	R5397648
% Silt	39.2		1.0	%		07-MAR-21	R5397648
% Clay	54.6		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-5 TH-5 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	2.0		1.0	%		07-MAR-21	R5397648
% Silt	38.1		1.0	%		07-MAR-21	R5397648
% Clay	59.9		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-6 TH-6 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	11.6		1.0	%		07-MAR-21	R5397648
% Silt	35.7		1.0	%		07-MAR-21	R5397648
% Clay	52.7		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2561414-6 TH-6 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
L2561414-7 TH-7 @ 0.6M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	9.6		1.0	%		07-MAR-21	R5397648
% Silt	36.6		1.0	%		07-MAR-21	R5397648
% Clay	53.8		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-8 TH-7 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	12.2		1.0	%		07-MAR-21	R5397648
% Silt	39.6		1.0	%		07-MAR-21	R5397648
% Clay	48.2		1.0	%		07-MAR-21	R5397648
Texture	Silty clay / Clay					07-MAR-21	R5397648
L2561414-9 TH-8 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	4.6		1.0	%		07-MAR-21	R5397648
% Silt	45.8		1.0	%		07-MAR-21	R5397648
% Clay	49.6		1.0	%		07-MAR-21	R5397648
Texture	Silty clay					07-MAR-21	R5397648
L2561414-10 TH-9 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	4.0		1.0	%		07-MAR-21	R5397648
% Silt	38.1		1.0	%		07-MAR-21	R5397648
% Clay	57.9		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-11 TH-10 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	4.6		1.0	%		07-MAR-21	R5397648
% Silt	46.9		1.0	%		07-MAR-21	R5397648
% Clay	48.6		1.0	%		07-MAR-21	R5397648
Texture	Silty clay					07-MAR-21	R5397648
L2561414-12 TH-11 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2561414-12 TH-11 @ 1.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	12.4		1.0	%		07-MAR-21	R5397648
% Silt	36.8		1.0	%		07-MAR-21	R5397648
% Clay	50.8		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-13 TH-12 @ 1.0M							
Sampled By: CLIENT on 19-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	8.6		1.0	%		07-MAR-21	R5397648
% Silt	40.2		1.0	%		07-MAR-21	R5397648
% Clay	51.2		1.0	%		07-MAR-21	R5397648
Texture	Silty clay / Clay					07-MAR-21	R5397648
L2561414-14 TH-13 @ 1.0M							
Sampled By: CLIENT on 19-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	8.2		1.0	%		07-MAR-21	R5397648
% Silt	30.0		1.0	%		07-MAR-21	R5397648
% Clay	61.8		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-15 TH-14 @ 0.8M							
Sampled By: CLIENT on 19-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	6.2		1.0	%		07-MAR-21	R5397648
% Silt	37.6		1.0	%		07-MAR-21	R5397648
% Clay	56.2		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-16 TH-15 @ 1.0M							
Sampled By: CLIENT on 19-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	16.0		1.0	%		07-MAR-21	R5397648
% Silt	38.9		1.0	%		07-MAR-21	R5397648
% Clay	45.1		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648
L2561414-17 TH-16 @ 0.6M							
Sampled By: CLIENT on 19-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	31.2		1.0	%		07-MAR-21	R5397648
% Silt	27.9		1.0	%		07-MAR-21	R5397648
% Clay	40.9		1.0	%		07-MAR-21	R5397648
Texture	Clay					07-MAR-21	R5397648

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2561414-18 TH-16 @ 1.0M							
Sampled By: CLIENT on 19-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	10.4		1.0	%		07-MAR-21	R5397648
% Silt	44.9		1.0	%		07-MAR-21	R5397648
% Clay	44.7		1.0	%		07-MAR-21	R5397648
Texture	Silty clay					07-MAR-21	R5397648
L2561414-19 TH-17 @ 1.0M							
Sampled By: CLIENT on 19-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	4.2		1.0	%		07-MAR-21	R5397649
% Silt	41.0		1.0	%		07-MAR-21	R5397649
% Clay	54.8		1.0	%		07-MAR-21	R5397649
Texture	Silty clay					07-MAR-21	R5397649
L2561414-20 TH-18 @ 1.0M							
Sampled By: CLIENT on 24-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	7.6		1.0	%		07-MAR-21	R5397649
% Silt	41.4		1.0	%		07-MAR-21	R5397649
% Clay	51.0		1.0	%		07-MAR-21	R5397649
Texture	Silty clay					07-MAR-21	R5397649
L2561414-21 TH-19 @ 1.2M							
Sampled By: CLIENT on 24-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	8.2		1.0	%		07-MAR-21	R5397649
% Silt	25.0		1.0	%		07-MAR-21	R5397649
% Clay	66.8		1.0	%		07-MAR-21	R5397649
Texture	Clay					07-MAR-21	R5397649
L2561414-22 TH-20 @ 1.5M							
Sampled By: CLIENT on 24-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	8.4		1.0	%		07-MAR-21	R5397649
% Silt	35.4		1.0	%		07-MAR-21	R5397649
% Clay	56.2		1.0	%		07-MAR-21	R5397649
Texture	Clay					07-MAR-21	R5397649
L2561414-23 TH-21 @ 1.0M							
Sampled By: CLIENT on 24-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	2.4		1.0	%		07-MAR-21	R5397649
% Silt	44.7		1.0	%		07-MAR-21	R5397649
% Clay	52.9		1.0	%		07-MAR-21	R5397649
Texture	Silty clay					07-MAR-21	R5397649

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2561414-23 TH-21 @ 1.0M							
Sampled By: CLIENT on 24-FEB-21							
Matrix: SOIL							
L2561414-24 TH-22 @ 1.5M							
Sampled By: CLIENT on 24-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	14.6		1.0	%		07-MAR-21	R5397649
% Silt	37.2		1.0	%		07-MAR-21	R5397649
% Clay	48.2		1.0	%		07-MAR-21	R5397649
Texture	Clay					07-MAR-21	R5397649
L2561414-26 TH-23 @ 1.2M							
Sampled By: CLIENT on 24-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	12.2		1.0	%		07-MAR-21	R5397649
% Silt	34.9		1.0	%		07-MAR-21	R5397649
% Clay	52.9		1.0	%		07-MAR-21	R5397649
Texture	Clay					07-MAR-21	R5397649
L2561414-27 TH-24 @ 1.0M							
Sampled By: CLIENT on 24-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	14.0		1.0	%		07-MAR-21	R5397649
% Silt	34.7		1.0	%		07-MAR-21	R5397649
% Clay	51.3		1.0	%		07-MAR-21	R5397649
Texture	Clay					07-MAR-21	R5397649
L2561414-28 MW-21-1 @ 9.0M							
Sampled By: CLIENT on 18-FEB-21							
Matrix: SOIL							
Particle Size							
% Sand	9.6		1.0	%		07-MAR-21	R5397649
% Silt	43.1		1.0	%		07-MAR-21	R5397649
% Clay	47.3		1.0	%		07-MAR-21	R5397649
Texture	Silty clay					07-MAR-21	R5397649

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Appendix C: Test Hole Logs

Project: Markin Level IV PSTS **File No:** 2021-1675 **Test Hole ID:** MW21-1-D

Address: Range Road 33, Springbank, AB

GPS Coordinates/Location: 51.05879°N, 114.35925°W

Drill Method: Solid Stem Auger

Sample Type: Grab

Driller: All Services Drilling Inc.

Logged By: KH

Test Hole Diameter: 0.15 meters

Drill Date: February 18, 2021

Ground Elevation: 1167.0 m asl

Casing Elevation: 1168.0 m asl

Water Elevation: 1159.95 m asl

Water Sampling Date: March 2, 2021

Groundwater Resources
Information Technologies Ltd.

Depth (m)	Sample Location	Lithology Log	Soil Description	Water Level	Well Construction Details
1–17			**Topsoil** - Black, under prairie grass		
			Silt - Light brown, dry, firm		
			Silt Clay - 2.5 Y 4/3 Olive Brown - Loose - Increased clay content below 2.0 meters - Moist below 2.5 meters - Mottled grey-brown below 3.5 meters	7.05 m March 2	
			Silt Clay - Rare gravels - Coal fragments - Mottled grey-olive brown - Firm - Moist		
			Clay - Grey-brown - Soft, damp		
			Silt Clay - Rare gravels - Grey-dark brown - Firm, damp		
			Sandstone - Fine-grained - Wet		
			Completed as Monitoring Well to 16.5 m		

Solid 2 inch PVC Pipe

Bentonite Fill

Slotted PVC Pipe

Sand Fill

Project: Markin Level IV PSTS **File No:** 2021-1675 **Test Hole ID:** MW21-1-S

Address: Range Road 33, Springbank, AB
GPS Coordinates/Location: 51.05879°N, 114.35925°W NW Corner of Property

Drill Method: Solid Stem Auger
Sample Type: Grab
Driller: All Services Drilling Inc.
Logged By: KH
Test Hole Diameter: 0.15 meters
Drill Date: February 18, 2021

Ground Elevation: 1167.0 m asl
Casing Elevation: 1167.95 m asl
Water Elevation: N/A
Water Sampling Date: N/A

Groundwater Resources Information Technologies Ltd.

Depth (m)	Sample Location	Lithology Log	Soil Description	Water Level	Well Construction Details
0			**Topsoil** - Black, under prairie grass		Solid 2 inch PVC Pipe Bentonite Fill
1			**Silt** - 10YR 5/4 Yellowish Brown -Loose, damp		
2			**Silt Clay** - Loose, medium plastic - 2.5Y 4/3 Olive Brown - Increasing clay content below 2.0 meters - Moist below 2.5 meters		
3	Bag		- Mottled grey-brown below 3.5m - Bag sample at 3.5 m		
4					
5					Slotted PVC Pipe Sand Fill
6					
7			**Silt Clay with Rare Gravel** - Coal fragments, firm, moist - Mottled grey-brown		
8			Completed as Monitoring Well to 7.5 m		

Project: Markin Level IV PSTS **File No:** 2021-1675 **Test Hole ID:** MW21-2

Address: Range Road 33, Springbank, AB

GPS Coordinates/Location: 51.05784°N, 114.35870°W
SW Corner of Property

Drill Method: Solid Stem Auger
Sample Type: Grab
Driller: All Services Drilling Inc.
Logged By: KH
Test Hole Diameter: 0.15 meters
Drill Date: February 18, 2021

Ground Elevation: 1169.20 m asl
Casing Elevation: 1170.15 m asl
Water Elevation: 1166.80 m asl
Water Sampling Date: March 2, 2021

Groundwater Resources
Information Technologies Ltd.

Depth (m)	Sample Location	Lithology Log	Soil Description	Water Level	Well Construction Details
0			**Topsoil** - Black, under prairie grass		Solid 2 inch PVC Pipe Bentonite Fill
1			**Silt** - Light brown, dry, firm		
2			**Silt Clay** - 2.5 Y 5/4 Light Olive Brown - firm - moist below 2.5 m - mottled below 3.0 m	2.94 m March 2	
3					
4					
5					Slotted PVC Pipe Sand Fill
6					
7	Bag				
8			Completed as Monitoring Well to 7.5 m		

Project: Markin Level IV PSTS **File No:** 2021-1675 **Test Hole ID:** MW21-3

Address: Range Road 33, Springbank, AB

GPS Coordinates/Location: 51.05971°N, 114.35155°W SE Corner of Property

Drill Method: Solid Stem Auger

Sample Type: Grab

Driller: All Services Drilling Inc.

Logged By: KH

Test Hole Diameter: 0.15 meters

Drill Date: February 18, 2021

Ground Elevation: 1168.0 m asl

Casing Elevation: 1168.95 m asl

Water Elevation: 1164.22 m asl

Water Sampling Date: March 2, 2021

Groundwater Resources Information Technologies Ltd.

Depth (m)	Sample Location	Lithology Log	Soil Description	Water Level	Well Construction Details
0			**Topsoil** - Black, under prairie grass		
1			**Silt Clay** - Light brown, frozen		
2			**Silt Clay** - 2.5 Y 5/4 Light Olive Brown - Firm - Damp - Plastic - Moist at 2.5 meters		
3				3.78 m March 2	
4	Bag		- Mottled brown-grey at 4.0 m - Occasional iron oxide nodules		
5					
6			- Dark grey-brown below 6.0 m		
7	Bag				
8			Completed as Monitoring Well to 7.5 m		

Solid 2 inch PVC Pipe

Bentonite Fill

Slotted PVC Pipe

Sand Fill

Appendix D: ALS Water Chemistry Analysis

Groundwater Information Technologies
(GRIT) LTD.
ATTN: ALANNA FELSKE
#44, 2110 - 41 Avenue NE
Calgary AB T2E 8Z7

Date Received: 02-MAR-21
Report Date: 11-MAR-21 11:21 (MT)
Version: FINAL

Client Phone: 403-470-1237

Certificate of Analysis

Lab Work Order #: L2562850

Project P.O. #:	NOT SUBMITTED
Job Reference:	MARKIN LEVEL IV PSTS
C of C Numbers:	17-768223
Legal Site Desc:	

Inayat Dhaliwal
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2562850-1 MW21-1-D							
Sampled By: CLIENT on 02-MAR-21 @ 11:30							
Matrix: WATER							
Miscellaneous Parameters							
Ammonia, Total (as N)	0.106		0.050	mg/L		08-MAR-21	R5398393
Chemical Oxygen Demand	29		10	mg/L		04-MAR-21	R5396747
Total Organic Carbon	10.7		1.0	mg/L		08-MAR-21	R5398132
Phosphorus (P)-Total	0.0500		0.0050	mg/L		08-MAR-21	R5398171
Total Coliforms and E. Coli by MPN							
MPN - E. Coli	<1		1	MPN/100mL		03-MAR-21	R5396714
MPN - Total Coliforms	<1		1	MPN/100mL		03-MAR-21	R5396714
Total Nitrogen							
Total Kjeldahl Nitrogen by Fluorescence							
Total Kjeldahl Nitrogen	1.3	DLM	1.0	mg/L		08-MAR-21	R5398719
Total Nitrogen (Calculation)							
Total Nitrogen	1.6		1.0	mg/L		10-MAR-21	
Routine Water Analysis							
Chloride in Water by IC							
Chloride (Cl)	18.2	DLHC	2.5	mg/L		10-MAR-21	R5398624
Dissolved Metals by ICPOES							
Dissolved Metals Filtration Location	LAB					07-MAR-21	R5397672
Calcium (Ca)-Dissolved	121		0.10	mg/L		07-MAR-21	R5397679
Magnesium (Mg)-Dissolved	55.2		0.10	mg/L		07-MAR-21	R5397679
Potassium (K)-Dissolved	5.14		0.50	mg/L		07-MAR-21	R5397679
Sodium (Na)-Dissolved	62.7		1.0	mg/L		07-MAR-21	R5397679
Fluoride in Water by IC							
Fluoride (F)	<0.10	DLHC	0.10	mg/L		10-MAR-21	R5398624
Ion Balance Calculation							
Ion Balance	109			%		10-MAR-21	
TDS (Calculated)	675			mg/L		10-MAR-21	
Hardness (as CaCO3)	529			mg/L		10-MAR-21	
Nitrate in Water by IC							
Nitrate (as N)	0.21	HTD	0.10	mg/L		10-MAR-21	R5398624
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	0.26		0.11	mg/L		10-MAR-21	
Nitrite in Water by IC							
Nitrite (as N)	0.053	HTD	0.050	mg/L		10-MAR-21	R5398624
Sulfate in Water by IC							
Sulfate (SO4)	149	DLHC	1.5	mg/L		10-MAR-21	R5398624
pH, Conductivity and Total Alkalinity							
pH	7.79		0.10	pH		09-MAR-21	R5399119
Conductivity (EC)	980		2.0	uS/cm		09-MAR-21	R5399119
Bicarbonate (HCO3)	534		5.0	mg/L		09-MAR-21	R5399119
Carbonate (CO3)	<5.0		5.0	mg/L		09-MAR-21	R5399119
Hydroxide (OH)	<5.0		5.0	mg/L		09-MAR-21	R5399119
Alkalinity, Total (as CaCO3)	438		2.0	mg/L		09-MAR-21	R5399119
L2562850-2 MW21-3							
Sampled By: CLIENT on 02-MAR-21 @ 11:50							
Matrix: WATER							
Miscellaneous Parameters							
Ammonia, Total (as N)	0.113		0.050	mg/L		08-MAR-21	R5398393
Chemical Oxygen Demand	59		10	mg/L		04-MAR-21	R5396747
Total Organic Carbon	17.1		1.0	mg/L		08-MAR-21	R5398132
Phosphorus (P)-Total	0.207	DLHC	0.010	mg/L		08-MAR-21	R5398171
Total Coliforms and E. Coli by MPN							

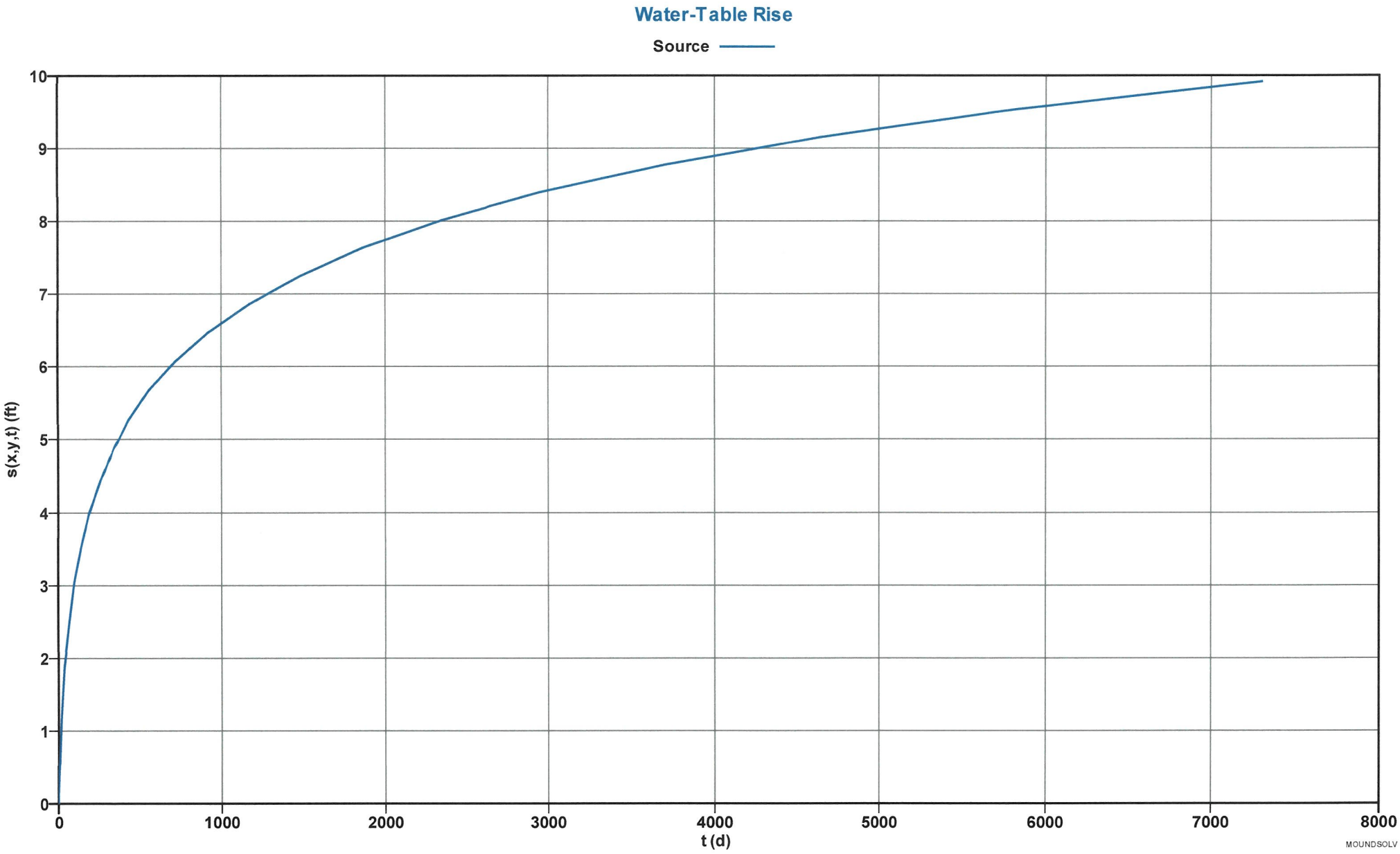
* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2562850-2 MW21-3							
Sampled By: CLIENT on 02-MAR-21 @ 11:50							
Matrix: WATER							
Total Coliforms and E. Coli by MPN							
MPN - E. Coli	<1		1	MPN/100mL		03-MAR-21	R5396714
MPN - Total Coliforms	110		1	MPN/100mL		03-MAR-21	R5396714
Total Nitrogen							
Total Kjeldahl Nitrogen by Fluorescence							
Total Kjeldahl Nitrogen	1.4	DLM	1.0	mg/L		08-MAR-21	R5398719
Total Nitrogen (Calculation)							
Total Nitrogen	2.6		1.0	mg/L		10-MAR-21	
Routine Water Analysis							
Chloride in Water by IC							
Chloride (Cl)	458	DLHC	2.5	mg/L		10-MAR-21	R5398624
Dissolved Metals by ICPOES							
Dissolved Metals Filtration Location	LAB					07-MAR-21	R5397672
Calcium (Ca)-Dissolved	256	DLDS	0.50	mg/L		07-MAR-21	R5397679
Magnesium (Mg)-Dissolved	128	DLDS	0.50	mg/L		07-MAR-21	R5397679
Potassium (K)-Dissolved	7.4	DLDS	2.5	mg/L		07-MAR-21	R5397679
Sodium (Na)-Dissolved	83.2	DLDS	5.0	mg/L		07-MAR-21	R5397679
Fluoride in Water by IC							
Fluoride (F)	<0.10	DLHC	0.10	mg/L		10-MAR-21	R5398624
Ion Balance Calculation							
Ion Balance	113	BL:INT		%		10-MAR-21	
TDS (Calculated)	1360			mg/L		10-MAR-21	
Hardness (as CaCO3)	1170			mg/L		10-MAR-21	
Nitrate in Water by IC							
Nitrate (as N)	1.20	HTD	0.10	mg/L		10-MAR-21	R5398624
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	1.29		0.11	mg/L		10-MAR-21	
Nitrite in Water by IC							
Nitrite (as N)	0.094	HTD	0.050	mg/L		10-MAR-21	R5398624
Sulfate in Water by IC							
Sulfate (SO4)	228	DLHC	1.5	mg/L		10-MAR-21	R5398624
pH, Conductivity and Total Alkalinity							
pH	7.75		0.10	pH		09-MAR-21	R5399119
Conductivity (EC)	2390		2.0	uS/cm		09-MAR-21	R5399119
Bicarbonate (HCO3)	385		5.0	mg/L		09-MAR-21	R5399119
Carbonate (CO3)	<5.0		5.0	mg/L		09-MAR-21	R5399119
Hydroxide (OH)	<5.0		5.0	mg/L		09-MAR-21	R5399119
Alkalinity, Total (as CaCO3)	315		2.0	mg/L		09-MAR-21	R5399119

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Appendix F: Water Table Mounding AQTESOLV Outputs


Water-Table Rise
Source
s(x,y,t) (ft)
10
9
8
7
6
5
4
3
2
1
0
0
1000
2000
3000
4000
5000
6000
7000
8000
t (d)
MOUNDSOLV