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To:	Saskatoon Health Region		
From:	Gord Will, P.Eng.		
Client:	Chris Cebryk		
Project Name	Cebryk Residential Development - Eagle Heights Subdivision		
Project No.	20124165.00		
Subject:	Preliminary Assessment of the Fate of OWTS Effluent		

TECHNICAL MEMORANDUM

1 INTRODUCTION

Associated Engineering (Sask.) Ltd. (AE) has been engaged by Chris Cebryk to complete a subdivision development site assessment (site assessment) for the proposed Eagle Heights country residential development. The proposed residential development is located on the W1/2 11-37-04 W3M, approximately 5.5 km northeast of Saskatoon in the Rural Municipality of Corman Park (Figure 1). The objective of the site assessment is to assess the potential adverse effects to groundwater from the use of onsite wastewater treatment systems (OWTS).

The site assessment was completed in accordance with the *Guidance Document for the Developments and Subdivision Where Onsite Wastewater Treatment Systems are Proposed* (Government of Saskatchewan, 2012) and the *Saskatchewan Onsite Wastewater Disposal Guide* (Saskatchewan Ministry of Health, 2009). The information presented in this Technical Memorandum will be used to support the Eagle Heights subdivision application to the approving authorities.

AE assessed the subdivision using the risk-based process presented in the Guidance Document (2012) by completing the following steps:

- screening for inclusion
- completing a desktop review and field program
- assessing if the OWTS can be isolated from a groundwater source.

The proposed subdivision area is approximately 128 hectares occupying almost the entire half section. It is planned to comprise of 83 lots with an average lot size of 1 hectare (2.5 acres) (Figure 2). As such, the proposed residential development is categorized under Scenario A of the Inclusion Criteria (Government of Saskatchewan, 2012) indicating that an assessment is required. The following sections provide the results of the desktop review, field program and hydrogeological study.

2 PRELIMINARY ASSESSMENT OF THE FATE OF OWTS EFFLUENT

2.1 Site Characteristics

The characteristics of the proposed subdivision are summarized as follows:

- The development area is currently undeveloped farmland with no buildings or other improvements present. The proposed land use is country residential with single family dwellings maintaining a minimum average lot size of 1 hectare.
- Other existing developments near this project include the 27 lot Eagle Ridge country residential subdivision located directly to the west on SE-10-037 -04 -W3M. Additionally, there are three isolated single severance farmsteads situated directly north of the development area. Agricultural lands represent the balance of land use surrounding the project area including a combination of cultivated and pasture lands.
- The subdivision site is located along the western side of the Strawberry Hills. Natural surface drainage on the site consists of three enclosed catchments (one in the SW quarter, one straddling the SW and NW quarter, and a larger catchment on the NW quarter that drains to the NE corner of the development (Figure 3)). The lowest elevations of each enclosed catchment are occupied by natural sloughs/ponds. The subdivision conceptual drainage plan intends to utilize the natural ground slope, field drains and the road layout to convey surficial runoff to the natural ponds in the three enclosed catchments. The three natural ponds will be maintained as stormwater retention facilities that will retain post development runoff for up to a 1:100 year 24-hour storm event.
- The natural slough/ponds described in the bullet point above will be designated Environmental Reserves. Vegetation is typical of prairie sloughs/ponds (surrounding fringe of low shrubs and grasses, and emergent macrophytes within the pond). There are no other public reserve lands intended within the development area.
- Inspection of satellite images indicate there are no cuts, banks or steep slopes on the development site that might have stability concerns related to effluent input from OWTS.
- There are no existing sewage systems on the development site. Proposed domestic wastewater systems will be OWTS mounds servicing individual lots. Set-backs requirements for the mounds will be as follows: 9 m from a basement/building; 1.5 m above the groundwater table; 3 m from a cut embankment; 3 m from a property boundary; 1.5 m from a walkway; 15 m from a water course; 15 m from a water source; and 60 m from a recreational area. In addition, the sewage mound on each lot should be located down gradient (in the direction of the groundwater flow) from the dwelling with the maximum possible distance to the down gradient boundary of the lot while observing the set-backs requirements.
- There are no existing wells on the development site listed in the Water Security Agency (WSA) well database. Two test holes are listed (one from 1967, the other from 1968) but no wells were developed because of the exploration. There are no proposed or anticipated uses of groundwater for water supply at the development site. Water will be supplied via a pipeline and service connections to individual parcels.
- Water usage at each lot is estimated to be 1245 L per site/day based upon average occupancy of three people per lot (249 people in the subdivision) and an estimated wastewater production rate of 415 L per capita per day (LPCD).

2.2 Site Hydrogeological Characteristics

Hydrogeological investigations (desktop and field) were conducted by AE. The key findings of the investigation are summarized as follows:

- A previous geotechnical investigation (SNC 2013) drilled 29 boreholes distributed over the site (Figure 4), sampled and logged the borehole lithology, and conducted engineering soil testing on the borehole samples. The results of the SNC investigation indicated:
  - The subdivision area is covered by a thin layer of top soil 0 to 800 mm thick, avg. 170 mm (Table1).
  - The top soils are followed by deposits of silt/clay materials to depths of 0 to 2.90, avg. 0.89 m below ground level (mbgl). The surficial silt/clay layer was not present in 7 of the 29 boreholes (Table 1)
  - Samples taken from the boreholes from 0.5 to 1.2 m depth were classified as silty clay loam, silt loam, loam or sandy loam based upon grain size analysis. The materials had 13%-34% clay content and 57%-80% passing through a number of 200 sieve ("fines" or material less than 0.075 mm)
  - The topsoil/silt/clay surface materials overlay silt till deposits to a depth of at least 12.1 mbgl (the maximum depth of the boreholes). The silt till deposits were extensive and found at every borehole location (Table 1).
  - Three of the 29 boreholes (SNC-01, SNC-10, and SNC-21; Figure 4) encountered a layer of silty sand at depths of 3.0, 4.0 and 1.8 mbgl, with thicknesses of 0.50 m, 0.83 m, 0.20 m, respectively (Table 1).
  - Groundwater was observed at depths ranging from 1.32 m to 5.99 mbgl, avg. 3.16 mbgl in piezometers installed in the boreholes (Table 1).
- A hydrogeological field investigation was conducted by AE October – November 2017. A total of eight monitoring wells were installed at distributed locations over the site (Figure 4)[1]. The monitoring wells were sampled and logged for lithology and were used to determine groundwater surface elevations and gradient. Pump tests were conducted on three of the monitoring wells to determine the hydraulic conductivity of the glacial till materials that overlay the site. The results of the AE hydrotechnical investigation indicated that:
  - The lithology of the AE monitoring well boreholes (Table 2) were in close agreement with previous investigation by SNC (SNC 2013).
  - Thin surface layer of top soil (100 to 200 mm) was present in three of the eight AE boreholes.
  - In two of the eight AE boreholes, top soil was followed by deposits of silt/clay materials with thickness of 400 and 900 mm respectively.
  - The topsoil/silt/clay surface materials overlay silt till deposits to a depth of at least 10.6 mbgl (the maximum depth of the boreholes). The silt till deposits were extensive and found at every AE borehole location.
  - No sand layers were encountered in any of the AE boreholes.

[1] The SNC boreholes and piezometers installed in 2013 had been decommissioned and therefore were unavailable for groundwater monitoring in 2017.

- Groundwater was observed in the monitoring wells at depths ranging from 1.88 m to 6.17 mbgl, avg. 3.49 mbgl in piezometers installed in the boreholes (Table 2).
- Falling head slug testing was conducted in AE monitoring wells 03, 05 and 06D to measure the hydraulic conductivity of the surficial till materials. The test results indicated the hydraulic conductivities were in the range 1.91 x 10-9 to 1.82 x 10-8 m/s (1.65 x 10-4 to 1.57 x.10-3 m/day).
- The sand layers that were found in three (3) of the 29 SNC boreholes (Table 1), but none of the 8 AE monitoring well boreholes (Table 2), are likely discontinuous and limited in extent based upon their low frequency of occurrence and the dispersed nature of their occurrence (Figure 4) (i.e. the sand lense occurrences were not found in proximity to each other).
- Groundwater gradient on the subdivision site is strongly correlated with ground surface elevation (Figure 5). Locally shallow groundwater likely moves toward the low spot in each of the three surface runoff catchments (Figure 3), but overall the deep groundwater moves in the direction of the lowest surface elevations near the large pond in the NE corner of the subdivision site.
- Local horizontal groundwater gradient on the subdivision site ranged from 0.01 to 0.003 based upon AE monitoring well observations, and horizontal groundwater velocity was calculated to range from 0.015 m/year to 0.00048 m/year based upon till material properties and monitoring well bail response testing.
- Mean annual precipitation at the site is expected to be approximately of 355 mm/year and potential evapotranspiration 565 mm/year (SRC 2016). Due to the annual moisture deficit the groundwater recharge rate is estimated to be only a few mm/yr (Ryan and Chu 2009, Keller et al. 1988) and recharge is likely to occur during wet periods only.
- A total of 8 driller's logs located in the ten quarter sections bordering the subdivision half section site were available in the WSA well database (Figure 6 and Table 3). Two of the 8 drill logs were for undeveloped test holes. Three were for bored wells completed in gravels at depths in the range of 11.0 to 19.5 mbgl. Three were for drilled wells completed in sands at depths in the range of 57.9 to 71.0 mbgl. The shallowest well completion
- (11 mbgl) was located to the NW, downslope of the subdivision site at a much lower elevation near Highway 41. The gravel materials that the bored wells were completed in were all overlain by layers of sandy clays and tills.
- A total of 10 additional driller's logs are located within the next ring of 18 quarter sections that surround the subdivision site and the 10 immediately adjoining quarter sections (Figure 6 and Table 3). Four of the 10 drill logs were for undeveloped test holes, but each had lithology records. The 6 drill logs for wells indicate completion in sand and/or gravel layers at 5.8 to 14.3 mbgl. The shallowest wells are located to the east and southeast at higher elevations than the subdivision site.

Regional groundwater aquifers are described as follows based upon descriptions and maps presented in SNC (2013), MDH (2011) Main Report and MDH (2011) Appendix F:

- Surficial stratified deposits may occur near the site. However, WSA mapping of the surficial stratified deposits (MDH (2011)) indicates the subdivision site is outside of the interpreted extend of the deposits.

- The subdivision site overlies the Saskatoon Group that contains the Lower and Middle Floral Formation stratified deposits. These stratified deposits are referred to as the inter-till Upper and Lower Floral Aquifers, or collectively as the Forestry Farm Aquifer (MDH (2011)). The surface of the Upper Floral Aquifer is located at depths ranging from approximately 20 to 25 m below grade near the subdivision site. The surface of the Lower Floral Aquifer is located at depths ranging from 60 to 62 m below grade near the subdivision site.
- The Tyner Valley Aquifer could potentially underlie the subdivision site at depths over 80 m below grade. However, WSA mapping of the Tyner Valley aquifer (MDH (2011)) indicates the subdivision site is outside of the interpreted extend of the aquifer.
- The Judith River Formation, a large bedrock aquifer, is located at depths greater than 140 m below grade near the subdivision site.

Interpretation of the WSA well logs in the area surrounding the subdivision indicated that no domestic wells have been completed in surficial aquifer deposits. The WSA well logs in the surrounding area do indicate the presence of domestic wells at depths of 6 to 19 mbgl and at depth 58 to 71 mbgl. Those depths correspond closely to the mapping descriptions of the Upper and Lower Floral formation aquifers (i.e. the Forestry Farm Aquifer).

2.3 Monitor Well Water Quality

Water quality samples were collected from 6 of the 8 recently installed monitor wells. The remaining 2 monitor wells were dry. Full analytical results are presented in Appendix A. The water quality indicates a wide and varied concentration of many of the typical indicator parameters showing little if any consistency between samples (Table 4).

There is little to no consistency between the water quality samples indicating that there is no shallow usable groundwater supply. With some of the wells being installed near existing sloughs, some within the agricultural zone and some located adjacent roadways (subject to winter salt spray) the water collected is a reflection of localized conditions and not from external influences. This type of water is a result of pour water pressure leaching from the adjacent soils and not from a groundwater supply. Water of this nature is not a sustainable supply and will rapidly dry out during times of drought.

This result, plus the findings from the hydrogeological assessment, supports the use of OWTS within the subdivision.

2.4 Conceptual Hydrogeological Model

A conceptual hydrogeological model for the subdivision site and vicinity was formulated based upon results of the hydrogeological investigation. The conceptual model is shown schematically in Figure 7. The proposed subdivision site is covered by low hydraulic conductivity silt till materials to a depth of 11 meters or more. Therefore, it is believed that effluent from OWTS on the site would be effectively isolated from the regional aquifers (Forestry Farm Aquifer in the upper and medium Floral Formation, located approximately 15 to 25 mbgl and 58 to 71 mbgl, respectively, near the site), and from discontinuous thin layer pockets of coarser materials potentially containing groundwater at depths of 2 to 4 meters mixed amongst the surficial tills as indicated by the SNC borehole logs. OWTS effluent is likely to move very slowly down gradient in the surficial tills toward local lower elevations on the site, and eventually toward the lowest elevation on the NE corner of the subdivision and then downslope toward Highway 41. Along that pathway the effluent components such as nitrate will be subjected to natural attenuating processes such as physical adsorption, microbial degradation and plant uptake. Effluent in the subsurface that eventually reaches the lower elevations down gradient will be subjected to dilution from infiltration of accumulated surface runoff in downslope surface depressions.

3 HYDROGEOLOGICAL ISOLATION OF OWTS EFFLUENT FROM WATER SUPPLY AQUIFERS

Based upon the hydrogeological site investigation and the conceptual hydrogeological model described above, it is AE's view that nitrate and other effluent components from OWTS located on the subdivision site (designed according to Saskatchewan Health guidelines) will be isolated from the nearest regional groundwater aquifers (estimated to be located 15 to 25 mbgl at the site) by the low hydraulic conductivity surficial silt till materials (> 11 m thick). Also, the surficial till materials will isolate the OWTS effluent from smaller scale discontinuous pockets of course materials potential containing groundwater located approximately 2 to 4 mbgl.

Preliminary calculations for an individual lot in the subdivision based on the per lot wastewater flow estimates of 1245 L per day and a loading rate of 13.72 L/m^2 show that mounds with a size of 91 m^2 should be sufficient to allow natural attenuation of nitrogen parameters through a combination of adsorption and biological uptake in the vadose zone.

Based on the conceptual hydrogeological model presented in this memorandum, AE requests that the proposed OWTS for the Eagle Heights Subdivision be designated as isolated from regional water supply aquifers, and that the subdivision Application for Approval be granted. We recommend traditional mounds, as described above, be used to dispose of effluent.

4 CLOSURE

This memo was prepared for the Saskatoon Health Region to provide a preliminary assessment of the fate of OWTS effluent for the Vista Ridge Development, to aid in the Application for Approval.

The services provided by Associated Engineering (Sask.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,

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TABLES

Table 1
SNC Borehole Lithology and Groundwater Depths and Elevations

Borehole No.	Top Soil Thickness (m)	Silt/Clay Thickness (m)	Till 1 Thickness (m)	Sand Thickness (m)	Till 2 Thickness (m)	Borehole Depth (m)	Depth to GW (m)	Ground Surf. Elev.† (m)	GW Surf. Elev. (m)
SNC-01	0.10	0.20	2.70	0.50	2.55	6.05	2.25	557.90	555.65
SNC-02	0.30	0.70	-	-	4.80	5.80	2.18	557.25	555.07
SNC-03	0.05	-	-	-	5.95	6.00	1.71	550.50	548.79
SNC-05	0.20	0.48	-	-	5.12	5.80	3.03	557.40	554.37
SNC-06	0.35	1.65	-	-	4.00	6.00	1.57	551.25	549.68
SNC-07	0.10	0.20	-	-	5.50	5.80	5.15	565.50	560.35
SNC-08	0.20	-	-	-	5.80	6.00	3.40	554.00	550.60
SNC-09	0.05	0.25	-	-	5.40	5.70	2.46	557.40	554.94
SNC-10	0.13	2.17	1.70	0.83	0.87	5.70	1.66	549.50	547.84
SNC-11	0.40	1.60	-	-	4.00	6.00	2.54	556.50	553.96
SNC-12	0.30	1.50	-	-	4.10	5.90	1.58	558.30	556.72
SNC-13	0.13	1.39	-	-	4.28	5.80	5.12	558.60	553.48
SNC-14	0.10	1.00	-	-	4.62	5.72	2.47	552.90	550.43
SNC-15	0.12	0.10	-	-	5.78	6.00	5.35	558.40	553.05
SNC-16	0.80	1.30	-	-	3.90	6.00	2.56	556.00	553.44
SNC-17	0.10	-	-	-	6.00	6.10	-	561.70	-
SNC-18	0.10	1.00	-	-	5.00	6.10	3.19	558.20	555.01
SNC-19	0.20	1.80	-	-	10.10	12.10	-	561.00	-
SNC-20	0.34	0.36	-	-	5.40	6.10	3.30	563.20	559.90
SNC-21	0.20	1.60	-	0.20	4.10	6.10	2.17	565.75	563.58
SNC-22	0.10	1.80	-	-	4.20	6.10	4.70	560.40	555.70
SNC-23	0.10	1.40	-	-	4.50	6.00	5.99	560.50	554.51
SNC-24	0.10	2.90	-	-	3.50	6.50	2.00	557.70	555.70
SNC-25	0.10	-	-	-	6.40	6.50	5.09	552.25	547.16

Borehole No.	Top Soil Thickness (m)	Silt/Clay Thickness (m)	Till 1 Thickness (m)	Sand Thickness (m)	Till 2 Thickness (m)	Borehole Depth (m)	Depth to GW (m)	Ground Surf. Elev.† (m)	GW Surf. Elev. (m)
SNC-26	0.10	-	-	-	6.00	6.10	5.56	558.75	553.19
SNC-27	0.10	-	-	-	5.70	5.80	3.13	561.60	558.47
SNC-29	-	1.80	-	-	2.90	4.70	1.32	558.75	557.43
SNC-30	-	0.70	-	-	5.40	6.10	4.05	559.80	555.75
SNC-31	-	-	-	-	5.80	5.80	1.72	559.50	557.78
avg	**0.19**	**1.18**		**0.51**		**6.15**	**3.16**		
min	**0.05**	**0.10**		**0.20**		**4.70**	**1.32**		
max	**0.80**	**2.90**		**0.83**		**12.10**	**5.99**		
number	**26**	**22**		**3**		**29**	**27**		

GW – Groundwater

† based upon ground surface contours from site topographic surveys

Table 2
AE Monitoring Well Borehole Lithology and Groundwater Depths and Elevations

Borehole No.	Top Soil Thickness (m)	Silt/Clay Thickness (m)	Till 1 Thickness (m)	Sand Thickness (m)	Till 2 Thickness (m)	Borehole Depth (m)	Depth to GW (m)	Ground Surf. Elev. (m)	GW Surf. Elev. (m)
MW17-01	0.10	-	-	-	4.00	4.10	3.37	558.34	554.97
MW17-02	0.20	0.90	-	-	1.90	3.00	2.15	560.62	558.47
MW17-03	-	-	-	-	10.60	10.60	6.17	562.40	556.23
MW17-04	-	-	-	-	4.50	4.50	-	552.87	-
MW17-05	0.10	0.40	-	-	8.60	9.10	4.03	555.03	551.00
MW17-06	-	-	-	-	7.00	7.00	3.23	552.38	549.15
MW17-06D	-	-	-	-	7.00	7.00	3.58	552.37	548.78
MW17-07	-	-	-	-	7.60	7.60	1.88	554.25	552.37
avg	0.13	0.65				6.61	3.49		
min	0.10	0.40				3.00	1.88		
max	0.20	0.90				10.60	6.17		
count	3	2				8	7		

GW – Groundwater

Table 3
Characteristics of Wells and Test Holes in the WSA Database near the Proposed Eagle Heights Subdivision

Group	Relative Position to Site	Land Description	Well No.	Year	Elevation (m)	Well Depth (m)	Water Depth (m)	Installation Type	Dia. (mm)	Use	Comments
Eagle Heights 1/2 Section	on-site	NW-11-037 -04 -W3	219323	1968	551.1	6.1	0.0	Augered	n/a	Soil Test Hole	No lithology
			219325	1967	548.0	6.1	0.0	Augered	n/a	Soil Test Hole	No lithology
Wells and test holes in the 1st ring of ten surrounding 1/4 sections	NW	SE-15-37 -04 -W3	090914	1988	533.4	18.3	9.8	Bored	1118	Domestic	9.8 m brown till; 11.0 m brown gravel; 18.3 m brown till
	E	NE-11-37-04-W3	219324	1968	547.1	14.3	0.0	Augered	n/a	Soil Test hole	No lithology
	SW	NE-03-37-04-W3	201875	2004	559.9	67.1	39.6	Drilled	130	Domestic	4.3 m brown till sandy; 4.6 m rock; 5.5 m till brown; 17.7 m grey till stoney; 18.3 m grey sand; 21.3 m grey clay soft; 22.6 m grey sand coarse; 28.0 m grey silty clay soft; 29 m grey sand medium; 51.2 m grey till; 57.9 m grey, black sand, fine; 67.1 m grey till clayey
	W	SE-10-37-04-W3	104450	1994	541.0	22.3	6.7	Bored	1067	Domestic	0.3 m topsoil; 3.0 m clay sandy; 7.6 m brown till; 16.8 m grey till; 18.9 m grey till with sand streaks;19.5 m gravel; 22.9 m grey till
			108001	1997	509.9	22.9	10.4	Bored	1067	Domestic	6.1 m brown till; 9.8 m grey till; 12.2 m grey till with sand streaks; 16.5 m brown till soft; 19.8 m brown till hard; 22.9 m grey till hard
			109357	1998	548.6	73.2	40.5	Drilled	130	Domestic	2.4 m brown sandy clay silty; 7.6 m brown till; 9.1 m brown till; 16.8 m grey till firm; 23.5 m grey clay silty; 28.0 m brown till sandy; 30.5 m brown till sandy; 51.8 m grey till rocky; 59.4 m grey sand with clay streaks; 73.2 m grey till with clay streaks
	W	-10-37-04-W3	099157	1990	533.4	85.3	0.0	Drilled	119	Test Hole	7.3 m brown till with boulders; 22.9 m grey till with cobblestones, 26.8 m gravel coarse; 61.6 m till grey; 70.4 m sand fine-medium; 77.4 m grey till; 85.3 m till oxidized.
			099158	1990	533.4	91.4	45.1	Drilled	119	Domestic	7.3 m brown till; 21.3 m grey till with cobblestones; 25.9 m gravel coarse; 60.4 m grey till; 71.0 m sand fine-medium; 78.9 m grey till;87.2 m till clayey, 91.4 m clay
Wells and test holes in 2nd ring of 18 surrounding 1/4 sections	E	NW-12-37 -04 -W3	031805	1961	563.9	18.3	0.0	Bored	914	Test Hole	0.3 m topsoil; 8.5 m brown clay; 18.3 m blue clay.
			031806	1961	563.9	15.2	0.0	Bored	914	Test Hole	0.3 m topsoil; 6.7 m brown clay; 15.2 m blue clay.
			031807	1961	563.9	17.4	0.0	Bored	914	Test Hole	0.3 m topsoil; 5.5 m brown clay; 17.4 m blue clay.
			056430	1978	563.9	12.2	4.6	Bored	1067	Domestic	0.3 m topsoil, 4.6 m yellow clay stoney; 5.8 m gravel coarse; 12.2 m blue clay.
	SE	SW-01-37 -04 -W3	087135	1987	556.3	12.8	0.0	Bored	914	Domestic	0.3 m topsoil; 5.2 m brown clay; 7.0 m grey clay; 8.2 m grey clay with gravel streaks; 8.8 m gravel, 12.8 m grey clay
			060654	1979	571.5	12.2	2.4	Bored	1067	Domestic	0.3 m topsoil; 2.4 m yellow clay with boulders; 6.7 m sand and gravel; 12.2 m blue
			064225	1980	556.3	80.8	28.7	Drilled	157	Domestic	7.3 m brown till stoney; 10.4 m blue clay; 11.3 m sand; 25.9 m grey till stoney; 62.5 m grey clay hard; 74.4 m sand with clay streaks; 80.8 m grey clay
	S	SW-02-37 -04 -W3	088787	1988	548.6	17.4	4.6	Bored	1118	Domestic	3.0 m brown till; 6.1 m brown till sandy; 7.3 m brown sand coarse; 13.7 m grey till sandy; 17.4 m grey till
	W	SW-10-37 -04 -W3	060826	1980	518.2	16.5	0.0	Augered	n/a	Test Hole	0.3 m topsoil; 2.7 m blue clay; 12.5 m brown clay sandy; 14.3 m sand; 16.5 m brown clay.
			060850	1980	518.2	21.9	6.4	Bored	1219	Domestic	0.3 m topsoil; 6.4 m yellow clay;16.2 m clay fractured; 21.9 m blue clay with boulders.

n/a not available

Table 4

Parameter	Total Nitrogen	Chloride	Dissolved Solids (TDS)
MW17-02	5.90	11.6	5150
MW17-03	76.2	135	8530
MW17-05	17.9	53.0	1050
MW17-06	1.77	16.5	1160
MW17-06D	1.24	16.1	505
MW17-07	24.5	45.2	4870

Note – all values are in mg/l

FIGURES

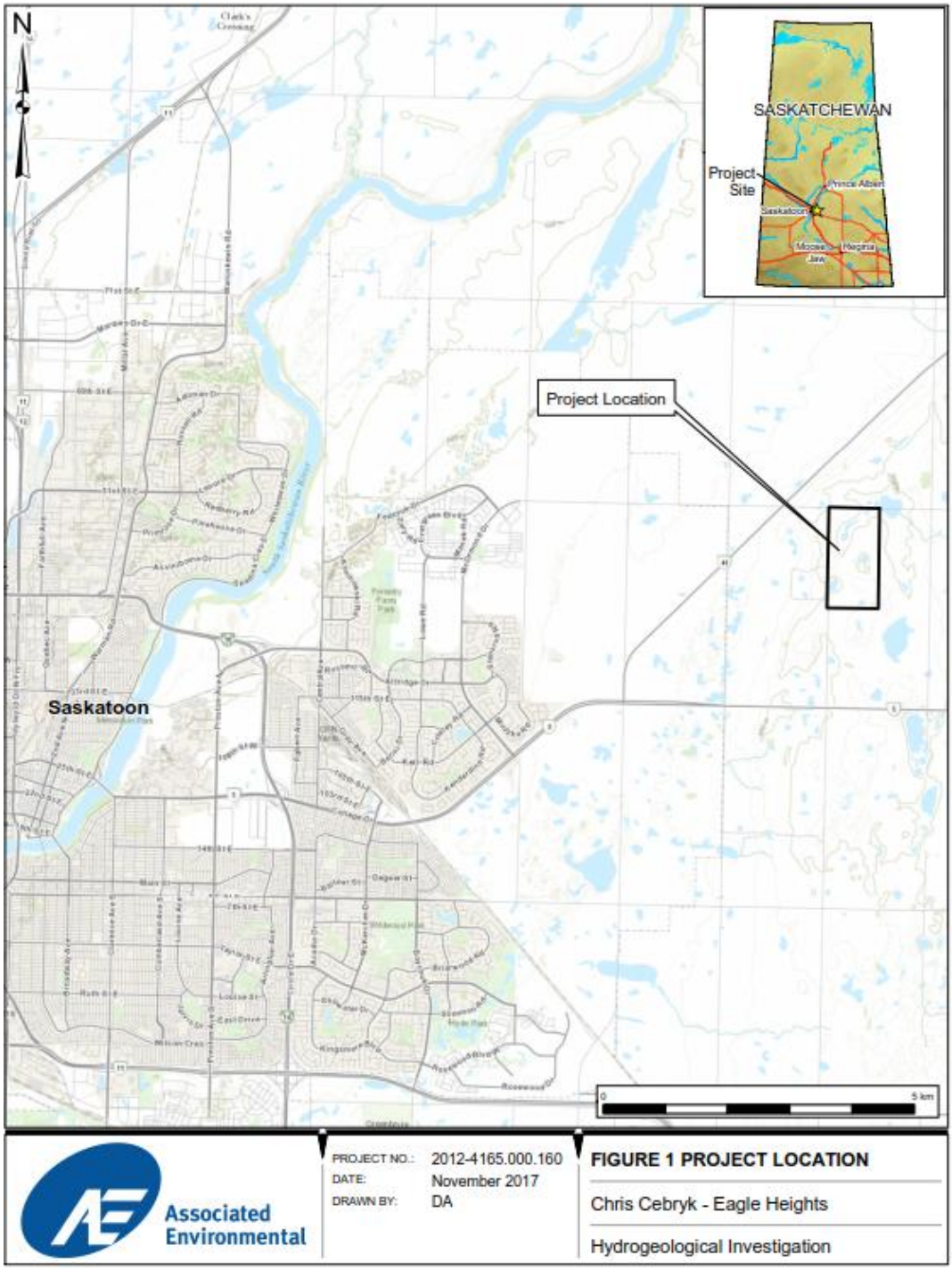

Figure 1
Location of Eagle Heights Subdivision

Figure 2
Eagle Heights Subdivision Concept Plan

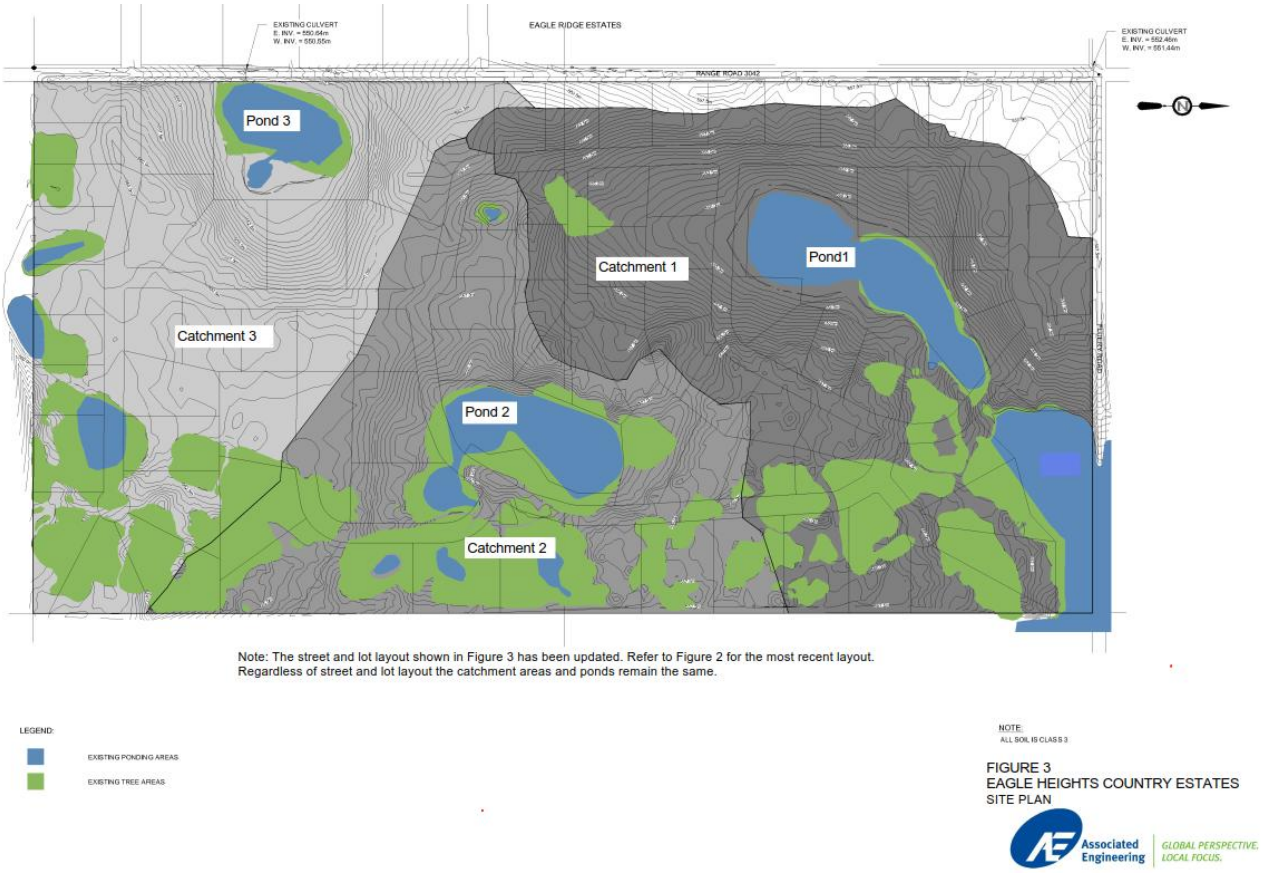

Figure 3
Eagle Heights Surface Drainage Concept

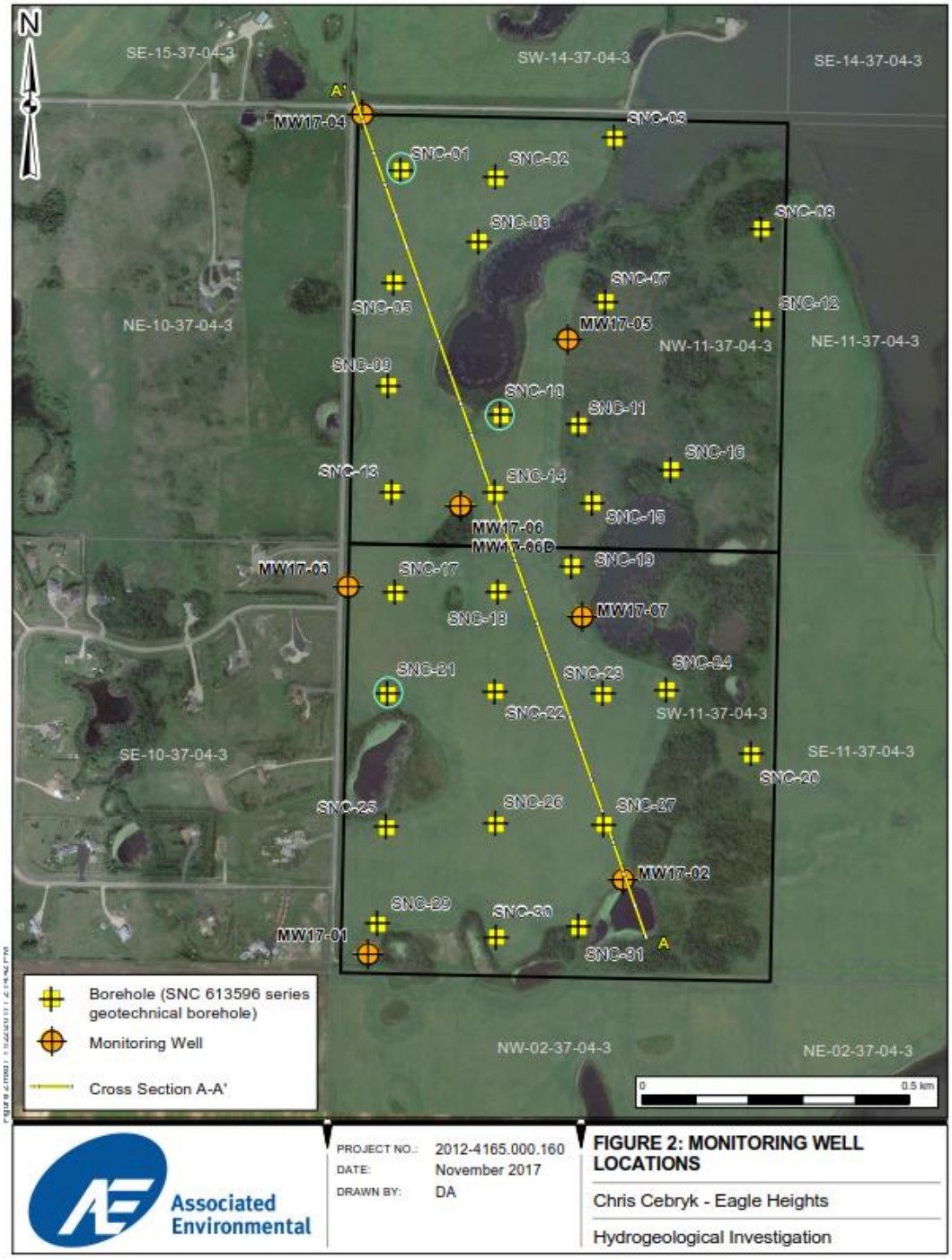

Figure 4
SNC Borehole and AE Monitoring Well Locations
Note: SNC 01, 10 and 21 denoted with green circles encountered thin sand layers

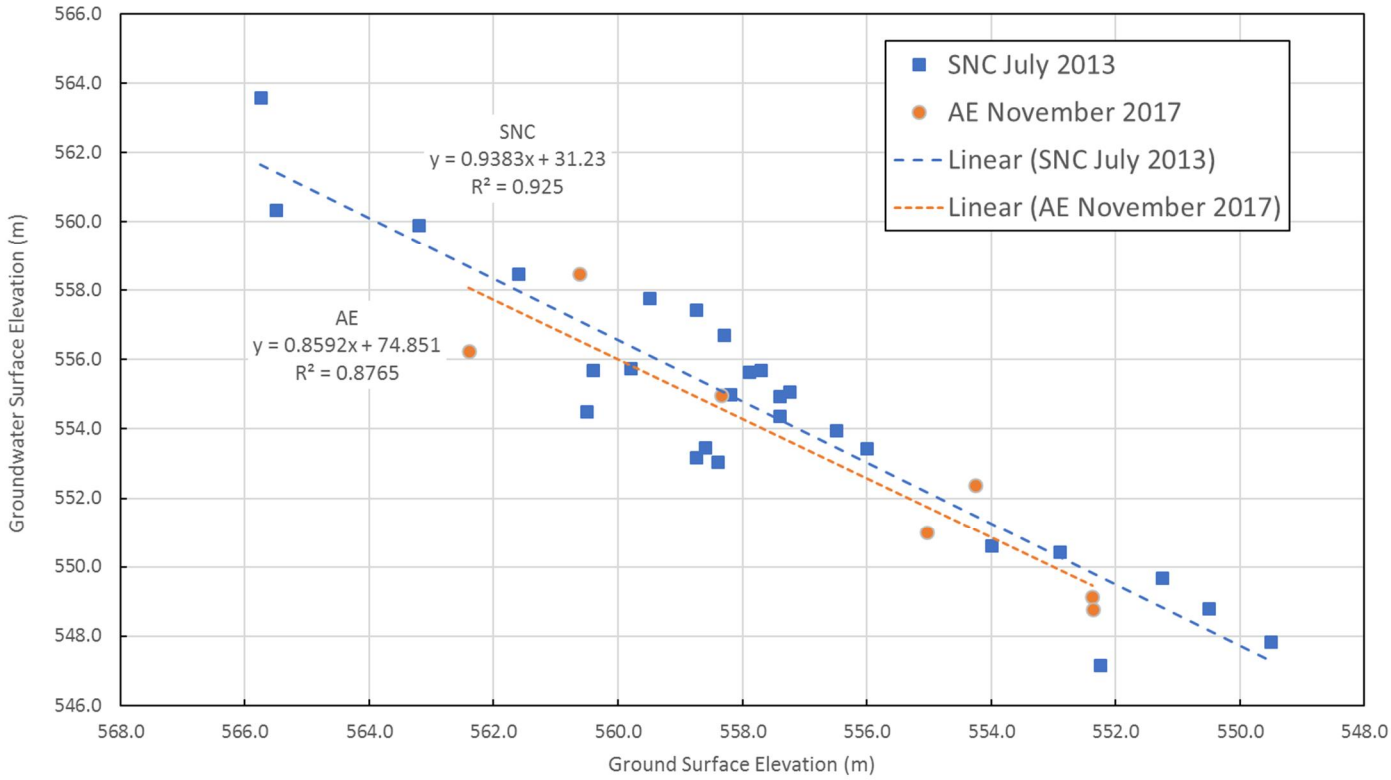

Figure 5
Groundwater Surface Elevations vs. Ground Surface Elevations

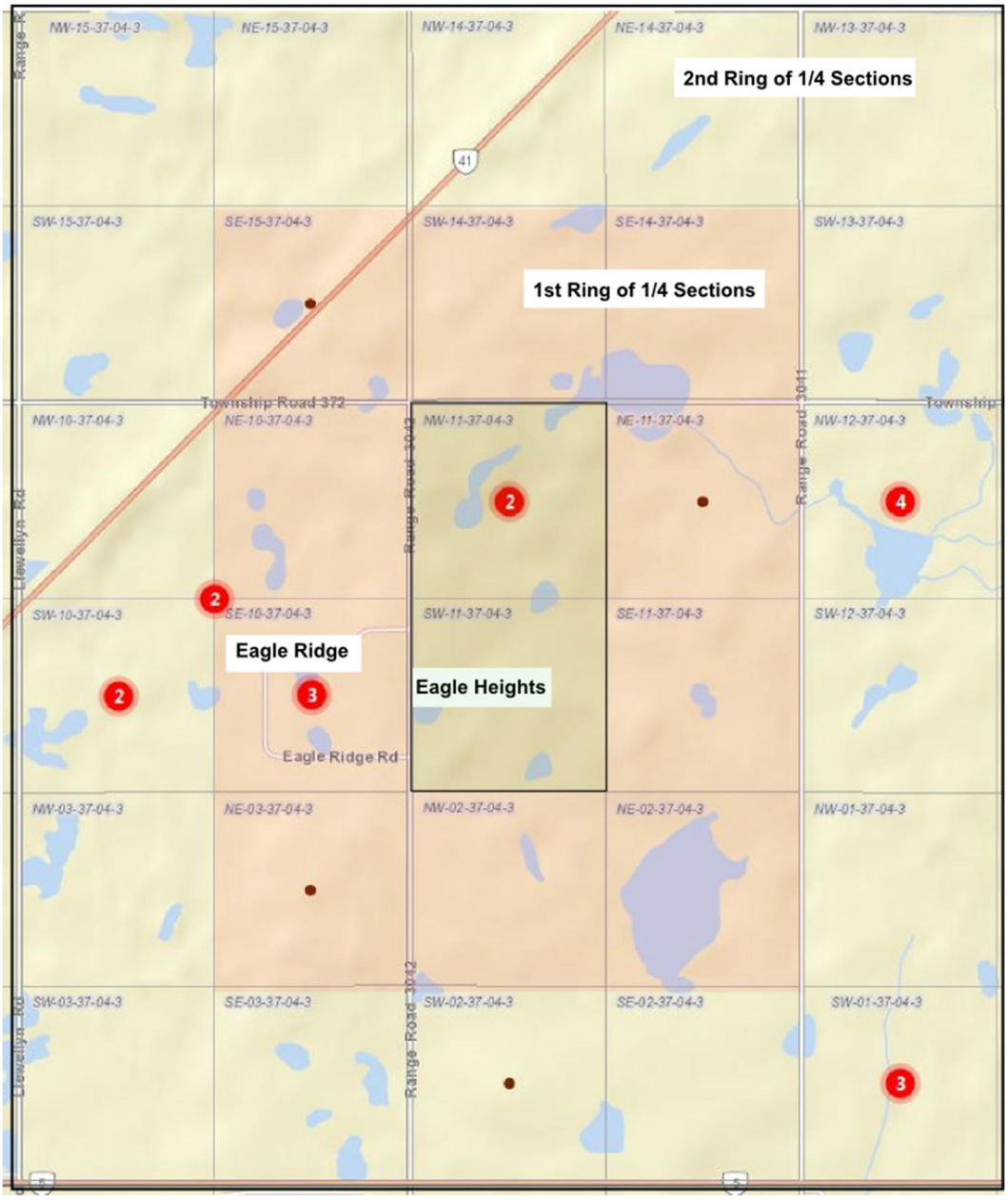

Figure 6
Quarter Sections with Well Log Information near the proposed Eagle Heights Subdivision Site. Red dots indicate ¼ section or section with well logs, number indicates number of logs, no number a single log. Adapted from WSA online database at
https://gis.wsask.ca/Html5Viewer/index.html?viewer=WaterWells.WellsViewer

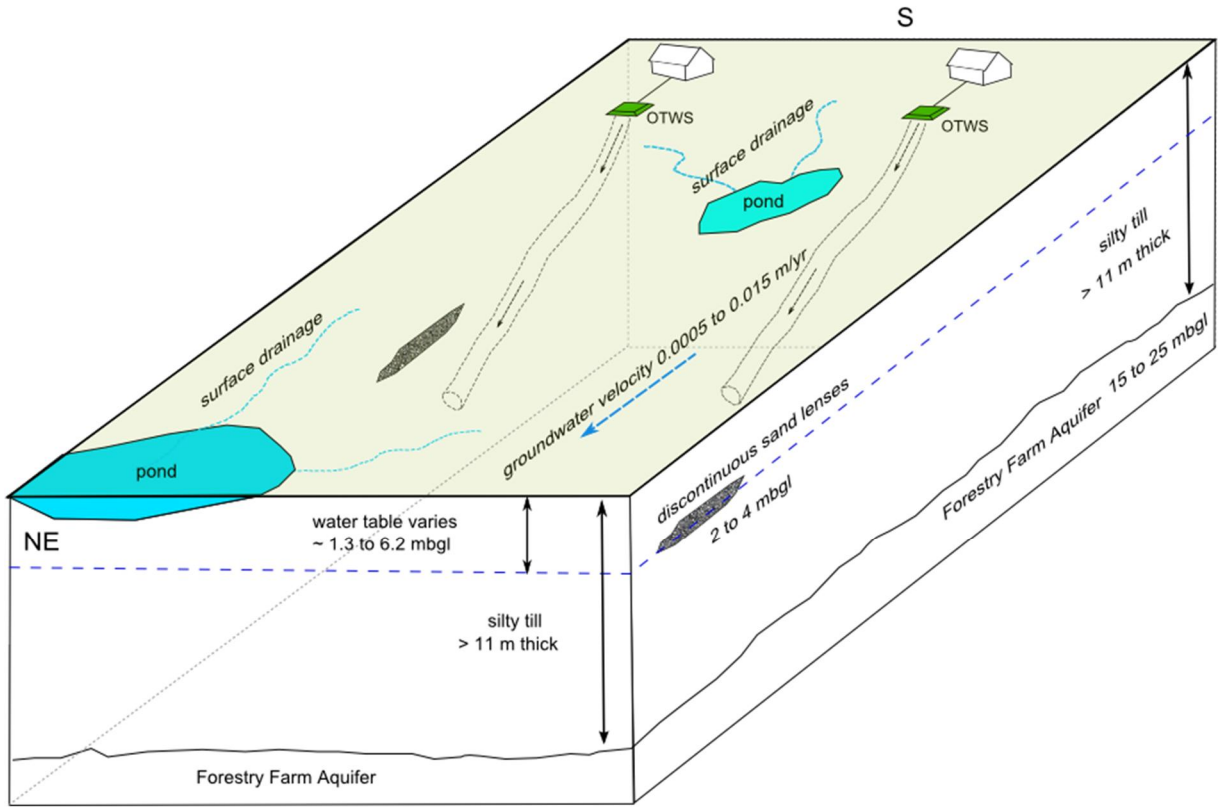

Figure 7
Conceptual Hydrogeological Model for the Eagle Heights Subdivision Site

APPENDIX A – CERTIFICATE OF ANALYSIS

Associated Environmental Consultants Inc.
ATTN: Dan McCrank
1 - 2225 Northridge Drive
Saskatoon SK S7L 6X6

Date Received: 24-OCT-17
Report Date: 07-NOV-17 15:06 (MT)
Version: FINAL

Client Phone: 306-715-3581

Certificate of Analysis

Lab Work Order #: L2012694

Project P.O. #: NOT SUBMITTED
Job Reference: 2012-4165
C of C Numbers: 15-540861
Legal Site Desc:

Brian Morgan, B.Sc. Hons.
Client Services Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2012694-1 MW17-02							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Single Metal in Water by ICPMS (Diss.)							
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB	SFP				01-NOV-17	R3872832
Iron (Fe)-Dissolved	<0.050	DLDS	0.050	mg/L		02-NOV-17	R3873502
Miscellaneous Parameters							
Ammonia, Total (as N)	1.03		0.050	mg/L	02-NOV-17	02-NOV-17	R3874267
Ferric Iron, Dissolved	<0.050		0.050	mg/L		31-OCT-17	
Phosphorus (P)-Total	0.59		0.30	mg/L	27-OCT-17	27-OCT-17	R3869361
Total Coliform, E. Coli - Quanti-Tray							
Total Coliforms	>200.5		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Escherichia Coli	0		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Diss. Ferrous Iron in Water by Colour							
Ferrous Iron, Dissolved	<0.020		0.020	mg/L	31-OCT-17	31-OCT-17	R3871051
Dissolved Fe2 Filtration Location	FIELD					31-OCT-17	R3870866
Total Nitrogen							
Nitrate, Nitrite and Nitrate+Nitrite-N							
Nitrate-N	2.48		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrite-N	0.052		0.050	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrate+Nitrite-N	2.53		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
TKN in Water by Colour							
Total Kjeldahl Nitrogen	3.37		0.20	mg/L	30-OCT-17	31-OCT-17	R3871346
Total Nitrogen (Calculation)							
Total Nitrogen	5.90		0.54	mg/L		01-NOV-17	
Routine Water Analysis (no Fluoride)							
Alkalinity by Auto. Titration							
Bicarbonate (HCO3)	581.		20	mg/L		26-OCT-17	R3866566
Hydroxide (OH)	<10.		10	mg/L		26-OCT-17	R3866566
Carbonate (CO3)	<10.		10	mg/L		26-OCT-17	R3866566
Alkalinity, Total (as CaCO3)	476		20	mg/L		26-OCT-17	R3866566
Chloride (Cl)							
Chloride (Cl)	11.6	DLDS	2.0	mg/L	30-OCT-17	30-OCT-17	R3869677
Conductivity (Automated)							
Conductivity	5260		10	uS/cm		26-OCT-17	R3866566
ICP Cations							
Calcium (Ca)	410	DLDS	10	mg/L	27-OCT-17	27-OCT-17	R3869618
Potassium (K)	50	DLDS	10	mg/L	27-OCT-17	27-OCT-17	R3869618
Magnesium (Mg)	706	DLDS	10	mg/L	27-OCT-17	27-OCT-17	R3869618
Sodium (Na)	132	DLDS	20	mg/L	27-OCT-17	27-OCT-17	R3869618
Sulfur (as SO4)	3540	DLDS	30	mg/L	27-OCT-17	27-OCT-17	R3869618
Ion Balance Calculation							
Cation - Anion Balance	1.1			%		30-OCT-17	
TDS (Calculated)	5150			mg/L		30-OCT-17	
Hardness (as CaCO3)	3930			mg/L		30-OCT-17	
pH by Meter (Automated)							
pH	7.68		0.10	pH		26-OCT-17	R3866566
L2012694-2 MW17-03							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Single Metal in Water by ICPMS (Diss.)							
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB	SFP				01-NOV-17	R3872832
Iron (Fe)-Dissolved	<0.10	DLDS	0.10	mg/L		02-NOV-17	R3873502
Miscellaneous Parameters							

* 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
L2012694-2 MW17-03							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Ammonia, Total (as N)	1.04	DLHC	0.10	mg/L	02-NOV-17	02-NOV-17	R3874267
Ferric Iron, Dissolved	<0.10		0.10	mg/L		31-OCT-17	
Phosphorus (P)-Total	<0.30		0.30	mg/L	27-OCT-17	27-OCT-17	R3869361
Total Coliform, E. Coli - Quanti-Tray							
Total Coliforms	145		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Escherichia Coli	0		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Diss. Ferrous Iron in Water by Colour							
Ferrous Iron, Dissolved	<0.020		0.020	mg/L	31-OCT-17	31-OCT-17	R3871051
Dissolved Fe2 Filtration Location	FIELD					31-OCT-17	R3870866
Total Nitrogen							
Nitrate, Nitrite and Nitrate+Nitrite-N							
Nitrate-N	76.1	DLHC	5.0	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrite-N	0.129		0.050	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrate+Nitrite-N	76.2	DLHC	5.0	mg/L	25-OCT-17	25-OCT-17	R3866688
TKN in Water by Colour							
Total Kjeldahl Nitrogen	2.42	TKNI	0.20	mg/L	30-OCT-17	31-OCT-17	R3871346
Total Nitrogen (Calculation)							
Total Nitrogen	78.7		5.0	mg/L		01-NOV-17	
Routine Water Analysis (no Fluoride)							
Alkalinity by Auto. Titration							
Bicarbonate (HCO3)	811.		20	mg/L		26-OCT-17	R3866566
Hydroxide (OH)	<10.		10	mg/L		26-OCT-17	R3866566
Carbonate (CO3)	<10.		10	mg/L		26-OCT-17	R3866566
Alkalinity, Total (as CaCO3)	665		20	mg/L		26-OCT-17	R3866566
Chloride (Cl)							
Chloride (Cl)	135	DLDS	10	mg/L	30-OCT-17	30-OCT-17	R3869677
Conductivity (Automated)							
Conductivity	8170		10	uS/cm		26-OCT-17	R3866566
ICP Cations							
Calcium (Ca)	498	DLDS	20	mg/L	27-OCT-17	27-OCT-17	R3869618
Potassium (K)	31	DLDS	20	mg/L	27-OCT-17	27-OCT-17	R3869618
Magnesium (Mg)	1290	DLDS	20	mg/L	27-OCT-17	27-OCT-17	R3869618
Sodium (Na)	234	DLDS	40	mg/L	27-OCT-17	27-OCT-17	R3869618
Sulfur (as SO4)	5610	DLDS	60	mg/L	27-OCT-17	27-OCT-17	R3869618
Ion Balance Calculation							
Cation - Anion Balance	0.9			%		30-OCT-17	
TDS (Calculated)	8530			mg/L		30-OCT-17	
Hardness (as CaCO3)	6560			mg/L		30-OCT-17	
pH by Meter (Automated)							
pH	7.48		0.10	pH		26-OCT-17	R3866566
L2012694-3 MW17-05							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Single Metal in Water by ICPMS (Diss.)							
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB	SFP				01-NOV-17	R3872832
Iron (Fe)-Dissolved	<0.010		0.010	mg/L		02-NOV-17	R3873502
Miscellaneous Parameters							
Ammonia, Total (as N)	0.348		0.050	mg/L	02-NOV-17	02-NOV-17	R3874267
Ferric Iron, Dissolved	<0.030		0.030	mg/L		31-OCT-17	
Phosphorus (P)-Total	0.31		0.30	mg/L	27-OCT-17	27-OCT-17	R3869361
Total Coliform, E. Coli - Quanti-Tray							

* 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
L2012694-3 MW17-05							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Total Coliform, E. Coli - Quanti-Tray							
Total Coliforms	15		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Escherichia Coli	0		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Diss. Ferrous Iron in Water by Colour							
Ferrous Iron, Dissolved	<0.020		0.020	mg/L	31-OCT-17	31-OCT-17	R3871051
Dissolved Fe2 Filtration Location	FIELD					31-OCT-17	R3870866
Total Nitrogen							
Nitrate, Nitrite and Nitrate+Nitrite-N							
Nitrate-N	17.9		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrite-N	<0.050		0.050	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrate+Nitrite-N	17.9		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
TKN in Water by Colour							
Total Kjeldahl Nitrogen	1.88		0.20	mg/L	30-OCT-17	31-OCT-17	R3871346
Total Nitrogen (Calculation)							
Total Nitrogen	19.8		0.54	mg/L		01-NOV-17	
Routine Water Analysis (no Fluoride)							
Alkalinity by Auto. Titration							
Bicarbonate (HCO3)	349.		20	mg/L		26-OCT-17	R3866566
Hydroxide (OH)	<10.		10	mg/L		26-OCT-17	R3866566
Carbonate (CO3)	<10.		10	mg/L		26-OCT-17	R3866566
Alkalinity, Total (as CaCO3)	286		20	mg/L		26-OCT-17	R3866566
Chloride (Cl)							
Chloride (Cl)	53.0		1.0	mg/L	30-OCT-17	30-OCT-17	R3869677
Conductivity (Automated)							
Conductivity	1480		10	uS/cm		26-OCT-17	R3866566
ICP Cations							
Calcium (Ca)	202		1.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Potassium (K)	9.3		1.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Magnesium (Mg)	83.7		1.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Sodium (Na)	19.7		2.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Sulfur (as SO4)	435		3.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Ion Balance Calculation							
Cation - Anion Balance	1.4			%		30-OCT-17	
TDS (Calculated)	1050			mg/L		30-OCT-17	
Hardness (as CaCO3)	849			mg/L		30-OCT-17	
pH by Meter (Automated)							
pH	7.75		0.10	pH		26-OCT-17	R3866566
L2012694-4 MW17-06							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Single Metal in Water by ICPMS (Diss.)							
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB	SFP				01-NOV-17	R3872832
Iron (Fe)-Dissolved	<0.010		0.010	mg/L		02-NOV-17	R3873502
Miscellaneous Parameters							
Ammonia, Total (as N)	0.511		0.050	mg/L	02-NOV-17	02-NOV-17	R3874267
Ferric Iron, Dissolved	<0.030		0.030	mg/L		31-OCT-17	
Phosphorus (P)-Total	1.34	DLR	0.90	mg/L	27-OCT-17	27-OCT-17	R3869361
Total Coliform, E. Coli - Quanti-Tray							
Total Coliforms	>200.5		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Escherichia Coli	0		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Diss. Ferrous Iron in Water by Colour							

* 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
L2012694-4 MW17-06							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Diss. Ferrous Iron in Water by Colour							
Ferrous Iron, Dissolved	<0.020		0.020	mg/L	31-OCT-17	31-OCT-17	R3871051
Dissolved Fe2 Filtration Location	FIELD					31-OCT-17	R3870866
Total Nitrogen							
Nitrate, Nitrite and Nitrate+Nitrite-N							
Nitrate-N	1.71		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrite-N	0.060		0.050	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrate+Nitrite-N	1.77		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
TKN in Water by Colour							
Total Kjeldahl Nitrogen	3.21		0.20	mg/L	30-OCT-17	31-OCT-17	R3871346
Total Nitrogen (Calculation)							
Total Nitrogen	4.98		0.54	mg/L		01-NOV-17	
Routine Water Analysis (no Fluoride)							
Alkalinity by Auto. Titration							
Bicarbonate (HCO3)	452.		20	mg/L		26-OCT-17	R3866566
Hydroxide (OH)	<10.		10	mg/L		26-OCT-17	R3866566
Carbonate (CO3)	<10.		10	mg/L		26-OCT-17	R3866566
Alkalinity, Total (as CaCO3)	370		20	mg/L		26-OCT-17	R3866566
Chloride (Cl)							
Chloride (Cl)	16.5		1.0	mg/L	30-OCT-17	30-OCT-17	R3869677
Conductivity (Automated)							
Conductivity	1590		10	uS/cm		26-OCT-17	R3866566
ICP Cations							
Calcium (Ca)	234	DLDS	2.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Potassium (K)	5.7	DLDS	2.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Magnesium (Mg)	77.2	DLDS	2.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Sodium (Na)	26.6	DLDS	4.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Sulfur (as SO4)	567	DLDS	6.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Ion Balance Calculation							
Cation - Anion Balance	-1.2			%		30-OCT-17	
TDS (Calculated)	1160			mg/L		30-OCT-17	
Hardness (as CaCO3)	902			mg/L		30-OCT-17	
pH by Meter (Automated)							
pH	7.57		0.10	pH		26-OCT-17	R3866566
L2012694-5 MW17-06D							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Single Metal in Water by ICPMS (Diss.)							
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB	SFP				01-NOV-17	R3872832
Iron (Fe)-Dissolved	<0.010		0.010	mg/L		02-NOV-17	R3873502
Miscellaneous Parameters							
Ammonia, Total (as N)	0.277		0.050	mg/L	02-NOV-17	02-NOV-17	R3874267
Ferric Iron, Dissolved	<0.030		0.030	mg/L		31-OCT-17	
Phosphorus (P)-Total	0.47		0.30	mg/L	27-OCT-17	27-OCT-17	R3869361
Total Coliform, E. Coli - Quanti-Tray							
Total Coliforms	50		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Escherichia Coli	0		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Diss. Ferrous Iron in Water by Colour							
Ferrous Iron, Dissolved	<0.020		0.020	mg/L	31-OCT-17	31-OCT-17	R3871051
Dissolved Fe2 Filtration Location	FIELD					31-OCT-17	R3870866
Total Nitrogen							

* 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
L2012694-5 MW17-06D							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Nitrate, Nitrite and Nitrate+Nitrite-N							
Nitrate-N	1.18		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrite-N	0.059		0.050	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrate+Nitrite-N	1.24		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
TKN in Water by Colour							
Total Kjeldahl Nitrogen	0.46		0.20	mg/L	30-OCT-17	31-OCT-17	R3871346
Total Nitrogen (Calculation)							
Total Nitrogen	1.71		0.54	mg/L		01-NOV-17	
Routine Water Analysis (no Fluoride)							
Alkalinity by Auto. Titration							
Bicarbonate (HCO3)	411.		20	mg/L		26-OCT-17	R3866566
Hydroxide (OH)	<10.		10	mg/L		26-OCT-17	R3866566
Carbonate (CO3)	<10.		10	mg/L		26-OCT-17	R3866566
Alkalinity, Total (as CaCO3)	337		20	mg/L		26-OCT-17	R3866566
Chloride (Cl)							
Chloride (Cl)	16.1		1.0	mg/L	30-OCT-17	30-OCT-17	R3869677
Conductivity (Automated)							
Conductivity	824		10	uS/cm		26-OCT-17	R3866566
ICP Cations							
Calcium (Ca)	104		1.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Potassium (K)	7.2		1.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Magnesium (Mg)	35.6		1.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Sodium (Na)	26.1		2.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Sulfur (as SO4)	109		3.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Ion Balance Calculation							
Cation - Anion Balance	-0.6			%		30-OCT-17	
TDS (Calculated)	506			mg/L		30-OCT-17	
Hardness (as CaCO3)	406			mg/L		30-OCT-17	
pH by Meter (Automated)							
pH	7.86		0.10	pH		26-OCT-17	R3866566
L2012694-6 MW17-07							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
Single Metal in Water by ICPMS (Diss.)							
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB	SFP				01-NOV-17	R3872832
Iron (Fe)-Dissolved	<0.050	DLDS	0.050	mg/L		02-NOV-17	R3873502
Miscellaneous Parameters							
Ammonia, Total (as N)	0.920		0.050	mg/L	02-NOV-17	02-NOV-17	R3874267
Ferric Iron, Dissolved	<0.050		0.050	mg/L		31-OCT-17	
Phosphorus (P)-Total	1.54	DLR	0.90	mg/L	27-OCT-17	27-OCT-17	R3869361
Total Coliform, E. Coli - Quanti-Tray							
Total Coliforms	>200.5		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Escherichia Coli	0		0	MPN/100mL	25-OCT-17	26-OCT-17	R3866975
Diss. Ferrous Iron in Water by Colour							
Ferrous Iron, Dissolved	0.029		0.020	mg/L	31-OCT-17	31-OCT-17	R3871051
Dissolved Fe2 Filtration Location	FIELD					31-OCT-17	R3870866
Total Nitrogen							
Nitrate, Nitrite and Nitrate+Nitrite-N							
Nitrate-N	18.1		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrite-N	0.061		0.050	mg/L	25-OCT-17	25-OCT-17	R3866688
Nitrate+Nitrite-N	18.1		0.50	mg/L	25-OCT-17	25-OCT-17	R3866688

* 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
L2012694-6 MW17-07							
Sampled By: DMC on 24-OCT-17 @ 12:00							
Matrix: WATER							
TKN in Water by Colour							
Total Kjeldahl Nitrogen	6.39		0.20	mg/L	30-OCT-17	31-OCT-17	R3871346
Total Nitrogen (Calculation)							
Total Nitrogen	24.5		0.54	mg/L		01-NOV-17	
Routine Water Analysis (no Fluoride)							
Alkalinity by Auto. Titration							
Bicarbonate (HCO3)	499.		20	mg/L		26-OCT-17	R3866566
Hydroxide (OH)	<10.		10	mg/L		26-OCT-17	R3866566
Carbonate (CO3)	<10.		10	mg/L		26-OCT-17	R3866566
Alkalinity, Total (as CaCO3)	409		20	mg/L		26-OCT-17	R3866566
Chloride (Cl)							
Chloride (Cl)	45.2	DLDS	2.0	mg/L	30-OCT-17	30-OCT-17	R3869677
Conductivity (Automated)							
Conductivity	4910		10	uS/cm		26-OCT-17	R3866566
ICP Cations							
Calcium (Ca)	478	DLDS	5.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Potassium (K)	9.7	DLDS	5.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Magnesium (Mg)	574	DLDS	5.0	mg/L	27-OCT-17	27-OCT-17	R3869618
Sodium (Na)	210	DLDS	10	mg/L	27-OCT-17	27-OCT-17	R3869618
Sulfur (as SO4)	3230	DLDS	15	mg/L	27-OCT-17	27-OCT-17	R3869618
Ion Balance Calculation							
Cation - Anion Balance	1.6			%		30-OCT-17	
TDS (Calculated)	4870			mg/L		30-OCT-17	
Hardness (as CaCO3)	3560			mg/L		30-OCT-17	
pH by Meter (Automated)							
pH	7.59		0.10	pH		26-OCT-17	R3866566

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

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLDS	Detection Limit Raised: Dilution required due to high Dissolved Solids / Electrical Conductivity.
DLHC	Detection Limit Raised: Dilution required due to high concentration of test analyte(s).
DLR	Detection Limit Raised due to required dilution, limited sample amount, and/or high moisture content (soil samples)
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
SFP	Sample was Filtered and Preserved at the laboratory
TKNI	TKN result may be biased low due to Nitrate interference. Nitrate-N is > 10x TKN.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-PCT-SK	Water	Alkalinity by Auto. Titration	APHA 2320 Alkalinity

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

CL-COL-SK	Water	Chloride (Cl)	APHA 4500-CL E

Thiocyanate ion (SCN) is liberated from mercuric thiocyanate by chloride ion to form un-ionized mercuric chloride. In the presence of ferric ion, the liberated SCN forms a colored ferric thiocyanate complex proportional to the original chloride concentration. Absorbance of the colored complex is measured using a Gallery discrete analyzer.

EC-PCT-SK	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

ETL-ROUTINE-ICP-SK	Water	ICP Cations	APHA 3120 B-ICP-OES-ROU

These ions are determined directly y ICP-OES.

Reference
Greenberg, Arnold E., Cleseri, Lenore S., Eaton, Andrew D., Standard Methods For The Examination of Water and Wastewater, 18th Edition, 1992, Method 3120B.

FE2-D-COL-VA	Water	Diss. Ferrous Iron in Water by Colour	APHA 3500-Fe B/James Ball et al (1999)

This analysis is carried out using procedures adapted from APHA 3500-Fe B and "A New Method for the Direct Determination of Dissolved Iron Concentration in Acid Mine Waters" published by James W. Ball et al (1999). The procedure involves preliminary sample filtration, and ferrous iron is determined using the "FerroZine" colourimetric method.

FE3-D-CALC-VA	Water	Ferric Iron - Calculated	APHA 3500 Fe

Dissolved Ferric Iron is determined by calculating the difference between Dissolved Iron and Dissolved Ferrous Iron.

IONBALANCE-OP03-SK	Water	Ion Balance Calculation	APHA 1030-E
MET-D-CCMS-SK	Water	Dissolved Metals in Water by CRC ICPMS	APHA 3030B / EPA 6020A

This procedure involves preliminary filtration through a 0.45 um filter followed by instrumental analysis using collision cell inductively coupled plasma - mass spectrometry (modifed from EPA Method 6020A).

N-T-CALC-SK	Water	Total Nitrogen (Calculation)	APHA 4500 N-Calculated

Total Nitrogen is a calculated parameter. Total Nitrogen = Total Kjeldahl Nitrogen + [Nitrate and Nitrite (as N)]

N2/N3-SK	Water	Nitrate, Nitrite and Nitrate+Nitrite-N	APHA 4500 NO3F

Nitrate is quantitatively reduced to nitrite by passage of the sample through a copperized cadmium column. The nitrite (reduced nitrate plus original nitrite) is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl)ethylenediamine dihydrochloride. The resulting water-soluble dye has a magenta color, which is measured at 520nm. Original nitrite can also be determined by removing the cadmium column and following the same procedure. Nitrate-N, Nitrite-N and NO3+NO2-N are reported.

NH4-SK	Water	Ammonia-N	APHA 4500 NH3-NITROGEN (AMMONIA)

Ammonium in the extract is mixed with hypochlorite and salicylate to form indophenol blue, which is determined colorimetrically by auto analysis at 660 nm.

P-T-COL-SK	Water	Total P in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
PH-PCT-SK	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

TC,EC-QT51-SK	Water	Total Coliform, E. Coli - Quanti-Tray	APHA 9223B 2B

The analysis of Total Coliform (TC) & Escherichia coli (EC) is processed by Quanti-tray (QT): Two substrates, ONPG for TC detection and MUG for EC detection are used. The substrates are added to the 100 ml sample dispensed into the 51 well tray. The tray is incubated at 35 Celcius for 24 hours. A colour reaction develops to indicate a positve reaction (presence of TC, EC). The number of positive wells are counted and converted to Most Probable Number Units (MPNU) per 100 ml.

TKN-CFA-ED	Water	TKN in Water by Colour	APHA 4500-NORG (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg "Nitrogen (Organic)". Total Kjeldahl Nitrogen is determined by sample digestion at 380 celcius with analysis using an automated colourimetric finish.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

15-540861

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: Associated Environmental Consultants Inc.
1 - 2225 Northridge Drive
Saskatoon SK S7L 6X6
Contact: Dan McCrank

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-PCT-SK	**Water**							
Batch R3866566								
WG2648495-1 DUP		**L2012694-3**						
Alkalinity, Total (as CaCO3)		286	284		mg/L	0.7	20	26-OCT-17
WG2648495-2 LCS		**PCT**						
Alkalinity, Total (as CaCO3)			98.6		%		85-115	26-OCT-17
WG2648495-5 LCS		**PCT**						
Alkalinity, Total (as CaCO3)			98.4		%		85-115	26-OCT-17
WG2648495-3 MB								
Alkalinity, Total (as CaCO3)			<20		mg/L		20	26-OCT-17
WG2648495-6 MB								
Alkalinity, Total (as CaCO3)			<20		mg/L		20	26-OCT-17
CL-COL-SK	**Water**							
Batch R3869677								
WG2649236-4 LCS		**50PPM-CL**						
Chloride (Cl)			95.1		%		90-110	30-OCT-17
WG2649236-1 MB								
Chloride (Cl)			<1.0		mg/L		1	30-OCT-17
WG2649236-5 MS		**L2012694-2**						
Chloride (Cl)			N/A	MS-B	%		-	30-OCT-17
EC-PCT-SK	**Water**							
Batch R3866566								
WG2648495-1 DUP		**L2012694-3**						
Conductivity		1480	1470		uS/cm	0.3	10	26-OCT-17
WG2648495-2 LCS		**PCT**						
Conductivity			97.9		%		90-110	26-OCT-17
WG2648495-5 LCS		**PCT**						
Conductivity			97.6		%		90-110	26-OCT-17
WG2648495-3 MB								
Conductivity			<10		uS/cm		10	26-OCT-17
WG2648495-6 MB								
Conductivity			<10		uS/cm		10	26-OCT-17
ETL-ROUTINE-ICP-SK	**Water**							
Batch R3869618								
WG2648279-3 LCS								
Calcium (Ca)			92.2		%		80-120	27-OCT-17
Potassium (K)			90.4		%		80-120	27-OCT-17
Magnesium (Mg)			92.2		%		80-120	27-OCT-17
Sodium (Na)			91.8		%		80-120	27-OCT-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ETL-ROUTINE-ICP-SK	**Water**							
Batch R3869618								
WG2648279-3 LCS								
Sulfur (as SO4)			93.4		%		90-110	27-OCT-17
WG2648279-1 MB								
Calcium (Ca)			<1.0		mg/L		1	27-OCT-17
Potassium (K)			<1.0		mg/L		1	27-OCT-17
Magnesium (Mg)			<1.0		mg/L		1	27-OCT-17
Sodium (Na)			<2.0		mg/L		2	27-OCT-17
Sulfur (as SO4)			<3.0		mg/L		3	27-OCT-17
FE2-D-COL-VA	**Water**							
Batch R3871051								
WG2652994-3 DUP		**L2012694-1**						
Ferrous Iron, Dissolved		<0.020	<0.020	RPD-NA	mg/L	N/A	20	31-OCT-17
WG2652994-2 LCS								
Ferrous Iron, Dissolved			98.3		%		80-120	31-OCT-17
WG2652994-1 MB								
Ferrous Iron, Dissolved			<0.020		mg/L		0.02	31-OCT-17
WG2652994-4 MS		**L2012694-2**						
Ferrous Iron, Dissolved			100.6		%		70-130	31-OCT-17
MET-D-CCMS-SK	**Water**							
Batch R3873502								
WG2654621-3 CRM		**TMRM_20**						
Iron (Fe)-Dissolved			106.0		%		80-120	02-NOV-17
WG2654621-2 DUP		**L2012694-5**						
Iron (Fe)-Dissolved		<0.010	<0.010	RPD-NA	mg/L	N/A	20	02-NOV-17
WG2654621-1 MB								
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	02-NOV-17
N2/N3-SK	**Water**							
Batch R3866688								
WG2648285-3 LCS								
Nitrate-N			104.3		%		90-110	25-OCT-17
Nitrite-N			95.4		%		90-110	25-OCT-17
Nitrate+Nitrite-N			103.1		%		90-110	25-OCT-17
WG2648285-2 MB								
Nitrate-N			<0.50		mg/L		0.5	25-OCT-17
Nitrite-N			<0.050		mg/L		0.05	25-OCT-17
Nitrate+Nitrite-N			<0.50		mg/L		0.5	25-OCT-17
NH4-SK	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH4-SK	**Water**							
Batch R3874267								
WG2648225-1 DUP		**L2012694-5**						
Ammonia, Total (as N)		0.277	0.265		mg/L	4.4	20	02-NOV-17
WG2648225-4 LCS		**0.75PPM-NH4-N**						
Ammonia, Total (as N)			98.8		%		85-115	02-NOV-17
WG2648225-3 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	02-NOV-17
P-T-COL-SK	**Water**							
Batch R3869361								
WG2648735-1 DUP		**L2012694-4**						
Phosphorus (P)-Total		1.34	1.40		mg/L	4.4	20	27-OCT-17
WG2648735-3 LCS								
Phosphorus (P)-Total			93.2		%		80-120	27-OCT-17
WG2648735-2 MB								
Phosphorus (P)-Total			<0.30		mg/L		0.3	27-OCT-17
WG2648735-4 MS		**L2012694-6**						
Phosphorus (P)-Total			82.0		%		70-130	27-OCT-17
PH-PCT-SK	**Water**							
Batch R3866566								
WG2648495-1 DUP		**L2012694-3**						
pH		7.75	7.72	J	pH	0.03	0.2	26-OCT-17
WG2648495-2 LCS		**PCT**						
pH			6.86		pH		6.76-6.96	26-OCT-17
WG2648495-5 LCS		**PCT**						
pH			6.89		pH		6.76-6.96	26-OCT-17
TC,EC-QT51-SK	**Water**							
Batch R3866975								
WG2648340-1 DUP		**L2012694-2**						
Total Coliforms		145	130		MPN/100mL	11	65	26-OCT-17
Escherichia Coli		0	0		MPN/100mL	0.0	65	26-OCT-17
WG2648340-2 MB								
Total Coliforms			0		MPN/100mL		1	26-OCT-17
Escherichia Coli			0		MPN/100mL		1	26-OCT-17
TKN-CFA-ED	**Water**							
Batch R3871346								
WG2652493-34 LCS								
Total Kjeldahl Nitrogen			108		%		75-125	31-OCT-17
WG2652493-35 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TKN-CFA-ED	**Water**							
Batch R3871346								
WG2652493-35 MB								
Total Kjeldahl Nitrogen			<0.20		mg/L		0.2	31-OCT-17

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	24-OCT-17 12:00	26-OCT-17 01:00	0.25	37	hours	EHTR-FM
	2	24-OCT-17 12:00	26-OCT-17 01:00	0.25	37	hours	EHTR-FM
	3	24-OCT-17 12:00	26-OCT-17 01:00	0.25	37	hours	EHTR-FM
	4	24-OCT-17 12:00	26-OCT-17 01:00	0.25	37	hours	EHTR-FM
	5	24-OCT-17 12:00	26-OCT-17 01:00	0.25	37	hours	EHTR-FM
	6	24-OCT-17 12:00	26-OCT-17 01:00	0.25	37	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L2012694 were received on 24-OCT-17 16:45.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

ALS Environmental
www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

L2012694-COFC

COC Number: 15 - 540861

Page 1 of 1

Report To	Contact and company name below will appear on the final report
Company:	Associated Engineering
Contact:	Dan McCrank
Phone:	306 715 3581
	Company address below will appear on the final report
Street:	1-1215 NO-Thirty Dr.
City/Province:	Saskatoon SK
Postal Code:	

Invoice To		
	Same as Report To	YES NO
	Copy of Invoice with Report	YES NO
Company:		
Contact:		

Project Information	
ALS Account # / Quote #:	23870
Job #:	2017-4165
PO / AFE:	
LSD:	
ALS Lab Work Order # (lab use only)	

Report Format / Distribution	
Select Report Format:	PDF EXCEL EDD (DIGITAL)
Quality Control (QC) Report with Report	YES NO
Compare Results to Criteria on Report - provide details below if box checked	
Select Distribution:	EMAIL MAIL FAX
Email 1 or Fax	mccrank@ae.ca
Email 2	
Email 3	

Invoice Distribution	
Select Invoice Distribution:	EMAIL MAIL FAX
Email 1 or Fax	
Email 2	

Oil and Gas Required Fields (client use)	
AFE/Cost Center:	PO#
Major/Minor Code:	Routing Code:
Requisitioner:	
Location:	

ALS Contact: B. Morgan Sampler: DMC

Select Service Level Below - Please confirm all E&P TATs with your AM - surcharges will apply

Regular [R] X — Standard TAT if received by 3 pm - business days - no surcharges apply

PRIORITY (Business Days): 4 day [P4] ☐ | 3 day [P3] ☐ | 2 day [P2] ☐

EMERGENCY: 1 Business day [E1] ☐ | Same Day, Weekend or Statutory holiday [E0] ☐

Date and Time Required for all E&P TATs:

For tests that can not be performed according to the service level selected, you will be contacted.

Analysis Request

Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Bacteriological (P)	Ferric Iron (F)	Routine Parameters (F/P)	NH3 - Total (P)	TKN - Total (P)	Number of Containers
	MW17-02	24-OCT-17	PM	Water	X	X	X	X	X	
	MW17-03	↓	↓	↓	X	X	X	X	X	
	MW17-05				X	X	X	X	X	
	MW17-06				X	X	X	X	X	
	MW17-06D				X	X	X	X	X	
	MW17-07				X	X	X	X	X	

Drinking Water (DW) Samples[1] (client use)	Special Instructions / Specify Criteria to add on report by clicking on the drop-down list below (electronic COC only)
Are samples taken from a Regulated DW System? YES ☐ NO ☒	
Are samples for human drinking water use? YES ☐ NO ☒	

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen ☐ SIF Observations Yes ☐ No ☐

Ice Packs ☐ Ice Cubes ☐ Custody seal intact ☒ Yes ☐ No ☐

Cooling Initiated ☐

INITIAL COOLER TEMPERATURES °C			FINAL COOLER TEMPERATURES °C		
10					

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by:	Date:	Time:	Received by:	Date:	Time:	Received by:	Date:	Time:
Dan McC	Oct 24, 2017		ADM	OCT 24/17	4:55			

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

OCTOBER 2015 FRONT

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1 If any water samples are taken from a **Regulated Drinking Water (DW) System**, please submit using an **Authorized DW COC form**.