November 24, 2015 Reference No. 1314930054-006-L-Rev0

Mr. Darren Enevoldson, Environmental Technician II
City of Kelowna
1435 Water Street
Kelowna, BC
V1Y 1J4

COVER LETTER – RESULTS OF HYDROGEOLOGICAL ASSESSMENT, GEOLOGICAL REVIEW AND WATER WELL SURVEY, GLENMORE LANDFILL, KELOWNA, BC

Dear Mr. Enevoldson,

As requested by the City of Kelowna (City), a hydrogeological assessment and a geological review/water well survey ("works") were conducted by Golder Associates Ltd. (Golder) and SLR Consulting Canada Ltd. (SLR), respectively, for the Glenmore Landfill (Landfill) in Kelowna, BC. Our efforts were undertaken to address the issue of the potential migration of landfill leachate to bedrock faults across, and in the vicinity of, the Landfill. The issue was raised in a technical memorandum entitled "*Glenmore Landfill Hydrogeology Summary*" that was submitted by CH2M HILL to the City on June 17, 2013. The overall objective of the works was to provide a level of risk associated with leachate migration across the Landfill and off-site such that the City can evaluate how to move forward with development of leachate recirculation in Phases 1 and 2 of the Landfill.

The scope of work, methodology, results and conclusions of the works are presented in the attached letter reports prepared by Golder and SLR[1]. SLR assessed that faults are likely present across, and in the vicinity of, the Landfill; however, these faults appear to predate the undisturbed glaciolacustrine sediments that fill the basin, and are inferred to be inactive with a low seismic risk. In addition, SLR confirmed that there are few water wells in the area, and those that are present are not at risk from Landfill leachate migration. Golder assessed that bedrock faults and/or associated fractures do not appear to be acting as drains for groundwater flow away from the Landfill. The predominance of upward hydraulic gradients between the bedrock and overlying glaciolacustrine deposits suggests that groundwater in the bedrock is a source of recharge for the basin deposits. Geochemically, there is no evidence of preferred leachate migration to depth.

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[1] Note that these letters were previously submitted to the City in Draft in May 2014 and subsequently reviewed by CH2M HILL in November 2014. The referenced letters are attached and now provided as Final versions.

Based on the works completed; with the data available at the time, and in accordance with any limitations expressed in the attached letter reports, both Golder and SLR conclude that there is a low likelihood for landfill leachate to migrate into bedrock faults and/or associated fractures, or to local groundwater supply. At this time, it is our firms' mutual opinion that additional investigations are not warranted to further assess the bedrock faults and/or associated fractures. Additional detailed assessment (including groundwater and leachate recirculation modelling) may assist in providing a higher level of certainty. It is recommended that a groundwater monitoring program be developed to monitor the effects of leachate recirculation on the groundwater system. The collaborative effort by Golder, SLR and guidance of CH2M Hill provides our collective confidence in these conclusions and the above recommendations. We trust that this provides you with the information you require at this time.

Yours truly,

GOLDER ASSOCIATES LTD.

Jacqueline Foley, M.Sc., Geo.L.
Associate, Senior Hydrogeologist

SLR CONSULTING (CANADA) LTD.

for Robin Jones, M.A.Sc., M.B.A., P.Eng.
Senior Technical Manager

JF/RJ/jc/kv

Attachments: SLR Consulting Canada Ltd. report dated November 19, 2015
Golder Associates Ltd. report dated November 24, 2015

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19 November 2015

Darren Enevoldson, Environmental Technician
City of Kelowna
Glenmore Landfill
2105 Glenmore Road North
Kelowna, BC V1V 2C5

Project No.: 219.05164.00002

Dear Mr. Enevoldson,

RE: WATER WELL SURVEY AND BEDROCK GEOLOGY REVIEW IN THE VICINITY OF THE GLENMORE LANDFILL – 2105 GLENMORE ROAD NORTH, KELOWNA, BC

On behalf of the City of Kelowna, SLR Consulting (Canada) Ltd. (SLR) completed a desktop review of the bedrock geology in the immediate vicinity of the Glenmore Landfill, located at 2105 Glenmore Road North, Kelowna, BC (the Landfill). SLR also completed a water well survey in the immediate vicinity of the Landfill. These efforts are in support of an overall assessment to understand if there are any scientific issues that may affect the future development of the landfill site. This work has previously been reported in draft, and since peer reviewed by both Golder Associates and CH2M Hill. This is the final report.

OBJECTIVE

The objective of this project was to obtain an understanding of the presence, location, behaviour, and potential risks associated with a bedrock fault suspected to be located in the vicinity of the Landfill. Furthermore, a door-to-door water well survey was completed to obtain a better understanding of the specific water use in the area and also to gather hydrogeologic information from water wells completed in the vicinity of the Landfill.

REVIEW OF GEOLOGIC INFORMATION

Information on bedrock geology for the Glenmore area was obtained from published geological maps and reports and from personal communication with local Geologists. Two geological maps exist for the area. The BC Geological Survey Preliminary Map 45 (Church, 1981), the Geological Survey of Canada map Open File 6839 (Okulitch, 2013). These and iMap BC (provincial mapping website) identify a series of faults in the vicinity of the landfill (see Drawing 1).

All references note the presence of a NNW trending normal fault[1] to the west of the landfill. Church (1981) and Okulitch (2013) note also the presence of a NNE trending normal fault structure in the vicinity of the Landfill, and potentially underlying Phase 3. The NNE trending fault intersects the NNW trending normal fault to the southwest of the Landfill. Beneath the Landfill both faults are mapped by Church (1981) as "approximate", suggesting some uncertainty regarding their presence and location.

Okulitch (2013) identifies the eastern wall of the NNE trending fault to be the hanging wall, with the younger White Lake Formation to the east and the older Marron Formation (part of the Penticton Group) to the west. The NNW trending fault is younger than the NNE fault, as it can be seen to offset the older NNE fault on Drawing 1. The hanging wall of the NNW fault lies to the north east, based on the similar geologic patterns as seen for the NNE fault. The White Lake Formation is described as being composed of carbonaceous siltstone, sandstone, conglomerates, and volcanic conglomerates (Roed, 2004 and Okulitch, 2013). This is consistent with the materials encountered during bedrock drilling investigations by SLR, Golder Associates Limited, Gartner Lee Limited, and EBA. The Marron Formation is described as being composed of grey intermediate andesitic lava flows with some breccias (Roed, 2004 and Okulitch, 2013).

Church (1981) does not describe the bedrock beneath the Landfill, as it is buried beneath glaciolacustrine sediments and therefore was not observed. The 1981 map indicates rocks of the Kettle River Formation to the north and northeast. The Kettle River formation is described as including lavas, breccias, siltstone and sandstone with some carbonaceous seams.

No report was written to accompany the Church map, however the map was likely compiled from field observations gathered during the author's work during the time period of 1963 to 1978. Much of this work was summarized in the paper *Tertiary Stratigraphy and Resource Potential in South-Central British Columbia (82 E, L),* B.N. Church, 1978. In this paper, Church describes a herringbone fault structure located along the length of the Glenmore Valley, with fault structures trending NNE and NNW off of the main fault structure.

Faults can represent a permeable pathway either along an opening in the rock, or an accompanying shear zone where the rock has been broken. Faults can also be sealed by infilled clayey sediments, or by subsequent hydrochemical precipitation of natural minerals. The fact that the NNE and NNW trending normal faults in the bedrock below the Landfill are inconsistently mapped is due to their buried nature. SLR made several attempts to contact the Geological Survey of Canada and iMap BC to determine why the fault is not mapped on iMap BC, and have concluded this is an electronic omission and not based on new evidence.

SLR contacted Dr. Murray Roed to discuss his understanding of the faults. Dr. Roed is a retired Professional Geologist, who had a long career working in the Okanagan Valley, and he indicated to SLR that the Church (1981) map is the most accurate information available. It is his belief that it is highly likely that the fault beneath the landfill exists, and is only masked by the glaciolacustrine sediments.

[1] A "normal" fault is where one side (hanging wall) moves downwards relative to the other (footwall) along an inclined vertical plane with no lateral offset. These types of faults occur in areas of bedrock extension. (stretching) and are perpendicular to the direction of the tensile forces. Fault lines are mapped by a discontinuity of outcrops.

SLR also contacted Dr. John D. Greenough, regarding the faults. Dr. Greenough is a bedrock geologist and a professor at the University of British Columbia's Okanagan campus. According to Dr. Greenough the fault beneath the Landfill is likely inferred based on bedrock mapped to the north northeast of the Landfill and therefore logically exists beneath it. Dr. Greenough is unaware of any current or former graduate students or organizations who have studied faults or movement along faults in the region. He stated that no significant bedrock mapping has occurred since the 1970s and early 1980s that might further confirm its presence and/or character.

There appears to be enough information between the two sets of information to conclude that it is likely an historic fault exists beneath the landfill site, and another to the west. It is common wisdom that groundwater is attracted to fault zones due to the greater hydraulic conductivity of fractured and loosened bedrock. Groundwater would therefore preferentially flow along the fault surface, as opposed to across it. An aquifer (such as bedding planes or discontinuities) that conducts groundwater towards a fault zone may be truncated at that point, with the groundwater being redirected into the fault zone. In this site setting hydraulic gradients are generally upwards suggesting that groundwater moves up into the basin sediments and towards the surface water and not down and away from the site. Some monitoring locations have downward gradients, which were hypothesized to move water into and away in the faults. The companion Golder letter identifies why this is not the case.

SEISMIC RISK

With the presumed presence of a fault structure in the bedrock underlying the landfill site, it is prudent to consider the risk of the fault becoming active.

Kelowna is located in a region of low seismic risk. SLR contacted the Geological Survey of Canada (GSC) and Natural Resources Canada (NRC) to determine the seismic risk in the vicinity of the Landfill. On SLR's request, the GSC created a map showing all known seismic events within a 20 km radius from the centre of the Landfill (reproduced on Drawing 2). The oldest seismic event on the map dates from 1936 and had a magnitude[2] of 4.5 (located at the very top of the map area in the centre, approximately 62 km from the Landfill). The GSC has only been able to record seismic events down to a magnitude of 3 ¼ since 1965 and down to 2 ¼ since 2000, so the minor events before those dates were not recorded.

The map shows that there have been very few seismic events recorded within 20 km of the Landfill and none with a magnitude greater than 3. The map also shows all recorded seismic events within an approximately 60 km radius from the Landfill. A cluster of events, with a maximum magnitude of 4, have been measured near Penticton about 55 km away. None of the earthquakes on the map area were large enough to cause damage, although several (approximately 45 on the map) were reportedly felt. Most of these felt events were very small and very close to Penticton (Stephen Halchuk, 2014). The size of the symbols on the map was

[2] The higher the magnitude, the greater amount of potential damage an earthquake can cause. The magnitude scale used by the GSC is logarithmically expressed. For example a Magnitude 3 is ten times less than a Magnitude 4. To provide some sense as to the meaning of these magnitudes, a magnitude 4 event is often felt by people, but very rarely causes damage. Shaking of indoor objects can be noticeable. In comparison, a magnitude 5 event can be felt by most people in an affected area, but only slightly felt outside and generally causes none to minimal damage to buildings.

increased by the GSC to show the distribution of these small events, as no large events have been recorded in the region.

SLR used the Seismic Hazard Calculator provided by Natural Resources Canada (NRC) on the internet[3], to determine the seismic risk at the Landfill. According to NRC, the seismic hazard for a site is derived from statistical analysis of past earthquakes and from interpretation of their knowledge of Canada's tectonic and geologic structure. Seismic hazard is expressed as the most powerful ground motion that is expected to occur in an area for a given probability level. Spectral acceleration is a measure of ground motion that takes into account the sustained shaking energy at a particular period. It is a better measure of potential damage than the peak ground acceleration.

The results of the seismic hazard calculation for the landfill are presented in the following table. For example, for a 1.0 second period, the spectral acceleration of 0.09 g has a 2% probability of exceedance in 50 years (corresponding to the 1 in 500 year return period).

Seismic Hazard Calculation Results for the Glenmore Landfill

Probability of exceedance in 50 years	Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA
2% (0.0004 per annum)	0.275	0.171	0.090	0.054	0.137
5% (0.001 per annum)	0.188	0.117	0.066	0.039	0.097
10% (0.002 per annum)	0.134	0.085	0.049	0.029	0.071
40% (0.010 per annum)	0.060	0.040	0.024	0.014	0.034

Notes:

- Sa: Spectral acceleration, values are given in units of g (acceleration due to gravity). 5% damped spectral acceleration (Sa(T), where T is the period in seconds).
- PGA – peak ground acceleration

Based on these results, the likelihood of a major earthquake originating in the Okanagan is low. According to Okanagan Geology (Roed, 2004) and personal communications with Stephen Halchuk of the GSC, there have been no specific studies of recent fault movement in the Okanagan Valley, however there have been numerous studies of Holocene age sediments (younger than 10,000 years), none of which report off-setting of sediments along faults. This is important and convincing evidence that significant seismic events have not occurred in a timeframe much greater than that of the landfill's expected lifetime.

Consideration of what might occur that would breach the protective clay sediments between the bedrock and the landfill, is also made. Liquefaction of loosely consolidated sediments is a consideration in the Kelowna area, however it would take an earthquake of magnitude 7.5 or higher centered in Vancouver to cause significant shaking in the Okanagan Valley, which could result in soil and sediment liquefaction. Based on geologic evidence, the frequency of such an event must be less than one in 10,000 years (Roed, 2004).

[3] [URL: http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index-eng.php]

Based on the above analysis of size and potential frequency of seismic events in the Kelowna region, it may be concluded that the risk is low and it is unlikely the existing faults would reactivate or change groundwater flow patterns.

WATER WELL RECONNAISSANCE SURVEY

A door to door water well reconnaissance survey was undertaken to determine the location, condition and use of wells located within a 500 m radius of the Glenmore Landfill. A review of the water well registry has shown no wells in this radius, however this registry is not comprehensive and hence the need for the on the ground survey. A 500 m limit was selected north and west of the Landfill, however it was extended slightly south of the landfill to include more properties in this laterally downgradient direction. The 500 m limit to the east is based on the presence of a ridge containing no occupied properties. The water well reconnaissance survey limit shown with respect to the location of the landfill is outlined in red on Drawing 3.

On March 3rd, 2014 the survey was completed by two SLR field staff and a City of Kelowna Employee from the Landfill. All property owners within the limit were contacted via a letter of introduction that contained call back numbers and contact information. The field staff carried copies of this letter for each homeowner contacted in the field. The survey asked the owner for their contact information and details on their well (e.g. history, use and condition). The detailed interview sheets are kept on file.

The inventory was completed during the day and evening of March 3rd, 2014. One remaining property was visited on March 25, 2014. If a property owner was not reached on the first visit, SLR tried another time of the day to reach them, via a visit. In this way SLR was able to reach the homeowners of all the properties within the designated boundary.

Table 1, following the text of the report, shows the results of the survey. In total 14 properties were visited and/or surveyed. All the properties in the area are serviced by the GEID and did not have a water well. However a pair of properties (2455 and 2655 Glenmore Road North, currently owned by the City of Kelowna, and presently unoccupied) had a well (BW3).

After speaking with the City of Kelowna personnel who have a long association with this area, it was identified that there were three other private water wells surrounding the Landfill. These have all been decommissioned or destroyed. One well (BW1) was located at 2102 Glenmore Road North and a second well was found and decommissioned in May 2012 at 1593 Glenmore Road North. The third well was located within what was known as the “Tutt Ranch”; however the location of this well is unknown and is not included in the survey table or the drawing. The well is presumed destroyed.

Based on the above findings of the water well reconnaissance survey, it can be confirmed that there are no groundwater users within 500 m of the landfill, and particularly in the downgradient direction. With no wells to affect, and municipal servicing available to future landowners, it is our conclusion there is currently very little risk that unanticipated effects from the landfill on the bedrock groundwater would be an issue.

Conclusions and Recommendations

Based on the foregoing analysis we provide the following conclusions.

- The presence of a NNE trending normal fault in the bedrock beneath the landfill appears to be likely, based upon a review of the scientific information at hand. It is a very old fault (100s of millions of years old) and is deemed to be inactive by the presence of the undisturbed overlying glaciolacustrine sediments of about 10,000 year age.
- The seismic risk in the area is low, and all recorded events in the area have been low magnitude. Certainly nothing has happened in the recent past to disturb the 10,000 year old sediments.
- No water wells exist that would be threatened by inadvertent impacts from the landfill. All existing residences are on a municipal water supply that is not sourced in the area.

Considering the above conclusions we offer the following recommendation.

- Investigation of the location and condition of the NNE or NNW faults in the bedrock beneath the landfill is not warranted at this time. This is because there are no immediate receptors to impacted water, and there appears to be little risk of breach of the intervening sediments by seismic events of enough magnitude.

Yours sincerely,
SLR Consulting (Canada) Ltd.

PROFESSIONAL
PROVINCE OF
S. J. USHER
36777 6/11/15
BRITISH COLUMBIA
GEOSCIENTIST

Steve Usher, P.Geo
Senior Hydrogeologist, P.Geo.

Erica Milligan, M.Sc., P.Ag.
Environmental Scientist

cc Golder Associates
Enc References
Table 1
Drawings 1 - 3

EM//SU

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TABLES

City of Kelowna
Glenmore Landfill
Water Well Survey and Bedrock Geology Review
SLR Project No.: 219.05164.00002

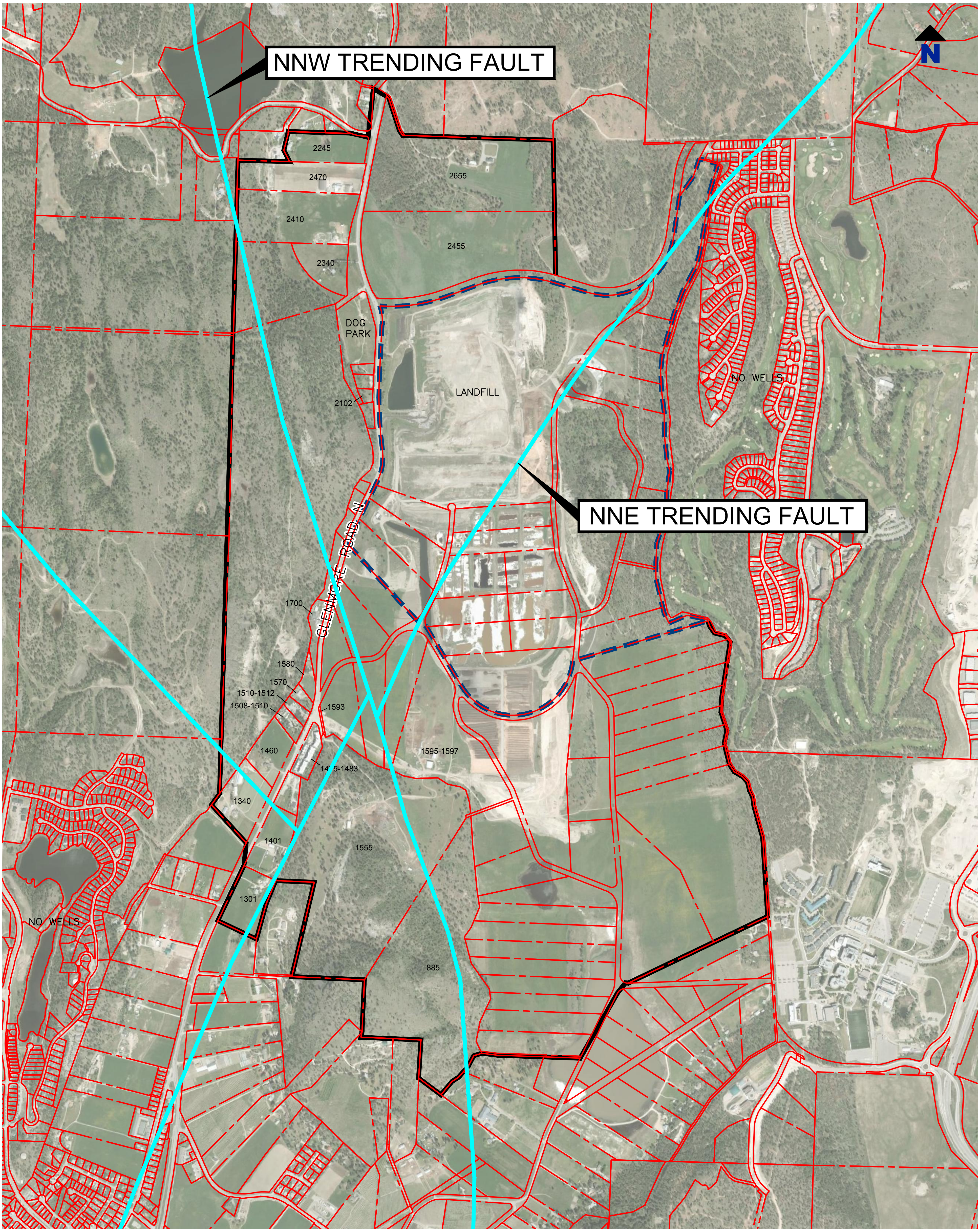
Table 1

Survey Details					Water Source Details				Comments
House #	Street	Completed Survey?	Date Interviewed	Property Type	Water Source	Well Type	Well Depth (m)	Location (N,E)	
2245	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
2470	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
2410	Glenmore Road North	Y	4-Mar-14	House	Water Main	-	-	-	GEID
2340	Glenmore Road North	Y	25-Mar-14	House	Water Main	-	-	-	Owned by City: Renter
1700	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
1580	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
1570	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
1508-1512	Glenmore Road North	Y	3-Mar-14	Trailer Park	Water Main	-	-	-	GEID
1460	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
1340	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
1401	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
1475-1483	Glenmore Road North	Assumed	3-Mar-14	Apartments	Water Main	-	-	-	GEID
2455 & 2655	Glenmore Road North	Y	3-Mar-14	House	Well	Dug	5.1	11 U 0325922 5535733	Owned by City: Vacant
1555	Glenmore Road North	Y	3-Mar-14	House	Water Main	-	-	-	GEID
1301	Glenmore Road North	Y	10-Mar-14	House	Water Main	-	-	-	GEID

	Total # Properties	Survey Complete				No Survey Completed		
		Total Complete	Well	Municipal	Other Source	Package Left	Assumed Well	Assumed Municipal
House	13	13	1	12	0	0	0	0
Apartments	1	0	0	0	0	0	0	1
Trailer Park	1	1	0	1	0	0	0	0
Abandoned House/ Empty Property	0	0	0	0	0	0	0	0
TOTAL NUMBER PROPERTIES	15	14	1	13	0	0	0	1

DRAWINGS

City of Kelowna
Glenmore Landfill
Water Well Survey and Bedrock Geology Review
SLR Project No.: 219.05164.00002



LEGEND

PROPERTY BOUNDARY
SURVEY BOUNDARY
LANDFILL BOUNDARY
NORMAL FAULT

NOTES

DRAWING COMPILED FROM CITY OF KELOWNA OPEN GIS DATA. IMAGERY: GOOGLE © CITY OF KELOWNA AND OKULITCH, A.V. (COMP), 2013. GEOLOGY, OKANAGAN WATERSHED, BRITISH COLUMBIA, GEOLOGICAL SURVEY OF CANADA, OPEN FILE 6839, SCALE 1:100 000. DOI 10.4095/292220

SCALE 1:15,000
WHEN PLOTTED AT 11 x 17 PAGE SIZE

0 250 500 1000 m

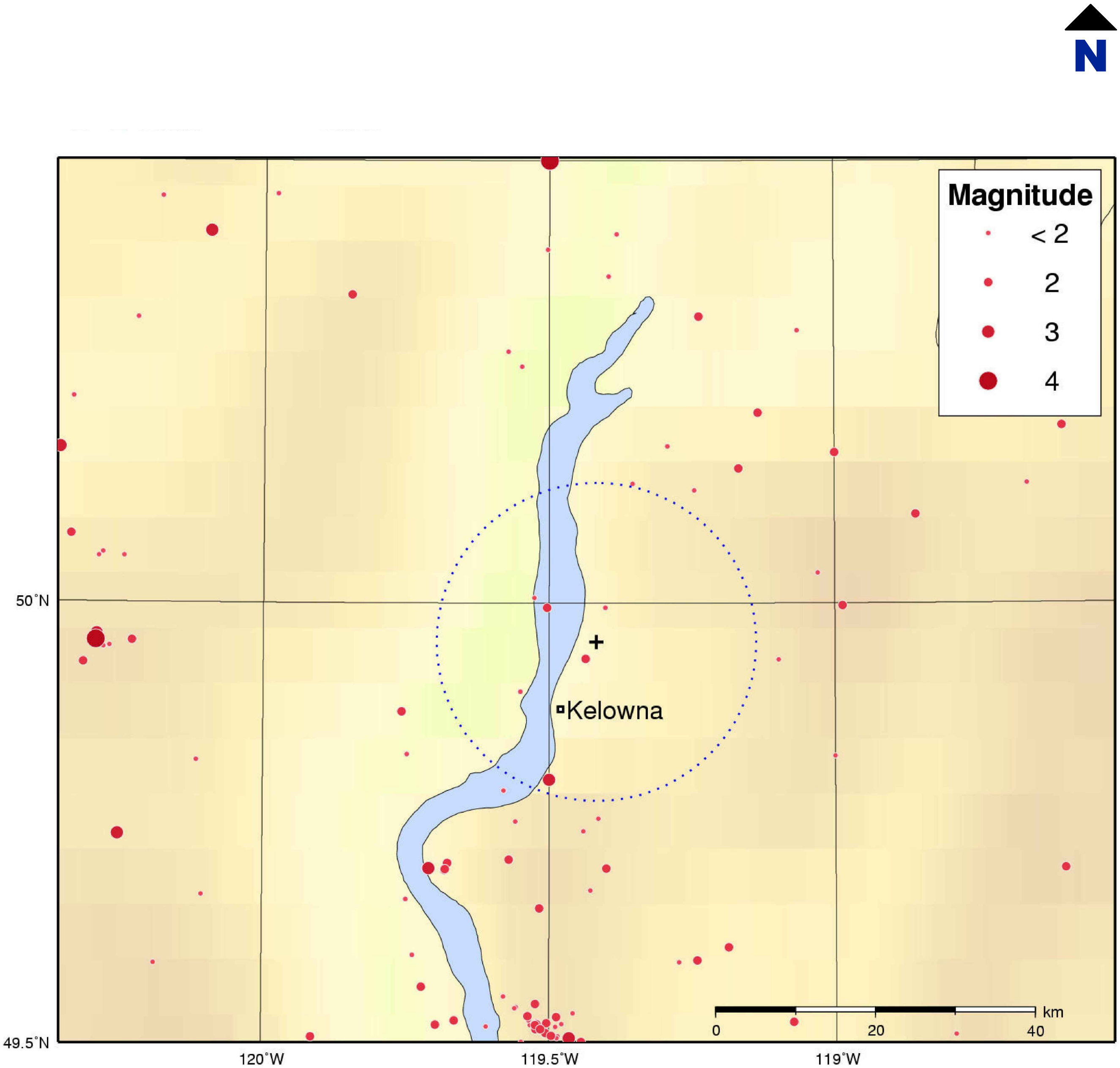
THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

CITY OF KELOWNA
2105 GLENMORE ROAD N
KELOWNA, BC

Report
WELL SURVEY AND GEOLOGY REVIEW

Drawing
SITE PLAN

Date	April 8, 2014	Scale	AS SHOWN	Drawing No.
File Name	S_219-05164-00002-B1	Project No.	219.05164.00002	1



NOTES

SOURCE: NATRUAL RESOURCES CANADA

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

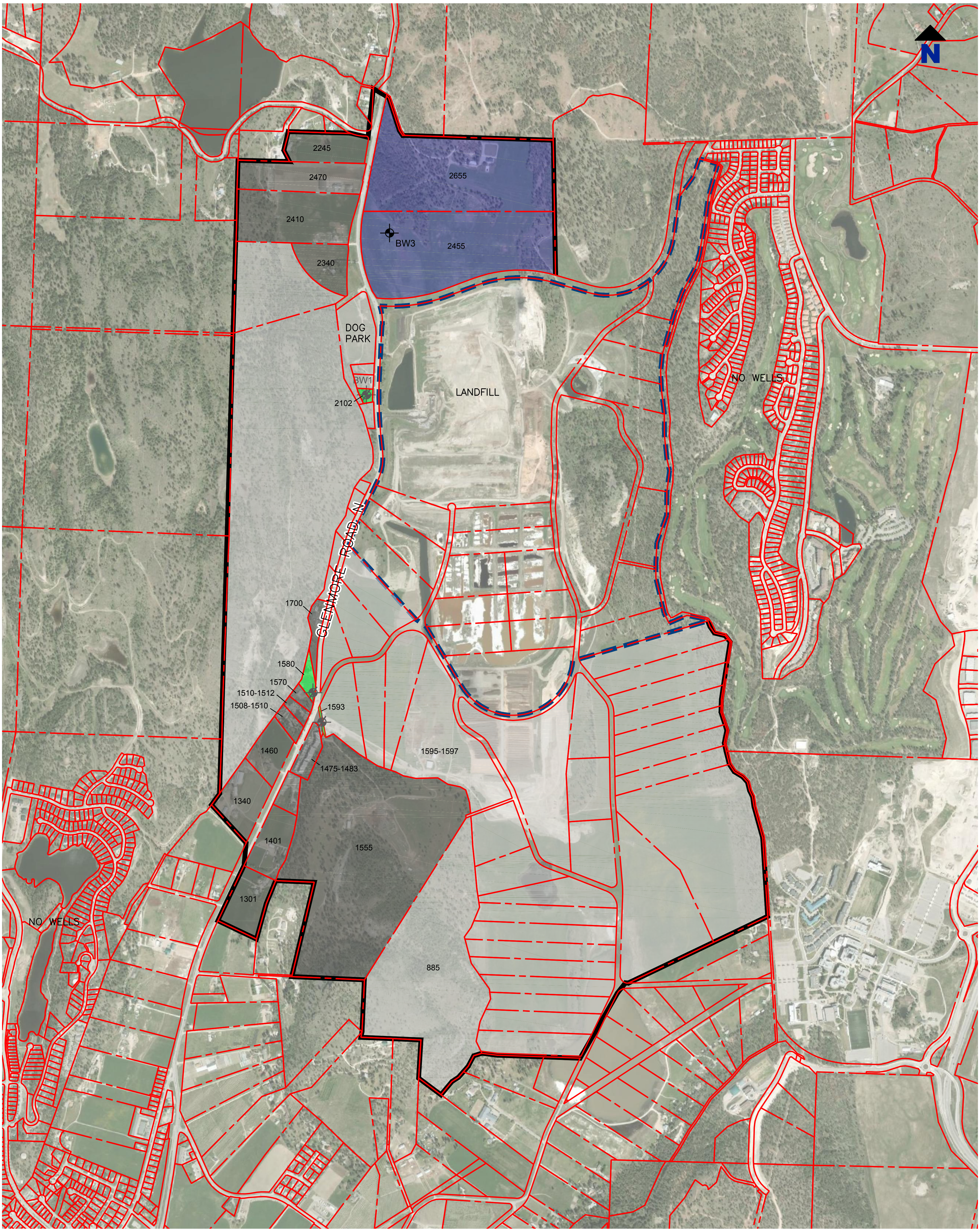
SLR

CITY OF KELOWNA
2105 GLENMORE ROAD NORTH
KELOWNA, BC

Report WATER WELL SURVEY AND GEOLOGY REVIEW IN THE VICINITY OF THE GLENMORE LANDFILL

Drawing SEISMICITY IN THE VICINITY OF THE GLENMORE LANDFILL

Date	April 1, 2014	Scale	AS SHOWN	Drawing No.
File Name	S_219-05164-00002-A3	Project No.	219.05164.00002	2



LEGEND

PROPERTY BOUNDARY

SURVEY BOUNDARY

LANDFILL BOUNDARY

RESIDENCE WITH WELL LOCATION

RESIDENCE – NO WELL

NO RESIDENCE

FORMER WELL LOCATION

WELL LOCATION

WELL LOCATION (DECOMMISSIONED OR DESTROYED)

NOTES

DRAWING COMPILED FROM CITY OF KELOWNA OPEN GIS DATA. IMAGERY: GOOGLE © CITY OF KELOWNA

SCALE 1:15,000
WHEN PLOTTED AT 11 x 17 PAGE SIZE

0 250 500 1000 m

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

CITY OF KELOWNA
2105 GLENMORE ROAD N
KELOWNA, BC

Report: WATER WELL SURVEY AND GEOLOGY REVIEW IN THE VICINITY OF THE GLENMORE LANDFILL

Drawing: WELL SURVEY RESULTS

Date	April 8, 2014	Scale	AS SHOWN	Drawing No.
File Name	S_219-05164-00002-B2	Project No.	219.05164.00002	3

REFERENCES

City of Kelowna
Glenmore Landfill
Water Well Survey and Bedrock Geology Review
SLR Project No.: 219.05164.00002

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November 24, 2015 Reference No. 1314930054-005-L-Rev0

Mr. Darren Enevoldson, Environmental Technician II
City of Kelowna
1435 Water Street
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HYDROGEOLOGICAL ASSESSMENT OF BEDROCK FAULTS IN TERMS OF THEIR POTENTIAL TO SUPPORT OFF-SITE GROUNDWATER AND LEACHATE MIGRATION – GLENMORE LANDFILL KELOWNA, BC

Dear Mr. Enevoldson,

Golder Associates Ltd. (Golder) is pleased to present the results of a supplementary hydrogeological assessment conducted for the Glenmore Landfill (Landfill) in Kelowna, BC. The hydrogeological assessment was completed as a desk top study, and was developed following a meeting held by the City of Kelowna (City) on December 2, 2013 and on a subsequent e-mail from Mr. Darren Enevoldson, Environmental Technician II with the City, dated December 18, 2013[1]. The overall objective of the assessment was to provide a level of risk associated with leachate migration across the Landfill and off-site, such that the City can evaluate how to move forward with development of the leachate recirculation in Phases 1 and 2 of the Landfill.

For the purposes of this report, “Landfill” refers to the entire area encompassed by the Glenmore Landfill (including Phase 1, Phase 2, Phase 3, Compost Facility, and Avocet Pond and lands further northeast), while “Landfill Footprint” refers to Phase 1, Phase 2 and Phase 3 of the Landfill. Where the term “basin” is used, it is inferred to represent the valley (depression) occupied by the Landfill Footprint.

1.0 SCOPE OF WORK

The supplementary hydrogeological assessment comprised an evaluation of the NNE and NNW trending faults and associated fractures that are inferred to be present across the Landfill, in terms of their potential to support off-site groundwater and leachate migration. This task included:

1) An evaluation, compilation and presentation of available bedrock characteristics (i.e., weathered zone, depth to bedrock, fracture characteristics), and of existing and relevant hydrogeological data as related to groundwater/leachate migration into these potential faults/fractures;

[1] We note that this letter report was previously submitted to the City in Draft in May 2014 and subsequently reviewed by CH2M HILL in November 2014. This is the Final version of the letter report; it has not been modified from the May 2014 Draft version except to include this statement, to include the word “shading” in the bracketed sections of the Figure 1 caption, and to provide Study Limitations (refer to Section 4.0 below).

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2) A discussion on the potential for migration of groundwater/leachate into these potential faults/fractures; and,

3) An opinion on the potential for groundwater and leachate to migrate off-site along these potential faults/fractures.

As part of this task, Golder considered information obtained by SLR Consulting (Canada) Ltd. (SLR, 2014) on the presence of the faults, the seismic hazard risks associated with these faults, and potential receptors down-gradient of the Landfill (specifically, water wells in the inferred down-gradient direction of the faults).

2.0 HYDROGEOLOGICAL ASSESSMENT

Golder reviewed available data for the Landfill and down-gradient areas to the south (UBC lands), including: borehole logs for the presence of a weathered zone, bedrock type, and fracture characteristics and frequency; historical water levels for vertical and horizontal hydraulic gradients; and historical and current surface water and groundwater quality data.

2.1 Site Geological Conditions

Golder reviewed a total of 22 borehole logs where bedrock was encountered. We note that boreholes located across the Landfill (including immediately south of the Compost Facility [GL28 well series]) were completed by three different engineering consultants (Gartner Lee Limited, Golder and SLR) over a period of 22 years between 1990 and 2012. Boreholes located south of the Landfill, on UBC lands, were completed by EBA Engineering Consultants Ltd. in 2009. A summary of the reported bedrock conditions is presented in Table A1, Attachment A. Two main bedrock types were identified during the drilling programs: sedimentary and volcanic. As discussed in the associated SLR report, these bedrock types are inferred to be part of the White Lake Formation, described by Okulitch (2013) as comprising siltstone, sandstone, and conglomerates (EWL_E); and volcanic breccia, rhyolite, pyroclastic rocks, etc. (EWL_V). A discussion of the bedrock types identified across the Landfill is provided in the following sections.

2.1.1 Sedimentary Bedrock

Sedimentary bedrock generally comprised light grey to dark grey siltstone, with mudstone and sandstone encountered at a few locations. These sedimentary rocks were identified along the west and east sides of the basin (at well series GL15, GL8/16, GL17, GL27, GL25 and GL26), within the centre of the basin (at well series GL18), and south of the basin (at well series GL28, 09BH05 and 09BH06), as shown by wells highlighted in blue in Figure 1 below. Sandstone or sandstone layers were generally only present along the west side of the basin. Conglomerate was encountered west of the Landfill Footprint at GL14; the bedrock description of "*subangular to angular gravel sizes in a medium to coarse sand matrix*" is suggestive of sedimentary deposition. Geochemical data for bedrock well GL14-1 is similar to that for bedrock wells GL17-1 and GL27-1, as discussed in Section 2.4 below. The bedrock description at well series GL5, also located west of the Landfill Footprint, was "*light grey crystalline*". Given the similarity of the geochemical data for bedrock well GL5-1 to bedrock wells GL14-1, GL17-1 and GL27-1, this too is suggestive of sedimentary deposition.

Within the centre of the basin, the sedimentary rocks appeared to be discontinuous (*i.e.*, they were only encountered at well series GL18). Where present, and based on the depth encountered, the sedimentary rocks generally sloped towards the centre and towards the south portion of the Landfill. Within the basin, these sedimentary rocks (including the weathered zone) were encountered at elevations of between 420 and 430 masl. East and west of the basin (at well series GL14, GL15, GL25 and GL26), they were encountered at elevations of between 435 and 450 masl; the higher elevations are inferred to correspond to the higher topographic elevations flanking the basin.

2.1.2 Volcanic Bedrock

Volcanic bedrock was generally described as "*volcanic*" on the borehole logs, or was differentiated by colour (*i.e.*, green, green/grey, white, black); no detailed description of the actual volcanic rock type was provided. Volcanic rocks were identified north of the basin (at well series GL0), within the basin (at well series GL3, GL33 and GL9; and at SLR boreholes BH11-9, BH11-10/11, BH11-23 and BH11-24), and along the east side of the basin (at well GL7). Within the basin, these volcanic rocks were encountered at elevations of between 390 and 420 masl, at lower elevations than those of the sedimentary rocks. Well locations where volcanic bedrock was encountered within the Landfill Footprint are highlighted yellow in Figure 1 (below).

It is possible that the (younger) sedimentary rocks were formed on top of the volcanic bedrock, and subsequent preferential weathering or erosion may have removed most of the sedimentary rocks, particularly along the centre of the basin. Alternately, the volcanic rocks observed at the centre of the basin may have been part of an intrusive volcanic occurrence. Note however, that no borehole was drilled deep enough into the bedrock to confirm the existence of sedimentary rock overlying volcanic rock.

2.1.3 Bedrock Faulting

As discussed in the associated SLR report (SLR, 2014), two faults are noted within, and in the vicinity of, the Landfill: a NNW-trending normal fault west of the Landfill and a NNE-trending normal fault that extends across Phase 2 and/or Phase 3 (Okulitch, 2013), The NNE-trending fault intersects the NNW-trending fault southwest of the Landfill. The approximate fault lines are shown in Figure 1 (below).

While it is inferred that the faults exists, based on the review of the borehole logs, it does not appear that a fault(s) or consistent fracture set was encountered during the drilling programs. Where bedrock was encountered during drilling, the borehole was extended up to several metres into the bedrock and a monitoring well installed. In some cases, the monitoring well was installed in the weathered zone above the bedrock, across the upper fractured portion of the bedrock, or across the interface between the bedrock and overlying unit. Few bedrock wells are screened in more-competent bedrock. As discussed in SLR (2014), unconsolidated glaciolacustrine deposits overlie bedrock, with an approximate 3 to 8 m thick clay layer at surface or directly below the MSW unit. Based on the review of the borehole logs and on cross-sections across and along the axis of the basin using information from the borehole logs, there were no apparent unconformities or truncations identified within the unconsolidated glaciolacustrine deposits, suggestive that faulting would have occurred prior to their deposition within, and in the vicinity of, the basin. Given the basin setting, the unconsolidated sediments pinch out (or are non-existent) against the sides of the basin adjacent to the bedrock walls (as observed in the area of GL7-1 along the east side of the basin; and GL14-1 along the west side of the basin), and are thicker in the centre of the basin. It can be inferred from the cross-sections that the sedimentary rocks and the upper portion of the volcanic rocks are continuous along the axis, and perpendicular to the axis, of the basin, with no significant vertical displacement in the documented bedrock. Cross-section figures are not included in this report; however, can be provided upon request.

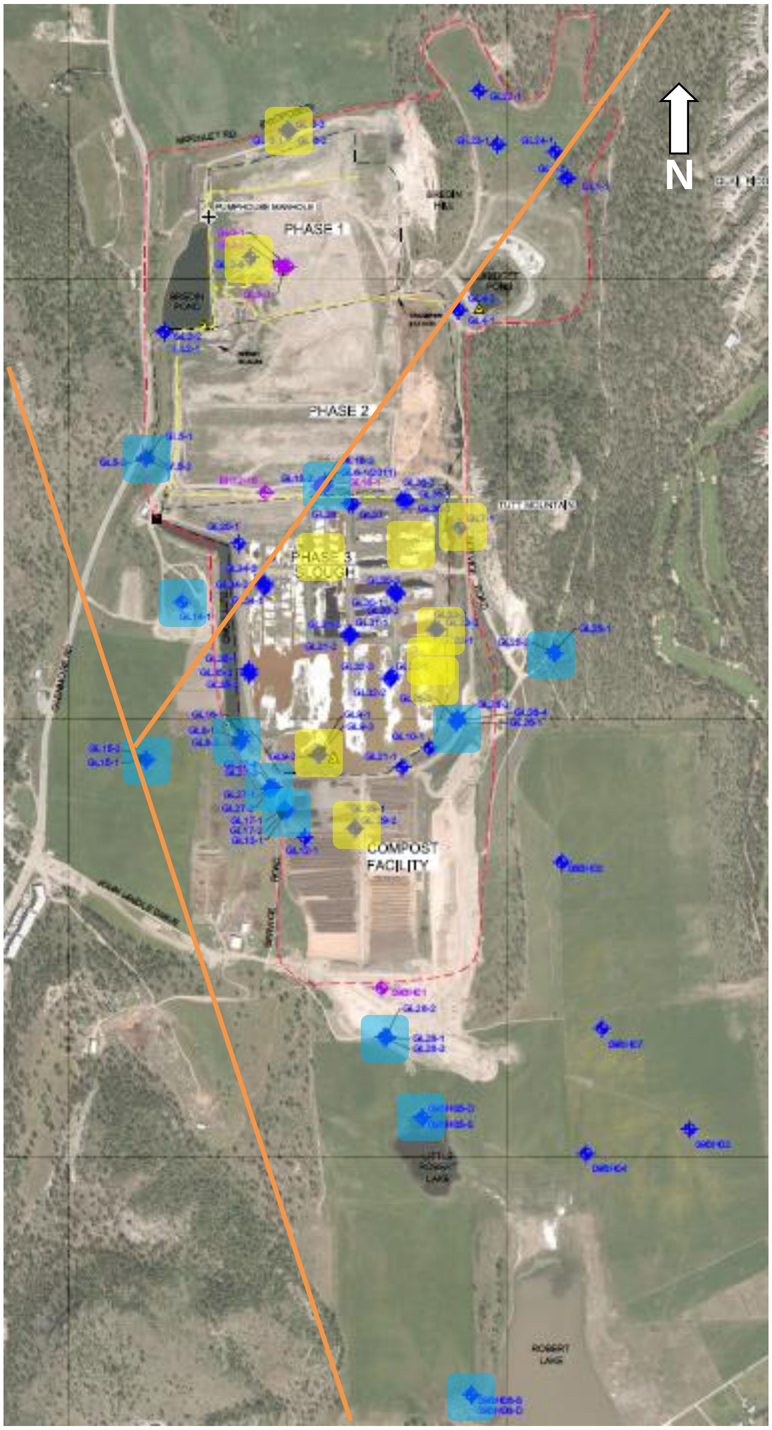

Figure 1. Plan of the Landfill showing areas where sedimentary bedrock (blue shading) and volcanic bedrock (yellow shading) were encountered during various drilling programs conducted between 1990 and 2012. Orange lines represent approximate locations of normal faults identified in Okulitch (2013).

2.2 Groundwater Elevations

2.2.1 Horizontal Hydraulic Gradients

2.2.1.1 Bedrock

Groundwater elevations measured in sedimentary bedrock were highest along the sides of the basin and lowest towards the centre of the basin:

- GL14-1 and GL15-1 were higher in elevation than GL16-1, GL17-1 and GL27-1; and,
- GL25-1 were higher in elevation than GL26-1.

These horizontal gradients suggest that groundwater in the bedrock is recharging the basin from the sides.

Groundwater elevations encountered in the volcanic bedrock along the axis of the basin (*i.e.*, GL0-1, GL3-1 [historical average] and GL9-1) were highest in the north portion of the basin (at GL0-1) and lowest in the south portion of the basin (at GL9-1), suggesting an overall southerly direction of flow in the deepest bedrock across the Landfill.

2.2.1.2 Glaciolacustrine Deposits

As in all previous reports completed for the Landfill, groundwater flow through the basin is inferred to primarily occur within the more permeable sand and gravel unit that is present beneath the MSW and clay units. Recharge to this unit is inferred to be from infiltration of precipitation and movement of groundwater along the basin (valley) walls (as referenced in Golder, 2012). Groundwater elevations reviewed as part of this assessment confirmed that groundwater in the sand and gravel unit travels in a southerly direction (see groundwater contour plan in Attachment B). There is no evidence that the sand and gravel unit truncates at a fault, and that the groundwater within the unit is being redirected into the associated fault zone.

2.2.2 Vertical Hydraulic Gradients

2.2.2.1 Within Bedrock

Groundwater elevations in bedrock wells completed within the basin suggest that in general an upward gradient exists within the bedrock, as shown by the following examples:

- There are three sedimentary bedrock wells located along the west side of the basin, southwest of Phase 3, within a distance of approximately 200 m from each other: GL16-1, GL17-1, and GL27-1. The screen at well GL16-1 is roughly 10 m higher than at wells GL17-1 and GL27-1. The highest groundwater elevations have consistently been reported at the deeper of the three wells (GL17-1 and GL27-1), by elevations of greater than 1 m. It is recognized that the distance between the wells may be too large for calculating a vertical gradient; however, it can be inferred that groundwater elevations at wells completed within deeper sedimentary bedrock are at a higher elevation than those completed within the shallow sedimentary bedrock.
- Groundwater elevations between the sedimentary bedrock and volcanic bedrock are best assessed along the axis of the basin, between bedrock wells GL3-1 in the north portion of the basin (volcanic bedrock), GL18-1 in the middle of the basin (sedimentary rock), and GL9-1 in the south portion of the basin (volcanic bedrock). The highest groundwater elevations were measured in the deeper volcanic bedrock wells (GL3-1

and GL9-1) relative to the shallower sedimentary well (GL18-1), suggestive that there is an upward gradient between the deeper volcanic rocks and the shallower sedimentary rocks in the centre of the basin. A downward gradient in the bedrock would have presented as lower groundwater elevations in the volcanic bedrock relative to the sedimentary bedrock.

If the NNW- and/or NNE-trending faults were drawing groundwater away from the basin, then it would be expected that downward gradients would be observed in all well sets that include bedrock wells and likely those well sets with wells that screen the deeper glaciolacustrine deposits above the bedrock. Were this to be the case, the entire basin would be a groundwater recharge area; this has not been observed.

2.2.2.2 Between Bedrock and Overlying Deposits

In general, where monitoring well sets are present within, and in the vicinity of, the Landfill Footprint, and where one of the wells is completed in bedrock or across the interface of the bedrock and overlying sediments, groundwater elevations in the bedrock well were up to several metres higher on average than groundwater elevations in well(s) screened in the overlying glaciolacustrine deposits. This suggests that within the basin, upward hydraulic gradients exist between the bedrock and the overlying deposits. A summary of these vertical hydraulic gradients is presented in Attachment C. As the Landfill Footprint is constructed in a basin, or inferred groundwater discharge area (*i.e.*, where groundwater is moving up into the basin from underlying bedrock), upward hydraulic gradients within the basin would be expected. As indicated above, downward gradients would be observed in all bedrock wells if the faults and associated fracture zone(s) were drawing groundwater away from the basin.

Two well series (GL15, southwest of the Landfill Footprint; and GL6/18, south end of Phase 2) have historically exhibited a downward vertical gradient between the lower bedrock well and the upper well set(s). Both well sets are coincidently located in the area of the NNW trending fault (GL15) and/or NNE trending fault (GL15 and GL6/18). A review of available geological and hydrogeological data suggests that the observed downward vertical gradients are likely a result of other factors, as follows:

Well Series GL15

A downward gradient of on average 0.6 m has been observed at well series GL15, between the shallow well (GL15-2) and the deeper well (GL15-1). The ground surface at the GL15 well series is at an elevation of approximately 452 masl. This elevation is roughly 13 m higher than the Slough area located within the Landfill Footprint (Slough is at an elevation of approximately 439 masl). Weathered bedrock (sandstone) was encountered at an elevation of 441.9 masl, followed by more competent bedrock at approximately 439.6 masl. No indication of a fault was identified in the upper portion of the bedrock. As the GL15 well series is located away from the Landfill Footprint and at a higher elevation than the Landfill Footprint, this area is inferred to be a source of recharge for the Slough and Landfill deposits, and thus, localized downward gradients can be expected (see Section 2.2.1 above). Groundwater at the GL15 well series also appears to respond to irrigation of the surrounding fields, where higher groundwater elevations at well GL15-1 are observed during the irrigation period through the summer and fall months (see Figure 2 below). The groundwater elevations in the shallow and deep wells fluctuate in a similar pattern, indicative of a hydraulic connection between the upper and lower units.

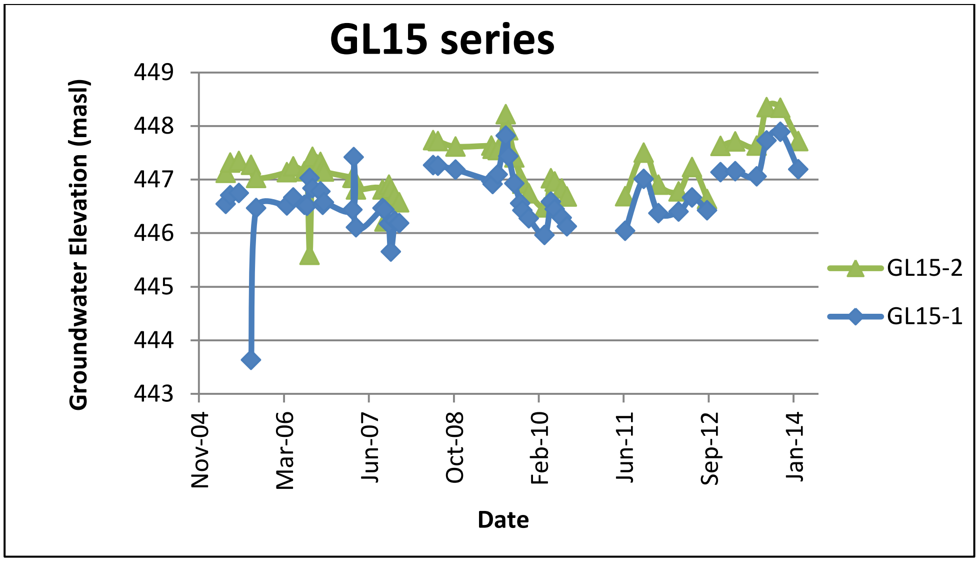

Figure 2. Historical groundwater elevations reported at GL15-1 (screened in sandstone containing few fractures) and GL15-2 (screen straddles the sand unit and top portion of underlying glacial till).

Well Series GL6/18

Groundwater elevations recorded for the bedrock well (GL18-1) between 2005 and 2008 were greater than the groundwater elevations in the MSW unit (GL18-3), but lower than groundwater elevations at the interface between the MSW and underlying clay (GL6-1) and in the sand unit (below the clay; GL18-2), as shown in Figure 3 below. By early 2009, groundwater elevations in the bedrock were reported to be lower than those in the MSW unit, but similar to those at the clay-MSW interface. Bedrock well GL18-1 was subsequently destroyed in mid-2009.

If one compares the groundwater elevations in the bedrock to those in the MSW, a downward gradient would be inferred, particularly after 2009. However, groundwater elevations in the sand relative to those in the MSW are indicative of an upward gradient. During the monitoring period, the groundwater elevation in the sand unit increased from 0.5 m to almost 3 m higher than the groundwater elevation in the bedrock and shallower wells. Higher elevations in the sand unit are inferred to be due to the confined nature of the sand unit and to the unit pinching out (getting thinner) from the north end of the Landfill towards the center of the Landfill[2]; the increasing trend is potentially due to increases in the MSW placed on the surface of Phase 2 (and thus, increased pressure on the groundwater system). Given the significant upward gradient in the sand unit and the presence of a thick clay unit below the MSW, leachate is not expected to migrate down through the clay unit and into the sand unit. High leachate indicator parameter concentrations observed in groundwater samples at GL18-2 are inferred to be due to either a poor seal around the well casing of GL18-2[3], or to leachate migrating into the sand unit from the sides of the basin. An increasing trend in groundwater levels within the MSW is apparent.

[2] Based on drilling by SLR across Phase 3, this sand unit appears to be present in the western portion of Phase 3; however, is discontinuous across the eastern and southern portion of Phase 3.

[3] Wells located across Phase 1 and Phase 2 are subject to movement and/or damage by landfill machinery.

We note that if groundwater in the bedrock was flowing towards the NNE-trending fault, then the groundwater elevation at GL18-1 is expected to have been lower than GL18-3 between 2005 and 2008.

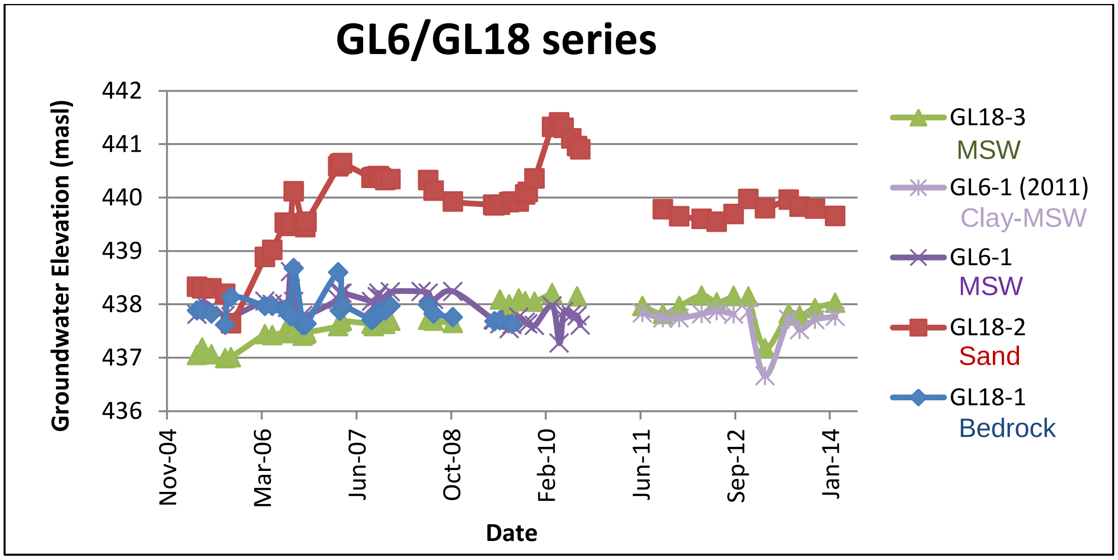

Figure 3. Historical groundwater elevations reported at well series GL6/18. Well GL6-1 (2011) replaced well GL6-1 in 2011. Bedrock well GL18-1 was screened below the weathered zone in siltstone/sandstone containing few fractures.

2.2.2.3 Within Glaciolacustrine Deposits

In general, where monitoring well sets are screened in the glaciolacustrine deposits across the Landfill Footprint, similar or higher groundwater elevations were observed in the deeper deposits relative to the shallower deposits (see Attachment C). Again, an upward gradient is expected within this basin setting. There are a few exceptions where lower groundwater elevations were observed in the deeper deposits, including at well series GL13/17, GL26, GL27, GL28, GL29 and GL31 (see Attachment C).

At well series GL13/17, GL26, GL27 and GL31, a downward gradient of less than 0.1 m/m (on average) was observed on one or more occasion between the upper wells. No seasonal pattern was noted in the assessment of hydraulic gradients. These downward gradients are inferred to be inconsistent and small in comparison to the upward gradients observed between the bedrock and the overlying glaciolacustrine deposits at these, and nearby, wells, where upward gradients ranged on average from 0.5 to 2.2 m/m. The cause of the variability of gradients is not known at this time; however it does not appear to be related to migration of groundwater into the faults.

Where groundwater is leaving the Landfill Footprint to the south, downward gradients between monitoring well sets screened within the glaciolacustrine deposits are more apparent, including at well series GL28 and GL29 (and potentially at the some of the wells identified above). South of the Compost Facility, the ground surface is at a lower elevation than at the Landfill Footprint, and the stratigraphic units appear to dip down towards the south. Downward gradients observed in these wells likely represent groundwater flowing away from the Landfill.

2.3 Summary of Vertical Hydraulic Gradients in Vicinity of Faults

A review of relative groundwater elevations for monitoring well sets located in the vicinity of the NNW- and NNE-trending faults were reviewed, including those for well series GL1, GL4, GL5, GL36, GL6/18, GL34, GL35, GL15 and GL8/16. In all but two well sets (*i.e.*, GL15 and GL6/18; see above), groundwater elevations in the deepest wells were higher than those in the shallowest wells (see Attachment C). It is expected that if the groundwater was being redirected towards, or into, the NNW- or NNE-trending faults, then downward gradients would be observed in at least the deepest well in these well series. The predominant upward gradients suggest that groundwater beneath the Landfill Footprint in these areas is not being drawn into the faults.

2.4 Groundwater Quality Data

A review of available groundwater quality data supports the conclusion that leachate is not migrating down into faults and away from the Landfill. The most recent available groundwater quality at each well is shown on a piper plot (Figure 4) below. As some wells are not currently sampled as part of the Landfill's annual water quality monitoring program, the last available groundwater quality data set was used. The following general observations were made with respect to groundwater quality across the Landfill in relation to the bedrock faults:

- Sedimentary bedrock wells located along the west side of the Landfill (GL5-1, GL14-1, GL17-1 and GL27-1) plot in a similar region at the bottom of the piper plot. These wells are inferred to not be impacted by landfill leachate. The characteristic groundwater quality at these wells is inferred to be due to recharge of these wells from groundwater originating in the uplands west of the Landfill.
- Volcanic bedrock wells located in the middle of the basin (GL3-1, GL9-1 and GL29-1) plot in a similar region at the bottom of the piper plot, just above the afore-mentioned sedimentary bedrock wells. These wells are inferred not to be impacted by landfill leachate.
- Non-leachate-impacted wells completed in glaciolacustrine deposits and in sedimentary bedrock along the middle and east side of the Landfill plot in a similar region in the central left side of the piper plot. Groundwater quality at these wells is inferred to be due to groundwater recharge of these wells from the north and east of the Landfill.
- The groundwater quality at leachate-impacted wells trend toward the upper right portion of the piper plot.
- If groundwater was flowing towards and into the bedrock faults from the glaciolacustrine deposits across the Landfill Footprint, groundwater quality at bedrock wells in the vicinity of the faults would trend towards the upper right portion of the piper plot, in the region of the leachate-impacted wells. Based on the available data, this trend is not observed.
- The most down-gradient bedrock wells at the Landfill (GL9-1, GL17-1 and GL27-1) do not show leachate impacts to groundwater quality.

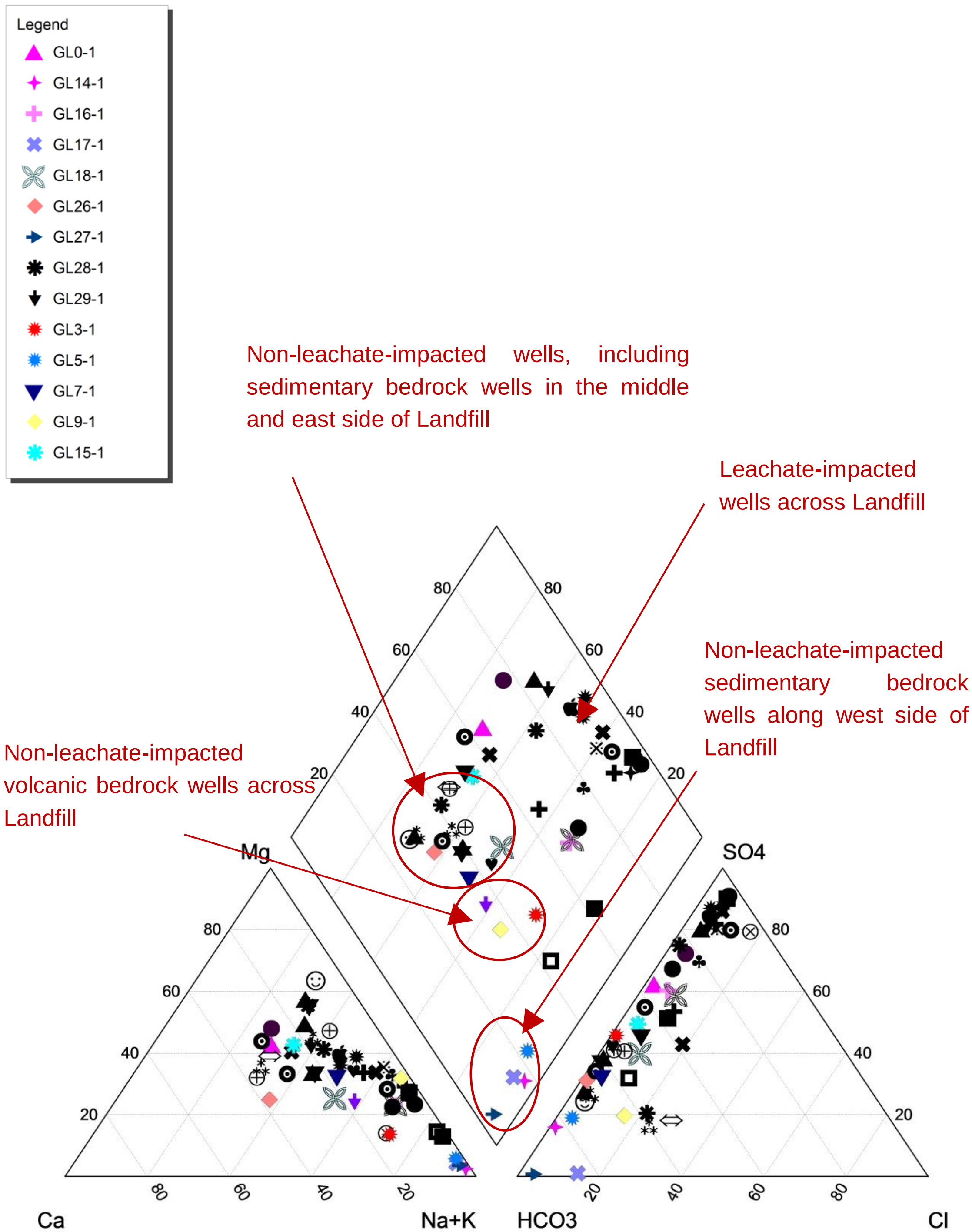

Figure 4: Piper plot showing most recent (2009 - 2013) available groundwater quality at each well. Bedrock wells are identified in legend and are shown in colour on piper plot.

Golder Associates

3.0 SUMMARY

Based on the results of the hydrogeological assessment, as well as the outcome of SLR's scope of work (SLR, 2014), the bedrock faults and/or associated fractures do not appear to be acting as drains for groundwater flow away from the Landfill. Rather, the predominance of upward gradients between the bedrock and overlying glaciolacustrine deposits is suggestive that groundwater in the bedrock is a source of recharge for the basin deposits.

The deeper bedrock faults and/or associated fractures are inferred to present a low likelihood to the City in terms of groundwater and leachate migration. It is our opinion that at this time additional investigations are not required to further assess the bedrock faults and/or fractures. However, it is recommended that a groundwater monitoring program be put in place to monitor the effects of leachate recirculation on the groundwater system. Golder should be consulted during subsequent planning for the leachate recirculation system to develop the monitoring program.

4.0 LIMITATIONS

This letter report (report) was prepared for the exclusive use of the City of Kelowna (the Client). Any use that a third party may make of this report, or any reliance on or decisions made based on it, is the responsibility of the third parties. We disclaim responsibility for consequential financial effects on transactions or property values, or requirements for follow-up actions and costs.

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The findings, interpretations and conclusions are based solely on the Site conditions at the time they were assessed. The data presented in this report represent the groundwater conditions at the sampling locations tested. Conditions may vary with location, depth, sampling, methodology, analytical techniques and other factors.

The services performed as described in this report were conducted in a manner consistent with the level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services. The content of this report is based on information collected during monitoring programs, our present understanding of Site conditions, the assumptions stated in this report, and our professional judgement in light of such information at the time of this report. This report provides a professional opinion and, therefore, no warranty is expressed, implied, or made as to the conclusions, advice and recommendations offered in this report. This report does not provide a legal opinion regarding compliance with applicable laws. With respect to regulatory compliance issues, it should be noted that regulatory statutes and the interpretation of regulatory statutes are subject to change. The findings and conclusions of this report are valid only as of the date of the report. If new information is discovered in future work, or if the assumptions stated in this report are not met, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

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5.0 CLOSURE

We trust that this report provides the information you require at this time. Should you have any questions or require additional information, please do not hesitate to contact the undersigned.

Regards,

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PA/JF/jc/kv

Attachments: Attachment A – Table A1 Bedrock Summary
Attachment B – Sand & Gravel Contours
Attachment C – Vertical Gradients Summary

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6.0 REFERENCES

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Okulitch, A.V. (comp.), 2013. Geology, Okanagan Watershed, British Columbia; Geological Survey of Canada, Open File 6839, scale 1:100,000. Doi:10.4095/292220.

SLR Consulting (Canada) Ltd. (SLR). 2014. Water Well Survey and Bedrock Geology Review in the Vicinity of the Glenmore Landfill – 2105 Glenmore Road North, Kelowna, BC. Project No. 219.05164.00002. Report submitted by SLR to the City of Kelowna in conjunction with this report.

ATTACHMENT A

Table A1 Bedrock Summary

Table A1: Summary of Bedrock Conditions (Elevations in metres above sea level [masl])

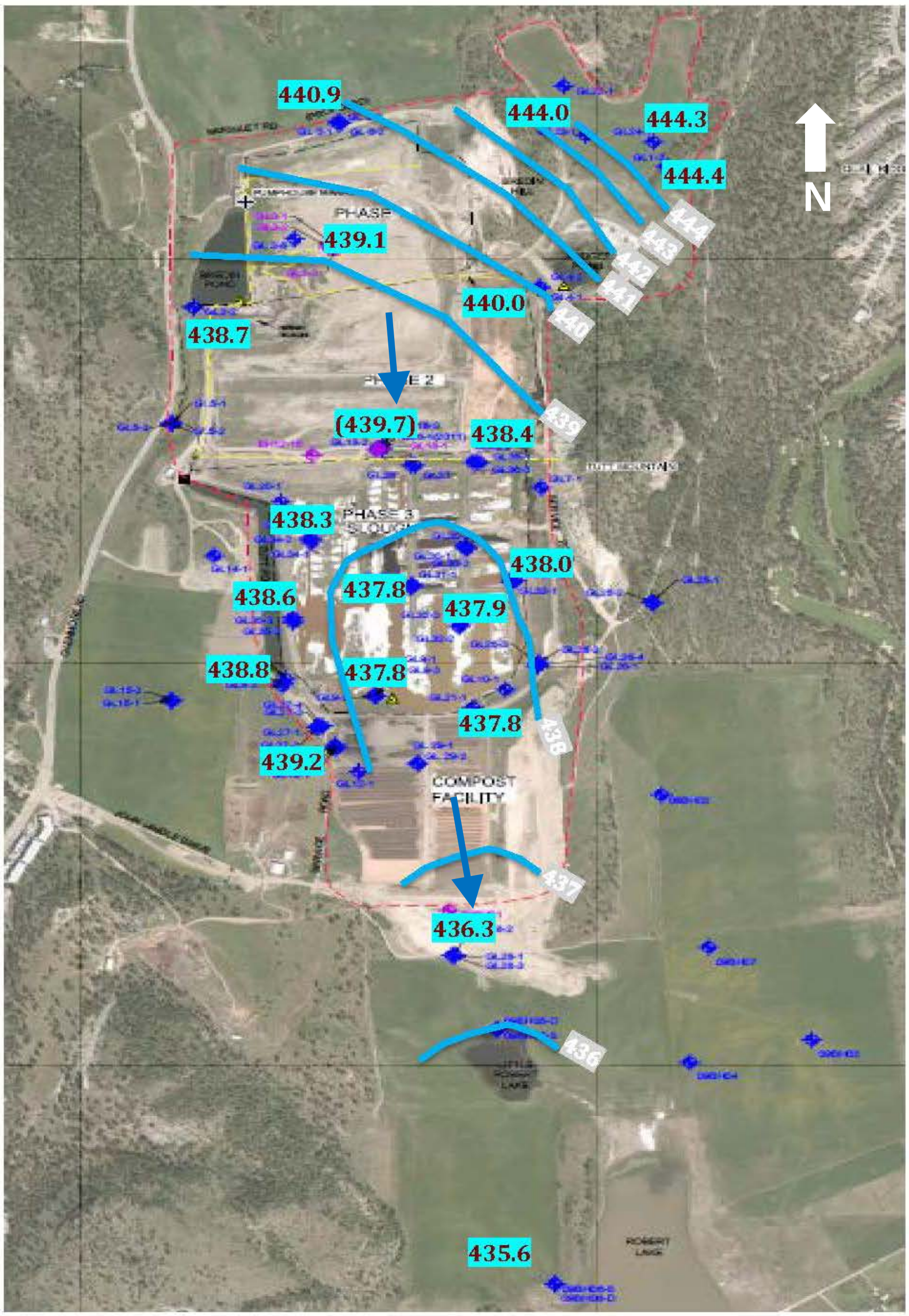
	Weathered Zone		Bedrock				
Borehole ID	**Top Elevation**	**Description**	**Top Elevation**	**Reported Bedrock Type**	**Fracture Frequency and Description**	**Other Observations**	**Bottom of Borehole Elevation**
GL0-1	"fractured green rock" between 432.8 and 429.5 masl		426.8	orange rusty colour on rock fragments, some volcanic ash, dense, light green, dry	Not indicated on borehole log	n/a	425.8
GL3-1	None reported		396.7	dark grey, volcanic	Not indicated on borehole log	Groundwater reportedly flowing artesian at time of drilling	392.8
GL5-1	None reported		424.6	light grey, crystalline	Not indicated on borehole log	n/a	419.6
GL7-1	438.5	"light brown/grey weathered bedrock"	436.7	light grey/green, fractured bedrock	Not indicated on borehole log	Well set in weathered zone	433.6
GL9-1	410.9	"gravel and coarse sand with some weathered bedrock" to "weathered bedrock"	406.4	green/grey, soft bedrock	Not indicated on borehole log	Well set in weathered zone	406.4
GL14-1	449.3	"…gravel, some silt, trace sand (weathered bedrock)"	444.9	grey (meta)conglomerate	0 to 3 fractures/m	Subangular to angular gravel sizes in a medium to coarse sand matrix	432.1
GL15-1	441.9	"…silty gravel, trace sand (weathered bedrock)"	439.6	dark grey, (meta)sandstone	2 to 4 fractures/m	n/a	433.9
GL16-1	429.7	"…silt grading to laminated silt (weathered bedrock)"	427.8	light grey, thinly bedded, interlayered siltstone and fine-grained sandstone	1 to 3 fractures/m; fracture feature at 426.2 masl; "numerous fractures/ weathered zone" at 424.7 masl	Evidence of rehealed joints	424.1

	Weathered Zone		Bedrock				
Borehole ID	**Top Elevation**	**Description**	**Top Elevation**	**Reported Bedrock Type**	**Fracture Frequency and Description**	**Other Observations**	**Bottom of Borehole Elevation**
GL17-1	421.4	"…gravel with dark brown organic clayey silt (weathered bedrock)"	420.5	dark brown/black mudstone, thinly bedded to laminated with occasional light grey fine sand or siltstone layers	"highly fractured bedrock"	Borehole log notes that "most breaks appear drilling-induced"	416.3
GL18-1	419.5	"….laminated silty sand, trace gravel (weathered bedrock)"	418.3	light grey, thinly layered to laminated siltstone; fine to medium grained sandstone between 416.0 and 416.9 masl	2 to 7 fractures/m	n/a	413.9
GL25-1	None reported		438.4	light grey to dark grey siltstone	Slightly fractured between 438.4 and 435.7 masl; some fractures between 435.7 and 434.8 masl	n/a	433.4
GL26-1	None reported		433.8	light grey to dark grey siltstone; becomes mudstone at 418.0 masl	Some fractures between 433.8 and 433.0 masl; occasional (few) fractures to 418.0 masl; some fractures 414.4 to masl	n/a	414.4
GL27-1	426.6	weathered and fractured siltstone	417.3	layered grey siltstone and dark grey sandstone	Highly fractured between 415.6 and 412.9	n/a	412.0
GL28-1	None reported		418.9	light grey to dark grey siltstone	"few fractures" between 418.9 and 411.7 masl; fractured between 411.7 and 411.1 masl, with a few clay infilled fractures; "few fractures" to 409.6 masl	Drilling water lost; inferred to have been lost into fractures at 411.7 masl	409.6
GL29-1	None reported		400.2	"large rock pieces"	Not indicated on borehole log	n/a	399.3
BH11-9 (between GL34 and GL30 well series)	408.8	weathered volcanic bedrock, weak, dry, grey; green and black layers throughout					393.0

	Weathered Zone		Bedrock				
Borehole ID	**Top Elevation**	**Description**	**Top Elevation**	**Reported Bedrock Type**	**Fracture Frequency and Description**	**Other Observations**	**Bottom of Borehole Elevation**
BH11-10/ BH11-11 (between GL30 and GL7 well series)	None reported		418.5	volcanic bedrock, grey, and dry, with green laminations and some black, rusty or white layers throughout	Not indicated on borehole log	n/a	396.6
GL33-3	None reported		427.0	volcanic bedrock, white with green layers, dry	Not indicated on borehole log	n/a	425.0
BH11-23 (between GL32 and GL33 well series)	None reported		422.0	volcanic bedrock, some black crystals throughout, green and white, dry	Not indicated on borehole log	n/a	420.0
BH11-24 (between GL32 and GL26 well series)	None reported		424.6	volcanic bedrock, hard, white, dry	Not indicated on borehole log	n/a	423.0
09BH05	None reported		412.1	mudstone	Not indicated on borehole log	n/a	412.0
09BH06	None reported		425.2	mudstone	Not indicated on borehole log	n/a	425.0

ATTACHMENT B
Sand & Gravel Contours

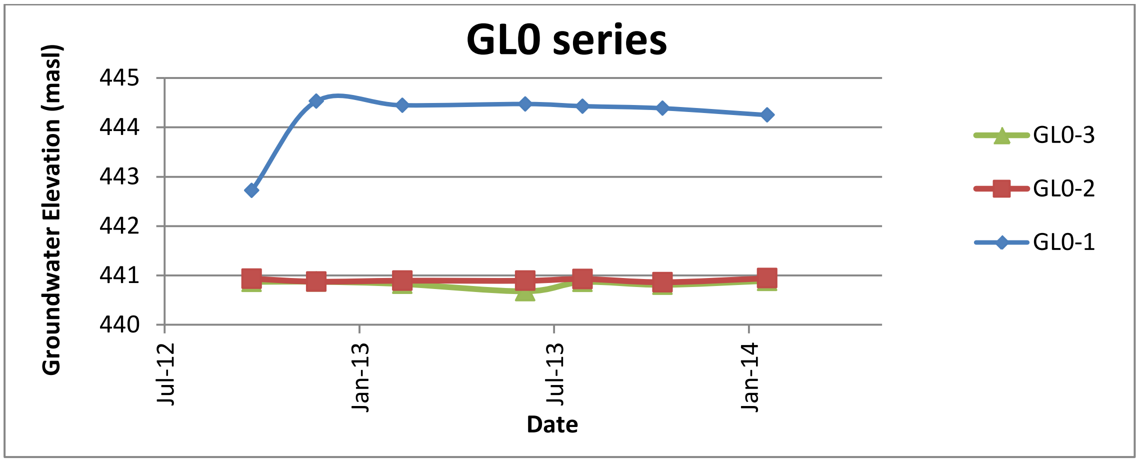
The inferred direction of groundwater flow in the sand and gravel unit at the Landfill is shown on the plan below (blue arrows). Groundwater elevations measured by the City of Kelowna on February 18, 2014. Blue lines represent inferred groundwater contours at 1m intervals.



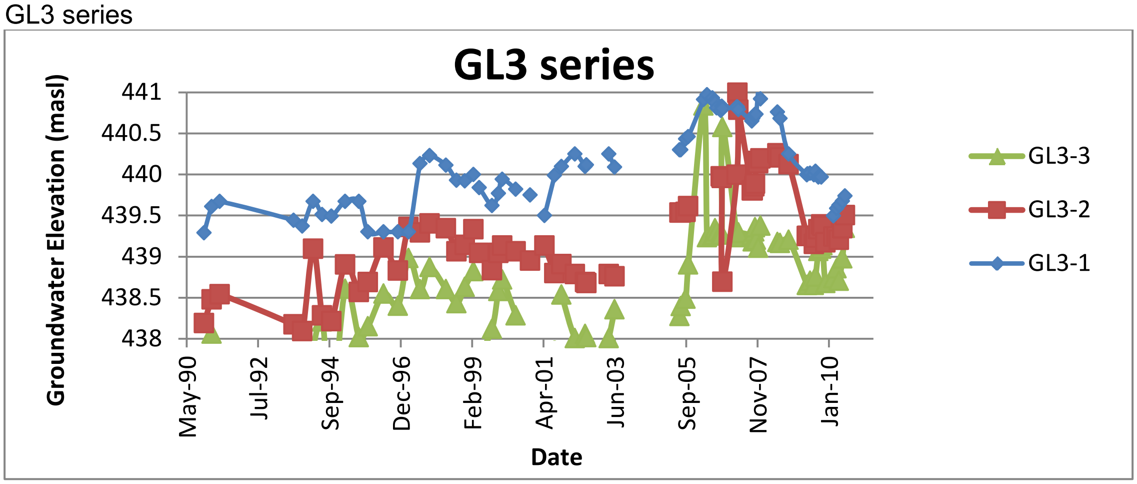
ATTACHMENT C
Vertical Gradients Summary

Vertical Hydraulic Gradients: Groundwater elevations trends are plotted for each well series. Blue line represents groundwater elevations of bedrock well; red line represents groundwater elevations of middle elevation well (where present); and green line (and purple line, where four wells are present) represents groundwater elevation(s) of shallowest well(s).

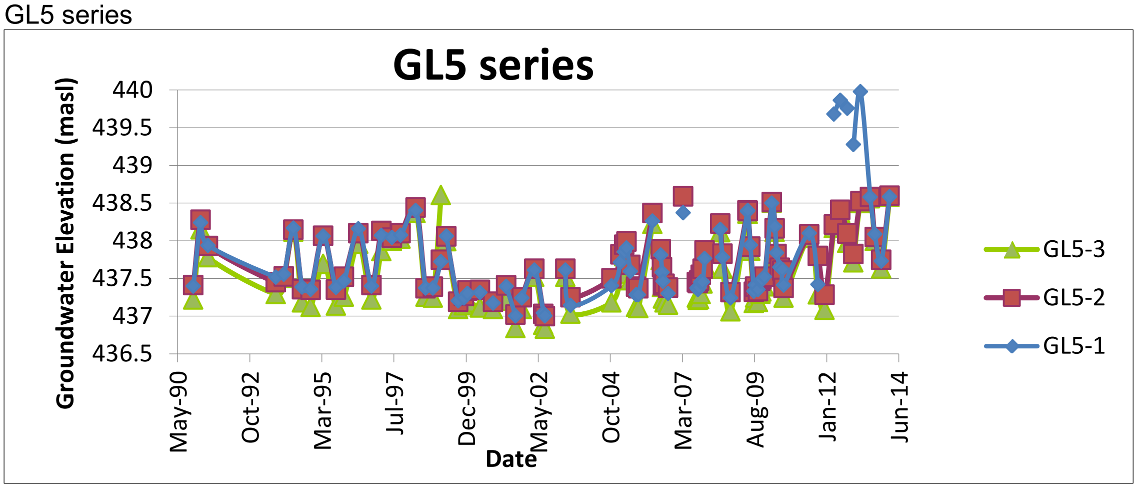
GL0 Series



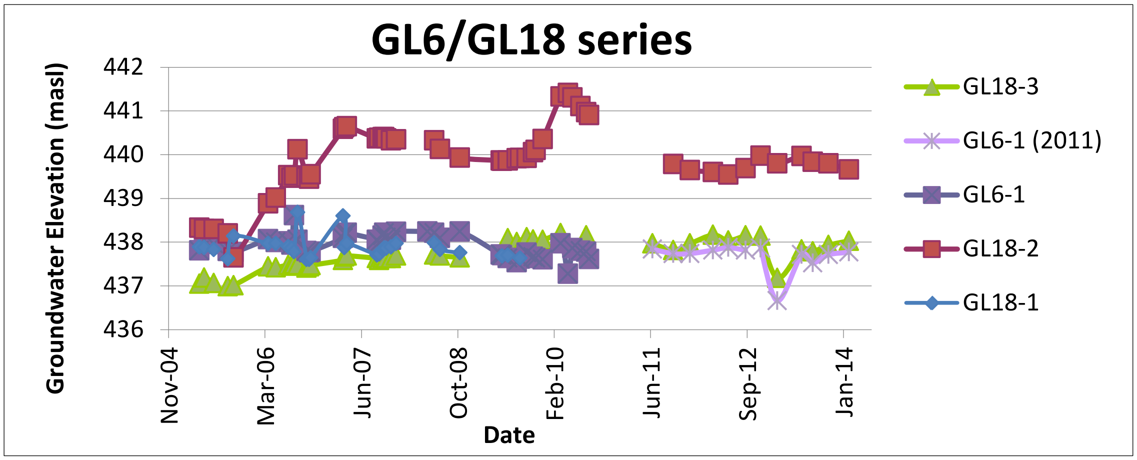
GL3 series



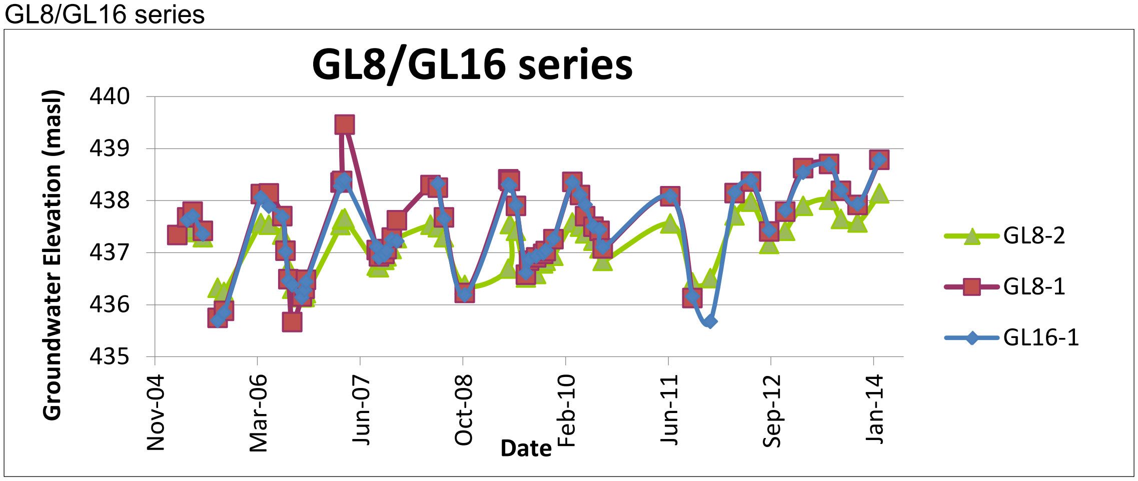
GL5 series



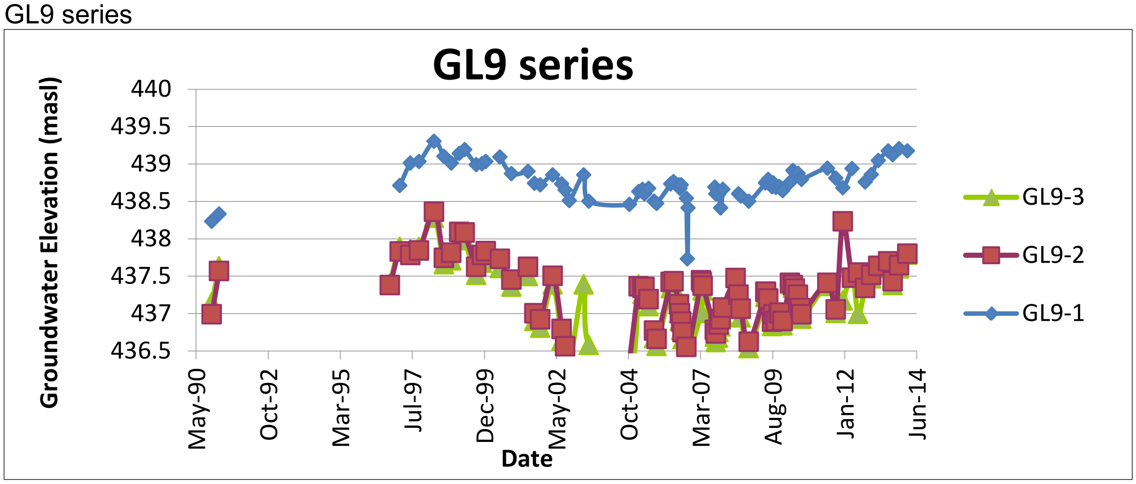
GL6/GL18 series



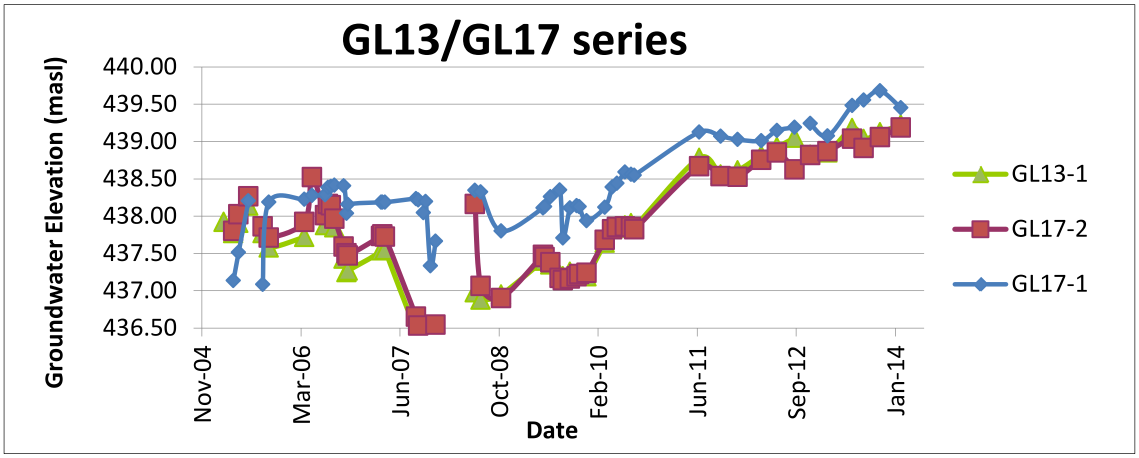
GL8/GL16 series



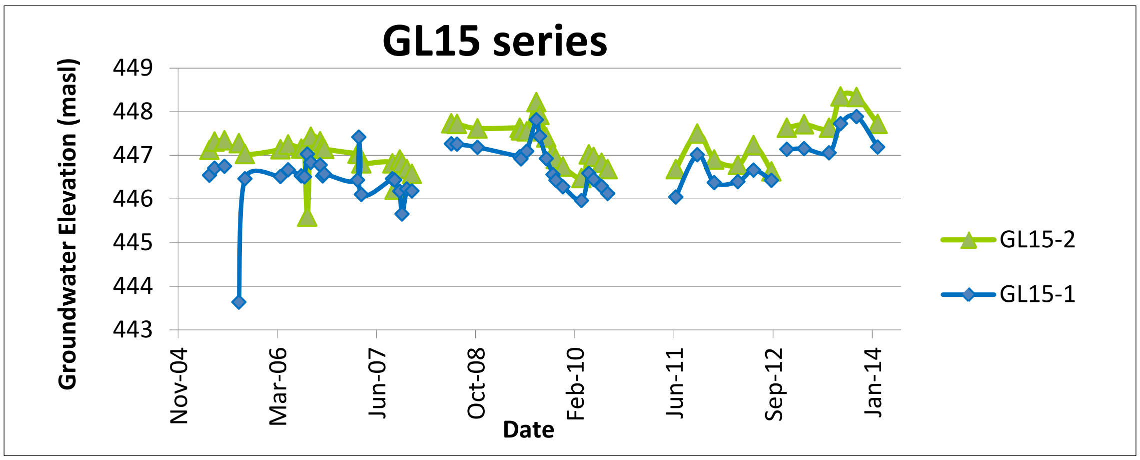
GL9 series



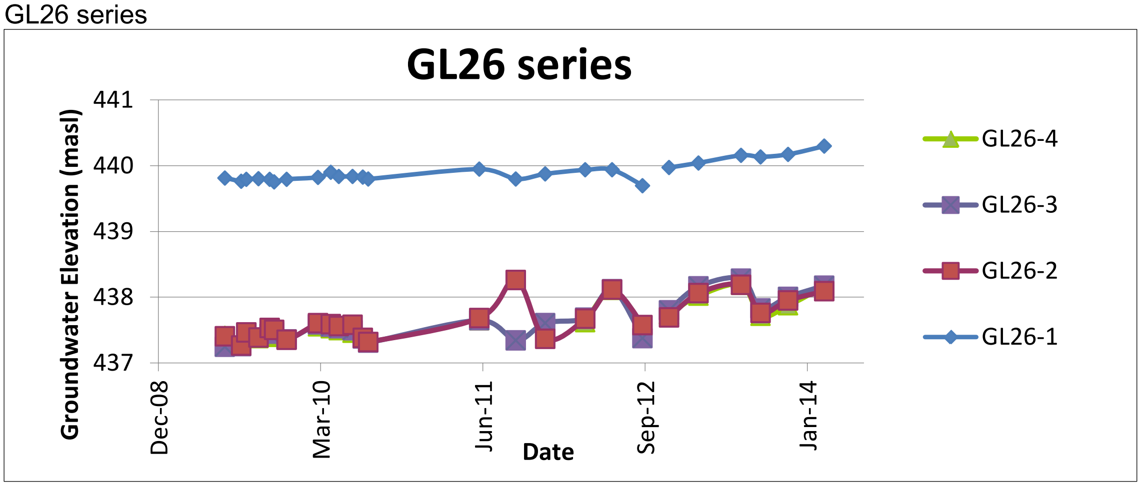
GL13/17 series



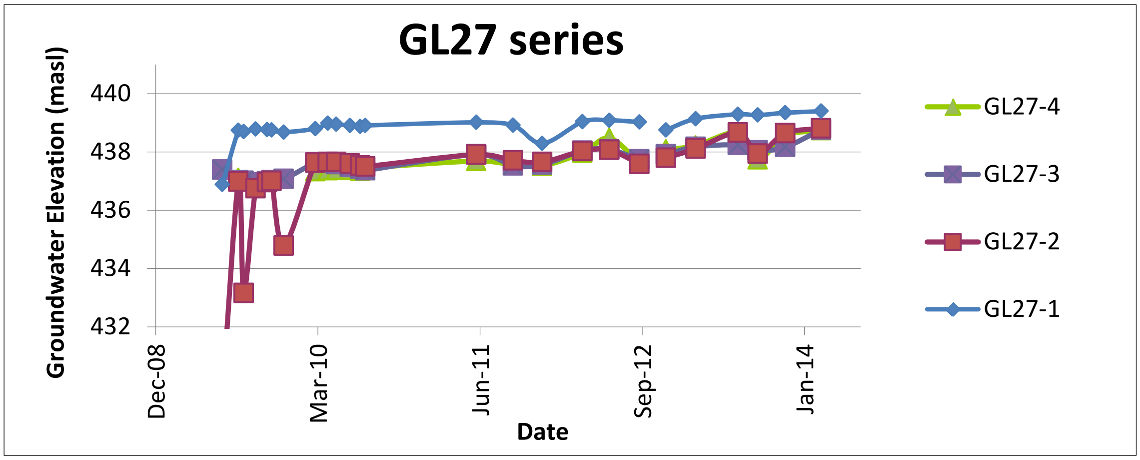
GL15 series



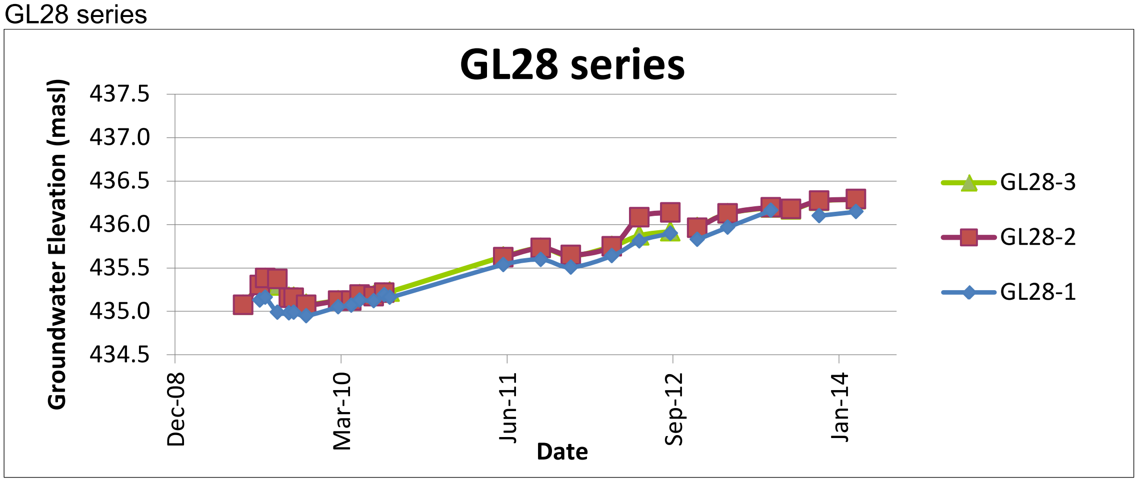
GL26 series



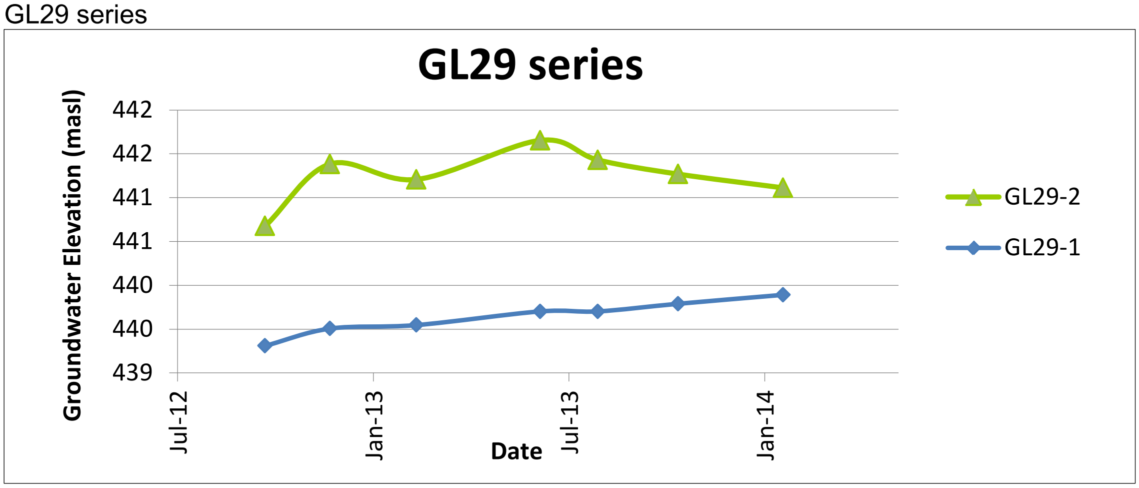
GL27 series



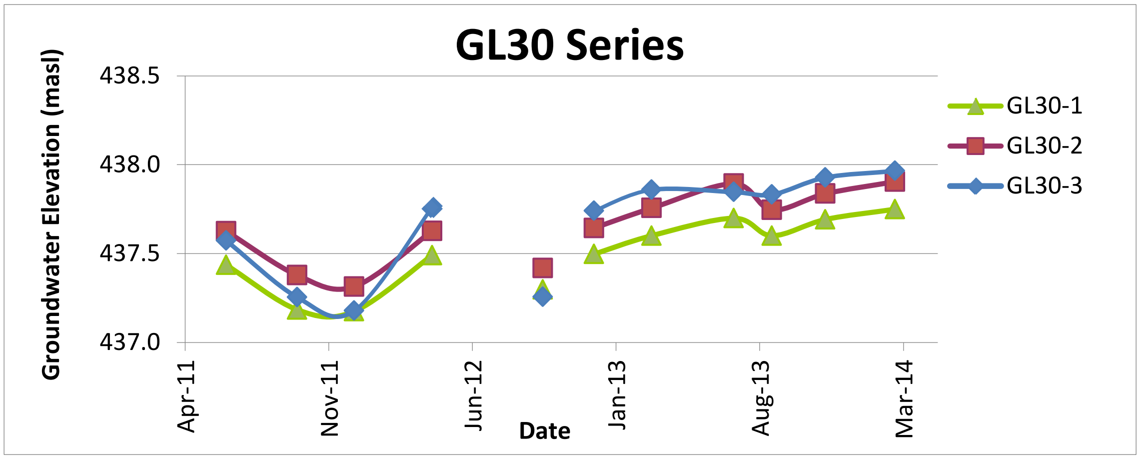
GL28 series



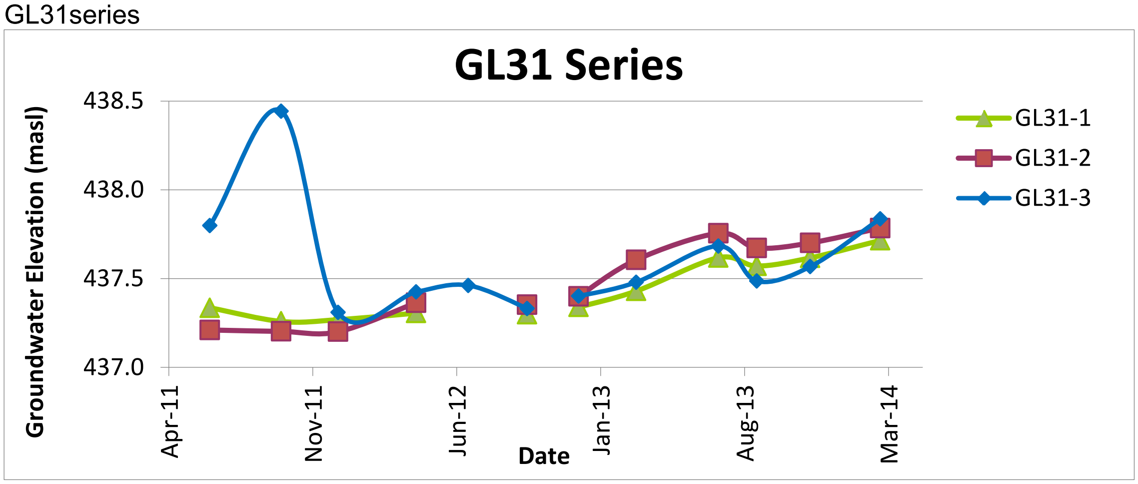
GL29 series



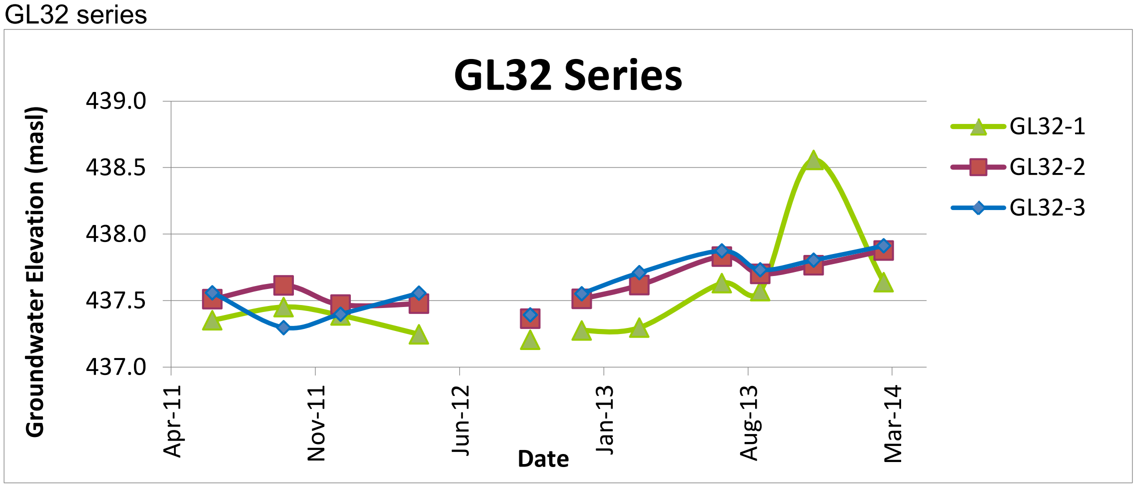
GL30 series



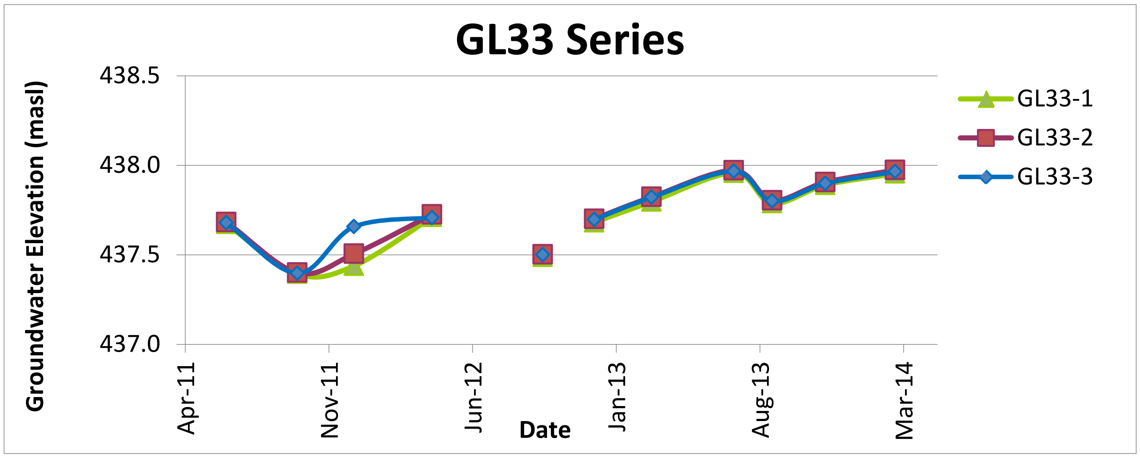
GL31series



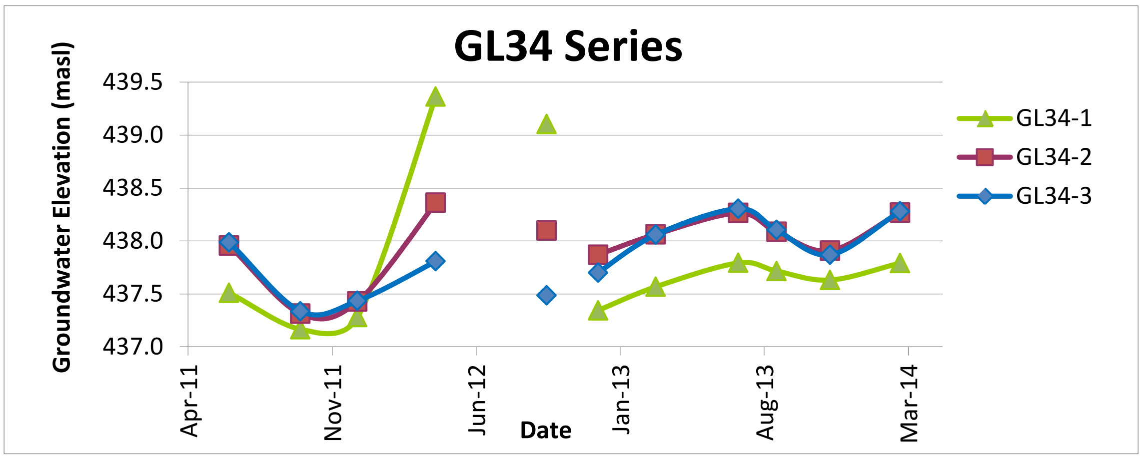
GL32 series



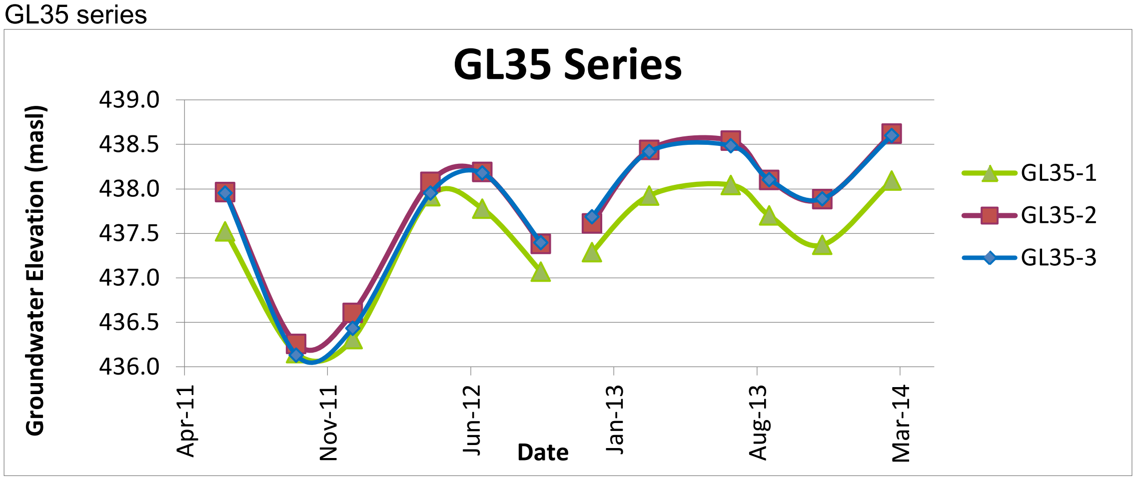
GL33 series



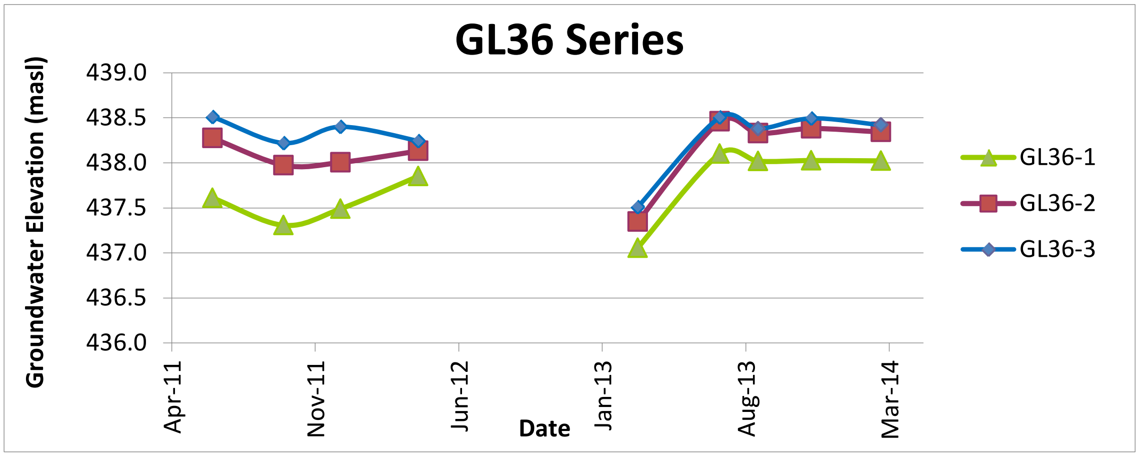
GL34 series



GL35 series



GL36 series


GL36 Series
Groundwater Elevation (masl)
439.0
438.5
438.0
437.5
437.0
436.5
436.0
Apr-11
Nov-11
Jun-12
Jan-13
Aug-13
Mar-14
Date
GL36-1
GL36-2
GL36-3