TECHNICAL MEMORANDUM

DATE June 13, 2019 **Project No.** 1520304.402.1

TO Mr. Travis Bennett
Holcim (US) Inc

CC Alan Noell, Washington State Department of Ecology

FROM Gary L. Zimmerman **EMAIL gzimmerman@golder.com**

2019 GEOPHYSICS SURVEY

On April 4, 2019 Golder Associates Inc. (Golder) conducted a geophysical investigation to further delineate the areas of potentially impacted shallow groundwater north and west of the Lower Disposal Area (LDA). A prior survey was conducted by Golder in 2010 over the capped LDA area and the area immediately west of the LDA. The prior survey effectively identified subsurface areas where relatively higher pH groundwater was present within the LDA capped area and immediately west of the LDA. The objectives of the additional investigation described in this letter report were to: expand the area of investigation and delineate the lateral extent of the high pH shallow groundwater downgradient of the South Pond and the Infiltration Ponds. The following is a brief discussion of the methods and instrumentation used for the survey, and a discussion of the survey results.

1.0 GEOPHYSICAL METHODS, INSTRUMENTATION, AND PROCEDURES

Golder employed a frequency domain electromagnetic (EM) methods to locate areas suspected to contain groundwater with high pH. The relatively higher pH groundwater exhibits a correspondingly higher electrical conductivity, which is measured by the EM instrument as described below.

Electromagnetic (EM) induction instruments (such as the Geonics EM-31MKII utilized in this investigation) are used to measure the apparent electrical conductivity of the near surface. A transmitter coil is used to induce an electrical (eddy) current into the ground. Electrically conductive materials in the ground induce secondary EM currents and a receiver coil measures the strength of the secondary EM field generated by these currents.

The quadrature component is primarily designed to be sensitive to materials that have a low induction number, such as earth materials, or poorly conducting metallic targets. Typically, the quadrature response is referred to as the apparent conductivity response since terrain conductivity is nearly linearly proportional to strength of the quadrature-phase component. The EM instrument's quadrature response is calibrated to give a measure of the bulk apparent conductivity of the subsurface centered at the measurement point. For this survey, quadrature-phase measurements were collected in order to provide a profile of measured apparent conductivity (given in units of milli-siemens per meter [mS/m]).

Apparent conductivity (also known as terrain conductivity) is a measure of the bulk conductivity of the subsurface, which is primarily a function of mineralogy, interconnected porosity, moisture content and the dissolved ion concentration in the pore fluid. An increase in any of these properties results in an elevated apparent conductivity. High pH water contains relatively higher concentration of hydroxyl anions (-OH).

The Geonics Ltd. EM-31MKII is a one-person operable electromagnetic induction device well-suited to mapping apparent terrain conductivity with the transmitter and receiver coils mounted at either end of a 3.7-meter-long (12.1 foot) boom. For this project, the field crew used a digital "mark two" version of the EM-31 (EM-31MKII) coupled with a Juniper Systems Allegro field computer acting as a data logger for both the EM data and GPS data.

Based on the response curve developed by the manufacturer, the depth of maximum contribution to EM-31 instrument response is roughly 8 feet; however, the instrument responds to significant changes in earth conductivity at all depth to approximately 6 meters (19.6 feet), which is the depth where the majority of the response is generated and is generally considered the "effective exploration depth." When this instrument is carried at waist height, the effective exploration depth is reduced by the height of the instrument above the ground surface.

2.0 GEOPHYSICAL RESULTS

The current survey area overlapped the western portion of the 2010 survey, which allowed a comparison of the two survey results in that area. The current survey extended to the west and north to include the area around the South Pond and the Infiltration Ponds. The site includes woods and brush that made surveying along a uniform grid impractical. The survey was conducted along pathways and through clearings with some brush cutting completed as needed to navigate through the survey area. The areas inside the fences that surround the South Pond and the Infiltration Ponds were not surveyed, because the ponds contained water preventing safe access. The geophysics investigate included both up- and down-gradient areas of the ponds and in the area downgradient of the diversion ditch.

The color contour plot generated by a composition of the data in Figure 1 shows area of higher conductivity shallow groundwater in red, and lower conductivity in blues and green. Figure 1 combines the 2010 and the April 2019 survey results into one figure and delineates the two surveys by outline. The presence of near-surface metal, such as fencing, influences the measured EM conductivity values and can generate higher conductivity, interpreted as false positives. The fencing around the diversion ditch, ponds and roadway were mostly avoided during the investigation but small sections were unavoidable. These known false positive higher conductivity areas were accounted for on Figure 1 to the extent possible. Results of the survey indicate the following:

- Consistent with the 2010 survey, the areas where high pH water is entering the seepage collection ditch appear as a zone of high conductivity in the survey. There also appears to be a possible buried metal pipe or culvert near the NW end of the collection ditch that extends to the northwest.
- In the area upgradient of the South Pond, higher conductivity extends from collection trench west towards the south pond. Downgradient (west to southwest direction) of the South Pond, the higher conductivity measurements extend approximately a maximum of 60 feet before attenuating to background levels. North and south of the South Pond, the groundwater electrical conductivity is at background levels within 20 feet of the fenced area of the pond.
- In the area around the Infiltration Ponds, higher conductivities values are only present along the north and western portions of the infiltration ponds. This is consistent with the groundwater monitoring data that is collected from monitoring wells surrounding the infiltration ponds. The wells located on the south and east sides of the infiltration ponds (MW-1A and MW-2A) do not exhibited elevated pH levels. High pH readings have been recorded in wells MW-5A and MW-6A located west and north, respectively, of the infiltration

ponds. The geophysics study indicates that the high conductivity groundwater does not extend more than 50 feet downgradient of the Infiltration Ponds. The survey was conducted in the early spring, following the seasonal wet season when flow to the infiltration ponds is the highest. As such, this measured extent of high conductivity likely represents the typical seasonal maximum extent.

Golder appreciates working with you on this continuing project and we trust this report meets your needs. Please feel free to reach out to us at 425-883-0777 or via email with any questions, clarifications, or concerns related to this work.

Sincerely,

GOLDER ASSOCIATES INC.

Peter E Fahringer
Associate and Senior Geophysicist

Gary L. Zimmerman
Principal and Practice Leader

PEF/GZ/em

https://golderassociates.sharepoint.com/sites/11287g/2019agreed order rifs2/2019-geophysics/2019-geophysics survey results-pef-gz.docx

Figure

NOTE(S)

1. BASE TOPOGRAPHY OUTSIDE OF LDA FOOTPRINT PREPARED BY AERO-METRIC, INC., SEATTLE, WA FROM AERIAL PHOTOS FLOWN ON FEBRUARY 10, 2007.

   HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD 27 US FEET - TRANSLATED TO NAD83/91 (HARN)
   VERTICAL DATUM: NGVD 29 - TRANSLATED TO NAVD88
   CONTOUR INTERVAL: 5 FT

2. BASE TOPOGRAPHY INSIDE OF LDA FOOTPRINT PREPARED BY PACIFIC GEOMATIC SERVICES, INC., MOUNTLAKE TERRACE, WA FROM FIELD DATA TAKEN ON NOVEMBER 1, 2007.

   HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD 27 US FEET - TRANSLATED TO NAD83/91 (HARN)
   VERTICAL DATUM: NGVD 29 - TRANSLATED TO NAVD88
   CONTOUR INTERVAL: 1 FT

3. BASE TOPOGRAPHY INSIDE OF DSP FOOTPRINT PREPARED BY PARAMETRIX, INC., BELLEVUE, WA FROM FIELD DATA TAKEN ON JULY 6, 2011.

   HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD 27 US FEET - TRANSLATED TO NAD83/91 (HARN)
   VERTICAL DATUM: NGVD 29 - TRANSLATED TO NAVD88
   CONTOUR INTERVAL: 1 FT

LEGEND

- APPROXIMATE 2019 GEOPHYSICS SURVEY EXTENTS
- APPROXIMATE 2010 GEOPHYSICS SURVEY EXTENTS
- MW-1A — ALLUVIAL MONITORING WELL
- MWB-1DDSP — BEDROCK MONITORING WELL
- MWB-2DSP — BEDROCK MONITORING WELL (NOTE 4)
- LDA SURFACE WATER SAMPLING LOCATION
- DSP BEDROCK SAMPLING LOCATION (PORTAL)
- INTERCEPTOR TRENCH SAMPLING LOCATION
- — x — x — FENCE LINE

0 100 200
1" = 100' FEET

CLIENT
HOLCIM

CONSULTANT
GOLDER

YYYY-MM-DD	2019-05-15
DESIGNED	PF
PREPARED	REDMOND
REVIEWED	GZ
APPROVED	GZ

PROJECT
RAVENSDALE

TITLE
2010 AND 2019 EM-31 APPARENT CONDUCTIVITY SURVEYS

PROJECT NO.	PHASE	REV.	FIGURE
1520304	402	A	1