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MEMORANDUM

DATE: January 22, 2009
TO: Christopher Prucha (WM)
C.C:
FROM: François Richard (WESA)
PROJECT #: K-B5691-6
SUBJECT: **WM Richmond Landfill: Groundwater Flow in the Zone 3-10 m below Top of Bedrock**

MESSAGE:

Chris:

This memorandum is an update to our previous memorandum with same subject, dated December 16, 2008. The only difference between the two documents is the removal of groundwater monitor OW57; because the well is screened in the upper one metre of bedrock, it should not have been included in the previous analysis. In particular, the shallow groundwater divide observed in the southwest portion of the site using water levels from shallow monitors (screened in overburden and/or upper 3 meters of bedrock) is also present in the interpreted groundwater surface using water levels from the deeper monitors (screened in the zone between 3 and 10 metres below bedrock (mbBR)). The conclusion that groundwater flow direction is consistent between the two zones has not changed as a result of this correction.

This memorandum addresses questions raised by MOE hydrogeologists Kyle Stephenson and Frank Crossley during our meeting held in Kingston on November 25, 2008. During the meeting, the site conceptual hydrogeologic model was discussed, including the rationale used to identify groundwater monitors representative of the active flow regime and therefore suitable for contouring. It was agreed that the primary pathway for groundwater flow and potential leachate migration is comprised of the saturated overburden and upper bedrock.

However, the MOE noted that most of the monitors retained for the contouring and interpretation of shallow groundwater flow direction are screened in overburden and/or in the upper 3 mbBR. Concerns were raised about water levels and groundwater flow directions in the portion of the bedrock immediately underlying this shallowest hydrostratigraphic unit, that is, groundwater flow in the zone 3-10 mbBR. Specifically, discussion focused on the hydraulic connectivity between this zone and the shallowest zone, and whether the groundwater flow direction is consistent between these two zones.

To address these questions, it was agreed that groundwater monitors screened between 3 and 10 mbBR would be examined and the groundwater flow interpretation reviewed. Monitors partially completed in the upper 3 mbBR were excluded in order to better assess the groundwater flow

regime in the 3-10 mbBR zone alone. Historical hydrographs and monitor construction details were carefully reviewed for each of the 35 monitors screened in this zone and located in proximity to the existing landfill, which were then classified in terms of their suitability for groundwater contouring in accordance with the agreed-upon methodology used previously (see Table 1). Suspect construction integrity and absence of hydraulic connection were the principal reasons to classify monitors as unsuitable for contouring.

Figure 1 identifies the monitors screened in the 3-10 mbBR zone, along with groundwater elevations measured on October 14, 2008. Monitors suitable for contouring are shown in green, while monitors not suitable for contouring are shown in red. Suitable water levels were contoured, and confirm that water levels in the 3-10 mbBR hydrostratigraphic unit are consistent with previous interpretations presented of shallow groundwater flow directions, most recently in a figure presented during the meeting (October 2008 groundwater elevations and contours), and previously in WESA (2008)[1] for groundwater elevations measured on June 27, 2008. In particular, the groundwater divide running approximately parallel to the Empey Hill drumlin has an influence on groundwater flow directions down in the 3-10 mbBR interval. Note that monitoring wells M6-3 and OW1 (both located to the north of the landfill) have historically been used in the contouring for the uppermost hydrostratigraphic unit; they are also used in the contouring of the 3-10 mbBR unit since they are screened in this zone.

Based on the information above, it can be concluded that the saturated overburden and the upper 10 mbBR behave as a single monitorable hydrostratigraphic unit. The interpreted shallow groundwater flow directions show minimal differences in the 3-10 mbBR zone compared to the shallower zone. It is therefore appropriate to use groundwater monitors screened in the overburden and/or in the upper 10 metres below the bedrock surface to characterize shallow groundwater flow at the Richmond Landfill.

[1] WESA, 2008: *June 2008 Supplemental Hydrogeological Investigation – Richmond Landfill*, memorandum to C. Prucha (WM), July 23, 2008

Table 1. Groundwater Monitor Details, Water Levels and Suitability for Contouring

Monitor	Type	Ground Elevation	Screen Top	Screen Bottom	BR Elev	BR-10m	BR-3m	Groundwater Elevation	Suitable	Notes
		(masl)	(masl)	(masl)	(masl)	(masl)	(masl)	(masl)		
M3A-3	multilevel	126.96	117.96	115.96	122.00	112.00	119.00	124.48	Yes	Seasonal fluctuations
M4-3	multilevel	125.64	117.14	115.64	122.64	112.64	119.64	123.36	Yes	Relatively constant water levels; possible seasonal fluctuations
M5-3	multilevel	123.20	117.20	115.70	122.44	112.44	119.44	123.33	Yes	Seasonal fluctuations
M6-3	multilevel	123.73	118.73	117.23	122.23	112.23	119.23	123.43	Yes	Appears suitable; possible integrity issues beginning
M9-3	multilevel	124.80	115.50	114.00	121.90	111.90	118.90	119.71	No	Suspect Integrity
M10-2	multilevel	126.47	114.47	112.47	123.47	113.47	120.47	125.11	No	Suspect Integrity
M10-3	multilevel	126.47	119.97	116.97	123.47	113.47	120.47	120.89	No	Suspect Integrity
M46-2	multilevel	123.96	117.66	116.16	123.66	113.66	120.66	123.33	Yes	Seasonal fluctuations
M47-1	multilevel	126.82	117.42	116.12	121.82	111.82	118.82	123.67	No	Still recovering
M48-2	multilevel	134.11	115.11	113.81	119.21	109.21	116.21	122.41	No	Suspect Integrity
M49-2	multilevel	125.47	114.97	112.67	122.77	112.77	119.77	119.64	No	Suspect Integrity
M50-3	multilevel	125.25	116.25	114.75	122.00	112.00	119.00	124.24	Yes	Seasonal fluctuations; use with caution (integrity issues in deeper screens M50-1 and -2)
M51-2	multilevel	129.75	117.75	115.75	124.95	114.95	121.95	124.29	Yes	Possible seasonal fluctuations
M52-3	multilevel	128.78	122.08	120.78	126.88	116.88	123.88	124.53	Yes	Very low K but water level equilibrated since ~2001
M54-3	single	123.99	111.99	108.99	119.88	109.88	116.88	123.35	Yes	Seasonal fluctuations
M56-2	single	126.12	112.32	109.32	118.20	108.20	115.20	122.45	Yes	Seasonal fluctuations and good producer
M58-3	single	125.32	116.32	113.32	121.21	111.21	118.21	122.45	Yes	Seasonal fluctuations
M59-4	single	124.63	117.63	115.43	124.02	114.02	121.02	122.44	No	Suspect Integrity
M60-3	single	125.86	113.36	110.86	122.66	112.66	119.66	124.34	Yes	Slow recovery but possible seasonal fluctuations
M68-3	single	124.41	112.41	109.91	122.28	112.28	119.28	123.91	Yes	Very slow recovery (1998-2000) but water level stable since
M70-2	multilevel	127.05	115.05	113.55	124.61	114.61	121.61	121.10	No	Suspect Integrity
M74	single	125.04	117.68	115.51	121.92	111.92	118.92	122.97	Yes	Seasonal fluctuations
M75	single	123.57	118.98	116.64	122.53	112.53	119.53	123.41	Yes	Seasonal fluctuations
M76	single	126.70	117.61	115.27	123.41	113.41	120.41	124.16	Yes	Seasonal fluctuations
M82-2	single	122.33	117.33	114.33	121.13	111.13	118.13	122.34	Yes	Not a lot of data; very fast recovery during slug test

Monitor	Type	Ground Elevation	Screen Top	Screen Bottom	BR Elev	BR-10m	BR-3m	Groundwater Elevation	Suitable	Notes
		(masl)	(masl)	(masl)	(masl)	(masl)	(masl)	(masl)		
M87-1	single	125.40	114.00	111.00	117.78	107.78	114.78	124.32	Yes	Weeks to recover but water level stable for ~2 years
M88-1	single	128.96	113.56	110.56	117.86	107.86	114.86	125.05	Yes	Slow recovery (2005-06) but water level stable since
M89-1	single	131.67	114.07	111.27	121.31	111.31	118.31	111.79	No	Non responsive
M99-1	single	130.49	114.34	111.29	120.74	110.74	117.74	DRY	No	No recovery (dry)
OW1	single	122.96	117.71	117.21	122.66	112.66	119.66	122.86	Yes	Seasonal fluctuations
OW4	single	123.96	118.71	118.21	122.36	112.36	119.36	123.25	Yes	Seasonal fluctuations
OW37-d	single	121.61	112.66	111.86	120.11	110.11	117.11	122.08	Yes	
OW54-i	multilevel	124.82	116.57	112.67	121.82	111.82	118.82	119.40	No	Suspect Integrity
OW55-i	multilevel	125.12	117.87	112.87	122.42	112.42	119.42	122.96	No	Suspect Integrity
OW56-i	multilevel	123.94	116.24	111.69	122.42	112.42	119.42	123.13	No	Suspect Integrity

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Figure 1:
Groundwater Elevations in 3-10 m below bedrock zone
October 2008

LEGEND

- M81 124.55 — Shallow Groundwater Monitor (3-10 m below bedrock) suitable for contouring Groundwater Elevation (masl)
- M81 — Shallow Groundwater Monitor (3-10 m below bedrock) not used for contouring
- M52-3 — Shallow Groundwater Monitor (overburden or upper 3 m below bedrock)
- Hydro Tower
- Contour Lines

Project : K-B5691-6
Data Source: WM Canada, WESA, HPA Ltd.
Date: January 20, 2009

0 12.5 25 50 75 100 Meters

Prepared by:
WESA Geomatics

Units:
UTM NAD 83 Zone 18

Scale: 1:5000

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