APPENDIX I

Potentiometric Groundwater Surface Maps and Groundwater Velocity Calculations

Regional Aquifer

King County
Water and Land Resources Division
Department of Natural Resources and Parks
King Street Center
201 South Jackson Street, Suite 600
Seattle, WA 98104-3855
206.296.6519 Fax 206.296.0192
TTY Relay: 711

Memorandum

To: Tom Theno
King County Solid Waste Division

From: Sevin Bilir
King County Water & Land Resources Division

Re: **Potentiometric Groundwater Surface Mapping & Groundwater Velocity Calculation**
First Quarter 2011 Results
Cedar Hills Landfill, King County, Washington
Project No. G13303 – Task 722

Date: May 10, 2011

King County Water & Land Resources Division (KCWLRD) submits this letter report on groundwater conditions during the first quarter of 2011 for the Cedar Hills Landfill (landfill), in accordance with the *Proposal for Potentiometric Groundwater Surface Maps & Groundwater Velocity Calculations* (KCWLRD, 2011). King County Solid Waste Division (KCSWD) personnel measured groundwater elevations at the landfill on January 3rd and 6th, 2011. These measurements were received by KCWLRD on March 3, 2011 and were used to:

1. Evaluate the potentiometric groundwater surface elevation for the Regional Aquifer;
2. Determine the groundwater flow direction and horizontal gradient for the Regional Aquifer; and
3. Calculate the groundwater velocity of the Regional Aquifer.

There have been no significant changes in the interpreted groundwater conditions since the previous report submitted for the fourth quarter of 2010 monitoring event.

Groundwater Elevation Data

KCSWD measured groundwater levels at 43 monitoring wells quarterly during 2010. These wells were completed in the Regional Aquifer as referred to in *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill* (Aspect, 2010). Monitoring well MW-78 and supply well WS-ATC-1 were not measured due to access issues. Table 1 lists the well identifications, locations, well details, measured groundwater levels and calculated groundwater elevations for the Regional Aquifer. Wells with screened intervals within 10 feet of the water table were used for potentiometric surface mapping purposes. A total of 25 wells with water levels within ten feet of the top of screen were selected. Figure 1 shows well locations, groundwater elevations at the 25 selected wells, groundwater potentiometric surface contours, and interpreted groundwater flow direction in the Regional Aquifer for the January 3rd and 6th, 2011 measurement event.

Direction of Groundwater Flow

Figure 1 shows groundwater potentiometric surface contours and interpreted groundwater flow directions in the Regional Aquifer, based on the January 3rd and 6th, 2011 measurements. Groundwater elevations indicate that groundwater in the Regional Aquifer generally flowed north beneath the southern and central portions of the landfill with minor components of flow to the north-northeast and north-northwest. At the northern end of the landfill, groundwater generally flowed to the northeast and east.

Groundwater Velocity

Horizontal groundwater velocity was calculated using the following formula:

$$v = \frac{1}{n_{eff}} K \frac{\Delta H}{\Delta L}$$

where:
v = Groundwater velocity [L/t]
n_{eff} = Effective porosity [dimensionless]
K = Hydraulic conductivity [L/t]
$\frac{\Delta H}{\Delta L}$ = Hydraulic gradient [L/L]

Horizontal groundwater velocity was calculated for the Regional Aquifer below the landfill. Horizontal groundwater velocity was calculated for the southern, central, and northern portions of the Regional Aquifer, based on spatial differences in aquifer parameters and hydraulic gradients. The hydraulic conductivity and effective porosity values were based on the range referred to in the *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill* (Aspect, 2010).

Table 2 presents a summary of the hydraulic parameters used to calculate a groundwater velocity from the first quarter 2011 data. The hydraulic gradient was greatest under the southern portion of the landfill and smallest under the northern portion. On January 3rd and 6th, 2011, average horizontal groundwater velocity within the Regional Aquifer ranged from 0.015 feet per day (ft/d) under the southern portion of the landfill to 2.2 ft/day under the central portion of the landfill.

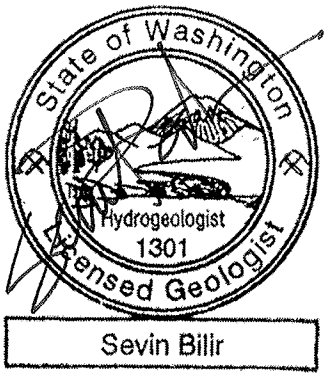
References

Aspect Consulting (Aspect). 2010. *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill*. Unpublished work. April 30.

King County Water & Land Resources Division (KCWLRD). 2011. *Proposal for Potentiometric Groundwater Surface Maps & Groundwater Velocity Calculations*. Unpublished.

Thank you for the opportunity to provide hydrogeologic services to the KCSWD. Please contact me if you have any questions.

Sincerely,



Sevin Bilir, WA LHG
Environmental Scientist III
King County Water & Land Resources Division

Attachments: Table 1: Groundwater Elevations - First Quarter 2011
Table 2: Groundwater Parameters - First Quarter 2011
Figure 1: Groundwater Potentiometric Surface Map – 1st Quarter -Regional Aquifer - 2011

Cedar Hills Landfill
King County, Washington

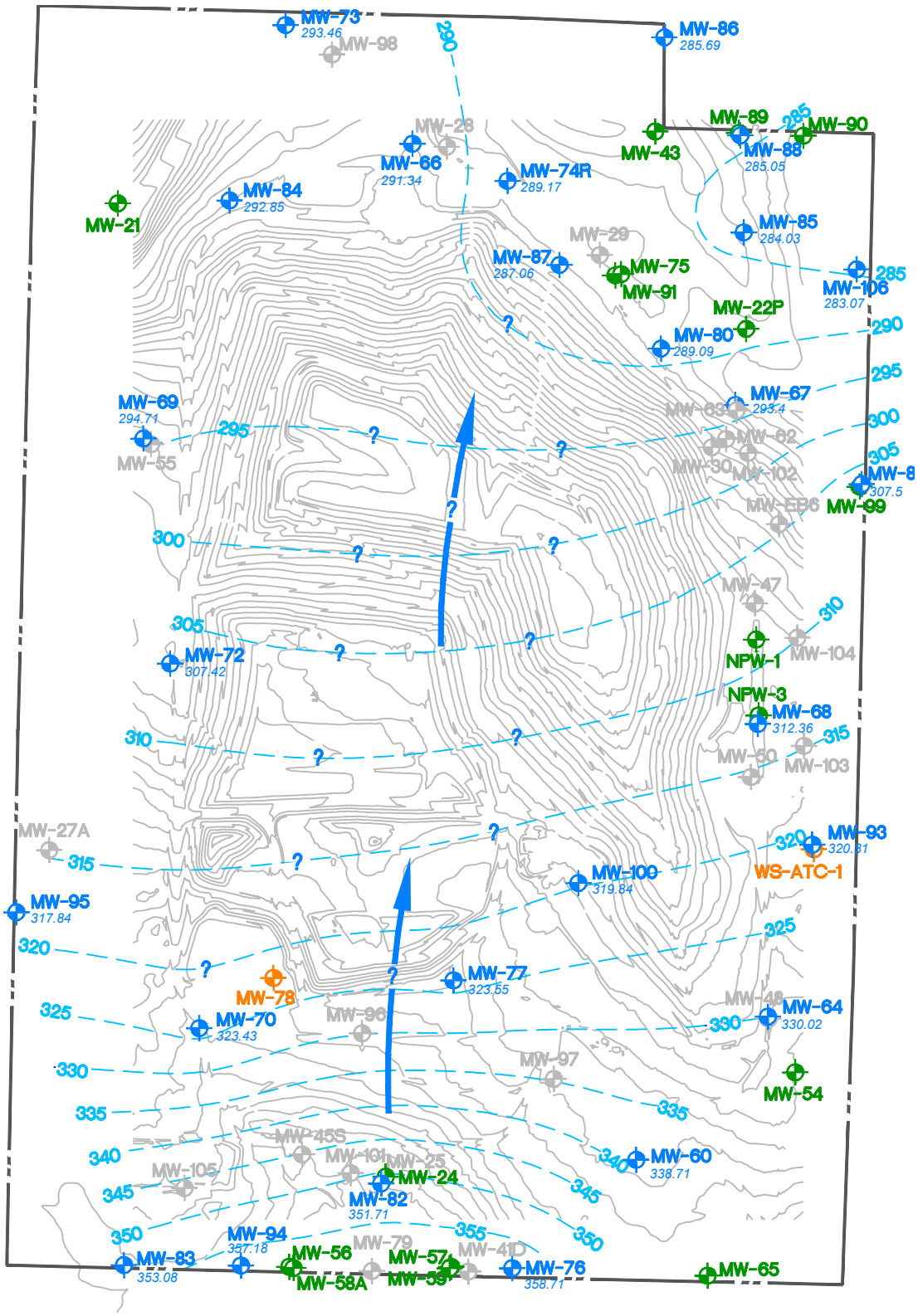
Regional Aquifer Unit	Well Identification	Easting	Northing	Top of Casing Elevation (feet MSL)	Top of Screen Elevation (feet)	Bottom of Screen Elevation (feet)	**1st Quarter 2011 (1/3-6/2011)** Measured Depth to Water (feet)	Groundwater Elevations (feet MSL)
Wells with water levels within 10 feet of the top of screen	MW-60	1701154.47	167873.20	567.15	334.81	325.81	228.44	338.71
	MW-64	1701980.27	168772.19	596.55	334.03	320.23	266.53	330.02
	MW-66	1699750.19	174250.32	531.28	294.39	280.59	239.94	291.34
	MW-67	1701776.69	172610.65	516.43	297.80	284.00	223.03	293.40
	MW-68	1701917.32	170609.35	647.07	311.29	292.29	334.71	312.36
	MW-69	1698061.86	172400.20	653.69	293.57	279.97	358.98	294.71
	MW-70	1698412.97	168699.89	530.57	322.75	309.05	207.14	323.43
	MW-72	1698229.92	170987.71	671.87	303.63	294.03	364.45	307.42
	MW-73	1698954.95	174995.59	485.70	288.11	278.81	192.24	293.46
	MW-74R	1700344.50	174020.41	531.26	289.90	280.40	242.09	289.17
	MW-76	1700376.23	167193.13	491.71	351.06	341.56	133	358.71
	MW-77	1700007.63	168999.71	552.67	320.47	310.97	229.12	323.55
	MW-80	1701309.78	172964.99	530.41	279.17	269.67	241.32	289.09
	MW-81	1702568.87	172113.99	493.66	309.19	300.19	186.16	307.50
	MW-82	1699553.72	167725.31	474.85	348.88	339.38	123.14	351.71
	MW-83	1697939.89	167212.27	496.81	350.19	340.69	143.73	353.08
	MW-84	1698602.89	173894.54	530.80	292.46	282.96	237.95	292.85
	MW-85	1701828.95	173694.52	531.76	282.56	273.06	247.73	284.03
	MW-86	1701331.25	174917.90	536.04	283.43	274.63	250.35	285.69
	MW-87	1700670.27	173493.76	537.31	283.68	274.38	250.25	287.06
	MW-88	1701807.87	174303.06	513.68	281.52	272.22	228.63	285.05
	MW-93	1702259.35	169851.24	632.15	319.87	310.07	311.34	320.81
	MW-94	1698674.21	167210.22	495.51	357.22	348.52	138.33	357.18
	MW-95	1697265.32	169426.92	571.54	314.60	305.90	253.7	317.84
	MW-100	1700791.72	169610.46	620.32	319.06	309.06	300.48	319.84
	MW-106	1702536.99	173461.69	475.47	280.04	270.04	192.4	283.07
Wells with water levels greater than 10 feet above the top of screen	MW-21	1697901.86	173876.38	420.66	263.22	255.22	127.01	293.65
	MW-22P	1701844.34	173088.17	517.09	236.02	231.22	234.08	283.01
	MW-24	1699582.39	167767.76	475.99	286.76	281.76	146.43	329.56
	MW-43	1701274.23	174327.14	547.06	245.63	235.63	264.58	282.48
	MW-54	1702154.28	168435.53	580.43	250.25	228.25	279.94	300.49
	MW-56	1698980.77	167214.82	480.33	323.15	313.15	124.18	356.15
	MW-57	1699993.32	167201.99	456.64	326.65	311.65	98.93	357.71
	MW-58A	1699006.59	167207.16	479.27	270.05	260.05	150.33	328.94
	MW-59	1699983.91	167193.44	457.13	285.08	275.08	124.68	332.45
	MW-65	1701602.10	167146.55	545.83	317.71	308.91	210.43	335.40
	MW-75	1701059.70	173432.42	532.40	271.10	261.00	247.37	285.03
	MW-89	1701799.57	174319.44	512.82	229.20	219.90	232.98	279.84
	MW-90	1702203.13	174300.67	502.22	235.16	226.16	222.48	279.74
	MW-91	1701023.09	173423.94	532.02	260.81	240.71	248.65	283.37
	MW-99	1702556.06	172098.73	493.64	221.77	212.77	202.37	291.27
	NPW-1	1701906.96	171138.99	646.33	299.87	284.87	334.29	312.04
	NPW-3	1701922.88	170663.28	645.81	284.87	276.87	333.85	311.96
Not used	MW-78	1698881.94	169027.58	537.35	322.34	309.84	NM	NM
	WS-ATC-1	1702268.95	169823.34	625.51	NI	NI	NM	NM

Notes
1. Water level measurements made by KCSWD personnel.
2. Northing & Easting coordinates are Washington State Plane Grid System.
3. Elevations reported in feet above Mean Sea Level based on the National Geodetic Vertical Datum, 1929.
4. NM, not measured due to no access
5. NI, no information

Regional Aquifer Zone Beneath the Landfill	Horizontal Hydraulic Conductivity (K)			Horizontal Hydraulic Gradient ($\Delta H/\Delta L$)	Effective Porosity (n_{eff})	Horizontal Groundwater Velocity (v)	General Groundwater Flow Direction
	Range	(cm/s)	(ft/d)	(ft/ft)		(ft/d)	
Southern	Minimum	6.40E-06	0.018	0.022	26%	0.0015	NNE, N, NNW
	Maximum	6.40E-04	1.8	0.022	26%	0.15	
	Mean	6.40E-05	0.18	0.022	26%	0.015	
Central	Minimum	2.10E-03	6	0.0087	24%	0.22	N, NNW
	Maximum	4.20E-02	120	0.0087	24%	4.4	
	Mean	2.10E-02	60	0.0087	24%	2.2	
Northern	Minimum	2.10E-03	6	0.0041	24%	0.103	NE, E
	Maximum	4.20E-02	120	0.0041	24%	2	
	Mean	2.10E-02	60	0.0041	24%	1.0	

Notes

1. Horizontal hydraulic conductivity values and effective porosity values from *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill (Aspect, 2010).*
2. Hydraulic gradients measured from the potentiometric surface map shown on Figure 1.
3. Mean hydraulic conductivity values are the geometric mean of the high and low values.
4. NNE, north northeast; NNW, north northwest; NE, northeast; N, north



Legend

- MW-X XXX.XX — Well completed in Regional Aquifer within 10 feet of the water table
- MW-X — Wells completed in Regional Aquifer more than 10 ft below water table
- MW-X XXX.XX — Wells not accessible
- MW-X — Wells screened in discontinuous Perched Zones
- 300 — Regional Aquifer Groundwater Elevation Contour *(feet MSL)*.
- ? — Inferred Horizontal Groundwater Flow Path

N

0 1000 2000

Feet

Notes:

1. Groundwater measurements made on January 3 and 6, 2011
2. Only wells completed in the Regional Aquifer within 10 feet of the water table were used for contouring

King County

Groundwater Potentiometric Surface Map
1st Quarter 2011 - Regional Aquifer
Cedar Hills Landfill
King County, Washington

DATE: May 2011	PROJECT NO. G13303
DESIGNED BY: SB	
DRAWN BY: LMT	FIGURE NO. 1
REVISED BY: SB	

King County

Water and Land Resources Division
Department of Natural Resources and Parks
King Street Center
201 South Jackson Street, Suite 600
Seattle, WA 98104-3855
206.296.6519 Fax 206.296.0192

Memorandum

To: Tom Theno
King County Solid Waste Division

From: Sevin Bilir
King County Water & Land Resources Division

Re: **Potentiometric Groundwater Surface Mapping & Groundwater Velocity Calculation**
Second Quarter 2011 Results
Cedar Hills Landfill, King County, Washington
Project No. G13303 – Task 722

Date: July 28, 2011

King County Water & Land Resources Division (KCWLRD) submits this letter report on groundwater conditions during the second quarter of 2011 for the Cedar Hills Landfill (landfill), in accordance with the *Proposal for Potentiometric Groundwater Surface Maps & Groundwater Velocity Calculations* (KCWLRD, 2011). King County Solid Waste Division (KCSWD) personnel measured groundwater elevations at the landfill on April 4, 2011. These measurements were received by KCWLRD on June 23, 2011 and were used to:

1. Evaluate the potentiometric groundwater surface elevation for the Regional Aquifer;
2. Determine the groundwater flow direction and horizontal gradient for the Regional Aquifer; and
3. Calculate the groundwater velocity of the Regional Aquifer.

There have been no significant changes in the interpreted groundwater conditions since the previous report submitted for the first quarter of the 2011 monitoring event.

Groundwater Elevation Data

KCSWD attempted groundwater level measurements at 45 monitoring wells quarterly during the second quarter of 2011. These wells were completed in the Regional Aquifer as referred to in *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill* (Aspect, 2010).

Table 1 lists the well identifications, locations, well details, measured groundwater levels and calculated groundwater elevations for the Regional Aquifer. Wells with screened intervals within 10 feet of the water table were used for potentiometric surface mapping purposes. A total of 27 wells with water levels within ten feet of the top of screen were selected.

Figure 1 shows well locations, groundwater elevations at the 27 selected wells, groundwater potentiometric surface contours, and interpreted groundwater flow direction in the Regional Aquifer for the April 4, 2011 measurement event.

Direction of Groundwater Flow

Figure 1 shows groundwater potentiometric surface contours and interpreted groundwater flow directions in the Regional Aquifer, based on the April 4, 2011 measurements. Groundwater elevations indicate that groundwater in the Regional Aquifer generally flowed north beneath the southern and central portions of the landfill with minor components of flow to the north-northeast and north-northwest. At the northern end of the landfill, groundwater generally flowed to the northeast and east.

Groundwater Velocity

Horizontal groundwater velocity was calculated using the following formula:

$$\text{where: } v = \frac{1}{n_{eff}} K \frac{\Delta H}{\Delta L}$$

v = Groundwater velocity [L/t]
n_{eff} = Effective porosity [dimensionless]
K = Hydraulic conductivity [L/t]
$\frac{\Delta H}{\Delta L}$ = Hydraulic gradient [L/L]

Horizontal groundwater velocity was calculated for the Regional Aquifer below the landfill. Horizontal groundwater velocity was calculated for the southern, central, and northern portions of the Regional Aquifer, based on spatial differences in aquifer parameters and hydraulic gradients. The hydraulic conductivity and effective porosity values were based on the range referred to in the *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill* (Aspect, 2010).

Table 2 presents a summary of the hydraulic parameters used to calculate a groundwater velocity from the second quarter 2011 data. The hydraulic gradient was greatest under the southern portion of the landfill and smallest under the northern portion. On April 4, 2011, average horizontal groundwater velocity within the Regional Aquifer ranged from 0.016 feet per day (ft/d) under the southern portion of the landfill to 2.1 ft/day under the central portion of the landfill.

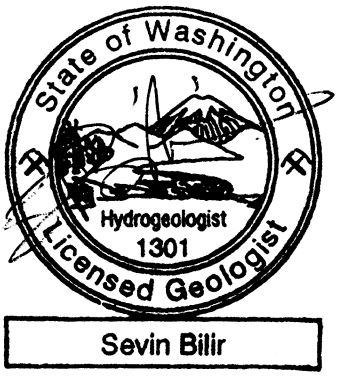
References

Aspect Consulting (Aspect). 2010. *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill*. Unpublished work. April 30.

King County Water & Land Resources Division (KCWLRD). 2011. *Proposal for Potentiometric Groundwater Surface Maps & Groundwater Velocity Calculations*. Unpublished.

Thank you for the opportunity to provide hydrogeologic services to the KCSWD. Please contact me if you have any questions.

Sincerely,



Sevin Bilir, WA LHG
Environmental Scientist III
King County Water & Land Resources Division

Attachments
Table 1: Groundwater Elevations - 2nd Quarter 2011
Table 2: Groundwater Parameters - 2nd Quarter 2011
Figure 1: Groundwater Potentiometric Surface Map - 2nd Quarter 2011 - Regional Aquifer

Table 1: Groundwater Elevations – 2nd Quarter 2011

Cedar Hills Landfill

King County, Washington

							2nd Quarter 2011 (4/4/2011)	
Regional Aquifer Unit	Well Identification	X	Y	Top of Casing Elevation (feet MSL)	Top of Screen Elevation (feet)	Bottom of Screen Elevation (feet)	Measured Depth to Water (feet)	Groundwater Elevations (feet MSL)
Wells with water levels within 10 feet of the top of screen	MW-60	167873.20	1701154.47	567.15	334.81	325.81	233.13	334.02
	MW-64	168772.19	1701980.27	596.55	334.03	320.23	266.35	330.20
	MW-66	174250.32	1699750.19	531.28	294.39	280.59	239.17	292.11
	MW-67	172610.65	1701776.69	516.43	297.80	284.00	222.49	293.94
	MW-68	170609.35	1701917.32	647.07	311.29	292.29	334.87	312.20
	MW-69	172400.20	1698061.86	653.69	293.57	279.97	358.72	294.97
	MW-70	168699.89	1698412.97	530.57	322.75	309.05	206.33	324.24
	MW-72	170987.71	1698229.92	671.87	303.63	294.03	364.14	307.73
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	MW-76	167193.13	1700376.23	491.71	351.06	341.56	131.54	360.17
	MW-77	168999.71	1700007.63	552.67	320.47	310.97	227.89	324.78
	MW-78	169027.58	1698881.94	537.35	322.34	309.84	213.75	323.60
	MW-80	172964.99	1701309.78	530.41	279.17	269.67	240.63	289.78
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	MW-83	167212.27	1697939.89	496.81	350.19	340.69	140.87	355.94
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	MW-95	169426.92	1697265.32	571.54	314.60	305.90	253.22	318.32
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	MW-43	174327.14	1701274.23	547.06	245.63	235.63	263.4	283.66
	MW-54	168435.53	1702154.28	580.43	250.25	228.25	279.02	301.41
	MW-56	167214.82	1698980.77	480.33	323.15	313.15	121.57	358.76
	MW-57	167201.99	1699993.32	456.64	326.65	311.65	96.93	359.71
	MW-58A	167207.16	1699006.59	479.27	270.05	260.05	148.87	330.40
	MW-59	167193.44	1699983.91	457.13	285.08	275.08	122.85	334.28
	MW-65	167146.55	1701602.10	545.83	317.71	308.91	208.53	337.30
	MW-75	173432.42	1701059.70	532.40	271.10	261.00	246.3	286.10
	MW-89	174319.44	1701799.57	512.82	229.20	219.90	231.74	281.08
	MW-90	174300.67	1702203.13	502.22	235.16	226.16	220.88	281.34
	MW-91	173423.94	1701023.09	532.02	260.81	240.71	247.6	284.42
	MW-99	172098.73	1702556.06	493.64	221.77	212.77	201.64	292.00
	NPW-1	171138.99	1701906.96	646.33	299.87	284.87	335.16	311.17
	NPW-3	170663.28	1701922.88	645.81	284.87	276.87	333.46	312.35
Not used	WS-ATC-1	169823.34	1702268.95	625.51	NI	NI	NM	NM

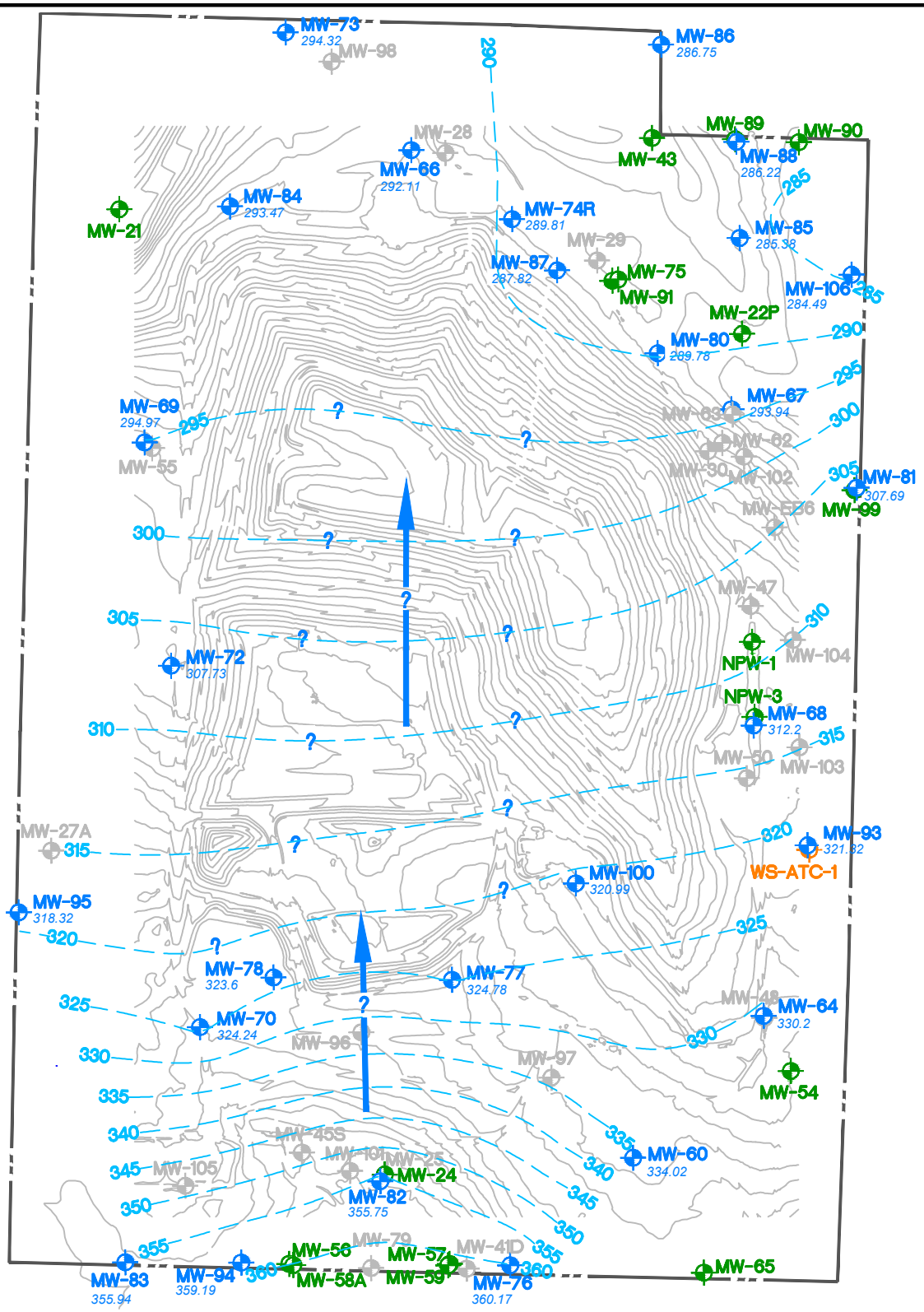
Notes

1. Water level measurements made by KCSWD personnel.
2. Reference datum for XY coordinates is the North American Datum of 1927 (NAD27)
3. Elevations reported in feet above Mean Sea Level based on the National Geodetic Vertical Datum, 1929.
4. NM, not measured due to no access
5. NI, no information

Regional Aquifer Zone Beneath the Landfill	Horizontal Hydraulic Conductivity (K) Range	(cm/s)	(ft/d)	Horizontal Hydraulic Gradient ($\Delta H/\Delta L$) (ft/ft)	Effective Porosity (n_{eff})	Horizontal Groundwater Velocity (v) (ft/d)	General Groundwater Flow Direction
Southern	Minimum	6.40E-06	0.018	0.023	26%	0.0016	NNE, N, NNW
	Maximum	6.40E-04	1.8	0.023	26%	0.16	
	Mean	6.40E-05	0.18	0.023	26%	0.016	
Central	Minimum	2.10E-03	6	0.00836	24%	0.21	N, NNW
	Maximum	4.20E-02	120	0.00836	24%	4.2	
	Mean	2.10E-02	60	0.00836	24%	2.1	
Northern	Minimum	2.10E-03	6	0.00566	24%	0.142	NE, E
	Maximum	4.20E-02	120	0.00566	24%	3	
	Mean	2.10E-02	60	0.00566	24%	1.4	

Notes

1. Horizontal hydraulic conductivity values and effective porosity values from *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill (Aspect, 2010).*
2. Hydraulic gradients measured from the potentiometric surface map shown on Figure 1.
3. Mean hydraulic conductivity values are the geometric mean of the high and low values.
4. NNE, north northeast; NNW, north northwest; NE, northeast; N, north



Legend

- MW-X XXX.XX — Well completed in Regional Aquifer within 10 feet of the water table
- MW-X — Wells completed in Regional Aquifer more than 10 ft below water table
- MW-X XXX.XX — Wells not accessible
- MW-X — Wells screened in discontinuous Perched Zones
- 300 — Regional Aquifer Groundwater Elevation Contour *(feet MSL)*.
- ? — Inferred Horizontal Groundwater Flow Path

N

0 1000 2000

Feet

Notes:

1. Groundwater measurements made on April 4, 2011
2. Only wells completed in the Regional Aquifer within 10 feet of the water table were used for contouring

King County

Groundwater Potentiometric Surface Map
2nd Quarter 2011 - Regional Aquifer
Cedar Hills Landfill
King County, Washington

DATE: July 2011	PROJECT NO. G13303
DESIGNED BY: SB	
DRAWN BY: LMT	FIGURE NO. 1
REVISED BY: SB	

CH_20112Q.dwg

King County

Water and Land Resources Division
Department of Natural Resources and Parks
King Street Center
201 South Jackson Street, Suite 600
Seattle, WA 98104-3855
206.296.6519 Fax 206.296.0192

Memorandum

To: Tom Theno
King County Solid Waste Division

From: Sevin Bilir
King County Water & Land Resources Division

Re: **Potentiometric Groundwater Surface Mapping & Groundwater Velocity Calculations**
Third Quarter 2011 Results
Cedar Hills Landfill, King County, Washington
Project No. G13303 – Task 722

Date: October 26, 2011

King County Water & Land Resources Division (KCWLRD) submits this letter report on groundwater conditions during the third quarter of 2011 for the Cedar Hills Landfill (landfill), in accordance with the *Proposal for Potentiometric Groundwater Surface Maps & Groundwater Velocity Calculations* (KCWLRD, 2011). King County Solid Waste Division (KCSWD) personnel measured groundwater elevations at the landfill on July 1, 2011. These measurements were received by KCWLRD on September 27, 2011 and were used to:

1. Evaluate the potentiometric groundwater surface elevation for the regional aquifer;
2. Determine the groundwater flow direction and horizontal gradient for the regional aquifer; and
3. Calculate the groundwater velocity of the regional aquifer.

There have been no significant changes in the interpreted groundwater conditions since the previous report submitted for the first quarter of the 2011 monitoring event.

Groundwater Elevation Data

KCSWD attempted groundwater level measurements at 45 monitoring wells during the third quarter of 2011. These wells were completed in the regional aquifer as referred to in *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill* (Aspect, 2010).

Table 1 lists the well identifications, locations, well details, measured groundwater levels and calculated groundwater elevations for the regional aquifer. Wells MW-93 and WS-ATC-1 were not accessible at the time of measurement. Wells with screened intervals within ten feet of the water table were used for potentiometric surface mapping purposes. A total of 25 wells with water levels within ten feet of the top of screen were selected.

Figure 1 shows well locations, groundwater elevations at the 25 selected wells, groundwater potentiometric surface contours, and interpreted groundwater flow direction in the regional aquifer for the July 1, 2011 measurement event.

Direction of Groundwater Flow

Figure 1 shows interpreted groundwater potentiometric surface contours and groundwater flow directions in the regional aquifer, based on the July 1, 2011 measurements. Groundwater elevations indicate that groundwater in the regional aquifer generally flowed north beneath the southern and central portions of the landfill with minor components of flow to the north-northeast and north-northwest. At the northern end of the landfill, groundwater generally flowed to the northeast and east.

Groundwater Parameters

Horizontal groundwater velocity was calculated using the following formula:

$$\text{where: } v = \frac{1}{n_{eff}} K \frac{\Delta H}{\Delta L}$$

v = Groundwater velocity [L/t]
n_{eff} = Effective porosity [dimensionless]
K = Hydraulic conductivity [L/t]
$\frac{\Delta H}{\Delta L}$ = Hydraulic gradient [L/L]

Horizontal groundwater velocity was calculated for the regional aquifer below the landfill. Horizontal groundwater velocity was calculated for the southern, central, and northern portions of the regional aquifer, based on spatial differences in aquifer parameters and hydraulic gradients. The hydraulic conductivity and effective porosity

values were based on the range referred to in the *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill* (Aspect, 2010).

Table 2 presents a summary of the groundwater parameters used to calculate a groundwater velocity from the third quarter 2011 data. The hydraulic gradient was greatest under the southern portion of the landfill and smallest under the northern portion. On July 1, 2011, average horizontal groundwater velocity within the regional aquifer ranged from 0.012 feet per day (ft/d) under the southern portion of the landfill to 1.7 ft/day under the central portion of the landfill.

References

Aspect Consulting (Aspect). 2010. *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill.* Unpublished work. April 30.

King County Water & Land Resources Division (KCWLRD). 2011. *Proposal for Potentiometric Groundwater Surface Maps & Groundwater Velocity Calculations.* Unpublished.

Thank you for the opportunity to provide hydrogeologic services to the KCSWD. Please contact me if you have any questions.

Sincerely,

Sevin Bilir, WA LHG
Environmental Scientist III
King County Water & Land Resources Division

Attachments
Table 1: Groundwater Elevations - Third Quarter 2011
Table 2: Groundwater Parameters - Third Quarter 2011
Figure 1: Groundwater Potentiometric Surface Map - Third Quarter 2011 – Regional Aquifer

Table 1: Groundwater Elevations – Third Quarter 2011

Cedar Hills Landfill

King County, Washington

Regional Aquifer Unit	Well Identification	X (ft)	Y (ft)	Top of Casing Elevation (ft MSL)	Top of Screen Elevation (ft)	Bottom of Screen Elevation (ft)	Third Quarter 2011 (4/4/2011) Measured Depth to Water (ft)	Third Quarter 2011 (4/4/2011) Groundwater Elevations (ft MSL)
Wells with water levels within 10 feet of the top of screen	MW-60	167873.20	1701154.47	567.15	334.81	325.81	224.00	343.15
	MW-64	168772.19	1701980.27	596.55	334.03	320.23	265.97	330.58
	MW-66	174250.32	1699750.19	531.28	294.39	280.59	238.88	292.40
	MW-67	172610.65	1701776.69	516.43	297.80	284.00	222.08	294.35
	MW-68	170609.35	1701917.32	647.07	311.29	292.29	334.54	312.53
	MW-69	172400.20	1698061.86	653.69	293.57	279.97	358.67	295.02
	MW-70	168699.89	1698412.97	530.57	322.75	309.05	205.77	324.80
	MW-72	170987.71	1698229.92	671.87	303.63	294.03	364.10	307.77
	MW-73	174995.59	1698954.95	485.70	288.11	278.81	191.17	294.53
	MW-74R	173813.79	1700386.85	531.26	289.90	280.40	241.13	290.13
	MW-76	167193.13	1700376.23	491.71	351.06	341.56	134.65	357.06
	MW-77	168999.71	1700007.63	552.67	320.47	310.97	227.21	325.46
	MW-78	169027.58	1698881.94	537.35	322.34	309.84	213.23	324.12
	MW-81	172113.99	1702568.87	493.66	309.19	300.19	185.68	307.98
	MW-82	167725.31	1699553.72	474.85	348.88	339.38	119.37	355.48
	MW-83	167212.27	1697939.89	496.81	350.19	340.69	141.38	355.43
	MW-84	173894.54	1698602.89	530.80	292.46	282.96	237.09	293.71
	MW-85	173694.52	1701828.95	531.76	282.56	273.06	246.55	285.21
	MW-86	174917.90	1701331.25	536.04	283.43	274.63	248.99	287.05
	MW-87	173493.76	1700670.27	537.31	283.68	274.38	249.30	288.01
	MW-88	174303.06	1701807.87	513.68	281.52	272.22	227.48	286.20
	MW-94	167210.22	1698674.21	495.51	357.22	348.52	138.15	357.36
	MW-95	169426.92	1697265.32	571.54	314.60	305.90	252.93	318.61
	MW-100	169610.46	1700791.72	620.32	319.06	309.06	299.08	321.24
	MW-106	173461.69	1702536.99	475.47	280.04	270.04	191.02	284.45
Wells with water levels greater than 10 feet above the top of screen	MW-21	173876.38	1697901.86	420.66	263.22	255.22	126.29	294.37
	MW-22P	173088.17	1701844.34	517.09	236.02	231.22	233.31	283.78
	MW-24	167767.76	1699582.39	475.99	286.76	281.76	144.87	331.12
	MW-43	174327.14	1701274.23	547.06	245.63	235.63	263.52	283.54
	MW-54	168435.53	1702154.28	580.43	250.25	228.25	278.48	301.95
	MW-56	167214.82	1698980.77	480.33	323.15	313.15	123.22	357.11
	MW-57	167201.99	1699993.32	456.64	326.65	311.65	99.41	357.23
	MW-58A	167207.16	1699006.59	479.27	270.05	260.05	148.86	330.41
	MW-59	167193.44	1699983.91	457.13	285.08	275.08	123.09	334.04
	MW-65	167146.55	1701602.10	545.83	317.71	308.91	208.60	337.23
	MW-75	173432.42	1701059.70	532.40	271.10	261.00	246.28	286.12
	MW-80	172964.99	1701309.78	530.41	279.17	269.67	240.46	289.95
	MW-89	174319.44	1701799.57	512.82	229.20	219.90	231.97	280.85
	MW-90	174300.67	1702203.13	502.22	235.16	226.16	221.57	280.65
	MW-91	173423.94	1701023.09	532.02	260.81	240.71	247.60	284.42
	MW-99	172098.73	1702556.06	493.64	221.77	212.77	201.52	292.12
	NPW-1	171138.99	1701906.96	646.33	299.87	284.87	334.78	311.55
	NPW-3	170663.28	1701922.88	645.81	284.87	276.87	337.93	307.88
Not used	MW-93	169851.24	1702259.35	632.15	NI	NI	NM	NM
	WS-ATC-1	169823.34	1702268.95	625.51	NI	NI	NM	NM

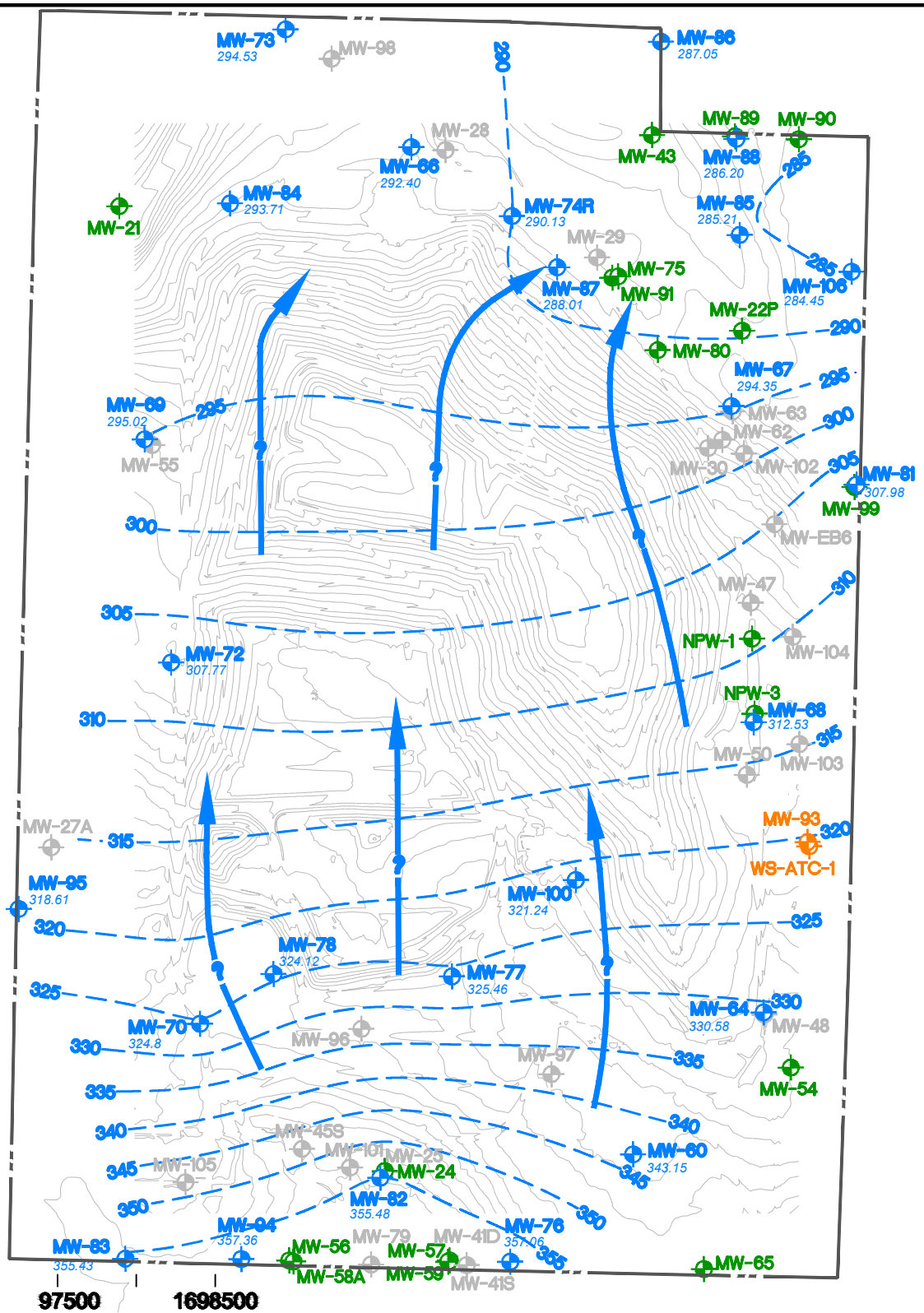
Notes

1. Water level measurements made by KCSWD personnel.
2. Reference datum for XY coordinates is the North American Datum of 1927 (NAD27)
3. Elevations reported in feet above Mean Sea Level based on the National Geodetic Vertical Datum, 1929.
4. NM, not measured due to no access
5. NI, no information

Table 2: Groundwater Parameters – Third Quarter 2011
Cedar Hills Landfill
King County, Washington

Regional Aquifer Zone Beneath the Landfill		Horizontal Hydraulic Conductivity (*K*)		Horizontal Hydraulic Gradient	Effective Porosity (n_{eff})	Horizontal Groundwater Velocity (*v*)	General Groundwater Flow Direction
	Range	(cm/s)	(ft/d)	(ft/ft)		(ft/d)	
Southern	Minimum	6.40E-06	0.018	0.018	26%	0.0012	NNE, N, NNW
	Maximum	6.40E-04	1.8	0.018	26%	0.12	
	Mean	6.40E-05	0.18	0.018	26%	0.012	
Central	Minimum	2.10E-03	6	0.0081	24%	0.20	N, NNW
	Maximum	4.20E-02	120	0.0081	24%	4.1	
	Mean	2.10E-02	60	0.0081	24%	2.0	
Northern	Minimum	2.10E-03	6	0.0066	24%	0.165	NE, E
	Maximum	4.20E-02	120	0.0066	24%	3	
	Mean	2.10E-02	60	0.0066	24%	1.7	

Notes
1. Horizontal hydraulic conductivity values and effective porosity values from
Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill (Aspect, 2010).
2. Hydraulic gradients measured from the potentiometric surface map shown on Figure 1.
3. Mean hydraulic conductivity values are the geometric mean of the high and low values.
4. NNE, north-northeast; NNW, north-northwest; NE, northeast; N, north



Legend

- MW-X / XXX.XX — Well completed in Regional Aquifer within 10 feet of the water table
- MW-X — Wells completed in Regional Aquifer more than 10 ft below water table
- MW-X / XXX.XX — Wells not accessible
- MW-X — Wells screened in discontinuous Perched Zones
- 300 — Regional Aquifer Groundwater Elevation Contour *(feet MSL)*.
- ? — Inferred Horizontal Groundwater Flow Path

N

0 1000 2000

Feet

Notes:

1. Groundwater measurements made on July 1, 2011
2. Only wells completed in the Regional Aquifer within 10 feet of the water table were used for contouring

King County

Groundwater Potentiometric Surface Map
Third Quarter 2011 - Regional Aquifer
Cedar Hills Landfill
King County, Washington

DATE: Oct. 2011	PROJECT NO. G13303
DESIGNED BY: SB	
DRAWN BY: LMT	FIGURE NO. 1
REVISED BY: SB	

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King County

Water and Land Resources Division
Department of Natural Resources and Parks
King Street Center
201 South Jackson Street, Suite 600
Seattle, WA 98104-3855
206.296.6519 Fax 206.296.0192

Memorandum

To: Tom Theno
King County Solid Waste Division

From: Sevin Bilir
King County Water & Land Resources Division

Re: Potentiometric Groundwater Surface Mapping & Groundwater Velocity Calculations
Fourth Quarter 2011 Results
Cedar Hills Landfill, King County, Washington
Project No. 1033379 – Task 02.14.137.20

Date: January 30, 2012

King County Water & Land Resources Division (KCWLRD) submits this letter report on groundwater conditions during the fourth quarter of 2011 for the Cedar Hills Landfill (landfill), in accordance with the *Proposal for Potentiometric Groundwater Surface Maps & Groundwater Velocity Calculations* (KCWLRD, 2011). King County Solid Waste Division (KCSWD) personnel measured groundwater elevations at the landfill on October 3, 2011. These measurements were received by KCWLRD on January 4, 2012 and were used to:

1. Evaluate the potentiometric groundwater surface elevation for the regional aquifer;
2. Determine the groundwater flow direction and horizontal gradient for the regional aquifer; and
3. Calculate the groundwater velocity of the regional aquifer.

There have been no significant changes in the interpreted groundwater conditions since the report submitted for the first quarter of the 2011 monitoring event.

Groundwater Elevation Data

KCSWD attempted groundwater level measurements at 45 monitoring wells during the fourth quarter of 2011. These wells were completed in the regional aquifer as referred to in *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill* (Aspect, 2010).

Table 1 lists the well identifications, locations, well details, measured groundwater levels and calculated groundwater elevations for the regional aquifer. Wells MW-77 and WS-ATC-1 were not accessible at the time of measurement. Wells with screened intervals within ten feet of the water table were used for potentiometric surface mapping purposes. A total of 26 wells with water levels within ten feet of the top of screen were selected.

Figure 1 shows well locations, groundwater elevations at the 26 selected wells, groundwater potentiometric surface contours, and interpreted groundwater flow direction in the regional aquifer for the October 3, 2011 measurement event.

Direction of Groundwater Flow

Figure 1 shows interpreted groundwater potentiometric surface contours and groundwater flow directions in the regional aquifer, based on the October 3, 2011 measurements. Groundwater elevations indicate that groundwater in the regional aquifer generally flowed north beneath the southern and central portions of the landfill with minor components of flow to the north-northeast and north-northwest. At the northern end of the landfill, groundwater generally flowed to the northeast and east.

Groundwater Parameters

Horizontal groundwater velocity was calculated using the following formula:

where: $$v = \frac{1}{n_{eff}} K \frac{\Delta H}{\Delta L}$$

v = Groundwater velocity [L/t]
n_{eff} = Effective porosity [dimensionless]
K = Hydraulic conductivity [L/t]
$\frac{\Delta H}{\Delta L}$ = Hydraulic gradient [L/L]

Horizontal groundwater velocity was calculated for the regional aquifer below the landfill. Horizontal groundwater velocity was calculated for the southern, central, and northern portions of the regional aquifer, based on spatial differences in aquifer parameters and hydraulic gradients. The hydraulic conductivity and effective porosity values were based on the range referred to in the *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill* (Aspect, 2010).

Table 2 presents a summary of the groundwater parameters used to calculate a groundwater velocity from the fourth quarter 2011 data. The hydraulic gradient was greatest under the southern portion of the landfill and smallest under the northern portion. On October 3, 2011, average horizontal groundwater velocity within the regional aquifer ranged from 0.01 feet per day (ft/d) under the southern portion of the landfill to 2.1 ft/d under the central portion of the landfill.

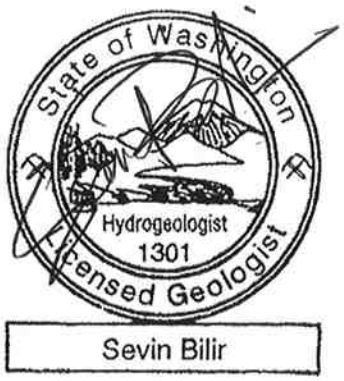
References

Aspect Consulting (Aspect). 2010. *Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill*. Unpublished work. April 30.

King County Water & Land Resources Division (KCWLRD). 2011. *Proposal for Potentiometric Groundwater Surface Maps & Groundwater Velocity Calculations*. Unpublished.

Thank you for the opportunity to provide hydrogeologic services to the KCSWD. Please contact me if you have any questions.

Sincerely,



Sevin Bilir, WA LHG
Environmental Scientist III
King County Water & Land Resources Division

Attachments

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Table 2: Groundwater Parameters - Fourth Quarter 2011
Figure 1: Groundwater Potentiometric Surface Map - Fourth Quarter 2011 – Regional Aquifer

Table 1: Groundwater Elevations – Fourth Quarter 2011

Cedar Hills Landfill

King County, Washington

							10/3/2011	
Regional Aquifer Unit	Well Identification	X (ft)	Y (ft)	Top of Casing Elevation (ft MSL)	Top of Screen Elevation (ft)	Bottom of Screen Elevation (ft)	Measured Depth to Water (ft)	Groundwater Elevations (ft MSL)
Wells with water levels within 10 feet of the top of screen	MW-60	1701154.47	167873.20	567.15	334.81	325.81	226.72	340.43
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	MW-75	1701059.70	173432.42	532.40	271.10	261.00	246.63	285.77
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	NPW-3	1701922.88	170663.28	645.81	284.87	276.87	332.38	313.43
Not used	MW-77	1700007.63	168999.71	552.67	320.47	310.97	NM	NM
	WS-ATC-1	1702268.95	169823.34	625.51	NI	NI	NM	NM

Notes

1. Water level measurements made by KCSWD personnel.
2. Reference datum for XY coordinates is the North American Datum of 1927 (NAD27)
3. Elevations reported in feet above Mean Sea Level based on the National Geodetic Vertical Datum, 1929.
4. NM, not measured due to no access
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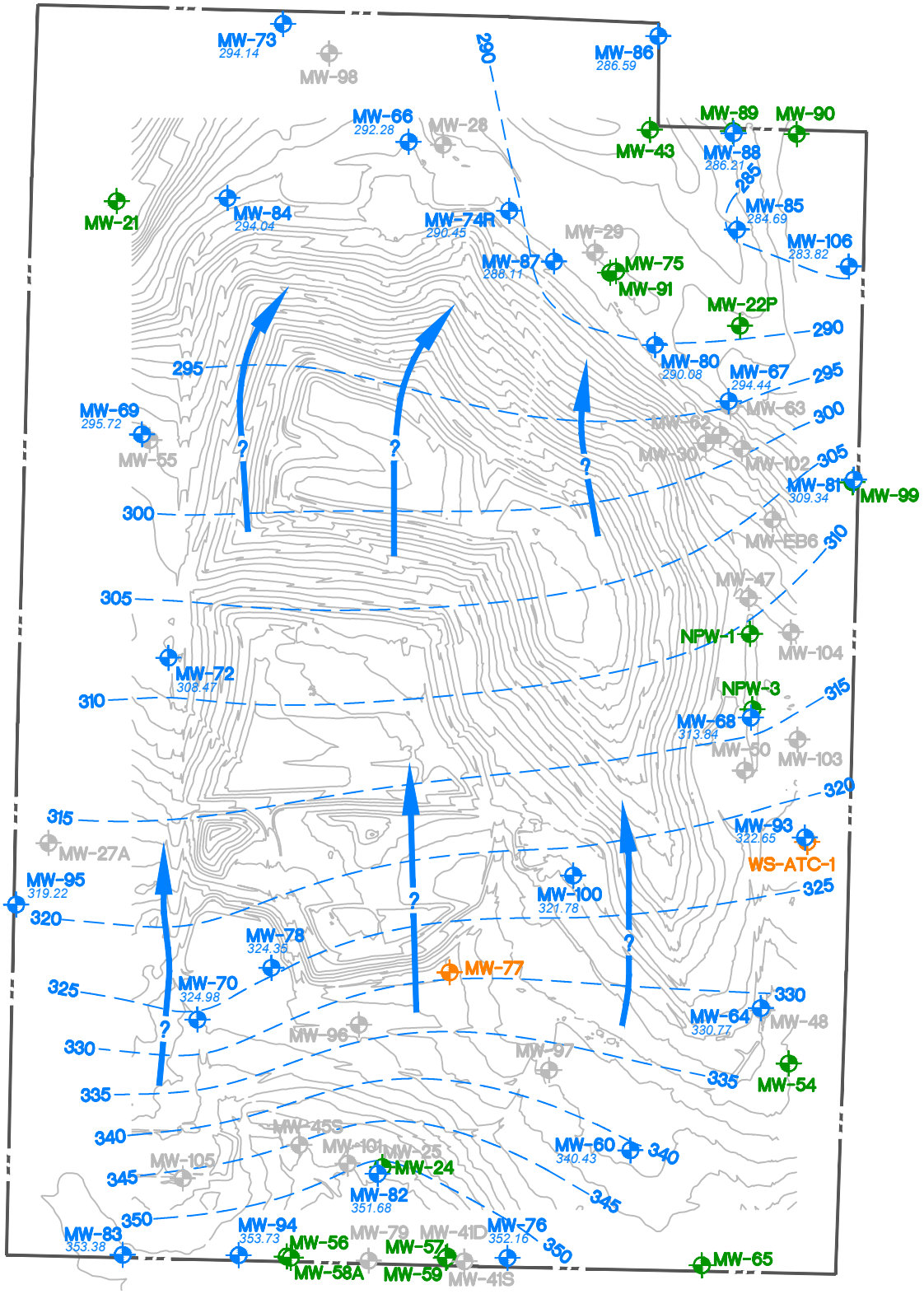
Table 2: Groundwater Parameters – Fourth Quarter 2011
Cedar Hills Landfill
King County, Washington

Regional Aquifer Zone Beneath the Landfill	Horizontal Hydraulic Conductivity (K)			Horizontal Hydraulic Gradient	Effective Porosity (n_{eff})	Horizontal Groundwater Velocity (v)	General Groundwater Flow Direction
	Range	(cm/s)	(ft/d)	(ft/ft)		(ft/d)	
Southern	Minimum	6.40E-06	0.018	0.014	26%	0.001	NNE, N, NNW
	Maximum	6.40E-04	1.8	0.014	26%	0.1	
	Mean	6.40E-05	0.18	0.014	26%	0.01	
Central	Minimum	2.10E-03	6	0.0086	24%	0.21	N, NNW
	Maximum	4.20E-02	120	0.0086	24%	4.3	
	Mean	2.10E-02	60	0.0086	24%	2.1	
Northern	Minimum	2.10E-03	6	0.0074	24%	0.186	NE, E
	Maximum	4.20E-02	120	0.0074	24%	4	
	Mean	2.10E-02	60	0.0074	24%	1.9	

Notes
1. Horizontal hydraulic conductivity values and effective porosity values from
Potentiometric Groundwater Surface Mapping and Groundwater Velocity Calculation – Cedar Hills Landfill (Aspect, 2010).
2. Hydraulic gradients measured from the potentiometric surface map shown on Figure 1.
3. Mean hydraulic conductivity values are the geometric mean of the high and low values.
4. NNE, north-northeast; NNW, north-northwest; NE, northeast; N, north



Legend

MW-X XXX.XX — Well completed in Regional Aquifer within 10 feet of the water table

MW-X — Wells completed in Regional Aquifer more than 10 ft below water table

MW-X XXX.XX — Wells not accessible

MW-X — Wells screened in discontinuous Perched Zones

300 — Regional Aquifer Groundwater Elevation Contour *(feet MSL)*.

? — Inferred Horizontal Groundwater Flow Path

N

0 1000 2000

Feet

Notes:

1. Groundwater measurements made on October 3, 2011
2. Only wells completed in the Regional Aquifer within 10 feet of the water table were used for contouring

King County

Groundwater Potentiometric Surface Map
Forth Quarter 2011 - Regional Aquifer
Cedar Hills Landfill
King County, Washington

DATE: Jan. 2012	PROJECT NO. 1033379
DESIGNED BY: SB	
DRAWN BY: LMT	FIGURE NO. 1
REVISED BY: SB	

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