Lake Goodwin Landfill 2014 Annual Environmental Monitoring Report

Photo taken 8/1/08 J. Greninger

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1.0 INTRODUCTION

The following report summarizes the annual ground water monitoring results for 2014 at the Lake Goodwin Landfill (*Lake Goodwin Landfill, Site*). The site is located immediately west of Frank Waters Road in northwestern Snohomish County, about one and one half (*1.5*) miles northwest of Lake Goodwin and about five-(*5*) miles south of Stanwood (*T31N, R4E, sections 17, 20 Willamette Meridian*). The landfill is located at 18520 Frank Waters Road, Stanwood, Washington, 98292. The location of the site relative to existing municipal improvements is shown on the **Vicinity Map** (*figure 1*).

1.1 BACKGROUND

The Lake Goodwin Landfill is sited within a former County gravel pit. Waste disposed at the landfill reportedly consisted of municipal waste, including garbage and demolition debris, and some industrial waste. Waste was placed in the landfill starting in the early 1960's under the direction of **Snohomish County's Road Maintenance Division**. The landfill was closed in September 1982. Upon closure a cover system was installed. The landfill is not lined nor does it have leachate or gas collection systems. The Lake Goodwin Landfill is currently permitted for post-closure monitoring by the **Snohomish Health District** (*SHD*) with a Solid Waste Facility Permit (*SW-085, 2015*). Monitoring results are reviewed by both the **SHD** and the **Department of Ecology** (***DOE***).

1.2 PERMIT INFORMATION

Monitoring activities at the landfill during 2014 were governed by the Solid Waste Facility Permit SW-085 (*landfill permit, Snohomish Health District 2014*). This permit requires post-closure ground water monitoring on a quarterly basis until the facility has been shown to be stable and/or not harmful to human health or the environment. The **SHD** permits and evaluates post-closure conditions at the Lake Goodwin Landfill using the Snohomish Health District Sanitary Codes, *Chapter 3.1, Solid Waste Handling Regulations*; *Chapter 173-304 WAC Minimum Functional Standards for Solid Waste*; *Chapter 173-200 WAC Water Quality Standards for Ground Waters*; and *Chapter 246-290 WAC Drinking Water Regulations.* There is an approved **Sampling & Analysis**

Plan (*SAP*) for this landfill (*Snohomish County Public Works, 2013*). The current **SAP** eliminated one well from sampling (*LG-03*), removed VOA analysis from the standard sampling suite, and pared down metals testing and analysis to only those detected in the last 10 years.

1.3 SITE DESCRIPTION AND PHYSICAL CONDITIONS

The closed landfill is approximately 11.5 acres in size and is part of a larger County owned parcel of land. The Lake Goodwin Landfill is bounded by private residential property or commercial forest to the south, west and north. The Frank Waters Road is located along the eastern side of the site. Access into the site is from a partially paved and partially graveled driveway off of the Frank Waters Road. Existing site improvements are shown on the **Site Map** (*figure 2*).

The Lake Goodwin Landfill is located on a topographic feature known as the Tulalip Plateau, a rolling upland area bounded by the Stillaquamish River to the north, the Puget Sound to the west and south, and by a topographic low called the Marysville Trough to the east. The general topography in the immediate vicinity of the site is typical of glaciated areas within western Washington State – gently rolling landscapes bisected by seasonal and/or year round drainages, creeks and rivers. Several small to medium sized lakes are found in the immediate vicinity of the site. Lake Martha, Lake Howard and Lake Goodwin are all located within 1.5 miles of the Landfill. There are no named drainages, creeks or rivers located in the immediate vicinity of the site. The Stillaquamish River is located approximately 3 miles north of the site. Elevations in the immediate vicinity of the landfill range from approximately el. 320 to el. 380 feet above mean sea level. Relative to existing surrounding topography the landfill itself is approximately 60 ft high. It has been graded and slopes gently in a north to northeast direction. Site Topography is shown on the **Topographic Map** (*figure 3*). In most places the landfill cover is well vegetated with grass, clover and weeds. A few Douglas fir have naturally reseeded in the fill cover near the edge of the site. There are no stormwater detention ponds or leachate collection ponds located on the site.

1.4 LOCAL GEOLOGY

Surficial geology of the site area has been mapped by the **USGS** and is shown on the "Geologic Map of the Stanwood Quadrangle, Snohomish County, WA." By J.P. Minard dated 1985. Surficial soil types mapped in the vicinity of the project site are typical for glaciated landscapes throughout Snohomish County. As shown on the **Geologic Map** (*figure 4*), Vashon Glacial Till (*Qvt*) and Vashon Advance Outwash (*Qva*) are the predominately mapped surficial soil units in the immediate vicinity of the project site.

Glacial Till (*Qvt*) consists of a non-sorted mixture of silt, sand and gravel deposited as a lodgment till below the Vashon aged glaciers as they advanced through this area. The deposits are generally very compact and where undisturbed will have a consistency similar to concrete. In this area Glacial Till (*Qvt*) is fairly sandy, with significant amounts of gravels and cobbles. Glacial Till (*Qvt*) is generally considered to be an aquiclude, not readily transmitting ground water through it. Locally, ground water may travel through and along discontinuous lenses of sand and gravel or through sandier portions of the Glacial Till (*Qvt*) within the upper couple of feet of the section. However, these discontinuous lenses of sand and gravel are difficult to characterize or quantify and are not considered to be reliable sources of ground water.

Advance Outwash (*Qva*) consists primarily of fine- to coarse-grained layers of sand and gravel deposited as the Vashon aged glaciers advanced into this area. At depth, these deposits can contain significant amounts of silt and/or clay. There is a gradational contact with the underlying Transitional Beds (*Qtb*) found below this geologic unit, with the silt/clay beds becoming thicker and more predominant with depth. The Advance Outwash (*Qva*) sands and gravels are generally very compact, having been overridden by thousands of feet of glacial ice. Advance Outwash (*Qva*) sands and gravels contain significant amounts of ground water and because of their relative shallow stratigraphic depth are the predominant source for ground water throughout the County.

Glacial Till (*Qvt*) was encountered within on upgradient well at the site (*LG-02*). The Glacial Till (*Qvt*) was overlying basal Advance Outwash (*Qva*) sands and gravels. All other explorations at the site (*LG-01, LG-03, LG-04 and LG-05*) encountered only and

were completed within Advance Outwash (*Qva*) sands and gravels. Several test borings were terminated in the gradational silt/clay zone at the base of the Advance Outwash (*Qva*) unit.

1.5 LOCAL HYDROGEOLOGY

Hydrogeologic conditions in the vicinity of the landfill have been studied by many including **EPA, USGS** and the **Army Corp of Engineers**. In the early to late 1980's, the **Seven Lakes Water Association** petitioned the **EPA** for consideration of a sole source aquifer area that included the landfill site. This petition was made in order to protect their rapidly degrading ground water resource which was the only source of ground water for the residences of the area at that time. The **EPA** consulted with the **USGS**, who, upon closer investigation, recommended that the boundaries of the proposed sole source aquifer be expanded to include a much larger area, which was named the **Tulalip Sole Source Aquifer**. The **USGS** expanded the boundaries of the Seven Lakes proposed sole source aquifer in order to protect the recharge source for a deep aquifer, found below the Tulalip Plateau and a larger area of Snohomish County. Recharge areas for this deep aquifer were determined to be located along the west margins of the Cascade Mountains. This deep aquifer is within pre-Glacial Undifferentiated Sands and Gravels (*Qu*) that are found stratigraphically lower than the Advance Outwash (*Qva*) aquifer. A thick sequence of Transitional Bed (*Qtb*) silts and clays act as an aquitard between the Advance Outwash (*Qva*) and Undifferentiated (*Qu*) aquifers. The petition for the **Tulalip Sole Source Aquifer** was eventually denied because other sources of water were available for domestic and commercial use over a large portion of the area.

Hydrogeologic conditions at the landfill were investigated by **Converse Consultants NW**. The results of their investigations were reported in their study titled "Hydrogeologic Study, Lake Goodwin Landfill" date July 1991. Subsequent site explorations were completed by **Golder Associates** and were documented in their report titled "Snohomish County Lake Goodwin Landfill" dated December 1991.

The Lake Goodwin Landfill is located on an upland area known as the Tulalip Plateau. Below the Tulalip Plateau the most productive aquifer is the Advance Outwash (*Qva*) aquifer which is underlain by Transitional Bed (*Qtb*) silts and clays. Where overlain by Glacial Till (*Qvt*), the aquifer is confined. In the vicinity of the Lake

Goodwin Landfill where Glacial Till (*Qvt*) is absent, ground water is unconfined. With the exception of the surficial Glacial Till (*Qvt*) found overlying the Advance Outwash (*Qva*) sands and gravels along the southern edge of the landfill (*LG-02*), permeable soils were encountered from the surface down in all site explorations at the landfill. Ground water elevations below the landfill range from el. 148 to el. 153 with a north to northwest gradient in an unconfined condition within the Advance Outwash (*Qva*) aquifer. At the observed elevations, ground water could be projected to discharge to the surface out of the exposed slopes above Puget Sound, north of Warm Beach or along the Stillaguamish River just south of Stanwood.

1.6 EXISTING MONITORING NETWORK

As outlined in the Solid Waste Facility Permit SW-085, quarterly monitoring of ground water, monthly monitoring of methane gas production and annual monitoring of landfill settlement has been carried out by Snohomish County personnel. Landfill gas was monitored at the landfill via 3 bar hole punches.

There are currently four-(*4*) ground water monitoring wells (*LG-01 and LG-02, and LG-04 and LG-05*) at the Lake Goodwin Landfill site that are monitored on a quarterly basis. Ground Water Monitoring Well locations are shown on the **Network Monitoring Map** (*figure 5*). Of these wells, one-(*1*) is considered to be an up-gradient well monitoring background ground water conditions in the immediate vicinity of the site (*LG-02*). The remaining three-(*3*) wells are located in and/or down gradient of the landfill (*LG-01, and LG-04, LG-05*) and monitor ground water conditions that may be impacted from the site. Ground water monitoring results are discussed in *section 2.0* below.

There is no methane gas collection system at the landfill. During the fourth quarter of 2011 a monthly methane gas monitoring program was initiated at the Lake Goodwin Landfill. Monitoring of methane gas production at the landfill is accomplished by a walking gas probe survey. Three-(*3*) bar hole punch probe locations are shown on the **Network Monitoring Map** (*figure 5*). This survey is performed on a monthly basis through 2014. **Monitoring Results for Methane Gas** production is discussed in *section 3.0* below.

Lastly, an annual settlement monitoring program was initiated during the last quarter of 2011 at the Lake Goodwin Landfill. New topographic survey data was compared to previous recorded surveys to delineate changes to the landfill cap. This year, in compliance with the **Department of Ecology's** "*Guidance for Preparation for Termination of Post Closure Care at Municipal Landfills*", the survey crew installed a permanent 100' grid on the landfill biomass to more accurately record changes in the landfills topography. The **Annual Settlement Monitoring Program** is discussed in detail in *section 4.0* of the report.

2.0 GROUND WATER MONITORING

Quarterly monitoring of the ground water wells at the Lake Goodwin Landfill was performed by **Snohomish County** personnel during 2014. Depth to water was measured and ground water samples were collected following approved sampling protocol. The following sections describe field procedures used and analytical results derived from the sampling event.

2.1 GROUND WATER LEVEL MEASUREMENTS

The depth to ground water within each well was measured prior to ground water sampling activities. The depth to ground water was measured using an electronic water level indicator in increments to the nearest 0.01 ft. as taken from a marked survey point on the top of each well casing.

Quarterly Ground Water Measurements are shown in *Table 1* below. Ground water elevations declined this year for the first time in five-(5) years when comparing Q-4 results. Readings confirm that the aquifer is unconfined in the immediate vicinity of the site.

Measured quarterly precipitation at the Stanwood Weather Station (*WA-SN-11 http://www.cocorahs.org/state.aspx?state=wa*) during the year was 12.19 inches (*1st quarter*), 7.82 inches (*2nd quarter*), 4.9 inches (*3rd quarter*) and 10.75 inches (*4th quarter*) for a total measured precipitation of 35.66 inches of rain. This is over ten inches more than during 2013.

Table 1 - Annual Groundwater Measurements and Elevations

Well Number	Casing Elevation	1st Quarter Reading	2nd Quarter Reading	3rd Quarter Reading	4th Quarter Reading	Annual Trend*
LG-01	239.18	152.96	152.97	154.65	151.45	-2.92
LG-02	268.67	154.23	153.82	155.62	152.63	-3.22
LG-04	206.93	151.49	151.39	151.93	150.97	-1.80
LG-05	235.00	152.10	152.17	153.08	151.75	-2.50

**as measured Q-4 2013 to Q-4 2014*

2.2 ANNUAL GROUND WATER SAMPLING RESULTS

Purging and sampling of each of the four-(*4*) monitoring wells was performed during each quarters sampling event by Snohomish County personnel in accordance with the facilities closure permit and 2012 Sampling and Analysis Plan. Water samples were collected by slowly filling laboratory-supplied containers in such a manner as to reduce aeration. Sample containers were filled so that no headspace or air bubbles remained within the container. Samples were placed in coolers and packed in ice to keep samples at approximately 4C for delivery to the laboratory for testing. Samples were picked up by **Amtest** and taken to their Kirkland, WA laboratory for analysis of dissolved metals, volatile organic compounds (*VOC's*), and conventional chemistry parameters. The quarterly analytical data was compared to the groundwater standards. A complete statistical analysis of each quarterly data set was also performed utilizing **DUMPStat**. Sens Trend analyses were performed for the entire data set stretching back to 1988 and the results of these analyses – increasing or decreasing trends are discussed below.

2.3 EVALUATION OF QUARTERLY GROUND WATER ANALYTICAL RESULTS

Quarterly ground water standard exceedances for each well are summarized in *Table 2* below.

Table 2 - Summary of Ground Water Standard Exceedances

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
LG-01	Arsenic	pH, Arsenic	pH, Arsenic	Arsenic
LG-02	Arsenic	Arsenic	Arsenic	Arsenic
LG-04	pH, arsenic	pH, arsenic	pH, arsenic	pH, arsenic
LG-05	Conductivity, nitrate nitrogen, pH, sodium, TDS, arsenic	Conductivity, nitrate pH, sodium, TDS, arsenic	Conductivity, pH, sodium, TDS, arsenic	Conductivity, nitrate sodium, TDS, arsenic

Other than arsenic, there were no measured exceedances to any dissolved metals or VOC's during the 2014 sampling events at the Lake Goodwin Landfill. Arsenic levels were compared to the "Implementation Guidance for the Ground Water Quality Standards". Although arsenic levels observed were not out of normal, exceedances were recorded when compared to these new standards.

Multiple exceedances to the ground water standards during 2014 were observed in down gradient well LG-05 as shown on table 2 above. The constituent exceedances in well LG-05 were consistent throughout the year. As shown on the **Quarterly Ground Water Contour Map,** observation well LG-05 is located along the calculated ground water flow gradient directly down-gradient from the landfill.

2.4 STATISTICAL EVALUATION

State health regulations under which the Lake Goodwin Landfill closure is permitted require that the landfill "...shall not cause exceedances of *Chapter 173-200 WAC*, **Water Quality Standards for Groundwater**, and *Chapter 246-290 WAC*, **Drinking Water Regulations**." The intent of these state regulations is to limit the impact that a landfill will have on the surrounding ground water resources. Collected ground water samples are tested for Primary and Secondary Drinking Water Standards, Dissolved Metals and Volatile Organic Compounds – and compared to the standards listed in the above referenced WAC's. Where an exceedance to the standards occurs, a statistical analysis is provided to determine the significance of the change or exceedance. Each of these exceedances has been statistically analyzed using **DUMPStat Software** (*version 2.1.9 by Robert D. Gibbons Lt., 2000*) per the *Subtitle D* regulations and as specifically referenced in the **U.S. EPA** guidance manual. Mean, standard deviation, prediction limits, and confidence values were calculated by **DUMPStat.**

The quarterly Trends Analyses have been run utilizing data sets from 2006 through 2014, allowing us to place multiple constituents on a single graph to better see potential correlations. Per **Ecology** and **Snohomish Health District** request, the prediction limit is updated in the first quarter of the year and subsequent data sets are compared against that prediction limit. The calculated statistical prediction limit may or may not be lower than the groundwater standard. **Quarterly Statistical Summary Exceedances** are shown in *Table 3* below.

Table 3 – Quarterly Statistical Summary Exceedances for 2014

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
LG-01	Alkalinity, bicarbonate, conductivity, barium, sulfate, magnesium, potassium, manganese	Alkalinity, pH, bicarbonate, sulfate, conductivity, barium, magnesium, potassium, manganese	Alkalinity, bicarbonate, conductivity, magnesium, potassium, sulfate	Alkalinity, bicarbonate, conductivity, magnesium, potassium, sulfate, barium
LG-02	None	None	None	None
LG-04	Chloride, pH, barium	pH, barium	Barium	Barium
LG-05	Alkalinity, bicarbonate, calcium, chloride, conductivity, magnesium, nitrate, nitrite, potassium, sodium, sulfate, TDS, barium, manganese,	Alkalinity, TDS, bicarbonate, calcium, chloride, nickel conductivity, barium, magnesium, nitrate, pH, nitrite, copper, potassium, sodium, sulfate, manganese,	Alkalinity, bicarbonate, calcium, chloride, conductivity, magnesium, nitrate, nitrite, potassium, sodium, sulfate, TDS, barium, iron	Alkalinity, bicarbonate, calcium, COD, chloride, conductivity, magnesium, nitrate, nitrite, potassium, sodium, sulfate, TDS, barium, nickel

Constituents and their trends over the year do not appear to respond directly or indirectly to precipitation. Statistical analysis over the year indicates no changes to the up-gradient ground water quality at the landfill (*LG-02*). Trends within the down-gradient wells were consistently decreasing, with minor increases in various constituents (*although with no apparent pattern*) shown quarterly over the year. Calcium and Nitrate were increasing trends in LG-01 over the year, although not at levels exceeding the MCL's. Based on the quarterly analyses in 2014, down-gradient ground water quality still shows an impact from the landfill in LG-05.

Table 4 – Significant Trend Summary 2014

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
LG-01	6-I, 2-D	8-I, 2-D	8-I, 2-D	9-I, 2-D
LG-02	3-I, 2-D	2-I, 2-D	2-I, 1-D	2-I, 1-D
LG-04	1-I, 7-D	1-I, 7-I	1-I, 7-D	1-I, 7-D
LG-05	2-I, 2-D	4-I, 2-D	4-I, 2-D	6-I, 2-D
Totals	12-I, 13-D	15-I, 13-D	15-I, 12-D	18-I, 12-D

3.0 METHANE GAS MONITORING

The landfill is not lined and there is no gas collection system. Nine-(*9*) bar holes for the purpose of monitoring landfill generated methane gas were placed at appropriate locations through the top of the biomass in 2011. Monthly methane gas monitoring of the

Lake Goodwin Landfill was initiated during the 4th quarter of 2011. The probes were vandalized in March, 2012. A new set of three-(3) bar holes was installed in November, 2013. Existing bar hole probe locations are shown on the **Monitoring Network Map** (*figure5*). **Bar Hole Punch Gas Probe Installation Details** are shown in *table 4* below.

Table 5 – Bar Hole Punch Gas Probe Installation Details

Probe I.D.	Depth of Bar Hole (*inches*)	Depth to Garbage (*inches*)	Depth to Screen (*inches*)
LG-A1	46	18	30
LG-B2	44	14	32
LG-C2	37	17	31

3.1 LANDFILL GAS MONITORING REQUIREMENTS

A monthly monitoring program has been initiated by Snohomish County Solid Waste personnel in order to establish a data base to be used in part for landfill stability determination and for Post Closure planning. Because the bar holes are placed through the cap and into the garbage, we anticipate measureable amounts of methane gas to be present for many years.

3.2 LANDFILL GAS MONITORING PROCEDURES

Initiated during the last quarter of 2011, three-(*3*) gas probes were sampled using a Gastech TLV Meter. This meter is designed to measure small concentrations of methane gas escaping through the probe monitoring ports. Methane concentrations will be measured in parts per million (*ppm*) and recorded by field personnel. 12 months of data was collected in 2014 from the gas probes. The **Landfill Gas Monitoring Results** are included in *Table 5* below.

Table 6 – 2014 Landfill Gas Monitoring Results

Probe	Date	% Methane	Oxygen	CO2	Barometer
LG-A1	2/6/14	13	0	16	
	4/23/14	11	0	16	
	8/7/14	16	0	25	
	10/22/14	14	1	22	
LG-B2	2/6/14	23	0	10	
	4/23/14	24	0	10	
	8/7/14	19	0	18	
	10/22/14	18	2	16	
LG-C2	2/6/14	14	0	12	

Probe	Date	% Methane	Oxygen	CO2	Barometer
	4/23/14	19	0	12	
	8/7/14	16	0	19	
	10/22/14	17	2	17	

4.0 SETTLEMENT MONITORING

Annual settlement monitoring was initiated by Snohomish County Solid Waste personnel in 2011 in order to establish landfill biomass stability for custodial care planning. In 2013, the survey crew installed a permanent 100 foot grid over the top of the biomass. This will allow us to meet the new Department of Ecology Guidance document.

4.1 SETTLEMENT MONITORING REQUIREMENTS

In order to comply with post closure requirements, cover surface slopes must remain between 2 and 5 percent grade, side slopes must remain below 33 percent slope and localized settlements must not impair cover drainage or cover integrity. Existing biomass stability will be determined based on these annual surveys.

4.2 SETTLEMENT MONITORING REQUIREMENTS

Settlement monitoring will be performed on an annual basis by taking direct measurements through topographic surveys and comparing them to existing and previous topographic surveys and/or to other appropriate data sets, such as Lidar Mapping, that covers the Lake Goodwin Landfill. Survey crews perform a field survey of the side slopes, grade breaks and additional points necessary to prepare a topographic contour map with maximum two-(*2*) ft contours.

4.3 SETTLEMENT MONITORING PROCEDURES

Topographic survey data is compared to previous and/or existing data for any changes, which includes historic topographic surveys and also current Lidar information, if available. Areas where settlement has occurred are highlighted on a maximum two-(*2*) foot contour topographic map of the site. Existing surface slope grades are also analyzed. Areas exceeding the maximum percent slope grades given in *section 4.1* above are highlighted and shown on an annual contour topographic map of the site.

The fourth Lake Goodwin Landfill survey was completed by the *Snohomish County Public Works Survey Group* in December 2014. Current survey results are on the **Lake Goodwin Landfill Settlement and Monitoring Exhibit**, *Figure 6* of this report. The **Slope Range Analysis** results from the 2014 annual survey are shown in *Figure 7*.

5.0 SUMMARY AND CONCLUSIONS/RECOMMENDATIONS

5.1 SUMMARY

The ground water data collected during the 2014 quarterly sampling events indicates the following:

- Overall ground water elevations below the landfill continue to rise in 2014, which is a continuing trend that has been documented since 2005. However, this year ground water elevations dropped between 1.8' and 3.22' when compared to the 2013 readings. The overall trend in ground water elevation is still increasing - see charts in Appendix A.
- Other than arsenic, there were no measured exceedances to the groundwater standards for any dissolved metals or VOC's during the 2014 sampling events at the Lake Goodwin Landfill.
- pH and arsenic were all reoccurring exceedances to the groundwater standards in both up-gradient and down-gradient wells during 2014. Conductivity levels observed at well LG-05 were significantly higher than the surrounding wells.
- Statistical analysis did show significant impacts to well LG-05. Lesser impacts where indicated in well LG-01 and lesser impacts were observed in LG-04. Time series plots based on the **DUMPStat** analysis indicates that there were more significant increasing trends (12-18 *per quarter*) than decreasing trends (*12-13 per quarter*) in 2014. The increasing trends are in LG-01 and LG-05 and are primarily in the geochemistry markers. pH is a decreasing trend, dropping below 7 in all wells except LG-02.
- There were very minimal impacts to the ground water from dissolved metals. Small exceedances to the calculated prediction limits for barium, manganese, and nickel were found in various down-gradient wells over the year.
- Due to the natural background levels of Arsenic in the ground water around the Lake Goodwin Landfill, it is difficult to determine the source of arsenic impacts to the groundwater.
- The bar hole methane readings are within acceptable levels for the age of the Lake Goodwin Landfill. A trend analysis will be completed when enough data has been collected to make a meaningful comparison.
- Annual settlement readings of the landfill cap were initiated during 2011. Initial readings indicate an overall stable landfill mass and cap. Measured settlements

within instrument tolerances except at point 1608, where an observed delta of 0.04 ft. may indicate small amounts of localized cap settlement during 2014.

5.2 CONCLUSIONS/RECOMMENDATIONS

Settlement surveys and landfill gas monitoring suggests that the landfill mass has stabilized. 2014 data indicates a continued moderate leachate impact to the underlying Advance Outwash (*Qva*) aquifer below the Lake Goodwin Landfill. The monitoring data indicates that a leachate impacted ground water plume extends beyond the landfill boundaries following the ground water gradient to the north-northeast.

We recommend that monitoring of the Lake Goodwin Landfill continue through 2015 per the SAP.

5.3 SIGNATURES

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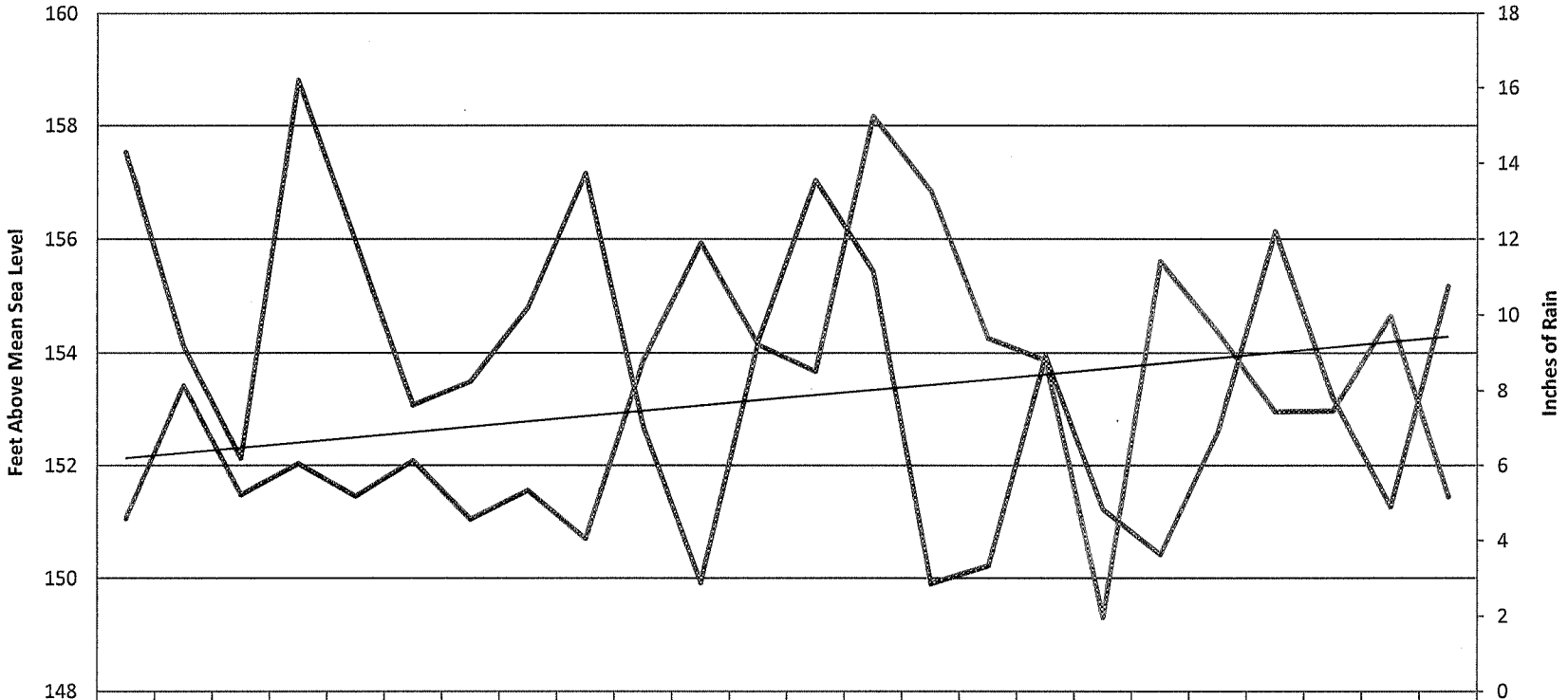
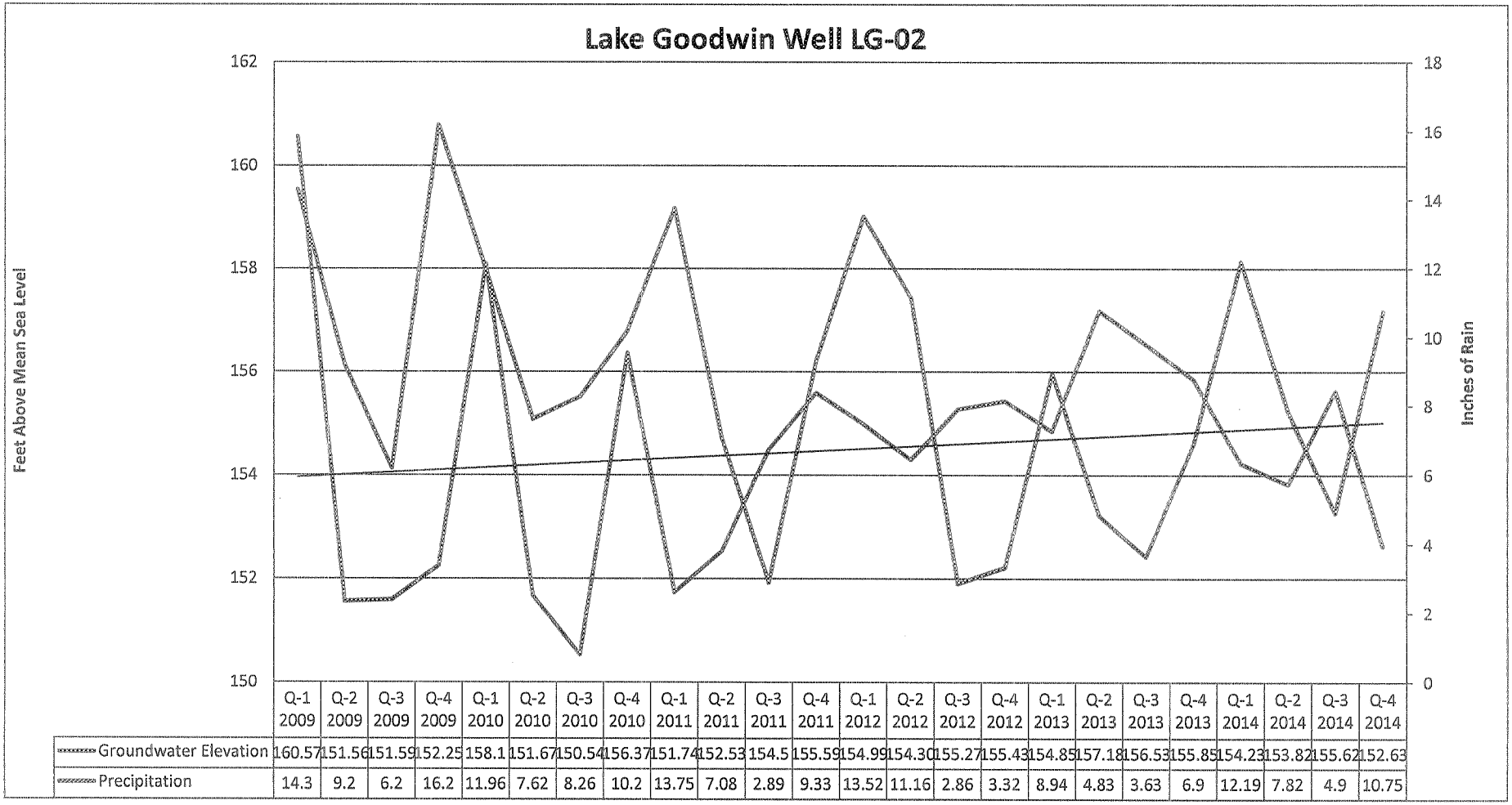
January 2014

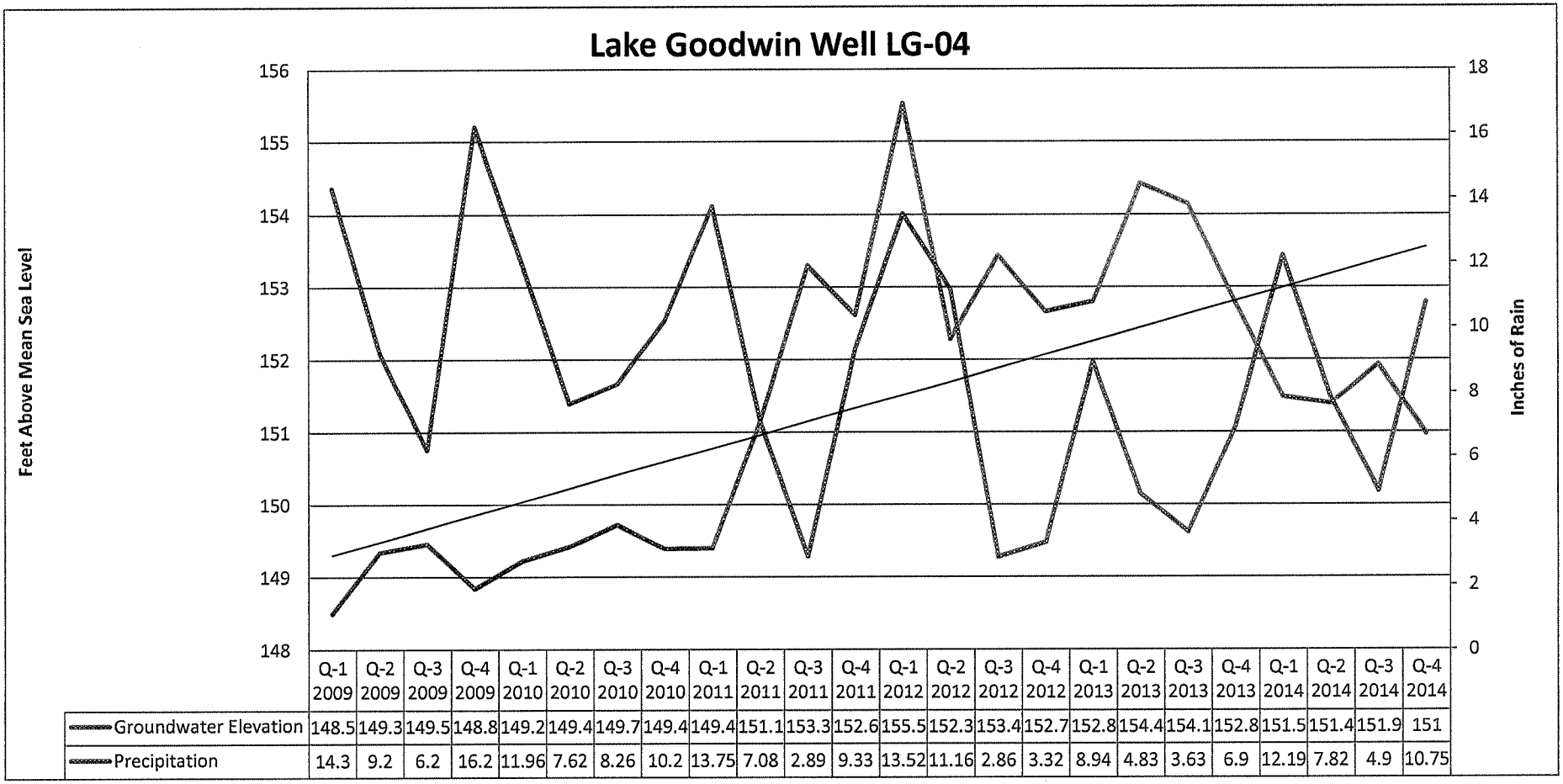
Lake Goodwin Well LG-01



	Q-1 2009	Q-2 2009	Q-3 2009	Q-4 2009	Q-1 2010	Q-2 2010	Q-3 2010	Q-4 2010	Q-1 2011	Q-2 2011	Q-3 2011	Q-4 2011	Q-1 2012	Q-2 2012	Q-3 2012	Q-4 2012	Q-1 2013	Q-2 2013	Q-3 2013	Q-4 2013	Q-1 2014	Q-2 2014	Q-3 2014	Q-4-2014
Depth to Water	151.1	153.4	151.5	152	151.5	152.1	151.1	151.6	150.7	153.9	155.9	154.2	153.7	158.2	156.9	154.3	153.9	149.3	155.6	154.4	153	153	154.7	151.5
Precipitation	14.3	9.2	6.2	16.2	11.96	7.62	8.26	10.2	13.75	7.08	2.89	9.33	13.56	11.16	2.86	3.32	8.94	4.83	3.63	6.9	12.19	7.82	4.9	10.75

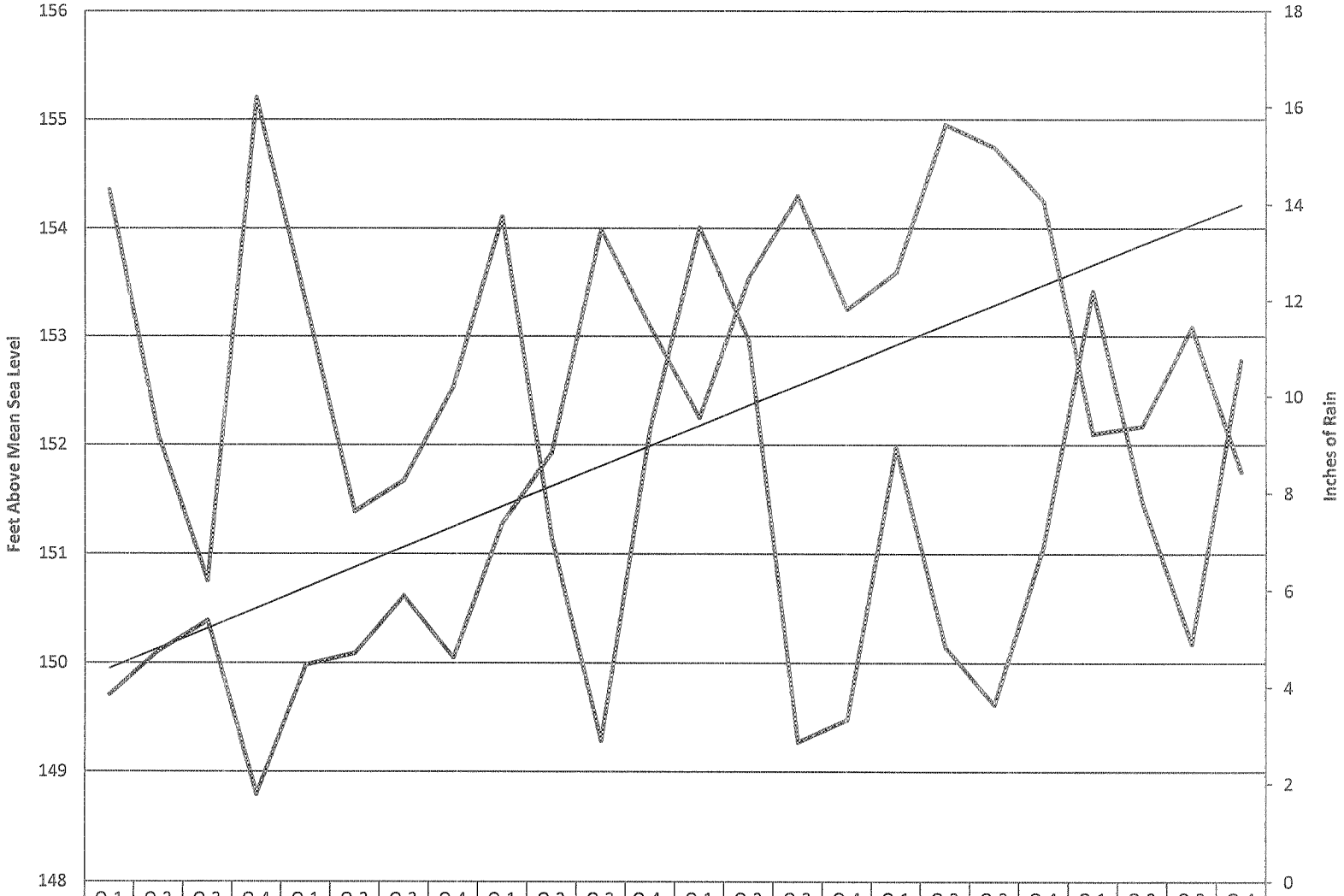


	Q-1 2009	Q-2 2009	Q-3 2009	Q-4 2009	Q-1 2010	Q-2 2010	Q-3 2010	Q-4 2010	Q-1 2011	Q-2 2011	Q-3 2011	Q-4 2011	Q-1 2012	Q-2 2012	Q-3 2012	Q-4 2012	Q-1 2013	Q-2 2013	Q-3 2013	Q-4 2013	Q-1 2014	Q-2 2014	Q-3 2014	Q-4 2014
Groundwater Elevation	160.57	151.56	151.59	152.25	158.1	151.67	150.54	156.37	151.74	152.53	154.5	155.59	154.99	154.30	155.27	155.43	154.85	157.18	156.53	155.85	154.23	153.82	155.62	152.63
Precipitation	14.3	9.2	6.2	16.2	11.96	7.62	8.26	10.2	13.75	7.08	2.89	9.33	13.52	11.16	2.86	3.32	8.94	4.83	3.63	6.9	12.19	7.82	4.9	10.75



	Q-1 2009	Q-2 2009	Q-3 2009	Q-4 2009	Q-1 2010	Q-2 2010	Q-3 2010	Q-4 2010	Q-1 2011	Q-2 2011	Q-3 2011	Q-4 2011	Q-1 2012	Q-2 2012	Q-3 2012	Q-4 2012	Q-1 2013	Q-2 2013	Q-3 2013	Q-4 2013	Q-1 2014	Q-2 2014	Q-3 2014	Q-4 2014
Groundwater Elevation	148.5	149.3	149.5	148.8	149.2	149.4	149.7	149.4	149.4	151.1	153.3	152.6	155.5	152.3	153.4	152.7	152.8	154.4	154.1	152.8	151.5	151.4	151.9	151
Precipitation	14.3	9.2	6.2	16.2	11.96	7.62	8.26	10.2	13.75	7.08	2.89	9.33	13.52	11.16	2.86	3.32	8.94	4.83	3.63	6.9	12.19	7.82	4.9	10.75

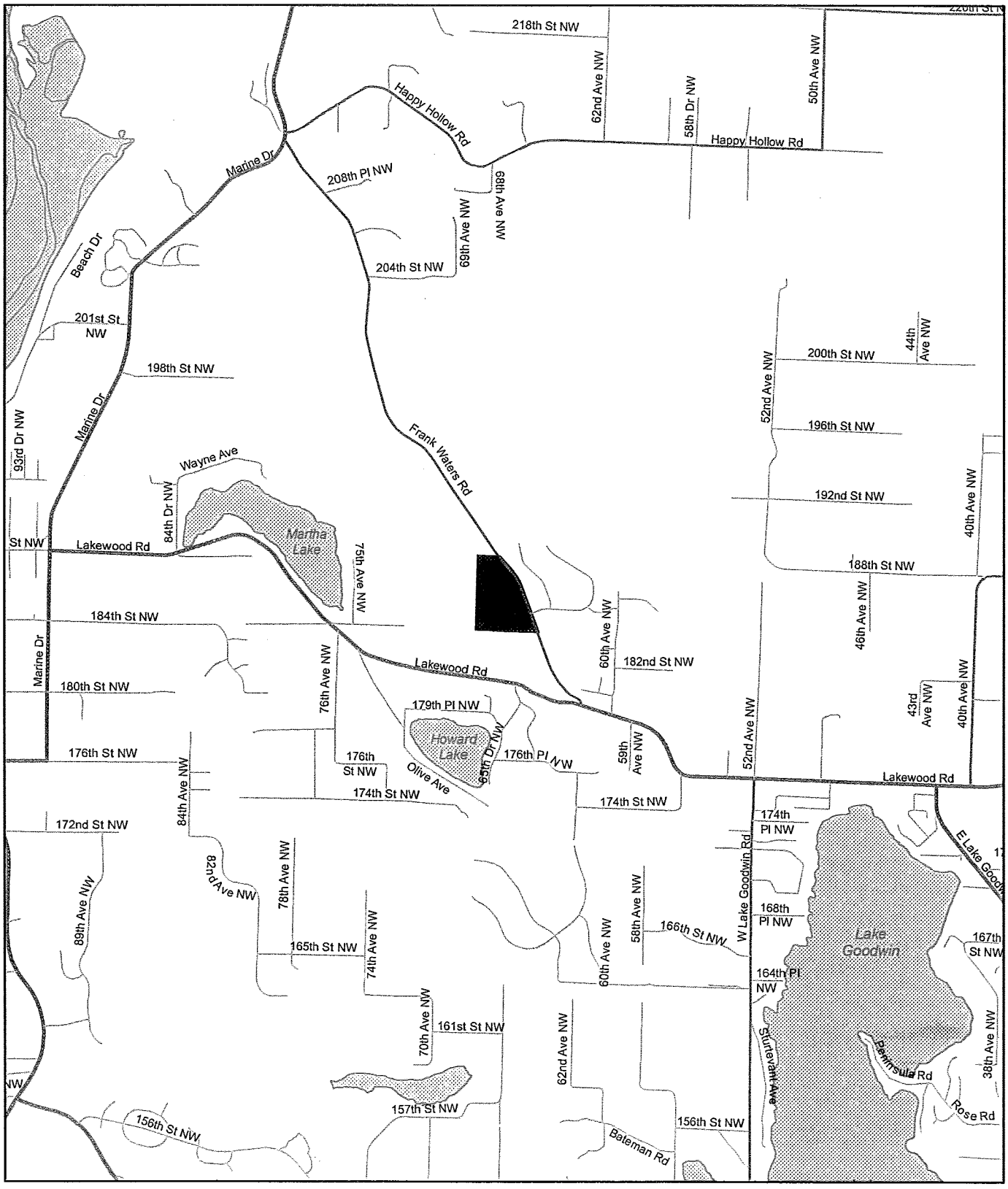
Lake Goodwin Well LG-05



	Q-1 2009	Q-2 2009	Q-3 2009	Q-4 2009	Q-1 2010	Q-2 2010	Q-3 2010	Q-4 2010	Q-1 2011	Q-2 2011	Q-3 2011	Q-4- 2011	Q-1 2012	Q-2 2012	Q-3 2012	Q-4 2012	Q-1 2013	Q-2 2013	Q-3 2013	Q-4 2013	Q-1 2014	Q-2 2014	Q-3 2014	Q-4 2014
Groundwater Elevation	149.7	150.1	150.4	148.8	150	150.1	150.6	150.1	151.3	151.9	154	153.1	152.3	153.5	154.3	153.3	153.6	155	154.8	154.3	152.1	152.2	153.1	151.8
Precipitation	14.3	9.2	6.2	16.2	11.96	7.62	8.26	10.2	13.75	7.08	2.89	9.33	13.52	11.16	2.86	3.32	8.94	4.83	3.63	6.9	12.19	7.82	4.9	10.75

Figure 1

Lake Goodwin Landfill

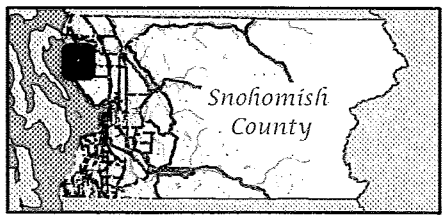


1 inch = 0.5 miles

0 0.15 0.3 0.6 0.9 Miles

0 0.25 0.5 1 1.5 Kilometers

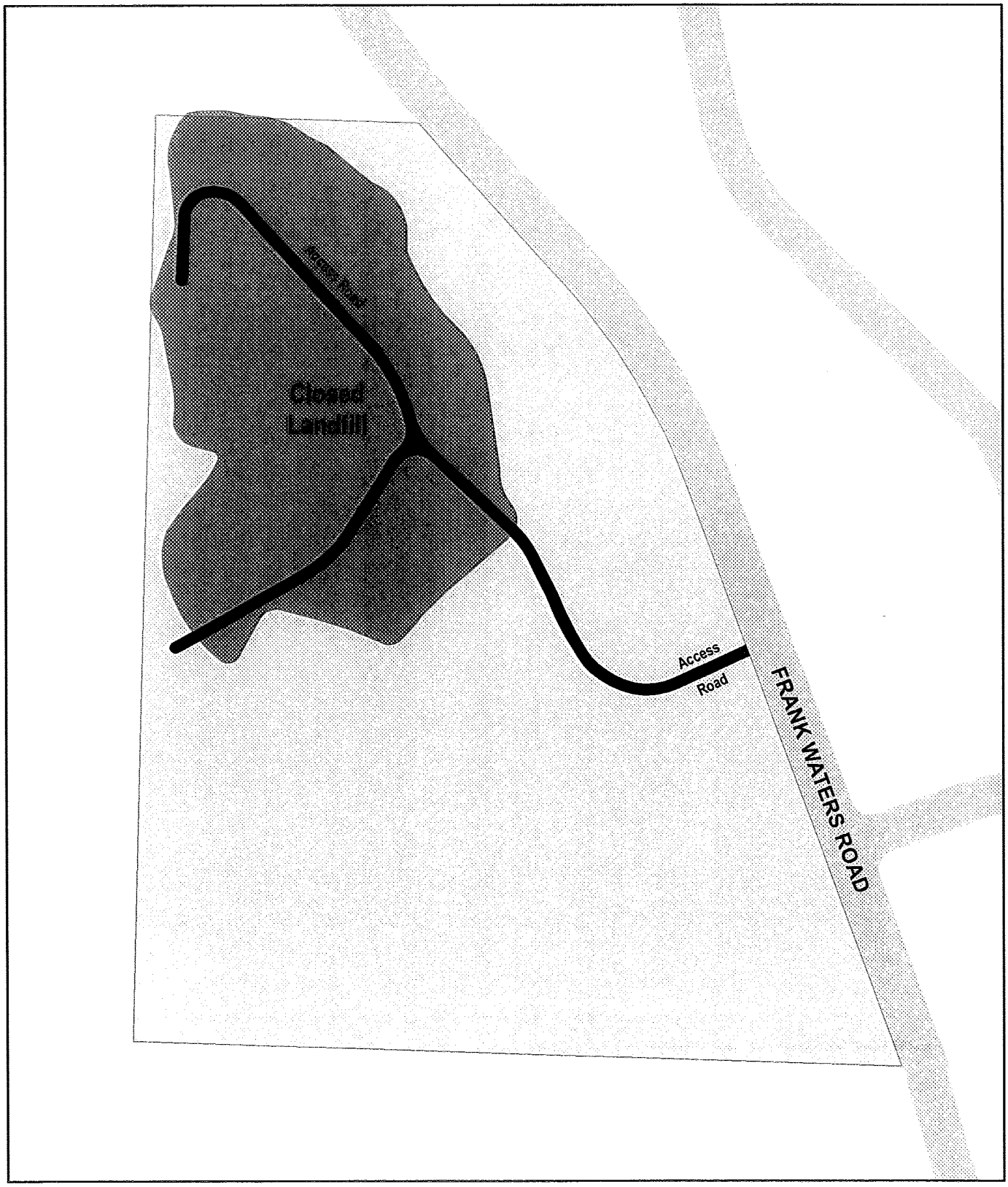
N W E S



Snohomish County
Public Works
Solid Waste Division
March 22, 2010

Figure 2

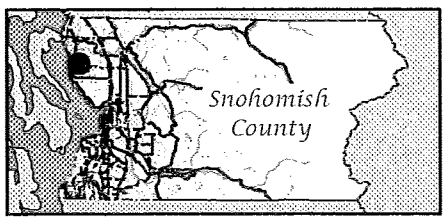
Lake Goodwin Landfill Site Map



0 0.015 0.03 0.06 Miles

0 70 140 280 420 Feet

N W E S



Snohomish County
Public Works
Solid Waste Division
March 25, 2010

Figure 3

Lake Goodwin Landfill

Topography

Map Features

- Parcel Boundary
- Subject Property Boundary
- 5 Foot Contours

N

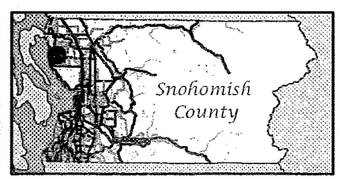
W E

S

1 inch = 200 feet

0 0.0125 0.025 0.05 0.075 0.1 0.125 Miles

0 85 170 340 510 680 Feet



Snohomish County
Public Works
Solid Waste Division
March 23, 2010

Figure 4

Lake Goodwin Landfill

Geologic Map

Map Features

- Parcel Boundary
- Subject Property Boundary

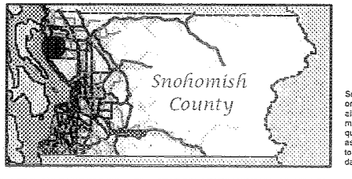
Geologic Description

- Vashon advance outwash (Qva)
- Vashon recessional outwash
- Vashon till (Qvt)
- Water
- Modified Land

1 inch = 600 feet

0 0.035 0.07 0.14 0.21 0.28 0.35 Miles

0 240 480 960 1,440 1,920 Feet



N W E S

Snohomish County
Public Works
Solid Waste Division
May 6, 2010

Figure 5

Lake Goodwin Landfill

Monitoring Network

Map Features

- Parcel Boundary
- Subject Property Boundary

Aquifer Unit (Active Wells)

- Deep Aquifer

Additional Sampling Points

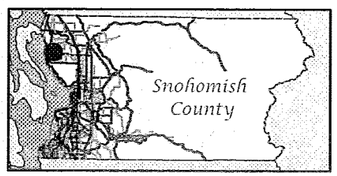
- Bar Hole Punch Gas Probe

X = decommissioned

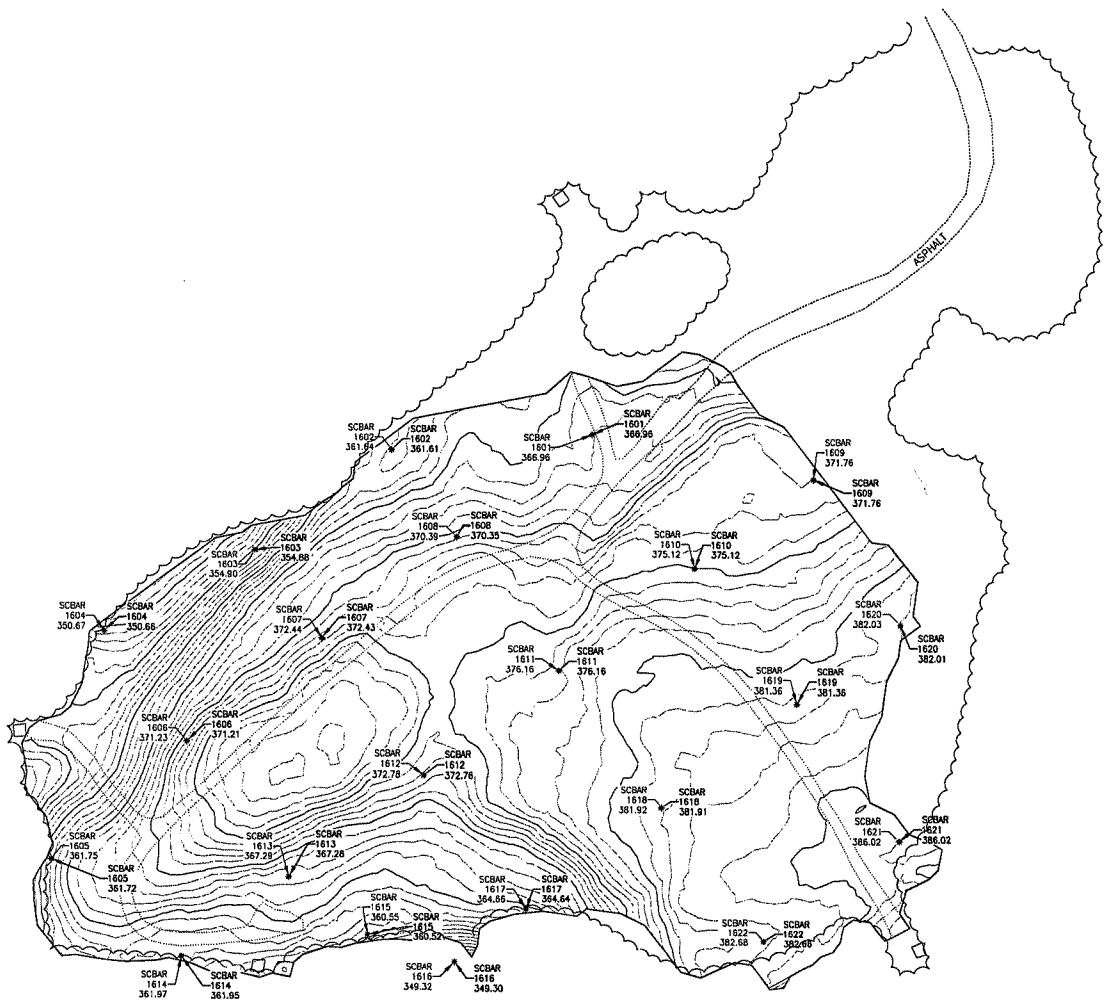
N
W E
S

0 0.015 0.03 0.06 0.09 0.12 Miles

0 80 160 320 480 640 Feet



Snohomish County
Public Works
Solid Waste Division
March 2, 2012



HORIZONTAL DATUM: STATE PLANE,
(WASHINGTON NORTH ZONE, NAD 83/2007 ADJUSTMENT)

DATUM

NAVD 88

VERTICAL DATUM: NAVD 88
BASED ON MULTI-SESSION GPS

BASED ON:
COUNTY FIELD MAPPING ON JANUARY, 2013.

CONTOUR INTERVAL = 1 FOOT

POINT NO.	DESC.	2013 ELEV.	2014 ELEV.	ELEV. CHANGE
1601	SCBAR	366.96	366.96	0
1602	SCBAR	361.64	361.61	-0.03
1603	SCBAR	354.9	354.88	-0.02
1604	SCBAR	350.67	350.66	-0.01
1605	SCBAR	361.75	361.72	-0.03
1606	SCBAR	371.23	371.21	-0.02
1607	SCBAR	372.44	372.43	-0.01
1608	SCBAR	370.39	370.35	-0.04
1609	SCBAR	371.77	371.76	-0.01
1610	SCBAR	375.12	375.12	0
1611	SCBAR	376.16	376.16	0
1612	SCBAR	372.78	372.76	-0.02
1613	SCBAR	367.29	367.28	-0.01
1614	SCBAR	361.97	361.95	-0.02
1615	SCBAR	360.55	360.52	-0.03
1616	SCBAR	349.32	349.3	-0.02
1617	SCBAR	364.66	364.64	-0.02
1618	SCBAR	381.92	381.91	-0.01
1619	SCBAR	381.36	381.36	0
1620	SCBAR	382.03	382.01	-0.02
1621	SCBAR	386.02	386.02	0
1622	SCBAR	382.68	382.66	-0.02

SNOHOMISH COUNTY DEPARTMENT OF PUBLIC WORKS

PROJECT NO. RR 8019

SURVEY NO. 3089

FIELD BOOK(S): 1740

DRAWN BY: ALJ

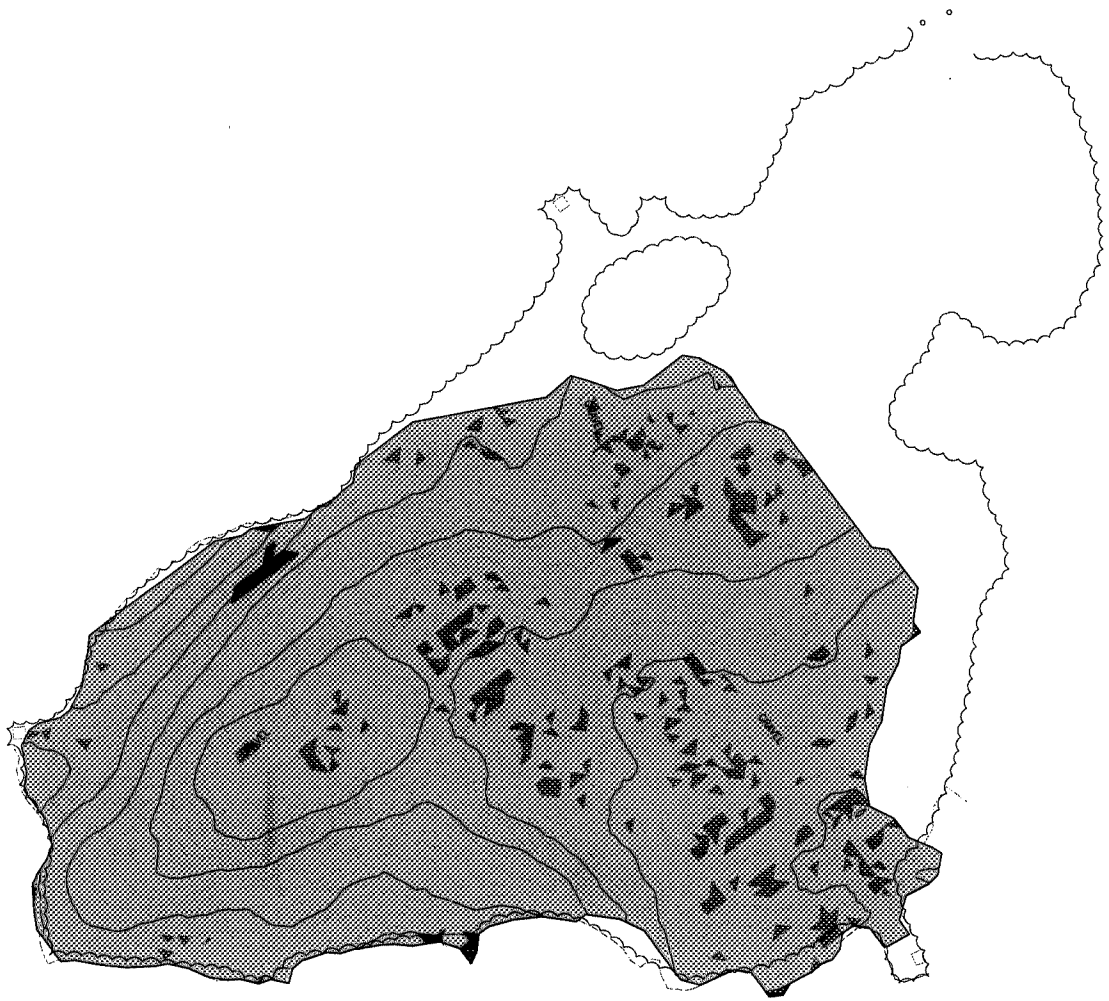
UPI# 09-0064-1A

LAKE GOODWIN LANDFILL

VERTICAL MOVEMENT STUDY OF MONITORING POINTS

REFERENCE SHEET NO.

SHEET 1 OF 1 SHEETS



N

60 0 60 120
SCALE IN FEET

HORIZONTAL DATUM: STATE PLANE,
(WASHINGTON NORTH ZONE, NAD 83/2007 ADJUSTMENT)

DATUM
NAVD 88

VERTICAL DATUM: NAVD 88
BASED ON MULTI-SESSION GPS

BASED ON:
COUNTY FIELD MAPPING ON AUGUST, 2014.

CONTOUR INTERVAL = 1 FOOT

Slope Range Table

Number	Min. Slope Range	Max. Slope Range	Area (sq ft)	Color
1	0.10%	2.00%	14710	
2	2.00%	33.00%	282482	
3	33.00%	131.99%	1341	

SNOHOMISH COUNTY
DEPARTMENT OF
PUBLIC WORKS
PROJECT NO. RR 8019

SURVEY NO. 3069
FIELD BOOK(S): 1740, 1797
DRAWN BY: ALJ
UPI# 09-0064-1A

LAKE GOODWIN LANDFILL

SLOPE STUDY
BASED ON 10' GRID MAPPING

REFERENCE SHEET NO.

SHEET 1 OF 1 SHEETS