



# 2020 ANNUAL ENVIRONMENTAL MONITORING REPORT

## INMAN LANDFILL

14506 Allen West Road  
Bow, Washington



Prepared by:

Skagit County Public Works Department  
1800 Continental Place  
Mount Vernon, Washington 98273-5625

March 2021

**2020 Annual Environmental Monitoring Report  
Inman Landfill  
Skagit County, Washington**

Prepared by:



**JOHN F. RAPP**

*John F. Rapp*  
John F. Rapp, LG, LHg

Skagit County Public Works Department  
1800 Continental Place  
Mount Vernon, Washington 98273-5625

March 2021

## TABLE OF CONTENTS

<b>1.0</b>	<b>INTRODUCTION .....</b>	<b>1</b>
1.1.	Site Background .....	1
1.2.	Landfill Closure .....	1
<b>2.0</b>	<b>LEACHATE .....</b>	<b>3</b>
2.1.	Leachate Collection System Operation .....	3
2.2.	Leachate Generation .....	3
<b>3.0</b>	<b>HYDROGEOLOGY .....</b>	<b>4</b>
3.1.	Perched Aquifer .....	4
3.2.	Upper Regional Aquifer .....	5
<b>4.0</b>	<b>GROUNDWATER SAMPLING METHODS .....</b>	<b>7</b>
4.1.	Sample Locations and Frequency .....	7
4.2.	Sample Collection .....	7
4.3.	Analytical Parameters .....	7
<b>5.0</b>	<b>GROUNDWATER QUALITY RESULTS .....</b>	<b>8</b>
5.1.	Perched Aquifer .....	8
5.2.	Upper Regional Aquifer .....	8
5.3.	Domestic Wells .....	9
<b>6.0</b>	<b>STATISTICAL EVALUATION OF GROUNDWATER RESULTS .....</b>	<b>10</b>
6.1.	Piper Diagrams .....	10
6.2.	Stiff Diagrams .....	10
6.3.	Cation-Anion Balance .....	11
6.4.	Box Plots .....	11
6.5.	Mann-Kendall Trend Test .....	13
<b>7.0</b>	<b>LANDFILL GAS EXTRACTION AND MONITORING ACTIVITIES .....</b>	<b>17</b>
7.1.	LFG Extraction System Operation .....	17
7.2.	Perimeter Monitoring .....	17
<b>8.0</b>	<b>INSPECTIONS .....</b>	<b>18</b>
<b>9.0</b>	<b>SUMMARY AND CONCLUSIONS .....</b>	<b>19</b>
<b>10.0</b>	<b>RECOMMENDATIONS .....</b>	<b>21</b>
<b>11.0</b>	<b>REFERENCES .....</b>	<b>22</b>

## TABLES

Table 1.	2020 Static Water Level Elevations: Perched Aquifer .....	4
Table 2.	2020 Static Water Level Elevations: Upper Regional Aquifer .....	5
Table 3.	Summary of Maximum Concentrations of Analytes Exceeding Groundwater Quality Standards in Perched Aquifer Wells: 2020 .....	8
Table 4.	Summary of Maximum Concentrations of Analytes Exceeding Groundwater Quality Standards in Upper Regional Aquifer Wells: 2020 .....	9
Table 5.	Summary of Box Plot Visual Analysis in Perched Aquifer Wells: 2020 .....	12
Table 6.	Summary of Box Plot Visual Analysis in Upper Regional Aquifer Wells: 2020 .....	13
Table 7.	Mann-Kendall Significant Trends: Perched Aquifer .....	14
Table 8.	Mann-Kendall Significant Trends: Upper Regional Aquifer .....	15
Table 8.	Mann-Kendall Significant Trends: Upper Regional Aquifer (cont). .....	16
Table F-1.	Perimeter Landfill Gas Measurements, 2020: Inman Landfill .....	Appendix F

**FIGURES**

Figure 1. Inman Landfill Location Map .....23  
Figure 2. Annual Volume of Leachate Disposed. ....24  
Figure 3. Perched Aquifer Monitoring Well Locations.....25  
Figure 3a. Potentiometric Surface Contour Map, Perched Aquifer, April 2020. ....26  
Figure 3b. Potentiometric Surface Contour Map Perched Aquifer, September 2020. ....27  
Figure 3c. Potentiometric Surface Contour Map, Perched Aquifer, December 2020. ....28  
Figure 4. Regional Aquifer Monitoring Well Locations. ....29  
Figure 4a. Potentiometric Surface Contour, Central Landfill, Regional Aquifer, April 2020.....30  
Figure 4b. Potentiometric Surface Contour, Central Landfill, Regional Aquifer, September 2020. ....31  
Figure 4c. Potentiometric Surface Contour, Central Landfill, Regional Aquifer, December 2020.....32  
Figure 5. Perched Aquifer Hydrograph, 1994-2020 .....33  
Figure 6. Regional Aquifer Hydrograph, 1994-2020 .....34  
Figure 7a. Potentiometric Surface Contour Map, Regional Aquifer, April 2020. ....35  
Figure 7b. Potentiometric Surface Contour Map, Regional Aquifer, September 2020. ....36  
Figure 7c. Potentiometric Surface Contour Map, Regional Aquifer, December 2020. ....37  
Figure 8. Inman Landfill Gas Extraction System Layout.....38  
Figure 9. Landfill Gas Perimeter Monitoring Probe Locations.....39

**APPENDICIES**

**APPENDIX A-1 2020 GROUNDWATER MONITORING DATA – PERCHED AQUIFER**  
**APPENDIX A-2 LONG TERM TIME SERIES PLOTS 1994-2020 – PERCHED AQUIFER**  
**APPENDIX B-1 2020 GROUNDWATER MONITORING DATA – UPPER REGIONAL AQUIFER**  
**APPENDIX B-2 LONG-TERM TIME SERIES PLOTS 1994-2020 – UPPER REGIONAL AQUIFER**  
**APPENDIX C DATA VALIDATION REPORT FOURTH QUARTER 2020**  
**APPENDIX D-1 PIPER DIAGRAMS 2020 – PERCHED AQUIFER**  
**APPENDIX D-2 STIFF DIAGRAMS 2020 – PERCHED AQUIFER**  
**APPENDIX D-3 BOX PLOTS 1994-2020 – PERCHED AQUIFER**  
**APPENDIX D-4 LONG-TERM MANN-KENDALL TREND TESTS 1994-2020 – PERCHED AQUIFER**  
**APPENDIX D-5 SHORT-TERM MANN-KENDALL TREND TESTS 2016-2020 – PERCHED AQUIFER**  
**APPENDIX E-1 PIPER DIAGRAMS 2020 – UPPER REGIONAL AQUIFER**  
**APPENDIX E-2 STIFF DIAGRAMS 2020 – UPPER REGIONAL AQUIFER**  
**APPENDIX E-3 BOX PLOTS 1994-2020 – UPPER REGIONAL AQUIFER**  
**APPENDIX E-4 LONG-TERM MANN-KENDALL TREND TESTS 1994-2020 – UPPER REGIONAL AQUIFER**  
**APPENDIX E-5 SHORT-TERM MANN-KENDALL TREND TESTS 2016-2020 – UPPER REGIONAL AQUIFER**  
**APPENDIX F LANDFILL GAS MONITORING DATA – 2020**

## 1.0 INTRODUCTION

This report presents a summary of environmental monitoring data collected during 2020 at the Inman Landfill. Annual reporting of environmental monitoring data is required by *Minimum Functional Standards for Solid Waste Handling* (Chapter 173-304 Washington Administrative Code [WAC]) and *Special Incinerator Ash Management Standards* (Chapter 173-306 WAC). This annual monitoring report includes a summary of leachate generation, groundwater quality and flow characteristics, landfill gas extraction system operations, and methane concentrations measured in perimeter gas probes.

### 1.1. Site Background

Inman Landfill is located in the northwestern portion of Skagit County, approximately 7.5 miles northwest of Mount Vernon, Washington (Figure 1). The site occupies a former gravel pit and was operated as a solid waste disposal facility by Skagit County beginning in 1973. The site stopped accepting waste in April 1994 and closure construction was completed in 1995.

Solid waste was first disposed in an unlined area covering approximately 16 acres in the eastern portion of the site (Phase I). Beginning in 1986, solid waste was disposed in a lined portion of the site (Phase II), which covers approximately 10 acres, part of which overlaps the Phase I area. Incinerator ash was also disposed in the lined (Phase II) area. The lined portion of the site includes a combination of composite, geomembrane, and soil liner systems. The leachate collection system consists of a series of perforated pipes placed above the bottom liner. The perforated pipes collect and route leachate through a pump station to a lined aeration pond where it is subsequently hauled to a local wastewater treatment plant for disposal.

### 1.2. Landfill Closure

The landfill stopped receiving waste on April 8, 1994. Closure activities followed in accordance with the approved closure plans. An assessment of potential contaminant sources was conducted in response to the detection of groundwater impacts in the landfill monitoring wells. Based on the results of this assessment, several corrective actions were incorporated into the final closure design to reduce or eliminate identified potential contaminant sources and to protect public health. Corrective actions implemented during and after closure included:

- Relining the leachate aeration pond and upgrading the pump station.
- Improving the surface water collection, conveyance, and storage facilities.
- Recapping the Phase I portion of the landfill with a cover that exceeded the standards required at the time.
- Connecting surrounding homes to a public water system and abandoning drinking water wells.

In addition to these corrective actions, closure activities also included the construction of a landfill gas (LFG) extraction system and expansion of the perimeter gas monitoring probe network. The LFG extraction system has operated since closure to alleviate the accumulation of methane beneath the landfill cap and to control off-site methane migration.

These measures were intended to reduce leachate generation by reducing surface water infiltration, minimizing the potential transport of contaminants in the gas stream into groundwater, and eliminating suspected groundwater contaminant sources and potential exposure pathways. Since closure was completed, these actions have resulted in a gradual long-term decrease in leachate generation and a long-term improvement of groundwater quality as discussed in subsequent sections of this report.

## **2.0 LEACHATE**

### **2.1. Leachate Collection System Operation**

Post-closure activities at Inman Landfill include operation of a leachate collection system. The leachate collection system consists of a network of drain pipes situated under the newer (Phase II) portion of the landfill. These drain pipes lead to a single concrete sump and pump station (PS#1). Leachate enters the sump and is pumped up to a double-lined leachate collection pond. Leachate in the pond is pre-treated with aerators. The pre-treated leachate is periodically pumped from the pond and hauled to the City of Mount Vernon wastewater treatment plant for disposal as authorized by a State Wastewater Discharge Permit.

### **2.2. Leachate Generation**

The amount of leachate collected from the lined, Phase II portion of the landfill generally increased each year until closure in 1994 (Figure 2). Since 1994 leachate generation has generally decreased. In 2006, leachate generation was 3 percent of the amount collected during 1991 and 1992, which was prior to installation of the landfill cover system. Leachate generation rates leveled off approximately twelve years ago, and then decreased again from 2002 through 2005 before increasing in 2007. There was an approximate four-fold increase between 2006 and 2007; this increase was due to the complete draining of the leachate pond during the third quarter of 2007 for cleaning and repair. In 2020, leachate was produced in quantities similar to those from 2005. In 2020, a total of 71,500 gallons was pumped from the leachate pond and transferred to the Wastewater Treatment Plant in Mount Vernon, Washington.

The stabilization of leachate generation rates during the late 1990s may indicate the removal of easily-drained leachate that entered the landfill prior to construction of the existing cover system. One point that is clear from the graph is that the landfill cover has been effective in reducing the amount of precipitation entering the landfill and, consequently the amount of leachate that is generated.

The Phase I area of the landfill does not have a bottom liner and therefore, no leachate collection system. A significant amount of leachate generated from this portion of the site does potentially reach the underlying groundwater system. However, since the landfill cover system placed over the Phase I area is similar to that placed over the Phase II area, it is reasonable to assume that potential leachate generated from the Phase I area has also decreased in amounts proportional to those observed for the Phase II area.

### 3.0 HYDROGEOLOGY

Inman Landfill is located on the north side of Bay View Ridge. Bay View Ridge is composed of a series of glacial and glaciomarine deposits and rises up to 200 feet above the surrounding delta valleys. A previous investigation concludes that the Inman Landfill site is underlain by two aquifers (Sweet Edwards & Associates 1987). These aquifers consist of a shallow, unconfined perched aquifer that is typically located above sea level, and a deeper regional aquifer (referred to as the upper regional aquifer or the regional aquifer) that is situated near or below sea level. The shallow perched aquifer occurs in a sand unit that is situated above a dense silt/clay layer at elevations of approximately 1 to 13 feet above sea level. The silt/clay layer appears to dip to the west and southwest into Bay View Ridge. Monitoring Wells B-6, B-7, B-8, B-9, B-11, and B-13 and Gas Probe GP-6 are screened in the perched aquifer (Figure 3). Previous groundwater measurements in these wells indicate that groundwater in this aquifer follows the dip of the silt/clay layer and flows generally to the southwest.

The upper regional aquifer is located in fine to coarse sand deposits that are present beneath the silt/clay layer (Sweet Edwards & Associates 1987). The upper regional aquifer is confined by the overlying silt/clay layer. The top of this aquifer is reportedly situated at elevations ranging from 6 to 14 feet below sea level. Monitoring Wells B-1, B-2, B-3, B-4, B-5, B-10, and B-12 are screened in the upper regional aquifer (Figure 4). Previous groundwater measurements in these wells indicate that groundwater in this aquifer flows in a radial pattern away from Bay View Ridge to the north, northeast, and east.

Water level measurements were collected during three quarterly monitoring events during 2020 (April, September, and December) from monitoring wells completed within each aquifer. Based on the measured water levels, computer-generated potentiometric surface maps were created for each aquifer for each of these quarters (Figures 3a-3c, 4a-4c). These maps were prepared with the kriging method in the Surfer™ version 12.8 contouring software package using elevations from the monitoring wells in each aquifer (Table 1 & 2). Wells B-7 and B-11 were not measured during the April measuring event in 2020; therefore, these wells were not used to construct the water table contour map for the second quarter. Hydrographs of groundwater elevations collected since landfill closure for both aquifers were also prepared (Figures 5 & 6).

#### 3.1. Perched Aquifer

Static water level elevations measured in 2020 for the perched aquifer ranged from a minimum of 9.18 feet above mean sea level (amsl) at B-11 (December) to a maximum of 13.43 feet amsl at GP-6 (April) (Table 1).

**Table 1. 2020 Static Water Level Elevations: Perched Aquifer**

	April	September	December
<b>B-6</b>	11.84	10.87	10.39
<b>B-7</b>	NM	11.25	10.85
<b>B-8</b>	12.28	11.48	12.88
<b>B-9</b>	10.70	10.17	9.87
<b>B-11</b>	NM	9.18	9.18
<b>B-13</b>	12.74	12.00	11.46
<b>GP-6</b>	13.43	13.33	11.43

Elevations are in feet above mean sea level (NGVD 29); NM = Not Measured

The water table contour maps indicate that perched groundwater flow was fairly consistent during 2020, flowing generally from the east towards the west (Figures 3a-3c). Local groundwater velocities can be variable because of the complex local groundwater flow patterns. For simplicity, the average groundwater velocity across the site within this aquifer was calculated using gradients observed across the central and southern portions of the site.

Based on these criteria, the average gradient in 2020 ranged from about 0.0015 to 0.0073 feet per foot (ft/ft), with an average gradient of approximately 0.0034 ft/ft. The average porosity of the perched aquifer material was estimated to be approximately 27.5 percent and the hydraulic conductivity was estimated to be approximately 28 feet per day (ft/day) (Sweet Edwards & Associates 1987). These parameters were used in conjunction with the average hydraulic gradient of 0.0034 ft/ft to estimate the average linear velocity of groundwater in the perched aquifer using Darcy's Law, where:  $V = Ki/n$ , and

$V$  = average linear velocity,  
 $K$  = hydraulic conductivity,  
 $i$  = hydraulic gradient, and  
 $n$  = porosity.

This calculation indicates that the average linear velocity of groundwater in the perched aquifer during 2020 was approximately 0.35 ft/day.

A review of the hydrograph for the perched aquifer (Figure 5) shows that the water levels fluctuate in a typical seasonal manner. Prior to 2004 the hydrograph shows an overall slightly decreasing trend in all of the wells since 1995; however, the 2004 through 2020 measurements indicate that this decreasing trend has stabilized. The decreasing trend may be a result of reduced infiltration of rainwater over the landfill since construction of the cap was completed in 1995.

### 3.2. Upper Regional Aquifer

Static water level elevations measured in 2020 for the upper regional aquifer ranged from a minimum of 2.24 feet amsl at B-5 (September) to a maximum of 9.44 feet amsl at B-2 (April) (Table 2).

**Table 2. 2020 Static Water Level Elevations: Upper Regional Aquifer**

Well	April	September	December
B-1	8.83	8.48	8.05
B-2	9.44	8.64	8.59
B-3	8.58	8.10	8.15
B-4	9.00	8.54	8.52
B-5	2.81	2.24	4.62
B-10	8.96	8.69	8.61
B-12	8.75	8.32	7.90

Elevations are in feet above mean sea level (NGVD 29)

The water table contour maps for 2020 indicate that the upper regional aquifer groundwater generally flowed from the west towards the east (Figures 4a-4c). Using the information in these maps, hydraulic gradients were calculated between Well B-10, the most upgradient well, and Well B-12, the most downgradient well for the majority of the monitoring events. The calculated hydraulic gradients from

Well B-10 to Well B-12 for 2020 ranged from 0.0001 to 0.0004 ft/ft, with an average of approximately 0.0002 ft/ft.

In addition to the construction of the potentiometric surface maps, groundwater elevations were also used to calculate estimated groundwater flow velocities for the upper regional aquifer. Because of the similarity in material in the perched and upper regional aquifers, the same values for porosity and hydraulic conductivity used for the perched aquifer were also used for the upper regional aquifer. These parameters were used in conjunction with the average hydraulic gradient for 2020 of 0.0002 ft/ft (calculated previously) to estimate the average linear velocity of groundwater in the upper regional aquifer using Darcy's Law. The result of this calculation indicates that the average linear velocity of groundwater in the upper regional aquifer during 2020 was approximately 0.02 ft/day across the central landfill site.

In addition to the potentiometric surface map showing the central landfill area, potentiometric surface maps were also prepared showing groundwater contours beyond the northern and eastern boundaries of the landfill and into the topographically lower Samish River Valley (Figures 7a-7c). These maps were also prepared with the wells used for the central landfill area in addition to elevations from a single well located in the valley (Well B-5; refer to Table 2) and estimated groundwater elevations for points located along nearby Joe Leary Slough. Groundwater elevations along Joe Leary Slough were estimated using the elevation of surface water measured in the slough. It should be noted that water level elevations at both the slough and at Well B-5 show significant tidal influence.

The flow pattern in the upper regional aquifer continues to be a radial flow into the Samish River valley, although the hydraulic gradient appears to increase significantly as groundwater enters the Samish River Valley from the central landfill area. Also, flow in the upper regional aquifer appears more radial than in the perched aquifer, flowing from the western side of the site toward the north, northeast, and east.

Hydraulic gradients were calculated from the west side of the landfill and extending into the valley. The gradients were calculated using the groundwater elevations measured at Well B-10, located in the southwestern portion of the site, and Well B-5, which is located in the valley and downgradient of Well B-10. The gradients calculated between these two points ranged from approximately 0.0012 to 0.0016 ft/ft during 2020, with an average of approximately 0.0015 ft/ft. This gradient is steeper than that calculated for the central landfill area because it combines the flatter gradient beneath the landfill with the steeper gradient measured between the landfill proper and the Samish Valley. As noted above, this gradient is significantly influenced by the tide. Using this average hydraulic gradient and the aquifer parameters presented above, the resulting average linear velocity of groundwater in the upper regional aquifer across the landfill area and into the Samish Valley in 2020 was approximately 0.27 ft/day.

A review of the hydrograph for the upper regional aquifer (Figure 6) shows that the water levels fluctuate in a typical seasonal manner. Well B-5 shows the greatest variation of all wells in the upper regional aquifer, but this variation is likely a reflection of different tidal stages in which measurements are made and is to a lesser extent due to seasonal variation. Prior to 2004 the hydrograph shows an overall slightly decreasing trend in all of the wells except Well B-5; however, since 2004 generally water levels have stabilized. The decreasing trend may be a result of reduced infiltration of rainwater over the landfill since construction of the cap was completed in 1995.

## 4.0 GROUNDWATER SAMPLING METHODS

### 4.1. Sample Locations and Frequency

Groundwater sampling at Inman Landfill is conducted on a quarterly basis. During 2020 no groundwater sampling was conducted during the 1<sup>st</sup> quarter which is usually scheduled for March. The Inman Landfill groundwater monitoring network consists of 13 monitoring wells: seven wells screened in the upper regional aquifer (B-1, B-2, B-3, B-4, B-5, B-10, and B-12), and six wells screened in the perched aquifer (B-6, B-7, B-8, B-9, B-11, and B-13). Quarterly sampling in 2020 was conducted in April, September, and December. Declining water levels in the perched aquifer prevented sample collection at Wells B-7, B-11, and B-13 during the 2020 sampling events. A groundwater sample was collected from B-8 during the 4<sup>th</sup> quarter of 2020 (December 2020). Well B-7 has been dry for over 20 years and has not been sampled since landfill closure in 1994. Monitoring well B-11 was last sampled during the first quarter of 2017 (March 2017). Monitoring well B-13 was last sampled during the fourth quarter of 2010 (December 2010).

### 4.2. Sample Collection

All monitoring wells were purged and sampled in accordance with the *Quality Assurance Project Plan* (QAPP) for Inman Landfill (Skagit County Public Works (SCPW) Dept., 2010).

### 4.3. Analytical Parameters

Groundwater samples were submitted to Edge Analytical of Burlington, Washington for analysis. Parameters tested consisted of analytes specified in the QAPP (SCPW Dept., 2010). Beginning with the second quarter of 2008 sampling event, additional parameters were tested during each subsequent quarterly sampling event. These additional parameters were measured for a two year period based on a request from the Washington Department of Ecology to further characterize groundwater at the landfill site. These additional parameters were measured for the last time during the first quarter 2010 monitoring event. These additional parameters included total dissolved solids (TDS), alkalinity, bicarbonate, total calcium, total magnesium, total potassium, total sodium, and the following dissolved metals: antimony, barium, beryllium, cobalt, copper, nickel, selenium, silver, thallium, and vanadium.

Based on a subsequent request from the Washington Department of Ecology, most of these additional parameters were sampled again beginning in the third quarter of 2011. Three parameters that were never detected above practical quantitation limits during the 2008 to 2010 sampling rounds were dropped from the sampling request, and included dissolved metals: beryllium, silver, and thallium. The additional parameters from the 2011 request that are presently analyzed for include TDS, alkalinity, bicarbonate, total magnesium, total potassium, and the following dissolved metals: antimony, barium, chromium, cobalt, copper, nickel, selenium, and vanadium. For quality assurance purposes, duplicate samples were collected from Well B-3 during each sampling round.

## 5.0 GROUNDWATER QUALITY RESULTS

A discussion of groundwater quality based on analytical results from the monitoring well network is presented in this section. Separate discussions are included for the perched and upper regional aquifers. A background well has not been established for either the perched aquifer or the upper regional aquifer monitoring networks because of apparent or potential landfill impacts at each monitoring well location as indicated by historical monitoring results.

Tabulated groundwater monitoring results for 2020 are presented in Appendices A-1 and B-1 for the perched and upper regional aquifers, respectively. Time-series plots were generated from data collected from 1994 through 2020 (102 sampling events).

For quality assurance purposes, a data validation report was generated that reviews laboratory groundwater quality data from the sampling event. The fourth quarter data validation report is presented in Appendix C.

### 5.1. Perched Aquifer

The perched aquifer monitoring system for the site is comprised of Monitoring Wells B-6, B-7, B-8, B-9, B-11, and B-13. As mentioned in Section 4.1, only monitoring wells B-6 and B-9 had sufficient water to collect representative groundwater samples during the three quarterly sampling events in 2020. A groundwater sample was collected from B-8 during the fourth quarter sampling event in 2020. One analyte (dissolved arsenic) was found to exceed state groundwater standards (Chapter 173-200 WAC) in the perched aquifer during 2020 (Table 3).

**Table 3. Summary of Maximum Concentrations of Analytes Exceeding Groundwater Quality Standards in Perched Aquifer Wells: 2020**

Contaminant	GW Quality Standards (173-200 WAC)	B-6	B-8	B-9
<b>Carcinogen</b>				
Arsenic (mg/L)	0.00005	0.00087	0.001	0.00093
<b>Secondary</b>				
Iron (mg/L)	0.3	NE	0.65	NE
Manganese (mg/L)	0.05	NE	0.0542	NE

NE Not Exceeded

The 2020 analytical data indicate that elevated concentrations of dissolved arsenic tended to be widespread, with exceedances of the water quality standards occurring in each of the perched aquifer wells sampled.

### 5.2. Upper Regional Aquifer

The upper regional aquifer monitoring well network comprises Wells B-1, B-2, B-3, B-4, B-5, B-10, and B-12. Seven wells were found to exceed state groundwater standards (Chapter 173-200 WAC) for at least one sampling event during 2020 in the upper regional aquifer (Table 4).

**Table 4. Summary of Maximum Concentrations of Analytes Exceeding Groundwater Quality Standards in Upper Regional Aquifer Wells: 2020**

Contaminant	GW Quality Standards (173-200 WAC)	Maximum Concentration Detected						
		B-1	B-2	B-3	B-4	B-5	B-10	B-12
<b>Carcinogen</b>								
Arsenic, dissolved (mg/L)	0.00005	0.052	0.001	0.0032	0.0029	0.0055	0.002	0.0044
Vinyl chloride (µg/L)	0.02	NE	NE	0.0471	NE	0.107	NE	NE
1,4 Dioxane (µg/L)	7	NE	NE	NE	NE	8.8	NE	NE
<b>Secondary</b>								
Iron, dissolved (mg/L)	0.3	3.16	NE	6.21	6.0	18.2	1.76	0.63
Manganese, dissolved (mg/L)	0.05	2.99	NE	0.602	1.39	2.37	0.528	0.0746
pH (standard units)	6.5-8.5	NE	NE	5.89	NE	6.45	NE	NE
Total dissolved solids (mg/L)	500	618	NE	NE	583	NE	NE	NE

NE: Not exceeded

The 2020 analytical data for the upper regional aquifer show areal distribution trends that are somewhat similar to those observed in the perched aquifer. Elevated concentrations of metals, tended to be widespread, with exceedances of water quality standards for dissolved arsenic, iron, and manganese occurring in almost all of the upper regional aquifer wells. Vinyl chloride concentrations tended to be more localized in the upper regional aquifer in 2020, with water quality standards exceeded in only two wells (B-3 and B-5), which are located in the northwestern and western margins of the landfill.

In general, concentrations of all analytes tended to be lower in upgradient wells (B-1, B-10, and B-12) and higher in downgradient wells (B-2, B-3, B-4, and B-5), as would be expected. VOCs were not detected above PQLs in either well B-1, B-2, B-4, B-10, or B-12, during any of the 2020 monitoring events.

### 5.3. Domestic Wells

No domestic wells were sampled in 2020. Domestic wells located to the southwest and southeast of the landfill site have been sampled previously. The results of these analyses were presented in earlier annual reports. Refer to those reports for a discussion of domestic well results.

## 6.0 STATISTICAL EVALUATION OF GROUNDWATER RESULTS

Statistical analysis of groundwater monitoring data from the Inman Landfill is conducted using Microsoft Excel and Sanitas (v.9.6.27) or equivalent software in accordance with the EPA guidance document (EPA 2009). Statistical analysis is conducted using data from the entire monitoring period (1994-2020) unless otherwise noted.

### 6.1. Piper Diagrams

Piper diagrams are a graphical display of the proportions of the major cations and anions in a sample. Piper diagrams are constructed by plotting the proportions of the major cations (calcium, magnesium, sodium and potassium) on one triangular diagram, the proportions of the major anions (alkalinity, chloride, sulfate) on another, and then combining the information from the two triangular plots onto a quadrilateral plot (Drever 2002). A piper diagram was created using the data from each quarterly monitoring event in 2020 for both the perched aquifer (Appendix D-1) and the upper regional aquifer (Appendix E-1).

#### 6.1.1. Perched Aquifer

The piper diagrams indicate that all the monitoring wells in the perched aquifer have similar chemical signatures. The results also show that general chemistry of the perched aquifer does not significantly change throughout the year.

#### 6.1.2. Regional Aquifer

The piper diagrams indicate that the monitoring wells in the regional aquifer have mostly similar chemical signatures. Wells B-2, B-4, and B-5 do appear to each have their own slightly different chemical signature that varies from the rest of the monitoring wells. The results also indicate that the general chemistry of the upper regional aquifer does not significantly change throughout the year.

### 6.2. Stiff Diagrams

A stiff diagram is another graphical representation of the major ion composition of a water analysis. A polygonal shape is created from three horizontal axes extending on either side of a vertical axis. The three major anions are plotted to the right of the center axis and the three major cations are plotted to the left of the center axis. The points are connected to create the polygonal shape. The larger the area of the polygonal shape, the greater the concentrations of the analytes (Drever 2002). Stiff diagrams were produced for every well with the data from each quarterly monitoring event in 2020 for both the perched (Appendix D-2) and upper regional (Appendix E-2) aquifers.

#### 6.2.1. Perched Aquifer

The polygons produced at each well are similar to each other in shape, but do vary in overall size. The polygon shapes and sizes remain similar for each quarterly monitoring event.

### **6.2.2. Upper Regional Aquifer**

Generally, the polygons produced at each well are similar to each other, and are similar for each quarterly monitoring event. Wells B-1 and B-4 have the largest polygonal shapes, which indicates that these wells have the greatest concentration of analytes.

### **6.3. Cation-Anion Balance**

Cation-anion balance is the ratio of cations to anions within the water sample. Since water samples are electrically neutral, the sum of the cations should equal the sum of the anions. The cations are magnesium, calcium, sodium and potassium. The anions are sulfate, chloride, carbonate and bicarbonate. The ratio would be determined as:

$$\text{Ratio} = (\text{sum of cations})/(\text{sum of anions}) * 100\%$$

Since water is electrically neutral, we would expect the ratio to be 1 or 100%. The cation-anion balance was calculated for the monitoring wells in each aquifer during every quarterly monitoring event of 2020. The results are displayed on the quarterly piper diagrams in Appendix D-1 and Appendix E-1.

The cation-anion balances calculated for each quarterly monitoring event in the perched aquifer are 11.1%, 11.1%, and 9.81%, respectively (Appendix D-1). The cation-anion balances calculated for each quarterly monitoring event in the upper regional aquifer are 5.44%, 6.66%, and 3.95%, respectively (Appendix E-1). These results indicate that there are more anions than cations in the results. There could be a couple of reasons for this ratio imbalance. One is the fact that some analyte values are for dissolved metals and some analyte values are for total metals. Another reason could be that not all species were analyzed in the water sample, and therefore were not included in the cation-anion balance. The most common species were analyzed, but there could be less common species present in the water that were not included in the calculation.

### **6.4. Box Plots**

Box plots are useful in providing a visual display of the distribution of a data set (EPA 2009). The central box of the plot shows the interquartile range from the 25<sup>th</sup> to the 75<sup>th</sup> percentiles. A line (whisker) is drawn to the minimum and maximum values from the 25<sup>th</sup> and 75<sup>th</sup> percentiles, respectively. The 50<sup>th</sup> percentile is drawn within the box. The mean value of the data set is plotted within the box as a separate mark. Significantly staggered boxes could be an indication of spatial variability.

Box-plots were created with data collected from 1994 through 2020. Eighteen plots were created from the perched aquifer analytical results (Appendix D-3) and twenty-seven plots were created from the upper regional aquifer analytical results (Appendix E-3). Box plots were not generated for parameters, particularly dissolved metals and VOCs, when the results were all or nearly all detected at levels below the laboratory practical quantitation limits.

The box plots were visually analyzed to see if there were significant differences between the wells (Table 5 & Table 6). A significant difference would be if one of the boxes in the plot did not overlap with any of the others. This significant difference could indicate that there are statistically different average concentrations between the wells.

#### 6.4.1. Perched Aquifer

Ten out of the eighteen analytes plotted had wells with statistically different average concentrations (Table 5). In all of the ten analytes (alkalinity, bicarbonate, total calcium, COD, magnesium, nitrate as nitrogen, potassium, TDS and total sodium) the values measured in B-8 were higher. These results indicate that B-8 shows the most impacts from the landfill. It should be noted that B-8 was sampled only once in 2020, the first time since June 2017.

**Table 5. Summary of Box Plot Visual Analysis in Perched Aquifer Wells: 2020**

Significantly Staggered Analyte	Distribution of Boxes
Alkalinity	B-8 is higher
Bicarbonate	B-6 and B-8 are higher
Calcium, total	B-8 is higher
Chemical oxygen demand (COD)	B-8 is higher
Bicarbonate	B-8 is higher
Magnesium, total	B-6 and B-8 are higher
Nitrate-N	B-6 is higher
Potassium	B-8 is higher
Total dissolved solids (TDS)	B-6 and B-8 are higher
Sodium, total	B-8 is higher

#### 6.4.2. Upper Regional Aquifer

Sixteen out of the twenty-seven analytes plotted had wells with statistically different average concentrations (Table 6). In six out of sixteen analytes (alkalinity, bicarbonate, Freon-22, magnesium, manganese, and TDS) the values measured in B-4 were significantly higher than the values measured in the rest of the wells. In three out of the sixteen analytes (CFC-12, nitrate-N, and potassium), the values measured in B-2 were significantly higher than the values measured in the rest of the wells. B-1 was significantly higher in one analyte (dissolved arsenic), and B-5 was significantly higher in four analytes (1,4-dioxane, dissolved iron, dissolved nickel, and vinyl chloride). Wells B-3 and B-5 were both significantly higher in diethyl ether than the other wells. Wells B-4 and B-5 were both significantly higher in dissolved manganese than the other wells.

These results indicate that the B-2, B-4, and B-5 have the highest concentrations of inorganic and organic analytes. B-1 and B-3 were both significantly higher in one analyte each. B-10 and B-12 were not significantly higher in any analyte in the upper regional aquifer.

**Table 6. Summary of Box Plot Visual Analysis in Upper Regional Aquifer Wells: 2020**

Significantly Staggered Analyte	Distribution of Boxes
1,4-dioxane	B-5 is higher
Alkalinity	B-4 is higher
Arsenic, dissolved	B-1 is higher
Bicarbonate	B-4 is higher
Chemical Oxygen Demand	B-5 is higher
Chlorodifluoromethane (Freon 22)	B-4 is higher
Dichlorodifluoromethane (CFC-12)	B-2 is higher
Diethyl ether	B-3 and B-5 are higher
Iron, dissolved	B-5 is higher
Magnesium, total	B-4 is higher
Manganese, dissolved	B-4 and B-5 are higher
Nickel	B-5 is higher
Nitrate-N	B-2 is higher
Potassium, total	B-2 is higher
Total dissolved solids	B-4 is higher
Vinyl Chloride	B-5 is higher

### 6.5. Mann-Kendall Trend Test

The presence of significant increasing or decreasing trends was determined using the Mann-Kendall test. The Mann-Kendall test evaluates possible trends by comparing random pairs of data within the data set. The test statistic will increase if the later value is greater than the earlier value, and decrease if the later value is less than the earlier value. After the test statistic is determined, the Z-score is calculated from the test statistic. The farther the Z-score is from zero, the more significant the trend (EPA 2009).

A Mann-Kendall test was run on each well in every long-term time-series plot, however, significant trends were examined for the three active perched aquifer wells B-6, B-8, and B-9. The Mann-Kendall results show the slope of the trend, the Z-score, the critical threshold of significance for the Z-score, and if the Z-score is significant at the 98% confidence interval. Each analyte concentration is tested. Mann-Kendall long-term trend test results for the perched and upper regional aquifers are included in Appendix D-4 and E-4, respectively. Mann-Kendall short-term trend test results for the perched and upper regional aquifers are included in Appendix D-5 and E-5, respectively. A positive slope indicates an increasing trend, and a negative slope indicates a decreasing trend. Some results state the presence of a statistically significant increasing or decreasing trend in the data, but there were either no or very few actual detections within the data set. These trends are not considered statistically significant since they are the result of a change in laboratory detection limit of the analyte, and not an actual change in detected concentrations.

#### 6.5.1. Perched Aquifer

Overall, the Mann-Kendall results indicate that every well shows stabilizing conditions in water quality (Table 7). Most of the statistically significant decreasing trends have been found in the long-term data set. Nitrate as nitrogen has shown a significant increasing in the long-term trend in the long-term data set in B-6. However, this parameter has never exceeded the groundwater quality criteria for Nitrate at

B-6. There is a significant increasing long-term trend of dissolved nickel at B-6; however, these values are slightly above the PQL. There is a significant short-term increasing trend of dissolved chromium at B-9; however, these values have always been well below the groundwater quality criteria for this contaminant. Additionally, pH has shown a significant increasing trend in the long-term data set in B-6 and B-9. However, pH values for these two wells have been within the 6.5 to 8.5 range the last several years.

**Table 7. Mann-Kendall Significant Trends: Perched Aquifer**

<b>Well</b>	<b>Analytes with Decreasing trends</b>		<b>Analytes with Increasing trends</b>
<b>B-6</b>	Antimony, dissolved Ammonia-N Arsenic, dissolved Alkalinity Barium, dissolved Bicarbonate Cadmium, dissolved Calcium, total Chemical oxygen demand Chromium, dissolved Cobalt, dissolved Copper, dissolved Iron, dissolved Lead, dissolved	Magnesium, total Manganese, dissolved Selenium, dissolved Sodium, total Specific conductance Sulfate Total Dissolved Solids (TDS) Total organic carbon (TOC) Vanadium, dissolved Zinc, dissolved	Nickel, dissolved Nitrate-N pH
<b>B-8</b>	Antimony, dissolved Arsenic, dissolved Calcium, total Cadmium, dissolved Chloride Chromium, dissolved Copper, dissolved	Lead, dissolved Selenium, dissolved Sodium, total Specific conductance Sulfate Vanadium, dissolved Zinc, dissolved	
<b>B-9</b>	1,1-dichloroethane <b>Alkalinity</b> Ammonia-N Arsenic, dissolved Barium, dissolved Bicarbonate Cadmium, dissolved Calcium, total <b>Chloride</b> Chromium, dissolved Cobalt, dissolved Copper, dissolved Dichlorofluoromethane (CFC-12)	Magnesium, total Manganese, dissolved Mercury, dissolved Potassium Selenium, dissolved Sodium, total <b>Specific conductance</b> Sulfate TDS TOC Vanadium, dissolved Zinc, dissolved	pH <i>Chromium, dissolved</i>

Regular text denotes a long-term trend only

**Bold text denotes both a long-term and short-term trend**

*Italicized text denotes a short-term trend only*

### 6.5.2. Upper Regional Aquifer

Statistically significant long-term and short-term trends discerned from the upper regional aquifer data indicate that Wells B-2 and B-3 show the most long-term decreasing concentration trends for landfill analytes during the long-term monitoring period (Table 8). Wells B-1, B-4, B-5, B-10, and B-12 show the most increasing concentration trends, in both the long-term and short-term data sets. These increasing trends are all inorganic analytes, except for Freon-22 in Wells B-1 and B-4.

**Table 8. Mann-Kendall Significant Trends: Upper Regional Aquifer**

Well	Analytes with Decreasing trends		Analytes with Increasing trends
<b>B-1</b>	Antimony, dissolved Cadmium, dissolved CFC-12 Copper, dissolved Lead, dissolved Mercury, dissolved Nitrate-N Selenium, dissolved Sulfate Zinc, dissolved		Alkalinity Ammonia-N Barium, dissolved Bicarbonate Calcium, total Cobalt, dissolved COD Chloride Freon 22 Iron, dissolved Magnesium, total <b>Manganese, dissolved</b> Nickel, dissolved Potassium, total Specific conductance Sodium, total Sulfate TDS TOC
<b>B-2</b>	1,1-dichloroethane Antimony, dissolved Arsenic, dissolved Barium, dissolved Cadmium, dissolved Calcium, total Chloride Chromium, dissolved Cobalt, dissolved Copper, dissolved CFC-12 Freon 22 Iron, dissolved	Lead, dissolved Manganese, dissolved Nickel, dissolved Selenium, dissolved Sodium, total Specific conductance Sulfate TDS TOC Vanadium, dissolved Vinyl chloride Zinc, dissolved	Copper, dissolved
<b>B-3</b>	Arsenic, dissolved Cadmium, dissolved Calcium, total CFC-12 Chloride Chromium, dissolved Cobalt, dissolved Copper, dissolved Diethyl ether Iron, dissolved Lead, dissolved Manganese, dissolved	Selenium, dissolved Sodium, total Specific conductance TOC Vanadium, dissolved Vinyl chloride Zinc, dissolved	pH

Regular text denotes a long-term trend only

**Bold text denotes both a long-term and short-term trend**

*Italicized text denotes a short-term trend only*

**Table 8. Mann-Kendall Significant Trends: Upper Regional Aquifer (cont).**

<b>Well</b>	<b>Analytes with Decreasing trends</b>		<b>Analytes with Increasing trends</b>	
<b>B-4</b>	Alkalinity <b>Ammonia-N</b> Arsenic, dissolved <b>Barium, dissolved</b> Bicarbonate Cadmium, dissolved CFC-12 <i>Calcium, total</i> Chromium, dissolved Cobalt, dissolved Copper, dissolved <i>Freon 22</i> <b>Magnesium, total</b> <b>Manganese, dissolved</b> Nitrate-N Potassium, total Selenium, dissolved	<b>Sulfate</b> <i>Sodium, total</i> TDS Vanadium, dissolved Vinyl chloride Zinc, dissolved	Ammonia-N Calcium, total Chloride COD Freon 22 Iron, dissolved	Sodium, total Specific conductance Sulfate TOC <i>Vinyl Chloride</i>
<b>B-5</b>	Arsenic, dissolved Freon 22 Cadmium, dissolved <i>Chloride</i> Chromium, dissolved Copper, dissolved CFC-12 Diethyl Ether Freon 22 Lead, dissolved	Selenium, dissolved <i>Specific conductance</i> TDS Vanadium, dissolved Vinyl chloride Zinc, dissolved	1,4-dioxane <i>Arsenic, dissolved</i> Calcium, total Cobalt, dissolved Chloride COD	Potassium, total Specific conductance <b>Sodium, total</b> Tetrahydrofuran TDS TOC
<b>B-10</b>	<b>Alkalinity</b> Arsenic, dissolved <i>Barium, dissolved</i> <i>Bicarbonate</i> Cadmium, dissolved <b>Calcium, total</b> CFC-12 Chromium, dissolved Cobalt, dissolved Copper, dissolved	Lead, dissolved <i>Magnesium, dissolved</i> Nitrate-N Selenium, dissolved Sodium, total <i>Specific conductance</i> <b>Sulfate</b> <b>TDS</b> Vanadium, dissolved Zinc, dissolved	Ammonia-N Calcium, total Chloride COD Iron, dissolved	Manganese, dissolved pH Sodium, total Specific conductance Sulfate TOC
<b>B-12</b>	Antimony, dissolved Arsenic, dissolved Cadmium, dissolved CFC-12 Chromium, dissolved Cobalt, dissolved Copper, dissolved Lead, dissolved	Manganese, dissolved Mercury, dissolved Nitrate-N Selenium, dissolved Specific conductance Sulfate TOC Zinc, dissolved	<b>Alkalinity</b> Ammonia-N <b>Barium, dissolved</b> <b>Bicarbonate</b> Calcium, total <b>Chloride</b> COD Iron, dissolved Magnesium, total	Potassium, total pH <b>Specific conductance</b> <b>Sodium, total</b> Sulfate <b>TDS</b>

Regular text denotes a long-term trend only

**Bold text denotes both a long-term and short-term trend**

*Italicized text denotes a short-term trend only*

## **7.0 LANDFILL GAS EXTRACTION AND MONITORING ACTIVITIES**

To alleviate the accumulation of methane beneath the landfill cap and to control off-site methane migration, Inman Landfill has a LFG extraction system consisting of 27 wells and trenches (Figure 8). The landfill also contains perimeter LFG monitoring probes to monitor for off-site migration of LFG.

### **7.1. LFG Extraction System Operation**

The LFG system was not operated during 2020 due to low methane levels within the landfill and over-capacity of the current equipment configuration of the system.

### **7.2. Perimeter Monitoring**

Section (2)(b)(i) of Chapter 173-304-460 WAC specifies minimum functional air quality standards for landfills. These standards limit the concentration of explosive gases at the property boundary to the lower explosive limit (LEL) for that gas. For methane, the LEL occurs at a concentration of approximately 5 percent by volume. To monitor for potential exceedance of this standard, concentrations of methane and associated landfill gases (oxygen and carbon dioxide) are measured in 10 nested perimeter LFG monitoring probe sets that include a total of 24 individual probes. Measurements of LFG concentrations in perimeter monitoring probes were conducted during the 2<sup>nd</sup> and 4<sup>th</sup> quarterly monitoring events in 2020. The results of these measurements are presented in Table G-1 located in Appendix G.

The LFG probes are located on all sides of the landfill perimeter as depicted in Figure 9. Some of the probes are co-located with groundwater monitoring wells (Wells B-6, B-7, B-9, B-11, and B-13) and some are stand-alone probes (Probes GDW-1, GDW-2, GDW-3, GDW-5, GP-6, and GP-7). The depths of the screened intervals of the probes vary from 7 to 87 feet below ground surface (Table F-1). For assessment purposes, methane concentrations measured in each probe were compared to the methane air quality standard of 5 percent methane by volume.

Comparisons of the methane results to the air quality standard shows that there no detections of methane exceeding the LEL in 2020. Historically, methane has been detected in GDW-1 and B-13 at concentrations above the LEL. Probe set GDW-1 is located near the southeastern corner of the Inman Landfill site. The properties adjacent to the east and south of the landfill are vacant. Currently, subsurface methane concentrations in this area do not appear to present an immediate risk to the public.

In general, concentrations detected in 2020 at GDW-1 were below the concentrations measured in 2019. The highest methane concentration measured in 2020 was 2.1% in the shallow probe of GDW-1 during the fourth quarter monitoring event.

## **8.0 INSPECTIONS**

Inspections were conducted in conjunction with quarterly groundwater monitoring in 2020.

## 9.0 SUMMARY AND CONCLUSIONS

Inman Landfill closed in 1994. Post-closure activities have been on-going since closure was completed in 1995. These activities include: leachate collection and disposal, LFG collection, perimeter groundwater monitoring, subsurface LFG monitoring, surface water monitoring, and site maintenance. Groundwater monitoring activities include collection of groundwater samples from two aquifers: an unconfined perched aquifer and a confined upper regional aquifer. Monitoring data indicate that groundwater in the perched aquifer generally flows to the west and southwest, and the upper regional aquifer flows in a radial pattern toward the north, northeast, and east.

Assessment of groundwater monitoring results shows that several groundwater quality standards were exceeded at one or more monitoring wells in both aquifers during 2020. Standards exceeded include the WAC 173-200 carcinogen standards for dissolved arsenic, 1,4-dioxane, and vinyl chloride, and the WAC 173-200 secondary standards for dissolved iron, dissolved manganese, total dissolved solids, and pH.

Only three of the original six perched aquifer wells had sufficient water to collect groundwater samples in 2020. These include B-6, B-8, and B-9. The three perched aquifer monitoring wells sampled during 2020 contained elevated concentrations of landfill-related analytes, specifically dissolved arsenic, relative to state standards. The only inorganic analytes that show a long-term increasing trend is dissolved nickel and Nitrate as nitrogen at B-6. However, there has never been an exceedance of Nitrate parameter above the WAC-173-200 primary contaminant standard. No VOCs show any increasing trends. Out of all of the perched aquifer wells, most inorganic analytes show decreasing trends, although dissolved arsenic, iron, and manganese have exceeded regulatory limits at B-8. B-8 was sampled in December 2020, the first time since June 2017.

All wells screened in the upper regional aquifer sampled during 2020 contained elevated concentrations of landfill-related analytes relative to state standards. Exceedance of standards for metals also tended to be widespread, while exceedance of standards for VOCs also tended to be more localized, occurring in only two wells (B-3 and B-5). Approximately nineteen inorganic analytes show increasing trends for the data analyzed (1994 to 2020). Four of these inorganic analytes (dissolved iron, dissolved manganese, pH, and TDS) exceed regulatory limits. Significant VOC concentrations were limited to wells B-3 and B-5. One VOC, Chlorodifluoromethane (Freon 22), shows an increasing long-term trend (1994-2020) at wells B-1 and B-4; however, this VOC does not show an increasing short-term trend (2016-2020) and additionally, Freon 22 has no regulatory limit. Approximately twenty-one inorganics and 5 VOCs are exhibiting decreasing trends with only one of these VOCs (vinyl chloride) currently exceeding regulatory limits. VOCs were not detected above laboratory PQLs in Wells B-10 and B-12 during 2020. This VOC distribution is consistent with the regional groundwater flow characteristics for this aquifer.

Although apparent impacts from the landfill continue within both aquifers, most of the time-series plots and Mann-Kendall trend tests for 1994-2020 show decreasing concentration trends in most wells, indicating that groundwater quality in the vicinity of the landfill has stabilized. Decreasing trends were most apparent in wells completed within the perched aquifer, which historically has shown the highest degree of impact. However, there are some increasing trends in the regional aquifer which could indicate continued impact to the groundwater quality below the landfill. Improvements to groundwater quality underlying the site appear to be directly attributable to several specific corrective actions conducted at suspected groundwater contaminant sources during general closure activities conducted in 1994 and 1995. These corrective actions included:

- Recapping the old, unlined (Phase I) portion of the landfill which reduced the amount of precipitation infiltrating the landfill, and consequently the amount of leachate entering groundwater.
- Eliminating leachate seeps that allowed leachate to enter into the drainage system.
- Improving the old infiltration basin and constructing a new infiltration basin.
- Relining the pre-treatment leachate pond and pump station.
- Constructing and operating an active LFG extraction system that reduced the potential for VOCs to enter groundwater via partitioning.
- Making other drainage improvements which eliminated surface water run-on to the site and consequently reduced the amount of leachate generated.

In addition to these corrective actions, Skagit County connected several homes located southwest and southeast of the landfill to a public water system and subsequently abandoned their drinking water wells. Because of their location and well construction characteristics, these wells had the potential to be impacted by contaminants from the landfill. These connections have removed the threat of impacts to nearby drinking water sources.

The results of perimeter gas monitoring activities indicate that the historical operation of the LFG system has been effective at controlling landfill gas migration.

## 10.0 RECOMMENDATIONS

The risk of potential impacts to domestic wells located southeast and southwest of the landfill has been eliminated due to their abandonment and the connection of the homes to a public water source. As a result of closure activities and the implementation of corrective actions, groundwater quality at the site has shown signs of significant stabilization.

Skagit County is recommending that the groundwater monitoring program at the Inman Landfill be modified to reflect the stabilizing trends over the last ten years of certain contaminants of concern (COC) particularly dissolved metals arsenic, iron, and manganese, and organic COCs vinyl chloride and 1,4-dioxane. It is recommended that the frequency of sampling be reduced to a semi-annual schedule coinciding with wet months when water levels are usually the highest (March-April), and dry months when water levels are usually the lowest (September-October). In addition, it is recommended that the list of analytes be reviewed with the objective of removing both inorganic and organic COCs that have never had exceedances, or have only been detected slightly above the laboratory practical quantification level.

Perimeter gas monitoring results indicate that the historical operation of the LFG system has been effective at controlling methane concentrations in the vicinity of GDW-1. However, it is anticipated that based on the capacity of the current system configuration, and decreasing levels of LFG measured over the last several years, future operation of the LFG extraction system is impractical. Skagit County is recommending that the LFG extraction piping system be modified to continuously and passively vent remaining concentrations of LFG at the site.

## **11.0 REFERENCES**

Environmental Protection Agency. 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. EPA 530-R-09-007. March 2009.

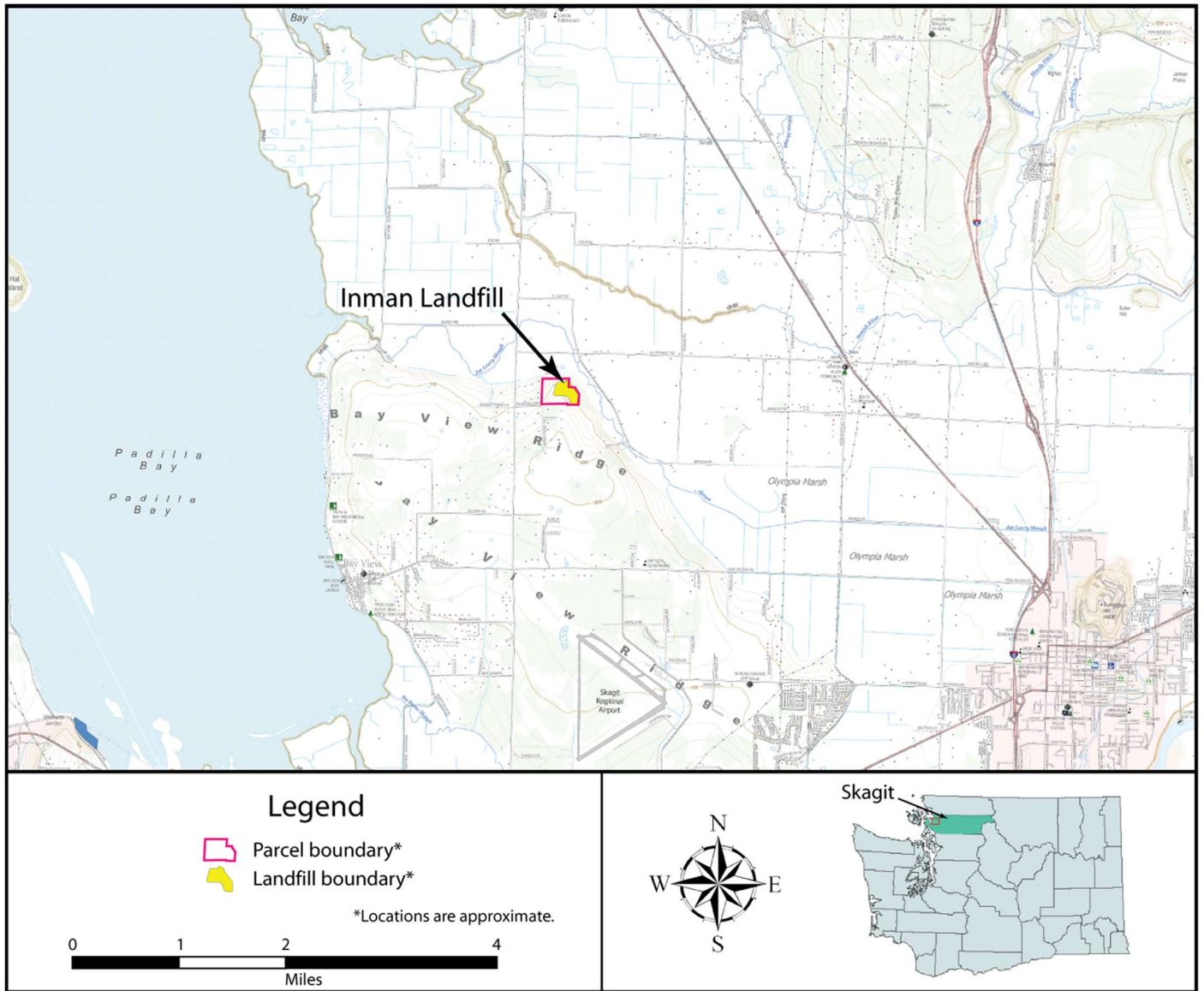
Skagit County Public Works Department. 2010. Quality Assurance Project Plan. Appendix B of Post-Closure Operations and Maintenance Manual, Inman Landfill. February 2010.

Sweet, Edwards, and Associates, Inc. 1987. Inman Landfill Hydrogeology Investigation Phase II Report. January 16, 1987.

## FIGURES



Figure 1. Inman Landfill Location Map



**Figure 2. Annual Volume of Leachate Disposed.**

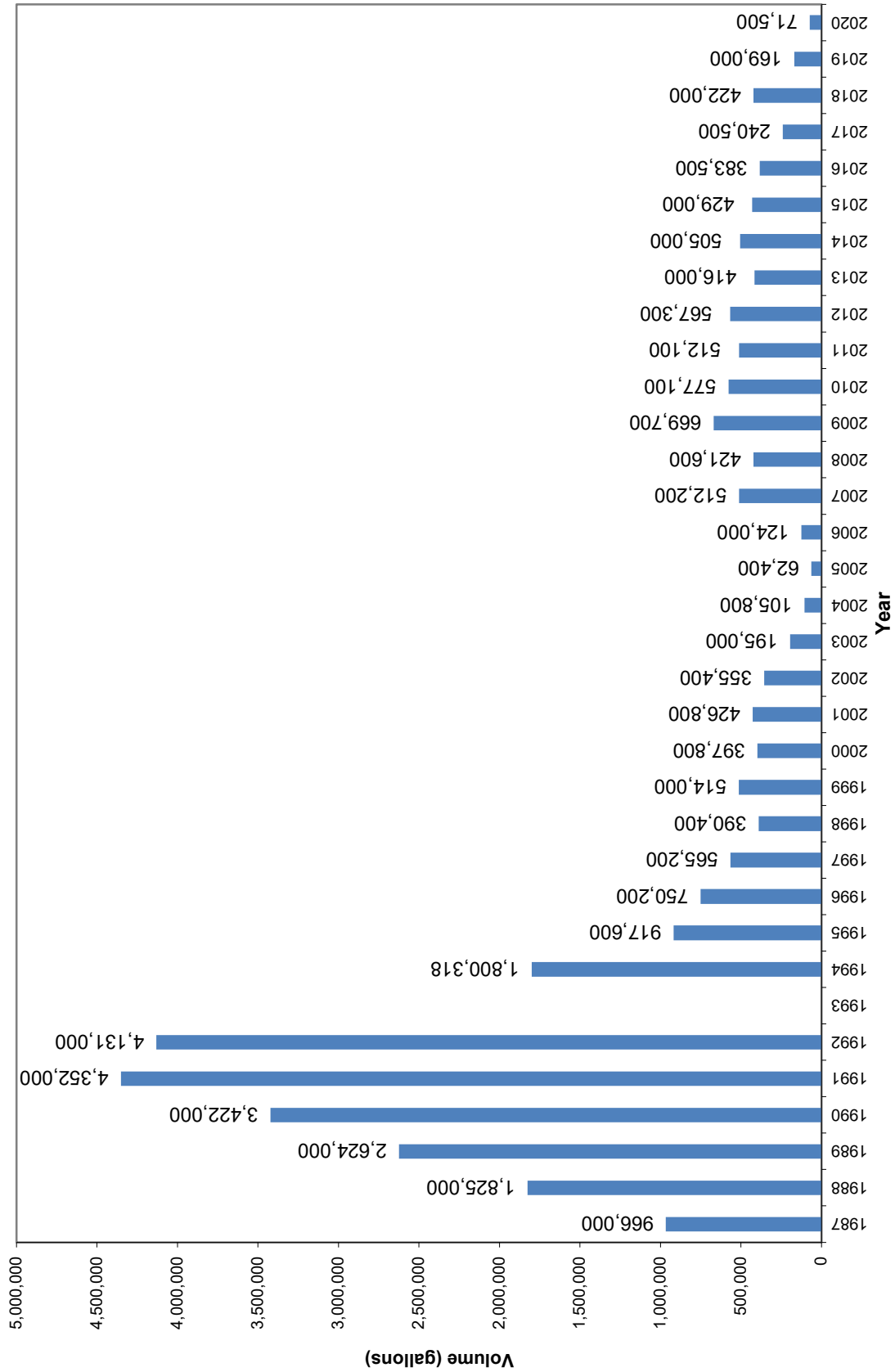
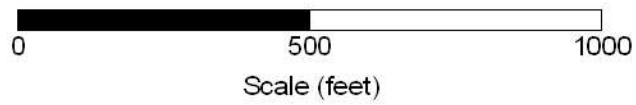


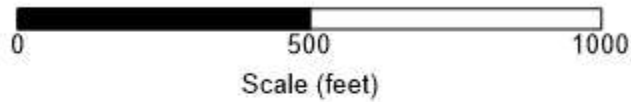
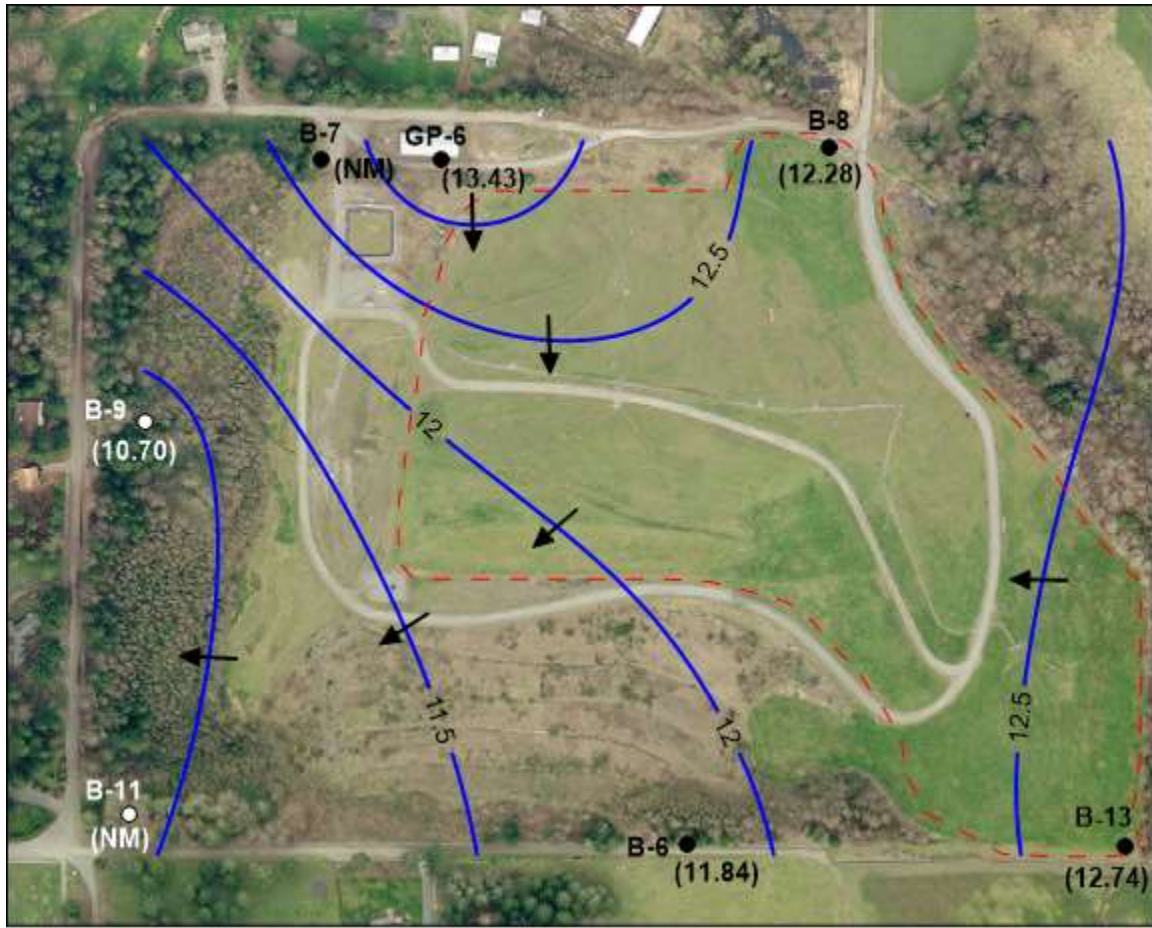
Figure 3. Perched Aquifer Monitoring Well Locations.



LEGEND

- B-6**  
● Monitoring Well
- - - Approximate Landfill Boundary

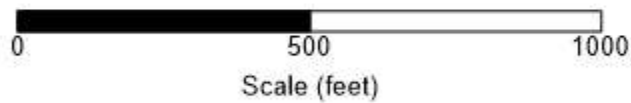
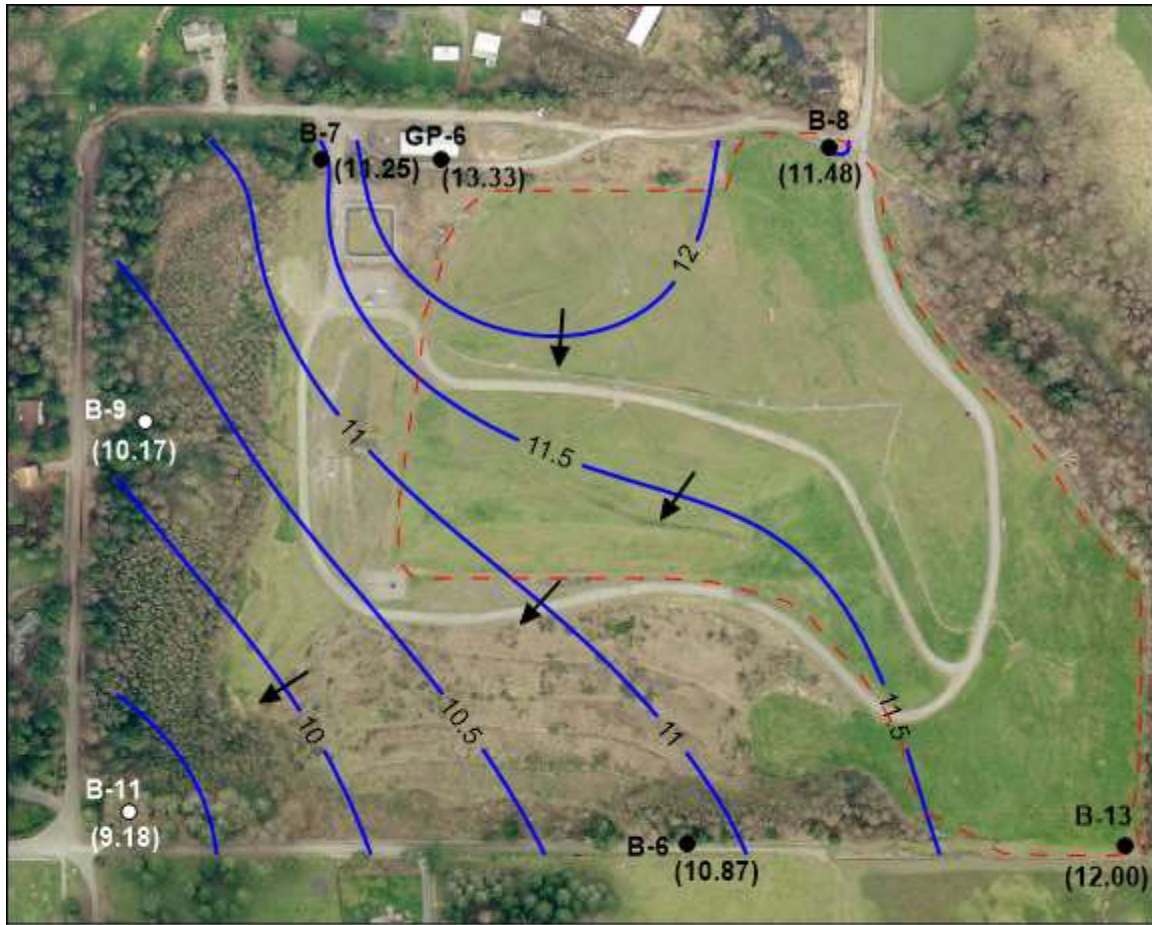
Figure 3a. Potentiometric Surface Contour Map, Perched Aquifer, April 2020.



**LEGEND**

- B-6** ● Monitoring Well
- 12.5—** Potentiometric Surface Contour (feet above MSL)
- ↙ Direction of Groundwater Flow
- (9.03)** Measured Static Water-Level Elevation (feet above MSL)
- Not Measured NM
- - - Approximate Landfill Boundary

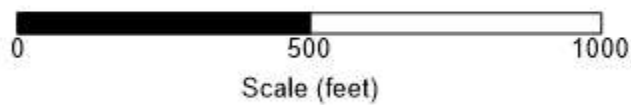
Figure 3b. Potentiometric Surface Contour Map Perched Aquifer, September 2020.



**LEGEND**

- B-6** ● Monitoring Well
- 12.5—** Potentiometric Surface Contour (feet above MSL)
- ↙ Direction of Groundwater Flow
- (9.03)** Measured Static Water-Level Elevation (feet above MSL)
- Not Measured NM
- - - Approximate Landfill Boundary

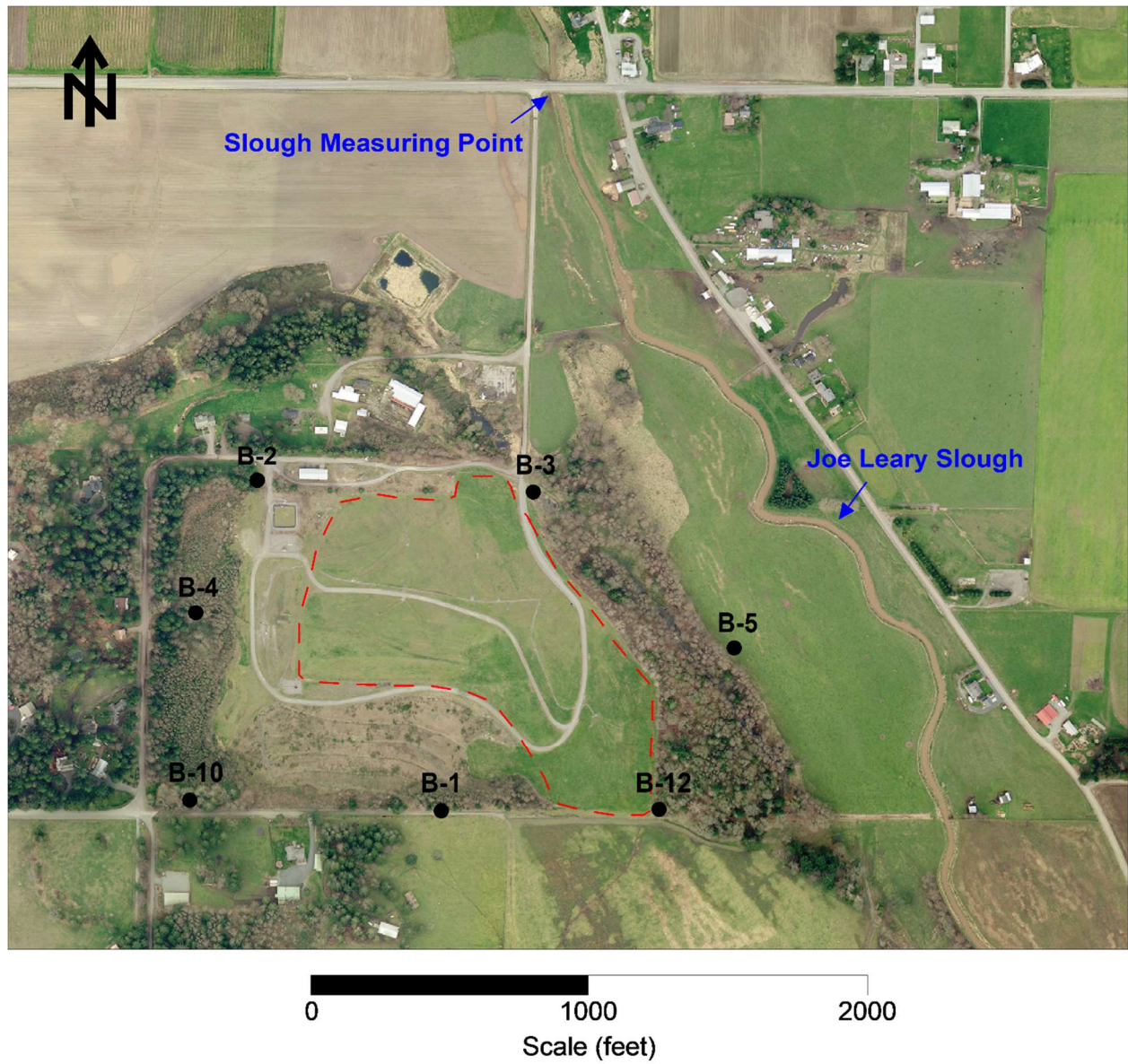
Figure 3c. Potentiometric Surface Contour Map, Perched Aquifer, December 2020.



LEGEND

-  B-6 Monitoring Well
-  —12.5— Potentiometric Surface Contour (feet above MSL)
-  Direction of Groundwater Flow
-  (9.03) Measured Static Water-Level Elevation (feet above MSL)
- Not Measured NM
-  - - - - - Approximate Landfill Boundary

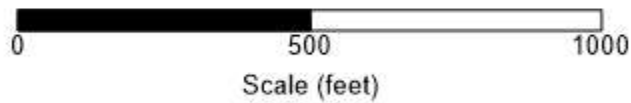
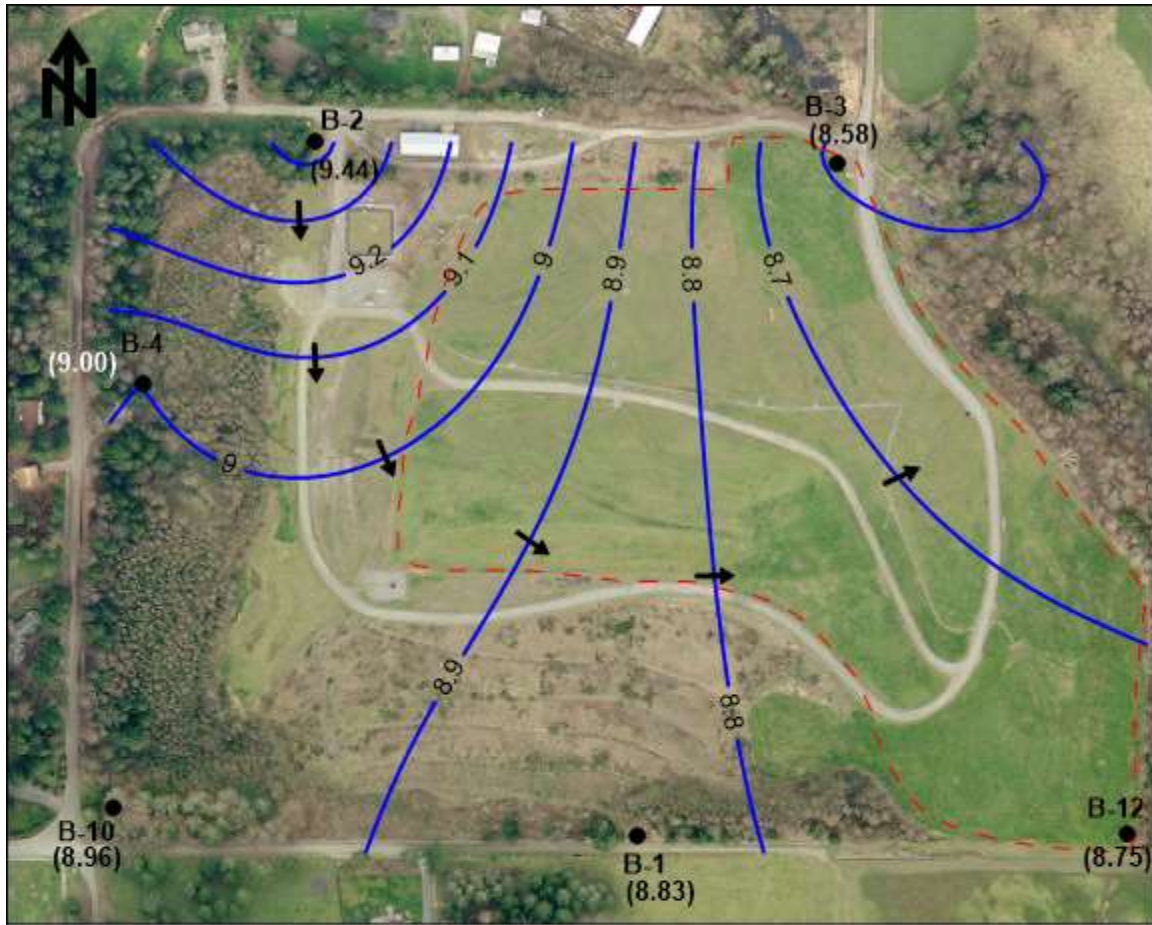
Figure 4. Regional Aquifer Monitoring Well Locations.



**LEGEND**

- B-10** ● Monitoring Well
- - - Approximate Landfill Boundary

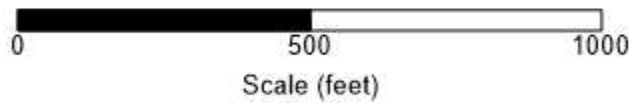
Figure 4a. Potentiometric Surface Contour, Central Landfill, Regional Aquifer, April 2020.



LEGEND

- B-6 Monitoring Well
- 8.2— Potentiometric Surface Contour (feet above MSL)
- Direction of Groundwater Flow
- (8.43) Measured Static Water-Level Elevation (feet above MSL)
- Approximate Landfill Boundary

Figure 4b. Potentiometric Surface Contour, Central Landfill, Regional Aquifer, September 2020.



LEGEND

-  B-6 Monitoring Well
-  —8.2— Potentiometric Surface Contour (feet above MSL)
-  → Direction of Groundwater Flow
-  (8.43) Measured Static Water-Level Elevation (feet above MSL)
-  - - - Approximate Landfill Boundary

Figure 4c. Potentiometric Surface Contour, Central Landfill, Regional Aquifer, December 2020.



LEGEND

-  B-6 Monitoring Well
-  8.2 Potentiometric Surface Contour (feet above MSL)
-  Direction of Groundwater Flow
-  (8.43) Measured Static Water-Level Elevation (feet above MSL)
-  - - - Approximate Landfill Boundary

Figure 5. Perched Aquifer Hydrograph, 1994-2020

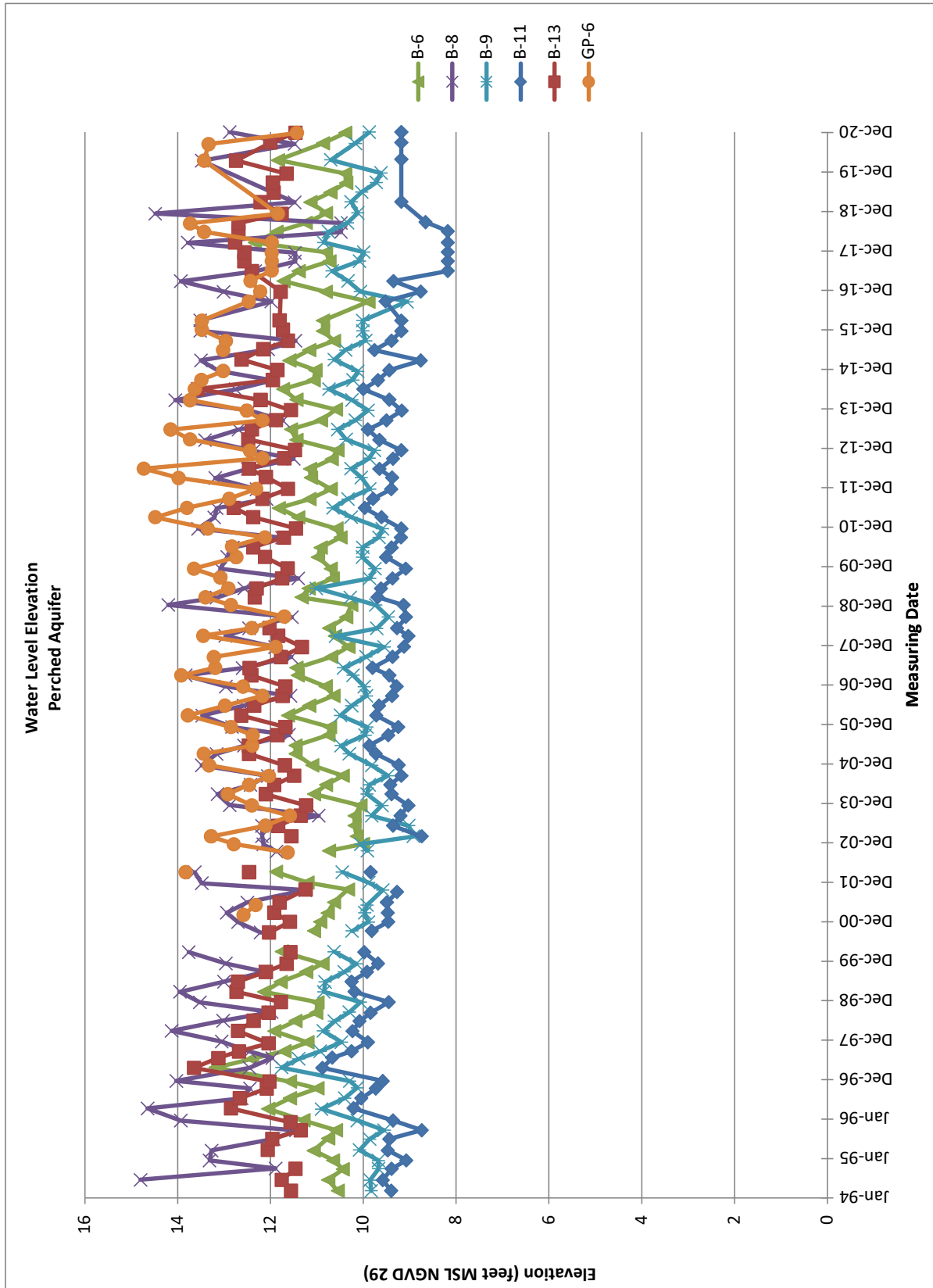


Figure 6. Regional Aquifer Hydrograph, 1994-2020

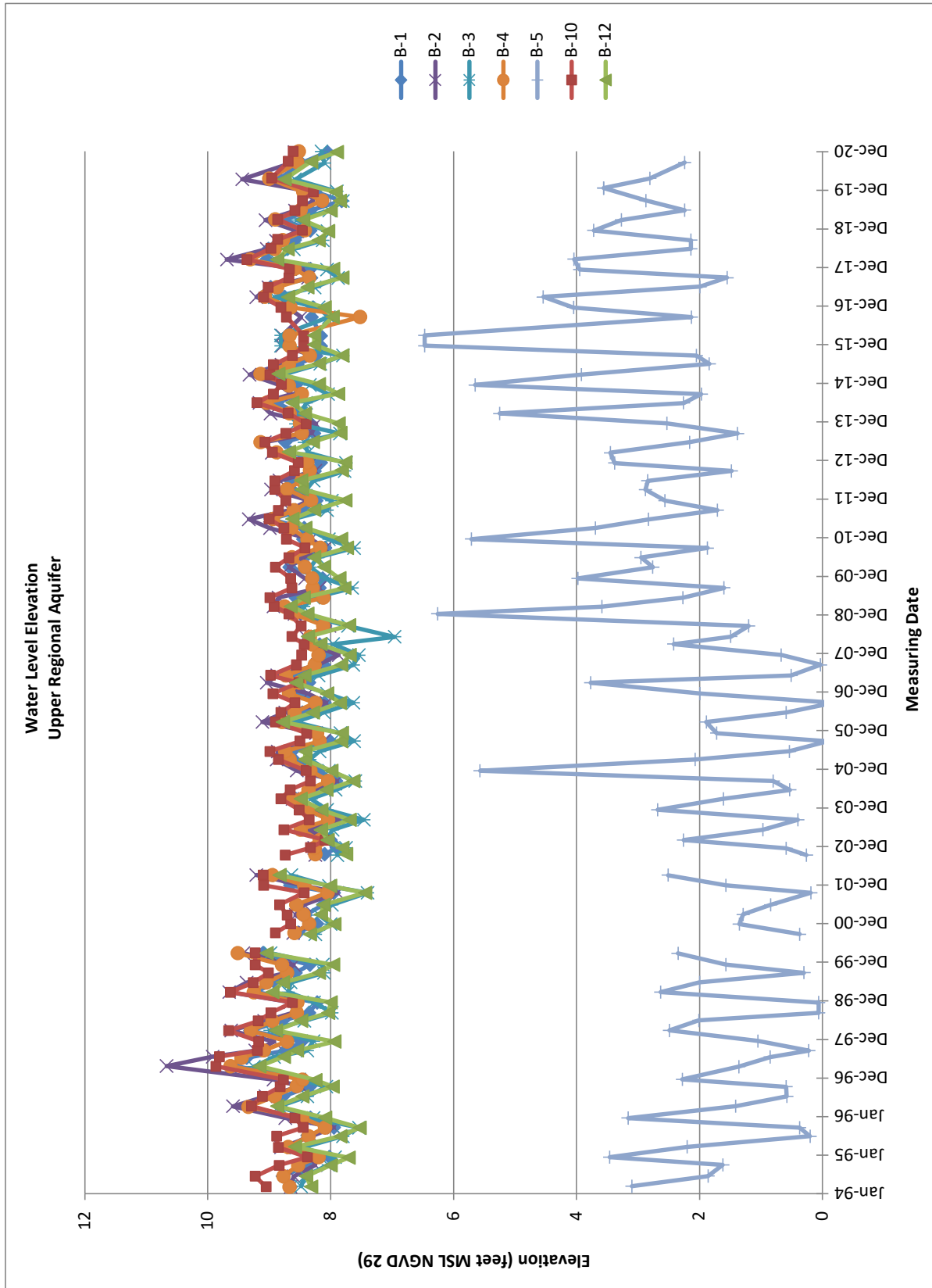
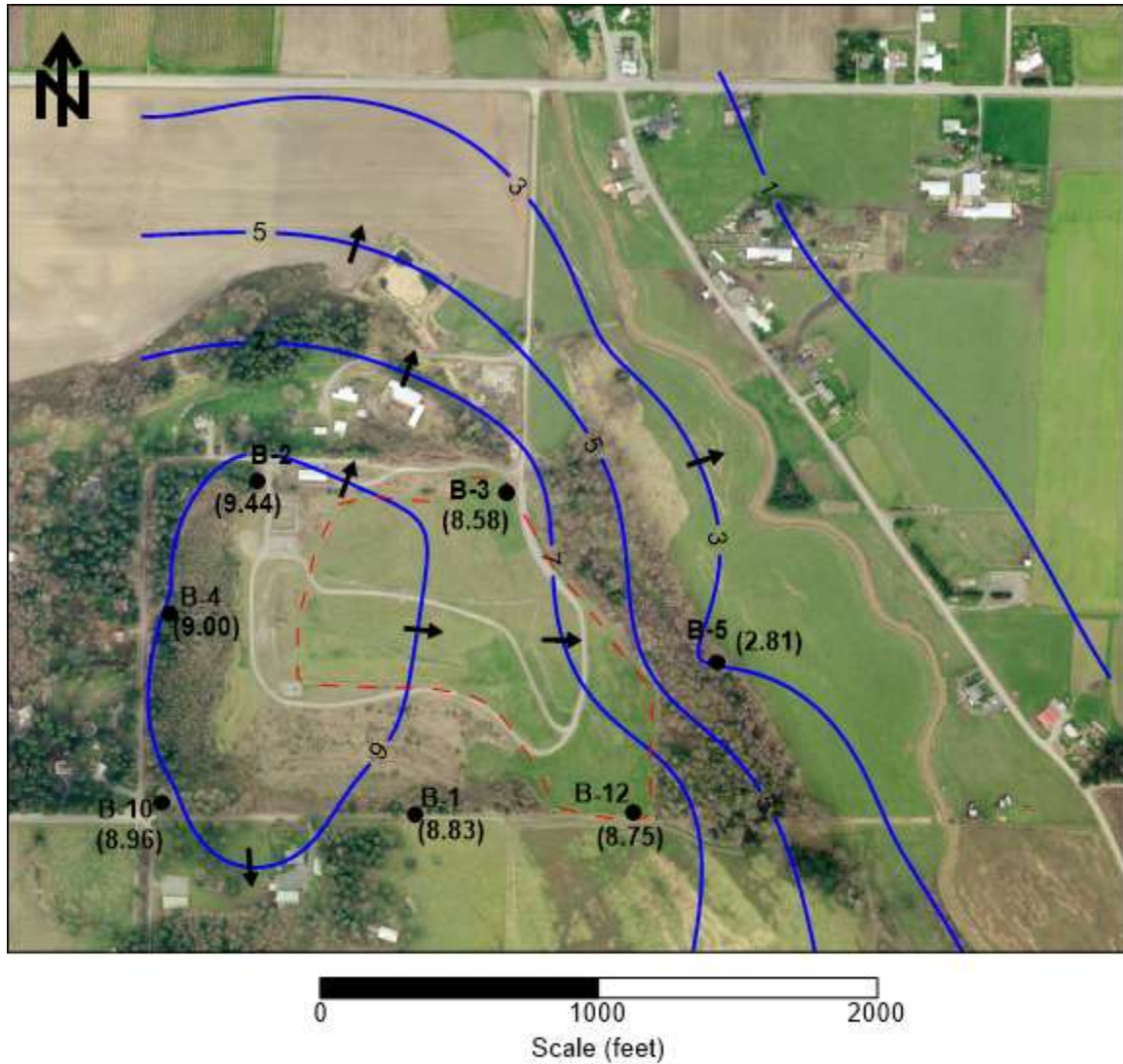


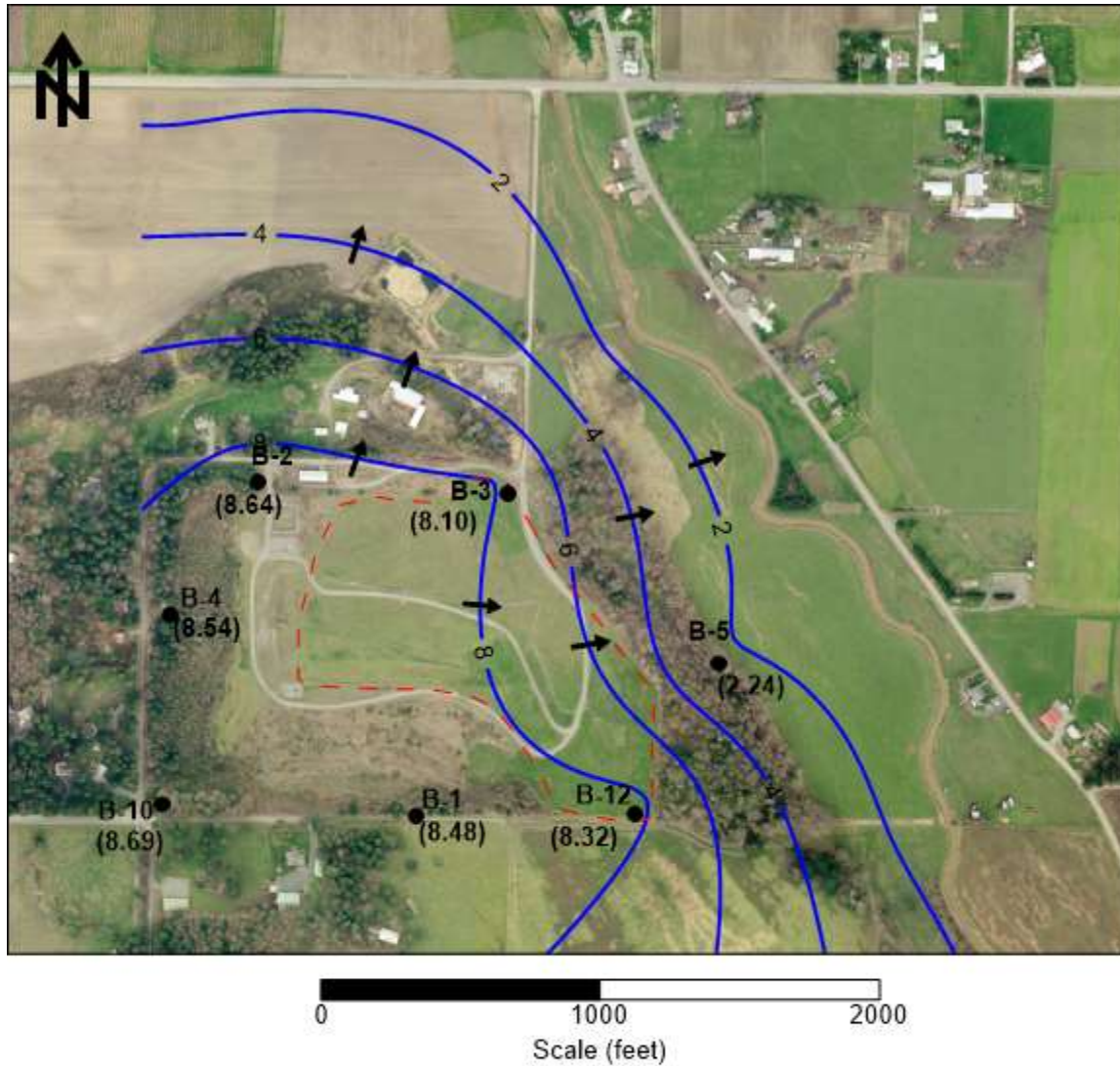
Figure 7a Potentiometric Surface Contour Map, Regional Aquifer, April 2020.



**LEGEND**

- B-10** ● Monitoring Well
- 8 — Potentiometric Surface Contour (feet above MSL)
- (8.18)** Measured Static Water-Level Elevation (feet above MSL)
- ➔ Direction of Groundwater Flow
- - - Approximate Landfill Boundary

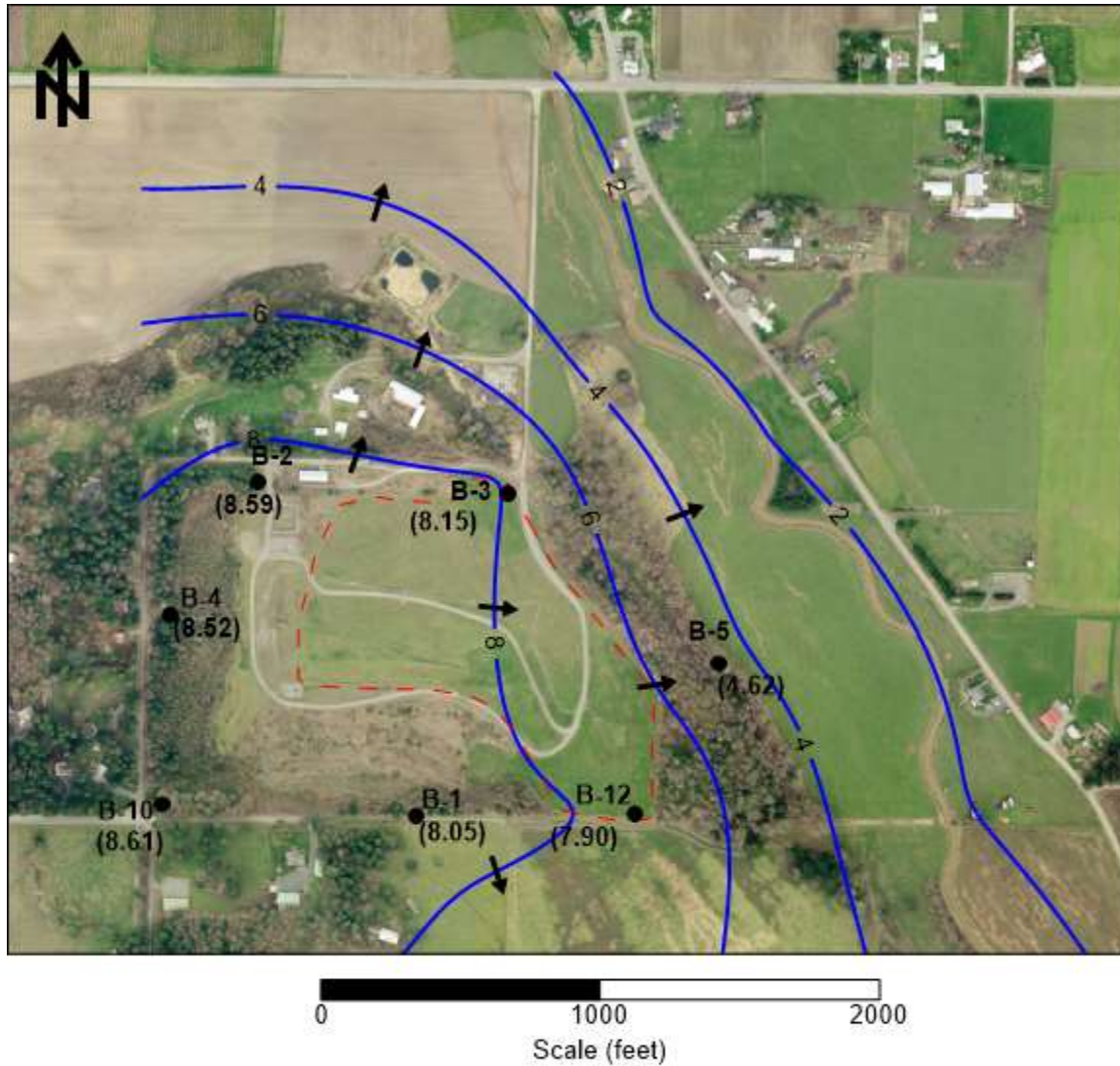
Figure 7b. Potentiometric Surface Contour Map, Regional Aquifer, September 2020.



**LEGEND**

- B-10** ● Monitoring Well
- 8 — Potentiometric Surface Contour (feet above MSL)
- (8.18) Measured Static Water-Level Elevation (feet above MSL)
- ➔ Direction of Groundwater Flow
- - - Approximate Landfill Boundary

Figure 7c. Potentiometric Surface Contour Map, Regional Aquifer, December 2020.



**LEGEND**

- B-10** ● Monitoring Well
- 8 — Potentiometric Surface Contour (feet above MSL)
- (8.18) Measured Static Water-Level Elevation (feet above MSL)
- ➔ Direction of Groundwater Flow
- - - Approximate Landfill Boundary

Figure 8. Inman Landfill Gas Extraction System Layout

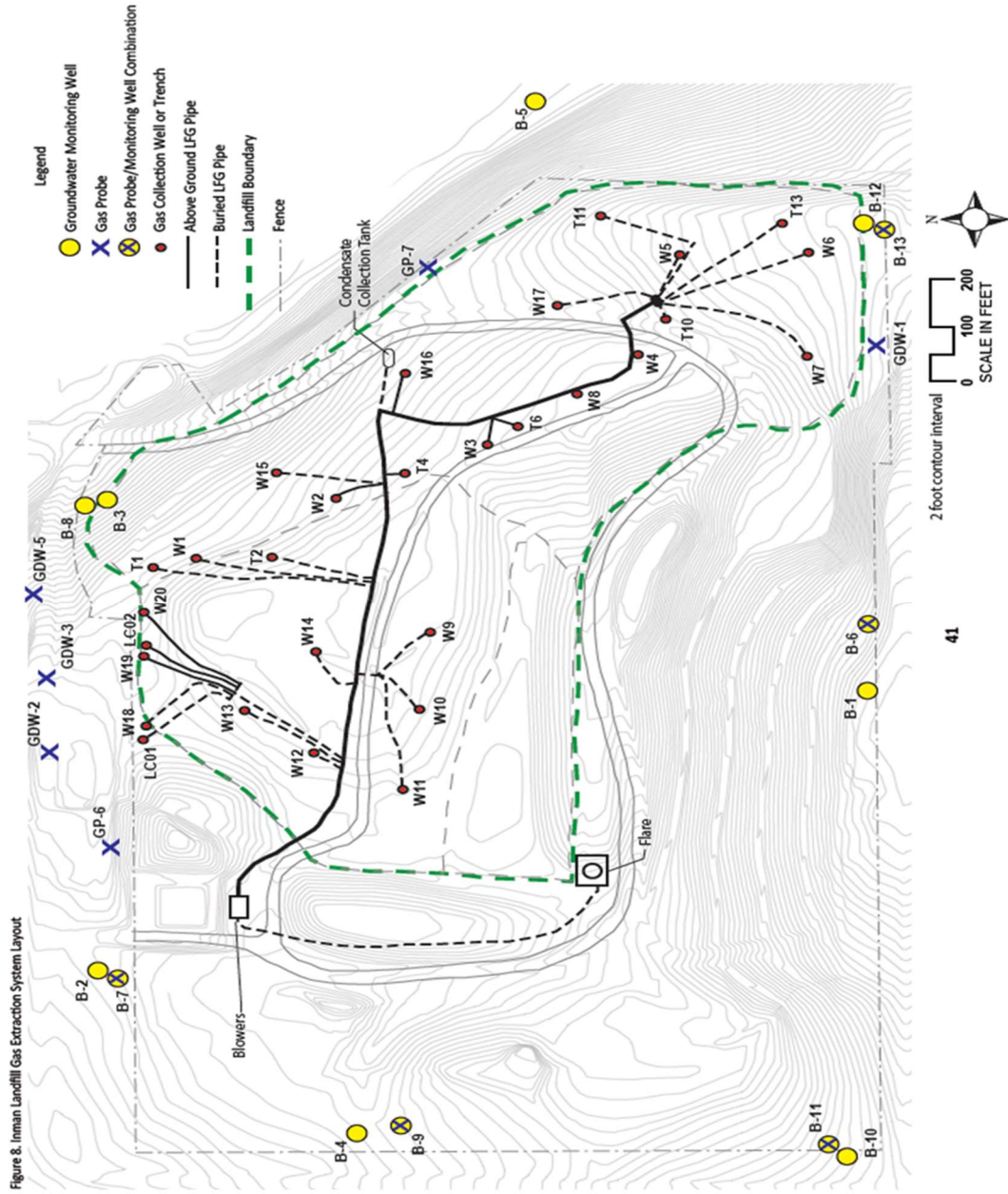
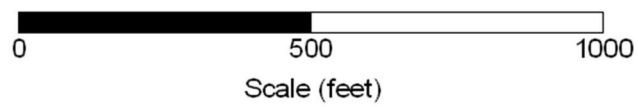


Figure 8. Inman Landfill Gas Extraction System Layout

Figure 9. Landfill Gas Perimeter Monitoring Probe Locations.



LEGEND

- B-6** ● Perimeter Gas Monitoring Well
- (6.9%)** Maximum methane concentration (<=0.1% for wells with no concentrations shown)
- - - Approximate Landfill Boundary