

# Bullseye Glass Area-Wide Phase 2

## Soil Sampling Report

October 2016



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State of Oregon  
**Department of  
Environmental  
Quality**

Last Updated: 10/10/2016  
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DEQ16-NWR-0036-TR

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## Background

DEQ collected soil samples from 22 sites encompassing areas to the northwest and southeast of Bullseye Glass Company (see Figure 2). DEQ performed the sampling to investigate additional areas surrounding the Bullseye Glass facility (located at 3722 SE 21<sup>st</sup> Avenue) that were not previously sampled and fall within the predominant prevailing direction of wind (Figure 3). Data collected from this sampling event provides broader spatial coverage of off-site areas and a more complete representation of soil conditions surrounding the facility.

Soil sampling objectives, study design, data collection methodology and data quality were implemented as described in the *Bullseye Phase 2 Area-Wide Soil Sampling and Analysis Plan (SAP)*, DEQ, July, 2016. Soil samples were collected on July 28, 2016 and were transferred to Environmental Science Corp. (ESC) Lab Sciences along with chain of custody documentation for analysis of a suite of metals.

Sidewalk strips adjacent to residential roads were chosen for soil sampling locations because they are generally undisturbed and have representative soil that has been exposed to air deposition over time (Figure 1).

Soil samples were analyzed for the following metals that were thought to be potentially associated with the glass manufacturing process and subsequently emitted and deposited onto soil.

- Aluminum (Al)
- Arsenic (As)
- Beryllium(Be)
- Cadmium (Cd)
- Cobalt (Co)
- Total Chromium (Cr)
- Hexavalent chromium (Chromium+6)
- Iron (Fe)
- Lead (Pb)
- Manganese (Mn)
- Mercury (Hg)
- Nickel (Ni)
- Selenium (Se)
- Zinc (Zn)

Zinc was added to the laboratory analyte list because of its relationship to metal uptake in plants.

## Sampling Methods

On July 28, 2016, DEQ collected soil samples from side-walk strips NW and SE of Bullseye Glass Company in accordance with DEQs *Bullseye Phase 2 Area-Wide Soil Sampling and Analysis Plan*, July, 2016. Discrete Soil Samples were collected in the upper 1-5 inches of soil, generally 1 inch below the grass sod or landscaped surface. A total of two soil samples were collected at depth which was between 5-12 inches below ground surface. Samples were placed in an iced cooler, transported to and analyzed at ESC Laboratories following standard analytical Quality Assurance/Quality Control (QA/QC) procedures.

Both laboratories are accredited under the National Environmental Laboratory Accreditation Program (NELAP).



Figure 1. Sidwalk strip soil sample location at SE Pershing Street  
July 28, 2016



Sidwalk strip soil sample location (under sod) at SE 19<sup>th</sup> Avenue.  
July 28, 2016

## Analytical Results

DEQ staff collected a total of 22 discrete surface samples, two additional deeper samples, and two replicate samples from sidewalk strips to the NW and SE of Bullseye Glass Company (see Figure 1). These sample locations and corresponding concentrations for select metals are presented and compared to Oregon background concentration, Oregon risk-based screening criteria and ATSDR screening concentrations (Agency for Toxic Substances and Disease Registry) on Figures 4 through 10 in Appendix B. Analytical data are presented and compared to screening criteria in Appendix A, Table 1.

Screening criteria used for comparison to analytical data are presented in Table 1, and referenced here:

1. Background Levels of Metals in Soils for Cleanups, Fact Sheet, Oregon DEQ, Land Quality Division, Environmental Cleanup Program, March 20, 2013. The background levels are available at:

<http://www.deq.state.or.us/lq/pubs/docs/cu/FSbackgroundmetals.pdf>

2. The Agency for Toxic Substances and Disease Registry (ATSDRs) Environmental Guidelines (EMEGs), used nationally. These guidelines are used during early or preliminary evaluations to quickly evaluate data at sites under investigation. Substances found at concentrations below the guidelines are not expected to pose public health hazards. Substances found at concentrations above EMEGs require further evaluation before drawing a public health conclusion. The guidelines are described at:

<http://www.atsdr.cdc.gov/hac/phamannual/appf.html>

3. DEQ's Risk-Based Concentrations (RBCs), last updated November 2015. DEQ publishes RBCs for assessing sites within the state. The DEQ RBCs were developed for assessing properties in Oregon, using procedures very similar to the U.S Environmental Protection Agency (US EPA). Properties with residual contamination at levels lower than the RBCs are generally considered to be acceptable under Oregon State standards. They are used in Oregon DEQ regulatory programs. The RBC's are available at:

[www.deq.state.or.us/lq/pubs/docs/RBDMTable.pdf](http://www.deq.state.or.us/lq/pubs/docs/RBDMTable.pdf)

The DEQ and ATSDR values are similar in application. That is, both are used for "screening" level assessments. ATSDR values are used nationally, while DEQ values are specific to Oregon. The two Agencies have used differing data or approaches in some instances to develop the final numeric values.

## Conclusions

Overall, the soil sampling results for Phase 2 show many metal concentrations are consistent at or near naturally occurring background levels. Analytical results for aluminum, beryllium, chromium (trivalent and total), cobalt, manganese, and nickel were all within or below ranges expected for naturally occurring levels of these metals (see Table 1).

Analytical results for cadmium, iron, lead, selenium, and zinc were above background levels in multiple samples, but below DEQ risk-based concentrations (RBCs).

Arsenic and hexavalent chromium, however, exceeded both background and DEQ risk-based concentrations in several locations, as shown on Figures 4 and 6.

The results for hexavalent chromium varied over the 22 sample locations, with no detections in the majority of samples. Hexavalent chromium exceeded RBCs at locations both northwest and southeast of Bullseye; nine samples ranging from 0.43 to 11.3 ppm, which exceeds the DEQ RBC but are less than the ATSDR screening value.

The results for arsenic were generally typical of background concentrations in an urban area with an average of 7.9 ppm. However, analytical results from 4 samples were 12 ppm and higher.

Analytical results for cadmium varied over the 22 sampling locations, from 0.28 ppm to 35.8 ppm with an average of 4 ppm which is well below the DEQ RBC of 78 ppm. Comparing cadmium concentrations in soil with the distance from the facility shows concentrations decreasing with increasing distance (Seidel, 2016).

Analytical results for iron show multiple sample locations exceeding background. However, none exceeded the DEQ RBC.

Analytical results for lead show numerous background exceedances northwest and southeast of Bullseye (Figure 8). However, lead is a common metal found in the urban environment and commonly persists near transportation corridors. Moreover, the pattern of lead detections does not suggest a spatial relationship to the Bullseye facility.

## Bullseye Glass Area-Wide Soil Sampling Report

The majority of selenium concentrations were elevated above DEQ background samples but below DEQ RBCs.

Zinc concentrations exceeded background in ten soil sample locations. There is no DEQ RBC for zinc, and the ATSDR value was not exceeded.

As discussed in this section, there are individual samples that exceed the screening values used for these preliminary comparisons. However individual samples are not typically used in a stand alone manner for decision making. Rather, estimates of averages are used over relevant sampling areas. Using estimates of average, arsenic exceeds DEQs estimate of background and the RBC, but not the ATSDR guideline. Similarly, cadmium exceeds the ATSDR guideline but not the DEQ RBC and hexavalent chromium exceeds the DEQ RBC but not the ATSDR guideline.

Arsenic has no spatial relationship to the facility and likely represents variability in urban ambient conditions from multiple sources. Similarly, there is no apparent pattern with respect to hexavalent chromium detections or the magnitude of detections. However, cadmium does show an apparent spatial relationship to the facility, and on average, slightly exceeds the ATSDR guideline, but not DEQ's RBC level. This finding suggests a need for some additional evaluation.

### **Comparison of Phase 1 and Phase 2 Analytical Results**

DEQ evaluated both the Phase 1 and Phase 2 Bullseye data sets of 93 soil sampling results. The hexavalent chromium and the lead concentrations appear to be spatially randomly dispersed with no clear relationship to the Bullseye facility (Figure 9 and 10). To explore other patterns among the soil data, DEQ conducted a statistical analysis. Overall, a pattern is apparent that shows a strong correlation for manganese and cobalt with distance from the Bullseye facility, and cadmium shows a correlation to a lesser extent (Seidel, 2016). This unique pattern could reflect a relationship with these 3 metals and Bullseye.

## References

Bullseye Area-Wide, Soil Sampling and Analysis Plan, Oregon Department of Environmental Quality, February 12, 2016.

[www.deq.state.or.us/nwr/docs/metalsem/bullseyeSAP.pdf](http://www.deq.state.or.us/nwr/docs/metalsem/bullseyeSAP.pdf)

Oregon Department of Environmental Quality, 2015. Oregon Administrative Rules, Division 41,

<http://www.deq.state.or.us/regulations/rules.htm>.

Oregon Department of Environmental Quality, 2013. Background Levels of Metals in Soils for Cleanups. March

2013. <http://www.deq.state.or.us/lq/pubs/docs/cu/FSbackgroundmetals.pdf>.

Oregon Department of Environmental Quality, 2015. Risk-Based Concentrations. November 2015.

[www.deq.state.or.us/lq/pubs/docs/RBDMTable.pdf](http://www.deq.state.or.us/lq/pubs/docs/RBDMTable.pdf).

Agency for Toxic Substances and Disease Registry (ATSDR), 2016. ATSDR values are environmental media evaluation guides (EMEGS). <http://www.atsdr.cdc.gov/hac/phamanual/appf.html>.

Environmental Science Corp (ESC) Laboratories. 12065 Lebanon Road, Mount Juliet, Tennessee, 37122, 615-773-9678, <http://www.esclabsciences.com/>

Seidel, Paul, Oregon Department of Environmental Quality, 2016. Memorandum: Bullseye Phase I and Phase II ECSI # 6073; DEQ Review of Analytical Data.

# Appendix A – Analytical Results

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# Bullseye Glass Area-Wide Soil Sampling Report

**Table 1. Bullseye Phase 2 (ppm dry weight)**

Sample	Date	Aluminum	Arsenic	Beryllium	Cadmium	Total Chromium	Trivalent Chromium	Cobalt	Hexavalent Chromium	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Zinc
NS-01-LAFAYETTE-NW-01	7/28/2016	22,200	6.3	0.645	<b>2.94</b>	24.5	23.3	19.6	1.17	<b>49,500</b>	<b>201</b>	978	<b>0.332</b>	28	<b>2.11</b>	<b>238</b>
NS-02-SE 21ST-SOUTH-01	7/28/2016	18,000	<b>9.19</b>	0.481	<b>35.8</b>	27	27	16	<1.09	35,600	<b>266</b>	682	0.0696	26.4	<b>7.8</b>	<b>407</b>
NS-03-SE 21ST-SOUTH-01	7/28/2016	17,100	5.56	0.412	<b>5.72</b>	25.6	25.6	14.4	<1.08	<b>37,500</b>	<b>377</b>	576	0.0714	23.2	<b>1.23</b>	<b>202</b>
NS-04-SE 21ST-NORTH-01	7/28/2016	17,000	8.63	0.53	<b>6.92</b>	43.8	43.3	15.2	0.506	<b>37,300</b>	<b>159</b>	677	0.0529	27.1	<b>2.59</b>	<b>226</b>
NS-05-LAFAYETTE-SOUTH-01	7/28/2016	21,900	5.79	0.492	<b>3.4</b>	28.4	28.4	14.2	<1.14	<b>38,600</b>	<b>216</b>	548	0.0692	30.1	<b>1.51</b>	<b>201</b>
NS-06--LAFAYETTE-SOUTH-06	7/28/2016	24,900	5.37	0.6	<b>1.6</b>	27.3	27.3	19	<1.13	<b>50,100</b>	<b>123</b>	866	0.0396	26.9	<b>1.33</b>	<b>191</b>
NS-07--LAFAYETTE-SOUTH-01	7/28/2016	17,700	5.48	0.539	0.275	19.8	19.8	16.3	<1.16	<b>37,500</b>	20	670	0.0241	24.8	<b>1.33</b>	73.5
NS-08-SE 20TH-S-DUPLICATE	7/28/2016	18,400	<b>9.02</b>	0.494	<b>1.44</b>	38.6	36.6	13.8	1.98	<b>41,100</b>	<b>144</b>	545	0.0551	23.5	<b>9.27</b>	153
NS-08-SE 20TH-SOUTH-01	7/28/2016	19,600	<b>9.97</b>	0.486	<b>1.59</b>	34.1	34.1	13.9	<1.09	<b>40,200</b>	<b>149</b>	565	0.104	22.8	<b>19.9</b>	155
NS-09-SE 20TH-MIDDLE-01	7/28/2016	14,300	7.57	0.313	<b>5.9</b>	33.2	32.8	13.7	0.442	33,200	77.9	539	0.0673	26.7	<b>2.26</b>	<b>379</b>
NS-10-PERSHING-EAST-01	7/28/2016	17,700	4.99	0.629	<b>0.655</b>	21.3	21.3	10.6	<1.31	28,300	<b>85.2</b>	398	0.076	18.5	<b>1.07</b>	120
NS-11-PERSHING-MIDDLE-01	7/28/2016	21,000	7.12	0.592	<b>0.952</b>	71.3	60.1	14.8	11.3	<b>37,900</b>	<b>136</b>	723	0.0923	22.1	<b>1.14</b>	135
NS-12-SE 19TH-01	7/28/2016	20,800	7.03	0.547	<b>0.915</b>	24.4	24	18.4	0.434	<b>37,300</b>	<b>128</b>	860	0.0508	19.2	<b>0.894</b>	<b>186</b>
NS-13-PERSHING-WEST-01	7/28/2016	24,400	7.41	0.699	0.378	26.2	26.2	20.5	<1.24	<b>42,300</b>	23.3	795	0.0234	20.4	<b>0.932</b>	112
NS-14-SE 21ST-NORTH-01	7/28/2016	17,400	5.57	0.503	<b>1.69</b>	32.3	32.3	17.1	<1.08	32,600	<b>307</b>	827	0.1	21.4	<b>1.19</b>	<b>234</b>
SS-15-SE BUSH-01	7/28/2016	22,700	<b>12.8</b>	0.545	<b>22.4</b>	23	23	23.1	<1.10	<b>43,700</b>	50.9	842	0.0256	22.8	<b>12.3</b>	138
SS-16-SE 22ND-01	7/28/2016	27,700	4.67	0.637	<b>1.6</b>	20.5	20.5	19.6	<1.14	<b>51,500</b>	22	966	0.0318	19.1	<b>2.1</b>	126
SS-17-SE 24TH-01	7/28/2016	16,400	5.39	0.584	<b>1.94</b>	42.4	42.4	14.3	<1.10	27,900	<b>251</b>	437	0.61	27.2	<b>1.6</b>	193
SS-18-SE 24TH-06	7/28/2016	16,600	6.37	0.399	<b>2.15</b>	37.8	33.2	14.2	4.59	31,800	<b>215</b>	478	0.783	26.2	<b>1.22</b>	<b>228</b>
SS-19-GLADSTONE-W-01	7/28/2016	20,300	6.43	0.574	<b>0.858</b>	25.6	24.9	19.5	0.721	<b>37,100</b>	27.4	933	0.026	19	<b>1.21</b>	129
SS-20-SE CORA-01	7/28/2016	16,700	<b>12.6</b>	0.595	<b>0.988</b>	26.4	26.4	11.5	<1.19	28,500	<b>125</b>	353	0.0669	17.2	<b>1.14</b>	123
SS-20-SE CORA-DUPLICATE	7/28/2016	15,100	<b>12.3</b>	0.537	<b>1.24</b>	26.4	26.4	10.4	<1.2	26,400	<b>120</b>	307	0.0729	15.7	<b>1.31</b>	124
SS-21-SE CORA-MIDDLE-01	7/28/2016	14,700	5.58	0.474	0.554	23.1	16.5	11.2	6.6	25,700	65.2	347	0.0449	11.8	<b>0.775</b>	168
SS-22-SE 25TH-01	7/28/2016	13,000	<b>22.9</b>	0.614	<b>1.2</b>	22.7	22.7	22.6	<1.15	<b>39,600</b>	<b>116</b>	1440	0.0639	16.3	<b>0.885</b>	151
SS-23-SE 26TH-SOUTH-01	7/28/2016	16,100	5.33	0.466	0.585	24.5	24.5	14.4	<1.08	32,500	<b>231</b>	430	0.0549	19	<b>0.94</b>	163
SS-24-SE 26TH-NORTH-01	7/28/2016	12,100	5.8	0.471	<b>1.42</b>	36.1	36.1	15.6	<1.09	28,600	<b>332</b>	520	0.107	17.2	0.57	<b>223</b>
<b>Screening Levels</b>																
DEQ Background Levels <sup>1</sup>		52,300	8.8	2	0.63	76	76	33	NA	36,100	79	1,800	0.23	47	0.71	180
DEQ Residential Screening RBCs <sup>2</sup>		77,000	0.43	160	78	120,000	120,000	23	0.3	55,000	400	1,800	23	1,500	390	NA
ATSDR Screening Values <sup>3</sup>		50,000	15	100	5	75,000	75,000	500	45	-	-	2,500	15	1,000	250	15,000

**Notes:**

Results reported on a dry weight basis.

Metals by EPA Method 6020A, except mercury by EPA Method 7471A.

**Bold** denotes a detected concentration exceeding its DEQ background level.

RBC = Risk-Based Concentration.

ATSDR = Agency for Toxic Substances and Disease Registry.

NA- Not Available

<sup>1</sup> DEQ Background Level for chromium is based on total chromium. Residential and ATSDR values are based on trivalent chromium.

DEQ Background Levels are from the DEQ metals fact sheet (DEQ 2013), except Aluminum, Iron, and cobalt.

Aluminum and Iron are averages from Clark County Washington- Ecology Pub No. 94-115; Cobalt is a DEQ calculated averages from Willamette Valley.

<sup>2</sup> DEQ Residential RBCs (DEQ 2015) used for all metals, except for EPA Regional Screening Level used for Aluminum, Iron, cobalt and zinc.

<sup>3</sup>ATSDR = <http://www.atsdr.cdc.gov/hac/phamannual/appf.html>

< = Not detected above the indicated laboratory method detection limit (MDL).

ppm = Part per million.

Shading denotes a detected concentration exceeding both the DEQ Background Level and the DEQ risk-based screening value

Bullseye Glass Area-Wide Soil Sampling Report

**Table 2. Screening Table (ppm dry weight)**

<b>Metal</b>	<b>DEQ Background<sup>1</sup></b>	<b>Residential<sup>2</sup></b>	<b>ATSDR Values<sup>3</sup></b>
Aluminum <sup>a</sup>	52,300 <sup>b</sup>	77,000	50,000
Arsenic	8.8	0.43	15
Beryllium	2.0	160	100
Cadmium	0.63	78	5
Total Chromium <sup>d</sup>	76	120,000	75,000
Chromium(VI)	NA	0.3	45
Cobalt <sup>a</sup>	33 <sup>c</sup>	23	500
Iron <sup>a</sup>	36,100 <sup>b</sup>	55,000	NA
Lead	79	400	NA
Manganese	1,800	1,800	2,500
Mercury	0.23	23	15
Nickel	47	1,500	1,000
Selenium <sup>a</sup>	0.71	390	250
Zinc <sup>a</sup>	180.0	23,000	15,000

1- Source DEQ background metals fact sheet, <http://www.deq.state.or.us/lq/pubs/docs/cu/FSbackgroundmetals.pdf>

2 - Residential values are DEQ soil screening values, where available, or EPA regional screening values (RSLs) when no DEQ residential value is published

*DEQ Residential values assume the following:*

- A person resides in the same residence 24 hours a day, 7 days a week, 350 days a year, for 26 years
- Adults incidentally ingest 100 mg of soil per day, children incidentally ingest 200 mg of soil per day

3 - Agency for Toxic Substances and Disease Registry (ATSDR) Screening Values. ATSDR values are environmental media evaluation guides (EMEGS), or reference dose media evaluation guides (RMEGs).

a - Residential values for these metals are the US EPA Regional Screening Values (RSLs) for residential use

b - Background value shown is from Washington Department of Ecology Pub. No. 94-115

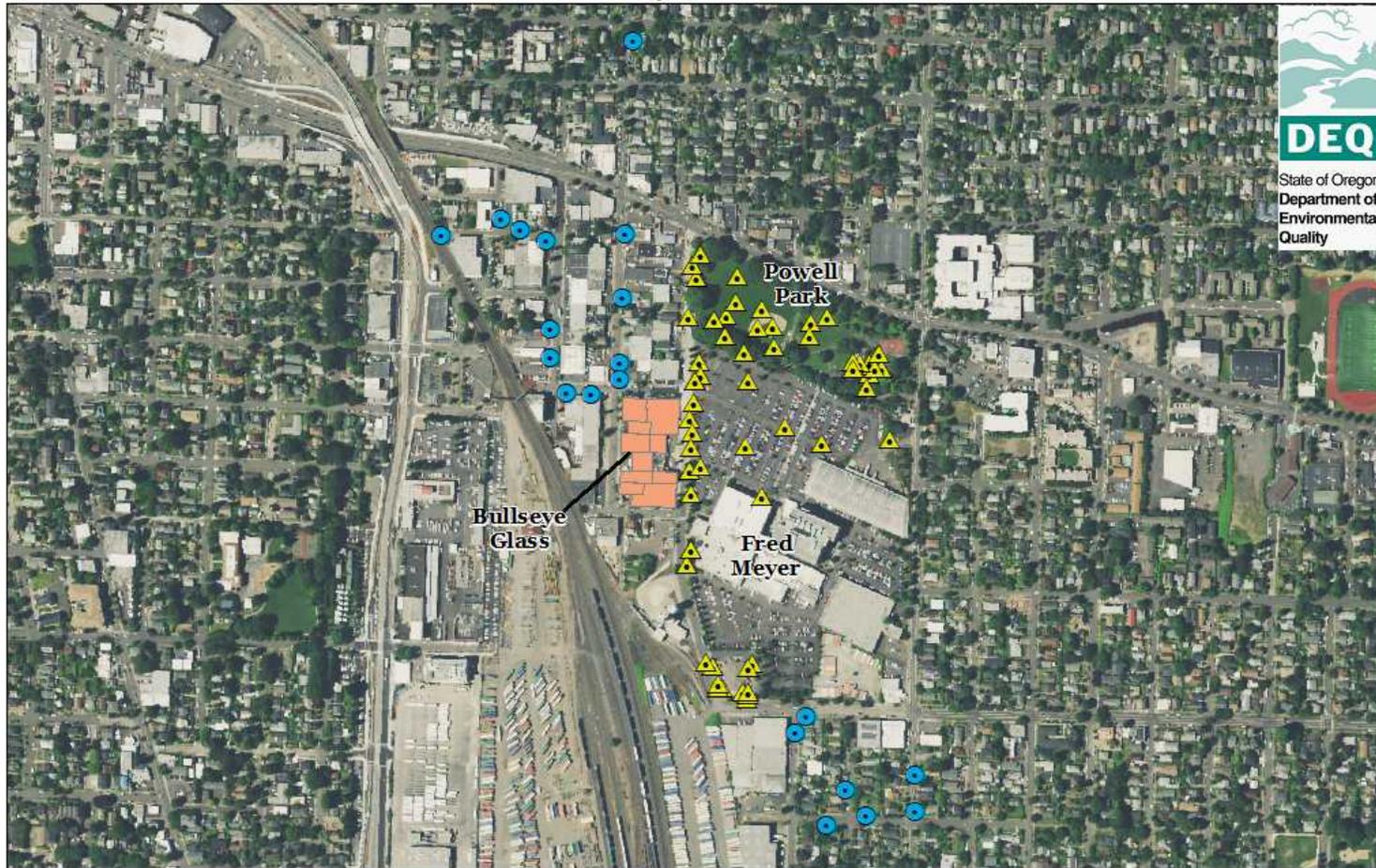
c - No background estimate for cobalt has been published by DEQ. Value shown is average of Willamette Valley soil from DEQ database

d- Background value is based on total chromium. Screening Values are based on trivalent chromium

# Appendix B – Figures

Figure 2.

### Soil Sample Locations



#### Sample Locations

-  Phase 1
-  Phase 2

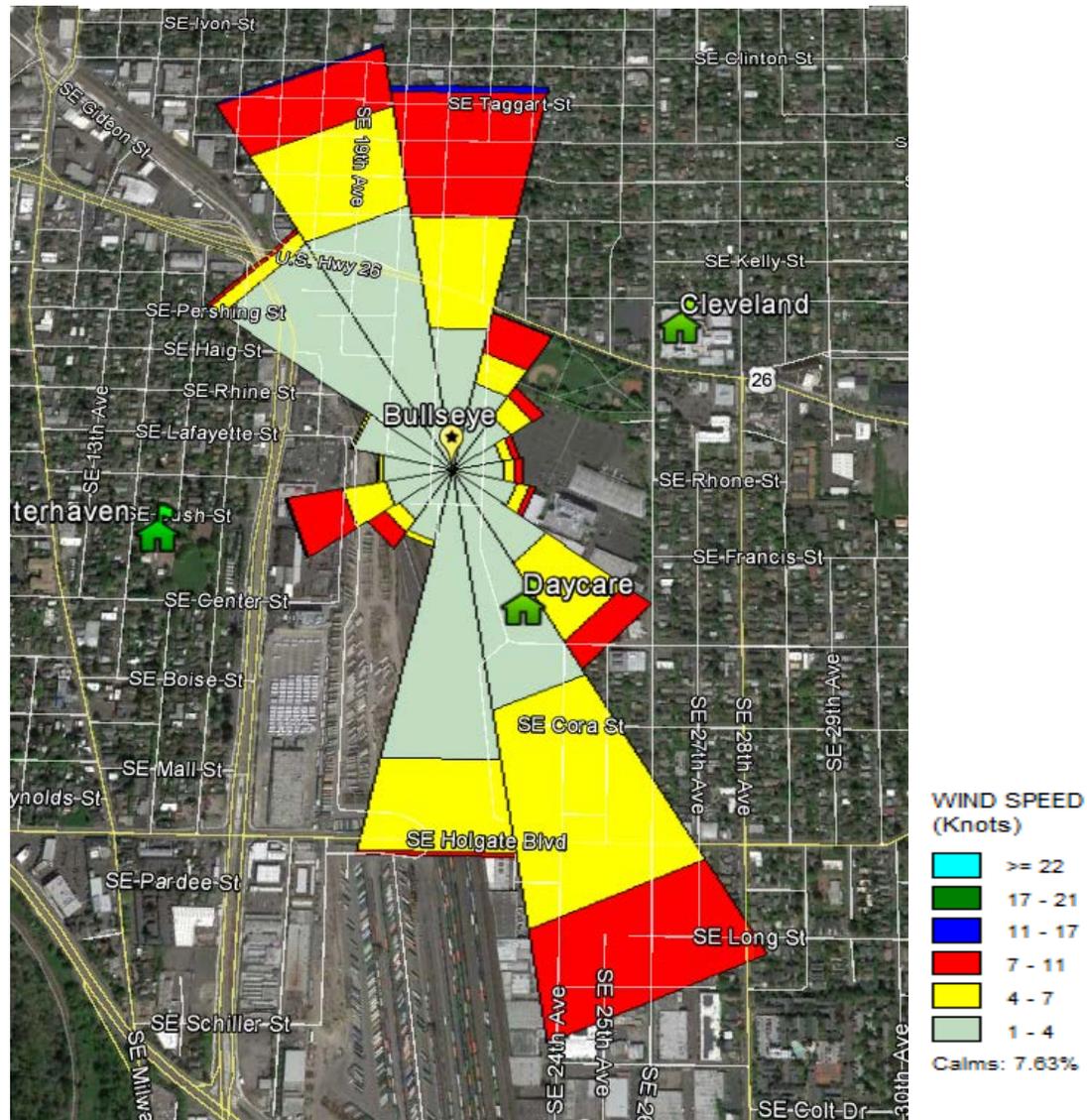
0 0.15 0.3 Miles



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Figure 3.

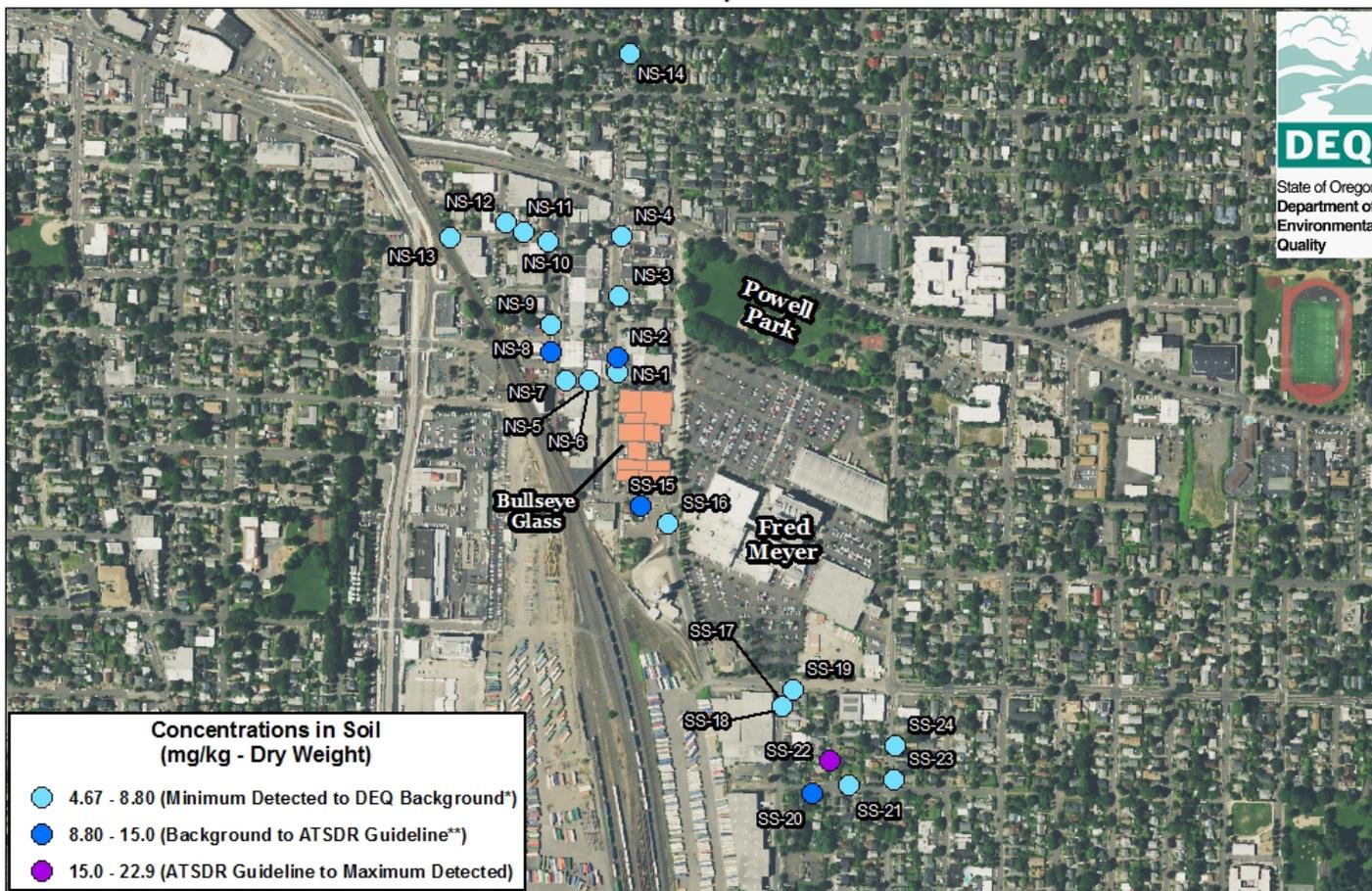
### Wind Vector for February - June 2016



Winds coming from center pointing to triangle

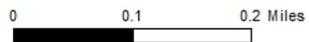
Figure 4.

### Arsenic Soil Sample Locations



\* DEQ's Background metals in soil fact sheet - <http://www.deq.state.or.us/lq/pubs/docs/cu/FSbackgroundmetals.pdf>

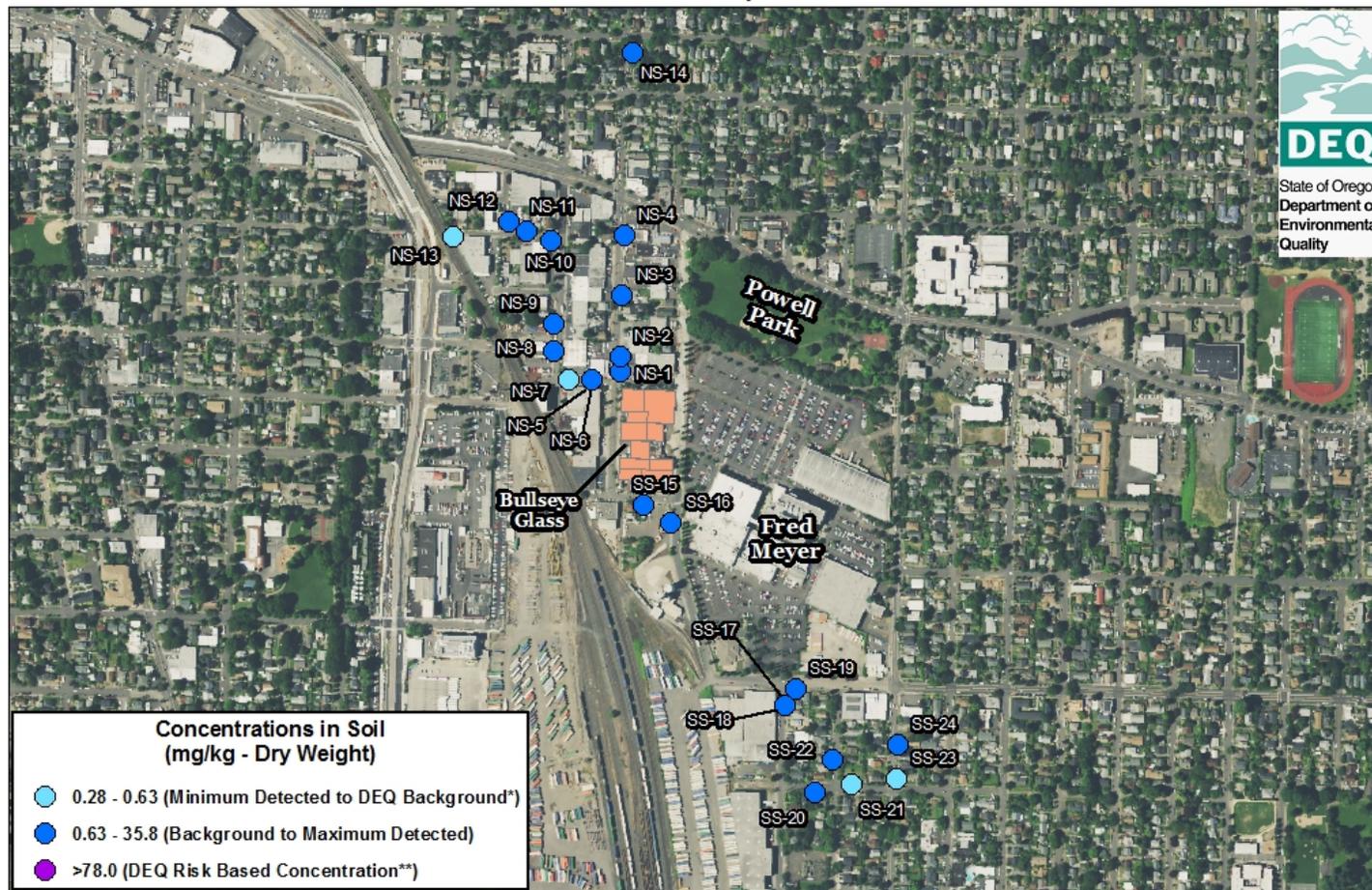
\*\* Agency for Toxic Substances and Disease Registry



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Figure 5.

### Cadmium Soil Sample Locations



\* DEQ's Background metals in soil fact sheet - <http://www.deq.state.or.us/lq/pubs/doc/cu/FSbackgroundmetals.pdf>

\*\* DEQ's Risk-Based Concentrations - <http://www.deq.state.or.us/lq/pubs/doc/s/RBDMTable.pdf>



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Figure 6.

### Chromium+6 Soil Sample Locations

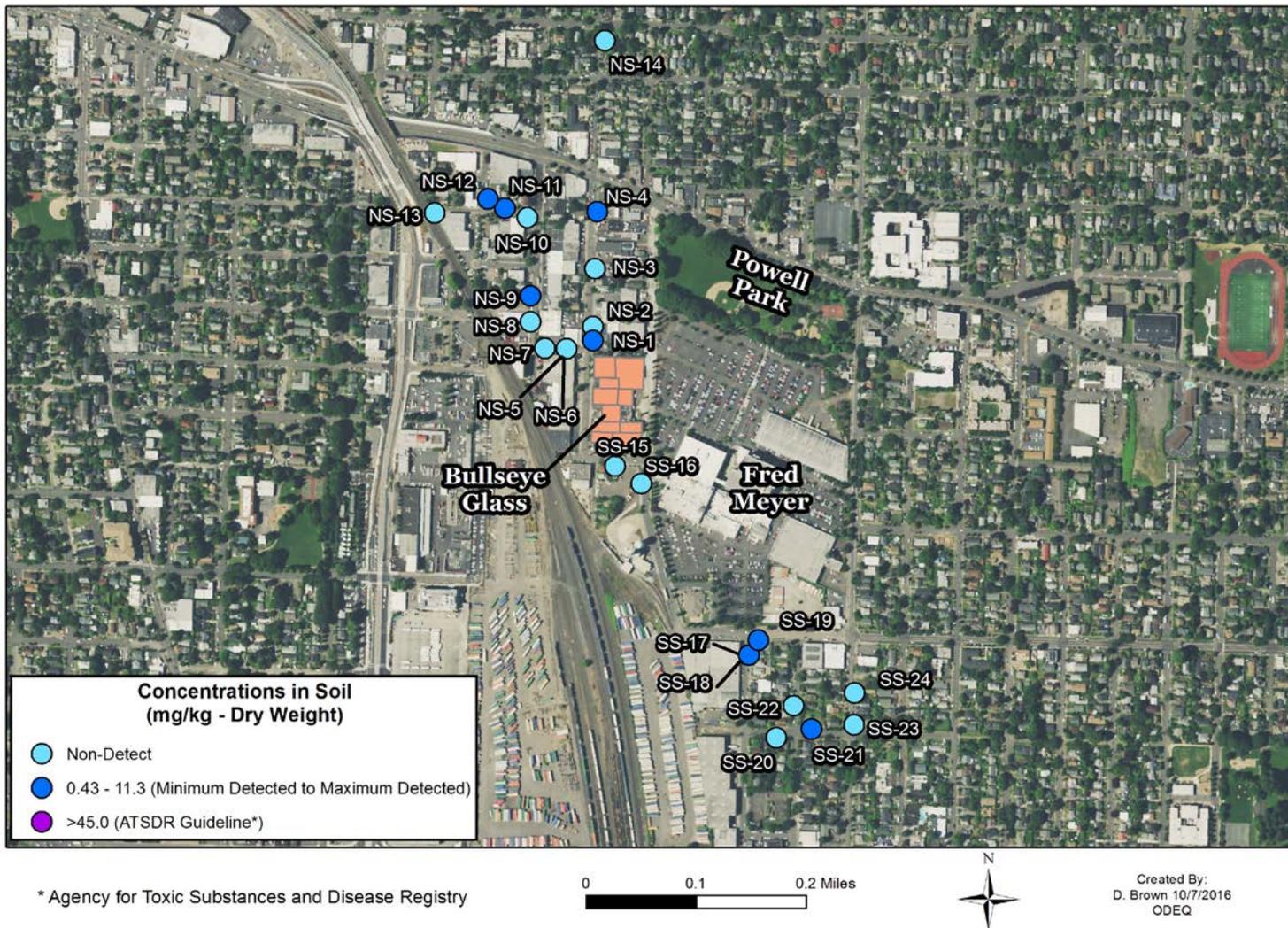
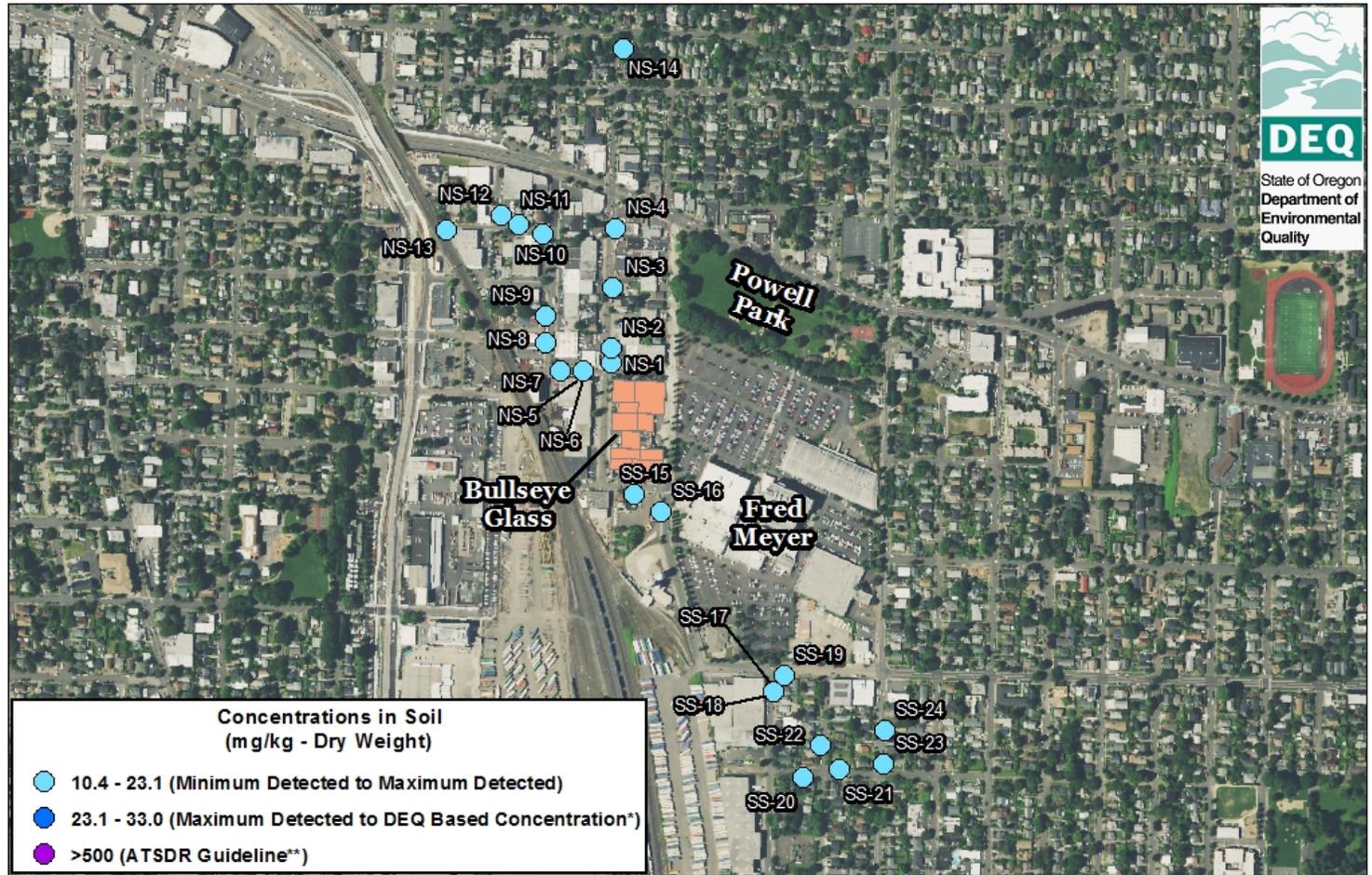


Figure 7.

### Cobalt Soil Sample Locations



\* DEQ's Background metals in soil fact sheet - <http://www.deq.state.or.us/lq/pubs/docs/cu/FSbackgroundmetals.pdf>

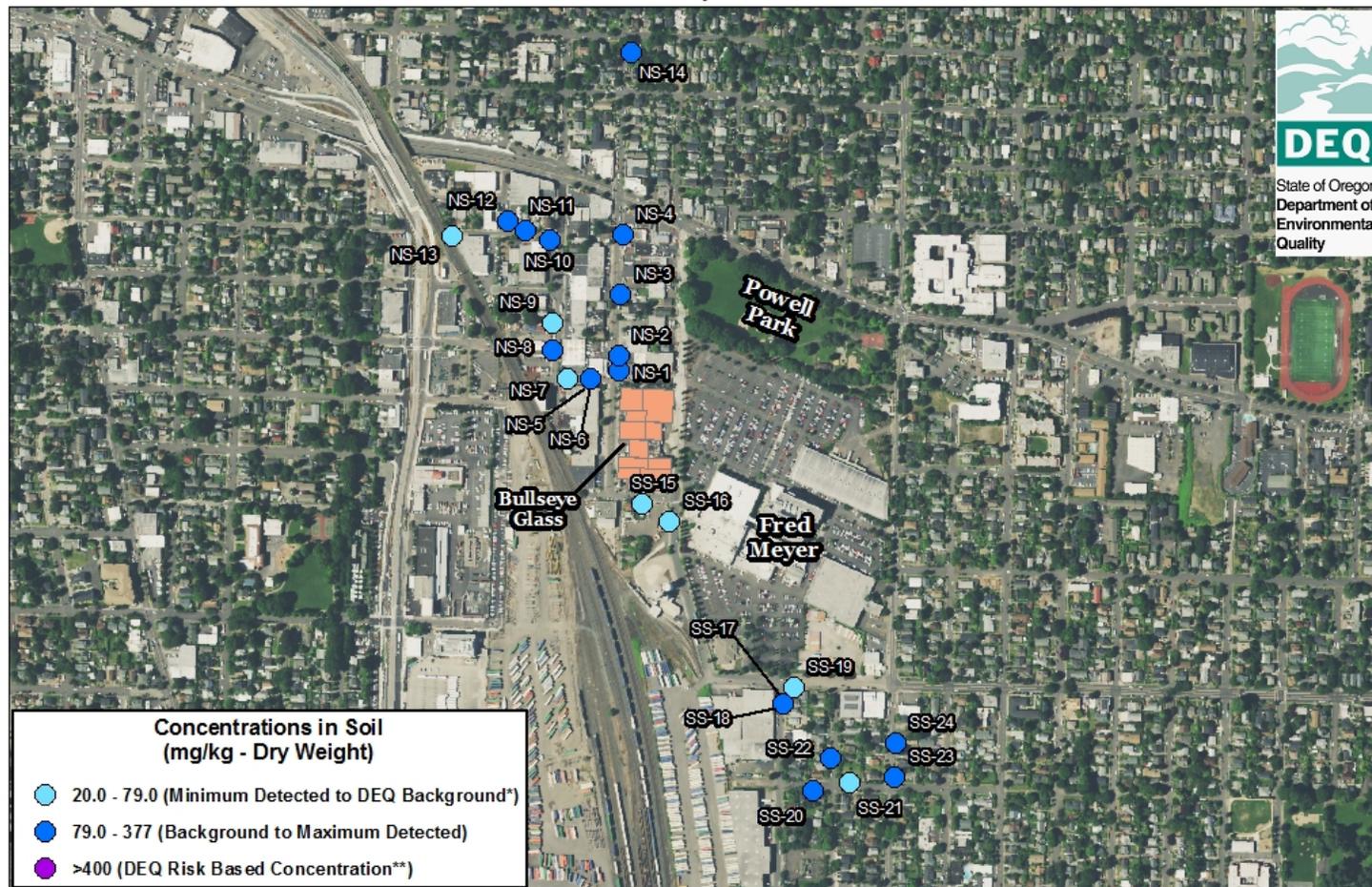
\*\* Agency for Toxic Substances and Disease Registry



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Figure 8.

### Lead Soil Sample Locations



\* DEQ's Background metals in soil fact sheet - <http://www.deq.state.or.us/lq/pubs/docs/cu/FSbackgroundmetals.pdf>

\*\* DEQ's Risk-Based Concentrations - <http://www.deq.state.or.us/lq/pubs/docs/RBDMTable.pdf>

Figure 9. Hexavalent Chromium Concentrations in Soil, Phase 1 and 2

### Chromium+6 Soil Sample Locations

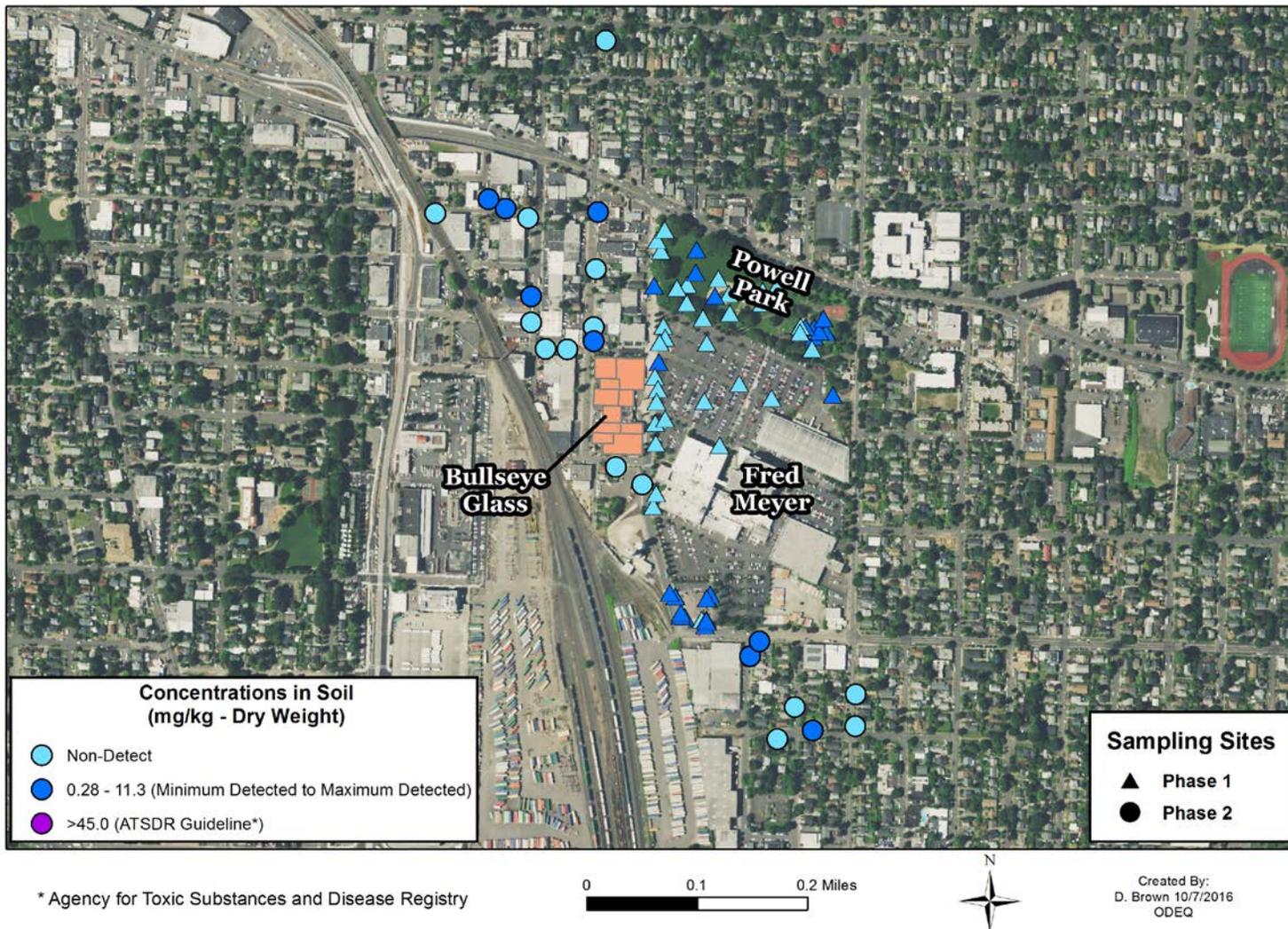
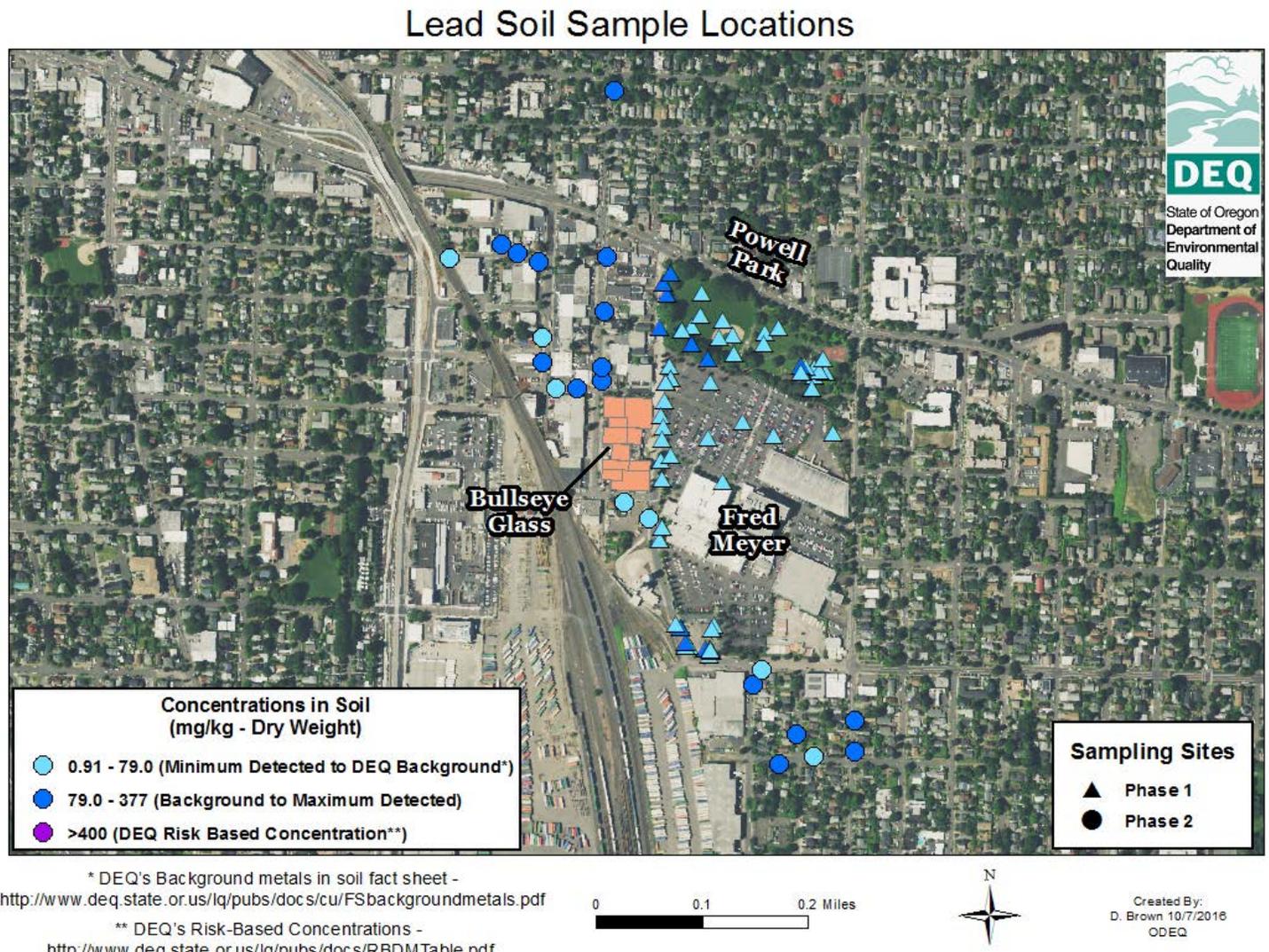


Figure 10. Lead Concentrations in Soil, Phase 1 and 2



# **Appendix C Memorandum Bullseye Phase 1 and Phase 2**

**State of Oregon  
Department of Environmental Quality**

**Memorandum**

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**Date:** October 03, 2016  
**To:** Ray Hoy – ODEQ NWR Cleanup Section  
**From:** Paul Seidel – ODEQ NWR Cleanup Section

**Subject:** Bullseye Phase I and Phase II ECSI # 6073; DEQ Review of Analytical Data

The purpose of this memorandum is to present findings from exploratory statistical analysis of soil data collected under the Bullseye Glass Area-Wide Soil Sampling and Analysis Plan for both Phase 1 and Phase 2 projects located in Southeast Portland. The aggregate data set at the time of this memorandum is 92 soil samples, DEQ pooled these data to create a common data matrix that could subsequently be used in exploratory multivariate analyses, and in a few regressions to inform inferences about possible source of trace metals to soil.

A dominant source of trace metals in soil in the Portland area are catastrophic flood events that occurred 12-15,000 years ago. Collectively, these events are referred to as the Missoula floods, having drained from ancient Lake Missoula. These floods were the defining recent geological event for the Portland basin and the soils deposited by these events form the baseline against which perturbations in trace metal composition may be compared.

The objectives of the exploratory multivariate analyses performed by DEQ were to:

- 1) Compare similarities and differences between soil samples; and,
- 2) Inform any inferences about potential sources of enrichment in metals in the soil samples based on relative similarity in sample groupings, and concentration gradients with distance from the Bullseye glass facility.

**Data Pre-Processing**

In order to prepare a data set for multivariate analyses several pre-processing steps are required. There is no single “standard” or accepted method for doing this pre-processing. The pre-processing steps for this data set were:

- 1) Select analytes to include in evaluation: Not all analytes were reported in both the phase I and phase II sampling events. A consistent common set of analytes must be used. uranium, zinc and beryllium were removed from the data set due to incomplete analysis in the samples. Total chromium was used, not trivalent. Sample FM-SS-18-01 was removed from the data set since it had no reported mercury result and nickel was non-detected. One sample is not expected to have a significant influence on the overall data set.

- 2) Process non-detected values: For multivariate analyses, no missing values can be allowed. Some numeric value must be used for each sample and analyte. Therefore, a choice must be made to either remove infrequently detected analytes entirely, which may risk losing some information, or imputing, or estimating, values to replace the non-detects. Hexavalent chromium was removed for this reason. Most remaining analytes were all detected above the method detection limit (MDL) with a few exceptions for cadmium, mercury and selenium. DEQ used a regression model based approach (lognormal robust ROS) as implemented in US EPA's ProUCL software to impute values for non-detects. The results of this procedure on visual inspection appeared reasonable.
- 3) Transformations: This step is likely the most significant pre-processing step in terms of influence on the analyses and interpretation. Data transformations are required in order to provide interpretable results. In this instance, DEQ mean-centered and scaled (i.e., standardized) the analytical data. This is necessary to prevent high influence of some analytes based on absolute abundance (e.g., iron or aluminum) and log transformed to control influence of outliers. Using these two transformations gave reasonable and interpretable results.
- 4) Distance to the Bullseye facility was calculated by taking the sampling position which was measured using a hand-held global positioning system and measuring the distance to the middle of the Bullseye Facility located at 3722 SE 21st Avenue, Portland, Oregon.

### **Exploratory analyses**

Using the transformed data matrices, exploratory evaluations using hierarchical cluster analysis (HCA) and principle component analyses (PCA) were performed using Pirouette® version 4.0. Graphical illustrations are presented in Figures 1 and 2 below.

Figure 1 is an HCA dendrogram. In an HCA analysis, samples are grouped according to the chemical similarity, with samples further apart in the dendrogram being more dissimilar and samples closer together being relatively more similar. The right panel shows a smaller grouping in green and other samples grouped in blue. The green grouped samples are expanded in the left panel with sample labels shown in brown. A common characteristic of the samples highlighted in the left panel is that they are relatively near to the Bullseye facility (see Appendix B, Bullseye Phase 2 Soil Report). The reason that the HCA evaluation clusters samples into a common grouping is that they are similar with respect to trace metal concentrations, and relatively dissimilar from other samples in the data set.

This result suggests that the samples that are closer to the Bullseye facility are uniquely similar with respect to the trace metals content. In particular, as described further herein, the metals determining the uniqueness of these samples are primarily cadmium, cobalt and manganese, and selenium to a lesser degree. This can be evaluated graphically by plotting what is known as a loadings plot, which is a geometric representation of the relative contribution of each unique analyte to the cluster assignment in an analysis similar to the HCA, termed a principle components analysis (PCA).

PCA was run on the aggregate data set, shown in Figure 2 is a three dimensional PCA loading and score plot (side by side) showing the relative similarity of samples in Euclidian (geometric) distance.

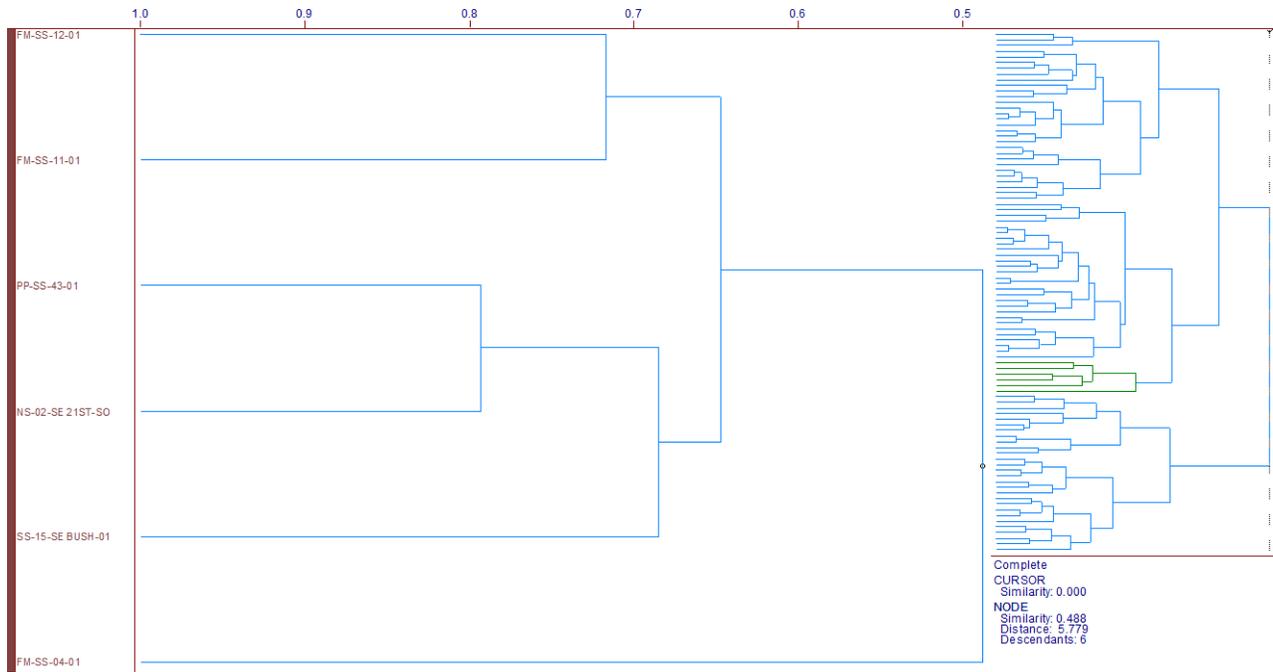


Figure 1: HCA showing a multivariate classification of soil samples into similar groups. Samples shown in right panel (in green) are expanded in brown on left panel.

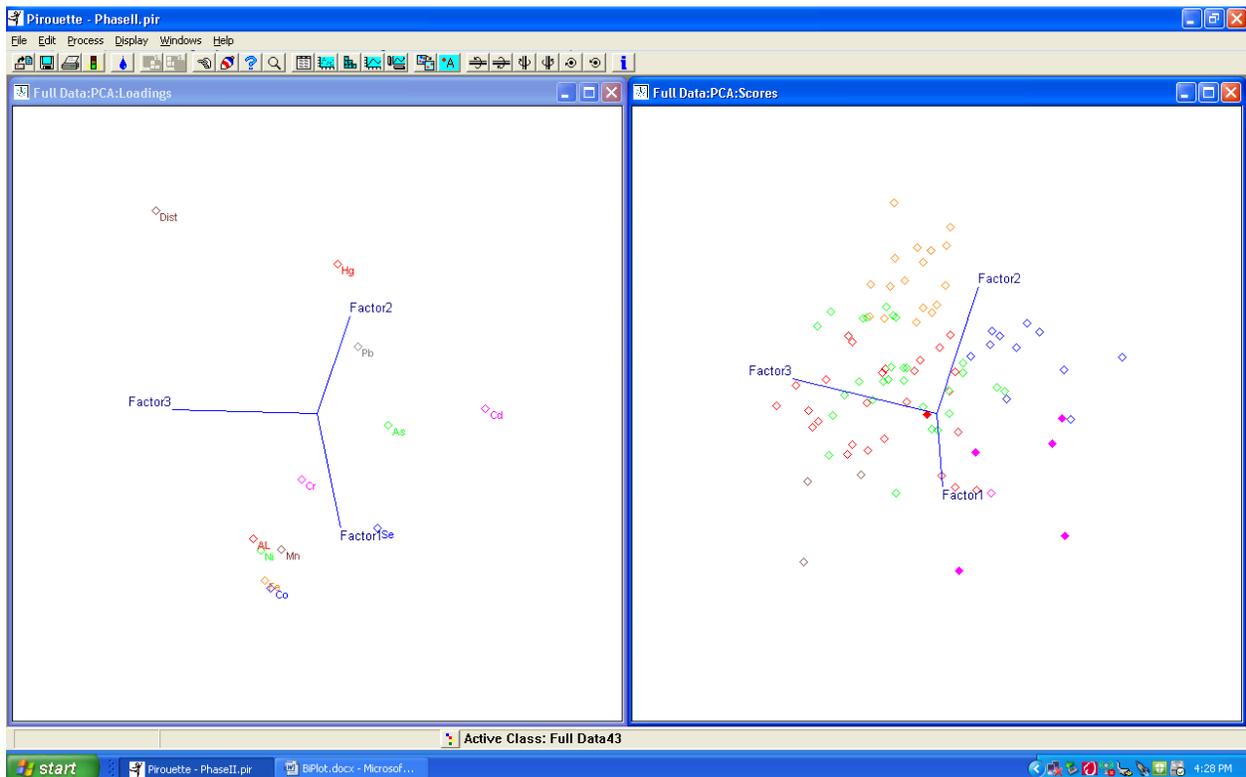


Figure 2: Three-dimensional PCA showing the relative similarity samples in multivariate space (explains 80% variance between samples)

The right panel of Figure 2 is a PCA score plot, which is analogous to the cluster dendrogram, except the samples are plotted in 3-D space. In this plot, the axes are the first three principle components (PCs) and the points are the samples plotted in the “PC space”. In this case, three dimensions are necessary, since it is not easy to visualize the influence of cadmium without including the third PC. The left panel is a loadings plot, which shows geometrically what this influence of individual metals is on the samples in the score plot. To illustrate, distance from the center of the Bullseye facility was included as a variable in the analysis, and coded with the text “Dist”. The text label “Dist” is shown in brown in the upper left of the loadings plot. Samples in the score plot on the right panel that plot close to the upper left portion, have larger distances (i.e., are further away from the center of the Bullseye facility). Samples that are further away from the word “Dist” are closer to the Bullseye facility (i.e., have smaller distance numbers). The inverse relation holds with the symbols for the metals. Samples with higher metals concentrations will plot closer to the region of score plot where the metal is plotted on the corresponding loadings plot.

In Figure 2, the samples in the right panel of Figure 1 (relatively closer to the Bullseye Glass facility) are the points in solid pink. The loadings and score plots are rotated in the same orientation for direct comparability. As shown, the metals that primarily influence the pink samples (close to Bullseye facility) and distinguish them from other soil samples is the influence of cadmium, selenium (shifting them to the right) and cobalt, manganese, iron and nickel which shift the samples further toward to bottom of the plot.

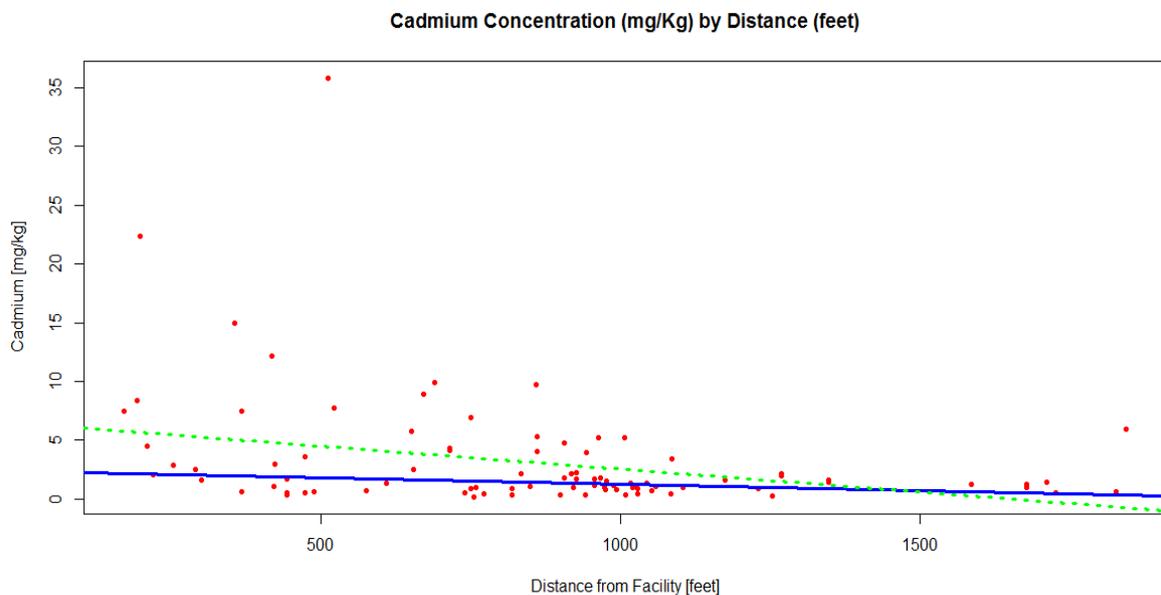
Each of the metals influencing the composition of these samples has been used as a glass colorant in Bullseye Glass operations. Thus these samples are: 1) spatially closer to Bullseye, and; 2) distinctly different from other samples as a consequence of influence by metals used by the facility in glass colorant operations. These factors suggest that Bullseye facility operations have likely impacted nearby soil.

As a cross check, DEQ checked the samples that are grouped with red, green and yellow colors on the score plot (Figure 2). These samples tend to score higher on PC 3 and PC 2 and are further away from the Bullseye facility, and in the case of the samples in yellow- higher in mercury and lead. These were generally the Powell park samples, which show lower concentrations and neighborhood samples collected in parking strips associated with roadways.

## Regressions

In order to further inform the question of relationship between distance from the Bullseye facility and trace metal concentrations, a set of regression plots were prepared for a set of metals appear to have the greatest influence on soil concentration in the exploratory analyses. These were cadmium, selenium, manganese and cobalt. Lead and mercury appear in the exploratory analyses to not have an influence on samples nearest to Bullseye. Cadmium, selenium, cobalt, and manganese are shown in Figures 3, 4, 5 and 6 respectively.

*Figure 3: Cadmium concentration by distance from Bullseye facility.*



The green dashed line in figure 3 is the least squares regression line. The relation is statistically significant with a probability of being due to chance alone being three in 1,000 ( $P = 0.0028$ ). However, because the data are not statistically normal<sup>1</sup>, and likely do not meet the assumptions necessary for a “parametric” test, a nonparametric regression alternative, the “Sen Thiel” line was also plotted as shown in blue. The slope of this line is shallower, but is significant at  $p = 0.01$ .

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<sup>1</sup> Meaning these samples cannot be shown to follow a normal statistical distribution and meet requirements of “parametric” statistical tests.

Figure 4: Selenium concentration by distance from Bullseye facility.

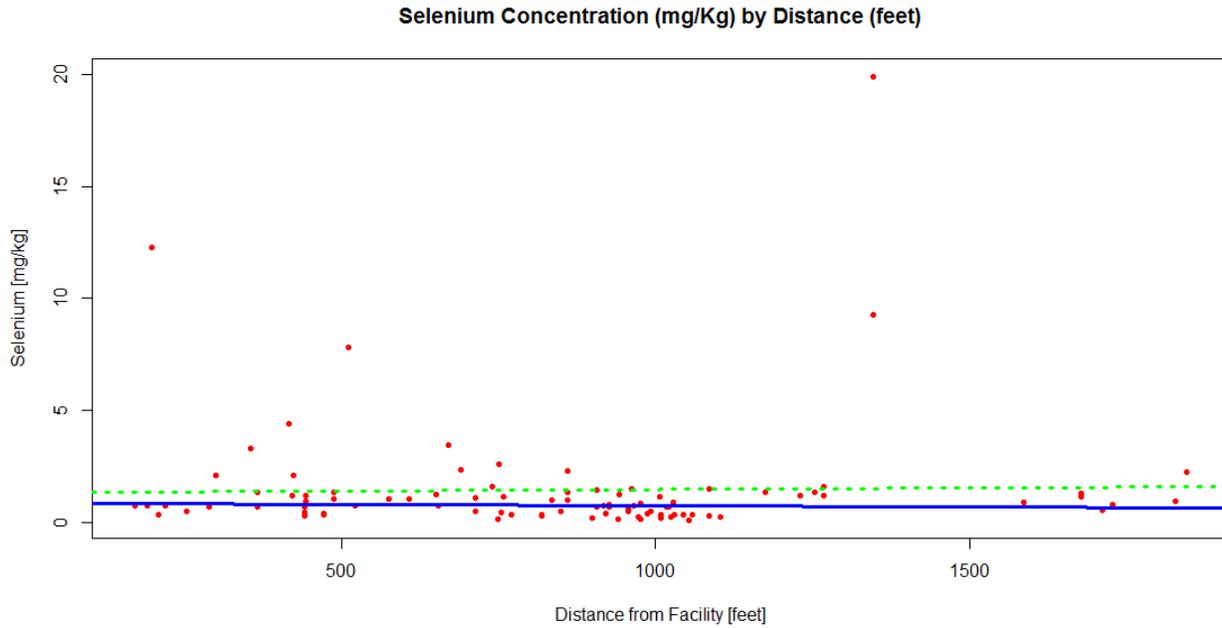
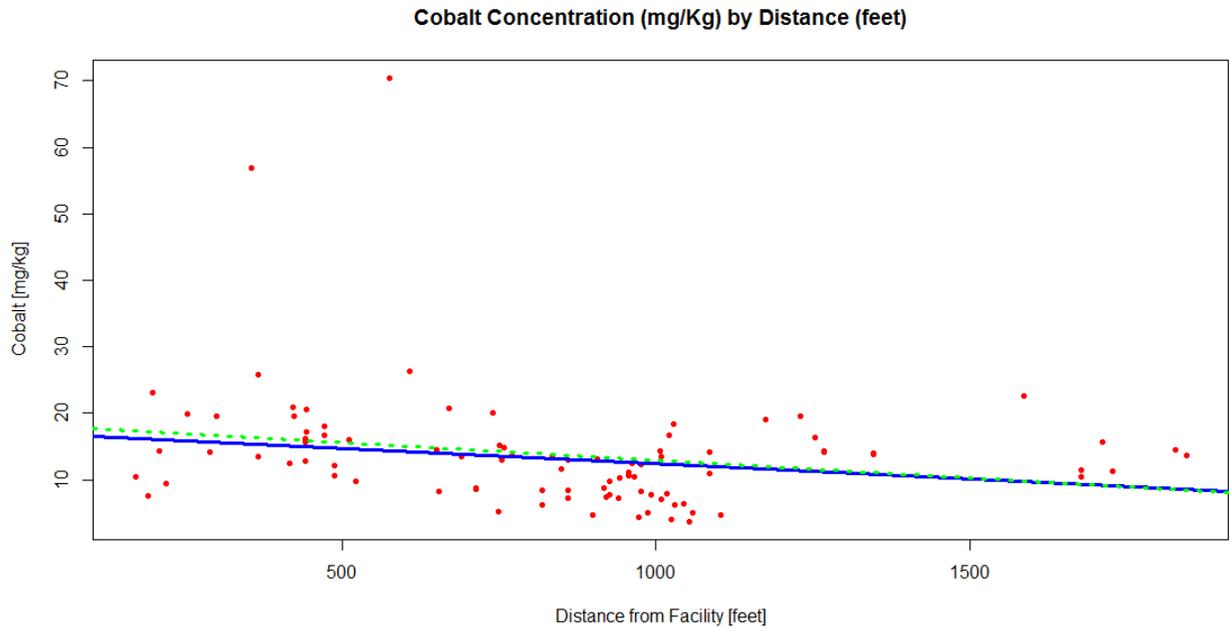


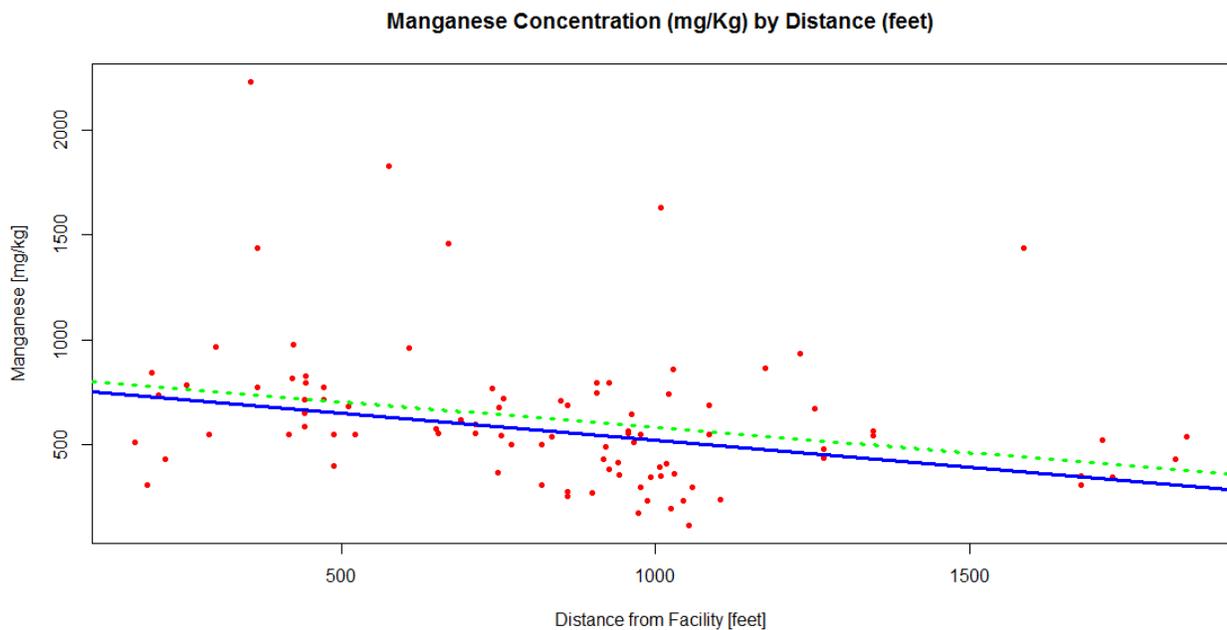
Figure 4 shows that the relation between distance and selenium alone is not significant. Although samples closer (< 1,000 feet) appear to have a greater proportion of elevated samples, an outlier sample location at NS-02-SE 21ST-SOUTH-01 (and its duplicate) are elevated for selenium masking any possible relation with distance. However, even if this sample location is eliminated, the overall relation with distance for selenium is weak.

Figure 5: Cobalt concentration by distance from Bullseye facility.



Cobalt concentrations by distance is presented in Figure 5. Figure 5 shows a slight but significant ( $P = 0.005$ ) trend with distance from the facility.

Figure 6: Manganese concentration by distance from Bullseye facility.



As shown in Figure 6, the relation between manganese with distance is significant. The p-value for the nonparametric regression is 0.000089, indicating a chance of 9 in 100,000 that this

would be due to chance alone. Notably, a batch ticket for manganese available to DEQ, indicates that 92% manganese was used. A higher output of manganese is a possible explanation for the apparently stronger relationship shown for this metal.

Other metals which are common urban contaminants with multiple sources include mercury, lead and arsenic. These are plotted on Figures 7 through 9 respectively. As shown, none of these metals shows a relation with distance from the Bullsseye facility.

Figure 7: Mercury concentration by distance from Bullseye facility.

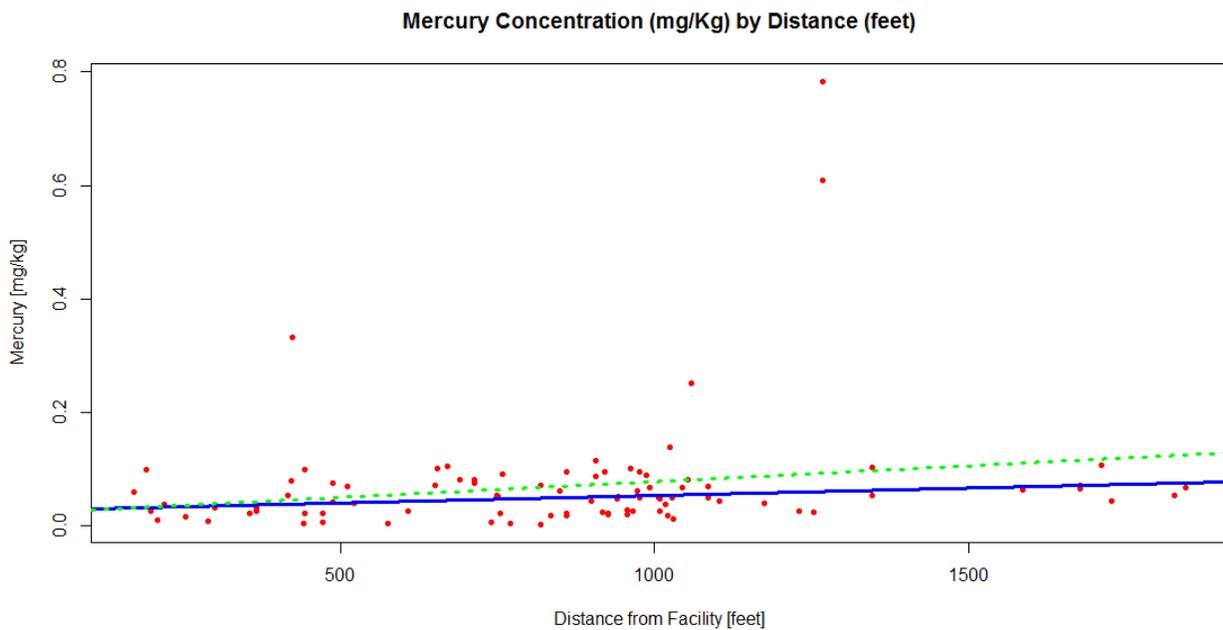


Figure 8: Lead concentration by distance from Bullseye facility.

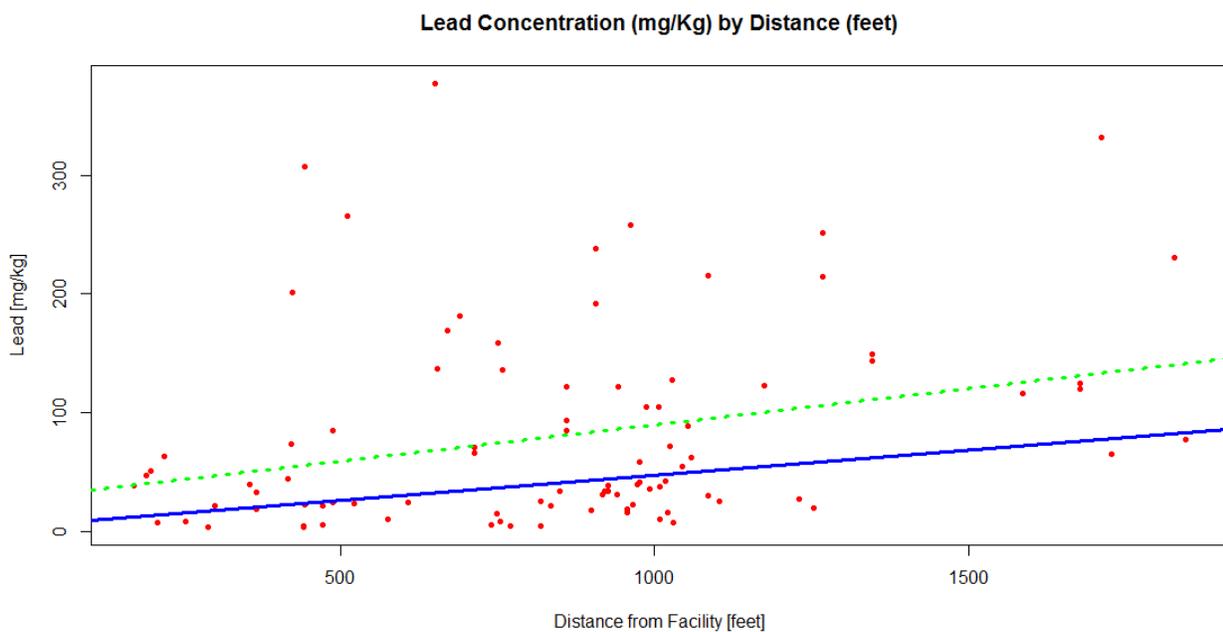
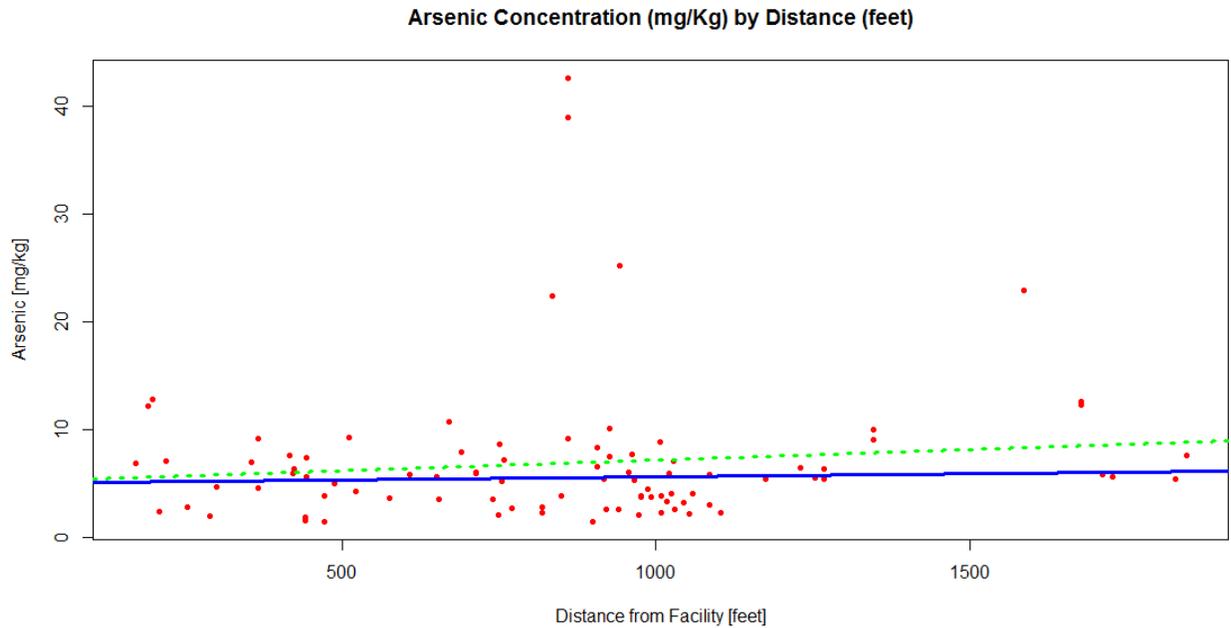


Figure 9: Arsenic concentration by distance from Bullseye facility.



### **Overall Interpretation**

Overall, the data present a pattern for manganese, cadmium, cobalt, and possibly selenium, suggesting that the concentrations of these metals in soil are related to distance from the Bullseye facility, with relatively closer samples having higher concentrations. In each of the plots, the metals concentration appears to decline to a baseline level by approximately 1,000 feet from the facility. To the extent that these metals are also used as glass colorants, the evidence supports an air deposition source has enriched the soil nearby to the Bullseye Glass facility with these metals. The significance of these findings to public health will be addressed elsewhere.