

Groundwater Evaluation for Ash Ponds at a Coal Fired Power Plant in Texas

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ABSTRACT

This paper discusses a response strategy employed to address regulatory agency concerns regarding possible leakage from ash ponds. Wells at the facility have been sampled semiannually for a number of years for a comprehensive list of metals and other general water quality parameters. The ash ponds were designed and built with a compacted native soil liner. Groundwater flow direction is generally established to be to the east in the northern portion of the pond area and to the south-southeast in the southern portion of the pond area. The review of site data has identified several wells, both up-, mid-, and downgradient of the ponds, that have concentrations of arsenic, cobalt, lead, and vanadium above the commercial/industrial groundwater standards. In addition, well data indicate that the source of the metals may be from a nearby upgradient naturally-occurring uranium ore deposit. These deposits can contribute metals to groundwater in an oxidizing and slightly basic pH environment. A review of potential data gaps was conducted to identify areas where additional information could help support a comprehensive background evaluation of groundwater conditions and whether this would provide benefit to the facility. In addition some statistical analysis of the available data was conducted to determine constituent trends and evaluate these in comparison to naturally occurring concentrations available in literature.

INTRODUCTION

This paper discusses the hydrogeologic setting of a Texas Power Plant, and includes groundwater flow direction, flow gradient, potentiometric surface, geochemical properties of the groundwater, and the potential influence of upgradient uranium ore bodies on trace-element groundwater concentrations in the vicinity of the Power Plant. This memorandum also identifies areas where additional groundwater data is needed to confirm the trends exhibited by the existing data.

GENERAL HYDROGEOLOGY

The Power Plant is located within the Gulf Coastal Plains Physiographic Province. It overlies the Gulf Coast Aquifer System (GCAS) which consists of the Jasper, Evangeline and Chicot aquifers. Sediments composing the GCAS have been deposited by river systems flowing from upland areas toward the Gulf of Mexico, resulting in prevailing stratigraphic dip nearly perpendicular to the coastline and general thickening of the beds from inland toward the coast¹⁰. The GCAS has regional groundwater flow direction towards the coast and the geologic units of the GCAS are, from oldest to youngest^{1, 4};

1. Catahoula Formation;
2. Oakville Sandstone/Fleming Formation;
3. Goliad Formation;
4. Pleistocene formations, the Willis, Lissie, and Beaumont; and
5. Quaternary terrace deposits and alluvium.

The Jasper aquifer is generally composed of the Miocene-age Oakville Sandstone and is composed of varying amounts of interbedded sand and clay and has been described as a sand-rich fluvial system overlying the confining Catahoula Formation⁵. Overlying the Jasper aquifer is the Burkeville confining system composed of the Miocene-age Fleming Formation and Lagarto Clay³.

The Evangeline aquifer overlies the Burkeville confining system and corresponds closely with the extent of the Pliocene-age Goliad Formation and is composed of water-bearing zones primarily within the Goliad Sand¹⁰. The upper part of the Goliad includes finer-grained sands that are cemented by calcium carbonate caliche⁹.

The Chicot aquifer overlies the Evangeline aquifer and is composed of the Pleistocene-age Lissie and Willis Formations³. The Chicot aquifer is conceptually distinguished from the Evangeline aquifer by its distinctly greater hydraulic conductivity, and greater percent sand¹⁰. The Power Plant is located on the Lissie Formation (mapped as QL) on the Geologic Atlas of Texas Beeville-Bay City Sheet². The Lissie Formation consists of clay, silt, sand, and minor amounts of gravel. Three units have been mapped within the Lissie Formation consisting of (1) undifferentiated alluvium including meander belt, levee, crevasse splay, and distributary sand, and flood-basin mud deposits with a thickness of approximately 200 feet; (2) fine-grained channel (alluvial sand, silt, and clay) deposits approximately 30 to 80 feet thick and thickening toward the coast; and (3) fine-grained overbank (alluvial silt and clay) deposits approximately 180 to 210 feet thick and thickening toward the coast¹¹. The Lissie Formation has a total thickness of approximately 420 to 490 feet.

Recharge to the GCAS is by infiltrating precipitation and losing streams that are in direct contact with geologic unit outcrops of respective aquifers¹⁰. The Jasper, Evangeline, and Chicot aquifers become confined downdip of the outcrop/recharge zone, and insignificant, if any, recharge is received from overlying units. However, some hydraulic

communication between the Jasper, Evangeline, and Chicot aquifers is possible through fractures or where confining units are locally absent¹⁰.

SITE SPECIFIC HYDROGEOLOGY

The Power Plant has four water management areas: the evaporation pond, the primary and secondary ash ponds, and the coal pile retention pond. The plant is located directly above the unconfined portion of the Chicot aquifer based on review of the lithology included in the boring logs for wells W-1 to W-8, and the Lissie Formation outcrop at the site². Wells W-1 to W-8 have well screen tops ranging from 74.9 to 94.8 feet mean sea level (msl) and well depths ranging from 50.1 to 74.9 feet msl. Assuming each well was screened to the well bottom, typical for well construction, then each well has a 20 foot screen interval with the exception of well W-7 which appears to have a 25 foot interval. The zone screened by wells W-1 to W-8 is primarily composed of saturated silty sand with interbedded clay, little gravel, with a white to yellow gray color. A cemented caliche layer was encountered at approximately 60 to 75 feet msl. This lithology is typical of the Lissie Formation (Chicot aquifer); however, the presence of the cemented caliche may indicate the presence of the Goliad Sand of the Evangeline aquifer. The contact between the Chicot and Evangeline aquifers or Lissie and Goliad Sand Formations at 60 to 75 feet msl indicates a local thickness of the Lissie Formation of 50 to 65 feet. A Lissie Formation thickness of 50 to 65 feet is within the estimated range of Lissie Formation thickness of 33 to 65 feet based on the site being located about 1.3 miles downdip of the Lissie and Goliad Formation Contact and assumes a northeast to southwest strike and a dip of 10 to 20 feet per mile^{2, 10}. Table 1 shows the top-of-screen elevation and well bottom elevation for wells W-1 to W-8. Based on this evaluation, it appears that wells with a screen bottom elevation of approximately 65 feet msl or less (i.e., wells W-1, W-2, W-4, W-5, W-6, and W-7) may be screened into the top of the Evangeline aquifer.

The groundwater flow direction of the Chicot/Evangeline aquifer at the Plant, and specifically in the vicinity of the Primary Ash Pond, is to the southeast with a hydraulic gradient of 0.0022 feet/foot based on the observed groundwater elevations from May 2010. In general, the groundwater flow direction is towards Perdido Creek, Sulphur Creek, and their confluence at the nearby reservoir. Potentiometric surfaces of the Chicot/Evangeline aquifer were drawn using the groundwater elevation data from November 2009 and May 2010 and area summarized on Figure 1. Water level elevation data from November 2006, July 2007, November 2009, and May 2010 is presented in Table 1. Review of the water levels in wells W-1 to W-8 indicates typical groundwater level fluctuations of less than 5 feet within the last four years (see Table 1). However, a relatively large increase in groundwater elevation of 5 to 10 feet was consistently observed in each well from October 1979 to May 1981 during the time that the reservoir was filling. This indicates that the Chicot/Evangeline aquifer located below the Plant is likely connected to the reservoir.

Though the filling of the reservoir has influenced the groundwater elevation of Chicot/Evangeline aquifer, it does not appear to have changed the general groundwater

flow direction to the south east, based on review of potentiometric surface maps of the Plant from November 1978.

GROUNDWATER GEOCHEMISTRY

A review of the groundwater analytical data for wells W-1 to W-8, P-2, and P-3 from May and October 2010 and piezometers BV-1 and BV-5 from January 2011 was performed (Figure 1 and Table 2). The facility's Texas Pollutant Discharge Elimination System (TPDES) permit has required the sampling and analysis of a range of metals and other water quality parameters; however, it does not specify any limits to which the results obtained should be compared. To that end, the available data was compared with the residential (Res) and commercial industrial (C/I) groundwater protective concentration levels (PCL) as published by the Texas Risk Reduction Program (TRRP) in Title 30 Texas Administrative Code (TAC) Chapter 350. The groundwater analytical results indicate that arsenic, cobalt, lead, and vanadium exceed the published Res and C/I groundwater PCLs for ingestion ($^{GW}GW_{Ing}$).

After review of the groundwater flow direction and gradient, the wells were classified as upgradient, "mid-" (i.e., between the two main pond areas), and downgradient. The overall distribution of constituents (arsenic, cobalt, lead, and vanadium) that exceed the C/I PCL does not fit the typical pattern of a non-impacted upgradient condition and elevated concentrations in the source area with concentrations propagated downgradient of the source area (Figure 1). A comparison of upgradient, midgradient, downgradient, and all wells for these constituents is presented with box and whisker plots (Figure 2).

The furthest upgradient groundwater sample location is from piezometer BV-1, collected in January 2011, which had cobalt, lead, and vanadium detected at concentrations above the C/I PCL. The cobalt and lead concentrations at this upgradient location are the highest detected at the site during the 2010-2011 period. This location also had one of the highest vanadium concentrations. The highest arsenic concentration observed is in well W-3 (0.019 mg/L arsenic) and possibly indicates a potential source area in the vicinity of the Coal Pile Retention Pond. However, the concentration is not significantly greater than the PCL and is similar to arsenic concentrations found at other widely-dispersed wells across the site. At this time, no other areas clearly demonstrate the characteristics of a potential source area based on the groundwater flow direction and distribution of constituents both above and below the C/I PCL (Figure 1). Uncertainty associated with the nature and extent of arsenic, cobalt, lead, and vanadium in groundwater may be further complicated by groundwater mixing with losing water from Perdido Creek, Sulphur Creek, and the discharge flume, as well as mobilization of arsenic and vanadium when exposed to oxidizing and slightly basic pH conditions.

Arsenic

Arsenic was detected at concentrations above the C/I PCL at midgradient location W-3 but not upgradient locations W-8, BV-5, and BV-1. Wells downgradient of W-3 include W-1, W-2, and W-5 and each has arsenic detections that exceed the C/I PCL.

Additionally, arsenic was detected in piezometer P-3 above the C/I PCL. Midgradient (wells W-2, W-3, and W-4) and downgradient wells (W-5, W-6, P-2, and P-3) have mean and median arsenic concentrations slightly greater than upgradient wells (W-7, W-8, BV-1, and BV-2 [Table 3]). Essentially no change in median and mean arsenic concentrations is observed from midgradient to downgradient wells (Figure 3 and 4). The middle 50% of the site arsenic data (1st Qtr. to 3rd Qtr.) is relatively elevated compared to Evangeline aquifer arsenic data (Table 3 and Figure 2). However, the maximum site arsenic concentration is less than the maximum arsenic concentrations reported in the Evangeline aquifer located in Karnes and Goliad Counties^{7, 10}.

Cobalt

Cobalt was detected at concentrations above the C/I PCL at wells W-1 to W-4, W-8, and piezometers BV-1 and BV-5. The highest cobalt detection (0.5 mg/L) was from upgradient piezometer BV-1. Only downgradient locations P-2, P-3, W-5, W-6 and upgradient location W-7 did not exceed the residential or C/I PCL for cobalt (Figure 1). Mean and median cobalt concentrations increase from upgradient to midgradient wells or is relatively unchanged (Figures 3 and 4). Mean and median downgradient cobalt concentrations are significantly less than midgradient and upgradient concentrations.

Lead

Well W-4 and piezometer BV-1 were the only locations where lead exceeded the PCL. At W-4, lead was detected above the PCL in May 2010 but was not detected in October 2010. Mean and median lead concentrations increase from up to midgradient wells. However, mean and median downgradient lead concentrations are much less than mid- and upgradient concentrations (Figures 3 and 4).

Vanadium

All the upgradient, mid- and downgradient wells had detected concentrations of vanadium above the C/I PCL with the exception of P-3 and W-7 (although it should be noted that the P-3 May 2010 result was just below the C/I PCL and the October 2010 non-detected result had a detection limit above the C/I PCL). Mid- and downgradient wells have slightly greater vanadium concentrations than upgradient wells. The middle 50% of the site vanadium data (1st Qtr. to 3rd Qtr. [Table 3]) is less than or equal to the middle 50% of the Evangeline aquifer vanadium data. Additionally, the maximum site vanadium concentration is less than the maximum vanadium concentrations in the Evangeline aquifer located in Karnes and Goliad Counties^{7, 10}.

Molybdenum and Selenium

Mean and median molybdenum concentrations increase from up to midgradient wells. However, mean and median downgradient molybdenum concentrations are less than midgradient concentrations and essentially equal to upgradient molybdenum concentrations. Selenium concentrations are unchanged from up- to mid- to downgradient well locations. Neither molybdenum or selenium were detected above the PCL.

Discussion

Median groundwater concentrations of cobalt, lead, molybdenum, and vanadium all decrease between mid- and downgradient well locations and only arsenic slightly increases from 0.11 to 0.12 mg/L from mid- and downgradient well locations (Figure 3). Similarly, mean cobalt, lead, and molybdenum concentrations all decrease, and arsenic remains equal from mid- to downgradient well locations. Only mean vanadium concentrations slightly increase from 0.022 to 0.024 mg/L from mid- to downgradient well locations (Figure 4). In general, mean and median arsenic, cobalt, lead, vanadium, and molybdenum groundwater concentrations increase from upgradient to midgradient well locations, and decrease from midgradient to downgradient well locations. This relatively consistent trend indicates that some geochemical reactions and/or chemical dissolution is occurring along the groundwater flow path.

Influence of Uranium Ore Bodies

Uranium ore bodies are present within the Gulf Coastal Plains, and specifically within the Goliad Formation⁸. Currently, the Uranium Energy Corporation (UEC) is preparing to operate an in situ recovery uranium mine within the Goliad Formation. Uranium in sedimentary deposits within the GCAS, including the Goliad Formation, is typically accompanied by oxyanions selenium, molybdenum, arsenic, and vanadium. The association of these oxyanions and uranium is well documented in the GCAS^{7, 12}. Potentially the occurrence of the elevated arsenic and vanadium at the site could, in part, be attributed to the solubilizing of arsenic and vanadium when exposed to oxidizing and slightly basic pH conditions. If conditions do exist to mobilize arsenic and vanadium, then it is expected that relatively elevated concentrations of the other associated oxyanions (selenium, molybdenum) would also be present. However, this is not the case (Figure 1 and Table 2). Uranium, and presumably its companion oxyanions, are being mobilized and transported today in portions of the GCAS with oxidizing and slightly basic conditions¹⁰.

CONCLUSIONS

Underlying geological contributions and hydraulic interactions for the site are complex and difficult to assess. This is partly due to the abundant mineral deposits available in the water sands as well as periods of extreme drought occurring during the past thirty-six months. While the specific impacts of the drought are unknown presently, the data clearly reflect two groupings; one for the coal storage pile and coal pile runoff impoundment and the other comprised of the ash impoundments and evaporation pond. Up gradient samples were collected to better understand several elevated readings for metals parameters in prior years. Arsenic, cobalt, vanadium, and lead recorded 2010 values above their published PCLs. The up-gradient wells record very similar values to the mid-gradient and down-gradient wells for the ash impoundments for 2011 and 2012. Additional samples are needed to statistically validate this observation and to more accurately quantify up-gradient contributions to both groupings noted above; however no clear indication of contribution from site activities is presented by the data collected to date, resulting in the conclusion that groundwater

concentrations are not being significantly influenced by the water and ash management ponds.

The following additional information could be collected to fill apparent data gaps and further clarify the groundwater conditions at the site:

1. A comprehensive groundwater and surface water level survey to provide a synoptic review of site conditions as they relate to the possible interconnected nature of the ponds and surrounding water bodies.
2. Additional groundwater and surface water chemical data including pH and redox potential collected during the same sampling event to attempt to relate constituent concentrations and occurrences, and further address the characteristics of the groundwater environment.
3. Identification of the gaining or losing nature of the nearby streams and flumes to determine any potential contributions to local groundwater.

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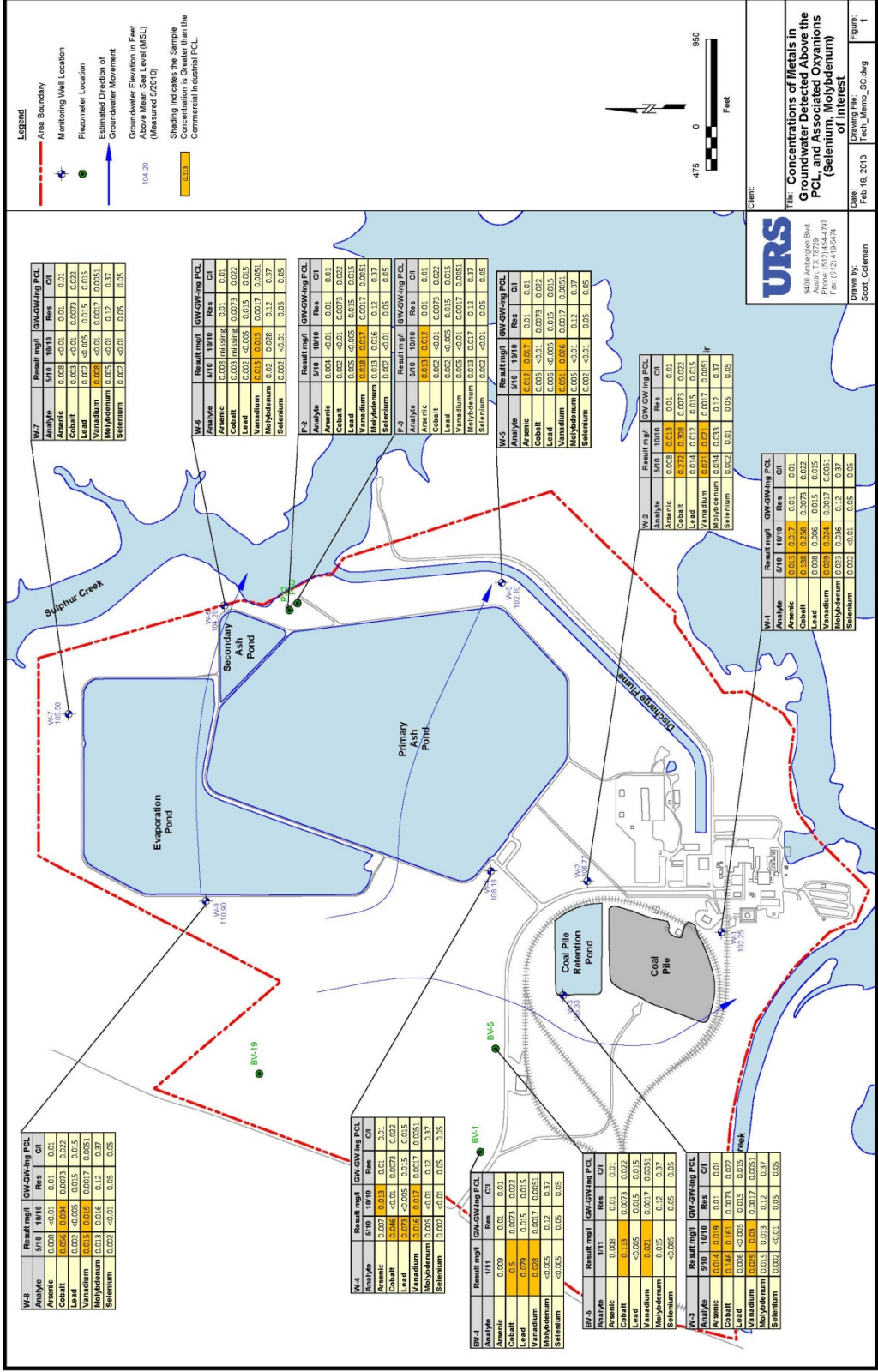
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Concentrations of Metals in Groundwater Detected Above the PCL and Associated Options (Selenium, Molybdenum) of Interest

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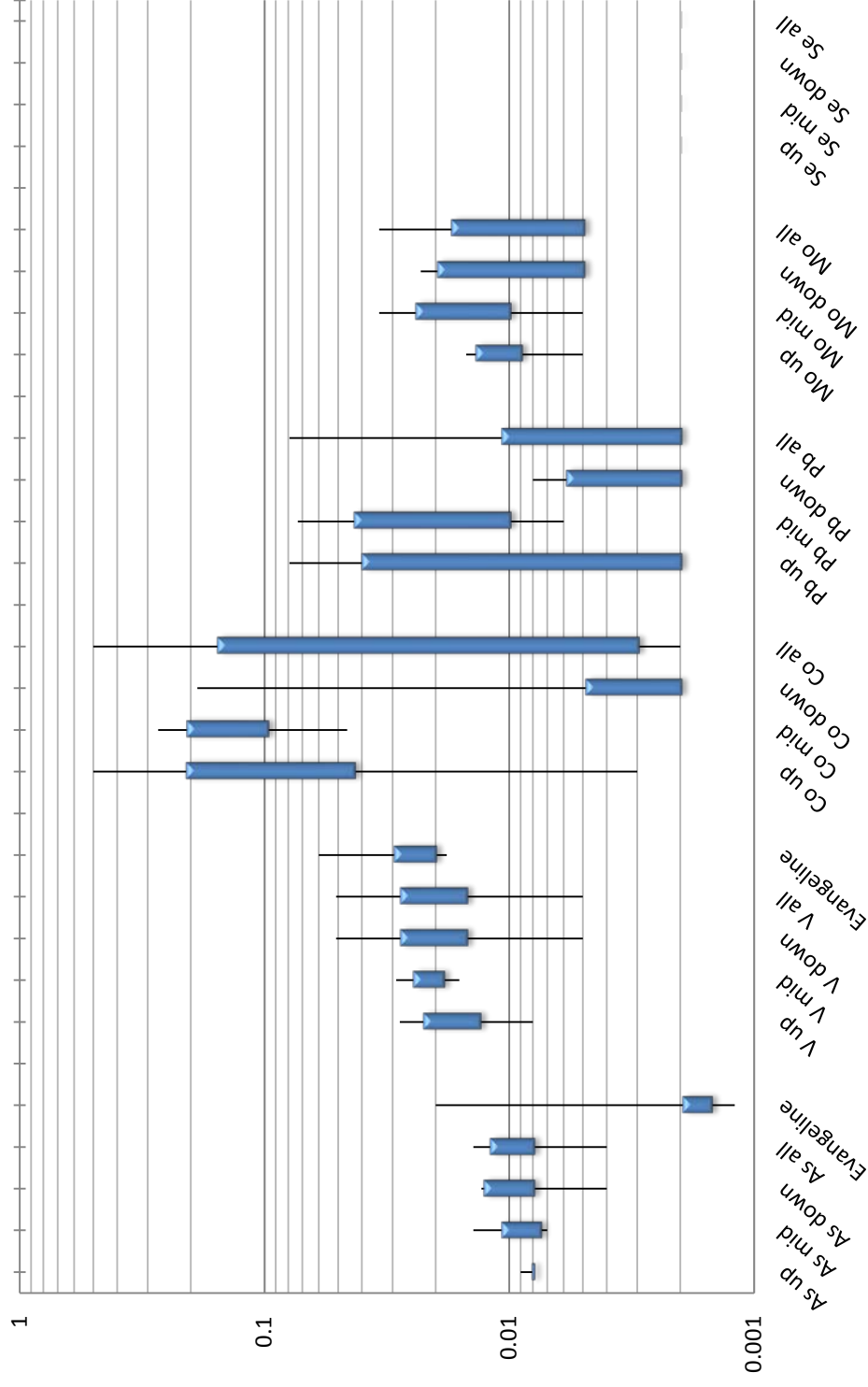
Drawn by: Scott Coleman

Date: Feb 18, 2013

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Figure: 1

Figure 2: Box and Whisker Plot of Trace Elements in Groundwater



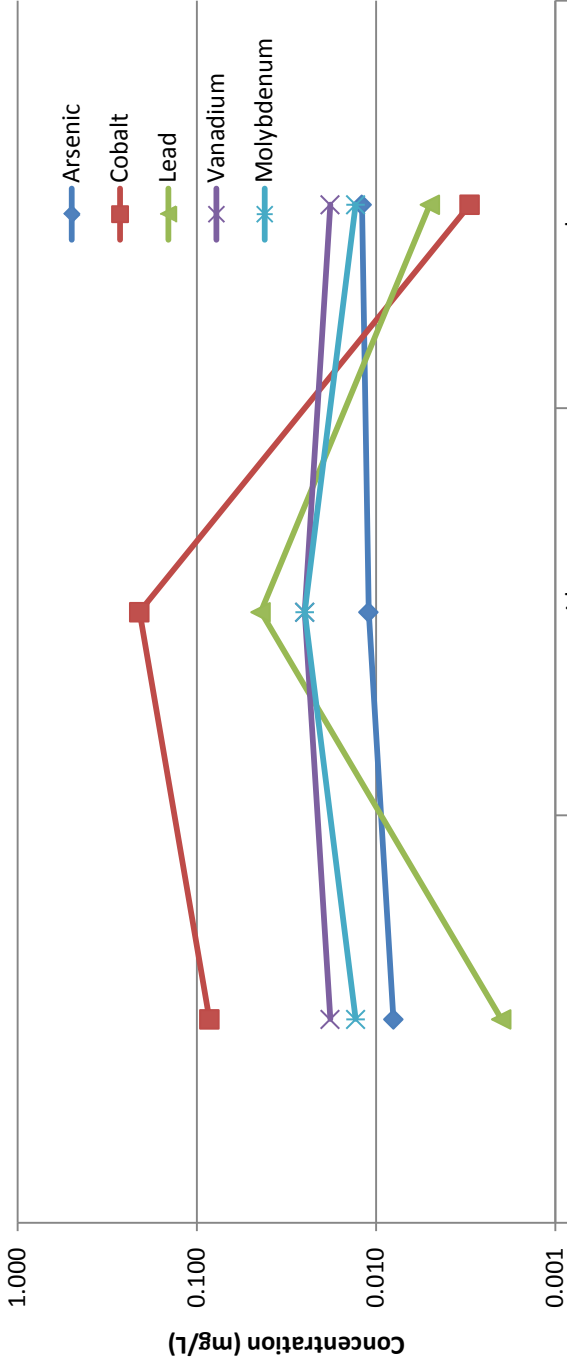
Note, up, mid, and down indicates the well hydraulic gradient relative to the ash and coal pile retention ponds.

Upgradient wells - MW-7, MW-8, BV-1, and BV-5. Midgradient wells - MW-2, MW-3, and MW-4.

Downgradient well - MW-1, MW-5, MW-6, P-2, and P-3. All wells - MW-1 to 8, BV-1, BV-2, P-2, and P-3.

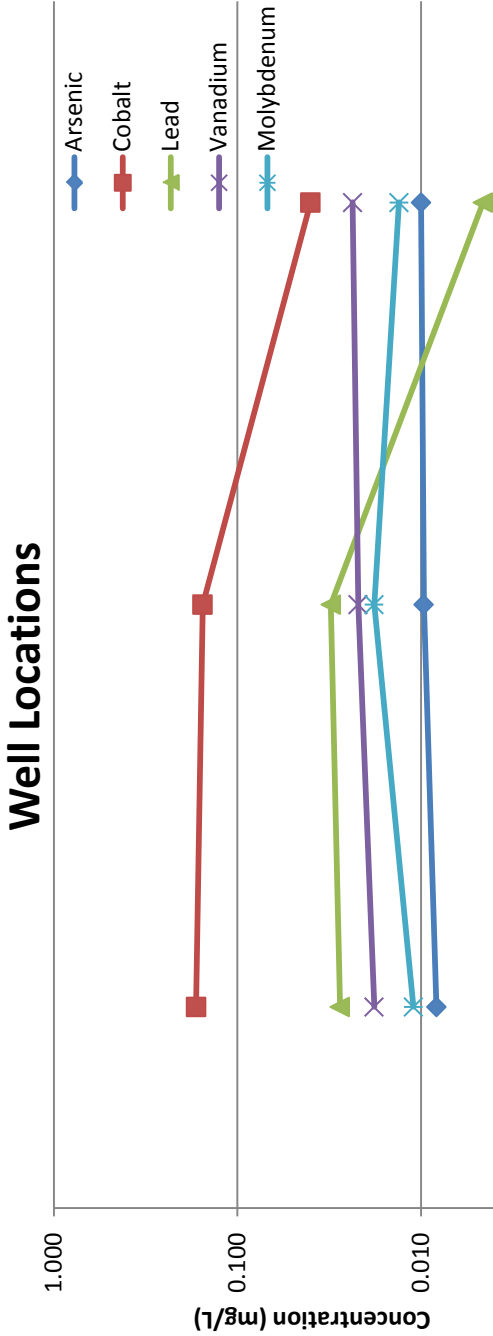
Evangeline - As and V data from Nicot et al., 2010 and Gates et al., 2009.

Figure 3: Median Trace Element Values for Up, Mid, and Downgradient Well Locations



	up	mid	down
Arsenic	0.008	0.011	0.012
Cobalt	0.085	0.209	0.003
Lead	0.002	0.044	0.005
Vanadium	0.018	0.025	0.018
Molybdenum	0.013	0.025	0.013

Figure 4: Mean Values for Up, Mid, and Downgradient Well Locations



	up	mid	down
Arsenic	0.008	0.010	0.010
Cobalt	0.168	0.155	0.040
Lead	0.028	0.031	0.005
Vanadium	0.018	0.022	0.024
Molybdenum	0.011	0.018	0.013

Table 1. Groundwater Elevation Summary

Well #	Well Bottom Elevation	Elevation, Top of Screen	Top of Casing Elevation	Depth to Water 5/2010	GW Elevation 5/2010	Depth to Water 11/2009	GW Elevation 11/2009	Depth to Water 7/2007	GW Elevation 7/2007	Depth to Water 11/2006	GW Elevation 11/2006
W-1	60.00	80.2-60.2	115.10	12.85	102.25	13.67	101.43	11.83	103.27	14.33	100.77
W-2	65.20	85.0-65.0	127.62	20.85	106.77	22.21	105.41	18.5	109.12	22.17	105.45
W-3	70.20	89.5-69.5	132.23	26.9	105.33	28.42	103.81	25.42	106.81	26.5	105.73
W-4	64.20	83.8-63.8	137.68	29.5	108.18	31.13	106.55	26.92	110.76	29.75	107.93
W-5	60.30	80.1-60.1	121.60	19.5	102.10	20.92	100.68	18.5	103.10	21.08	100.52
W-6	55.20	75.1-55.1	119.30	15.1	104.20	16.5	102.80	11.75	107.55	16.33	102.97
W-7	50.10	74.9-54.9	130.06	24.5	105.56	27.04	103.02	23.83	106.23	24.25	105.81
W-8	74.90	94.8-74.8	134.80	23.9	110.90	26.71	108.09	21	113.80	24	110.80

Note: All elevations in feet mean sea level (ft msl).

Table 2. Analytes Detected Above PCLs
(All Concentrations mg/L)

Analyte	GW _{ing} PCL		W-7 (cross-up)		W-8 (up)		BV-1 (up)		BV-5 (up)	
	Res	C/I	5/10	10/10	5/10	10/10	1/11	1/11	1/11	1/11
Arsenic	0.01	0.01	0.008	<0.01	0.008	<0.01	0.009	0.009	0.008	0.008
Cobalt	0.0073	0.022	0.003	<0.01	0.056	0.094	0.5	0.113	0.113	0.113
Lead	0.015	0.015	0.002	<0.005	0.002	<0.005	0.079	<0.005	<0.005	<0.005
Vanadium	0.0017	0.0051	0.008	<0.01	0.015	0.019	0.028	0.021	0.021	0.021
Molybdenum	0.12	0.37	0.005	<0.01	0.013	0.016	<0.005	0.015	0.015	0.015
Selenium	0.05	0.05	0.002	<0.01	0.002	<0.01	<0.005	<0.005	<0.005	<0.005

Analyte	GW _{ing} PCL		W-2 (mid)		W-4 (mid)		W-3 (mid)	
	Res	C/I	5/10	10/10	5/10	10/10	5/10	10/10
Arsenic	0.01	0.01	0.008	0.013	0.007	0.013	0.014	0.019
Cobalt	0.0073	0.022	0.272	0.308	0.046	<0.01	0.146	0.161
Lead	0.015	0.015	0.014	0.012	0.073	<0.005	0.006	<0.005
Vanadium	0.0017	0.0051	0.021	0.021	0.016	0.017	0.029	0.03
Molybdenum	0.12	0.37	0.034	0.033	0.005	<0.01	0.015	0.013
Selenium	0.05	0.05	0.002	0.01	0.002	<0.01	0.002	<0.01

Analyte	GW _{ing} PCL		W-1 (down)		W-5 (down)		W-6 (down)		P-2 (down)		P-3 (down)	
	Res	C/I	5/10	10/10	5/10	10/10	5/10	10/10	5/10	10/10	5/10	10/10
Arsenic	0.01	0.01	0.013	0.017	0.012	0.017	0.008	missing	0.004	<0.01	0.013	0.012
Cobalt	0.0073	0.022	0.188	0.258	0.005	<0.01	0.003	missing	0.002	<0.01	0.002	<0.01
Lead	0.015	0.015	0.008	0.006	0.006	<0.005	0.002	<0.005	0.005	<0.005	0.002	<0.005
Vanadium	0.0017	0.0051	0.029	0.024	0.051	0.026	0.015	0.013	0.018	0.017	0.005	<0.01
Molybdenum	0.12	0.37	0.023	0.036	0.005	<0.01	0.02	0.028	0.005	<0.01	0.013	0.017
Selenium	0.05	0.05	0.002	<0.01	0.002	<0.01	0.002	<0.01	0.002	<0.01	0.002	<0.01

Note: BOLD indicates exceedance over PCL.

Table 3. Groundwater Elevation Summary

	Minimum	1st Qtr.	Arithmetic Mean	2nd Qtr., Median	3rd Qtr.	Maximum	Note
Arsenic (As)							
Up	0.008	0.008	0.008	0.008	0.008	0.009	Mid- and downgradient wells have slightly greater As concentrations than upgradient wells. The middle 50% of the data (1st Qtr. to 3rd Qtr.) is relatively elevated compared to Evangeline aquifer As data, however, the maximum plant As concentration is < maximum Evangeline aquifer As concentrations.
Mid	0.007	0.008	0.010	0.011	0.011	0.014	
Down	0.004	0.008	0.010	0.012	0.013	0.013	
All	0.004	0.008	0.009	0.008	0.012	0.014	
Evangeline (1)	0.001	0.002	NA	NA	0.002	0.020	
Vanadium (V)							
Up	0.008	0.013	0.018	0.018	0.023	0.028	Mid- and downgradient wells have slightly greater V concentrations than upgradient wells. The middle 50% of the data (1st Qtr. to 3rd Qtr.) is ≤ to the middle 50% of the Evangeline aquifer V data.
Mid	0.016	0.019	0.022	0.025	0.025	0.029	
Down	0.005	0.015	0.024	0.018	0.028	0.051	
All	0.005	0.015	0.021	0.020	0.028	0.051	
Evangeline (1)	0.018	0.020	NA	NA	0.030	0.060	
Cobalt (Co)							
Up	0.003	0.043	0.168	0.085	0.210	0.500	Mean and median Co concentrations increase from up to midgradient wells or are relatively unchanged. Mean and median downgradient Co concentrations are << mid- and upgradient concentrations.
Mid	0.046	0.096	0.155	0.209	0.209	0.272	
Down	0.002	0.002	0.040	0.003	0.005	0.188	
All	0.002	0.003	0.111	0.051	0.157	0.500	
Lead (Pb)							
Up	0.002	0.002	0.028	0.002	0.041	0.079	Mean and median Pb concentrations increase from up to midgradient wells. However, mean and median downgradient Pb concentrations are << mid- and upgradient concentrations.
Mid	0.006	0.010	0.031	0.044	0.044	0.073	
Down	0.002	0.002	0.005	0.005	0.006	0.008	
All	0.002	0.002	0.018	0.006	0.011	0.079	
Molybdenum (Mo)							
Up	0.005	0.009	0.011	0.013	0.014	0.015	Mean and median Mo concentrations increase from up to midgradient wells. However, mean and median downgradient Mo concentrations are < midgradient concentrations and are essentially equal to upgradient Mo concentrations.
Mid	0.005	0.010	0.018	0.025	0.025	0.034	
Down	0.005	0.005	0.013	0.013	0.020	0.023	
All	0.005	0.005	0.014	0.018	0.018	0.034	
Selenium (Se)							
Up	0.002	0.002	0.002	0.002	0.002	0.002	Se concentrations are unchanged from up to mid- to downgradient well locations. No detections.
Mid	0.002	0.002	0.002	0.002	0.002	0.002	
Down	0.002	0.002	0.002	0.002	0.002	0.002	
All	0.002	0.002	0.002	0.002	0.002	0.002	

1-Nicot et al., 2010 and from Gates et al., 2009.

0.209 Shading indicates that the sample concentration is greater than the C/I PCL.