#### APPENDIX 19 PREVIOUS STUDY BY SWG OF STEWART CREEK DOWNSTREAM OF FOP

#### SUPPLEMENTAL SITE INVESTIGATION Additional Sampling of Stewart Creek

Property:

Stewart Creek 4<sup>th</sup> Army Memorial Parkway to BNSF Railroad Bridge Frisco, Texas

> March 5, 2014 Project No. 0111C278A

> > Prepared for:

City of Frisco C/O Russell & Rodriguez, L.L.P. 1633 Williams Drive Building 2, Suite 200 Georgetown, TX 78628

Prepared by:



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March 5, 2014

City of Frisco c/o Russell & Rodriguez, L.L.P. 1633 Williams Drive Building 2, Suite 200 Georgetown, TX 78628 Attn : Mr. Kerry Russell

Re: Supplemental Site Investigation Additional Sampling of Stewart Creek 4<sup>th</sup> Army Memorial to BNSF Railroad Bridge Frisco, Texas SWG Project No. 0111C278A

Dear Mr. Russell:

SWG is pleased to submit this Supplemental Site Investigation (SSI) report for the abovereferenced Site. This investigation was performed in accordance with SWG's Proposal Number P0113C1098 dated March 26, 2013.

We appreciate the opportunity to perform these services for the City of Frisco, c/o Russell & Rodriguez, L.L.P. Please contact either of the undersigned at (214) 350-5469 if you have questions regarding the information provided in the report.

Sincerely, SOUTHWEST GEOSCIENCE

Prepared by:

Jason T. Minter, P.G. Manager, Environmental Field Services

Enclosure





Environmental & Hydrogeologic Consultants



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#### SUPPLEMENTAL SITE INVESTIGATION

Additional Sampling of Stewart Creek 4<sup>th</sup> Army Memorial Parkway to BNSF Railroad Bridge Frisco, Texas SWG Project No. 0111C278A March 5, 2014

#### 1.0 INTRODUCTION

#### 1.1 Site Description

SWG has completed a Supplemental Site Investigation (SSI) in Stewart Creek from 4<sup>th</sup> Army Memorial Parkway to the BNSF Railroad Bridge in Frisco, Texas. It should be noted that the portion of Stewart Creek located west of Legacy Drive and north of a high voltage utility easement (approximately 3,300 feet south of Stonebrook Parkway) is not included in this report. This area is a private property.

A topographic map is included as Figure 1, and sample location maps depicting segments of Stewart Creek assessed are included as Figure 2A and Figure 2B, Appendix A.

#### 1.2 Scope of Work

The proposed scope of work was based on the request of the City of Frisco for additional sampling and analysis of sediment and "as-generated" wastes (e.g., chips, potential slag and slag) along Stewart Creek as shown on the attached Figure 2A and Figure 2B.

The objective of the proposed scope of services was to evaluate arsenic, cadmium, lead, total organic carbon along Stewart Creek in sediment samples collected from eighteen (18) sampling locations (SC-SED-31 through SC-SED-48). A grain size analysis was also conducted on the sediment samples. This scope of work was performed in accordance with SWG's Proposal Number P0113C1098 dated March 26, 2013. In addition, at the request of the Client, SWG collected the following representative "as-generated" waste samples: six (6) chip, three (3) potential slag, and two (2) slag sample locations. At the Client's request, SWG also collected field data on the approximate depth of sediment along Stewart Creek and pH in surface water at select locations during the walking survey.

It should be noted that SWG previously collected 30 sediment samples (SC-SED-1 through SC-SED-30) along Stewart Creek. The investigation activities and results were presented in SWG's report titled "Limited Site Investigation: Sediment Sampling of Stewart Creek" dated March 27, 2013 (SWG Project No. 0111278). Laboratory results from SWG's LSI are summarized in the tables included in Appendix C. An excerpted copy of this report is included in Appendix F.

Additionally, SWG conducted a visual survey of Stewart Creek from F.M.423 (located near the east shore of Lewisville Lake) to the BNSF Railroad Bridge from March 28, 2013 to April 19, 2013 to document the presence of the "as-generated" wastes. The findings of this survey were documented in SWG's report titled "Interim Report: Visual Survey of Stewart Creek" dated May 14, 2013. An excerpted copy of this report is included in Appendix G.

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#### 1.3 Standard of Care

SWG's services were performed in accordance with standards customarily provided by a firm rendering the same or similar services in the area during the same time period. SWG makes no warranties, express or implied, as to the services performed hereunder. Additionally, SWG does not warrant the work of third parties supplying information used in the report (e.g. laboratories, regulatory agencies or other third parties). This scope of services was performed in accordance with the scope of work agreed with the client, as detailed in our proposal.

#### 1.4 Additional Scope Limitations

Findings, conclusions and recommendations resulting from these services are based upon information derived from the on-site activities and other services performed under this scope of work and it should be noted that this information is subject to change over time. Certain indicators of the presence of hazardous substances, petroleum products, or other constituents may have been latent, inaccessible, unobservable, or not present during these services, and SWG cannot represent that the site contains no hazardous substances, toxic materials, petroleum products, or other latent conditions beyond those identified during this LSI. Environmental conditions at other areas or portions of the Site may vary from those encountered at actual sample locations. SWG's findings and recommendations are based solely upon data available to SWG at the time of these services.

#### 1.5 Reliance

This report has been prepared for the exclusive use of the City of Frisco, and any authorization for use or reliance by any other party (except a governmental entity having jurisdiction over the site) is prohibited without the express written authorization of the City of Frisco and SWG. Any unauthorized distribution or reuse is at the client's sole risk. Notwithstanding the foregoing, reliance by authorized parties will be subject to the terms, conditions and limitations stated in the proposal, LSI report, and SWG's Agreement. The limitation of liability defined in the agreement is the aggregate limit of SWG's liability to the client and all relying parties unless otherwise agreed in writing.

#### 2.0 FIELD ACTIVITIES

SWG's LSI field activities were conducted between June 13, 2013 and June 21, 2013 by Mr. Tommy Kim, Mr. Jason Minter, P.G., SWG environmental professionals and Ms. Mahlia Abaya, a SWG field scientist.

#### 2.1 Sampling Activities

#### 2.1.1 Sediment

The sediment sampling activities were concentrated in depositional areas along Stewart Creek and conducted in general accordance with the Texas Commission on Environmental Quality (TCEQ) *Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods (RG-415),* revised August 2012. Sediment sampling activities took place between 4<sup>th</sup> Army Memorial Parkway and Stonebrook Parkway.

Sample locations were targeted in areas of soft sediment deposition/accumulation within the



depositional features and documented using field GPS equipment. At each location, sediment samples were collected from the 0.0 to 0.5 foot depth interval; however, finer grained bed sediments were sampled preferentially over coarser grained bed sediments. Sediment samples were collected utilizing a disposable scoop at each location.

The sediment samples were collected from 18 sampling locations along Stewart Creek between 4<sup>th</sup> Army Memorial and Stonebrook Parkway as shown on Figure 1. The sediment sample locations were designated SC-SED-31 (east of the 4<sup>th</sup> Army Memorial) Parkway through SC-SED-48 (south of Stonebrook Parkway).

Figure 1 presents the general boundaries and topography of the Site on the USGS topographic quadrangle map of Frisco, Texas (Appendix A).

#### 2.1.2. "As-Generated" Wastes

Sample locations were targeted in areas where concentrated "as-generated" wastes were identified within the depositional features and documented using field GPS equipment. "As-generated" waste sampling activities took place between 4<sup>th</sup> Army Memorial Parkway and the BNSF Railroad Bridge. Descriptions of the limited sampling locations are as follows:

#### Chip (6-20)-2/Chip (6-20)-2 Base

A single chip was identified and collected at this location for analysis. This location was selected because it was the most downstream location where a chip was identified. The "Base" suffix denotes a sample of the media (soil/sand/gravel) located beneath the chip that was also collected for analysis.

Chip (6-21)-1 / Chip (6-21)-1 BaseComp: Chip (6-21)-2 / Chip (6-21)-2 BaseComp: Chip (6-21)-4 / Chip (6-21)-4 BaseComp; Chip (6-21)-5 / Chip (6-21)-5 BaseComp; PS (6-21)-1 / PS (6-21)-1 BaseComp; PS (6-21)-2 / PS (6-21)-2 BaseComp; and PS (6-24)-3 / PS (6-24)-3 BaseComp

These locations consisted of single areas where concentrated chips or potential slag were identified. At each location, SWG collected multiple chips or potential slag for analysis (eg, Chip (6-21)-1, PS (6-21)-1, etc.). The "BaseComp" suffix denotes a sample of the media located under each collected chip or potential slag that was collected and composited for that area.

## Chip (6-24)-3 / Chip (6-24)-3 Comp / Chip (6-24)-3 BaseComp / Chip (6-24)-3 Wall Base / Chip (6-24)-3 SED

The location was selected because it was an area where concentrated chips were identified along the bank wall. Multiple chips were collected at this location for analysis. The "Comp" suffix denotes a mixture sample of chips and the underlying media. The "BaseComp" suffix denotes a sample of the media located under each collected chip that was collected and composited for that area. The "Wall Base" suffix denotes a sample of the media along the base of the wall below the chip layer. The "SED" suffix denotes a sample of the sediment at this location.



Slag (6-24)-1 / Slag (6-24)-1 Base and Slag (6-24)-2 / Slag (6-24)-2 Base

Representative samples of the slag were collected at these locations. The "Base" suffix denotes a sample of the media located beneath the slag that was also collected for analysis. SWG targeted the location where the slag appeared to have settled for a period of time.

#### 2.1.3 Sampling Program

With the exception of the slag, the samples were collected and placed in laboratory prepared glassware and placed on ice in a cooler which was secured with a custody seal. Due to their size, the slag samples were collected and placed in a Ziploc® bag and placed on ice in a cooler. The sample coolers and completed chain-of-custody forms were relinquished to Pace Analytical's laboratory in Allen, Texas for normal turnaround. It should be noted that sediment samples were also relinquished to Accutest Laboratories' analytical laboratory in Dayton, New Jersey for grain size analysis on normal turnaround.

#### 2.2 Transect Activities

At the request of the Client, SWG took approximate measurements of sediment depths along Stewart Creek at various locations (i.e., Transect 1, etc.) as depicted on Figure 2.

Based on the collected data, it appears sediment depths along Stewart Creek from the 4<sup>th</sup> Army Memorial Parkway to the BNSF Railroad Bridge ranged from 0.0 feet to 4.5 feet thick. The creek width ranged from 16 feet to 31 feet wide. Additionally, pH was measured at each of the transect locations as summarized in Table 3, Appendix C.

#### 3.0 LABORATORY ANALYTICAL METHODS

The sediment samples were analyzed for arsenic, cadmium, and lead utilizing EPA Method SW-846 #6010B, total organic carbon utilizing EPA Method SW-846 #9060M and grain size analysis utilizing ASTM D422-63. The "as-generated" waste samples were analyzed for arsenic, cadmium, and lead utilizing EPA Method SW-846 #6010B. Additionally, select "as-generated" waste samples were analyzed for toxicity characteristic leaching procedure (TCLP) arsenic and lead utilizing EPA Method SW-846 #1311/6010B.

Laboratory results are summarized in the tables included in Appendix C. The executed chainof-custody form and laboratory data sheets are provided in Appendix D.

Upon receipt of the final laboratory analytical reports, the data was evaluated for completeness and data usability summaries were prepared in accordance with the TRRP-13 guidance document "Review and Reporting of COC Concentration Data under TRRP". Data usability summaries are included with the laboratory data sheets provided in Appendix D.

#### 4.0 DATA EVALUATION

SWG compared the arsenic, cadmium, and lead concentrations detected in the sediment samples collected during the SSI activities to the freshwater sediment benchmarks and second effects levels for sediment referenced in the TCEQ guidance document *Update to Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas RG-263 (Revised),* 



dated January 2006.

#### Sediment Samples

#### Arsenic

The arsenic concentrations detected in the sediment samples collected during the SSI activities ranged from 7.0 mg/Kg in SC-SED-40 to 26.1 mg/Kg in SC-SED-46. Arsenic concentrations detected in sediment at each location with the exception of SC-SED-40 exceeded the TCEQ ecological benchmark for sediment of 9.79 mg/Kg. None of the sediment samples exceeded the TCEQ second effects level for arsenic of 33 mg/Kg.

#### Cadmium

The cadmium concentrations detected in the sediment samples collected during the SSI activities ranged from 0.16 mg/Kg in SC-SED-40 to 2.4 mg/Kg in SC-SED-48. Cadmium concentrations detected in sediment at five locations exceeded the TCEQ ecological benchmark for sediment of 0.99 mg/Kg; however, none of the detected sediment concentrations exceeded the TCEQ second effects level for cadmium of 4.98 mg/Kg.

#### Lead

The lead concentrations detected in the sediment samples collected during the SSI activities ranged from 8.6 mg/Kg in SC-SED-42R to 19.6 mg/Kg in SC-SED-47.

Based on the analytical results, none of the lead concentrations exceeded the TCEQ ecological benchmark for sediment.

#### "As-Generated" Waste Samples

#### Arsenic

The arsenic concentrations detected in the "chip" only samples ranged from 3.3 mg/Kg in Chip (6-24)-3 to 14.4 mg/Kg in Chip (6-20)-2. The arsenic concentrations detected in the "Base" or "Base Comp" samples for the chip locations ranged from 8.9 mg/Kg in Chip (6-24)-5 Base Comp to 17.7 mg/Kg in Chip (6-21)-1 Base Comp. The arsenic concentrations detected at the Chip (6-24)-3 Comp and Chip (6-24)-3 Wall Base were 11.5 mg/Kg and 8.1 mg/Kg, respectively.

The arsenic concentration detected in Chip (6-24)-3 SED was 10.4 mg/Kg which exceeded the TCEQ ecological benchmark for sediment. However, this sample did not exceed the TCEQ second effects level for arsenic.

The arsenic concentrations detected in the "potential slag" only samples were below the TCEQ ecological benchmark for sediment with concentrations ranging from 3.0 mg/Kg in PS (6-24)-3 to 7.2 mg/Kg in PS (6-21)-2. The arsenic concentrations detected in the "Base Comp" samples for the potential slag samples ranged from 11.8 mg/Kg in PS (6-24)-3 Base Comp to 44.6 mg/Kg in PS (6-21)-2 Base Comp.

Arsenic concentrations detected in the "Base Comp" samples exceeded the TCEQ ecological benchmark for sediment. Additionally, the sample collected for PS (6-21)-2 Base Comp



exceeded the TCEQ ecological benchmark and second effects level for sediment.

The arsenic concentrations detected in the "slag" only sample were 118 mg/Kg in Slag (6-24)-1 and 38.7 mg/Kg in Slag (6-24)-2. The arsenic concentrations detected in the "Base" samples for the slag locations were 16.4 mg/Kg in Slag (6-24)-1 Base and 279 mg/Kg in Slag (6-24)-2 Base.

The arsenic concentrations detected in the "slag" only samples collected for Slag (6-24)-1 and Slag (6-24)-2 exceeded the TCEQ ecological benchmark and second effects level for sediment. Additionally, the sample collected for Slag (6-24)-1 exceeded the TCEQ Texas Risk Reduction Program (TRRP) human health sediment Protective Concentration Level (PCL) of 110 mg/Kg. The arsenic concentration detected in the "Base" sample collected for Slag (6-24)-1 exceeded the TCEQ ecological benchmark for sediment. Additionally, the sample collected for Slag (6-24)-2 Base exceeded the TRRP ecological benchmark, second effects level and human health sediment PCL for arsenic.

#### Cadmium

The cadmium concentrations detected in the "chip" only samples ranged from 0.077J mg/Kg in Chip (6-24)-4 to 0.29 mg/Kg in Chip (6-24)-3. The cadmium concentrations detected in the "Base" or "Base Comp" samples for the chip locations ranged from 0.54 mg/Kg in Chip (6-21)-2 Base Comp to 1.1 mg/Kg in Chip (6-24)-3 Base Comp. The cadmium concentrations detected at the Chip (6-24)-3 Comp and Chip (6-24)-3 Wall Base were 1.4 mg/Kg and 0.92 mg/Kg, respectively.

The cadmium concentration detected in Chip (6-24)-3 SED was 0.79 mg/Kg, which did not exceed the TCEQ ecological benchmark for sediment or the TCEQ second effects level for cadmium.

The cadmium concentrations detected in the "potential slag" only samples ranged 0.17J mg/Kg in PS (6-24)-3 to 0.59 mg/Kg in PS (6-21)-2. The cadmium concentrations detected in the "Base Comp" samples for the potential slag samples ranged from samples ranged 0.52 mg/Kg in PS (6-21)-2 Base Comp to 4.2 mg/Kg in PS (6-21)-1 Base Comp.

The cadmium concentration for the "slag" only sample was only detected in Slag (6-24)-2 at 1.9 mg/Kg. The cadmium concentration for the "Base" was only detected in Slag (6-24)-1 at 0.56 mg/Kg.

Based on the analytical results, the cadmium concentrations detected in the "as-generated" waste samples collected for Chip (6-24)-3 Comp, Chip (6-24)-3 Base Comp, PS (6-21)-1 Base Comp and Slag (6-24)-2 were above the TCEQ ecological benchmark for cadmium,

#### Lead

The lead concentrations detected in the "chip" only samples ranged from 3.8 mg/Kg in Chip (6-21)-2 to 180 mg/Kg in Chip (6-21)-1. The lead concentrations detected in the "Base" or "Base Comp" samples for the chip locations ranged from 8.2 mg/Kg in Chip (6-20)-2 Base Comp to 76.7 mg/Kg in Chip (6-24)-5 Base Comp. The lead concentrations detected at the Chip (6-24)-3 Comp and Chip (6-24)-3 Wall Base were 32.6 mg/Kg and 15.7 mg/Kg, respectively.

The "chip" samples collected for Chip (6-21)-1, Chip (6-24)-4 and Chip (6-24)-5 Base Comp



exceed the TCEQ ecological benchmark for sediment. Additionally, the sample collected for Chip (6-21)-1 exceeded the second effects level for sediment.

The lead concentrations detected in the "potential slag" only samples ranged 4.4 mg/Kg in PS (6-24)-3 to 9.7 mg/Kg in PS (6-21)-2. The lead concentrations detected in the "Base Comp" samples for the potential slag samples ranged from samples ranged 9.7 mg/Kg in PS (6-21)-2 Base Comp to 89 mg/Kg in PS (6-21)-1 Base Comp.

Based on the analytical results, the "potential slag" sample collected for in PS (6-21)-1 Base Comp exceeded the TCEQ ecological benchmark for sediment.

The lead concentrations detected in the "slag" only sample were 35,200 mg/Kg in Slag (6-24)-1 and 20,600 mg/Kg in Slag (6-24)-2. The lead concentrations detected in the "Base" samples for the slag locations were 17.8 mg/Kg in Slag (6-24)-1 Base and 459 mg/Kg in Slag (6-24)-2 Base.

Based on the analytical results, the "slag only" samples collected for Slag (6-24)-1, Slag (6-24)-2 and Slag (6-24)-2 Base exceed the ecological benchmark and second effects level for sediment. Additionally, the "slag only" sample collected for Slag (6-24)-1 exceeded the human health sediment PCL for lead.

#### <u>TCLP</u>

#### TCLP - Arsenic

Based on the analytical results, SWG resubmitted the samples collected for Slag (6-24)-1, Slag (6-24)-2 and Slag (6-24)-1 Base for TCLP analysis. TCLP arsenic was not detected in the sample collected for Slag (6-24)-2; however, TCLP arsenic concentrations of 0.084 mg/L were detected in the samples collected for Slag (6-24)-1 and Slag (6-24)-1 Base.

Based on SWG's review, the TCLP concentrations detected in Slag (6-24)-1 and Slag (6-24)-1 Base are below the TCLP Class 1 Non-Hazardous Waste threshold of 1.8 mg/L and below the TCLP Maximum Contaminant Concentration of 5.0 mg/L for hazardous waste.

#### TCLP – Cadmium

Since cadmium concentrations were not detected above the TCEQ second effects level, TCLP was not evaluated for cadmium in the sediment samples collected.

#### TCLP - Lead

Based on the analytical results, SWG resubmitted the samples collected for Chip (6-21)-1, Slag (6-24)-1, Slag (6-24)-2 and Slag (6-24)-1 Base for TCLP analysis. TCLP lead concentrations detected in the samples ranged from 4.1 mg/L in Chip (6-21)-1 to 37.8 mg/L in Slag (6-24)-2.

Based on SWG's review, the TCLP concentrations detected in Chip (6-21)-1, Slag (6-24)-1, Slag (6-24)-2 and Slag (6-24)-1 Base are above the TCLP Class 1 Non-Hazardous Waste threshold of 1.5 mg/L. Additionally, the TCLP concentrations detected in Slag (6-24)-1, Slag (6-24)-2 and Slag (6-24)-1 Base were above the TCLP Maximum Contaminant Concentration of 5.0 mg/L for hazardous waste.



#### <u>Total Organic Carbon</u>

Total Organic Carbon concentrations detected in the sediment samples ranged from 11.9 mg/Kg in SC-SED-44 to 62.8 mg/Kg in SC-SED-36.

#### <u>Grain Size Analysis</u>

The sediment samples grain sizes ranged Based on the grain size analytical results, the sediment samples collected range from 0.67% to 33.1% gravel, 29.9% to 90% sand and 2% to 65% silt, clay and colloids. A table summarizing the grain size analytical results is included as Table 2, Appendix B. The grain size analytical reports prepared by Accutest are included in Appendix E.

#### Background Study

In 2013, SWG conducted background soil sampling activities in seven select locations in Frisco, Texas to establish background concentrations of RCRA 8 metals on native soils within the City of Frisco municipal boundaries for reference purposes. The background locations were targeted in previously undeveloped areas located outside of the suspected range of potential effects of the former Exide Technologies, Inc. (Exide) facility located at 7471 South 5<sup>th</sup> Street, Frisco, Texas.

ToxStrategies, Inc. (Toxstrategies) utilized the data collected to calculate summary statistics for each of the RCRA 8 metals as documented in ToxStrategies' *Memorandum - Background surface soil concentrations for metals in Frisco, TX*, dated March 3, 2014 (hereinafter, the "memorandum"), Toxstrategies memorandum is included as Appendix H. The results are summarized in the following table:



Statistic	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
Number of samples	70	70	70	70	70	70	70	70
Number of detects	70	70	64	70	70	70	30	28
Min	3.6	77	0.0	15.7	6.8	0.005	0.21	0.096
Мах	11.4	251	1.7	56.4	30.0	0.033	3.50	1.500
Mean	6.7	124.5	0.3	27.9	11.5	0.0	0.9	0.2
95% UCL on the mean	7.1	131.7	0.4	29.7	12.4	0.0	1.1	0.3
Median	6.4	120	0.3	27.4	11.1	0.013	0.11	0.150
95% UTL on the median	6.8	129	0.3	28.7	11.9	0.015	0.97	0.270
75 <sup>th</sup> percentile (75% UPL)	7.6	137	0.3	30.8	12.8	0.016	1.90	0.360
95% UTL on 75 <sup>th</sup> percentile	8.6	161	0.4	32.7	13.7	0.019	2.10	0.440
95 <sup>th</sup> percentile (95% UPL)	9.5	179	0.5	48.5	17.0	0.021	3.00	0.870
95% UTL on 95 <sup>th</sup> percentile	**	**	**	**	**	**	**	**
99 <sup>th</sup> percentile (95% UPL)	11.4	251	1.7	56.4	30.0	0.033	3.50	1.500
95% UTL on 99 <sup>th</sup> percentile	**	**	**	**	**	**	**	**

\*\* - Could not be estimated from the data.

- For definitions of acronyms, refer to ToxStrategies' memorandum provided as Appendix F.

#### Literature Review

SWG further conducted a literature review of background concentrations for the region.

SWG reviewed available literature to evaluate background concentrations for arsenic and lead in the geographic region. During the literature review, SWG referenced:

- The University of Texas at Austin Bureau of Economic Geology (BEG) report titled *Evaluation of Arsenic Contamination in Texas*, dated August 2005,
- An excerpt of a report contained in a United Stated Environmental Protection Agency Record of Decision (EPA/ROD/R06-97/124 1997) for RSR Corporation OU3; Dallas, Texas 1997 titled *Elements in North American Soils*, prepared by the Hazardous Materials Control Resources Institute (HMCRI), dated 1991.

Based on the results of the literature review, background arsenic concentrations in agricultural settings range from 0.1 mg/Kg to 40 mg/Kg based on the BEG report and 1 mg/Kg to 18 mg/Kg based on the HMCRI report. The arsenic values detected during SWG's background study fall within the range of concentrations documented in the HMCRI report; however, background arsenic concentrations in the Frisco area could be higher depending on the proximity and duration of agricultural land use, specifically cotton farming.

The lead concentrations detected in the background soil samples (from 6.8 mg/Kg to 30.0 mg/Kg) are within the regional background concentration range documented in the HMCRI report from below detection limits to 30 mg/Kg.

The BEG report and the excerpted portion of the HMCRI report are provided in Appendix I.



#### 5.0 FINDINGS AND RECOMMENDATIONS

The objective of the proposed scope of services was to evaluate arsenic, cadmium, lead, total organic carbon along Stewart Creek in sediment samples. A grain size analysis was also conducted on the sediment samples. In addition, at the request of the Client, SWG also collected the following "as-generated" wastes: six (6) chip, three (3) potential slag, and two (2) slag sample locations. This scope of work was performed in accordance with SWG's Proposal Number P0113C1098 dated March 26, 2013.

The findings and recommendations of this investigation are as follows:

#### <u>Sediment</u>

- A total of eighteen (18) sediment samples were collected in Stewart Creek between 4<sup>th</sup> Army Memorial Parkway and Stonebrook Parkway.
- Sample locations were targeted in areas of soft sediment deposition/accumulation within the stream bed and documented using field GPS equipment. At each location, sediment samples were collected from the 0.0 to 0.5 foot depth interval; however, finer grained bed sediments were sampled preferentially over coarser grained bed sediments.
- The laboratory analytical results indicate that arsenic, cadmium, and lead and sulfate concentrations were detected in each of the samples collected.
- Arsenic, cadmium and lead concentrations were detected in the samples collected during the SSI activities above the TCEQ ecological benchmarks for sediment.

#### "As-Generated" Waste

- A total of six (6) chip, three (3) potential slag, and two (2) slag sample locations were collected between 4<sup>th</sup> Army Memorial Parkway and the BNSF Railroad Bridge.
- The laboratory analytical results indicate that arsenic, cadmium, and lead and sulfate concentrations were detected in each of the samples collected.
- Arsenic, cadmium and lead concentrations were detected above the TCEQ ecological benchmarks for sediment in the "as-generated" waste samples.
- Arsenic and lead concentrations were detected above the TCEQ second effects levels and human health sediment PCLs in the "as-generated" waste samples.

#### <u>TCLP</u>

- TCLP arsenic concentrations detected in Slag (6-24)-1 and Slag (6-24)-1 Base are below the TCLP Class 1 Non-Hazardous Waste Criteria concentration of 1.5 mg/L.
- TCLP lead concentrations detected in Chip (6-21)-1, Slag (6-24)-1, Slag (6-24)-2 and Slag (6-24)-1 Base are above the TCLP Class 1 Non-Hazardous Waste Criteria concentration of 1.8 mg/L. Additionally, the TCLP concentrations detected in Slag (6-24)-1, Slag (6-24)-2 and Slag (6-24)-1 Base were above the TCLP Maximum Contaminant Concentration of 5.0 mg/L for



hazardous waste.

Based on the results of SWG's LSI, additional assessment is necessary to further evaluate the arsenic, cadmium and lead concentrations above the TCEQ ecological benchmarks and/or second effects levels for sediment and to further evaluate the presence of battery chips and potential slag observed during field activities.

TCLP analysis was conducted for the "as-generated" waste materials to screen for potential waste characterization and classification. Based on the TCLP analytical results, further evaluation of the "as-generated" waste materials encountered in Stewart Creek is necessary. Additional waste characterization evaluation may be required to classify the waste materials for subsequent disposition in accordance with applicable local, state and federal regulations.



#### <u>References</u>

ToxStrategies, Inc. (2014). *Memorandum - background surface soil concentrations for metals in Frisco, TX.* 

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APPENDIX A

Figures







#### Legend

•	Chip/Slag/Potential Slag Sample Locations
	2013 Base Sample Locations
	2013 Sediment Sample Locations
	2011 Sediment Sample Locations
	Transect Location
	Stewart Creek



#### Figure 2A

Sample Location Map Stewart Creek N. of Stonebrook Pkwy. to BNSF Railroad

> City of Frisco Stewart Creek Sediment Sampling Frisco, Texas SWG Project No. 0111C278A







## Legend • Chip/Slag/Potential Slag Sample Locations ▲ 2013 Base Sample Locations ▲ 2013 Sediment Sample Locations Transect Location - Stewart Creek Feet Figure 2B Sample Location Map Stewart Creek E. of 5th Army Memorial Pkwy. City of Frisco Stewart Creek Sediment Sampling Frisco, Texas SWG Project No. 0111C278A Southwest





#### Legend

- Transect Location
- Chip/Slag/Potential Slag Sample Locations
- 2013 Base Sample Locations
- ▲ 2013 Sediment Sample Locations
- ▲ 2011 Sediment Sample Locations
- Stewart Creek

Note: **Blue** denotes a concentration that exceeds the TRRP Ecological Benchmark for Sediment; **Green** denotes a concentration that exceeds the TCEQ Second Effects Level; **Red** denotes a concentration that exceeds the TCEQ Human Health Sediment PCL



#### Figure 3A

Sample Location Map Stewart Creek N. of Stonebrook Pkwy. to BNSF Railroad

> City of Frisco Stewart Creek Sediment Sampling Frisco, Texas SWG Project No. 0111C278A







#### Legend

- Chip/Slag/Potential Slag Sample Locations
- ▲ 2013 Base Sample Locations
- ▲ 2013 Sediment Sample Locations
- Transect Location

Stewart Creek

Note: **Blue** denotes a concentration that exceeds the TRRP Ecological Benchmark for Sediment; **Green** denotes a concentration that exceeds the TCEQ Second Effects Level; **Red** denotes a concentration that exceeds the TCEQ Human Health Sediment PCL



#### Figure 3B

Sample Location Map Stewart Creek E. of 5th Army Memorial Pkwy.

City of Frisco Stewart Creek Sediment Sampling Frisco, Texas SWG Project No. 0111C278A





## APPENDIX B

Photographs





1.) General view of depositional area in creek.

March 28, 2013



2.) General view of creek.

June 13, 2013





3.) General View of Creek

June 19, 2013



4.) View of battery chips in creek bank wall.







5.) Battery chips on the creek bank wall.

April 11, 2013



6.) Photo of battery chips under water on top of sediment in Stewart Creek.

April 11, 2013





7.) Representative photos of battery chips on a gravel/sand deposit in Stewart Creek.

April 11, 2013



8.) Battery post.

April 18, 2013





9.) Potential Slag.

April 18, 2013



10.) Potential slag.

June 24, 2013





### APPENDIX C

Tables

TABLE 1A													
	SEDIMENT ANALYTICAL RESULTS												
	Stewar	t Creek Eas	t and West	of the Dall	as North To	ollway							
			Frisco,	Texas		Total							
Sample I.D.	Sample Date	Depth (feet)	Arsenic (mg/Kg)	Cadmium (mg/Kg)	Lead (mg/Kg)	Organic Carbon mg/Kg	Selenium (mg/Kg)	Sulfate (mg/Kg)					
TRRP Ecological Ben	chmarks for Se	ediment	9.79	0.99	35.8	NE	NE	NE					
TRRP Human Health Sedime	ent Protective (	Concentration	33	4.98	128	NE	NE	NE					
Lev	vels	onocintration	110	1,100	500	NE	2,700	NE					
SC-SED-1	11/18/11	0-0.5	11.9	0.61	38.2	N/A	<1.09	39.3					
SC-SED-2	11/18/11	0-0.5	11.2	0.75	46.9	N/A	<1.15	87.8					
SC-SED-3	11/18/11	0-0.5	18.6	2.01	63.8	N/A	<1.06	85.5					
SC-SED-4	11/18/11	0-0.5	12.0	0.95	39.1	N/A	<1.09	69.8					
SC-SED-5	11/17/11	0-0.5	14.4	0.90	397	N/A N/A	<1.20	241 55.0					
SC-SED-7	11/17/11	0-0.5	16.2	0.54	35.6	N/A	<1.00	60.2					
SC-SED-8	11/17/11	0-0.5	47.2	0.96	35.2	N/A	<1.10	52.7					
SC-SED-9	11/17/11	0-0.5	20.5	4.16	162	N/A	<1.06	43.1					
SC-SED-10	11/17/11	0-0.5	12.3	0.72	22.5	N/A	<1.01	45.0					
SC-SED-11	11/17/11	0-0.5	29.4	1.11	46.8	N/A	<1.02	38.2					
SC-SED-12	11/18/11	0-0.5	11.3	0.79	56.7	N/A	<1.26	172					
SC-SED-13	11/18/11	0-0.5	31.1	0.84	33.7	N/A	<1.00	58.3					
SC-SED-14	11/18/11	0-0.5	12.7	0.79	27.7	N/A	<0.97	48.2					
SC-SED-15	11/18/11	0-0.5	12.9	1.54	35.3	N/A	<1.01	58.0					
SC-SED-16	11/18/11	0-0.5	14.6	1.49	59.0	N/A	<1.00	35.6					
SC-SED-18	11/18/11	0-0.5	8 10	0.43	20.5	N/A	<0.97	40.2					
SC-SED-19	11/18/11	0-0.5	19.5	1.47	37.6	N/A	<1.18	93.0					
SC-SED-20	11/18/11	0-0.5	17.4	1.07	38.5	N/A	<1.03	54.2					
SC-SED-21	11/18/11	0-0.5	18.0	2.19	49.5	N/A	<0.96	31.0					
SC-SED-22	11/18/11	0-0.5	19.2	2.01	53.2	N/A	<0.93	78.5					
SC-SED-23	11/18/11	0-0.5	16.1	3.69	34.2	N/A	<1.15	190					
SC-SED-24	11/18/11	0-0.5	32.1	2.00	49.5	N/A	<1.03	39.8					
SC-SED-25	11/18/11	0-0.5	15.1	1.03	21.6	N/A	<1.07	45.0					
SC-SED-26	11/17/11	0-0.5	16.5	0.87	30.1	N/A	<1.07	66.3					
SC-SED-27	11/1//11	0-0.5	14.3	1.09	31.8	N/A	<1.00	54.1					
SC-SED-28	11/18/11	0-0.5	14.1	1.23	29.0	N/A	<0.96	63.0 27.2					
SC-SED-29	11/10/11	0-0.5	18.5	2.41	31.3	N/A	< 1.00	58.0					
SC-SED-31	06/12/13	0-0.5	19.2	0.38	12.7	33.0	<0.50 N/A	N/A					
SC-SED-32	06/12/13	0-0.5	19.3	0.64	12.3	18.7	N/A	N/A					
SC-SED-33	06/12/13	0-0.5	18.5	0.42	14.6	34.3	N/A	N/A					
SC-SED-34	06/12/13	0-0.5	16.0	0.67	14.3	20.1	N/A	N/A					
SC-SED-35	06/12/13	0-0.5	17.8	0.45	13.0	21.9	N/A	N/A					
SC-SED-36	06/12/13	0-0.5	17.7	0.61	11.5	62.8	N/A	N/A					
SC-SED-37	06/12/13	0-0.5	16.2	0.57	12.1	28.6	N/A	N/A					
SC-SED-38	06/12/13	0-0.5	12.7	0.33	9.7	25.8	N/A	N/A					
SC-SED-39	06/12/13	0-0.5	11.6	0.47	10.6	51.1	N/A	N/A					
30-3ED-40	06/12/13	0-0.5	7.0	0.16	12.9	38.4	IN/A	N/A					
SC-SED-41R	06/12/13	0-0.5	10.8	0.35	86	40.5	N/A	N/A					
SC-SED-42R	06/12/13	0-0.5	20.1	1.5	14.3	17.5	N/A	N/A					
SC-SED-44	06/12/13	0-0.5	12.8	0.39	12.1	11.9	N/A	N/A					
SC-SED-45	06/12/13	0-0.5	14.0	1.7	11.4	12.8	N/A	N/A					
SC-SED-46	06/12/13	0-0.5	26.1	1.1	11.8	19.6	N/A	N/A					
SC-SED-47	06/12/13	0-0.5	16.9	1.2	19.6	17.6	N/A	N/A					
SC-SED-48	06/12/13	0-0.5	24.8	2.4	13.8	15.6	N/A	N/A					

mg/Kg - milligrams/Kilogram

(j) - Denotes an estimated value between the laboratory sample detection limit (SDL) and the laboratory method detection limit (MDL).

Shading indicates a concentration above the TRRP Ecological Benchmark for Sediment

Bold and shading indicates a concentration above the TCEQ Second Effects Level

Bold and shading indicates a concentration above the TCEQ Human Health Sediment PCLs

Benchmarks obtained from theTCEQ guidance document Update to Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas RG-263 (Revised), dated January 2006.

< - Not detected above laboratory SDL.

N/A - Not Applicable

NE - Not Established

TABLE 1B												
CHIP, POTENTIAL SLAG, SLAG AND OTHER ANALYTICAL RESULTS												
	Stewa	rt Creek Eas	t and West	of the Dalla	as North To	lway						
Frisco, Texas												
Sample I.D.	Sample Date Depth (fee		Arsenic (mg/Kg)	Cadmium (mg/Kg)	Lead (mg/Kg)	Total Organic Carbon mg/Kg	Selenium (mg/Kg)	Sulfate (mg/Kg)				
TRRP Ecological Bend	chmarks for Se	diment	9.79	0.99	35.8	NE	NE	NE				
TCEQ Second Effects	Levels for Sec	liment	33	4.98	128	NE	NE	NE				
TRRP Human Health Sedime Lev	nt Protective C els	oncentration	110	1,100	500	NE	2,700	NE				
Chip (6-20)-2	06/20/13		14.4	0.26	19.1	N/A	N/A	N/A				
Chip (6-20)-2 Base	06/20/13		10.6	0.62	8.2	N/A	N/A	N/A				
Chip (6-21)-1	06/21/13		8.3	0.086(j)	180	N/A	N/A	N/A				
Chip (6-21)-1 Base Comp	06/21/13		17.7	0.87	13.3	N/A	N/A	N/A				
Chip (6-21)-2	06/21/13		10.5	0.24	3.8	N/A	N/A	N/A				
Chip (6-21)-2 Base Comp	06/21/13		12.3	0.54	9.5	N/A	N/A	N/A				
Chip (6-24)-3	06/24/13		3.3	0.29	27.0	N/A	N/A	N/A				
Chip (6-24)-3 Comp	06/24/13		11.5	1.4	32.6	N/A	N/A	N/A				
Chip (6-24)-3 Base Comp	06/24/13		9.2	1.1	27.7	N/A	N/A	N/A				
Chip (6-24)-3 Wall Base	06/24/13		8.1	0.92	15.7	N/A	N/A	N/A				
Chip (6-24)-3 SED	06/24/13		10.4	0.79	39.3	N/A	N/A	N/A				
Chip (6-24)-4	06/24/13		3.8	0.077(j)	62.1	N/A	N/A	N/A				
Chip (6-24)-4 Base Comp	06/24/13		9.2	0.63	15.3	N/A	N/A	N/A				
Chip (6-24)-5	06/24/13		5.4	0.088(j)	15.4	N/A	N/A	N/A				
Chip (6-24)-5 Base Comp	06/24/13		8.9	0.63	76.7	N/A	N/A	N/A				
PS-(6-21)-1	06/21/13		6.0	<0.12	6.0	N/A	N/A	N/A				
PS-(6-21)-1 Base Comp	06/21/13		25.2	4.2	89.0	N/A	N/A	N/A				
PS-(6-21)-2	06/21/13		7.2	0.59	9.7	N/A	N/A	N/A				
PS-(6-21)-2 Base Comp	06/21/13		44.6	0.52	9.7	N/A	N/A	N/A				
PS (6-24)-3	06/24/13		3.0	0.17(j)	4.4	N/A	N/A	N/A				
PS (6-24)-3 Base Comp	06/24/13		11.8	0.82	13.6	N/A	N/A	N/A				
Slag (6-24)-1	06/24/13		118	<0.019	35,200	N/A	N/A	N/A				
Slag (6-24)-1 Base	06/24/13		16.4	0.56	17.8	N/A	N/A	N/A				
Slag (6-24)-2	06/24/13		38.7	1.9	20,600	N/A	N/A	N/A				
Slag (6-24)-2 Base	06/24/13		279	<0.040	459	N/A	N/A	N/A				

mg/Kg - milligrams/Kilogram

Samples collected from sediments and soils directly beneath or adjacent to Chip, Slag, or Potential Slag from Table 1A are presented in/TAL/CS

Base denotes sample was collected disctetely directly beneath the Chip, Slag, or Potential Slag

Comp denotes the sample was collected as a composite from beneath the Chip, Slag, or Potential Slag, or contained multiple chips

SED denotes the sample was collected discretely from sediment beneath the base at the water interface

Wall denotes the sample was collected discretely further down the feature beneath the base but above the SED sample

(j) - Denotes an estimated value between the laboratory sample detection limit (SDL) and the laboratory method detection limit (MDL).

Shading indicates a concentration above the TRRP Ecological Benchmark for Sediment

Bold and shading indicates a concentration above the TCEQ Second Effects Level

Bold and shading indicates a concentration above the TCEQ Human Health Sediment PCLs

Benchmarks obtained from theTCEQ guidance document Update to Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas RG-263 (Revised), dated January 2006.

< - Not detected above laboratory SDL.

N/A - Not Applicable

NE - Not Established

TABLE 1C   TCLP ANALYTICAL RESULTS   Stewart Creek East and West of the Dallas North Tollway   Frisco, Texas										
Sample I.D.	Sample Date	Depth (feet)	Total Arsenic (mg/Kg)	Total Lead (mg/Kg)	TCLP Arsenic (mg/L)	TCLP Lead (mg/L)				
TCLP Maximum Contamina	ant Concentration (	40 CFR Part 261)			5.0	5.0				
TCLP Class 1 Non-haza	rdous Waste Criteri	a (30TAC 335)			1.8	1.5				
Chip (6-20)-2	06/20/13		14.4	19.1	N/A	N/A				
Chip (6-20)-2 Base	06/20/13		10.6	8.2	N/A	N/A				
Chip (6-21)-1	06/21/13		8.3	180	N/A	4.1				
Chip (6-21)-1 Base Comp	06/21/13		17.7	13.3	N/A	N/A				
Chip (6-21)-2	06/21/13		10.5	3.8	N/A	N/A				
Chip (6-21)-2 Base Comp	06/21/13		12.3	9.5	N/A	N/A				
Chip (6-24)-3	06/24/13		3.3	27.0	N/A	N/A				
Chip (6-24)-3 Comp	06/24/13		11.5	32.6	N/A	N/A				
Chip (6-24)-3 Base Comp	06/24/13		9.2	27.7	N/A	N/A				
Chip (6-24)-3 Wall Base	06/24/13		8.1	15.7	N/A	N/A				
Chip (6-24)-3 SED	06/24/13		10.4	39.3	N/A	N/A				
Chip (6-24)-4	06/24/13		3.8	62.1	N/A	N/A				
Chip (6-24)-4 Base Comp	06/24/13		9.2	15.3	N/A	N/A				
Chip (6-24)-5	06/24/13		5.4	15.4	N/A	N/A				
Chip (6-24)-5 Base Comp	06/24/13		8.9	76.7	N/A	N/A				
PS-(6-21)-1	06/21/13		6.0	6.0	N/A	N/A				
PS-(6-21)-1 Base Comp	06/21/13		25.2	89.0	N/A	N/A				
PS-(6-21)-2	06/21/13		7.2	9.7	N/A	N/A				
PS-(6-21)-2 Base Comp	06/21/13		44.6	9.7	N/A	N/A				
PS (6-24)-3	06/24/13		3.0	4.4	N/A	N/A				
PS (6-24)-3 Base Comp	06/24/13		11.8	13.6	N/A	N/A				
Slag (6-24)-1	06/24/13		118	35,200	0.084	23.7				
Slag (6-24)-1 Base	06/24/13		16.4	17.8	N/A	N/A				
Slag (6-24)-2	06/24/13		38.7	20,600	<0.020	37.8				
Slag (6-24)-2 Base	06/24/13		279	459	0.084	20.6				

mg/Kg - milligrams/Kilogram

mg/L - milligrams/Liter

Samples collected from sediments and soils directly beneath or adjacent to Chip, Slag, or Potential Slag from Table 1A are presented in *ITALICS* Base denotes sample was collected discretely directly beneath the Chip, Slag, or Potential Slag

Comp denotes the sample was collected as a composite from beneath the Chip, Slag, or Potential Slag, or contained multiple chips

SED denotes the sample was collected discretely from sediment beneath the base at the water interface

Wall denotes the sample was collected discretely further down the feature beneath the base but above the SED sample

(j) - Denotes an estimated value between the laboratory sample detection limit (SDL) and the laboratory method detection limit (MDL).

Bold and shading indicates a concentration above the TCLP Maximum Contaminant Concentration

Bold and shading indicates a concentration above the TCEQ Class 1 Non-hazardous waste criteria

< - Not detected above laboratory SDL.

N/A - Not Applicable

NE - Not Established

#### 2014 EXIDE APAR PAGE 2571 OF 3116

	TABLE 2   GRAIN SIZE ANALYSIS SUMMARY   Stewart Creek   Frisco, Texas																		
Sample I.D.	Date	3 Inch Sieve	1.5 Inch Sieve	0.75 Inch Sieve	0.375 Inch Sieve	No.4 Sieve (4.75 mm)	No.8 Sieve (2.36 mm)	No.10 Sieve (2.00 mm)	No.16 Sieve (1.18 mm)	No.30 Sieve (0.60 mm)	No.50 Sieve (0.30 mm)	No.100 Sieve (0.15 mm)	No.200 Sieve (0.075 mm)	0.030 mm (Hydrometer)	0.005 mm (Hydrometer)	0.0015 mm (Hydrometer)	% Gravel	% Sand	% Silt, Clay, Colloids
PERCENT F	ASSING	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
SC-SED-31	6/12/2013	100	100	100	100	99.3	93.6	91.1	71.9	39.4	18.9	13.3	12.3	10	6	4.7	0.67	87	12
SC-SED-32	6/12/2013	100	100	100	98.5	73.2	36.7	28.2	11.3	5.7	4.9	4.3	3.8	2.6	1.4	1.4	26.8	69.4	4
SC-SED-33	6/12/2013	100	100	100	97.4	91.6	72	65.6	39.1	13.1	7.9	7	6.7	3.4	3	2	8.4	85	7
SC-SED-34	6/12/2013	100	100	100	100	97.6	85.8	81.3	37.8	14.1	9.9	9.1	8.7	7.5	5	4.1	2.4	88.9	9
SC-SED-35	6/12/2013	100	100	100	98.5	66.9	16.2	9.1	4.7	2.6	2.1	1.9	1.8	0.84	0.84	0.84	33.1	65.2	2
SC-SED-36	6/12/2013	100	100	100	98.2	89.6	63.1	56.1	32.1	19.4	16.2	15	14.2	12.3	9	7	10.4	75.4	14
SC-SED-37	6/12/2013	100	100	100	98.7	92.1	79	74.5	53.7	22.9	9.8	8.1	7.8	7.8	7	6	7.9	84.3	8
SC-SED-38	6/12/2013	100	100	100	98.5	91	76.2	71.1	44.2	17.2	12.1	11.4	11.2	7.9	6.5	4	9	79.9	11
SC-SED-39	6/12/2013	100	100	100	92.6	71.6	49	45	32.7	22.3	19.9	18	16.5	16	13	8	28.4	55.1	17
SC-SED-40	6/12/2013	100	100	100	97.3	94.6	87.7	85.6	81.3	77	73.5	67.2	64.8	59	44	31	5.4	29.9	65
SC-SED-41R	6/19/2013	100	100	100	98.3	83.5	66.7	62.7	54.2	44.6	39.2	36	34.1	28	20	0.46	16.5	49.4	34.1
SC-SED-42R	6/19/2013	100	100	100	93.1	76.3	55.6	51.2	39.8	29.7	24	19.8	18.5	15	0.42	7	23.7	57.8	18.5
SC-SED-43R	6/19/2013	100	100	100	100	96	68.1	58.6	31.3	10.7	6.8	6.3	6	1.8	<0.59	<0.59	4	90	6.0
SC-SED-44	6/19/2013	100	100	100	95.1	83.6	66.9	63.3	54.7	44.5	40.5	37.9	36.2	29	22	17	16.4	47.4	36.2
SC-SED-45	6/19/2013	100	100	100	98.8	90.6	65.3	58.1	47.2	38.3	35.5	34	32.5	25	18	13	9.4	58.1	32.5
SC-SED-46	6/19/2013	100	100	100	97.2	78.6	43.6	36.2	21.9	15.2	13.7	12.4	11.5	8	6	4.8	21.4	67	11.5
SC-SED-47	6/19/2013	100	100	100	95.8	82.1	59.2	54.4	43.3	27.7	17.1	12.1	10.8	5	2	1.6	17.9	71.3	10.8
SC-SED-48	6/19/2013	100	100	100	98.5	81.8	51.1	44.6	28.2	17.8	14.5	12.5	11.7	7	5	4	18.2	70.2	11.7

# TABLE 3TRANSECT DATAStewart Creek - Fields PropertyFrisco, Texas

		Ş			
Location I.D.	Creek Width (feet)	*North Bank (feet)	Center Bank (feet)	*South Bank (feet)	рН
Transect 1	16	1.0	2.7	1.0	7.28
Transect 2	21	1.6	2.5	1.0	7.33
Transect 3	16	0.6	1.8	0.8	8.24
Transect 4	18	3.0	3.0	2.5	8.25
Transect 5	22	N/A	N/A	N/A	8.32
Transect 6	19	2.3	0.5	2.2	8.21
Transect 7	24	2.3	3.5	4.5	8.31
Transect 8	23	2.1	3.2	1.5	7.73
Transect 9	20	0.5	4.0	1.0	8.21
Transect 10	24	0	3	1	8.19
Transect 11	29	4.5	3.2	0	8.45
Transect 12	25	0	3.2	3.0	8.33
Transect 13	23	1.0	3.2	2.7	8.30
Transect 14	31	2.0	2.7	1	8.40
Transect 15	31	1.0	1	1	8.41

N/A - Not Applicable; on shale

\* The transects in the table indicate the width of the creek channel along with sediment depths near the "North Bank", the "Center of Channel" and near the "South Bank". Although the stream meanders, SWG utilized the convention of an east-west oriented stream when defining the "North Bank" and "South Bank".



## APPENDIX D

Laboratory Data Reports and Chain-of-Custody Documentation
# DATA USABILITY SUMMARY

John J. LeGolvan reviewed one data package from Pace Analytical Services, Inc. (Pace) for the analysis of sediment samples collected June 12, 2013 at the Stewart Creek site in Frisco, Texas. Data were reviewed for conformance to the requirements of the guidance document, *Review and Reporting of COC Concentration Data* (RG-366/TRRP-13) and adherence to project objectives.

**Intended Use of Data**: The objective of the sediment sampling event was to provide current data on concentrations of chemicals of concern (COCs) in the sediment at the affected property.

Analyses requested included:

- EPA 6010 RCRA 3 Metals (Arsenic, Cadmium, and Lead)
- EPA 9060M Extractable Organic Carbon

Data were reviewed and validated as described in *Review and Reporting of COC Concentration Data*, (RG-366/TRRP-13) and the results of the review/validation are discussed in this Data Usability Summary (DUS). The following laboratory submittals and field data were examined:

- the reportable data,
- the laboratory review checklists and associated exception reports, and
- the field notes with respect to sampling procedures, and preservation procedures prior to shipping the samples to the laboratory.

The results of supporting quality control (QC) analyses were summarized on the Laboratory Review Checklists (LRCs), Exception Reports (ERs) and in the case narratives, all of which were included in this review.

The complete laboratory analytical data package including LRCs, associated ERs, and reportable data included in this review are attached to this DUS.

## Introduction

Ten (10) sediment samples were collected from the site and analyzed for RCRA Metals arsenic, cadmium, and lead analyses and extractable organic carbon. Table 1 lists the field sample identification cross-referenced to the laboratory identification.

# Project Objectives

RCRA 3 Metals (Arsenic, Cadmium, and Lead) Recovery 75-125% RPD 0-20%

Extractable Organic Carbon Recovery 80-120% RPD 0-20%

# TABLE 1 Stewart Creek, Frisco, Texas DATA USABILITY SUMMARY - FIELD/LAB IDENTIFICATION CORRELATION

Field Identification	Laboratory Identification				
SC-Sed-31-1/2/3	756036001				
SC-Sed-32-1/2/3	756036002				
SC-Sed-33-1/2/3	756036003				
SC-Sed-34-1/2/3	756036004				

# TABLE 1Stewart Creek, Frisco, TexasDATA USABILITY SUMMARY - FIELD/LAB IDENTIFICATION CORRELATION

Field Identification	Laboratory Identification					
SC-Sed-35-1/2/3	756036005					
SC-Sed-36-1/2/3	756036006					
SC-Sed-37-1/2/3	756036007					
SC-Sed-38-1/2/3	756036008					
SC-Sed-39-1/2/3	756036009					
SC-Sed-40-1/2/3	756036010					

## Data Review / Validation Results

#### Analytical Results

Qualified sample data is listed in Table 2. Non-detected results were reported as U, which is less than the Sample Detection Limits (SDLs) as reported by Pace.

# Preservation and Holding Times

Sediment samples were evaluated for agreement with the chain-of-custody (C-O-C) and the Laboratory Review Checklist. All samples were received in the appropriate containers and in good condition with the paperwork filled out properly. Sample receipt temperatures were within the acceptance criteria of  $4 \pm 2$  °C. Samples were preserved in the field as specified in SW-846 Table 2-36. Samples were prepared and analyzed within holding times specified in SW-846 Table 2-36.

#### Calibrations

According to the LRC, initial calibration data met SW-846 method requirements for the analytes.

#### Blanks

Laboratory method blank data was reported for each of the selected analytes. None of the analytes were detected above the laboratory MDLs in the method blanks; therefore, it appears that no laboratory contaminants were introduced in the method blank analyses.

## Internal Standard and Surrogate Recoveries (RCRA 3 Metals)

Due to the method in use, internal standards and surrogates were not used in the analyses.

# Laboratory Control Samples

RCRA 3 Metals laboratory control sample (LCS) recoveries met project objectives of 75 to 125% recovery. Extractable Organic Carbon laboratory control sample (LCS) recoveries met project objectives of 80 to 120% recovery.

#### Matrix Spike/Matrix Spike Duplicates

The MS recoveries from batch 6806 for arsenic, cadmium, and lead were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

The MSD recoveries from batch 6806 for arsenic, cadmium, and lead were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

TABLE 2 Stewart Creek, Frisco, Texas DATA USABILITY SUMMARY - QUALIFIED DATA									
Field Identification	Analyte	Qualification	Reason for Qualification						
	Not Applicable								

# **Field Procedures**

The laboratory did not produce a duplicate analysis of the sediment samples collected at the site. A field precision sample was not collected in the field.

# Summary

The laboratory analyses were performed within the guidelines of the standards specified in the TRRP-13 guidance document. The laboratory QC indicates acceptable instrument calibration and performance. MS/MSD results indicated lower than expected recovery results from the batch which was run; however, the LCS/LCSD recoveries in each case were within the lab QC limits and within the project objective. The overall quality of the laboratory data appears to be acceptable for the project objective. The sediment analytical data are usable for the purpose of determining current COC concentrations in sediment at the affected property.



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

June 26, 2013

Rusty Simpson Southwest Geoscience 2351 W. Northwest Hwy Suite 3321 Dallas, TX 75220

RE: Pace Project 756036 Project ID: 0111C278A/SC Sediment Sampling

Dear Rusty Simpson:

Enclosed are the analytical results for sample(s) received by the laboratory on June 13, 2013. Results reported herin conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

SC-Sed-41, SC-Sed-42 and SC-Sed-43 were canceled by the customer on 06/17/13.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Skelly Cornelly/

Shelly Connelly shelly.connelly@pacelabs.com

Laboratory Certifications Pace Dallas : Texas Certification #: T104704232-12-4



# **REPORT OF LABORATORY ANALYSIS**

This report shall not be reproduced, except in full, without the written consent of Pace Analytical Services, Inc.



# Pace Project No.: 756036

# Client: <u>Southwest Geoscience</u> Project ID: <u>0111C278A/SC Sediment Sampling</u>

Client Sample ID	Lab ID	Matrix	Collection Date/Time	Received Date/Time
SC-Sed-31-1/2/3	756036001	Solid	06/12/2013 13:42	06/13/2013 13:25
SC-Sed-32-1/2/3	756036002	Solid	06/12/2013 14:13	06/13/2013 13:25
SC-Sed-33-1/2/3	756036003	Solid	06/12/2013 14:44	06/13/2013 13:25
SC-Sed-34-1/2/3	756036004	Solid	06/12/2013 15:12	06/13/2013 13:25
SC-Sed-35-1/2/3	756036005	Solid	06/12/2013 16:02	06/13/2013 13:25
SC-Sed-36-1/2/3	756036006	Solid	06/12/2013 16:28	06/13/2013 13:25
SC-Sed-37-1/2/3	756036007	Solid	06/12/2013 17:56	06/13/2013 13:25
SC-Sed-38-1/2/3	756036008	Solid	06/12/2013 18:14	06/13/2013 13:25
SC-Sed-39-1/2/3	756036009	Solid	06/12/2013 18:35	06/13/2013 13:25
SC-Sed-40-1/2/3	756036010	Solid	06/12/2013 18:54	06/13/2013 13:25



# **Project Narrative**

Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Pace Project No.: 756036

Holding Times:

All holding times were met.

Blanks:

All blank results were below reporting limits.

Laboratory Control Samples:

All LCS recoveries were within QC limits.

Matrix Spikes and Duplicates:

MS or MSD recoveries outside of QC limits are qualified in the Report of Quality Control section.

Surrogate:

All surrogate recoveries were within QC limits.

#### 2014 EXIDE APAR PAGE 2580 OF 3116

Appendix A

# LABORATORY DATA PACKAGE COVER PAGE

This data package is for Job No. 756036 and consists of:

This signature page, the laboratory review checklist, and the following reportable data:

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- R1 Field chain-of-custody documentation;
- R2 Sample identification cross-reference;
- R3 Test reports (analytical data sheets) for each environmental sample that includes:
  - a. Items consistent with NELAC Chapter 5,
  - b. Dilution factors,
  - c. Preparation methods,
  - d. Cleanup methods, and
  - e. If required for the project, tentatively identified compounds (TICs).
- R4 Surrogate recovery data including:
  - a. Calculated recovery (%R), and
  - b. The laboratory's surrogate QC limits.
- R5 Test reports/summary forms for blank samples;
- R6 Test reports/summary forms for laboratory control samples (LCSs) including:
  - a. LCS spiking amounts,
  - b. Calculated %R for each analyte, and
  - c. The laboratory's LCS QC limits.
- R7 Test reports/summary forms for matrix spike/matrix spike duplicates (MS/MSDs) including:
  - a. Samples associated with the MS/MSD clearly identified,
  - b. MS/MSD spiking amounts,
  - c. Concentration of each MS/MSD analyte measured in the parent and spiked samples,
  - d. Calculated %Rs and relative percent differences, and
  - e. The laboratory's MS/MSD QC limits.
- R8 Laboratory analytical duplicate (if applicable) recovery and precision:
  - a. The amount of analyte measured in the duplicate,
  - b. The calculated RPD, and,
  - c. The laboratory's QC limits for analytical duplicated.
  - R9 List of method quantitation limits (MQLs) and detectability check sample results for each analyte and
  - R10 Other problems or anomalies.

The exception Report for each "No" or "Not Reviewed (NR) " item in the Laboratory Review Checklist and for each analyte, matrix, and method for which the laboratory does not hold NELAC accreditation under the Texas Laboratory Accreditation Program.

**Release Statement:** I am responsible for the release of this laboratory data package. This laboratory is NELAC accredited under the Texas Laboratory Accreditation Program for all the methods, analytes, and matrices reported in this data package except as noted in the Exception Reports. The data have been reviewed and are technically compliant with the requirements of the methods used, except where noted by the laboratory in the Exception Reports. By my signature below, I affirm to the best of my knowledge all problems/anomalies observed by the laboratory have been identified in the Laboratory Review Checklist, and no information affecting the quality of the data has been knowingly withheld.

Check, if applicable: [] This laboratory meets an exception under 30 TAC §25.6 and was last inspected by [X] TCEQ on 02/24/2012

Any findings affecting the data in this laboratory data package are noted in the Exception Reports herin. The official signing the cover page of the report in which these data are used is responsible for releasing this data package and is by signature affirming the above release statement is true.

Name	(Printed)
Shelly	Connelly

<u>Official Title (Printed)</u> Project Manager <u>Date</u> 06/26/2013

X X

Х



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-31-</u> Lab ID: <u>756036001</u> Collected: <u>06/12/2013</u>	Ed-31-1/2/3 Moisture: 22.9%   6001 Received: 06/13/2013 1					Project ID: 0111C278A/SC Sediment Pace Project No.: 756036 13:25 Matrix: Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	lytical Method:	EPA 6010		Prepa	ration Met	hod: EPA 3050			
Arsenic	1	19.2	n	ng/kg	0.31	0.12	06/19/2013 16:54	06/18/2013 17:33	6806	75ICP1
Cadmium	1	0.38	n	ng/kg	0.12	0.025	06/19/2013 16:54	06/18/2013 17:33	6806	75ICP1
Lead	1	12.7	n	mg/kg		0.062	06/19/2013 16:54	06/18/2013 17:33	6806	75ICP1
Extractable Organic Carbon	Ana	lytical Method:	EPA 906	50M	Prepa	Preparation Method: EPA 9060M				
Total Organic Carbon	1	33.0	n	ng/kg	6.5	3.3	06/24/2013 11:31	06/21/2013 12:14	6975	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-32-</u> Lab ID: <u>756036002</u> Collected: <u>06/12/2013</u>	<u>1/2/:</u> 14:1	<u>3</u> Moiste <u>3</u> Receiv	ure: <u>14</u> ved: <u>06</u> ,	<u>.7%</u> /13/2013	<u>3 13:25</u>	Project ID: 0111C278A/SC Sediment Pace Project No.: 756036 13:25 Matrix: Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	ytical Method:	EPA 6010		Prepa	ration Met	hod: EPA 3050				
Arsenic	1	19.3	n	ng/kg	0.29	0.12	06/19/2013 17:00	06/18/2013 17:33	6806	75ICP1	
Cadmium	1	0.64	n	ng/kg	0.12	0.023	06/19/2013 17:00	06/18/2013 17:33	6806	75ICP1	
Lead	1	12.3	mg/kg		0.23	0.059	06/19/2013 17:00	06/18/2013 17:33	6806	75ICP1	
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	SOM	Prepa	Preparation Method: EPA 9060M					
Total Organic Carbon	1	18.7	n	ng/kg	6.0	3.0	06/24/2013 13:33	06/21/2013 12:14	6975	75WTA1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-33-</u> Lab ID: <u>756036003</u> Collected: <u>06/12/2013</u>	<u>-1/2/3</u> 14:4	Moistu <u>4</u> Receiv	ure: <u>19</u> ed: <u>06</u>	<u>.3%</u> /13/2013	<u>3 13:25</u>	Project ID: 0111C278A/SC Sediment Pace Project No.: 756036 3:25 Matrix: Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Anal	ytical Method:	EPA 6010		Prepa	ration Met	hod: EPA 3050			
Arsenic	1	18.5	n	ng/kg	0.31	0.12	06/19/2013 17:06	06/18/2013 17:33	6806	75ICP1
Cadmium	1	0.42	n	ng/kg	0.12	0.025	06/19/2013 17:06	06/18/2013 17:33	6806	75ICP1
Lead	1	14.6	mg/kg		0.25	0.062	06/19/2013 17:06	06/18/2013 17:33	6806	75ICP1
Extractable Organic Carbon	Anal	ytical Method:	EPA 906	50M	Prepa	Preparation Method: EPA 9060M				
Total Organic Carbon	1	34.3	n	ng/kg	6.3	3.2	06/24/2013 14:08	06/21/2013 12:14	6975	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-34-</u> Lab ID: <u>756036004</u> Collected: <u>06/12/2013</u>	<u>1/2/:</u> 15:1	<u>3</u> Moiste <u>2</u> Receiv	ure: <u>17</u> /ed: <u>06</u>	<u>.6%</u> /13/2013	<u>3 13:25</u>	Project ID:0111C278A/SC SedimentPace Project No.:75603613:25Matrix:Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 601	EPA 6010		ration Met	hod: EPA 3050			
Arsenic	1	16.0	n	ng/kg	0.32	0.13	06/19/2013 17:11	06/18/2013 17:33	6806	75ICP1
Cadmium	1	0.67	n	ng/kg	0.13	0.025	06/19/2013 17:11	06/18/2013 17:33	6806	75ICP1
Lead	1	14.3	n	mg/kg		0.063	06/19/2013 17:11	06/18/2013 17:33	6806	75ICP1
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	Preparation Method: EPA 9060M				
Total Organic Carbon	1	20.1	n	ng/kg	6.2	3.1	06/24/2013 14:41	06/21/2013 12:14	6975	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-35-</u> Lab ID: <u>756036005</u> Collected: <u>06/12/2013</u>	<u>1/2/:</u> 16:0	<u>3</u> Moistu <u>2</u> Receiv	ure: <u>22</u> /ed: <u>06</u> /	<u>%</u> /13/2013	<u>3 13:25</u>	Project ID: 0111C278A/SC Sediment Pace Project No.: 756036 13:25 Matrix: Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 6010		Prepa	ration Met	hod: EPA 3050			
Arsenic	1	17.8	n	ng/kg	0.31	0.13	06/19/2013 17:17	06/18/2013 17:33	6806	75ICP1
Cadmium	1	0.45	n	ng/kg	0.13	0.025	06/19/2013 17:17	06/18/2013 17:33	6806	75ICP1
Lead	1	13.0	mg/kg		0.25	0.063	06/19/2013 17:17	06/18/2013 17:33	6806	75ICP1
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	Preparation Method: EPA 9060M				
Total Organic Carbon	1	21.9	n	ng/kg	6.5	3.2	06/24/2013 15:15	06/21/2013 12:14	6975	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-36-</u> Lab ID: <u>756036006</u> Collected: <u>06/12/2013</u>	<u>6-1/2/3</u> <u>6</u> Moisture: <u>15.8%</u> <u>3 16:28</u> Received: <u>06/13/2013 1</u>					Project ID:0111C278A/SC SedimentPace Project No.:75603613:25Matrix:Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	ytical Method:	EPA 6010		Prepa	ration Met	hod: EPA 3050				
Arsenic	1	17.7	n	ng/kg	0.30	0.12	06/19/2013 17:22	06/18/2013 17:33	6806	75ICP1	
Cadmium	1	0.61	n	ng/kg	0.12	0.024	06/19/2013 17:22	06/18/2013 17:33	6806	75ICP1	
Lead	1	11.5	mg/kg		0.24	0.061	06/19/2013 17:22	06/18/2013 17:33	6806	75ICP1	
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	Preparation Method: EPA 9060M					
Total Organic Carbon	1	62.8	n	ng/kg	8.2	4.1	06/24/2013 15:50	06/21/2013 12:14	6975	75WTA1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-37-</u> Lab ID: <u>756036007</u> Collected: <u>06/12/2013</u>	<u>1/2/:</u> 17:5	<u>3</u> Moistu <u>6</u> Receiv	ure: <u>19</u> ved: <u>06</u> ,	<u>.9%</u> /13/2013	<u>3 13:25</u>	Pac	Project ID: <u>(</u> e Project No.: <u>7</u> Matrix: <u>S</u>	0 <u>111C278A/SC S</u> 2 <u>56036</u> Solid	<u>ediment</u>	
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	16.2	n	ng/kg	0.32	0.13	06/19/2013 17:44	06/18/2013 17:33	6806	75ICP1
Cadmium	1	0.57	n	ng/kg	0.13	0.025	06/19/2013 17:44	06/18/2013 17:33	6806	75ICP1
Lead	1	12.1	n	ng/kg	0.25	0.064	06/19/2013 17:44	06/18/2013 17:33	6806	75ICP1
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M			
Total Organic Carbon	1	28.6	n	ng/kg	6.5	3.2	06/24/2013 17:00	06/21/2013 12:14	6975	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-38-</u> Lab ID: <u>756036008</u> Collected: <u>06/12/2013</u>	<u>1/2/:</u> 18:1	<u>3</u> Moistu <u>4</u> Receiv	ure: <u>23</u> ved: <u>06</u>	<u>%</u> /13/2013	<u>13:25</u>	Pac	Project ID: <u>(</u> ce Project No.: <u>7</u> Matrix: <u>S</u>	0111C278A/SC S 756036 Solid	<u>ediment</u>	
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	12.7	n	ng/kg	0.33	0.13	06/19/2013 17:50	06/18/2013 17:33	6806	75ICP1
Cadmium	1	0.33	n	ng/kg	0.13	0.026	06/19/2013 17:50	06/18/2013 17:33	6806	75ICP1
Lead	1	9.7	n	ng/kg	0.26	0.066	06/19/2013 17:50	06/18/2013 17:33	6806	75ICP1
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M			
Total Organic Carbon	1	25.8	n	ng/kg	6.5	3.3	06/24/2013 17:34	06/21/2013 12:14	6975	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-39</u> Lab ID: <u>756036009</u> Collected: <u>06/12/2013</u>	<u>1/2/3</u> 18:3	<u>3</u> Moistu <u>5</u> Receiv	ure: <u>20</u> ved: <u>06</u> ,	. <u>5%</u> /13/2013	<u>3 13:25</u>	Pac	Project ID: <u>(</u> e Project No.: <u>7</u> Matrix: <u>S</u>	0111C278A/SC S 756036 Solid	<u>ediment</u>	
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	11.6	n	ng/kg	0.32	0.13	06/19/2013 17:56	06/18/2013 17:33	6806	75ICP1
Cadmium	1	0.47	n	ng/kg	0.13	0.025	06/19/2013 17:56	06/18/2013 17:33	6806	75ICP1
Lead	1	10.6	n	ng/kg	0.25	0.064	06/19/2013 17:56	06/18/2013 17:33	6806	75ICP1
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M			
Total Organic Carbon	1	51.1	n	ng/kg	6.3	3.2	06/24/2013 18:09	06/21/2013 12:14	6975	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-Sed-40-</u> Lab ID: <u>756036010</u> Collected: <u>06/12/2013</u>	<u>1/2/3</u> 18:5	<u>3</u> Moistu <u>4</u> Receiv	ure: <u>29</u> ed: <u>06</u>	. <u>2%</u> /13/2013	<u>3 13:25</u>	Pac	Project ID: <u>(</u> ce Project No.: <u>7</u> Matrix: <u>S</u>	0111C278A/SC S 756036 Solid	<u>ediment</u>	
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	7.0	n	ng/kg	0.36	0.14	06/19/2013 18:01	06/18/2013 17:33	6806	75ICP1
Cadmium	1	0.16	n	ng/kg	0.14	0.029	06/19/2013 18:01	06/18/2013 17:33	6806	75ICP1
Lead	1	12.9	n	ng/kg	0.29	0.072	06/19/2013 18:01	06/18/2013 17:33	6806	75ICP1
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M			
Total Organic Carbon	1	38.4	n	ng/kg	7.4	3.7	06/24/2013 18:44	06/21/2013 12:14	6975	75WTA1



# **Quality Control**

Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Batch: <u>6885</u> Method: <u>ASTM</u>	<u>D2974-87</u>		Pa	ce Project No Instrument II	.: <u>756036</u> D: <u>75BAL3</u>		
Duplicate: 27658 Original for Sam	<b>ple:</b> Client sample F-1	0 (0-1)					
Parameters	Original Result	Dup Result	Units	RPD	Max RPD	Quals	
Percent Moisture	19.1	21.2	%	11	20		

06/26/2013 15:50:09



# **Quality Control**

Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

# Batch: 6806 Method: EPA 6010 Prep Method: EPA 3050

# Pace Project No.: 756036

Instrument ID: 75ICP1

Blank: 27347								
Parameters	Dilution	Quals	Result	Units	MQL	SDL	Analysis Date	Prep Date
Arsenic	1	U	<0.10	mg/kg	0.25	0.10	06/19/2013 14:20	06/18/2013 17:33
Cadmium	1	U	<0.020	mg/kg	0.10	0.020	06/19/2013 14:20	06/18/2013 17:33
_ead	1	U	<0.050	mg/kg	0.20	0.050	06/19/2013 14:20	06/18/2013 17:33
Laboratory Control	Sample: 27348							

Parameters	Spk Amt	LCS Result	Units	LCS %Rec	% Rec Limits	LCS Quals
Arsenic	50	48.4	mg/kg	97	80-120	
Cadmium	50	48.1	mg/kg	96	80-120	
Lead	50	51.0	mg/kg	102	80-120	

Matrix Spike: 27349

Matrix Spike Duplicate: 27350

Original for Sample: Batch sample 754768017

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	4.3	56.1	55.1	37.8	38.0	mg/kg	60	61	75-125	0	20	M1
Cadmium	0.076J	56.1	55.1	33.8	34.3	mg/kg	60	62	75-125	1	20	M1
Lead	8.9	56.1	55.1	39.2	39.0	mg/kg	54	55	75-125	0	20	M1

Matrix Spike: 27351

Matrix Spike Duplicate: 27352

Original for Sample: Batch sample 754768018

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic		52.2	54.7	34.6	38.7	mg/kg	59	63	75-125	11	20	M1
Cadmium		52.2	54.7	31.0	35.5	mg/kg	59	65	75-125	13	20	M1
Lead	9.0	52.2	54.7	36.3	39.8	mg/kg	52	56	75-125	9	20	M1



# **Quality Control**

Batch: <u>6975</u> Method: <u>EPA 90</u> Prep Method: <u>EPA 90</u>	<u>60M</u> 60M					Pace Ins	Project N strument	No.: <u>756</u> ID: <u>75</u> V	036 VTA1			
Blank: 28154												
Parameters	Dilution	Qı	uals	Result	Units	MQL	SDI	_ A	nalysis Da	ate	Prep	Date
Total Organic Carbon	1		J	3.2	mg/kg	5.0	2.5	06	/24/2013 10	):51	06/21/2	013 12:14
Laboratory Control Sa	ample: 2815	5										
Parameters			Spk Amt	LCS Result	Un	its	LCS %Rec	9 L	6 Rec .imits	l Q	_CS luals	
Total Organic Carbon	-	-	100	109	mg/	′kg	109	8	0-120			
Matrix Spike: 28156					Matrix Spi	ke Dupli	cate: 281	57				
Original for Sam	ple: Project s	ample	SC-Sed-	31-1/2/3								
Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Total Organic Carbon	33.0	130	127	167	164	mg/kg	103	103	80-120	2	20	
Matrix Spike: 28158					Matrix Spi	ke Dupli	cate: 281	59				
Original for Sam	ple: Client sa	mple S	CF-Sed-	9-1/2/3								
Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Total Organic Carbon	18.5	130	128	154	150	mg/kg	105	103	80-120	3	20	



# Pace Project No.: 756036

Analyte	Method	Unadjusted MQL	Reporting Units
Arsenic	EPA 6010	0.25	mg/kg
Cadmium	EPA 6010	0.10	mg/kg
Lead	EPA 6010	0.20	mg/kg
Total Organic Carbon	EPA 9060M	5.0	mg/kg



# Pace Project No.: 756036

# DEFINITIONS

- DF Dilution Factor
- J Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.
- U Indicates the compound was analyzed for, but not detected.
- SDL Sample Detection Limit
- MQL Method Quantitation Limit
- LCS(D) Laboratory Control Sample (Duplicate)
- MS(D) Matrix Spike (Duplicate)
- DUP Sample Duplicate
- RPD Relative Percent Difference
- TNI The Nelac Institute

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

# ANALYTE QUALIFIERS

Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

# 2014 EXIDE APAR PAGE 2596 OF 3116

		TRRP LABORATORY REVIEW CHECKLIST					
L	aboratory	Pace Analytical Services, Inc. LRC Date: 06	/26/2013				
Proje	ect Name:	0111C278A/SC Sediment Sampling Laboratory Job Number: 75	6036				
Review	ver Name:	Shelly Connelly Prep Batch Number(s): Set	e exception	report.			
#1	<b>A</b> <sup>2</sup>	Description	Yes	No	NA <sup>3</sup>	NR <sup>4</sup>	ER #
R1	OI	Chain-of-custody (C-O-C)					
		Did samples meet the laboratory's standard conditions of sample acceptability upon receipt?	x				
		Were all departures from standard conditions described in an exception report?	×				
D2	0	Sample and quality control (OC) identification					
Π <b>2</b>	U	Are all field cample ID numbers cross referenced to the laboratory ID numbers?	v				
		Are all laboratory ID numbers cross referenced to the corresponding OC data?					
D2	0		^				
КJ	U	Were all camples prepared and analyzed within helding times?	v				
		Other than those results < MQL, were all other raw values bracketed by calibration standards'	2				
			X				
		Were calculations checked by a peer or supervisor?	Х				
		Were all analyte identifications checked by a peer or supervisor?	Х				
		Were sample detection limits reported for all analytes not detected?	Х				
		Were all results for soil and sediment samples reported on a dry weight basis?	Х				
		Were % moisture (or solids) reported for all soil and sediment samples?	Х				
		Were bulk soils/solids samples for volatile analysis extracted with methanol per SW846 Metho	d		Х		
		5035?					
D4	0	Surrogate recovery data			^		
π4	U	Were surrogates added prior to extraction?			v		
		Were surrogates added phot to extraction?					
DE		Test reporte/summary forms for black samples					
КĴ	U	Were appropriate type(e) of blank applyzed?	v				
		Were block analyzed at the appropriate frequency?					
		Were method blanks taken through the entire analytical process including preparation and if	^				
		applicable, cleanup procedures?	Х				
		Were blank concentrations < MQL?	Х				
R6	OI	Laboratory control samples (LCS):					
		Were all COCs included in the LCS?	Х				
		Was each LCS taken through the entire analytical procedure, including prep and cleanup step	s? X				
		Ware LCSs applyized at the required frequency?	v				
		Were LCS analyzed at the required frequency:					
		Does the detectability check sample data document the laboratory's capability to detect the C					
		at the MDL used to calculate the SDLs?	X				
		Was the LCSD RPD within QC limits?			Х		
R7	OI	Matrix spike (MS) and matrix spike duplicate (MSD) data					
		Were the project/method specified analytes included in the MS and MSD?	Х				
		Were MS/MSD analyzed at the appropriate frequency?	Х				
		Were MS (and MSD, if applicable) %Rs within the laboratory QC limits?		Х			R7.3
		Were MS/MSD RPDs within laboratory QC limits?	Х				
R8	OI	Analytical duplicate data					
		Were appropriate analytical duplicates analyzed for each matrix?	Х				
		Were analytical duplicates analyzed at the appropriate frequency?	Х				
	-	Were RPDs or relative standard deviations within the laboratory QC limits?	Х				
R9	OI	Method quantitation limits (MQLs):					
		Are the MQLs for each method analyte included in the laboratory data package?	Х				
		Do the MQLs correspond to the concentration of the lowest non-zero calibration standard?	X				
		Are unadjusted MQLs and DCSs included in the laboratory data package?	X				
R10	OI	Other problems/anomalies					
		Are all known problems/anomalies/special conditions noted in this LRC and FR?	X				
		Was applicable and available technology used to lower the SDL to minimize the matrix		1			
		interference effects on the sample results?	X				
		Is the laboratory NELAC-accredited under the Texas Laboratory Accreditation Program for the	) X				
1.	Items identifie	entarytes, mannees, and memous associated with this laboratory data package ? ed by the letter "R" must be included in the laboratory in the laboratory data package submitted in the TRRP-required reports(s	). Items identifie	d by the	1	1	1
0	letter "S" sho	uld be retained and made available upon request for the appropriate retention period;					
2. 3.	NA = Not app	anaiyses, i – morganic anaiysises (anu generai Chemistry, When applicable); Nicable;					
4. F	NR = Not rev	iewed; tion Papart identification number (an Exception Papart should be completed for an item if "NP" or "No" is shorted)					
ວ.	ER# = Excep	non report achuncation number (an Exception report should be completed for an item it ink or no is checked).					

#### 2014 EXIDE APAR PAGE 2597 OF 3116 **TRRP LABORATORY REVIEW CHECKLIST** Laboratory Pace Analytical Services, Inc. LRC Date: 06/26/2013 **Project Name:** 0111C278A/SC Sediment Sampling Laboratory Job Number: 756036 **Reviewer Name:** Shelly Connelly Prep Batch Number(s): See exception report. NA<sup>3</sup> NR<sup>4</sup> ER #<sup>5</sup> **#**<sup>1</sup> $A^2$ Description Yes No **S1** OI Initial calibration (ICAL) Х Were response factors and/or relative response factors for each analyte within QC limits? Were percent RSDs or correlation coefficient criteria met? Х Was the number of standards recommended in the method used for all analytes? Х Were all points generated between the lowest and highest standard used to calculate the curve? Х Are ICAL data available for all instruments used? Х Has the initial calibration curve been verified using an appropriate second source standard? Х Initial and continuing calibration verification (ICCV and CCV) and continuing calibration S2 OI blank (CCB): Was the CCV analyzed at the method-required frequency? Х Were precent differences for each analyte within the method-required QC limits? Х Was the ICAL curve verified for each analyte? Х Х Was the absolute value of the analyte concentration in the inorganic CCB < MDL? **S**3 Ο Mass spectral tuning Was the appropriate compound for the method used for tuning? Х Were ion abundance data within the method-required QC limits? Х S4 ο Internal standards (IS) Were IS area counts and retention times within the method-required QC limits? Х OI **S**5 Raw data (NELAC Section 5.5.10) Х Were the raw data (for example, chromatograms, spectral data) reviewed by an analyst? Were data associated with manual integrations flagged on the raw data? Х **S6** Ο Dual column confirmation Did dual column confirmation results meet the method-required QC? Х **S7** Ο Tentatively identified compounds (TICs) If TICs were requested, were the mass spectra and TIC data subject to appropriate checks? х **S8** Т Interference Check Sample (ICS) results Х Were percent recoveries within method QC limits? **S**9 L Serial dilutions, post digestion spikes, and method of standard additions Were percent differences, recoveries, and the linearity within the QC limits specified in the Х method? S10 OI Method detection limit (MDL) studies Was a MDL study performed for each reported analyte? Х Х is the MDL either adjusted or supported by the analysis of DCSs? S11 OI Proficiency test reports Was the laboratory's performance acceptable on the applicable proficiency tests or evaluation Х studies? S12 OI Standards documentation Are all standards used in the analyses NIST-traceable or obtained from other appropriate Х sources? S13 OI Compound/analyte identification procedures Are the procedures for compound/analyte identification documented? Х S14 OI Demonstration of analyst competency (DOC) Х Was DOC conducted consistent with NELAC Chapter 5? Х is documentation of the analyst's competency up-to-date and on file? Verification/validation documentation for methods (NELAC Chapter 5) S15 οι Are all the methods used to generate the data documented, verified, and validated, where Х applicable? Laboratory standard operating procedures (SOPs) S16 οι Are laboratory SOPs current and on file for each method performed? Х Items identified by the letter "R" must be included in the laboratory in the laboratory data package submitted in the TRRP-required reports(s). Items identified by the 1. letter "S" should be retained and made available upon request for the appropriate retention period; 2. O = Organic analyses; I = inorganic analysises (and general chemistry, when applicable); NA = Not applicable; 3. 4 NR = Not reviewed:

5. ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked).

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		TRRP LABORATORY	REVIEW CHECKLIST								
La	aboratory	Pace Analytical Services, Inc.	LRC Date:	06/26/2013							
Proje	ect Name:	0111C278A/SC Sediment Sampling	Laboratory Job Number:	756036							
Review	er Name:	Shelly Connelly	Prep Batch Number(s):	6806,6885,6975							
ER # <sup>1</sup>		Γ	Description								
R7.3	MS Sample	#27349: Arsenic 60% spike recovery outside laboratory	QC limit of 75-125%.								
R7.3	MS Sample	#27349: Cadmium 60% spike recovery outside laborato	ry QC limit of 75-125%.								
R7.3	MS Sample #27349: Lead 54% spike recovery outside laboratory QC limit of 75-125%.										
R7.3	MS Sample #27351: Arsenic 59% spike recovery outside laboratory QC limit of 75-125%.										
R7.3	MS Sample #27351: Cadmium 59% spike recovery outside laboratory QC limit of 75-125%.										
R7.3	MS Sample	#27351: Lead 52% spike recovery outside laboratory Q	C limit of 75-125%.								
R7.3	MSD Samp	le #27350: Arsenic 61% spike recovery outside laborator	y QC limit of 75-125%.								
R7.3	MSD Samp	le #27350: Cadmium 62% spike recovery outside laboration	tory QC limit of 75-125%.								
R7.3	MSD Samp	le #27350: Lead 55% spike recovery outside laboratory (	QC limit of 75-125%.								
R7.3	MSD Samp	le #27352: Arsenic 63% spike recovery outside laborator	y QC limit of 75-125%.								
R7.3	MSD Sample #27352: Cadmium 65% spike recovery outside laboratory QC limit of 75-125%.										
R7.3	.3 MSD Sample #27352: Lead 56% spike recovery outside laboratory QC limit of 75-125%.										
1.	1. ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked).										

			Zhovet (Victor Burn Hill Charles)			I	<u> </u>	<u>د</u> ا	<sup>7</sup> אי ר.	-91		-		~	~~	1		9792/2009284		
	mp. of coolers ep received (C°): 0/2 3 4 5	je 1 of Zu			e ID (Lab Use Only)	00	003-1	0031	004 2	0022	0062	8	008 3	2 400	010-			~ ~	n	άλλη τη την την την την την την την την την
756036 756036	Tem	Page			Lab Sample										· · · · · · · · · · · · · · · · · · ·	NOTES:	Sc-Sed-31-1 through Sc-Sed-31-3	56-5ed-32-1 through Sc-Sed-32-3		* Temp blank included
ANALYSIS REQUESTED	0107 #	17-12 14 7/23	2 Sw.	E10 / 90	12 Jet 21	XX				-					××	Time:	1. 1. Time:	//3 /3 <i>25</i>	Time	
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Laborat	ts Address	Phone:	Sampler's	nt Seume	I ing Marks of Sam	ed - 31 -1	Jed-31-2	xd -31- 3	rd-3L-	Sed - 32-	Sed - 32-	320-33-	id- 33.	Rd- 39.	Ed-34-		7 1 6 %	1	Timo:	
Vest	logic consultan	Wosdi	Ichia A	oject Name Schimer	G Identify	X SC-S	1 Sc - 1	Sc-1	Sc- (	- X	Ś	s. S	Sc-S	15-5	$ X  S_{-3}$	Date:	Date:	0.0 6/13/13 Date:	Data.	
uthv	an Dalla	ager R. Sim	linter N	5 48	- Time	1736	1339	1342	10-11	1409	1413	1437	1441	1444	1504	(Signature)	/ (Signature)	<u>9,45   4 A I La</u> 1 (Signatube)	(Cicrosture)	
	Environmen	Project Man	Sampler's Nam Luson Num	PINC27	Aatrix Date	S WID13	میں میں اور		201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 - 201 -						S What	Jelinquished by	Relinquished by	Chapter 6 .	Solinguiched by	

WOT 150036 CHAIN OF CUSTODY RECORD	Lab use only Due Date: Tema. of coolers	when peceived (C°):	Page L of Det			Lab Sample ID (Lab Use Only)	700	004	500	605 05	200	200	20	900	607	600		situ de fellovine:	through SC-sed-34-3	Humple Sc - Sed - 36 - 3	1 through Sc - Sed -37-3	
	ALYSIS DUESTED	48-115 105 - 56 105 - 56	+ 755 #	2. C.	Toland P. Toland	12421	~							-		×		U.4.0 Please compe	Time:	Time: \$5 - 20 - 50 - 1	Time: , 50 ~ 5ed - 37 ~	oal tube SL - sludge O - Oil stic or other
	Inallyficol Rea	-1123		A. M. S. M.	No/Type of Containers	VOA A/G 250 P/O										× –		ure) Date: ノスチーCON 6//3//3	ure) Date: Mare 113/13	ure) Date:	ure) Date:	A - Air Bag C - Charc alass wide mouth P/O - Plas
	aboratory: <u>PACE</u> A	ontact: 972-727-	none:	ampler's Signature	Sampling	of Sample(s) Cepth Start Depth	-2	34-3	35-1-	35-2 -	35-3 +	36-1	-36-2 -	-36-3	- 37- 1	- 37-2 +	0% Rush	Hereived by: (Signatu	ne: Received by: (Signatu	ne: Received by: (Signatu	ne: Received by: (Signatu	Soil SD - Solid L - Liquid ilass 1 Liter 250 ml - G
	WEST La NO E A	ts, TX c	A Wysch	Nahlia Alaaya	roject Name SC Sediment	C G I G Identifying Marks	× 8-5434	Sc-Sed-	Sc-Sed-	Sc-Sed-	Sc-Sed-	Se-Sed-	Sc-Sed-	Sc - Sed.	1 Sc - Sed	X Sc- Sed	al25% Rush5	Date: Tin	Tin Date: Tin	Date: Tin	Date: Tin	W - Water S - A/G - Amber / Or G
	South GEOSC Frienmental & Hindraded	Office Location Dalla	Project Manager R. Sit	Sampler's Name Jason Numter Tommy Kim P	Proj. No. / P	Matrix Date Time	S 1/12/13 1508	1 1512	1556	1559	1002	1622	1625	8211	0511	S 4/12/13 1753	Turn around time	Relinquished by (Signature)	Relinquished by (Signature)	Relinquished by (Signature)	Relinquished by (Signature)	Matrix WW - Wastewater Container VOA - 40 ml vial

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SOUTHWEST GEOSCIENCE • 2351 W. Northwest Hwy., Suite 3321 • Dallas, Texas 75220 • Office: 214-350-5469 • Fax 214-350-2914

CST Lab	ooratory: Pace Analyfico	ANALYSIS REQUESTED	Temp. of coolers
S. TX Con	11act: 972-757- 1133	- M5 (109 #	231
DSUN PON	one:	The second	Page of 27
lahliq Abay	npler's Signature	M. C.	
st Name Stoli ment	Sampline Nortype of Config	iners 200	
G r ldentifying Marks of b	f Sample(s) the Depth OA A/G 25( Starth Depth VOA A/G 25( Depth Depth VOA A/G 25( 11t. ml	124-51 OId C	Lab Sample ID (Lab Use Only)
X Sc-Sud-3-	1-2-1	× ×	200
1 Sc - Sed - 3			008
Sc-Sed-3	38-2		008
S-Sed	36-3		008
Sc-Sid-	39-1 -		500
Sc - Sed -	39-2 -		600
S- Sed -	39:3 -		000
Sc - Seol - 1	- 1-04		010
- Sed -	40-2 -		010
X SC - Sed - ( 1 25% Rich 750%			(DI O
Date: Time:	Received by: (Signature)	Date: Time: NOTES:	
Eustry rit	S JACKIL GUBS / BAICON	6/13/13 12 4 Please compo	osite the following:
6/13/13 1.25	Katha /////mw/Pare	1/3/3/3/335- 5C-Sed-38-1	fliring Sc-Sed-38-3
Date: Time:	Received by: (Signature)	Date: Time: $-5c - 5cd - 59 - ($	through Sc - Sed - 59 - 3 through Sc - Sed - 40 - 3
Date: Time:	Received by: (Signature)	Date: Time: 20 - 20 - 50	)
W - Water S - So	oil SD - Solid L - Liquid A - Air Bag	C - Charcoal tube SL - sludge O - Oil	

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#### 2014 EXIDE APAR PAGE 2602 OF 3116

۸.	2014 EX	XIDE A	PAR P	AGE 2603 OF 3116
Sam	ple Co	ondit	ion l	Jpon Receipt
Face Analytical Client Name:	Sol	vthi	URST	Geoscience Pace #: 156036
Courier: Fed Ex UPS USPS Client	Юс	ourier	□ls	O Pace Other
Custody Seal on Cooler/Box Present: $\sqrt{2}$		<b>`</b>	Soole	
	L (1C	,	Seals	
Packing Material: Bubble Wrap Bubble B	ags	∐No	ine	
Cooler Temperature	Type / ice \	of Ice: /isible	Wet in Sar	Image: Provide the second state of
Corrected, if applicable)				Comments:
Sample Receiving				
Chain of Custody Present:	Î∕ <b>⊠</b> Yes	□No	□N/A	1.
Chain of Custody Filled Out:	₽Yes	□No	□n/a	2.
Chain of Custody Relinquished:	₿Yes	□No	□n/a	3.
Sampler Name & Signature on COC:	<b>P</b> Yes	□No	□n/a	4.
Short Hold Time Analysis (<72hr):	□Yes	No	□n/A	5.
Rush Turn Around Time Requested:	□Yes	Mo	□n/a	6.
Containers Intact:	Fres	□No	□n/a	7.
Sample Labels match COC:	ØYes	□No	□n/a	8.
-Includes date/time/ID/Analysis				
All containers needing acid/base pres. have been checked?	□Yes	□No	1 <b>µ⊡</b> N/A	9. (Circle) HNO3 H2SO4 NaOH HCI
exceptions: VOA, coliform, O&G				If applicable see below.
All containers needing preservation are found to be in compliance with EPA recommendation.	□Yes	□No	<b>I</b> €N/A	pH strip lot #:
				······································
				Potassium lodide strip lot #:
				Lead Acetate strip lot #:
Headspace in VOA Vials ( >6mm):	□Yes	□No		10.
Trip Blank Present:	□Yes	□No	ØN/A	11.
Trip Blank Custody Seals Present	□Yes	□No	DON/A	
Samples Arrived within Hold Time:	<b>∳</b> Yes	□No	□n/a	12.
Sufficient Volume:	AYes	□No	⊡n/A	13.
Correct Containers Used:	<b>₽</b> Yes	□No	□n/A	14.
Client Notification/ Resolution:				
Person Contacted:			_Date/	Time:
Comments/ Resolution:				
· · · · · · · · · · · · · · · · · · ·			_	
Project Manager Review:	i	m	Ċ	Date: 10-77-13

Sample Container Count

Face Analytical"

COC PAGE \_\_\_\_\_ of \_\_\_\_\_ COC ID# \_\_\_\_\_\_

756036 Pace Project #\_

BP20			:
AG1S			
BG1H			
BP2U		-	
BP1U			
BP2S			
VG9H			
VG9U			
AG1U			
2N			

Comments												
GFU WGKU	m											
SP5T W	,			ເງ 	M		m		1	ίη	Μ	$\sum$
BP20												
AG1S												
BG1H												
BP2U											-	
BP1U												
BP2S		~										
NG9H												
VG9U												
AG1U										1		
BP2N												
Sample Line Item	-	6	1 0	4	5	. c	7 0	- ~	ი ი	10		5

Г				1	1			[							
	DG9P 40mL TSP amber vial	DG9S 40mL H2SO4 amber vial	DG9T 40mL Na Thio amber vial	DG9U 40mL unpreserved amber vial	I Wipe/Swab	JGFU 4oz unpreserved amber wide	U Summa Can	VG9H 40mL HCL clear vial	VG9T 40mL Na Thio. clear vial	VG9U 40mL unpreserved clear vial	VSG Headspace septa vial & HCL	WGFX 4oz wide jar w/hexane wipe	ZPLC Ziploc Bag	GN General unpreserved	
	P1N 1 liter HNO3 plastic	P1S 1 liter H2SO4 plastic	P1U 1 liter unpreserved plastic	P1Z 1 liter NaOH, Zn, Ac	P2A 500mL NaOH, Asc Acid plastic	P20 500mL NaOH plastic	P2Z 500mL NaOH, Zn Ac	P3A 250mL NaOh, Asc Acid plastic	P3C 250mL NaOH plastic	P3Z 250mL NaOH, Zn Ac plastic	C Air Cassettes	G9B 40mL Na Bisulfate amber vial	39M 40mL MeOH clear vial	P5U 120mL Coliform unpreserved	
	AF Air Filter	AG1H 1 liter HCL amber glass E	AG1S 1 liter H2SO4 amber glass E	AG1T 1 liter Na Thiosulfate amber gl	AG2N 500mL HNO3 amber glass E	AG2S 500mL H2SO4 amber glass B	AG2U 500mL unpreserved amber gla E	AG3U 250mL unpreserved amber gla E	BG1H 1 liter HCL clear dlass E	BG1S 1 liter H2SO4 clear glass E	BG1T 1 liter Na Thiosulfate clear gla	BG1U 1 liter unpreserved glass D	BP1A 1 liter NaOH, Asc Acid plastic D	SP5T 120mL Coliform Na Thiosulfate S	
Container Codes	40mL HCL amber voa vial	1liter unpreserved amber glass	4oz clear soil iar	terra core kit	500mL HNO3 plastic	500mL unpreserved plastic	500ml H2SO4 plastic	250mL HNO3 plastic	250ml innreserved plastic	250ml H2SO4 plastic	250ml H2SO4 dlass amber	1 liter H2SO4 amber dlass	1 liter unbreserved plastic	Rnz wide iar ubreserved	Other
)	DG9H	AG1U	WGFU		BP2N	BP2U	RP2S	RP3N	BD311	BP3S	AG3S	AG1S		MGKU 5	Other

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Sample Container Count



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DC PAGE	

Pace Project # 75h036

coc ID#	Sample Line Item		5	e	4	5	9	7	ø	6	10	 12
	BP2N											
	AG1U											
I	VG9U											
	VG9H											
	BP2S											
	BP1U											
	BP2U											
Pace F	BG1H											
Project	AG1S											
~// #	BP20											
09	SP5T											
20	WGFU V	3										
l	VGKU											
	Comn									-		
	nents											-
	F							1	1	-	1	

ſ															
	DG9P 40mL TSP amber vial	DG9S 40mL H2SO4 amber vial	DG9T 40mL Na Thio amber vial	DG9U 40mL unpreserved amber vial	I Wipe/Swab	JGFU 4oz unpreserved amber wide	U Summa Can	VG9H 40mL HCL clear vial	VG9T 40mL Na Thio. clear vial	VG9U 40mL unpreserved clear vial	VSG Headspace septa vial & HCL	NGFX 4oz wide jar w/hexane wipe	ZPLC Ziploc Bag	GN General unpreserved	
	BP1N 1 liter HNO3 plastic	BP1S 1 liter H2SO4 plastic	BP1U 1 liter unpreserved plastic	BP1Z 1 liter NaOH, Zn, Ac	BP2A 500mL NaOH, Asc Acid plastic	BP20 500mL NaOH plastic	BP2Z 500mL NaOH, Zn Ac	BP3A 250mL NaOh, Asc Acid plastic	BP3C 250mL NaOH plastic	BP3Z 250mL NaOH, Zn Ac plastic	C Air Cassettes	DG9B 40mL Na Bisulfate amber vial	DG9M 40mL MeOH clear vial	SP5U 120mL Coliform unpreserved	
	AF Air Filter	AG1H 1 liter HCL amber glass	AG1S 1 liter H2SO4 amber glass	AG1T 1 liter Na Thiosulfate amber gl	AG2N 500mL HNO3 amber glass	AG2S 500mL H2SO4 amber glass	AG2U 500mL unpreserved amber gla	AG3U 250mL unpreserved amber gla	BG1H 1 liter HCL clear glass	BG1S 1 liter H2SO4 clear glass	BG1T 1 liter Na Thiosulfate clear gla	BG1U 1 liter unpreserved glass	BP1A 1 liter NaOH, Asc Acid plastic 1	SP5T 120mL Coliform Na Thiosulfate	
Container Codes	40mL HCL amber voa vial	1liter unpreserved amber glass	4oz clear soil jar	terra core kit	500mL HNO3 plastic	500mL unpreserved plastic	500mL H2SO4 plastic	250mL HNO3 plastic	250mL unpreserved plastic	250mL H2SO4 plastic	250mL H2SO4 glass amber	1 liter H2SO4 amber glass	1 liter unpreserved plastic	8oz wide jar upreserved	Other
	DG9H	AG1U	WGFU	R	BP2N	BP2U	BP2S	BP3N	BP3U	BP3S	AG3S	AG1S	BP1U	WGKU	Other

# 2014 EXIDE APAR PAGE 2605 OF 3116

# DATA USABILITY SUMMARY

John J. LeGolvan reviewed one data package from Pace Analytical Services, Inc. (Pace) for the analysis of sediment samples collected June 19, 2013 at the Stewart Creek site in Frisco, Texas. Data were reviewed for conformance to the requirements of the guidance document, *Review and Reporting of COC Concentration Data* (RG-366/TRRP-13) and adherence to project objectives.

**Intended Use of Data**: The objective of the sediment sampling event was to provide current data on concentrations of chemicals of concern (COCs) in the sediment at the affected property.

Analyses requested included:

- EPA 6010 RCRA 3 Metals (Arsenic, Cadmium, and Lead)
- EPA 9060M Extractable Organic Carbon

Data were reviewed and validated as described in *Review and Reporting of COC Concentration Data*, (RG-366/TRRP-13) and the results of the review/validation are discussed in this Data Usability Summary (DUS). The following laboratory submittals and field data were examined:

- the reportable data,
- the laboratory review checklists and associated exception reports, and
- the field notes with respect to sampling procedures, and preservation procedures prior to shipping the samples to the laboratory.

The results of supporting quality control (QC) analyses were summarized on the Laboratory Review Checklists (LRCs), Exception Reports (ERs) and in the case narratives, all of which were included in this review.

The complete laboratory analytical data package including LRCs, associated ERs, and reportable data included in this review are attached to this DUS.

## Introduction

Eight (8) sediment samples were collected from the site and analyzed for RCRA Metals arsenic, cadmium, and lead analyses and extractable organic carbon. Table 1 lists the field sample identification cross-referenced to the laboratory identification.

## **Project Objectives**

RCRA 3 Metals (Arsenic, Cadmium, and Lead) Recovery 75-125% RPD 0-20%

Extractable Organic Carbon Recovery 80-120% RPD 0-20%

# TABLE 1 Stewart Creek, Frisco, Texas DATA USABILITY SUMMARY - FIELD/LAB IDENTIFICATION CORRELATION

Field Identification	Laboratory Identification
SC-SED-41-1R/2R/3R	756280001
SC-SED-42-1R/2R/3R	756280002
SC-SED-43-1R/2R/3R	756280003
SC-SED-44-1/2/3	756280004

# TABLE 1Stewart Creek, Frisco, TexasDATA USABILITY SUMMARY - FIELD/LAB IDENTIFICATION CORRELATION

Field Identification	Laboratory Identification	
SC-SED-45-1/2/3	756280005	
SC-SED-46-1/2/3	756280006	
SC-SED-47-1/2/3	756280007	
SC-SED-48-1/2/3	756280008	

#### Data Review / Validation Results

#### Analytical Results

Qualified sample data is listed in Table 2. Non-detected results were reported as U, which is less than the Sample Detection Limits (SDLs) as reported by Pace.

## Preservation and Holding Times

Sediment samples were evaluated for agreement with the chain-of-custody (C-O-C) and the Laboratory Review Checklist. All samples were received in the appropriate containers and in good condition with the paperwork filled out properly. Sample receipt temperatures were within the acceptance criteria of  $4 \pm 2$  °C. Samples were preserved in the field as specified in SW-846 Table 2-36. Samples were prepared and analyzed within holding times specified in SW-846 Table 2-36.

## Calibrations

According to the LRC, initial calibration data met SW-846 method requirements for the analytes.

#### Blanks

Laboratory method blank data was reported for each of the selected analytes. None of the analytes were detected above the laboratory MDLs in the method blanks; therefore, it appears that no laboratory contaminants were introduced in the method blank analyses.

## Internal Standard and Surrogate Recoveries (RCRA 3 Metals)

Due to the method in use, internal standards and surrogates were not used in the analyses.

# Laboratory Control Samples

RCRA 3 Metals laboratory control sample (LCS) recoveries met project objectives of 75 to 125% recovery. Extractable Organic Carbon laboratory control sample (LCS) recoveries met project objectives of 80 to 120% recovery.

#### Matrix Spike/Matrix Spike Duplicates

The MS recoveries from batch 7029 for arsenic, cadmium, and lead were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

The MSD recoveries from batch 7029 for arsenic, cadmium, and lead were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

TABLE 2 Stewart Creek, Frisco, Texas				
DATA USABILITY SUMMARY - QUALIFIED DATA				
Field Identification	Analyte	Qualification	Reason for Qualification	
Not Applicable				

# **Field Procedures**

The laboratory did not produce a duplicate analysis of the sediment samples collected at the site. A field precision sample was not collected in the field.

# Summary

The laboratory analyses were performed within the guidelines of the standards specified in the TRRP-13 guidance document. The laboratory QC indicates acceptable instrument calibration and performance. MS/MSD results indicated lower than expected recovery results from several batches which were run; however, the LCS/LCSD recoveries in each case were within the lab QC limits and within the project objective. The overall quality of the laboratory data appears to be acceptable for the project objective. The sediment analytical data are usable for the purpose of determining current COC concentrations in sediment at the affected property.



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

July 01, 2013

Rusty Simpson Southwest Geoscience 2351 W. Northwest Hwy Suite 3321 Dallas, TX 75220

RE: Pace Project 756280 Project ID: 0111C278A/SC Sediment Sampling

Dear Rusty Simpson:

Enclosed are the analytical results for sample(s) received by the laboratory on June 20, 2013. Results reported herin conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Shelly Connelly/

Shelly Connelly shelly.connelly@pacelabs.com

Laboratory Certifications Pace Dallas : Texas Certification #: T104704232-12-4



# **REPORT OF LABORATORY ANALYSIS**

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### Pace Project No.: 756280

### Client: <u>Southwest Geoscience</u> Project ID: <u>0111C278A/SC Sediment Sampling</u>

Client Sample ID	Lab ID	Matrix	Collection Date/Time	Received Date/Time
SC-SED-41-1R/2R/3R	756280001	Solid	06/19/2013 11:58	06/20/2013 13:26
SC-SED-42-1R/2R/3R	756280002	Solid	06/19/2013 12:22	06/20/2013 13:26
SC-SED-43-1R/2R/3R	756280003	Solid	06/19/2013 12:48	06/20/2013 13:26
SC-SED-44-1/2/3	756280004	Solid	06/19/2013 14:18	06/20/2013 13:26
SC-SED-45-1/2/3	756280005	Solid	06/19/2013 14:50	06/20/2013 13:26
SC-SED-46-1/2/3	756280006	Solid	06/19/2013 15:08	06/20/2013 13:26
SC-SED-47-1/2/3	756280007	Solid	06/19/2013 15:48	06/20/2013 13:26
SC-SED-48-1/2/3	756280008	Solid	06/19/2013 16:11	06/20/2013 13:26



### **Project Narrative**

Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Pace Project No.: 756280

Holding Times:

All holding times were met.

Blanks:

All blank results were below reporting limits.

Laboratory Control Samples:

All LCS recoveries were within QC limits.

Matrix Spikes and Duplicates:

MS or MSD recoveries outside of QC limits are qualified in the Report of Quality Control section.

Surrogate:

All surrogate recoveries were within QC limits.

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Appendix A

#### LABORATORY DATA PACKAGE COVER PAGE

This data package is for Job No. 756280 and consists of:

This signature page, the laboratory review checklist, and the following reportable data:

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- R1 Field chain-of-custody documentation;
- R2 Sample identification cross-reference;
- R3 Test reports (analytical data sheets) for each environmental sample that includes:
  - a. Items consistent with NELAC Chapter 5,
  - b. Dilution factors,
  - c. Preparation methods,
  - d. Cleanup methods, and
  - e. If required for the project, tentatively identified compounds (TICs).
- R4 Surrogate recovery data including:
  - a. Calculated recovery (%R), and
  - b. The laboratory's surrogate QC limits.
- R5 Test reports/summary forms for blank samples;
- R6 Test reports/summary forms for laboratory control samples (LCSs) including:
  - a. LCS spiking amounts,
  - b. Calculated %R for each analyte, and
  - c. The laboratory's LCS QC limits.
- R7 Test reports/summary forms for matrix spike/matrix spike duplicates (MS/MSDs) including:
  - a. Samples associated with the MS/MSD clearly identified,
  - b. MS/MSD spiking amounts,
  - c. Concentration of each MS/MSD analyte measured in the parent and spiked samples,
  - d. Calculated %Rs and relative percent differences, and
  - e. The laboratory's MS/MSD QC limits.
- R8 Laboratory analytical duplicate (if applicable) recovery and precision:
  - a. The amount of analyte measured in the duplicate,
  - b. The calculated RPD, and,
  - c. The laboratory's QC limits for analytical duplicated.
  - R9 List of method quantitation limits (MQLs) and detectability check sample results for each analyte and
  - R10 Other problems or anomalies.

The exception Report for each "No" or "Not Reviewed (NR) " item in the Laboratory Review Checklist and for each analyte, matrix, and method for which the laboratory does not hold NELAC accreditation under the Texas Laboratory Accreditation Program.

**Release Statement:** I am responsible for the release of this laboratory data package. This laboratory is NELAC accredited under the Texas Laboratory Accreditation Program for all the methods, analytes, and matrices reported in this data package except as noted in the Exception Reports. The data have been reviewed and are technically compliant with the requirements of the methods used, except where noted by the laboratory in the Exception Reports. By my signature below, I affirm to the best of my knowledge all problems/anomalies observed by the laboratory have been identified in the Laboratory Review Checklist, and no information affecting the quality of the data has been knowingly withheld.

Check, if applicable: [] This laboratory meets an exception under 30 TAC §25.6 and was last inspected by [X] TCEQ on 02/24/2012

Any findings affecting the data in this laboratory data package are noted in the Exception Reports herin. The official signing the cover page of the report in which these data are used is responsible for releasing this data package and is by signature affirming the above release statement is true.

Name (Printed)	
Shelly Connelly	

<u>Signature</u> Stally (orrelg) <u>Official Title (Printed)</u> Project Manager Date

07/01/2013



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-SED-41</u> Lab ID: <u>756280001</u> Collected: <u>06/19/2013</u>	41-1R/2R/3R 11 Moisture: <u>29.3%</u> 3 11:58 Received: <u>06/20/2013 13</u>					Project ID:0111C278A/SC SedimentPace Project No.:7562803:26Matrix:Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Anal	ytical Method:	EPA 60 <sup>2</sup>	10	Prepa	ration Met	hod: EPA 3050				
Arsenic	1	24.9	n	ng/kg	0.37	0.15	06/25/2013 20:22	06/24/2013 05:00	7029	75ICP1	
Cadmium	1	0.35	n	ng/kg	0.15	0.029	06/25/2013 20:22	06/24/2013 05:00	7029	75ICP1	
Lead	1	13.1	n	ng/kg	0.29	0.074	06/25/2013 20:22	06/24/2013 05:00	7029	75ICP1	
Extractable Organic Carbon	Anal	ytical Method:	EPA 906	60M	Prepa	ration Met	hod: EPA 9060M				
Total Organic Carbon	1	40.5	n	ng/kg	7.1	3.5	06/28/2013 11:53	06/25/2013 14:38	7100	75WTA1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-SED-42</u> Lab ID: <u>756280002</u> Collected: <u>06/19/2013</u>	<u>-1R/2R/3R</u> Moisture: <u>19.5%</u> <u>12:22</u> <b>Received:</b> <u>06/20/2013 13:26</u>					Project ID: 0111C278A/SC Sediment Pace Project No.: 756280 Matrix: Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	10.8	n	ng/kg	0.31	0.12	06/25/2013 20:47	06/24/2013 05:00	7029	75ICP1
Cadmium	1	0.35	n	ng/kg	0.12	0.025	06/25/2013 20:47	06/24/2013 05:00	7029	75ICP1
Lead	1	8.6	n	ng/kg	0.25	0.061	06/25/2013 20:47	06/24/2013 05:00	7029	75ICP1
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M			
Total Organic Carbon	1	32.6	n	ng/kg	6.1	3.1	06/28/2013 13:42	06/25/2013 14:38	7100	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-SED-43</u> Lab ID: <u>756280003</u> Collected: <u>06/19/2013</u>	<u>B-1R/2R/3R</u> Moisture: <u>29.4%</u> 12:48 Received: <u>06/20/2013 13:2</u>					Project ID: 0111C278A/SC Sediment Pace Project No.: 756280 26 Matrix: Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Anal	/tical Method:	EPA 601	10	Prepa	ration Met	hod: EPA 3050				
Arsenic	1	20.1	n	ng/kg	0.37	0.15	06/25/2013 20:54	06/24/2013 05:00	7029	75ICP1	
Cadmium	1	1.5	n	ng/kg	0.15	0.030	06/25/2013 20:54	06/24/2013 05:00	7029	75ICP1	
Lead	1	14.3	n	ng/kg	0.30	0.074	06/25/2013 20:54	06/24/2013 05:00	7029	75ICP1	
Extractable Organic Carbon	Anal	tical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M				
Total Organic Carbon	1	17.5	n	ng/kg	6.9	3.5	06/28/2013 14:16	06/25/2013 14:38	7100	75WTA1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-SED-44</u> Lab ID: <u>756280004</u> Collected: <u>06/19/2013</u>	<u>-1/2</u> 14:1	/ <u>3</u> Moiste 18 Receiv	ure: <u>22</u> ved: <u>06</u>	<u>.5%</u> /20/2013	<u>13:26</u>	Project ID: 0111C278A/SC Sediment Pace Project No.: 756280 Matrix: Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	lytical Method:	EPA 60 <sup>2</sup>	10	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	12.8	n	ng/kg	0.34	0.13	06/25/2013 21:01	06/24/2013 05:00	7029	75ICP1
Cadmium	1	0.39	n	ng/kg	0.13	0.027	06/25/2013 21:01	06/24/2013 05:00	7029	75ICP1
Lead	1	12.1	r	ng/kg	0.27	0.067	06/25/2013 21:01	06/24/2013 05:00	7029	75ICP1
Extractable Organic Carbon	Ana	lytical Method:	EPA 906	60M	Prepa	ration Met	hod: EPA 9060M			
Total Organic Carbon	1	11.9	n	ng/kg	6.2	3.1	06/28/2013 14:48	06/25/2013 14:38	7100	75WTA1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-SED-45</u> Lab ID: <u>756280005</u> Collected: <u>06/19/2013</u>	D-45-1/2/3   0005 Moisture: 19.7%   2013 14:50 Received: 06/20/2013 13					Project ID:0111C278A/SC SedimentPace Project No.:7562803:26Matrix:Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050				
Arsenic	1	14.0	n	ng/kg	0.31	0.12	06/25/2013 21:08	06/24/2013 05:00	7029	75ICP1	
Cadmium	1	1.7	n	ng/kg	0.12	0.024	06/25/2013 21:08	06/24/2013 05:00	7029	75ICP1	
Lead	1	11.4	n	ng/kg	0.24	0.061	06/25/2013 21:08	06/24/2013 05:00	7029	75ICP1	
Extractable Organic Carbon	Ana	lytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M				
Total Organic Carbon	1	12.8	n	ng/kg	6.4	3.2	06/28/2013 15:19	06/25/2013 14:38	7100	75WTA1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-SED-46</u> Lab ID: <u>756280006</u> Collected: <u>06/19/2013</u>	<u>-1/2/</u> 15:0	<u>3</u> Moiste <u>8</u> Receiv	ure: <u>16</u> ved: <u>06</u>	<u>%</u> /20/2013	<u>3 13:26</u>	Project ID:0111C278A/SC SedimentPace Project No.:75628013:26Matrix:Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050				
Arsenic	1	26.1	n	ng/kg	0.30	0.12	06/25/2013 21:15	06/24/2013 05:00	7029	75ICP1	
Cadmium	1	1.1	n	ng/kg	0.12	0.024	06/25/2013 21:15	06/24/2013 05:00	7029	75ICP1	
Lead	1	11.8	n	ng/kg	0.24	0.060	06/25/2013 21:15	06/24/2013 05:00	7029	75ICP1	
Extractable Organic Carbon	Ana	ytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M				
Total Organic Carbon	1	19.6	n	ng/kg	6.1	3.0	06/28/2013 15:53	06/25/2013 14:38	7100	75WTA1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-SED-47</u> Lab ID: <u>756280007</u> Collected: <u>06/19/2013</u>	<u>′-1/2</u> 15:4	/ <u>3</u> Moistu ⊦8 Receiv	ure: <u>29</u> ved: <u>06</u>	<u>.1%</u> /20/2013	<u>3 13:26</u>	Project ID: 0111C278A/SC Sediment Pace Project No.: 756280 ::26 Matrix: Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050				
Arsenic	1	16.9	n	ng/kg	0.35	0.14	06/25/2013 21:22	06/24/2013 05:00	7029	75ICP1	
Cadmium	1	1.2	n	ng/kg	0.14	0.028	06/25/2013 21:22	06/24/2013 05:00	7029	75ICP1	
Lead	1	19.6	n	ng/kg	0.28	0.070	06/25/2013 21:22	06/24/2013 05:00	7029	75ICP1	
Extractable Organic Carbon	Ana	lytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M				
Total Organic Carbon	1	17.6	n	ng/kg	7.0	3.5	06/28/2013 17:03	06/25/2013 14:38	7100	75WTA1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>SC-SED-48</u> Lab ID: <u>756280008</u> Collected: <u>06/19/2013</u>	<u>-1/2</u> 16:1	/ <u>3</u> Moiste <u>1</u> Receiv	ure: <u>21</u> ved: <u>06</u>	<u>.7%</u> /20/2013	<u>3 13:26</u>	Project ID:0111C278A/SC SedimentPace Project No.:7562806Matrix:Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	lytical Method:	EPA 601	10	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	24.8	n	ng/kg	0.32	0.13	06/25/2013 21:28	06/24/2013 05:00	7029	75ICP1
Cadmium	1	2.4	n	ng/kg	0.13	0.026	06/25/2013 21:28	06/24/2013 05:00	7029	75ICP1
Lead	1	13.8	n	ng/kg	0.26	0.064	06/25/2013 21:28	06/24/2013 05:00	7029	75ICP1
Extractable Organic Carbon	Ana	lytical Method:	EPA 906	50M	Prepa	ration Met	hod: EPA 9060M			
Total Organic Carbon	1	15.6	n	ng/kg	6.7	3.4	06/28/2013 17:36	06/25/2013 14:38	7100	75WTA1



### **Quality Control**

Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

### Batch: 7029 Method: EPA 6010 Prep Method: EPA 3050

# Pace Project No.: 756280

Instrument ID: 75ICP1

Blank: 28378								
Parameters	Dilution	Quals	Result	Units	MQL	SDL	Analysis Date	Prep Date
Arsenic	1	U	<0.10	mg/kg	0.25	0.10	06/25/2013 17:44	06/24/2013 05:00
Cadmium	1	U	<0.020	mg/kg	0.10	0.020	06/25/2013 17:44	06/24/2013 05:00
Lead	1	U	<0.050	mg/kg	0.20	0.050	06/25/2013 17:44	06/24/2013 05:00
Laboratory Control	<b>Sample:</b> 28379							
		Snk	109			109	% Poc	108

Parameters	Amt	Result	Units	%Rec	Limits	Quals	
Arsenic	50	49.0	mg/kg	98	80-120		
Cadmium	50	49.2	mg/kg	98	80-120		
Lead	50	52.6	mg/kg	105	80-120		

### Matrix Spike: 28488

Matrix Spike Duplicate: 28489

#### Original for Sample: Batch sample 756247002

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	3.4	51.8	51.8	40.7	37.1	mg/kg	72	65	75-125	9	20	M1
Cadmium	<0.021	51.8	51.8	38.0	33.8	mg/kg	73	65	75-125	12	20	M1
Lead	8.2	51.8	51.8	43.2	40.0	mg/kg	68	61	75-125	8	20	M1

Matrix Spike: 28490

Matrix Spike Duplicate: 28491

Original for Sample: Batch sample 756247004

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	2.2	52	53	40.5	40.9	mg/kg	74	73	75-125	1	20	M1
Cadmium	<0.021	52	53	38.3	38.6	mg/kg	74	73	75-125	1	20	M1
Lead	4.0	52	53	40.4	39.9	mg/kg	70	68	75-125	1	20	M1



### **Quality Control**

#### Batch: 7100 Pace Project No.: 756280 Method: EPA 9060M Instrument ID: 75WTA1 Prep Method: EPA 9060M Blank: 28636 Analysis Date **Parameters** Dilution Quals Result Units MQL SDL **Prep Date** Total Organic Carbon 1 U <2.5 mg/kg 5.0 2.5 06/28/2013 11:14 06/25/2013 14:38 Laboratory Control Sample: 28637 Spk LCS LCS % Rec LCS **Parameters** Amt Result Units %Rec Limits Quals **Total Organic Carbon** 100 104 104 80-120 mg/kg Matrix Spike: 28638 Matrix Spike Duplicate: 28639 Original for Sample: Project sample SC-SED-41-1R/2R/3R Original MS MSD MSD MS MSD % Rec MS Max **Parameters** Result Spk Spk Result Result Units %Rec %Rec Limits RPD Quals RPD Total Organic Carbon 40.5 186 201 114 80-120 141 141 mg/kg 103 8 20



### Pace Project No.: 756280

Analyte	Method	Unadjusted MQL	Reporting Units
Arsenic	EPA 6010	0.25	mg/kg
Cadmium	EPA 6010	0.10	mg/kg
Lead	EPA 6010	0.20	mg/kg
Total Organic Carbon	EPA 9060M	5.0	mg/kg



### Pace Project No.: 756280

### DEFINITIONS

- DF Dilution Factor
- J Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.
- U Indicates the compound was analyzed for, but not detected.
- SDL Sample Detection Limit
- MQL Method Quantitation Limit
- LCS(D) Laboratory Control Sample (Duplicate)
- MS(D) Matrix Spike (Duplicate)
- DUP Sample Duplicate
- RPD Relative Percent Difference
- TNI The Nelac Institute

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

### ANALYTE QUALIFIERS

Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

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		TRRP LABORATORY REVIEW CHECKLIST						
L	aboratory	Pace Analytical Services, Inc.	07/01/2	013				
Proj	ect Name:	0111C278A/SC Sediment Sampling Laboratory Job Number:	756280					
Review	wer Name:	Shelly Connelly Prep Batch Number(s):	See exc	eption	report.			
# <sup>1</sup>	A <sup>2</sup>	Description		Yes	No	NA <sup>3</sup>	NR <sup>4</sup>	ER #5
R1	OI	Chain-of-custody (C-O-C)						
	-	Did samples meet the laboratory's standard conditions of sample acceptability upon receipt	t?	x				
				<u></u>				
		Were all departures from standard conditions described in an exception report?		<u>X</u>				
R2	OI	Sample and quality control (QC) identification						
		Are all field sample ID numbers cross-referenced to the laboratory ID numbers?		Х				
	-	Are all laboratory ID numbers cross-referenced to the corresponding QC data?		X				
R3	OI	Test reports						
		Were all samples prepared and analyzed within holding times?		Х				
		Other than those results < MQL, were all other raw values bracketed by calibration standar	ds?	Х				
		Were calculations checked by a peer or supervisor?		х				
		Were all analyte identifications checked by a peer or supervisor?		X				
		Were sample detection limits reported for all analytes not detected?		X				
		Were all results for soil and sediment samples reported on a dry weight basis?		X				
		Were all results for solidal reported for all soil and sodiment samples?		×				
		Were bulk soils/solids samples for volatile analysis extracted with methanol per SW846 Me	thod	~				
		5035?	liicu			X		
		If required for the project, are TICs reported?				Х		
R4	0	Surrogate recovery data						
		Were surrogates added prior to extraction?				Х		
		Were surrogate percent recoveries in all samples within the laboratory QC limits?				Х		
R5	OI	Test reports/summary forms for blank samples						
	-	Were appropriate type(s) of blanks analyzed?		Х				
		Were blanks analyzed at the appropriate frequency?		Х				
		Were method blanks taken through the entire analytical process, including preparation and	, if	Y				
		applicable, cleanup procedures?		~				
		Were blank concentrations < MQL?	_	X				
R6	OI	Laboratory control samples (LCS):						
		Were all COCs included in the LCS?	tam a 2	Х				
		vvas each LCS taken through the entire analytical procedure, including prep and cleanup s	teps?	Х				
		Were LCSs analyzed at the required frequency?		Х				
		Were LCS (and LCSD, if applicable) %Rs within the laboratory QC limits?		Х				
		Does the detectability check sample data document the laboratory's capability to detect the	COCs	V				
		at the MDL used to calculate the SDLs?		^				
	_	Was the LCSD RPD within QC limits?				X		
R7	OI	Matrix spike (MS) and matrix spike duplicate (MSD) data						
		Were the project/method specified analytes included in the MS and MSD?		Х				
		Were MS/MSD analyzed at the appropriate frequency?		Х				
		Were MS (and MSD, if applicable) %Rs within the laboratory QC limits?			Х			R7.3
	-	Were MS/MSD RPDs within laboratory QC limits?		Х				
R8	OI	Analytical duplicate data						
		Were appropriate analytical duplicates analyzed for each matrix?				Х		
		Were analytical duplicates analyzed at the appropriate frequency?				Х		
		Were RPDs or relative standard deviations within the laboratory QC limits?				Х		
R9	OI	Method quantitation limits (MQLs):						
		Are the MQLs for each method analyte included in the laboratory data package?		Х				
		Do the MQLs correspond to the concentration of the lowest non-zero calibration standard?		х				
				~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~				
<b>D</b> 40	<b>O</b> !	Are unadjusted iniques and DUSS included in the laboratory data package?		X				
K10	U			~				
		Are all known problems/anomalies/special conditions noted in this LRC and ER?		Х				
		interference effects on the sample results?		Х				
		Is the laboratory NELAC-accredited under the Texas Laboratory Accreditation Program for	the	Y		1		
	line and the state	analytes, matrices, and methods associated with this laboratory data package?	ta(a) //	<b>^</b>	مالم، ۱۰۰			
1.	Items identifie letter "S" sho	ea by the letter ∵κ⊂ must be included in the laboratory in the laboratory data package submitted in the TRRP-required repor uld be retained and made available upon request for the appropriate retention period;	rs(s). Items	s identifie	a by the			
2.	O = Organic	analyses; I = inorganic analysises (and general chemistry, when applicable);						
3. 4	NA = Not app NR = Not rev	plicable; jewed:						
5.	ER# = Excep	tion Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked).						

#### 2014 EXIDE APAR PAGE 2626 OF 3116 **TRRP LABORATORY REVIEW CHECKLIST** Laboratory Pace Analytical Services, Inc. LRC Date: 07/01/2013 **Project Name:** 0111C278A/SC Sediment Sampling Laboratory Job Number: 756280 **Reviewer Name:** Shelly Connelly Prep Batch Number(s): See exception report. NA<sup>3</sup> NR<sup>4</sup> ER #<sup>5</sup> **#**<sup>1</sup> $A^2$ Description Yes No **S1** OI Initial calibration (ICAL) Х Were response factors and/or relative response factors for each analyte within QC limits? Were percent RSDs or correlation coefficient criteria met? Х Was the number of standards recommended in the method used for all analytes? Х Were all points generated between the lowest and highest standard used to calculate the curve? Х Are ICAL data available for all instruments used? Х Has the initial calibration curve been verified using an appropriate second source standard? Х Initial and continuing calibration verification (ICCV and CCV) and continuing calibration S2 OI blank (CCB): Was the CCV analyzed at the method-required frequency? Х Were precent differences for each analyte within the method-required QC limits? Х Was the ICAL curve verified for each analyte? Х Х Was the absolute value of the analyte concentration in the inorganic CCB < MDL? **S**3 Ο Mass spectral tuning Was the appropriate compound for the method used for tuning? Х Were ion abundance data within the method-required QC limits? Х S4 ο Internal standards (IS) Were IS area counts and retention times within the method-required QC limits? Х OI **S**5 Raw data (NELAC Section 5.5.10) Х Were the raw data (for example, chromatograms, spectral data) reviewed by an analyst? Were data associated with manual integrations flagged on the raw data? Х **S6** Ο Dual column confirmation Did dual column confirmation results meet the method-required QC? Х **S7** Ο Tentatively identified compounds (TICs) If TICs were requested, were the mass spectra and TIC data subject to appropriate checks? х **S8** Т Interference Check Sample (ICS) results Х Were percent recoveries within method QC limits? **S**9 L Serial dilutions, post digestion spikes, and method of standard additions Were percent differences, recoveries, and the linearity within the QC limits specified in the Х method? S10 OI Method detection limit (MDL) studies Was a MDL study performed for each reported analyte? Х Х is the MDL either adjusted or supported by the analysis of DCSs? S11 OI Proficiency test reports Was the laboratory's performance acceptable on the applicable proficiency tests or evaluation Х studies? S12 OI Standards documentation Are all standards used in the analyses NIST-traceable or obtained from other appropriate Х sources? S13 OI Compound/analyte identification procedures Are the procedures for compound/analyte identification documented? Х S14 OI Demonstration of analyst competency (DOC) Х Was DOC conducted consistent with NELAC Chapter 5? Х is documentation of the analyst's competency up-to-date and on file? Verification/validation documentation for methods (NELAC Chapter 5) S15 οι Are all the methods used to generate the data documented, verified, and validated, where Х applicable? OI Laboratory standard operating procedures (SOPs) S16 Are laboratory SOPs current and on file for each method performed? Х Items identified by the letter "R" must be included in the laboratory in the laboratory data package submitted in the TRRP-required reports(s). Items identified by the 1. letter "S" should be retained and made available upon request for the appropriate retention period; 2. O = Organic analyses; I = inorganic analysises (and general chemistry, when applicable); NA = Not applicable; 3. 4 NR = Not reviewed:

5. ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked).

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		TRRP LABORATORY	REVIEW CHECKLIST						
La	aboratory	Pace Analytical Services, Inc.	LRC Date:	07/01/2013					
Proje	ect Name:	0111C278A/SC Sediment Sampling	Laboratory Job Number:	756280					
Review	ver Name:	Shelly Connelly	Prep Batch Number(s):	7012,7029,7100					
ER #1			Description						
R7.3	MS Sample	e #28488: Arsenic 72% spike recovery outside laboratory	QC limit of 75-125%.						
R7.3	3 MS Sample #28488: Cadmium 73% spike recovery outside laboratory QC limit of 75-125%.								
R7.3	3 MS Sample #28488: Lead 68% spike recovery outside laboratory QC limit of 75-125%.								
R7.3	3 MS Sample #28490: Arsenic 74% spike recovery outside laboratory QC limit of 75-125%.								
R7.3	MS Sample	e #28490: Cadmium 74% spike recovery outside laborato	ry QC limit of 75-125%.						
R7.3	MS Sample	e #28490: Lead 70% spike recovery outside laboratory Q	C limit of 75-125%.						
R7.3	MSD Samp	ble #28489: Arsenic 65% spike recovery outside laborator	ry QC limit of 75-125%.						
R7.3	MSD Samp	ble #28489: Cadmium 65% spike recovery outside labora	tory QC limit of 75-125%.						
R7.3	MSD Samp	ble #28489: Lead 61% spike recovery outside laboratory (	QC limit of 75-125%.						
R7.3	MSD Samp	ble #28491: Arsenic 73% spike recovery outside laborator	ry QC limit of 75-125%.						
R7.3	MSD Samp	ble #28491: Cadmium 73% spike recovery outside labora	tory QC limit of 75-125%.						
R7.3	MSD Samp	ble #28491: Lead 68% spike recovery outside laboratory	QC limit of 75-125%.						
1.	ER# = Exc	ception Report identification number (an Exception Repor	t should be completed for an item	if "NR" or "No" is checked).					



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Face Analytical Client Name:	ple Co	onditi	ion U	pon Receipt + Crossiance Pace #: うらいみをつ
	<u></u>	$\underline{001}$	<u>urs</u>	
Courier: Fed Ex UPS USPS Client Tracking #: Falcon-Xoress	Xc	ourier		D Pace Other
Custody Seal on Cooler/Box Present: Xyes	no	I	Seals i	ntact: 🕅 yes 🔲 no 🔲 N/A
Packing Material: Bubble Wrap Bubble B	ags	No	ne [	X] Other
Thermometer Used (IR-01) IR-02	Туре	of Ice:	Wet	Blue None IX Samples on ice, cooling process has begun
Cooler Temperature $O \cdot f^{OC}$	lce \	/isible	in San	nple Containers: yes no
(Corrected, if applicable)				Date and Initials of person examining
Temp should be above freezing to 6°C				Comments: $contents: \prod_{i=1}^{n} \frac{\psi^{i} (1-1)}{2}$
Sample Receiving	A.			
Chain of Custody Present:	(UYes			1
Chain of Custody Filled Out:	Yes			2
Chain of Custody Relinquished:	121Yes			3.
Sampler Name & Signature on COC:	WYes			4.
Short Hold Time Analysis ( 2hr):</td <td></td> <td>LUNO Pana</td> <td></td> <td>5.</td>		LUNO Pana		5.
Rush Turn Arouna Time Requested:				7
Sample Labele metablooc				v.
-Includes date/time/ID/Applysis	163			
All containers needing acid/base pres. have been checked? exceptions: VOA, coliform, 0&G	⊡Yes	□No	(GN/A	9. (Circle) HNO3 H2SO4 NaOH HCI If applicable see below.
All containers needing preservation are found to be in compliance with EPA recommendation.	□Yes	⊡No		pH strip lot #:
				Potassium lodide strip lot #:
	•			Lead Acetate strip lot #:
Headspace in VOA Vials ( >6mm):	□Yes	□No	<b>O</b> N/A	10.
Trip Blank Present:	□Yes	□No	ØN/A	11.
Trip Blank Custody Seals Present	□Yes	□No	/2N/A	
Samples Arrived within Hold Time:	Yes	□No	□n/A	12.
Sufficient Volume:	Yes	□No	□n/a	13.
Correct Containers Used:	A Yes	□No	⊡n/a	14.
Client Notification/ Resolution:	,		Detal	Time
Comments/ Resolution:	·		Date/	
Project Manager Review:		m	ic	Date: (n-21-13
				Personal Persona Personal Personal Pe Personal Personal P

F-DAL-C-001rev.00 11-5-2012

Sample Container Count

Pace Analytical"

30 COC PAGE \_\_\_\_ COC ID# \_\_\_\_

101 H JS 6 JRD

	-  -							Расе Р	rojec
ole Line œm	BP2N	AG1U	VG9U	VG9H	BP2S	BP1U	BP2U	BG1H	AG1
~~					-				
5									

Comments												
IFU WGKU												
SP5T WG	Pa A	m	5	[m	Σ	Ŋ			>			
BP20												
AG1S	-											
BG1H												
BP2U												
BP1U												
BP2S												
VG9H												
VG9U												
AG1U												
BP2N												
Sample Line Item	~		1 0	0 4	гл	) u	7 0	- 0	0 0	10	11	12

Г		T		1	1		- 1	- 1				···			
	DG9P 40mL TSP amber vial	DG9S 40mL H2SO4 amber vial	DG9T 40mL Na Thio amber vial	DG9U 40mL unpreserved amber vial	I Wipe/Swab	JGFU 4oz unpreserved amber wide	U Summa Can	VG9H 40mL HCL clear vial	VG9T 40mL Na Thio. clear vial	VG9U 40mL unpreserved clear vial	VSG Headspace septa vial & HCL	WGFX 4oz wide jar w/hexane wipe	ZPLC Ziploc Bag	GN General unpreserved	
	BP1N 1 liter HNO3 plastic	BP1S 1 liter H2SO4 plastic	BP1U 1 liter unpreserved plastic	BP1Z 1 liter NaOH, Zn, Ac	BP2A 500mL NaOH, Asc Acid plastic	BP20 500mL NaOH plastic	BP2Z 500mL NaOH, Zn Ac	BP3A 250mL NaOh, Asc Acid plastic	BP3C 250mL NaOH plastic	BP3Z 250mL NaOH, Zn Ac plastic	C Air Cassettes	DG9B 40mL Na Bisulfate amber vial	DG9M 40mL MeOH clear vial	SP5U 120mL Coliform unpreserved	
	AF Air Filter	AG1H 1 liter HCL amber glass	AG1S 1 liter H2SO4 amber glass	AG1T 1 liter Na Thiosulfate amber gl	AG2N 500mL HNO3 amber glass	AG2S 500mL H2SO4 amber glass	AG2U 500mL unpreserved amber gla	AG3U 250mL unpreserved amber gla	BG1H 1 liter HCL clear glass	BG1S 1 liter H2SO4 clear dlass	BG1T 1 liter Na Thiosulfate clear gla	BG1U 1 liter unpreserved glass	BP1A 1 liter NaOH, Asc Acid plastic	SP5T 120mL Coliform Na Thiosulfate	
Container Codes	40mL HCL amber voa vial	1liter unpreserved amber glass	4oz clear soil jar	terra core kit	500mL HNO3 plastic	500mL unpreserved plastic	500mL H2SO4 plastic	250mL HNO3 plastic	250ml unnreserved plastic	250ml H2SO4 plastic	250mL H2SO4 dlass amber	1 liter H2SO4 amber class	1 liter unbreserved plastic	8oz wide jar upreserved	Other
	DG9H	AG1U	WGFU	R	BP2N	BP2U	BP2S	BP3N	BP3U	22.22	AG3S	AG1S	BP1U	WGKU	Other

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## DATA USABILITY SUMMARY

John J. LeGolvan reviewed one data package from Pace Analytical Services, Inc. (Pace) for the analysis of sediment samples collected June 21, 2013 at the Stewart Creek site in Frisco, Texas. Data were reviewed for conformance to the requirements of the guidance document, *Review and Reporting of COC Concentration Data* (RG-366/TRRP-13) and adherence to project objectives.

**Intended Use of Data**: The objective of the sediment sampling event was to provide current data on concentrations of chemicals of concern (COCs) in the sediment at the affected property.

Analyses requested included:

• EPA 6010 – RCRA 3 Metals (Arsenic, Cadmium, and Lead)

Data were reviewed and validated as described in *Review and Reporting of COC Concentration Data*, (RG-366/TRRP-13) and the results of the review/validation are discussed in this Data Usability Summary (DUS). The following laboratory submittals and field data were examined:

- the reportable data,
- the laboratory review checklists and associated exception reports, and
- the field notes with respect to sampling procedures, and preservation procedures prior to shipping the samples to the laboratory.

The results of supporting quality control (QC) analyses were summarized on the Laboratory Review Checklists (LRCs), Exception Reports (ERs) and in the case narratives, all of which were included in this review.

The complete laboratory analytical data package including LRCs, associated ERs, and reportable data included in this review are attached to this DUS.

#### Introduction

Eight (8) sediment samples were collected from the site and analyzed for RCRA Metals arsenic, cadmium, and lead analyses. Table 1 lists the field sample identification cross-referenced to the laboratory identification.

#### Project Objectives

RCRA 3 Metals (Arsenic, Cadmium, and Lead) Recovery 75-125% RPD 0-20%

### TABLE 1 Stewart Creek, Frisco, Texas DATA USABILITY SUMMARY - FIELD/LAB IDENTIFICATION CORRELATION

Field Identification	Laboratory Identification
PS (6-21)-1	756304001
PS (6-21)-1 Base Comp	756304002
Chip (6-21)-1	756304003
Chip (6-21)-1 Base Comp	756304004
PS (6-21)-2	756304005
PS (6-21)-2 Base Comp	756304006
Chip (6-21)-2	756304007
Chip (6-21)-2 Base Comp	756304008

#### Data Review / Validation Results

#### Analytical Results

Qualified sample data is listed in Table 2. Non-detected results were reported as U, which is less than the Sample Detection Limits (SDLs) as reported by Pace.

#### Preservation and Holding Times

Sediment samples were evaluated for agreement with the chain-of-custody (C-O-C) and the Laboratory Review Checklist. All samples were received in the appropriate containers and in good condition with the paperwork filled out properly. Sample receipt temperatures were within the acceptance criteria of  $4 \pm 2$  °C. Samples were preserved in the field as specified in SW-846 Table 2-36. Samples were prepared and analyzed within holding times specified in SW-846 Table 2-36.

#### Calibrations

According to the LRC, initial calibration data met SW-846 method requirements for the analytes.

#### Blanks

Laboratory method blank data was reported for each of the selected analytes. None of the analytes were detected above the laboratory MDLs in the method blanks; therefore, it appears that no laboratory contaminants were introduced in the method blank analyses.

#### Internal Standard and Surrogate Recoveries (RCRA 3 Metals)

Due to the method in use, internal standards and surrogates were not used in the analyses.

#### Laboratory Control Samples

RCRA 3 Metals laboratory control sample (LCS) recoveries met project objectives of 75 to 125% recovery.

#### Matrix Spike/Matrix Spike Duplicates

The MS recoveries from batch 7126 for arsenic, cadmium, and lead were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

The MSD recoveries from batch 7126 for arsenic, cadmium, and lead were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

The RPD of the MSD from batch 7126 exceeded the laboratory QC limit for lead.

### TABLE 2 Stewart Creek, Frisco, Texas DATA USABILITY SUMMARY - QUALIFIED DATA

Field Identification	Analyte	Qualification	Reason for Qualification
	Arsenic		Matrix spike
		M1-flag	recovery
	Cadmium		exceeded QC
			limits.
PS (6-21)-1			Matrix spike
		M1-flag	recovery
		MITHAG	exceeded QC
	Lead		limits.
	Leau		Relative percent
		D1 flog	difference was
		RT-llag	outside control
			limits.
			Analyte detected
Chip (6-21)-1	Cadmium	J-flag	below method
/		Ŭ	quantitation limit

#### Field Procedures

The laboratory did not produce a duplicate analysis of the sediment samples collected at the site. A field precision sample was not collected in the field.

#### Summary

The laboratory analyses were performed within the guidelines of the standards specified in the TRRP-13 guidance document. The laboratory QC indicates acceptable instrument calibration and performance. MS/MSD results indicated lower than expected recovery results from several batches which were run; however, the LCS/LCSD recoveries in each case were within the lab QC limits and within the project objective. The overall quality of the laboratory data appears to be acceptable for the project objective. The sediment analytical data are usable for the purpose of determining current COC concentrations in sediment at the affected property.



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

July 02, 2013

Rusty Simpson Southwest Geoscience 2351 W. Northwest Hwy Suite 3321 Dallas, TX 75220

RE: Pace Project 756304 Project ID: 0111C278A/Stewart Creek

Dear Rusty Simpson:

Enclosed are the analytical results for sample(s) received by the laboratory on June 22, 2013. Results reported herin conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Shelly Connelly/

Shelly Connelly shelly.connelly@pacelabs.com

Laboratory Certifications Pace Dallas : Texas Certification #: T104704232-12-4



### **REPORT OF LABORATORY ANALYSIS**

This report shall not be reproduced, except in full, without the written consent of Pace Analytical Services, Inc.



### Pace Project No.: 756304

Client: <u>Southwest Geoscience</u> Project ID: <u>0111C278A/Stewart Creek</u>

Client Sample ID	Lab ID	Matrix	Collection Date/Time	Received Date/Time
PS (6-21)-1	756304001	Solid	06/21/2013 14:05	06/22/2013 10:10
PS (6-21)-1 Base Comp	756304002	Solid	06/21/2013 14:05	06/22/2013 10:10
Chip (6-21)-1	756304003	Solid	06/21/2013 14:32	06/22/2013 10:10
Chip (6-21)-1 Base Comp	756304004	Solid	06/21/2013 14:32	06/22/2013 10:10
PS (6-21)-2	756304005	Solid	06/21/2013 14:42	06/22/2013 10:10
PS (6-21)-2 Base Comp	756304006	Solid	06/21/2013 14:42	06/22/2013 10:10
Chip (6-21)-2	756304007	Solid	06/21/2013 14:55	06/22/2013 10:10
Chip (6-21)-2 Base Comp	756304008	Solid	06/21/2013 14:55	06/22/2013 10:10



### **Project Narrative**

Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Pace Project No.: 756304

Holding Times:

All holding times were met.

Blanks:

All blank results were below reporting limits.

Laboratory Control Samples:

All LCS recoveries were within QC limits.

Matrix Spikes and Duplicates:

MS or MSD recoveries outside of QC limits are qualified in the Report of Quality Control section.

Surrogate:

All surrogate recoveries were within QC limits.

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Appendix A

#### LABORATORY DATA PACKAGE COVER PAGE

This data package is for Job No. 756304 and consists of:

This signature page, the laboratory review checklist, and the following reportable data:

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- R1 Field chain-of-custody documentation;
- R2 Sample identification cross-reference;
- R3 Test reports (analytical data sheets) for each environmental sample that includes:
  - a. Items consistent with NELAC Chapter 5,
  - b. Dilution factors,
  - c. Preparation methods,
  - d. Cleanup methods, and
  - e. If required for the project, tentatively identified compounds (TICs).
- R4 Surrogate recovery data including:
  - a. Calculated recovery (%R), and
  - b. The laboratory's surrogate QC limits.
- R5 Test reports/summary forms for blank samples;
- R6 Test reports/summary forms for laboratory control samples (LCSs) including:
  - a. LCS spiking amounts,
  - b. Calculated %R for each analyte, and
  - c. The laboratory's LCS QC limits.
- R7 Test reports/summary forms for matrix spike/matrix spike duplicates (MS/MSDs) including:
  - a. Samples associated with the MS/MSD clearly identified,
  - b. MS/MSD spiking amounts,
  - c. Concentration of each MS/MSD analyte measured in the parent and spiked samples,
  - d. Calculated %Rs and relative percent differences, and
  - e. The laboratory's MS/MSD QC limits.
- R8 Laboratory analytical duplicate (if applicable) recovery and precision:
  - a. The amount of analyte measured in the duplicate,
  - b. The calculated RPD, and,
  - c. The laboratory's QC limits for analytical duplicated.
  - R9 List of method quantitation limits (MQLs) and detectability check sample results for each analyte and
  - R10 Other problems or anomalies.

The exception Report for each "No" or "Not Reviewed (NR) " item in the Laboratory Review Checklist and for each analyte, matrix, and method for which the laboratory does not hold NELAC accreditation under the Texas Laboratory Accreditation Program.

**Release Statement:** I am responsible for the release of this laboratory data package. This laboratory is NELAC accredited under the Texas Laboratory Accreditation Program for all the methods, analytes, and matrices reported in this data package except as noted in the Exception Reports. The data have been reviewed and are technically compliant with the requirements of the methods used, except where noted by the laboratory in the Exception Reports. By my signature below, I affirm to the best of my knowledge all problems/anomalies observed by the laboratory have been identified in the Laboratory Review Checklist, and no information affecting the quality of the data has been knowingly withheld.

Check, if applicable: [] This laboratory meets an exception under 30 TAC §25.6 and was last inspected by [X] TCEQ on 02/24/2012

Any findings affecting the data in this laboratory data package are noted in the Exception Reports herin. The official signing the cover page of the report in which these data are used is responsible for releasing this data package and is by signature affirming the above release statement is true.

Name	(Printed)
Shelly	Connelly

<u>Signature</u>	
Shelly Conselly	

<u>Official Title (Printed)</u> Project Manager <u>Date</u> 07/02/2013

X X

Х



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: PS (6-21)-1   Lab ID: 756304001 Moisture: 17.8%   Collected: 06/21/2013 14:05 Received: 06/22/2013 10					<u>3 10:10</u>	Project ID:0111C278A/Stewart CreekPace Project No.:75630410:10Matrix:Solid					
Parameters	DF	Results	Qua	I Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	lytical Method	d: EPA 6	6010	Prepa	ration Met	hod: EPA 3050				
Arsenic	1	6.0	M1	mg/kg	0.30	0.12	06/27/2013 17:14	06/27/2013 05:46	7126	75ICP1	
Cadmium	5	< 0.12	U,M1	mg/kg	0.61	0.12	06/30/2013 13:43	06/27/2013 05:46	7126	75ICP1	
Lead	1	6.0	M1,R1	mg/kg	0.24	0.061	06/27/2013 17:14	06/27/2013 05:46	7126	75ICP1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: PS (6-21)-1 Base Comp   Lab ID: 756304002 Moisture: 7.3%   Collected: 06/21/2013 14:05 Received: 06/22/2013 10:10					<u>3 10:10</u>	Project ID: <u>0111C278A/Stewart Creek</u> Pace Project No.: <u>756304</u> <u>0</u> Matrix: <u>Solid</u>						
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.		
6010 Metals, Total	Anal	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050					
Arsenic	5	25.2	m	ig/kg	1.3	0.51	06/30/2013 13:48	06/27/2013 05:46	7126	75ICP1		
Cadmium	5	4.2	m	ig/kg	0.51	0.10	06/30/2013 13:48	06/27/2013 05:46	7126	75ICP1		
Lead	5	89.0	m	ig/kg	1.0	0.26	06/30/2013 13:48	06/27/2013 05:46	7126	75ICP1		



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: Chip (6-21)-1   Lab ID: 756304003 Moisture: 1.7%   Collected: 06/21/2013 14:32 Received: 06/22/2013 10				<u>3 10:10</u>	Project ID:0111C278A/Stewart CreekPace Project No.:75630410:10Matrix:Solid						
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	lytical Method:	EPA 60	10	Prepa	ration Meth	nod: EPA 3050				
Arsenic	1	8.3	r	ng/kg	0.24	0.094	06/27/2013 17:27	06/27/2013 05:46	7126	75ICP1	
Cadmium	1	0.086	J r	ng/kg	0.094	0.019	06/27/2013 17:27	06/27/2013 05:46	7126	75ICP1	
Lead	1	180	r	ng/kg	0.19	0.047	06/27/2013 17:27	06/27/2013 05:46	7126	75ICP1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: Chip (6-21)-1 Base Comp   Lab ID: 756304004 Moisture: 4.1%   Collected: 06/21/2013 14:32 Received: 06/22/2013 10:1					<u>3 10:10</u>	Project ID:0111C278A/Stewart CreekPace Project No.:7563040:10Matrix:Solid						
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.		
6010 Metals, Total	Anal	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050					
Arsenic	1	17.7	m	ig/kg	0.26	0.10	06/27/2013 17:34	06/27/2013 05:46	7126	75ICP1		
Cadmium	1	0.87	m	ig/kg	0.10	0.020	06/27/2013 17:34	06/27/2013 05:46	7126	75ICP1		
Lead	1	13.3	m	ng/kg	0.20	0.051	06/27/2013 17:34	06/27/2013 05:46	7126	75ICP1		



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: PS (6-21)-2   Lab ID: 756304005 Moisture: 4.3%   Collected: 06/21/2013 14:42 Received: 06/22/2013 103					<u>3 10:10</u>	Project ID:0111C278A/Stewart CreekPace Project No.:75630410:10Matrix:Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050				
Arsenic	1	7.2	m	ig/kg	0.26	0.10	06/27/2013 17:57	06/27/2013 05:46	7126	75ICP1	
Cadmium	1	0.59	m	ig/kg	0.10	0.020	06/27/2013 17:57	06/27/2013 05:46	7126	75ICP1	
Lead	1	9.7	m	ng/kg	0.20	0.051	06/27/2013 17:57	06/27/2013 05:46	7126	75ICP1	



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: PS (6-21)-2 Base Comp   Lab ID: 756304006 Moisture: 1.6%   Collected: 06/21/2013 14:42 Received: 06/22/2013 10:10					<u>3 10:10</u>	Project ID:0111C278A/Stewart CreekPace Project No.:75630410Matrix:Solid						
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.		
6010 Metals, Total	Anal	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050					
Arsenic	1	44.6	m	ig/kg	0.26	0.11	06/27/2013 18:04	06/27/2013 05:46	7126	75ICP1		
Cadmium	1	0.52	m	ig/kg	0.11	0.021	06/27/2013 18:04	06/27/2013 05:46	7126	75ICP1		
Lead	1	9.7	m	ng/kg	0.21	0.053	06/27/2013 18:04	06/27/2013 05:46	7126	75ICP1		


Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>Chip (6-21)</u> Lab ID: <u>756304007</u> Collected: <u>06/21/2013</u>	Moist	Moisture: <u>2.6%</u> <u>6</u> Received: <u>06/22/2013 10:10</u>				Project ID: <u>(</u> e Project No.: <u>7</u> Matrix: <u>S</u>	<u>0111C278A/Stewart Creek</u> <u>756304</u> Solid			
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Met	nod: EPA 3050			
Arsenic	1	10.5	m	ig/kg	0.26	0.10	06/27/2013 18:11	06/27/2013 05:46	7126	75ICP1
Cadmium	1	0.24	m	ig/kg	0.10	0.021	06/27/2013 18:11	06/27/2013 05:46	7126	75ICP1
Lead	1	3.8	m	ig/kg	0.21	0.052	06/27/2013 18:11	06/27/2013 05:46	7126	75ICP1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID:   Chip (6-21)-2 Base Comp     Lab ID:   756304008   Moisture:   16     Collected:   06/21/2013 14:55   Received:   06					Project ID:   0111C278A/Stewart Cre     16.1%   Pace Project No.:   756304     06/22/2013 10:10   Matrix:   Solid							
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.		
6010 Metals, Total	Anal	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050					
Arsenic	1	12.3	m	ig/kg	0.30	0.12	06/27/2013 18:17	06/27/2013 05:46	7126	75ICP1		
Cadmium	1	0.54	m	ig/kg	0.12	0.024	06/27/2013 18:17	06/27/2013 05:46	7126	75ICP1		
Lead	1	9.5	m	ig/kg	0.24	0.060	06/27/2013 18:17	06/27/2013 05:46	7126	75ICP1		



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

### Batch: 7126 Method: EPA 6010 Prep Method: EPA 3050

# Pace Project No.: 756304

Instrument ID: 75ICP1

Blank: 28695								
Parameters	Dilution	Quals	Result	Units	MQL	SDL	Analysis Date	Prep Date
Arsenic	1	U	<0.10	mg/kg	0.25	0.10	06/27/2013 16:34	06/27/2013 05:46
Cadmium	1	U	<0.020	mg/kg	0.10	0.020	06/27/2013 16:34	06/27/2013 05:46
Lead	1	U	<0.050	mg/kg	0.20	0.050	06/27/2013 16:34	06/27/2013 05:46
Laboratory Control	Sample: 28696							

Parameters	Spk Amt	LCS Result	Units	LCS %Rec	% Rec Limits	LCS Quals
Arsenic	50	45.4	mg/kg	91	80-120	
Cadmium	50	45.3	mg/kg	91	80-120	
Lead	50	48.1	mg/kg	96	80-120	

#### Matrix Spike: 28697

Matrix Spike Duplicate: 28698

Original for Sample: Project sample PS (6-21)-1

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	6.0	60.8	57.4	41.2	49.7	mg/kg	58	76	75-125	19	20	M1
Cadmium	<0.023	60.8	57.4	36.3	44.3	mg/kg	60	77	75-125	20	20	M1
Lead	6.0	60.8	57.4	38.8	59.5	mg/kg	54	93	75-125	42	20	M1,R1

Matrix Spike: 29093

Matrix Spike Duplicate: 29094

Original for Sample: Client sample Chip (6-24)-3 Comp

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	11.5	55.3	54.7	39.0	38.2	mg/kg	50	49	75-125	2	20	M1
Cadmium	1.4	55.3	54.7	28.8	29.9	mg/kg	50	52	75-125	4	20	M1
Lead	32.6	55.3	54.7	55.0	55.0	mg/kg	40	41	75-125	0	20	M1



### Pace Project No.: 756304

Analyte	Method	Unadjusted MQL	Reporting Units	
Arsenic	EPA 6010	0.25	mg/kg	
Cadmium	EPA 6010	0.10	mg/kg	
Lead	EPA 6010	0.20	mg/kg	



### Pace Project No.: 756304

#### DEFINITIONS

- DF Dilution Factor
- J Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.
- U Indicates the compound was analyzed for, but not detected.
- SDL Sample Detection Limit
- MQL Method Quantitation Limit
- LCS(D) Laboratory Control Sample (Duplicate)
- MS(D) Matrix Spike (Duplicate)
- DUP Sample Duplicate
- RPD Relative Percent Difference
- TNI The Nelac Institute

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

### ANALYTE QUALIFIERS

- Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
- R1 RPD value was outside control limits.

### 2014 EXIDE APAR PAGE 2651 OF 3116

		TRRP LABORATORY REVIEW CHECKLIST						
L	aboratory	Pace Analytical Services, Inc. LRC Date: 0	7/02/2013	3				
Proj	ect Name:	0111C278A/Stewart Creek Laboratory Job Number: 7	56304					
Reviev	ver Name:	Shelly Connelly Prep Batch Number(s): S	ee except	ion	report.			
#1	<b>A</b> <sup>2</sup>	Description	Ye	es	No	NA <sup>3</sup>	NR <sup>₄</sup>	ER # <sup>5</sup>
R1	OI	Chain-of-custody (C-O-C)						
			×	(				
		Were all departures from standard conditions described in an exception report?	×	(				
R2	OI	Sample and guality control (QC) identification						
		Are all field sample ID numbers cross-referenced to the laboratory ID numbers?	X	(				
		Are all laboratory ID numbers cross-referenced to the corresponding QC data?	X	(				
R3	OI	Test reports						
		Were all samples prepared and analyzed within holding times?	X	(				
		Other than those results < MQL, were all other raw values bracketed by calibration standard	s? x	(				
				`````		-		
		Were calculations checked by a peer or supervisor?	×	( /				
		Were all analyte identifications checked by a peer or supervisor?	×	( /				
		Were sample detection limits reported for all analytes not detected?	×	( /		-		
		were all results for soil and sediment samples reported on a dry weight basis?		( /		-		+
		were with soils/solids samples for volatile analysis extracted with methanol per SW946 Moth						
		5035?				Х		
		If required for the project, are TICs reported?				Х		1
R4	0	Surrogate recovery data						
	•	Were surrogates added prior to extraction?				Х		
		Were surrogate percent recoveries in all samples within the laboratory QC limits?				Х		
R5	OI	Test reports/summary forms for blank samples						
		Were appropriate type(s) of blanks analyzed?	×	(				
		Were blanks analyzed at the appropriate frequency?	×	(				
		Were method blanks taken through the entire analytical process, including preparation and,	if X	(				
		applicable, cleanup procedures?		/				
P6	0	aboratory control samples (I CS):		<u>`</u>				
NU	U	Were all COCs included in the LCS2		(				
		Was each LCS taken through the entire analytical procedure, including prep and cleanup ste	eps?	<u> </u>				
			X	(				
		Were LCSs analyzed at the required frequency?	×	(				
		Were LCS (and LCSD, if applicable) %Rs within the laboratory QC limits?	X	(				
		Does the detectability check sample data document the laboratory's capability to detect the (	COCs X	(				
		Was the LCSD RPD within QC limits?				X		
R7	OI	Matrix spike (MS) and matrix spike duplicate (MSD) data						
	_	Were the project/method specified analytes included in the MS and MSD?	×	(				
		Were MS/MSD analyzed at the appropriate frequency?	×	(				
		Were MS (and MSD, if applicable) %Rs within the laboratory QC limits?			Х			R7.3
		Were MS/MSD RPDs within laboratory QC limits?			Х			R7.4
R8	OI	Analytical duplicate data						
		Were appropriate analytical duplicates analyzed for each matrix?	X	(				
		Were analytical duplicates analyzed at the appropriate frequency?	×	(				
		Were RPDs or relative standard deviations within the laboratory QC limits?			Х			R8.3
R9	OI	Method quantitation limits (MQLs):						
		Are the MQLs for each method analyte included in the laboratory data package?	×	(				
		Do the MQLs correspond to the concentration of the lowest non-zero calibration standard?	×	(				
		Are unadjusted MOLe and DCCs included in the laboratory data pockage?		/				
<b>P10</b>		Other problems/anomalies		\				
1110		Are all known problems/anomalies/special conditions noted in this LRC and EP?		(				
		Was applicable and available technology used to lower the SDL to minimize the matrix		` `				
		interference effects on the sample results?	X	(				
		Is the laboratory NELAC-accredited under the Texas Laboratory Accreditation Program for the	ne X	(				
1.	Items identifie	principles, mannees, and methods associated with this taboratory data package? ad by the letter "R" must be included in the laboratory in the laboratory data package submitted in the TRRP-required reports	(s). Items ide	ntifie	d by the	1	I	I
^	letter "S" sho	uld be retained and made available upon request for the appropriate retention period;			~			
2.	NA = Not app	anaryses, r – morganic anarysises (and general chennishy, when applicable), Jicable;						
4. F	NR = Not rev	iewed; tion Report identification number (an Exception Report should be completed for an itom if "ND" or "No" is checked						
ວ.	= 1.4 = Exceb	מיר הספרה מטרומוטמוטה העוחטטו למה באטטעוטה הבעטרו פוטעוע שב טטוועופנכע וטו מד ונפוד וד זיול טו אט וא טופנגעפע).						

#### 2014 EXIDE APAR PAGE 2652 OF 3116 TRRP LABORATORY REVIEW CHECKLIST Laboratory Pace Analytical Services, Inc. LRC Date: 07/02/2013 **Project Name:** 0111C278A/Stewart Creek Laboratory Job Number: 756304 **Reviewer Name:** Shelly Connelly Prep Batch Number(s): See exception report. NA<sup>3</sup> NR<sup>4</sup> ER #<sup>5</sup> **#**<sup>1</sup> $A^2$ Description Yes No **S1** OI Initial calibration (ICAL) Х Were response factors and/or relative response factors for each analyte within QC limits? Were percent RSDs or correlation coefficient criteria met? Х Was the number of standards recommended in the method used for all analytes? Х Were all points generated between the lowest and highest standard used to calculate the curve? Х Are ICAL data available for all instruments used? Х Has the initial calibration curve been verified using an appropriate second source standard? Х Initial and continuing calibration verification (ICCV and CCV) and continuing calibration S2 OI blank (CCB): Was the CCV analyzed at the method-required frequency? Х Were precent differences for each analyte within the method-required QC limits? Х Was the ICAL curve verified for each analyte? Х Х Was the absolute value of the analyte concentration in the inorganic CCB < MDL? **S**3 Ο Mass spectral tuning Was the appropriate compound for the method used for tuning? Х Were ion abundance data within the method-required QC limits? Х S4 ο Internal standards (IS) Were IS area counts and retention times within the method-required QC limits? Х OI **S**5 Raw data (NELAC Section 5.5.10) Х Were the raw data (for example, chromatograms, spectral data) reviewed by an analyst? Were data associated with manual integrations flagged on the raw data? Х **S6** Ο Dual column confirmation Did dual column confirmation results meet the method-required QC? Х **S7** Ο Tentatively identified compounds (TICs) If TICs were requested, were the mass spectra and TIC data subject to appropriate checks? х **S8** Т Interference Check Sample (ICS) results Х Were percent recoveries within method QC limits? **S**9 L Serial dilutions, post digestion spikes, and method of standard additions Were percent differences, recoveries, and the linearity within the QC limits specified in the Х method? S10 OI Method detection limit (MDL) studies Was a MDL study performed for each reported analyte? Х Х is the MDL either adjusted or supported by the analysis of DCSs? S11 OI Proficiency test reports Was the laboratory's performance acceptable on the applicable proficiency tests or evaluation Х studies? S12 OI Standards documentation Are all standards used in the analyses NIST-traceable or obtained from other appropriate Х sources? S13 OI Compound/analyte identification procedures Are the procedures for compound/analyte identification documented? Х S14 OI Demonstration of analyst competency (DOC) Х Was DOC conducted consistent with NELAC Chapter 5? Х is documentation of the analyst's competency up-to-date and on file? Verification/validation documentation for methods (NELAC Chapter 5) S15 οι Are all the methods used to generate the data documented, verified, and validated, where Х applicable? OI Laboratory standard operating procedures (SOPs) S16 Are laboratory SOPs current and on file for each method performed? Х Items identified by the letter "R" must be included in the laboratory in the laboratory data package submitted in the TRRP-required reports(s). Items identified by the 1. letter "S" should be retained and made available upon request for the appropriate retention period; 2. O = Organic analyses; I = inorganic analysises (and general chemistry, when applicable); NA = Not applicable; 3. 4 NR = Not reviewed:

5. ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked).

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	TRRP LABORATORY REVIEW CHECKLIST											
La	aboratory	Pace Analytical Services, Inc.	LRC Date:	07/02/2013								
Proje	ect Name:	0111C278A/Stewart Creek	Laboratory Job Number:	756304								
Review	ver Name:	Shelly Connelly	Prep Batch Number(s):	7102,7103,7126,7128								
ER #1	ER #1 Description											
R7.3	MS Sample	e #28697: Arsenic 58% spike recovery outside laboratory	QC limit of 75-125%.									
R7.3	MS Sample	e #28697: Cadmium 60% spike recovery outside laborato	ry QC limit of 75-125%.									
R7.3	MS Sample	e #28697: Lead 54% spike recovery outside laboratory Q	C limit of 75-125%.									
R7.3	MS Sample	e #29093: Arsenic 50% spike recovery outside laboratory	QC limit of 75-125%.									
R7.3	MS Sample	e #29093: Cadmium 50% spike recovery outside laborato	ry QC limit of 75-125%.									
R7.3	MS Sample	e #29093: Lead 40% spike recovery outside laboratory Q	C limit of 75-125%.									
R7.3	MSD Samp	ble #29094: Arsenic 49% spike recovery outside laborator	y QC limit of 75-125%.									
R7.3	MSD Samp	ble #29094: Cadmium 52% spike recovery outside labora	tory QC limit of 75-125%.									
R7.3	MSD Samp	ble #29094: Lead 41% spike recovery outside laboratory (	QC limit of 75-125%.									
R7.4	MSD Samp	ble #28698: Lead RPD of 42 exceeds laboratory QC limit	of 20.									
R8.3	Laboratory	Duplicate Sample #28643: Percent Moisture RPD of52 e	xceeds laboratory QC limit of 20.									
1.	ER# = Exc	eption Report identification number (an Exception Repor	t should be completed for an item	if "NR" or "No" is checked).								



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SOUTHWEST GEOSCIENCE • 2351 W. Northwest Hwy., Suite 3321 • Dallas, Texas 75220 • Office: 214-350-5469 • Fax 214-350-2914

2014 EXIDE	APAR PAGE	2655 OF	3116
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Sam	ple Condition Upon Receipt
Pace Analytical Client Name:	Southwast Georgiance Pace #: DLasof
Courier: Fed Ex UPS USPS Client	Courier LSO Pace Other
Custody Seal on Cooler/Box Present: Xyes	🗌 no Seals intact: 📈 yes 🗌 no 🔲 N/A
Packing Material: Bubble Wrap Bubble E	Bags XNone Other
Thermometer Used	Type of Ice: Wet Blue None 🗌 Samples on ice, cooling process has begun
Cooler Temperature 3.8°C	Ice Visible in Sample Containers: ves no
(Corrected, if applicable)	Date and Initials of person examining
Temp should be above freezing to 6°C	Comments: contents h (42-11/3
Sample Receiving	· · · · · · · · · · · · · · · · · · ·
Chain of Custody Present:	Qres □No □NA 1
Chain of Custody Filled Out:	Vres □No □N/A 2
Chain of Custody Relinquished:	Xes □No □N/A 3
Sampler Name & Signature on COC:	Ves 🗆 No 🗆 N/A 4.
Short Hold Time Analysis (<72hr):	□Yes □N/A 5.
Rush Turn Around Time Requested:	
Containers Intact:	
Sample Labels match COC:	
-Includes date/time/ID/Analysis	
All containers needing acid/base pres. have been checked?	□Yes □No ☑/N/A 9. (Circle) HNO3 H2SO4 NaOH HCI
exceptions: VOA, coliform, O&G	If applicable see below.
All containers needing preservation are found to be in compliance with EPA recommendation.	□Yes □No JON/A pH strip lot #:
	Potassium Iodide strip lot #:
Headspace in VOA Vials ( >6mm):	
Trip Blank Present:	
Trip Blank Custody Seals Present	
Samples Arrived within Hold Time:	<u>N</u> _lyes ∐No ∐N/A 12.
Sufficient Volume:	13
Correct Containers Used:	ŪYes □No □N/A 14.
Client Notification/ Resolution:	Date/Time <sup>.</sup>
Comments/ Resolution:	
Project Manager Review:	Date: 6-25-13

**Sample Container Count** 

Face Analytical"

COC PAGE of of coc ID#

Pace Project # \_\_\_\_\_\_

	imple Line Item BP	~	5	ო	4	ц	0 1	 		» :	10	 C ¥	
	2N AG1(											 	
	J VG9L												
	L VG9H				-						-		
	BP2S							 	1				
	BP1U												
	BP2U												
	BG1H												_
	AG1S												-
	BP20											 	
	SP5T												
•	VGFU WGK					مىرىنى بىلەر تىلىرىن							
	Comments												

	nber vial	amber vial	amber vial	erved amber vial		red amber wide		ear vial	o. clear vial	erved clear vial	epta vial & HCL	//hexane wipe		served
	9P 40mL TSP am	9S 40mL H2SO4	9T 40mL Na Thio	OU 40mL unprese	I Wipe/Swab	-U 4oz unpreserv	U Summa Can	9H 40mL HCL cle	9T 40mL Na Thio	<b>9U 40mL unprese</b>	G Headspace se	-X 4oz wide jar w	-C Ziploc Bag	aN General unpre
	ÖÖ	ğ	ğ	ğ		ġ		Š	N S O N	090 V	SV	WG	ZPL	
	1 liter HNO3 plastic	1 liter H2SO4 plastic	1 liter unpreserved plastic	1 liter NaOH, Zn, Ac	500mL NaOH, Asc Acid plastic	500mL NaOH plastic	500mL NaOH, Zn Ac	250mL NaOh, Asc Acid plastic	250mL NaOH plastic	250mL NaOH, Zn Ac plastic	Air Cassettes	40mL Na Bisulfate amber vial	40mL MeOH clear vial	120mL Coliform unpreserved
	BP1N	BP1S	BP1U	BP1Z	BP2A	BP20	BP2Z	<b>BP3A</b>	BP3C	BP3Z	0	DG9B	DG9M	SP5U
	Air Filter	1 liter HCL amber glass	1 liter H2SO4 amber glass	1 liter Na Thiosulfate amber gl	500mL HNO3 amber glass	500mL H2SO4 amber glass	500mL unpreserved amber gla	250mL unpreserved amber gla	1 liter HCL clear dlass	1 liter H2SO4 clear glass	1 liter Na Thiosulfate clear gla	1 liter unpreserved glass	1 liter NaOH, Asc Acid plastic	120mL Coliform Na Thiosulfate
	AF	AG1H	AG1S	AG1T	AG2N	AG2S	AG2U	AG3U	BG1H	BG1S	BG1T	BG1U	BP1A	SP5T
Container Codes	40mL HCL amber voa vial	1 liter unpreserved amber glass	4oz clear soil iar	terra core kit	500mL HNO3 plastic	500mL unpreserved plastic	500ml H2SO4 plastic	250ml HNO3 plastic	250ml unbreserved plastic	25001112 dispressives pressive	250ml H2SO4 glass amber	1 liter H7SO4 amber class	1 liter unbreserved plastic	soz wide jar upreserved
	DG9H	AG1U	WGFU		BP2N	BP2U	BP2S	RP3N			00-10 00-10	AG1S	RP111	WGKU E

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F-DAL-C-003 rev.00 11-5-2012

### DATA USABILITY SUMMARY

John J. LeGolvan reviewed one data package from Pace Analytical Services, Inc. (Pace) for the analysis of soil samples collected June 24, 2013 at the Stewart Creek site in Frisco, Texas. Data were reviewed for conformance to the requirements of the guidance document, *Review and Reporting of COC Concentration Data* (RG-366/TRRP-13) and adherence to project objectives.

**Intended Use of Data**: The objective of the soil sampling event was to provide current data on concentrations of chemicals of concern (COCs) in the soil at the affected property.

Analyses requested included:

• EPA 6010 – RCRA 3 Metals (Arsenic, Cadmium, and Lead)

Data were reviewed and validated as described in *Review and Reporting of COC Concentration Data*, (RG-366/TRRP-13) and the results of the review/validation are discussed in this Data Usability Summary (DUS). The following laboratory submittals and field data were examined:

- the reportable data,
- the laboratory review checklists and associated exception reports, and
- the field notes with respect to sampling procedures, and preservation procedures prior to shipping the samples to the laboratory.

The results of supporting quality control (QC) analyses were summarized on the Laboratory Review Checklists (LRCs), Exception Reports (ERs) and in the case narratives, all of which were included in this review.

The complete laboratory analytical data package including LRCs, associated ERs, and reportable data included in this review are attached to this DUS.

#### Introduction

Fifteen (15) soil samples were collected from the site and analyzed for RCRA Metals arsenic, cadmium, and lead analyses. Table 1 lists the field sample identification cross-referenced to the laboratory identification.

#### Project Objectives

RCRA 3 Metals (Arsenic, Cadmium, and Lead) Recovery 75-125% RPD 0-20%

#### TABLE 1 Stewart Creek, Frisco, Texas DATA USABILITY SUMMARY - FIELD/LAB IDENTIFICATION CORRELATION

Field Identification	Laboratory Identification
Chip (6-24)-3	756325001
Chip (6-24)-3 Comp	756325002
Chip (6-24)-3 Base Comp	756325003
Chip (6-24)-3 Wall Base	756325004
Chip (6-24)-3 SED	756325005
PS (6-24)-3	756325006
PS (6-24)-3 Base Comp	756325007
Chip (6-24)-4	756325008
Chip (6-24)-4 Base Comp	756325009

# TABLE 1Stewart Creek, Frisco, TexasDATA USABILITY SUMMARY - FIELD/LAB IDENTIFICATION CORRELATION

Field Identification	Laboratory Identification
Chip (6-24)-5	7563250010
Chip (6-24)-5 Base Comp	7563250011
Slag (6-24)-1	7563250012
Slag (6-24)-1 Base	7563250013
Slag (6-24)-2	7563250014
Slag (6-24)-2 Base	7563250015

#### Data Review / Validation Results

#### Analytical Results

Qualified sample data is listed in Table 2. Non-detected results were reported as U, which is less than the Sample Detection Limits (SDLs) as reported by Pace.

#### Preservation and Holding Times

Soil samples were evaluated for agreement with the chain-of-custody (C-O-C) and the Laboratory Review Checklist. All samples were received in the appropriate containers and in good condition with the paperwork filled out properly. Sample receipt temperatures were within the acceptance criteria of  $4 \pm 2$  °C. Samples were preserved in the field as specified in SW-846 Table 2-36. Samples were prepared and analyzed within holding times specified in SW-846 Table 2-36.

#### Calibrations

According to the LRC, initial calibration data met SW-846 method requirements for the analytes.

#### Blanks

Laboratory method blank data was reported for each of the selected analytes. None of the analytes were detected above the laboratory MDLs in the method blanks; therefore, it appears that no laboratory contaminants were introduced in the method blank analyses.

#### Internal Standard and Surrogate Recoveries (RCRA 3 Metals)

Due to the method in use, internal standards and surrogates were not used in the analyses.

#### Laboratory Control Samples

RCRA 3 Metals laboratory control sample (LCS) recoveries met project objectives of 75 to 125% recovery.

#### Matrix Spike/Matrix Spike Duplicates

The MS recoveries from batch 7126 for arsenic, cadmium, and lead were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

The MS recoveries from batch 7171 for arsenic and cadmium were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

The MSD recoveries from batch 7126 for arsenic, cadmium, and lead were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

The MSD recoveries from batch 7171 for arsenic and cadmium were lower than expected. This indicates a possible low bias for these compounds on samples reported from this batch; however the LCS recoveries were within project objectives and the data from this batch was accepted.

The RPD of the MSD from batch 7126 exceeded the laboratory QC limit for lead.

### TABLE 2 Stewart Creek, Frisco, Texas DATA USABILITY SUMMARY - QUALIFIED DATA

Field Identification	Analyte	Qualification	Reason for Qualification
	Arsenic		Matrix spike
Chip (6-24)-3 Comp	Cadmium	M1-flag	recovery
	Lead		limits.
PS (6-24)-3	Cadmium	J-flag	Analyte detected below method quantitation limit
Chip (6-24)-4	Cadmium	J-flag	Analyte detected below method quantitation limit
Chip (6-24)-5	Cadmium	J-flag	Analyte detected below method quantitation limit
Chin (6.24) 5 Pase Comp	Arsenic	M1 flog	Matrix spike recovery
Chip (0-24)-5 Base Comp	Cadmium	in ridg	exceeded QC limits.

#### Field Procedures

The laboratory did not produce a duplicate analysis of the soil samples collected at the site. A field precision sample was not collected in the field.

#### Summary

The laboratory analyses were performed within the guidelines of the standards specified in the TRRP-13 guidance document. The laboratory QC indicates acceptable instrument calibration and performance. MS/MSD results indicated lower than expected recovery results from several batches which were run; however, the LCS/LCSD recoveries in each case were within the lab QC limits and within the project objective. The overall quality of the laboratory data appears to be acceptable for the project objective. The soil analytical data are usable for the purpose of determining current COC concentrations in soil at the affected property.



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

July 02, 2013

Rusty Simpson Southwest Geoscience 2351 W. Northwest Hwy Suite 3321 Dallas, TX 75220

RE: Pace Project 756325 Project ID: 0111C278A/Stewart Creek

Dear Rusty Simpson:

Enclosed are the analytical results for sample(s) received by the laboratory on June 25, 2013. Results reported herin conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Shelly Connelly/

Shelly Connelly shelly.connelly@pacelabs.com

Laboratory Certifications Pace Dallas : Texas Certification #: T104704232-12-4



#### **REPORT OF LABORATORY ANALYSIS**

This report shall not be reproduced, except in full, without the written consent of Pace Analytical Services, Inc.



### Pace Project No.: 756325

Client: <u>Southwest Geoscience</u> Project ID: <u>0111C278A/Stewart Creek</u>

Client Sample ID	Lab ID	Matrix	Collection Date/Time	Received Date/Time
Chip (6-24)-3	756325001	Solid	06/24/2013 11:40	06/25/2013 08:55
Chip (6-24)-3 Comp	756325002	Solid	06/24/2013 11:40	06/25/2013 08:55
Chip (6-24)-3 Base Comp	756325003	Solid	06/24/2013 11:40	06/25/2013 08:55
Chip (6-24)-3 Wall Base	756325004	Solid	06/24/2013 11:40	06/25/2013 08:55
Chip (6-24)-3 SED	756325005	Solid	06/24/2013 11:40	06/25/2013 08:55
PS (6-24)-3	756325006	Solid	06/24/2013 12:20	06/25/2013 08:55
PS (6-24)-3 Base Comp	756325007	Solid	06/24/2013 12:20	06/25/2013 08:55
Chip (6-24)-4	756325008	Solid	06/24/2013 14:10	06/25/2013 08:55
Chip (6-24)-4 Base Comp	756325009	Solid	06/24/2013 14:10	06/25/2013 08:55
Chip (6-24)-5	756325010	Solid	06/24/2013 15:50	06/25/2013 08:55
Chip (6-24)-5 Base Comp	756325011	Solid	06/24/2013 15:50	06/25/2013 08:55
Slag (6-24)-1	756325012	Solid	06/24/2013 16:25	06/25/2013 08:55
Slag (6-24)-1 Base	756325013	Solid	06/24/2013 16:25	06/25/2013 08:55
Slag (6-24)-2	756325014	Solid	06/24/2013 16:40	06/25/2013 08:55
Slag (6-24)-2 Base	756325015	Solid	06/24/2013 16:40	06/25/2013 08:55



### **Project Narrative**

Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Pace Project No.: 756325

Holding Times:

All holding times were met.

Blanks:

All blank results were below reporting limits.

Laboratory Control Samples:

All LCS recoveries were within QC limits.

Matrix Spikes and Duplicates:

MS or MSD recoveries outside of QC limits are qualified in the Report of Quality Control section.

Surrogate:

All surrogate recoveries were within QC limits.

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Appendix A

#### LABORATORY DATA PACKAGE COVER PAGE

This data package is for Job No. 756325 and consists of:

This signature page, the laboratory review checklist, and the following reportable data:

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- R1 Field chain-of-custody documentation;
- R2 Sample identification cross-reference;
- R3 Test reports (analytical data sheets) for each environmental sample that includes:
  - a. Items consistent with NELAC Chapter 5,
  - b. Dilution factors,
  - c. Preparation methods,
  - d. Cleanup methods, and
  - e. If required for the project, tentatively identified compounds (TICs).
- R4 Surrogate recovery data including:
  - a. Calculated recovery (%R), and
  - b. The laboratory's surrogate QC limits.
- R5 Test reports/summary forms for blank samples;
- R6 Test reports/summary forms for laboratory control samples (LCSs) including:
  - a. LCS spiking amounts,
  - b. Calculated %R for each analyte, and
  - c. The laboratory's LCS QC limits.
- R7 Test reports/summary forms for matrix spike/matrix spike duplicates (MS/MSDs) including:
  - a. Samples associated with the MS/MSD clearly identified,
  - b. MS/MSD spiking amounts,
  - c. Concentration of each MS/MSD analyte measured in the parent and spiked samples,
  - d. Calculated %Rs and relative percent differences, and
  - e. The laboratory's MS/MSD QC limits.
- R8 Laboratory analytical duplicate (if applicable) recovery and precision:
  - a. The amount of analyte measured in the duplicate,
  - b. The calculated RPD, and,
  - c. The laboratory's QC limits for analytical duplicated.
  - R9 List of method quantitation limits (MQLs) and detectability check sample results for each analyte and
  - R10 Other problems or anomalies.

The exception Report for each "No" or "Not Reviewed (NR) " item in the Laboratory Review Checklist and for each analyte, matrix, and method for which the laboratory does not hold NELAC accreditation under the Texas Laboratory Accreditation Program.

**Release Statement:** I am responsible for the release of this laboratory data package. This laboratory is NELAC accredited under the Texas Laboratory Accreditation Program for all the methods, analytes, and matrices reported in this data package except as noted in the Exception Reports. The data have been reviewed and are technically compliant with the requirements of the methods used, except where noted by the laboratory in the Exception Reports. By my signature below, I affirm to the best of my knowledge all problems/anomalies observed by the laboratory have been identified in the Laboratory Review Checklist, and no information affecting the quality of the data has been knowingly withheld.

Check, if applicable: [] This laboratory meets an exception under 30 TAC §25.6 and was last inspected by [X] TCEQ on 02/24/2012

Any findings affecting the data in this laboratory data package are noted in the Exception Reports herin. The official signing the cover page of the report in which these data are used is responsible for releasing this data package and is by signature affirming the above release statement is true.

Name (Printed)	
Shelly Connelly	

<u>Signature</u> Study (orwelly) <u>Official Title (Printed)</u> Project Manager <u>Date</u> 07/02/2013

X X

Х



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: <u>Chip (6-24</u> Lab ID: <u>75632500</u> Collected: <u>06/24/201</u>	Moiste <u>0</u> Receiv	ure: <u>2%</u> ved: <u>06/</u>	25/2013	<u>3 08:55</u>	Pac	Project ID: <u>(</u> e Project No.: <u>7</u> Matrix: <u>S</u>	0 <u>111C278A/Stew</u> 2 <u>56325</u> Solid	art Creek	<u>X</u>	
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	3.3	m	ig/kg	0.24	0.095	06/27/2013 18:37	06/27/2013 05:46	7126	75ICP1
Cadmium	1	0.29	m	ig/kg	0.095	0.019	06/27/2013 18:37	06/27/2013 05:46	7126	75ICP1
Lead	1	27.0	m	ig/kg	0.19	0.048	06/27/2013 18:37	06/27/2013 05:46	7126	75ICP1



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Client ID: <u>Chip (6-24</u> Lab ID: <u>756325003</u> Collected: <u>06/24/2013</u>	<u>omp</u> Mois 0 Rece	ture: <u>9</u> ived: <u>0</u>	). <u>6%</u> )6/25/2013	<u>3 08:55</u>	Pac	Project ID: ( e Project No.: 7 Matrix: 5	<u>0111C278A/Stewart Creek</u> <u>756325</u> Solid			
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total Analytical Method: EPA 6010 Prepa				Prepa	reparation Method: EPA 3050					
Arsenic	1	11.5	M1	mg/kg	0.28	0.11	06/27/2013 18:44	06/27/2013 05:46	7126	75ICP1
Cadmium	1	1.4	M1	mg/kg	0.11	0.023	06/27/2013 18:44	06/27/2013 05:46	7126	75ICP1
Lead	1	32.6	M1	mg/kg	0.23	0.056	06/27/2013 18:44	06/27/2013 05:46	7126	75ICP1



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID:   Chip (6-24)-3 Base Comp     Lab ID:   756325003   Moisture:   7%     Collected:   06/24/2013 11:40   Received:   06/25/2013 08:					<u>3 08:55</u>	Project ID:0111C278A/Stewart CreekPace Project No.:75632508:55Matrix:Solid						
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.		
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050					
Arsenic	1	9.2	m	ig/kg	0.28	0.11	06/27/2013 18:51	06/27/2013 05:46	7126	75ICP1		
Cadmium	1	1.1	m	ig/kg	0.11	0.022	06/27/2013 18:51	06/27/2013 05:46	7126	75ICP1		
Lead	1	27.7	m	ig/kg	0.22	0.055	06/27/2013 18:51	06/27/2013 05:46	7126	75ICP1		



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID:   Chip (6-24)-3 Wall Base     Lab ID:   756325004   Moisture:   14.6%     Collected:   06/24/2013 11:40   Received:   06/25/2013 (0					Project ID: 0111C278A/Stewart Creek   Pace Project No.: 756325   08:55 Matrix:							
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.		
6010 Metals, Total	Anal	ytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050					
Arsenic	1	8.1	rr	ig/kg	0.29	0.12	06/27/2013 18:58	06/27/2013 05:46	7126	75ICP1		
Cadmium	1	0.92	rr	ig/kg	0.12	0.023	06/27/2013 18:58	06/27/2013 05:46	7126	75ICP1		
Lead	1	15.7	r	ng/kg	0.23	0.059	06/27/2013 18:58	06/27/2013 05:46	7126	75ICP1		



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Client ID: <u>Chip (6-2</u> Lab ID: <u>7563250</u> Collected: <u>06/24/20</u>	ure: <u>24.</u> ved: <u>06/</u>	<u>3%</u> 25/2013	0111C278A/Stew 756325 Solid	art Creek	<u> </u>					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method:	EPA 601	0	Prepa	ration Metl	nod: EPA 3050			
Arsenic	1	10.4	m	ig/kg	0.34	0.14	06/27/2013 19:21	06/27/2013 05:46	7126	75ICP1
Cadmium	1	0.79	m	ig/kg	0.14	0.028	06/27/2013 19:21	06/27/2013 05:46	7126	75ICP1
Lead	1	39.3	m	ig/kg	0.28	0.069	06/27/2013 19:21	06/27/2013 05:46	7126	75ICP1



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Client ID: <u>PS (6-24)-</u> Lab ID: <u>756325000</u> Collected: <u>06/24/2013</u>	<u>3</u> 6 3 12:2	Moist	ure: <u>N//</u> ved: <u>06</u> /	<u>4</u> /25/201:	<u>3 08:55</u>	Pac	art Creek	<u>X</u>		
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Met	nod: EPA 3050			
Arsenic	1	3.0	n	ng/kg	0.26	0.10	06/27/2013 19:28	06/27/2013 05:46	7126	75ICP1
Cadmium	2	0.17	J n	ng/kg	0.21	0.042	07/01/2013 20:29	06/27/2013 05:46	7126	75ICP1
Lead	1	4.4	n	ng/kg	0.21	0.052	06/27/2013 19:28	06/27/2013 05:46	7126	75ICP1



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Client ID: <u>PS (6-24)-</u> Lab ID: <u>75632500</u> Collected: <u>06/24/2013</u>	<u>3 Bas</u> 7 3 12:2	Base Comp     Moisture:   3.2%     12:20   Received:   06/25/2013 08:55					Project ID: ( e Project No.: 7 Matrix: 5	art Creek	<u> </u>	
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Metl	nod: EPA 3050			
Arsenic	1	11.8	m	ig/kg	0.25	0.098	06/27/2013 19:34	06/27/2013 05:46	7126	75ICP1
Cadmium	1	0.82	m	ng/kg	0.098	0.020	06/27/2013 19:34	06/27/2013 05:46	7126	75ICP1
Lead	1	13.6	m	ng/kg	0.20	0.049	06/27/2013 19:34	06/27/2013 05:46	7126	75ICP1



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Client ID: <u>Chip (6-24)</u> Lab ID: <u>756325008</u> Collected: <u>06/24/2013</u>	Client ID: Chip (6-24)-4   Moisture: 3.7%     Lab ID: 756325008   Moisture: 3.7%     ollected: 06/24/2013 14:10   Received: 06/25/2013 08:3					Project ID:0111C278A/Stewart CreekPace Project No.:75632508:55Matrix:Solid						
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.		
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Metl	hod: EPA 3050					
Arsenic	1	3.8	n	ng/kg	0.25	0.10	06/27/2013 19:41	06/27/2013 05:46	7126	75ICP1		
Cadmium	1	0.077	J n	ng/kg	0.10	0.020	06/27/2013 19:41	06/27/2013 05:46	7126	75ICP1		
Lead	1	62.1	n	ng/kg	0.20	0.050	06/27/2013 19:41	06/27/2013 05:46	7126	75ICP1		



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Client ID:   Chip (6-24)-4 Base Comp     Lab ID:   756325009   Moisture:   25.8%     Collected:   06/24/2013 14:10   Received:   06/25/2013 08:55					Project ID: 0111C278A/Stewart Creek   Pace Project No.: 756325   S55 Matrix:					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	9.2	m	ig/kg	0.33	0.13	06/27/2013 19:48	06/27/2013 05:46	7126	75ICP1
Cadmium	1	0.63	m	ig/kg	0.13	0.027	06/27/2013 19:48	06/27/2013 05:46	7126	75ICP1
Lead	1	15.3	m	ig/kg	0.27	0.067	06/27/2013 19:48	06/27/2013 05:46	7126	75ICP1



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Client ID: <u>Chip (6-24)</u> Lab ID: <u>756325010</u> Collected: <u>06/24/2013</u>	24)-5   Moisture:   8.1%     010   Received:   06/25/2013   08:5					Project ID: <u>0111C278A/Stewart Creek</u> Pace Project No.: <u>756325</u> 08:55 Matrix: <u>Solid</u>					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	lytical Method:	EPA 60	10	Prepa	ration Met	hod: EPA 3050				
Arsenic	1	5.4	r	ng/kg	0.27	0.11	06/27/2013 19:55	06/27/2013 05:46	7126	75ICP1	
Cadmium	1	0.088	J r	ng/kg	0.11	0.022	06/27/2013 19:55	06/27/2013 05:46	7126	75ICP1	
Lead	1	15.4	r	ng/kg	0.22	0.055	06/27/2013 19:55	06/27/2013 05:46	7126	75ICP1	



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Client ID:   Chip (6-24)-5 Base Comp     Lab ID:   756325011   Moisture:   26.8%     Collected:   06/24/2013 15:50   Received:   06/25/2013 08:55						Project ID: 0111C278A/Stewart Creek Pace Project No.: 756325 Matrix: Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	lytical Method	I: EPA 6	010	Prepa	ration Met	nod: EPA 3050				
Arsenic	1	8.9	M1	mg/kg	0.35	0.14	06/27/2013 20:44	06/27/2013 05:44	7171	75ICP1	
Cadmium	1	0.63	M1	mg/kg	0.14	0.028	06/27/2013 20:44	06/27/2013 05:44	7171	75ICP1	
Lead	1	76.7		mg/kg	0.28	0.070	06/27/2013 20:44	06/27/2013 05:44	7171	75ICP1	



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Client ID: <u>Slag (6-24</u> Lab ID: <u>75632501</u> Collected: <u>06/24/201</u>	4 <u>)-1</u>   <u>2</u>  3 16:2	Mois <u>5</u> Rece	ture: <u>N/</u> ved: <u>06</u>	<u>A</u> 5/25/2013	<u>3 08:55</u>	Project ID: 0111C278A/Stewart Cre Pace Project No.: 756325 8:55 Matrix: Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	ytical Method	I: EPA 60	10	Prepa	ration Met	hod: EPA 3050			
Arsenic	1	118	ı	ng/kg	0.24	0.097	06/27/2013 20:51	06/27/2013 05:44	7171	75ICP1
Cadmium	1	< 0.019	U ı	ng/kg	0.097	0.019	06/27/2013 20:51	06/27/2013 05:44	7171	75ICP1
Lead	100	35200	ı	ng/kg	19.3	4.8	07/01/2013 11:28	06/27/2013 05:44	7171	75ICP1



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Client ID: <u>Slag (6-24)</u> Lab ID: <u>756325013</u> Collected: <u>06/24/2013</u>	-1 Ba	<u>1 Base</u> <b>Moisture:</b> <u>18%</u> <u>16:25</u> <b>Received:</b> <u>06/25/2013 08:55</u>					Project ID:   0111C278A/Stewart Creation     Pace Project No.:   756325     Matrix:   Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.	
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Metl	nod: EPA 3050				
Arsenic	1	16.4	m	g/kg	0.31	0.13	06/27/2013 20:58	06/27/2013 05:44	7171	75ICP1	
Cadmium	1	0.56	m	g/kg	0.13	0.025	06/27/2013 20:58	06/27/2013 05:44	7171	75ICP1	
Lead	1	17.8	m	g/kg	0.25	0.063	06/27/2013 20:58	06/27/2013 05:44	7171	75ICP1	



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Client ID: <u>Slag (6-24)</u> Lab ID: <u>756325014</u> Collected: <u>06/24/2013</u>	<u>-2</u> 16:4	Moisture: <u>4.3%</u> 40 Received: <u>06/25/2013 08:5</u>				Project ID:   0111C278A/Stewart Creel     Pace Project No.:   756325     B:55   Matrix:   Solid				
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, Total	Ana	lytical Method:	EPA 601	0	Prepa	ration Metl	nod: EPA 3050			
Arsenic	2	38.7	m	ig/kg	0.50	0.20	06/30/2013 14:49	06/27/2013 05:44	7171	75ICP1
Cadmium	2	1.9	m	ig/kg	0.20	0.040	06/30/2013 14:49	06/27/2013 05:44	7171	75ICP1
Lead	100	20600	m	ng/kg	20.1	5.0	07/01/2013 11:33	06/27/2013 05:44	7171	75ICP1



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Client ID: <u>Slag (6-24</u> Lab ID: <u>75632501</u> Collected: <u>06/24/201</u>	ient ID:   Slag (6-24)-2 Base     Lab ID:   756325015     Moisture:   N/A     lected:   06/24/2013 16:40						Project ID:0111C278A/Stewart CreekPace Project No.:7563258:55Matrix:Solid					
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.		
6010 Metals, Total	Ana	ytical Method	: EPA 60	10	Prepa	ration Metl	nod: EPA 3050					
Arsenic	1	279	I	mg/kg	0.25	0.10	06/27/2013 21:12	06/27/2013 05:44	7171	75ICP1		
Cadmium	2	< 0.040	U	mg/kg	0.20	0.040	06/30/2013 14:55	06/27/2013 05:44	7171	75ICP1		
Lead	2	459	I	mg/kg	0.40	0.10	07/01/2013 11:39	06/27/2013 05:44	7171	75ICP1		



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Batch: 7103 Method: ASTM	D2974-87		lo.: <u>756325</u> ID: <u>75BAL3</u>				
Duplicate: 28643 Original for Sar	<b>nple:</b> Client sample Chi	p (6-21)-1					
Parameters	Original Result	Dup Result	Units	RPD	Max RPD	Quals	
Percent Moisture	1.7	2.9	%	52	20	D6	



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### Batch: 7126 Method: EPA 6010 Prep Method: EPA 3050

# Pace Project No.: 756325

Instrument ID: 75ICP1

Blank: 28695								
Parameters	Dilution	Quals	Result	Units	MQL	SDL	Analysis Date	Prep Date
Arsenic	1	U	<0.10	mg/kg	0.25	0.10	06/27/2013 16:34	06/27/2013 05:46
Cadmium	1	U	<0.020	mg/kg	0.10	0.020	06/27/2013 16:34	06/27/2013 05:46
_ead	1	U	<0.050	mg/kg	0.20	0.050	06/27/2013 16:34	06/27/2013 05:46

#### Laboratory Control Sample: 28696

Parameters	Spk Amt	LCS Result	Units	LCS %Rec	% Rec Limits	LCS Quals
Arsenic	50	45.4	mg/kg	91	80-120	
Cadmium	50	45.3	mg/kg	91	80-120	
Lead	50	48.1	mg/kg	96	80-120	

#### Matrix Spike: 28697

Matrix Spike Duplicate: 28698

#### Original for Sample: Client sample PS (6-21)-1

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	6.0	60.8	57.4	41.2	49.7	mg/kg	58	76	75-125	19	20	M1
Cadmium	<0.023	60.8	57.4	36.3	44.3	mg/kg	60	77	75-125	20	20	M1
Lead	6.0	60.8	57.4	38.8	59.5	mg/kg	54	93	75-125	42	20	M1,R1

Matrix Spike: 29093

Matrix Spike Duplicate: 29094

Original for Sample: Project sample Chip (6-24)-3 Comp

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	11.5	55.3	54.7	39.0	38.2	mg/kg	50	49	75-125	2	20	M1
Cadmium	1.4	55.3	54.7	28.8	29.9	mg/kg	50	52	75-125	4	20	M1
Lead	32.6	55.3	54.7	55.0	55.0	mg/kg	40	41	75-125	0	20	M1



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### Batch: 7171 Method: EPA 6010 Prep Method: EPA 3050

Blank: 28885

# Pace Project No.: 756325

Instrument ID: 75ICP1

Parameters	Dilution	Quals	Result	Units	MQL	SDL	Analysis Date	Prep Date
Arsenic	1	U	<0.10	mg/kg	0.25	0.10	06/27/2013 20:01	06/27/2013 05:44
Cadmium	1	U	<0.020	mg/kg	0.10	0.020	06/27/2013 20:01	06/27/2013 05:44
_ead	1	J	0.059	mg/kg	0.20	0.050	06/27/2013 20:01	06/27/2013 05:44
Laboratory Contr	rol Sample: 28886							
		Spk	LCS			LCS	% Rec	LCS

Parameters	Amt	Result	Units	%Rec	Limits	Quals
Arsenic	50	42.8	mg/kg	86	80-120	
Cadmium	50	42.3	mg/kg	85	80-120	
Lead	50	43.5	mg/kg	87	80-120	

Matrix Spike: 28887

Matrix Spike Duplicate: 28888

Original for Sample: Project sample Chip (6-24)-5 Base Comp

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	8.9	64.4	64.4	47.1	47.0	mg/kg	59	59	75-125	0	20	M1
Cadmium	0.63	64.4	64.4	38.8	38.8	mg/kg	59	59	75-125	0	20	M1
Lead	76.7	64.4	64.4	148	153	mg/kg	111	119	75-125	3	20	


## Pace Project No.: 756325

Analyte	Method	Unadjusted MQL	<b>Reporting Units</b>	
Arsenic	EPA 6010	0.25	mg/kg	
Cadmium	EPA 6010	0.10	mg/kg	
Lead	EPA 6010	0.20	mg/kg	



### Pace Project No.: 756325

#### DEFINITIONS

- DF Dilution Factor
- J Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.
- U Indicates the compound was analyzed for, but not detected.
- SDL Sample Detection Limit
- MQL Method Quantitation Limit
- LCS(D) Laboratory Control Sample (Duplicate)
- MS(D) Matrix Spike (Duplicate)
- DUP Sample Duplicate
- RPD Relative Percent Difference
- TNI The Nelac Institute

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

### ANALYTE QUALIFIERS

- Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
- R1 RPD value was outside control limits.

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		TRRP LABORATORY REVIEW CHECKLIST					
L	aboratory	Pace Analytical Services, Inc. LRC Date: 07	/02/2013				
Proj	ect Name:	0111C278A/Stewart Creek Laboratory Job Number: 75	6325				
Reviev	ver Name:	Shelly Connelly Prep Batch Number(s): Se	e exception	report.	-		
#1	<b>A</b> <sup>2</sup>	Description	Yes	No	NA <sup>3</sup>	NR <sup>4</sup>	ER #5
R1	OI	Chain-of-custody (C-O-C)					
		Did samples meet the laboratory's standard conditions of sample acceptability upon receipt?	X				
		Were all departures from standard conditions described in an exception report?	Y				-
P2	0	Sample and quality control (OC) identification	~				
112		Are all field sample ID numbers cross referenced to the laboratory ID numbers?	v				
		Are all laboratory ID numbers cross referenced to the corresponding OC data?					
D2	0						
КJ	U	Were all camples prepared and analyzed within helding times?	×				
		Other than those results < MQL, were all other raw values bracketed by calibration standards'	?				-
			X				
		Were calculations checked by a peer or supervisor?	Х				
		Were all analyte identifications checked by a peer or supervisor?	Х				
		Were sample detection limits reported for all analytes not detected?	Х				
		Were all results for soil and sediment samples reported on a dry weight basis?	Х				
		Were % moisture (or solids) reported for all soil and sediment samples?	Х				
		Were bulk soils/solids samples for volatile analysis extracted with methanol per SW846 Metho	bd		X		
		5035? If required for the project, are TICe reported?					+
D4	0	Surregete receivery date					-
Κ4	0	Surrogate recovery data					+
		Were surrogate percent recovering in all complex within the leheretery OC limits?					+
DE		Test reporte/summary forms for black complex					-
КJ	U	Were appropriate type(a) of blacks applyzed?	v				+
		Were appropriate type(s) or biallies analyzed?					-
		Were method blanks taken through the entire analytical process, including preparation and, if	~				-
		applicable, cleanup procedures?	Х				
		Were blank concentrations < MQL?	Х				
R6	OI	Laboratory control samples (LCS):					
		Were all COCs included in the LCS?	Х				
		Was each LCS taken through the entire analytical procedure, including prep and cleanup step	S? X				
		Were LCSs analyzed at the required frequency?	X				
		Were LCS (and LCSD, if applicable) %Rs within the laboratory OC limits?	X				+
		Does the detectability check sample data document the laboratory's capability to detect the C	OCs V				-
		at the MDL used to calculate the SDLs?	X				
		Was the LCSD RPD within QC limits?			X		
R7	OI	Matrix spike (MS) and matrix spike duplicate (MSD) data					
		Were the project/method specified analytes included in the MS and MSD?	Х				
		Were MS/MSD analyzed at the appropriate frequency?	Х				_
		Were MS (and MSD, if applicable) %Rs within the laboratory QC limits?		Х	<u> </u>		R7.3
		Were MS/MSD RPDs within laboratory QC limits?		Х			R7.4
R8	OI	Analytical duplicate data					
		Were appropriate analytical duplicates analyzed for each matrix?			Х		<u> </u>
		Were analytical duplicates analyzed at the appropriate frequency?			Х		
		Were RPDs or relative standard deviations within the laboratory QC limits?			X		
R9	OI	Method quantitation limits (MQLs):					
		Are the MQLs for each method analyte included in the laboratory data package?	Х				_
		Do the MucLs correspond to the concentration of the lowest non-zero calibration standard?	X				
		Are unadjusted MQLs and DCSs included in the laboratory data package?	Х				
R10	OI	Other problems/anomalies					
		Are all known problems/anomalies/special conditions noted in this LRC and ER?	X				
		Was applicable and available technology used to lower the SDL to minimize the matrix					
		interference effects on the sample results?	~				
		Is the laboratory NELAC-accredited under the Texas Laboratory Accreditation Program for the	X				
1.	Items identifie	energies, matrices, and metricus associated with this laboratory data package submitted in the TRRP-required reports(s	). Items identifie	d by the	1	1	<u> </u>
<u>_</u>	letter "S" sho	uld be retained and made available upon request for the appropriate retention period;					
2.	NA = Not app	anaryses, i – morganic anarysises (and general chemistry, when applicable), Jicable;					
4. F	NR = Not rev	iewed; tion Report identification number (an Excention Report should be completed for an item if "NP" or "No" is chocked)					
э.	EIV# - EXCeb						

#### 2014 EXIDE APAR PAGE 2685 OF 3116 TRRP LABORATORY REVIEW CHECKLIST Laboratory Pace Analytical Services, Inc. LRC Date: 07/02/2013 **Project Name:** 0111C278A/Stewart Creek Laboratory Job Number: 756325 **Reviewer Name:** Shelly Connelly Prep Batch Number(s): See exception report. NA<sup>3</sup> NR<sup>4</sup> ER #<sup>5</sup> **#**<sup>1</sup> $A^2$ Description Yes No **S1** OI Initial calibration (ICAL) Х Were response factors and/or relative response factors for each analyte within QC limits? Were percent RSDs or correlation coefficient criteria met? Х Was the number of standards recommended in the method used for all analytes? Х Were all points generated between the lowest and highest standard used to calculate the curve? Х Are ICAL data available for all instruments used? Х Has the initial calibration curve been verified using an appropriate second source standard? Х Initial and continuing calibration verification (ICCV and CCV) and continuing calibration S2 OI blank (CCB): Was the CCV analyzed at the method-required frequency? Х Were precent differences for each analyte within the method-required QC limits? Х Was the ICAL curve verified for each analyte? Х Х Was the absolute value of the analyte concentration in the inorganic CCB < MDL? **S**3 Ο Mass spectral tuning Was the appropriate compound for the method used for tuning? Х Were ion abundance data within the method-required QC limits? Х S4 ο Internal standards (IS) Were IS area counts and retention times within the method-required QC limits? Х OI **S**5 Raw data (NELAC Section 5.5.10) Х Were the raw data (for example, chromatograms, spectral data) reviewed by an analyst? Were data associated with manual integrations flagged on the raw data? Х **S6** Ο Dual column confirmation Did dual column confirmation results meet the method-required QC? Х **S7** Ο Tentatively identified compounds (TICs) If TICs were requested, were the mass spectra and TIC data subject to appropriate checks? х **S8** Т Interference Check Sample (ICS) results Х Were percent recoveries within method QC limits? **S**9 L Serial dilutions, post digestion spikes, and method of standard additions Were percent differences, recoveries, and the linearity within the QC limits specified in the Х method? S10 OI Method detection limit (MDL) studies Was a MDL study performed for each reported analyte? Х Х is the MDL either adjusted or supported by the analysis of DCSs? S11 OI Proficiency test reports Was the laboratory's performance acceptable on the applicable proficiency tests or evaluation Х studies? S12 OI Standards documentation Are all standards used in the analyses NIST-traceable or obtained from other appropriate Х sources? S13 OI Compound/analyte identification procedures Are the procedures for compound/analyte identification documented? Х S14 OI Demonstration of analyst competency (DOC) Х Was DOC conducted consistent with NELAC Chapter 5? Х is documentation of the analyst's competency up-to-date and on file? Verification/validation documentation for methods (NELAC Chapter 5) S15 οι Are all the methods used to generate the data documented, verified, and validated, where Х applicable? OI Laboratory standard operating procedures (SOPs) S16 Are laboratory SOPs current and on file for each method performed? Х Items identified by the letter "R" must be included in the laboratory in the laboratory data package submitted in the TRRP-required reports(s). Items identified by the 1. letter "S" should be retained and made available upon request for the appropriate retention period; 2. O = Organic analyses; I = inorganic analysises (and general chemistry, when applicable); NA = Not applicable; 3. 4 NR = Not reviewed:

5. ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked).

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		TRRP LABORATORY	REVIEW CHECKLIST			
La	aboratory	Pace Analytical Services, Inc.	LRC Date:	07/02/2013		
Proje	ect Name:	0111C278A/Stewart Creek	Laboratory Job Number:	756325		
Review	er Name:	Shelly Connelly	Prep Batch Number(s):	7103,7126,7129,7171		
ER # <sup>1</sup>		Γ	Description			
R7.3	MS Sample	e #28697: Arsenic 58% spike recovery outside laboratory	QC limit of 75-125%.			
R7.3	MS Sample	e #28697: Cadmium 60% spike recovery outside laborato	ry QC limit of 75-125%.			
R7.3	MS Sample	e #28697: Lead 54% spike recovery outside laboratory Q	C limit of 75-125%.			
R7.3	MS Sample	e #28887: Arsenic 59% spike recovery outside laboratory	QC limit of 75-125%.			
R7.3	MS Sample	e #28887: Cadmium 59% spike recovery outside laborato	ry QC limit of 75-125%.			
R7.3	3 MS Sample #29093: Arsenic 50% spike recovery outside laboratory QC limit of 75-125%.					
R7.3	'.3 MS Sample #29093: Cadmium 50% spike recovery outside laboratory QC limit of 75-125%.					
R7.3	'.3 MS Sample #29093: Lead 40% spike recovery outside laboratory QC limit of 75-125%.					
R7.3	MSD Samp	ole #28888: Arsenic 59% spike recovery outside laborato	y QC limit of 75-125%.			
R7.3	MSD Samp	ole #28888: Cadmium 59% spike recovery outside labora	tory QC limit of 75-125%.			
R7.3	MSD Samp	ole #29094: Arsenic 49% spike recovery outside laborato	y QC limit of 75-125%.			
R7.3	MSD Samp	ole #29094: Cadmium 52% spike recovery outside labora	tory QC limit of 75-125%.			
R7.3	MSD Samp	ble #29094: Lead 41% spike recovery outside laboratory	QC limit of 75-125%.			
R7.4	MSD Samp	ole #28698: Lead RPD of 42 exceeds laboratory QC limit	of 20.			
1.	ER#=Exc	ception Report identification number (an Exception Report	t should be completed for an item	if "NR" or "No" is checked).		



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2014 EXIDE	APAR	PAGE	2689	OF	31	16
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<i>FaceAnalytical</i> Client Name: SWGee        Pace #: NG335             Courier: Fed Ex       UPS       USPS       Client       Courier       ESO       Pace       Other	Sam	ple Co	ondit	ion U	Ipon Receipt
Courter:    Fad EX    UPS    USPS    Client    Courter    LSO    Pace Other	Face Analytical Client Name:	<u>Si</u>	U	Ge	0 Pace #: 75(3)5
Dustody Seal on Cooler/Box Present:       Dyss       no       Seals intact:       Dyss       no       N/A         Packing Material:       Bubble Wrap       Bubble Bags       INone       Other       Incommeter Used       Incommeter Used <td>Courier:  Fed Ex UPS USPS Client Fracking #:</td> <td></td> <td>ourier</td> <td></td> <td>O Pace Other</td>	Courier:  Fed Ex UPS USPS Client Fracking #:		ourier		O Pace Other
Packing Material:       Bubble Wrep       Bubble Bags       None       Samples on ice, cooling process has be Cooler Temperature         Corrected, if applicable)       Breaz       Type of Ice:       Wet Blue None       Samples on ice, cooling process has be Ice Visible in Sample Containers:       Description         Corrected, if applicable)       Dread of Containers:       Dread of C	Custody Seal on Cooler/Box Present: Xyes	🗌 no		Seals i	intact: 🔎 yes 🗌 no 🔲 N/A
Thermometer Used       IR.02       IYpe of Ice:       Wet Blue None       Samples on ice, cooling process has been Cooler transporture         Corrected, if applicable)       IR.02       Corrected, if applicable)       Description       Descri	Packing Material: 🔲 Bubble Wrap 🛛 🕅 Bubble B	Bags	ĹNo	ne [	Other
Cooler Temperature       A.9.°C       Ice Visible in Sample Containers:       yes       no         Corrected, if applicable)       Tom should be above freazing to 6°C       Comments:       Date and (Miglig of person example containers:       yes       no         Tamp should be above freazing to 6°C       Comments:	Thermometer Used (IR-0) IR-02	Туре с	of Ice:	Wet	Blue None 🎽 Samples on ice, cooling process has begun
Corrected, if applicable)       Data and [hit]alig of person sexply:         Temp should be above freeding to 6°C       Comments:       Data and [hit]alig of person sexply:         Sample Receiving       Sample Receiving       Image: Sample Receiving       Sample Receiving         Chain of Custody Present:       Image: Sample Receiving	Cooler Temperature 2.800	lce V	lsible	in San	nple Containers: 🎦 yes 🔤 no
Sample Receiving       Comments:       Contents: 9 0 C 2/2 V// -         Chain of Custody Present:       Yes       No       NA       1.         Chain of Custody Filed Out:       Yes       No       NA       2.         Chain of Custody Filed Out:       Yes       No       NA       3.         Sampler Name & Signature on COC:       Ima       No       NA       4.         Short Hold Time Analysis (<72hr):	(Corrected, if applicable)				Date and Initials of person examining
Sample Keeving         Chain of Custody Present:         Chain of Custody Filled Out:         Chain of Custody Relinquished:         Sample Name & Signature on COC:         Sample Name & Signature on COC:         Short Hold Time Analysis (<72hr):	Temp should be above freezing to 6 C				Comments: contents:
Chain of Clustody Filed Out:       Image: Stepse in the image: Stepse: Stepse in the image: Stepse in the image: Ste		<del>.</del>			
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Chain of Custody Relinquisitied:       Extes       Live       5.         Sampler Name & Signature on COC:       Difes       INo       DNA       4.         Short Hold Time Analysis (<72hr):	Chain of Custody Filled Out:	12 Ny es			2.
Sample Name & Signature on COC. Bries Divo Divo A. Short Hold Time Analysis (<72hr): Dive Divo Divo A. Rush Tum Around Time Requested: Dive Divo A. Rush Tum Around Time Requested: Dive Divo A. Sample Labels match COC: Dive Divo A. -Includes date/time/ID/Analysis All containers needing add/base pres. have been checked? Dive Divo A. All containers needing add/base pres. have been checked? Dive Divo A. All containers needing add/base pres. have been checked? Dive Divo A. All containers needing add/base pres. have been checked? Dive Divo A. All containers needing add/base pres. have been checked? Dive Divo A. Headspace in VOA Vials (>6mm): Divo A. Trip Blank Present: Dive Divo Divo A. Trip Blank Present: Dive Divo Divo A. Samples Arrived within Hold Time: Dive Divo Elvert Sufficient Volume: Dives Divo Elvert Person Contacted: Dive Divo DiviA. Person Contacted: Dive Divo DiviA. Person Contacted: Dive Divo DiviA. Person Contacted: Dive Divo DiviA. Person Contacted: Dive Divo DiviA. Date/Time: Comments/ Resolution: DiviA. Dive Divo DiviA. Date/Time: DiviA. Date/Time: DiviA. Date/Time: DiviA. Date/Time: DiviA. Date/Time: DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA. DiviA.	Sempler Name & Signature on COCI				3.
Short Hold Thile Analysis (-7211):       Ites       Ites<	Sampler Name & Signature on COC:				<i>z</i>
Kush Tuhn Around Thile Requested:       Image:	Short Hold Time Analysis ( 2017):</td <td></td> <td></td> <td></td> <td>o.</td>				o.
Containers intect.       Euls       INV       IV       IV <t< td=""><td>Containere Intert</td><td></td><td></td><td></td><td>7</td></t<>	Containere Intert				7
Sample Labes Inter COC.		Nes			8
Include statistics       Include s	Includes date/time/ID/Analysis	L1460-			<b>0.</b>
exceptions: VOA, collorm, 0&G         All containers needing preservation are found to be in compliance with EPA recommendation.         Person Data Preservation are found to be in compliance with EPA recommendation.         Person Data Preservation are found to be in compliance with EPA recommendation.         Press DNo         Person Data Preservation are found to be in compliance with EPA recommendation.         Press DNo         Press DNo <tr< td=""><td>All containers needing acid/base pres. have been checked?</td><td></td><td></td><td></td><td></td></tr<>	All containers needing acid/base pres. have been checked?				
All containers needing preservation are found to be in compliance with EPA recommendation.       PH strip lot #:         Potassium lodide strip lot #:       Potassium lodide strip lot #:         Headspace in VOA Vials (>6mm):       Pyes         Trip Blank Present:       Pyes         Trip Blank Custody Seals Present       Pyes         Samples Arrived within Hold Time:       Pyes         Sufficient Volume:       Pyes         Even       No         Even       No         Preson Contacted:       Preson         Person Contacted:       Person         Comments/ Resolution:       Date/Time:	exceptions: VOA, coliform, O&G	1103			If applicable see below.
Potassium Iodide strip Iot #:         Lead Acetate strip Iot #:         Headspace in VOA Vials (>6mm):       Image: Second Seco	All containers needing preservation are found to be in compliance with EPA recommendation.	□Yes	⊡No	BINA	pH strip lot #:
Lead Acetate strip lot #:         Headspace in VOA Vials (>6mm):       IVes       INo       IVes       10.         Trip Blank Present:       IVes       INo       IVes       11.         Trip Blank Custody Seals Present       IVes       INo       IVes       INo         Samples Arrived within Hold Time:       IVes       INo       INvit       12.         Sufficient Volume:       IVes       INo       INvit       13.         Correct Containers Used:       IVes       INo       INvit       14.         Client Notification/ Resolution:       Person Contacted:       Date/Time:					Potassium lodide strip lot #:
Headspace in VOA Vials (>6mm):       Image: Present		•			Lead Acetate strip lot #:
Trip Blank Present: IYes INo II.   Trip Blank Custody Seals Present IYes INo INA   Samples Arrived within Hold Time: IVes INo INA   Sufficient Volume: IVes INo INA   Correct Containers Used: IYes INo INA   Person Contacted: Date/Time: Image: Comments/ Resolution:	Headspace in VOA Vials ( >6mm):	□Yes	□No	UN/A	10.
Trip Blank Custody Seals Present       IYes       INo       ENNA         Samples Arrived within Hold Time:       IXes       INo       INA         Sufficient Volume:       IXes       INo       INA         Sufficient Volume:       IYes       INo       INA         Correct Containers Used:       IYes       INo       INA         Client Notification/ Resolution:       IYes       INo       INA         Person Contacted:       Date/Time:       Image: I	Trip Blank Present:	□Yes	□No	GK1/A	11.
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Sufficient Volume:       Image: Constant of the second secon	Samples Arrived within Hold Time:	<u>∏</u> {¥eş	⊡No	□n/a	12.
Correct Containers Used:       Image: Correct Containers Used:       14.         Client Notification/ Resolution:       Date/Time:	Sufficient Volume:	<b>⊠<del>Ye</del>s</b>	□No	□n/A	13.
Client Notification/ Resolution: Person Contacted: Date/Time: Comments/ Resolution:	Correct Containers Used:	Yes	□No	⊡n/a	14.
Person Contacted:Date/Time: Comments/ Resolution:	Client Notification/ Resolution:				
Comments/ Resolution:	Person Contacted:			_Date/	Time:
	Comments/ Resolution:	<u> </u>			
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Sample Container Count

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Sample Line Item	BP2N	AG1U	VG9U	VG9H	BP2S	BP1U	BP2U	BG1H	AG1S	BP20	SP5T	WGFU M	/GKU	_	Comments
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	Container Codes							-
DG9H	40mL HCL amber voa vial	AF	Air Filter	BP1N	1 liter HNO3 plastic	DG9P	40mL TSP amber vial	
AG1U	1liter unpreserved amber glass	AG1H	1 liter HCL amber glass	BP1S	1 liter H2SO4 plastic	DG9S	40mL H2SO4 amber vial	
WGFU	4oz clear soil iar	AG1S	1 liter H2SO4 amber glass	BP1U	1 liter unpreserved plastic	DG9T	40mL Na Thio amber vial	
L C	terra core kit	AG1T	1 liter Na Thiosulfate amber gl	BP1Z	1 liter NaOH, Zn, Ac	DG9U	40mL unpreserved amber vial	
BP2N	500mL HNO3 plastic	AG2N	500mL HNO3 amber glass	BP2A	500mL NaOH, Asc Acid plastic	-	Wipe/Swab	
BP2U	500mL unpreserved plastic	AG2S	500mL H2SO4 amber glass	BP20	500mL NaOH plastic	JGFU	4oz unpreserved amber wide	
BP7S	500mL H2SO4 plastic	AG2U	500mL unpreserved amber gla	BP2Z	500mL NaOH, Zn Ac		Summa Can	,
RP3N	250ml HNO3 plastic	AG3U	250mL unpreserved amber gla	BP3A	250mL NaOh, Asc Acid plastic	VG9H	40mL HCL clear vial	,
ED31	250ml unnreserved plastic	BG1H	1 liter HCL clear class	BP3C	250mL NaOH plastic	VG9T	40mL Na Thio. clear vial	
			1 liter H2SO4 clear glass	BP3Z	250mL NaOH, Zn Ac plastic	VG9U	40mL unpreserved clear vial	<del>,</del>
00-10 00-20	250mit 112004 plasmo	BG1T	1 liter Na Thiosulfate clear gla	U	Air Cassettes	VSG	Headspace septa vial & HCL	;;;;;;
AG1S	1 liter H2SO4 amber class	BG1U	1 liter unpreserved glass	DG9B	40mL Na Bisulfate amber vial	WGFX	4oz wide jar w/hexane wipe	
RP1U	1 liter unbreserved plastic	BP1A	1 liter NaOH, Asc Acid plastic	DG9M	40mL MeOH clear vial	ZPLC	Ziploc Bag	
MGKU	8oz wide jar upreserved	SP5T	120mL Coliform Na Thiosulfate	SP5U	120mL Coliform unpreserved	ßN	General unpreserved	
Other	Other							

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F-DAL-C-003 rev.00 11-5-2012

Sample Container Count

Face Analytical" www.pacetats.com

COC PAGE A of A COC ID#

Pace Project # 77 Lo335

	BP2S BP1U BP2U BG1H AG1S BP20 SP5T WGFU WGKU Comments										
<u>L</u>	P1U BP2U B										
	9H BP2S E										
	VG9U VG										
	AG1U										
	BP2N										
	Sample Line Item	-	2	с	4	5	9	 - α		0.	

	Container Codes							-
DG9H	40ml HCl amber voa vial	AF	Air Filter	BP1N	1 liter HNO3 plastic	DG9P 40mL TSP a	amber vial	
4011	1 liter unbreserved amber diass	AG1H	1 liter HCL amber class	BP1S	1 liter H2SO4 plastic	DG9S 40mL H2SO	)4 amber vial	
MGFU	407 clear soil iar	AG1S	1 liter H2SO4 amber glass	BP1U	1 liter unpreserved plastic	DG9T 40mL Na Th	nio amber vial	
2 2 2 2	terra core kit	AG1T	1 liter Na Thiosulfate amber gl	BP1Z	1 liter NaOH, Zn, Ac	DG9U 40mL unpre	served amber vial	
BP2N	500mL HNO3 plastic	AG2N	500mL HNO3 amber glass	BP2A	500mL NaOH, Asc Acid plastic	I Wipe/Swab		
11002	500ml unpreserved plastic	AG2S	500mL H2SO4 amber glass	BP20	500mL NaOH plastic	JGFU 4oz unprese	erved amber wide	
	500ml H2SOA plastic	AG2U	500mL unpreserved amber gla	BP2Z	500mL NaOH, Zn Ac	U Summa Car		
	ocome necos practic	AG3U	250ml unpreserved amber dia	BP3A	250mL NaOh, Asc Acid plastic	VG9H 40mL HCL o	clear vial	
	200111 111000 prastic	RG1H	1 liter HCL clear class	BP3C	250mL NaOH plastic	VG9T 40mL Na Th	nio. clear vial	
	20011L UIDESELVED Plasmo		1 liter HOSO4 clear class	BP3Z	250mL NaOH. Zn Ac plastic	VG9U 40mL unpre	served clear vial	
0000	200111 12304 plastic		1 liter Na Thiosulfate clear dla		Air Cassettes	VSG Headspace	septa vial & HCL	
	2 Julie 1/2004 guber class	BG11	1 liter unbreserved dlass	DG9B	40mL Na Bisulfate amber vial	WGFX 4oz wide jar	w/hexane wipe	
	1 liter unpreconted plactic	RP1A	1 liter NaOH Asc Acid plastic	DG9M	40mL MeOH clear vial	ZPLC Ziploc Bag		
NU-10	Roz wide jar upreserved	SP5T	120mL Coliform Na Thiosulfate	SP5U	120mL Coliform unpreserved	GN General unpi	reserved	
Other	Other							

#### 2014 EXIDE APAR PAGE 2691 OF 3116



Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

July 29, 2013

Rusty Simpson Southwest Geoscience 2351 W. Northwest Hwy Suite 3321 Dallas, TX 75220

RE: Pace Project 756761 Project ID: 0111C278A/Stewart Creek

Dear Rusty Simpson:

Enclosed are the analytical results for sample(s) received by the laboratory on July 12, 2013. Results reported herin conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Shelly Connelly/

Shelly Connelly shelly.connelly@pacelabs.com

Laboratory Certifications Pace Dallas : Texas Certification #: T104704232-12-4



#### **REPORT OF LABORATORY ANALYSIS**

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# Pace Project No.: 756761

## Client: <u>Southwest Geoscience</u> Project ID: <u>0111C278A/Stewart Creek</u>

Client Sample ID	Lab ID	Matrix	Collection Date/Time	Received Date/Time
Chip (6-21)-1	756761001	Solid	06/21/2013 14:32	07/12/2013 11:36
Slag (6-24)-1	756761002	Solid	06/24/2013 16:25	07/12/2013 11:36
Slag (6-24)-2	756761003	Solid	06/24/2013 16:40	07/12/2013 11:36
Slag (6-24)-2 Base	756761004	Solid	06/24/2013 16:40	07/12/2013 11:36



# **Project Narrative**

Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Pace Project No.: 756761

Holding Times:

All holding times were within method requirements.

Blanks:

All blank results were below reporting limits.

Laboratory Control Samples:

All LCS recoveries were within QC limits.

Matrix Spikes and Duplicates:

MS or MSD recoveries outside of QC limits are qualified in the Report of Quality Control section.

Surrogate:

All surrogate recoveries were within QC limits.

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Appendix A

#### LABORATORY DATA PACKAGE COVER PAGE

This data package is for Job No. 756761 and consists of:

This signature page, the laboratory review checklist, and the following reportable data:

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- R1 Field chain-of-custody documentation;
- R2 Sample identification cross-reference;
- R3 Test reports (analytical data sheets) for each environmental sample that includes:
  - a. Items consistent with NELAC Chapter 5,
  - b. Dilution factors,
  - c. Preparation methods,
  - d. Cleanup methods, and
  - e. If required for the project, tentatively identified compounds (TICs).
- R4 Surrogate recovery data including:
  - a. Calculated recovery (%R), and
  - b. The laboratory's surrogate QC limits.
- R5 Test reports/summary forms for blank samples;
- R6 Test reports/summary forms for laboratory control samples (LCSs) including:
  - a. LCS spiking amounts,
  - b. Calculated %R for each analyte, and
  - c. The laboratory's LCS QC limits.
- R7 Test reports/summary forms for matrix spike/matrix spike duplicates (MS/MSDs) including:
  - a. Samples associated with the MS/MSD clearly identified,
  - b. MS/MSD spiking amounts,
  - c. Concentration of each MS/MSD analyte measured in the parent and spiked samples,
  - d. Calculated %Rs and relative percent differences, and
  - e. The laboratory's MS/MSD QC limits.
- R8 Laboratory analytical duplicate (if applicable) recovery and precision:
  - a. The amount of analyte measured in the duplicate,
  - b. The calculated RPD, and,
  - c. The laboratory's QC limits for analytical duplicated.
  - R9 List of method quantitation limits (MQLs) and detectability check sample results for each analyte and
  - R10 Other problems or anomalies.

The exception Report for each "No" or "Not Reviewed (NR) " item in the Laboratory Review Checklist and for each analyte, matrix, and method for which the laboratory does not hold NELAC accreditation under the Texas Laboratory Accreditation Program.

**Release Statement:** I am responsible for the release of this laboratory data package. This laboratory is NELAC accredited under the Texas Laboratory Accreditation Program for all the methods, analytes, and matrices reported in this data package except as noted in the Exception Reports. The data have been reviewed and are technically compliant with the requirements of the methods used, except where noted by the laboratory in the Exception Reports. By my signature below, I affirm to the best of my knowledge all problems/anomalies observed by the laboratory have been identified in the Laboratory Review Checklist, and no information affecting the quality of the data has been knowingly withheld.

Check, if applicable: [] This laboratory meets an exception under 30 TAC §25.6 and was last inspected by [X] TCEQ on 02/24/2012

Any findings affecting the data in this laboratory data package are noted in the Exception Reports herin. The official signing the cover page of the report in which these data are used is responsible for releasing this data package and is by signature affirming the above release statement is true.

Name	(Printed)
Shelly	Connelly

<u>Signature</u> Staty (orrely) <u>Official Title (Printed)</u> Project Manager <u>Date</u> 07/29/2013

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Pace Analytical Services, Inc. 400 W. Bethany Drive, Suite 190 Allen, TX 75013 (972) 727-1123

Client ID: Chip (6-21)	<u>-1</u>						Project ID: (	0111C278A/Stewa	art Creek	<u>&lt;</u>
Lab ID: <u>756761001</u>		Moistu	u <b>re:</b> <u>N//</u>	7		Pac	e Project No.: 7	<u>′56761</u>		
Collected: 06/21/2013	14:32	Receiv	<b>ed:</b> <u>07/</u>	12/2013	<u> 11:36</u>		Matrix: S	Solid		
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, TCLP	Analy	tical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3010	Leachate Metho	d: EPA 13	11
Lead	14	.1	rr	ng/L	0.050	0.020	07/19/2013 17:16	07/19/2013 12:00	7952	75ICP1



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Client ID: <u>Slag (6-24)</u> Lab ID: <u>756761002</u> Collected: <u>06/24/2013</u>	<u>)-1</u> 2 3 16:2	Moist	ure: <u>N//</u> ved: <u>07/</u>	<u>A</u> (12/2013	<u>3 11:36</u>	Pac	Project ID: <u>(</u> e Project No.: <u>7</u> Matrix: <u>S</u>	0 <u>111C278A/Stew</u> 2 <u>56761</u> Solid	art Creel	<u>X</u>
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, TCLP	Ana	lytical Method:	EPA 601	0	Prepa	ration Met	hod: EPA 3010	Leachate Metho	d: EPA 13	11
Arsenic	1	0.084	rr	ig/L	0.050	0.020	07/19/2013 17:22	07/19/2013 12:00	7952	75ICP1
Lead	1	23.7	rr	ng/L	0.050	0.020	07/19/2013 17:22	07/19/2013 12:00	7952	75ICP1



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Client ID: <u>Slag (6-24)</u> Lab ID: <u>756761003</u> Collected: <u>06/24/2013</u>	<u>-2</u> 8 16:4	Moist <u>0</u> Recei	ure: <u>N</u> ved: <u>07</u>	/ <u>A</u> 7/12/2013	<u>3 11:36</u>	Pac	Project ID: <u>(</u> e Project No.: <u>7</u> Matrix: <u>S</u>	0 <u>111C278A/Stewa</u> 2 <u>56761</u> Solid	<u>art Cree</u> ł	<u>\</u>
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
6010 Metals, TCLP	Ana	lytical Method	: EPA 60	10	Prepa	ration Met	hod: EPA 3010	Leachate Metho	d: EPA 13	511
Arsenic	1	< 0.020	U	mg/L	0.050	0.020	07/22/2013 23:35	07/22/2013 15:59	7990	75ICP1
Lead	1	37.8	M1	mg/L	0.050	0.020	07/22/2013 23:35	07/22/2013 15:59	7990	75ICP1



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Client ID: <u>Slag (6-24)</u> Lab ID: <u>756761004</u> Collected: <u>06/24/2013</u>	<u>-2 Ba</u> : : : 16:4	<u>se</u> Moist <u>0</u> Receiv	ure: <u>N//</u> ved: <u>07/</u>	<u>A</u> (12/2013	<u>3 11:36</u>	Pac	Project ID: <u>(</u> e Project No.: <u>7</u> Matrix: <u>S</u>	0 <u>111C278A/Stew</u> 2 <u>56761</u> Solid	art Creel	2
Parameters	DF	Results	Qual	Units	MQL	SDL	Analysis Date	Prep Date	Batch	Instr.
<b>6010 Metals, TCLP</b> Arsenic Lead	Anal 1 1	ytical Method: 0.084 20.6	EPA 601 m m	0 ng/L ng/L	Prepa 0.050 0.050	ration Met 0.020 0.020	hod: EPA 3010 07/19/2013 17:27 07/19/2013 17:27	Leachate Metho 07/19/2013 12:00 07/19/2013 12:00	d: EPA 13 7952 7952	75ICP1 75ICP1 75ICP1



## **Quality Control**

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#### Batch: 7952 Pace Project No.: 756761 Method: EPA 6010 Instrument ID: 75ICP1 Prep Method: EPA 3010 Blank: 32169 **Parameters** Dilution Units MQL SDL Quals Result **Analysis Date Prep Date** mg/L Arsenic <0.020 0.050 0.020 07/19/2013 14:30 07/19/2013 12:00 1 υ Lead U <0.020 0.050 0.020 07/19/2013 12:00 1 mg/L 07/19/2013 14:30 Laboratory Control Sample: 32170 LCS LCS Spk LCS % Rec **Parameters** Result Units %Rec Limits Quals Amt Arsenic 10 9.7 mg/L 97 80-120 10.3 103 Lead 10 mg/L 80-120 Matrix Spike: 32171 Matrix Spike Duplicate: 32172 Original for Sample: Batch sample 756789001 MSD Original MS MSD MS MS MSD % Rec Max **Parameters** Result Result %Rec %Rec Limits RPD Quals Spk Spk Result Units RPD Arsenic <0.020 10 10 10.0 10.0 mg/L 100 100 75-125 0 20 Lead <0.020 10 10 10.1 10.2 mg/L 101 102 75-125 1 20 Matrix Spike: 32173 Matrix Spike Duplicate: 32174 Original for Sample: Batch sample 756789002 MSD Original MS MSD MS MS MSD % Rec Max RPD **Parameters** Result Result %Rec Quals Spk Spk Result Units %Rec Limits RPD Arsenic <0.020 10 10.1 10.1 101 75-125 10 101 0 20 mg/L Lead <0.020 10 10 10 10 mg/L 100 100 75-125 0 20



# **Quality Control**

# Batch: 7990 Method: EPA 6010

# Pace Project No.: 756761

Prep Method: EPA 3010

Instrument ID: 75ICP1

Blank: 32294								
Parameters	Dilution	Quals	Result	Units	MQL	SDL	Analysis Date	Prep Date
Arsenic	1	U	<0.020	mg/L	0.050	0.020	07/22/2013 22:51	07/22/2013 15:59
Lead	1	U	<0.020	mg/L	0.050	0.020	07/22/2013 22:51	07/22/2013 15:59
Laboratory Contro	I Sample: 32295							
Parameters		Spk Amt	LCS Result	Unit	s	LCS %Rec	% Rec Limits	LCS Quals
Arsenic		10	9.7	mg/L		97	80-120	
Lead		10	9.9	mg/L	-	99	80-120	

Matrix Spike: 32296

Matrix Spike Duplicate: 32297

Original for Sample: Project sample Slag (6-24)-2

Parameters	Original Result	MS Spk	MSD Spk	MS Result	MSD Result	Units	MS %Rec	MSD %Rec	% Rec Limits	RPD	Max RPD	Quals
Arsenic	<0.020	10	10	10	10.2	mg/L	100	102	75-125	2	20	
Lead	37.8	10	10	44.2	44.7	mg/L	64	70	75-125	1	20	M1



# Pace Project No.: 756761

Analyte	Method	Unadjusted MQL	<b>Reporting Units</b>	
Arsenic	EPA 6010	0.050	mg/L	
Lead	EPA 6010	0.050	mg/L	



Pace Project No.: 756761

#### DEFINITIONS

- DF Dilution Factor
- J Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.
- U Indicates the compound was analyzed for, but not detected.
- SDL Sample Detection Limit
- MQL Method Quantitation Limit
- LCS(D) Laboratory Control Sample (Duplicate)
- MS(D) Matrix Spike (Duplicate)
- DUP Sample Duplicate
- RPD Relative Percent Difference
- TNI The Nelac Institute

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

### ANALYTE QUALIFIERS

Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

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		TRRP LABORATORY REVIEW CHECKLIST					
L	aboratory	Pace Analytical Services, Inc. LRC Date: 07	7/29/2013				
Proj	ect Name:	0111C278A/Stewart Creek Laboratory Job Number: 75	56761				
Reviev	ver Name:	Shelly Connelly Prep Batch Number(s): Se	e exception	report.			
#1	A <sup>2</sup>	Description	Yes	No	NA <sup>3</sup>	NR <sup>4</sup>	ER #5
R1	OI	Chain-of-custody (C-O-C)					
		Did samples meet the laboratory's standard conditions of sample acceptability upon receipt?	х				
		Mana all des actives from standard and "l'incoder a described in a superior".					
		Were all departures from standard conditions described in an exception report?	X				
R2	OI	Sample and quality control (QC) identification					
		Are all field sample ID numbers cross-referenced to the laboratory ID numbers?	X				
		Are all laboratory ID numbers cross-referenced to the corresponding QC data?	X				
R3	OI	Test reports					
		Were all samples prepared and analyzed within holding times?	X				
			' X				
		Were calculations checked by a peer or supervisor?	Х				
		Were all analyte identifications checked by a peer or supervisor?	Х				
		Were sample detection limits reported for all analytes not detected?	X				
		Were all results for soil and sediment samples reported on a dry weight basis?			X		
		Were % moisture (or solids) reported for all soil and sediment samples?			X		
		Were bulk soils/solids samples for volatile analysis extracted with methanol per SW846 Metho	bd		X		
		5035?			X		
	_	If required for the project, are TICs reported?			X		
R4	0	Surrogate recovery data					
		Were surrogates added prior to extraction?			Х		
		Were surrogate percent recoveries in all samples within the laboratory QC limits?			Х		
R5	OI	Test reports/summary forms for blank samples					
		Were appropriate type(s) of blanks analyzed?	Х				
		Were blanks analyzed at the appropriate frequency?	Х				
		Were method blanks taken through the entire analytical process, including preparation and, if	x				
		Applicable, cleanup procedures?	v				
P6	0	Laboratory control samples (I CS):					
NU		Were all COCs included in the LCS2	x				
		Wate all COOS included in the ECO: Was each LCS taken through the entire analytical procedure, including prep and cleanup ster	05?				
		······································	Х				
		Were LCSs analyzed at the required frequency?	Х				
		Were LCS (and LCSD, if applicable) %Rs within the laboratory QC limits?	Х				
		Does the detectability check sample data document the laboratory's capability to detect the C	OCs X				
		at the MDL used to calculate the SDLs?			- v		
D7		Was the LCSD RFD within QC limits?			^		
<u>Γ</u>	U	Wath Spike (WS) and matrix spike dupicate (WSD) data	v				
		Were MS/MSD analyzed at the appropriate frequency?					
		Were MS/MSD analyzed at the appropriate frequency?	^				D7 0
		Were MS (and MSD, il applicable) %RS within the laboratory QC limits?	v	^			R7.3
Do	0	Analytical duplicate data	~				
κó		Mara appropriate analytical duplicates analyzed for each metric?			V		
		Were appropriate analytical outplicates analyzed for each matrix?					
		Were analytical duplicates analyzed at the appropriate frequency?					
DO		Were RPDs or relative standard deviations within the laboratory QC limits?					
КŸ		wethou quantitation limits (www.s):					
		Are the MQLs for each method analyte included in the laboratory data package?	X				
			X				
		Are unadjusted MQLs and DCSs included in the laboratory data package?	Х				
R10	OI	Other problems/anomalies					
	•	Are all known problems/anomalies/special conditions noted in this LRC and ER?	Х				
		Was applicable and available technology used to lower the SDL to minimize the matrix	v	1			
		interference effects on the sample results?					
		is the laboratory NELAC-accredited under the Lexas Laboratory Accreditation Program for th analytes, matrices, and methods associated with this laboratory data package?	т   Х	1			
1.	Items identifie	ed by the letter "R" must be included in the laboratory in the laboratory data package submitted in the TRRP-required reports(	s). Items identifi	ed by the	1	1	1
n	letter "S" sho	uld be retained and made available upon request for the appropriate retention period;					
2.	NA = Not app	Slicable;					
4.	NR = Not rev	iewed; tion Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked)					
5.		the second of th					

#### 2014 EXIDE APAR PAGE 2705 OF 3116 TRRP LABORATORY REVIEW CHECKLIST Laboratory Pace Analytical Services, Inc. LRC Date: 07/29/2013 **Project Name:** 0111C278A/Stewart Creek Laboratory Job Number: 756761 **Reviewer Name:** Shelly Connelly Prep Batch Number(s): See exception report. NA<sup>3</sup> NR<sup>4</sup> ER #<sup>5</sup> **#**<sup>1</sup> $A^2$ Description Yes No **S1** OI Initial calibration (ICAL) Х Were response factors and/or relative response factors for each analyte within QC limits? Were percent RSDs or correlation coefficient criteria met? Х Was the number of standards recommended in the method used for all analytes? Х Were all points generated between the lowest and highest standard used to calculate the curve? Х Are ICAL data available for all instruments used? Х Has the initial calibration curve been verified using an appropriate second source standard? Х Initial and continuing calibration verification (ICCV and CCV) and continuing calibration S2 OI blank (CCB): Was the CCV analyzed at the method-required frequency? Х Were precent differences for each analyte within the method-required QC limits? Х Was the ICAL curve verified for each analyte? Х Х Was the absolute value of the analyte concentration in the inorganic CCB < MDL? **S**3 Ο Mass spectral tuning Was the appropriate compound for the method used for tuning? Х Were ion abundance data within the method-required QC limits? Х S4 ο Internal standards (IS) Were IS area counts and retention times within the method-required QC limits? Х OI **S**5 Raw data (NELAC Section 5.5.10) Х Were the raw data (for example, chromatograms, spectral data) reviewed by an analyst? Were data associated with manual integrations flagged on the raw data? Х **S6** Ο Dual column confirmation Did dual column confirmation results meet the method-required QC? Х **S7** Ο Tentatively identified compounds (TICs) If TICs were requested, were the mass spectra and TIC data subject to appropriate checks? х **S8** Т Interference Check Sample (ICS) results Х Were percent recoveries within method QC limits? **S**9 L Serial dilutions, post digestion spikes, and method of standard additions Were percent differences, recoveries, and the linearity within the QC limits specified in the Х method? S10 OI Method detection limit (MDL) studies Was a MDL study performed for each reported analyte? Х Х is the MDL either adjusted or supported by the analysis of DCSs? S11 OI Proficiency test reports Was the laboratory's performance acceptable on the applicable proficiency tests or evaluation Х studies? S12 OI Standards documentation Are all standards used in the analyses NIST-traceable or obtained from other appropriate Х sources? S13 OI Compound/analyte identification procedures Are the procedures for compound/analyte identification documented? Х S14 OI Demonstration of analyst competency (DOC) Х Was DOC conducted consistent with NELAC Chapter 5? Х is documentation of the analyst's competency up-to-date and on file? Verification/validation documentation for methods (NELAC Chapter 5) S15 οι Are all the methods used to generate the data documented, verified, and validated, where Х applicable? OI Laboratory standard operating procedures (SOPs) S16 Are laboratory SOPs current and on file for each method performed? Х Items identified by the letter "R" must be included in the laboratory in the laboratory data package submitted in the TRRP-required reports(s). Items identified by the 1. letter "S" should be retained and made available upon request for the appropriate retention period; 2. O = Organic analyses; I = inorganic analysises (and general chemistry, when applicable); NA = Not applicable; 3. 4 NR = Not reviewed:

5. ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked).

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		TRRP LABORATORY	REVIEW CHECKLIST	
La	aboratory	Pace Analytical Services, Inc.	LRC Date:	07/29/2013
Proje	ct Name:	0111C278A/Stewart Creek	Laboratory Job Number:	756761
Review	er Name:	Shelly Connelly	Prep Batch Number(s):	7952,7990
ER # <sup>1</sup>			Description	
R7.3	MS Sample	#32296: Lead 64% spike recovery outside laboratory Q	C limit of 75-125%.	
R7.3	MSD Samp	le #32297: Lead 70% spike recovery outside laboratory (	QC limit of 75-125%.	
		· · · ·		
1.	ER# = Exc	eption Report identification number (an Exception Repor	t should be completed for an item	if "NR" or "No" is checked).

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#### Shelly Connelly - Sample resubmission

From: "Rusty Simpson" <rusty.simpson@southwestgeoscience.com> To: <shelly.connelly@pacelabs.com> Date: 7/12/2013 11:36 AM Subject: Sample resubmission CC: "Kerry Russell" <krussell@txadminlaw.com>, "Mack Borchardt" <MBorcha.

Shelly - Please resubmit the following samples for the following analyses on normal turnaround:

Laboratory ID	SWG Sample ID	TCLP Arsenic	TCLP Lead
756304003	Chip (6-21)-1		X
756325012	Slag (6-24)-1	Х	X
756325014	Slag (6-24)-2	Х	Х
756325015	Slag (6-24)-2 Base	Х	Х

Thanks and call with any questions.

Rusty L. Simpson, P.G., C.P.G. [Principal Southwest Geoscience | 2351 W. Northwest Highway, Suite 3321 | Dallas, Texas 75220 #214.350.5469 x205 | #214.350.2914 | C 214.507.1570 www.southwestgeoscience.com



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Sam	ple Condition Upon Receipt
Pace Analytical Client Name:	SouthwastGesselencePace #: 756304
Courier: Fed Ex UPS USPS Client	Courier LSO Pace Other
Custody Seal on Cooler/Box Present: A yes	🗌 no Seals intact: 📈 yes 🗌 no 🔲 N/A
Packing Material: Bubble Wrap Bubble B	Bags XNone Other
Thermometer Used	Type of Ice: Wet Blue None Samples on ice, cooling process has begun
Cooler Temperature <u>3.8C</u>	Ice Visible in Sample Containers: yes / no
(Corrected, if applicable) Temp should be above freezing to 6°C	Comments:
Sampla Baceliving	
Chain of Custody Present:	
Chain of Custody Filled Out	
Chain of Custody Relinguished:	
Sampler Name & Signature on COC'	
Short Hold Time Analysis (<72hr):	□Yes □µ6 □N/A 5.
Rush Turn Around Time Requested:	□Yes ( □N/A 6.
Containers Intact:	
Sample Labels match COC:	
-Includes date/time/ID/Analysis	
All containers needing acid/base pres. have been checked?	□Yes □No ☑N/A 9. (Circle) HNO3 H2SO4 NaOH HCI
exceptions: VOA, coliform, O&G	If applicable see below.
All containers needing preservation are found to be in compliance with EPA recommendation.	DYes DNo WIN/A pH strip lot #:
	Potassium Iodide strip lot #:
	Lead Acetate strip lot #:
Headspace in VOA Vials ( >6mm):	
Trip Blank Present:	□Yes □No ZN/A 11.
Trip Blank Custody Seals Present	
Samples Arrived within Hold Time:	Yes □No □N/A 12.
Sufficient Volume:	₩Yes □No □N/A 13
Correct Containers Used:	ŬYes □No □N/A 14.
Client Notification/ Resolution:	DetaTima
Comments/ Resolution:	
Project Manager Review:	M. Date: 10-25-12
	<u> </u>

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COC PAGE of

Sample Container Count ワテレアレー

Face Analytical" www.pacootec.com

9-0000555222299-0005552222

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Coc ID# Sample Line Item 3 3 5	BP2N	AG1U	AG9H	BP2S	BP1U	BP2U	Pace F BG1H	AG1S	# BP20	SP51		Comments	
6 9 11 12 12													

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	DG9P 40mL TSP amber vial	DG9S 40mL H2SO4 amber vial	DG9T 40mL Na Thio amber vial	DG9U 40mL unpreserved amber vial	I Wipe/Swab	JGFU 4oz unpreserved amber wide	U Summa Can	VG9H 40mL HCL clear vial	VG9T 40mL Na Thio. clear vial	VG011 40ml unnreserved clear vial		VSG Headspace septa vial & HCL	WGFX 4oz wide jar w/hexane wipe	ZPLC Ziploc Bag	GN General unpreserved		
	P1N 1 liter HNO3 plastic	P1S 1 liter H2SO4 plastic	21U 1 liter unpreserved plastic	P1Z 1 liter NaOH, Zn, Ac	P2A 500mL NaOH, Asc Acid plastic	20 500mL NaOH plastic	P2Z 500mL NaOH, Zn Ac	P3A 250mL NaOh, Asc Acid plastic	P3C 250mL NaOH plastic		P32 2001112 NaUT, 211 AU Plasur	C Air Cassettes	39B 40mL Na Bisulfate amber vial	39M 40mL MeOH clear vial	25U 120mL Coliform unpreserved		
	AF Air Filter BF	AG1H 1 liter HCL amber class BF	AG1S 1 liter H2SO4 amber glass BF	AG1T 1 liter Na Thiosulfate amber gl BF	AG2N 500mL HNO3 amber glass BF	AG2S 500mL H2SO4 amber glass BF	AG2U 500mL unpreserved amber gla BF	AG3U 250mL unpreserved amber dla BF	BC4H 1 liter HCI clear diace		BG1S 1 liter H2SO4 clear glass br	BG1T 1 liter Na Thiosulfate clear gla	BG1U 1 liter unbreserved glass DG	BD10 1 liter NaOH Asc Acid plastic DG	CDGT 100ml Coliform Na Thiosulfate SF		
Container Codes	40mL HCL amber voa vial	dliter unbreserved amber glass	407 clear soil iar	terra core kit	500mL HNO3 plastic	500mL unpreserved plastic	500ml H2SO4 plastic	oromi HNO3 nlastic			250mL H2SO4 plastic	250ml H2SO4 diass amber	1 liter H9SO4 amhar diass			802 WIDE Jai upreserveu	Other
	DG9H	0011	WGFU		BP2N	BP2U	SCOR	NECO NECO		BF3U	BP3S	0035				NGKU	Othert

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NECA 444 6 (5)

Sal	$\frac{101}{101} = \frac{1}{1000} = $	**
Pace Analytical Client Name	SWGeo Pace #: $SG325$	<u> </u>
Courier:	nt Courier LSO Pace Other	
Custody Seal on Cooler/Box Present: Xyes	🗌 no Seals intact: 📈 yes 🗌 no 🗌 N/A	
Packing Material: 🔲 Bubble Wrap 🛛 🕅 Bubble	Bags Done Other	
Thermometer Used IR-02 IR-02	Type of Ice: Wet Blue None 🏼 🎽 Samples on ice, cooling process has begin	un
Cooler Temperature 2.9°C	Ice Visible in Sample Containers: 🎢 yes 📉 no	
(Corrected, if applicable) Temp should be above freezing to 6°C	Date and initials of person examinity	ng
Chain of Custody Present:		
Chain of Custody Filled Out:		
Chain of Custody Relinquished:	⊠xes □No □N/A 3.	
Sampler Name & Signature on COC:		
Short Hold Time Analysis (<72hr):		
Rush Turn Around Time Requested:		
Containers Intact:	Refes DNO DNA 7.	
Sample Labels match COC:		
-Includes date/time/ID/Analysis	· · · · · · · · · · · · · · · · · · ·	
	□Yes □No ♥44 9. (Circle) HNO3 H2SO4 NaOH HCl	
All containers needing preservation are found to be in		
compliance with EPA recommendation.	□Yes □No □N/A pH strip lot #:	
	Potassium lodide strip lot #:	
Hardshaca in VOA Vizis ( >6mm);		
Trip Blank Present		
Trip Blank Custody Seals Present		
Samples Arrived within Hold Time:		
Sufficient Volume:	<sup>2</sup> <del>2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 </del>	
Correct Containers Used:	EYes □No □N/A 14.	
Client Notification/ Resolution:		
Person Contacted:	Date/Time:	
		<u> </u>

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F-DAL-C-003 rev.00 11-5-2012

VSG Headspace septa vial & HCL WGFX 4oz wide jar w/hexane wipe

GN General unpreserved

ZPLC Ziploc Bag

DG9B 40mL Na Bisulfate amber vial

C Air Cassettes

BG1T 1 liter Na Thiosulfate clear gla

AG3S 250mL H2SO4 glass amber AG1S 1 liter H2SO4 amber glass

BP1U 1 liter unpreserved plastic WGKU 8oz wide jar upreserved

Other Other

SP5U 120mL Coliform unpreserved

SP5T 120mL Coliform Na Thiosulfate

BP1A 1 liter NaOH, Asc Acid plastic

BG1U 1 liter unpreserved glass

DG9M 40mL MeOH clear vial

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Pace Analytical"	Comments														DG9P 40mL TSP amber vial	DG9S 40mL H2SO4 amber vial	DG9T 40mL Na Thio amber vial	DG9U 40mL unpreserved amber vial	I Wipe/Swab	JGFU 4oz unpreserved amber wide	U Summa Can	VG9H 40mL HCL clear vial	VG9T 40mL Na Thio. clear vial	VG9U 40mL unpreserved clear vial	VSG Headspace septa vial & HUL
Ian Cal	SP5T WGFU WGKU														1 liter HNO3 plastic	1 liter H2SO4 plastic	1 liter unpreserved plastic	1 liter NaOH, Zn, Ac	500mL NaOH, Asc Acid plastic	500mL NaOH plastic	500mL NaOH, Zn Ac	250mL NaOh, Asc Acid plastic	250mL NaOH plastic	250mL NaOH, Zn Ac plastic	Air Cassettes
	BP20														BP1N	BP1S	BP1U	BP1Z	BP2A	BP20	BP2Z	BP3A	BP3C	BP3Z	O
Pace Project	BP1U BP2U BG1H AG1S														Air Filter	1 liter HCL amber glass	1 liter H2SO4 amber glass	1 liter Na Thiosulfate amber gl	500mL HNO3 amber glass	500mL H2SO4 amber glass	500mL unpreserved amber gla	250mL unpreserved amber gla	1 liter HCL clear glass	1 liter H2SO4 clear glass	1 liter Na Thiosulfate clear gla
	BP2S														AF	AG1H	AG1S	AG1T	AG2N	AG2S	AG2U	AG3U	BG1H	BG1S	BG1T
Lof D	BP2N AG1U VG9U VG9H													Container Codes	40mL HCL amber voa vial	1 liter unpreserved amber glass	4oz clear soil iar	terra core kit	500mL HNO3 plastic	500mL unpreserved plastic	500mL H2SO4 plastic	250mL HNO3 plastic	250mL unpreserved plastic	250mL H2SO4 plastic	250ml H2SO4 dlass amber
SOC PAGE	Sample Line Item	5	7	3	4	ъ 2	9	~	 8	0	10	11	12		HGDU	AG1U	WGFU		BP2N	BP2U	BP2S	BP3N	BP3U	BP3S	AG3S

F-DAL-C-003 rev.00 11-5-2012

WGFX 4oz wide jar w/hexane wipe

DG9B 40mL Na Bisulfate amber vial

SP5U 120mL Coliform unpreserved DG9M 40mL MeOH clear vial

SP5T 120mL Coliform Na Thiosulfate

BP1A 1 liter NaOH, Asc Acid plastic BG1U 1 liter unpreserved glass

AG3S 250mL H2SO4 glass amber AG1S 1 liter H2SO4 amber glass

BP1U 1 liter unpreserved plastic WGKU 8oz wide jar upreserved

Other Other

GN General unpreserved

ZPLC Ziploc Bag

00000

22922

Sample Container Count

2014 EXIDE APAR PAGE 2715 OF 3116



# APPENDIX E

Grain Size Analysis Reports



e-Hardcopy 2.0 Automated Report

07/05/13

# **Technical Report for**

# **Southwest Geoscience**

0111C278A/ SC Sediment Sampling

Accutest Job Number: TC32298



**Report to:** 

Southwest Geoscience 2351 W. Northwest Highway Suite 3321 Dallas, TX 75220 jason.minter@southwestgeoscience.com; rusty.simpson@southwestgeoscience.com

ATTN: Jason Minter

## Total number of pages in report: 38





Test results contained within this data package meet the requirements of the National Environmental Laboratory Accreditation Conference and/or state specific certification programs as applicable.

Client Service contact: Sylvia Garza 713-271-4700

Certifications: TX (T104704220-13-10) AR (12-029-0) AZ (AZ0769) FL (E87628) KS (E-10366) LA (85695/04004) OK (2012-059)

This report shall not be reproduced, except in its entirety, without the written approval of Accutest Laboratories. Test results relate only to samples analyzed.

Gulf Coast • 10165 Harwin Drive • Suite 150 • Houston, TX 77036 • tel: 713-271-4700 • fax: 713-271-4770 • http://www.accutest.com




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# Sample Summary

Southwest Geoscience

**Job No:** TC32298

0111C278A/ SC Sediment Sampling

Sample Number	Collected Date	Time By	Received	Matr Code	ix Type	Client Sample ID
TC32298-1	06/12/13	13:36	06/15/13	SO	Soil	SC-SED-31
TC32298-2	06/12/13	13:39	06/15/13	SO	Soil	SC-SED-32
TC32298-3	06/12/13	13:42	06/15/13	SO	Soil	SC-SED-33
TC32298-4	06/12/13	14:06	06/15/13	SO	Soil	SC-SED-34
TC32298-5	06/12/13	14:09	06/15/13	SO	Soil	SC-SED-35
TC32298-6	06/12/13	14:13	06/15/13	SO	Soil	SC-SED-36
TC32298-7	06/12/13	14:37	06/15/13	SO	Soil	SC-SED-37
TC32298-8	06/12/13	14:41	06/15/13	SO	Soil	SC-SED-38
TC32298-9	06/12/13	14:44	06/15/13	SO	Soil	SC-SED-39
TC32298-10	06/12/13	15:06	06/15/13	SO	Soil	SC-SED-40

Soil samples reported on a dry weight basis unless otherwise indicated on result page.





### SAMPLE DELIVERY GROUP CASE NARRATIVE

Client:	Southwest Geoscience	Job No	TC32298
Site:	0111C278A/ SC Sediment Sampling	Report Date	7/3/2013 5:04:19 PM

10 Samples were collected on 06/12/2013 and were received intact at Accutest on 06/15/2013 and properly preserved in 1 cooler at 2 Deg C These Samples received an Accutest job number of TC32298. A listing of the Laboratory Sample ID, Client Sample ID and dates of collection are presented in the Results Summary Section of this report.

Except as noted below, all method specified calibrations and quality control performance criteria were met for this job. For more information, please refer to QC summary pages.

### Wet Chemistry By Method ASTM D422-63

Matrix	SO	Batch ID: N:GP72913

Analysis performed at Accutest Laboratories, Dayton, NJ.

Accutest Laboratories Gulf Coast (ALGC) certifies that this report meets the project requirements for analytical data produced for the samples as received at ALGC and as stated on the COC. ALGC certifies that the data meets the Data QualityObjectives for precision, accuracy and completeness as specified in the ALGC Quality Manual except as noted above. This report is to be used in its entirety. ALGC is not responsible for any assumptions of data quality if partial data packages are used

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# **CASE NARRATIVE / CONFORMANCE SUMMARY**

Client:	Accutest Laboratories Gulf Coast, Inc.	Job No	TC32298
Site:	SGTXD: 0111C278A/ SC Sediment Sampling	Report Date	7/2/2013 8:13:50 AM

On 06/20/2013, 10 Sample(s), 0 Trip Blank(s) and 0 Field Blank(s) were received at Accutest Laboratories at a temperature of 3.5 C. Samples were intact and chemically preserved, unless noted below. An Accutest Job Number of TC32298 was assigned to the project. Laboratory sample ID, client sample ID and dates of sample collection are detailed in the report's Results Summary Section.

Specified quality control criteria were achieved for this job except as noted below. For more information, please refer to the analytical results and QC summary pages.

### Wet Chemistry By Method ASTM D422-63

	Matrix: SO	Batch ID:	GP72913
-	Sample(s) TC32298-10DUP were used a	as the QC samples	s for % Gravel, % Sand, % Silt, Clay, Colloids, 0.0015 mm
	(Hydrometer), 0.005 mm (Hydrometer), 0	).030 mm (Hydro	meter), 0.375 Inch Sieve, 0.75 inch sieve, 1.5 Inch Sieve, 3 inch sieve,
	No.10 Sieve (2.00 mm), No.100 Sieve (0	.15 mm), No.16 S	Sieve (1.18 mm), No.200 Sieve (0.075 mm), No.30 Sieve (0.60 mm),
	No.4 Sieve (4.75 mm), No.50 Sieve (0.30	) mm), No.8 Siev	e (2.36 mm).

- TC32298-9 for 0.030 mm (Hydrometer): Data extrapolated from higher and lower data points due to possible analytical problem with hydrometer analysis at short analysis times.
- TC32298-7 for 0.030 mm (Hydrometer): Data extrapolated from higher and lower data points due to possible analytical problem with hydrometer analysis at short analysis times.

Accutest certifies that data reported for samples received, listed on the associated custody chain or analytical task order, were produced to specifications meeting Accutest's Quality System precision, accuracy and completeness objectives except as noted.

Estimated non-standard method measurement uncertainty data is available on request, based on quality control bias and implicit for standard methods. Acceptable uncertainty requires tested parameter quality control data to meet method criteria.

Accutest Laboratories is not responsible for data quality assumptions if partial reports are used and recommends that this report be used in its entirety. Data release is authorized by Accutest Laboratories indicated via signature on the report cover



Page 1 of 1



Job Number:	TC32298
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/12/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method
TC32298-1 SC-SED-31					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	99.3			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	93.6			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	91.1			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	71.9			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	39.4			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	18.9			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	13.3			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	12.3			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	10.0			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	6.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	4.7			%	ASTM D422-63
% Gravel <sup>a</sup>	0.67			%	ASTM D422-63
% Sand <sup>a</sup>	87.0			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	12.3			%	ASTM D422-63
TC32298-2 SC-SED-32					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.5			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	73.2			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	36.7			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	28.2			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	11.3			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	5.7			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	4.9			%	ASTM D422-63
No. 100 Sieve (0.15 mm) <sup>a</sup>	4.3			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	3.8			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	2.6			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	1.4			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	1.4			%	ASTM D422-63
% Gravel <sup>a</sup>	26.8			%	ASTM D422-63
% Sand <sup>a</sup>	69.4			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	3.8			%	ASTM D422-63
TC32298-3 SC-SED-33					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63

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Job Number:	TC32298
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/12/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	97.4			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	91.6			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	72.0			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	65.6			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	39.1			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	13.1			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	7.9			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	7.0			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	6.7			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	3.4			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	3.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	2.0			%	ASTM D422-63
% Gravel <sup>a</sup>	8.4			%	ASTM D422-63
% Sand <sup>a</sup>	85.0			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	6.7			%	ASTM D422-63
TC32298-4 SC-SED-34					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	97.6			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	85.8			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	81.3			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	37.8			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	14.1			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	9.9			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	9.1			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	8.7			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	7.5			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	5.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	4.1			%	ASTM D422-63
% Gravel <sup>a</sup>	2.4			%	ASTM D422-63
% Sand <sup>a</sup>	88.9			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	8.7			%	ASTM D422-63
TC32298-5 SC-SED-35					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.5			%	ASTM D422-63

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TC32298

TC32298

Job Number:	TC32298
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/12/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method
No.4 Sieve (4.75 mm) <sup>a</sup>	66.9			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	16.2			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	9.1			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	4.7			%	ASTM D422-63
No. 30 Sieve (0.60 mm) <sup>a</sup>	2.6			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	2.1			%	ASTM D422-63
No. 100 Sieve (0. 15 mm) <sup>a</sup>	1.9			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	1.8			%	ASTM D422-63
% Gravel <sup>a</sup>	33.1			%	ASTM D422-63
% Sand <sup>a</sup>	65.2			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	1.8			%	ASTM D422-63
TC32298-6 SC-SED-36					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.2			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	89.6			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	63.1			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	56.1			%	ASTM D422-63
No. 16 Sieve (1.18 mm) <sup>a</sup>	32.1			%	ASTM D422-63
No. 30 Sieve (0.60 mm) <sup>a</sup>	19.4			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	16.2			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	15.0			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	14.2			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	12.3			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	9.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	7.0			%	ASTM D422-63
% Gravel <sup>a</sup>	10.4			%	ASTM D422-63
% Sand <sup>a</sup>	75.4			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	14.2			%	ASTM D422-63
TC32298-7 SC-SED-37					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.7			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	92.1			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	79.0			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	74.5			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	53.7			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	22.9			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	9.8			%	ASTM D422-63

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Job Number:	TC32298
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/12/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method
No.100 Sieve (0.15 mm) <sup>a</sup>	8.1			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	7.8			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>b</sup>	7.8			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	7.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	6.0			%	ASTM D422-63
% Gravel <sup>a</sup>	7.9			%	ASTM D422-63
% Sand <sup>a</sup>	84.3			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	7.8			%	ASTM D422-63
TC32298-8 SC-SED-38					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.5			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	91.0			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	76.2			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	71.1			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	44.2			%	ASTM D422-63
No. 30 Sieve (0.60 mm) <sup>a</sup>	17.2			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	12.1			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	11.4			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	11.2			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	7.9			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	6.5			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	4.0			%	ASTM D422-63
% Gravel <sup>a</sup>	9.0			%	ASTM D422-63
% Sand <sup>a</sup>	79.9			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	11.2			%	ASTM D422-63
TC32298-9 SC-SED-39					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	92.6			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	71.6			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	49.0			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	45.0			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	32.7			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	22.3			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	19.9			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	18.0			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	16.5			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>b</sup>	16.0			%	ASTM D422-63

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Job Number:	TC32298
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/12/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method
0.005 mm (Hydrometer) <sup>a</sup>	13.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	8.0			%	ASTM D422-63
% Gravel <sup>a</sup>	28.4			%	ASTM D422-63
% Sand <sup>a</sup>	55.1			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	16.5			%	ASTM D422-63
TC32298-10 SC-SED-40					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	97.3			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	94.6			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	87.7			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	85.6			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	81.3			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	77.0			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	73.5			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	67.2			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	64.8			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	59.0			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	44.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	31.0			%	ASTM D422-63
% Gravel <sup>a</sup>	5.4			%	ASTM D422-63
% Sand <sup>a</sup>	29.9			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	64.8			%	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.

(b) Data extrapolated from higher and lower data points due to possible analytical problem with hydrometer analysis at short analysis times. Analysis performed at Accutest Laboratories, Dayton, NJ.







Sample Results

Report of Analysis

TC32298

	Report of Analy	ysis	]	Page 1 of 1
Client Sample ID:	SC-SED-31			
Lab Sample ID:	TC32298-1	Date Sampled:	06/12/13	
Matrix:	SO - Soil	Date Received:	06/15/13	
		Percent Solids:	n/a	
Project:	0111C278A/ SC Sediment Sampling			
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# **Report of Analysis**

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydrom	eter Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	99.3		%	1	06/29/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	93.6		%	1	06/29/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	91.1		%	1	06/29/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	71.9		%	1	06/29/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	39.4		%	1	06/29/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	18.9		%	1	06/29/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	13.3		%	1	06/29/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	12.3		%	1	06/29/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	10.0		%	1	06/29/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	6.0		%	1	06/29/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	4.7		%	1	06/29/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	0.67		%	1	06/29/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	87.0		%	1	06/29/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	12.3		%	1	06/29/13	ANJ	ASTM D422-63



	<b>Report of Analysis</b>			Page
Client Sample ID:	SC-SED-32		06/10/10	
Lab Sample ID:	TC32298-2	Date Sampled:	06/12/13	
Matrix:	SO - Soil	Date Received: Percent Solids:	06/15/13 n/a	
Project:	0111C278A/ SC Sediment Sampling			
Concerci Chamister				

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve a	and Hydromete	r Testin	lg)				
3 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.5		%	1	06/30/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	73.2		%	1	06/30/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	36.7		%	1	06/30/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	28.2		%	1	06/30/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	11.3		%	1	06/30/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	5.7		%	1	06/30/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	4.9		%	1	06/30/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	4.3		%	1	06/30/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	3.8		%	1	06/30/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	2.6		%	1	06/30/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	1.4		%	1	06/30/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	1.4		%	1	06/30/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	26.8		%	1	06/30/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	69.4		%	1	06/30/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	3.8		%	1	06/30/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



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	Report of Anal	ysis		Page 1 of 1
Client Sample ID:	SC-SED-33			
Lab Sample ID:	TC32298-3	Date Sampled:	06/12/13	
Matrix:	SO - Soil	Date Received:	06/15/13	
		Percent Solids:	n/a	
Project:	0111C278A/ SC Sediment Sampling			
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# **Report of Analysis**

**General Chemistry** 

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydromet	er Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	97.4		%	1	06/30/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	91.6		%	1	06/30/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	72.0		%	1	06/30/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	65.6		%	1	06/30/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	39.1		%	1	06/30/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	13.1		%	1	06/30/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	7.9		%	1	06/30/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	7.0		%	1	06/30/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	6.7		%	1	06/30/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	3.4		%	1	06/30/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	3.0		%	1	06/30/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	2.0		%	1	06/30/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	8.4		%	1	06/30/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	85.0		%	1	06/30/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	6.7		%	1	06/30/13	ANJ	ASTM D422-63



	<b>Report of Analysis</b>			Page
Client Sample ID: Lab Sample ID: Matrix:	SC-SED-34 TC32298-4 SQ = Soil	Date Sampled:	06/12/13	
Project:	0111C278A/ SC Sediment Sampling	Percent Solids:	n/a	
General Chemistry				

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydromete	er Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	97.6		%	1	06/29/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	85.8		%	1	06/29/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	81.3		%	1	06/29/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	37.8		%	1	06/29/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	14.1		%	1	06/29/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	9.9		%	1	06/29/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	9.1		%	1	06/29/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	8.7		%	1	06/29/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	7.5		%	1	06/29/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	5.0		%	1	06/29/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	4.1		%	1	06/29/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	2.4		%	1	06/29/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	88.9		%	1	06/29/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	8.7		%	1	06/29/13	ANJ	ASTM D422-63





	Report of Analysis	5		Page 1 of 1
Client Sample ID:	SC-SED-35			
Lab Sample ID:	TC32298-5	Date Sampled:	06/12/13	
Matrix:	SO - Soil	Date Received:	06/15/13	
		<b>Percent Solids:</b>	n/a	
Project:	0111C278A/ SC Sediment Sampling			
General Chemistry				

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydrom	eter Testir	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.5		%	1	06/29/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	66.9		%	1	06/29/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	16.2		%	1	06/29/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	9.1		%	1	06/29/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	4.7		%	1	06/29/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	2.6		%	1	06/29/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	2.1		%	1	06/29/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	1.9		%	1	06/29/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	1.8		%	1	06/29/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	U	0.84	%	1	06/29/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	U	0.84	%	1	06/29/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	U	0.84	%	1	06/29/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	33.1		%	1	06/29/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	65.2		%	1	06/29/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	1.8		%	1	06/29/13	ANJ	ASTM D422-63





# Client Sample ID: SC-SED-36 Lab Sample ID: TC32298-6 Matrix: SO - Soil Project: 0111C278A/ SC Sediment Sampling

**Report of Analysis** 

Analyte Result RL Units DF Analyzed Bv Method Particle Size Analysis (Sieve and Hydrometer Testing) 3 Inch Sieve <sup>a</sup> % 1 06/30/13 100 ANJ ASTM D422-63 1.5 Inch Sieve a 100 % 1 06/30/13 ANJ ASTM D422-63 0.75 Inch Sieve a 100 % 1 06/30/13 ANJ ASTM D422-63 0.375 Inch Sieve a 98.2 % 1 06/30/13 ANJ ASTM D422-63 No.4 Sieve (4.75 mm) a 89.6 % 1 06/30/13 ANJ ASTM D422-63 No.8 Sieve (2.36 mm) a 63.1 % 1 06/30/13 ANJ ASTM D422-63 No.10 Sieve (2.00 mm) a % 56.1 1 06/30/13 ANJ ASTM D422-63 No.16 Sieve (1.18 mm) a 32.1 % 1 06/30/13 ANJ ASTM D422-63 No.30 Sieve (0.60 mm) a 19.4 % 1 06/30/13 ANJ ASTM D422-63 No.50 Sieve (0.30 mm) a 16.2 % 1 06/30/13 ANJ ASTM D422-63 No.100 Sieve (0.15 mm) a 15.0 % 1 06/30/13 ANJ ASTM D422-63 No.200 Sieve (0.075 mm) a 14.2% 1 06/30/13 ANJ ASTM D422-63 0.030 mm (Hydrometer) a 12.3 % 1 06/30/13 ANJ ASTM D422-63 0.005 mm (Hydrometer) <sup>a</sup> 9.0 % 1 06/30/13 ANJ ASTM D422-63 0.0015 mm (Hydrometer) <sup>a</sup> 7.0 % 1 06/30/13 ANJ ASTM D422-63 % Gravel <sup>a</sup> 10.4 % 1 06/30/13 ANJ ASTM D422-63 % Sand <sup>a</sup> 75.4 % 1 06/30/13 ANJ ASTM D422-63 % Silt, Clay, Colloids a 14.2 % 1 06/30/13 ANJ ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



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Client Sample ID:	SC-SED-37			
Lab Sample ID:	TC32298-7	Date Sampled:	06/12/13	
Matrix:	SO - Soil	Date Received:	06/15/13	
		Percent Solids:	n/a	
Project:	0111C278A/ SC Sediment Sampling			

**Report of Analysis** 

**General Chemistry** 

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydromet	er Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.7		%	1	06/29/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	92.1		%	1	06/29/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	79.0		%	1	06/29/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	74.5		%	1	06/29/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	53.7		%	1	06/29/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	22.9		%	1	06/29/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	9.8		%	1	06/29/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	8.1		%	1	06/29/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	7.8		%	1	06/29/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>b</sup>	7.8		%	1	06/29/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	7.0		%	1	06/29/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	6.0		%	1	06/29/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	7.9		%	1	06/29/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	84.3		%	1	06/29/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	7.8		%	1	06/29/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.

(b) Data extrapolated from higher and lower data points due to possible analytical problem with hydrometer analysis at short analysis times. Analysis performed at Accutest Laboratories, Dayton, NJ.





<b>Report of Analysis</b>					
Client Sample ID:	SC-SED-38				
Lab Sample ID:	TC32298-8	Date Sampled:	06/12/13		
Matrix:	SO - Soil	Date Received:	06/15/13		
		Percent Solids:	n/a		
Project:	0111C278A/ SC Sediment Sampling				
General Chemistry					

Result	RL	Units	DF	Analyzed	By	Method
and Hydrometer	r Testing)	)				
100		%	1	06/30/13	ANJ	ASTM D422-63
100		%	1	06/30/13	ANJ	ASTM D422-63
100		%	1	06/30/13	ANJ	ASTM D422-63
98.5		%	1	06/30/13	ANJ	ASTM D422-63
91.0		%	1	06/30/13	ANJ	ASTM D422-63
76.2		%	1	06/30/13	ANJ	ASTM D422-63
71.1		%	1	06/30/13	ANJ	ASTM D422-63
44.2		%	1	06/30/13	ANJ	ASTM D422-63
17.2		%	1	06/30/13	ANJ	ASTM D422-63
12.1		%	1	06/30/13	ANJ	ASTM D422-63
11.4		%	1	06/30/13	ANJ	ASTM D422-63
11.2		%	1	06/30/13	ANJ	ASTM D422-63
7.9		%	1	06/30/13	ANJ	ASTM D422-63
6.5		%	1	06/30/13	ANJ	ASTM D422-63
4.0		%	1	06/30/13	ANJ	ASTM D422-63
9.0		%	1	06/30/13	ANJ	ASTM D422-63
79.9		%	1	06/30/13	ANJ	ASTM D422-63
11.2		%	1	06/30/13	ANJ	ASTM D422-63
	Result 100 100 100 98.5 91.0 76.2 71.1 44.2 17.2 12.1 11.4 11.2 7.9 6.5 4.0 9.0 79.9 11.2	Result         RL           100         100           100         100           100         100           98.5         91.0           76.2         71.1           44.2         17.2           12.1         11.4           11.2         7.9           6.5         4.0           9.0         79.9           11.2         11.2	ResultRLUnits100%100%100%100%98.5%91.0%76.2%71.1%44.2%17.2%12.1%11.4%11.2%9.0%9.0%79.9%11.2%	ResultRLUnitsDF100%1100%1100%1100%198.5%191.0%176.2%171.1%144.2%117.2%111.4%111.2%19.0%19.0%111.2%111.2%1	ResultRLUnitsDFAnalyzed100%106/30/13100%106/30/13100%106/30/1398.5%106/30/1391.0%106/30/1376.2%106/30/1371.1%106/30/1317.2%106/30/1311.4%106/30/1311.2%106/30/1311.2%106/30/139.0%106/30/139.9%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/1311.2%106/30/13	ResultRLUnitsDFAnalyzedBy100%106/30/13ANJ100%106/30/13ANJ100%106/30/13ANJ98.5%106/30/13ANJ91.0%106/30/13ANJ76.2%106/30/13ANJ71.1%106/30/13ANJ44.2%106/30/13ANJ17.2%106/30/13ANJ11.4%106/30/13ANJ11.2%106/30/13ANJ9.0%106/30/13ANJ9.0%106/30/13ANJ9.9%106/30/13ANJ11.2%106/30/13ANJ9.9%106/30/13ANJ11.2%106/30/13ANJ11.2%106/30/13ANJ11.2%106/30/13ANJ11.2%106/30/13ANJ11.2%106/30/13ANJ11.2%106/30/13ANJ



Client Sample ID:	SC-SED-39		0.5.11.2.11.2
Lab Sample ID:	TC32298-9	Date Sampled:	06/12/13
Matrix:	SO - Soil	Date Received:	06/15/13
		Percent Solids:	n/a
Project:	0111C278A/ SC Sediment Sampling		

**Report of Analysis** 

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydromete	r Testin	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	06/30/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	92.6		%	1	06/30/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	71.6		%	1	06/30/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	49.0		%	1	06/30/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	45.0		%	1	06/30/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	32.7		%	1	06/30/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	22.3		%	1	06/30/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	19.9		%	1	06/30/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	18.0		%	1	06/30/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	16.5		%	1	06/30/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>b</sup>	16.0		%	1	06/30/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	13.0		%	1	06/30/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	8.0		%	1	06/30/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	28.4		%	1	06/30/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	55.1		%	1	06/30/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	16.5		%	1	06/30/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.

(b) Data extrapolated from higher and lower data points due to possible analytical problem with hydrometer analysis at short analysis times. Analysis performed at Accutest Laboratories, Dayton, NJ.



4.9 **4** 

Project:	0111C278A/ SC Sediment Sampling			
		Percent Solids:	n/a	
Matrix:	SO - Soil	Date Received:	06/15/13	
Lab Sample ID:	TC32298-10	Date Sampled:	06/12/13	
Client Sample ID:	SC-SED-40			

# **Report of Analysis**

**General Chemistry** 

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydrom	eter Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	06/29/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	97.3		%	1	06/29/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	94.6		%	1	06/29/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	87.7		%	1	06/29/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	85.6		%	1	06/29/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	81.3		%	1	06/29/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	77.0		%	1	06/29/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	73.5		%	1	06/29/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	67.2		%	1	06/29/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	64.8		%	1	06/29/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	59.0		%	1	06/29/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	44.0		%	1	06/29/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	31.0		%	1	06/29/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	5.4		%	1	06/29/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	29.9		%	1	06/29/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	64.8		%	1	06/29/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



Page 1 of 1



Misc. Forms	
Custody Documents and Other Forms	
	_
Includes the following where applicable:	
<ul> <li>Chain of Custody</li> <li>LRC Form</li> <li>LRC Form (Accutest New Jersey)</li> </ul>	

**Section 5** 



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### TC32298: Chain of Custody Page 1 of 3



5

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### Accutest Laboratories Sample Receipt Summary

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Accutest Job N	lumber:	TC32298	Client:	SOUTHWEST GEOSCIENCE	Project:	SC SEDIMENT SAMPLING
Date / Time Received: 6/15/2013			Delivery Method:	Airbill #'s:	558744953896	
No. Coolers:	1	Therm ID:	IR-5;		Temp Adjus	stment Factor: 0;
Coolor Tomps	(Initial/A	diustod), #1.(2/2)				

Cooler Temps (Initial/Adjusted): <u>#</u>

Cooler Security Y	or M	N		Yo	or N	Sample Integrity - Documentation	Y	or	N	
1. Custody Seals Present:       ☑         2. Custody Seals Intact:       ☑	[	3. 4. Sn	COC Present: npl Dates/Time OK	<ul><li>✓</li></ul>		<ol> <li>Sample labels present on bottles:</li> <li>Container labeling complete:</li> </ol>	V			
Cooler Temperature	Y	or N				3. Sample container label / COC agree:	$\checkmark$			
1. Temp criteria achieved:	✓					Sample Integrity - Condition	<u>Y</u>	or	N	
2. Cooler temp verification:						1. Sample recvd within HT:	$\checkmark$			
3. Cooler media:		Ice (Bag)				2. All containers accounted for:	$\checkmark$			
Quality Control Preservation	Y	or N	N/A	WTB	STB	3. Condition of sample:	I	Intact		
1. Trip Blank present / cooler:						Sample Integrity - Instructions	Y	or	N	N/A
2. Trip Blank listed on COC:			$\checkmark$			1. Analysis requested is clear:	$\checkmark$	١		
3. Samples preserved properly:	✓					2. Bottles received for unspecified tests		E	✓	
4. VOCs headspace free:			$\checkmark$			3. Sufficient volume recvd for analysis:	$\checkmark$	ſ		
						4. Compositing instructions clear:		[		$\checkmark$
						5. Filtering instructions clear:		[		$\checkmark$
Comments										

Accutest Laboratories V:713.271.4700

10165 Harwin Drive F: 713.271.4770

Houston, TX 77036 www/accutest.com

TC32298: Chain of Custody Page 2 of 3



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### Sample Receipt Log

Page 2 of 2

Job #: TC32298

Date / Time Received: 6/15/2013 10:15:00 AM

Initials: EC

Client: SOUTHWEST GEOSCIENCE

Cooler #	Sample ID:	Vol	Bot #	Location	Pres	рН	Therm ID	Initial Temp	Therm CF	Corrected Temp
1	TC32298-1	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-2	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-3	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-4	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-5	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-6	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-7	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-8	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-9	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-10	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-11	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-12	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2
1	TC32298-13	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR-5	2	0	2

TC32298: Chain of Custody Page 3 of 3



#### Laboratory Data Package Cover Page Appendix A

This signature page, the laboratory review sheeklist, and the following reportable date

TC32298 This data package consists of

-	11113 312	filature paye, the laboratory review	Checklist, and the following reportable data.
Ū.	R1	Field chain-of-custody docum	entation;
Ū.	R2	Sample identification cross-re	ference;
	R3	Test reports (analytical data s	heets) for each environmental sample that includes:
		a)	Items consistent with NELAC 5.13 or ISO/IEC 17025 Section 5.10
		b)	dilution factors,
		c)	preparation methods,
		d)	cleanup methods, and
		e)	if required for the project, tentatively identified compounds (TICs).
Ģ	R4	Surrogate recovery data inclue	ding:
		a)	Calculated recovery (%R), and
		b)	The laboratory's surrogate QC limits.
Ģ	R5	Test reports/summary forms for	or blank samples;
Ģ	R6	Test reports/summary forms for	or laboratory control samples (LCSs) including:
		a)	LCS spiking amounts,
		b)	Calculated %R for each analyte, and
		c)	The laboratory's LCS QC limits.
Ģ	R7	Test reports for project matrix	spike/matrix spike duplicates (MS/MSDs) including:
		a)	Samples associated with the MS/MSD clearly identified,
		b)	MS/MSD spiking amounts,
		c)	Concentration of each MS/MSD analyte measured in the parent and
		d)	Calculated %Rs and relative percent differences (RPDs), and
		e)	The laboratory's MS/MSD QC limits
Ģ	R8	Laboratory analytical duplicate	e (if applicable) recovery and precision:
		a)	The amount of analyte measured in the duplicate,
		b)	The calculated RPD, and
		c)	The laboratory's QC limits for analytical duplicates.
Ģ	R9	List of method quantitation lim	its (MQLs) and detectability check sample results for each analyte for each
Ģ	R10	Other problems or anomalies.	

The Exception Report for each "No" or "Not Reviewed (NR)" item in Laboratory Review Checklist and for each analyte, matrix, and method for which the laboratory does not hold NELAC accreditation under the Texas Laboratory Accreditation Program.

Release Statement: I am responsible for the release of this laboratory data package. This laboratory is NELAC accredited under the Texas Laboratory Accreditation Program for all the methods, analytes, and matrices reported in this data package except as noted in the Exception Report. This data package has been reviewed by the laboratory and is complete and technically compliant with the requirements of the methods used, except where noted by the laboratory in the attached exception reports. By my signature below, I affirm to the best of my knowledge, all problems/anomalies, observed by the laboratory as having the potential to affect the quality of the data, have been identified by the laboratory in the Laboratory Review Checklist, and no information or data have been knowingly withheld.

Check, if applicable: This laboratory meets an exception under 30 TAC&25.6 and was last inspection by

[X] TCEQ or [] \_\_\_\_\_\_ on April 2011. Any findings affecting the data in this laboratory data package are noted in the Exception Reports herein. The official signing the cover page of the report in which these data are used is responsible for releasing this data package and is by signature affirming the above release statement is true.

QA Manager

[]

Name (Printed)

Official Title (printed) Laboratory Director

Date

Richard Rodriguez

Signature

7/3/2013

5.2

G



LABORATORY REVIEW CHECKLIST: REPORTABLE DATA								
Laboratory	Name:	Accutest Gulf Coast	LRC Date:	7/3	/2013			
		0111C278A/ SC Sediment						
Project Nar	me:	Sampling	Laboratory Project Number:	TC	32298	3		
Reviewer	Name:	Richard Rodriguez	Prep Batch Number(s):					5
#'	A-	DESCRIPTION		YES	NO	NA°	NR <sup>-</sup>	ER #°
<u></u> R1	01	CHAIN-OF-CUSTODY (C-O-C):				_		
		Upon receipt?	andard conditions of sample acceptability					
		Were all departures from standard co	onditions described in an exception report?	X				
R2	0	Sample and quality control (QC) id						
	•.	Are all field sample ID numbers cross	s-referenced to the laboratory ID numbers?	X				
		Are all laboratory ID numbers cross-r	referenced to the corresponding OC data?	X				
R3	0	Test reports						
	•.	Were samples prepared and analyze	ed within holding times?					
		Other than those results <mql, th="" were<=""><th>all other raw values bracketed by calibration</th><th></th><th></th><th></th><th></th><th></th></mql,>	all other raw values bracketed by calibration					
		standards?				Х		
		Were calculations checked by a peer	r or supervisor?			Х		
		Were all analyte identifications check	ked by a peer or supervisor?			Х		
		Were sample detection limits reporte	d for all analytes not detected?			Х		
		Were all results for soil and sediment	t samples reported on a dry weight basis?			Х		
		Were % moisture (or solids) reported	I for all soil and sediment samples?			Х		
		Were bulk solis/solids samples for vo	biatile analysis extracted with methanol per			Х		
		If required for the project are TIC's re	eported?			Х		
R4	0	Surrogate recovery data				~		
		Were surrogates added prior to extra	ction?			Х		
		Were surrogate percent recoveries in all samples within the laboratory QC limits?				Х		
R5	OI	Test reports/summary forms for blank samples						
		Were appropriate type(s) of blanks analyzed?				Х		
		Were blanks analyzed at the appropr	riate frequency?			Х		
		Were method blanks taken through the	he entire analytical process, including			х		
		preparation and, if applicable, cleanu Were blank concentrations <mqi ?<="" th=""><th>ip procedures?</th><th></th><th></th><th>x</th><th></th><th></th></mqi>	ip procedures?			x		
R6	OI	Laboratory control samples (LCS)	:					
		Were all COCs included in the LCS?				Х		
		Was each LCS taken through the ent	tire analytical procedure, including prep and			v		
		cleanup steps?				^		
		Were LCSs analyzed at required free	quency?			Х		
		Were LCS (and LCSD, if applicable)	%Rs within the laboratory QC limits?			Х		
		Does the detectablility check sample	data document the laboratory's capability to			Х		
		detect the COCs at the MDL used to	calculate the SDLs?			V		
P7	0	Mastrix spike (MS) and matrix spike	, duplicate (MSD) data			^		
<u>N</u> /	0	Were the project/method specified ar	palytes included in the MS and MSD?			Х	_	
		Were MS/MSD analyzed at the appro-	opriate frequency?			X		
		Were MS (and MSD, if applicable) %	Rs within the laboratory QC Limits?			Х		
		Were the MS/MSD RPDs within labo	pratory QC limits?			Х		
R8	OI	Analytical duplicate data						
		Were appropriate analytical duplicate	es analyzed for each matrix?			Х		
		Were analytical duplicates analyzed	at the appropriate frequency?			Х		
		Were RPDs or relative standard devi	ations within the laboratory QC limits?			Х		[
R9	OI	Method quantitation limits (MQLs)				V		
		Are the MQLs for each method analyte included in the laboratory data package?				X		
		Are unadjusted MOLs and DCSs incl	luded in the laboratory data package?			^ Y		
R10	OI	Other problems/anomalies				^		
	0.	Are all known problems/anomalies/sr	pecial conditions noted in this LRC and ER?		1	Х		
		Was applicable and available techno	logy used to lower the SDL to minimize the			X		
		Is the laboratory NELAC-accredited u	under the Texas Laboratory Accreditation					
		Program for the analytes, matrices, a	nd methods associated with this laboratory	X				3
		data package?	lata package?					



Laboratory Name:		Accutest Gulf Coast	LRC Date:	7/3/2013				
Project Na	me:	0111C278A/ SC Sediment Sampl Laboratory Project Number:			3229	8		
Reviewer	Name:	Richard Rodriguez	Prep Batch Number(s):					
# <sup>1</sup>	A <sup>2</sup>	DESCRIPTION		YES	NO	$NA^3$	$NR^4$	ER # <sup>5</sup>
S1	OI	Initial calibration (ICAL)						
		Were response factors and/or relative response factors for each analyte within QC				x		i i
		limits?				~		
		Were percent RSDs or correlation co	efficient criteria met?			Х		
		Was the number of standards recom	mended in the method used for all analytes?			Х		
		Were all points generated between th	ne lowest and highest standard used to			x		i i
		calculate the curve?				~		
		Are ICAL data available for all instrum	nents used?			Х		
		Has the initial calibration curve been	verified using an appropriate second source			х		i i
		standard?				~		
S2	0	Initial and continuing calibration ve	erification (ICCV AND CCV) and continuing			Х		
		Was the CCV analyzed at the method	d-required frequency?			Х		I
		Were percent differences for each an	alyte within the method-required QC limits?			Х		<b></b>
		Was the ICAL curve verified for each	analyte?			Х		
		Was the absolute value of the analyte	e concentration in the inorganic CCB <mdl?< th=""><th></th><th>_</th><th>Х</th><th></th><th></th></mdl?<>		_	Х		
S3	0	Mass spectral tuning				X		
		Was the appropriate compound for th	ne method used for tuning?			Х		
	-	Were ion abundance data within the	method-required QC limits?		_	X		
S4	0	Internal standards (IS)				X		
		Were IS area counts and retention tin	nes within the method-required QC limits?		_	X		
<u> </u>	01	Raw data (NELAC Section 5.5.10)				Х		
		Were the raw data (for example, chromatograms, spectral data) reviewed by an				х		i i
		analyst?	to event in a flag and any the serve date 2			V		
		Were data associated with manual integrations flagged on the raw data?			_	X		L
56	0	Dual column confirmation				X		
		Did dual column confirmation results meet the method-required QC?				X		
- 5/	0	I entatively identified compounds	(IICS):			^		
		If TICS were requested, were the mas	ss spectra and TIC data subject to appropriate			Х		Í
58	1	Interference Check Sample (ICS) r	esults			х		
	•	Were percent recoveries within meth	od QC limits?			X		
<b>S</b> 9	1	Serial dilutions, post digestion spi	kes, and method of standard additions			X		
		Were percent differences, recoveries	and the linearity within the QC limits					
		specified in the method?	,			X		i i
S10	01	Method detection limit (MDL) studi	es			Х		
		Was a MDL study performed for each	n reported analyte?			Х		
		Is the MDL either adjusted or support	ted by the analysis of DCSs?			Х		
S11	OI	Proficiency test reports				Х		
		Was the laboratory's performance ac	ceptable on the applicable proficiency tests or			v		
		evaluation studies?				^		
S12	OI	Standards documentation				Х		
		Are all standards used in the analyse	s NIST-traceable or obtained from other			Y		1
		appropriate source?				^		
S13	OI	Compound/analyte identification p	rocedures			Х		
		Are the procedures for compound/and	alyte identification documented?			Х		
S14	01	Demonstration of analyst compete	ency (DOC)			Х		
		Was DOC conducted consistent with	NELAC Chapter 5?			Х		
		Is documentation of the analyst's competency up-to-date and on file?				Х		
S15	01	Verification/validation documentat	ion for methods (NELAC Chapter 5)			Х		
		Are all the methods used to generate	the data documentated, verified, and			x		1
		validated, where applicable?				~		
S16	OI	Laboratory standard operating pro	ocedures (SOPs)			Х		
	1	Are laboratory SOPs current and on f	ile for each method performed?			Х		í –



	LABORATORY REVIEW CHECKLIST (continued): Exception Reports								
Laboratory	Name:	Accutest Gulf Coast	LRC Date:	7/3/2013					
Project Na	me:	0111C278A/ SC Sediment Sampl	Laboratory Project Number:	TC32298					
Reviewer	Name:	Richard Rodriguez	Prep Batch Number(s):						
ER# <sup>1</sup>	Description								
	For reporting purposes, the MQL is defined in the report as the RL. The unadjusted MQL/RL is reported in the method								
1	blank. The	SDL is defined in the report as the MI	DL.						
	For reporti	For reporting purposes, the method blank represents the unadjusted MQL. The DCS is on file in the laboratory and is not							
2	included in	the laboratory data package.							
	The labora	tory is NELAC-accredited under the T	exas Laboratory Accreditation Program for the	analytes, matrices, and					
3	methods a	ssociated with this laboratory data pac	kage for analytes that are listed in the Texas F	elds of Accreditation.					
4	All anomal	es are discussed in the case narrative							

1ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked on



# Appendix A Laboratory Data Package Cover Page

This data	a pack	ages consists of:
Х	This s	ignature page, the laboratory review checklist, and the following reportable data:
Х	R1	Field chain-of-custody documentation;
Х	R2	Sample identification cross-reference;
Х	R3	Test reports (analytical data sheets) for each environmental sample that includes:
		a) Items consistent with NELAC 5.13 or ISO/IEC 17025 Section 5.10
		b) dilution factors,
		c) preparation methods,
		d) cleanup methods, and
		e) if required for the project, tentatively identified compounds (TICs).
N/A	R4	Surrogate recovery data including:
		a) Calculated recovery (%R), and
		b) The laboratory's surrogate QC limits.
Х	R5	Test reports/summary forms for blank samples;
Х	R6	Test reports/summary forms for laboratory control samples (LCSs) including:
		a) LCS spiking amounts,
		b) Calculated %R for each analyte, and
		c) The laboratory's LCS QC limits.
Х	R7	Test reports for project matrix spike/matrix spike duplicates (MS/MSDs) including:
		a) Samples associated with the MS/MSD clearly identified,
		b) MS/MSD spiking amounts,
		c) Concentration of each MS/MSD analyte measured in the parent and spiked samples,
		d) Calculated %Rs and relative percent differences (RPDs), and
		e) The laboratory's MS/MSD QC limits
Х	R8	Laboratory analytical duplicate (if applicable) recovery and precision:
		a) The amount of analyte measured in the duplicate,
		b) The calculated RPD, and
		c) The laboratory's QC limits for analytical duplicates.
Х	R9	List of method quantitation limits (MQLs) and detectability check sample results for each analyte
for each	metho	d and matrix;
Х	R10	Other problems or anomalies.
The Exce	ption R	eport for each "No" or "Not Reviewed (NR)" item in Laboratory Review Checklist and for each analyte, matrix,
and meth	od for v	which the laboratory does not hold NELAC accreditation under the Texas Laboratory Accreditation Program.

Release Statement: I am responsible for the release of this laboratory data package. This laboratory is NELAC accredited under the Texas Laboratory Accreditation Program for all the methods, analytes, and matrices reported in this data package except as noted in the Exception Report. This data package has been reviewed by the laboratory and is complete and technically compliant with the requirements of the methods used, except where noted by the laboratory in the attached exception reports. By my signature below, I affirm to the best of my knowledge, all problems/anomalies, observed by the laboratory as having the potential to affect the quality of the data, have been identified by the laboratory in the Laboratory Review Checklist, and no information or data have been knowingly withheld.

**Check, if applicable:** [] This laboratory meets an exception under 30 TAC&25.6 and was last inspected by [X ] TCEQ or [ ] \_ \_ on April 2011. Any findings affecting the data in this laboratory data package are noted in the Exception Reports herein. The official signing the cover page of the report in which these data are used is responsible for releasing this data package and is by signature affirming the above release statement is true.

Nicholas C. Straccione

All Cha

QA Officer

07/02/13

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Name (Printed)

Signature

Official Title (printed)

Date

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### 2014 EXIDE APAR PAGE 2747 OF 3116

Appendix A (cont'd): Laboratory Review Checklist: Reportable Data								
Labo	orator	y Name: Accutest Laboratories New Jersey	LRC Date: 7/2/13					
Proj	ject N	Jame:0111C278A/ SC Sediment Sampling, SGTXD16590	Laboratory Job Number: TC32298					
Revi	iewer	Name: Nicholas Straccione	Prep Batch Number(s):					
$\#^1$	$A^2$	Description	Yes No NA <sup>3</sup> I				NR <sup>4</sup>	ER# <sup>5</sup>
		Chain-of-custody (C-O-C)						
R1	OI	Did samples meet the laboratory's standard conditions of	f sample acceptability upon receipt?	х				
		Were all departures from standard conditions described i	n an exception report?	х				3
R2	OI	Sample and quality control (QC) identification					-	
		Are all field sample ID numbers cross-referenced to the l	aboratory ID numbers?	Х			-	
		Are all laboratory ID numbers cross-referenced to the co	rresponding QC data?	х				
R3	OI	Test reports						
		Were all samples prepared and analyzed within holding t	times?	Х				
		Other than those results < MQL, were all other raw value	es bracketed by calibration standards?	Х				
		Were calculations checked by a peer or supervisor?		Х				
		Were all analyte identifications checked by a peer or sup	ervisor?	х				
		Were sample detection limits reported for all analytes no	t detected?	х				
		Were all results for soil and sediment samples reported o	n a dry weight basis?	х				
		Were % moisture (or solids) reported for all soil and sed	iment samples?	х				
		Were bulk soil/solids samples for volatile analysis extrac	ted with methanol per SW846 Method 5035?	1		х		
		If required for the project, TICs reported?	*			х		
R4	0	Surrogate recovery data						
		Were surrogates added prior to extraction?						
	Were surrogate percent recoveries in all samples within the laboratory QC limits?					х		
R5	OI	I Test reports/summary forms for blank samples						
		Were appropriate type(s) of blanks analyzed?						
		Were blanks analyzed at the appropriate frequency?				Х		
		Were method blanks taken through the entire analytical process, including preparation and, if applicable,						
		cleanup procedures?						
		Were blank concentrations < MQL?				Х		
R6	OI	Laboratory control samples (LCS):					-	
		Were all COCs included in the LCS?		Х				
		Was each LCS taken through the entire analytical proced	lure, including prep and cleanup steps?	Х				
		Were LCSs analyzed at the required frequency?		Х				
		Were LCS (and LCSD, if applicable) %Rs within the lab	oratory QC limits?	Х				
		Does the detectability check sample data document the la	aboratory's capability to detect the COCs at the	х				
		MDL used to calculate the SDLs?					-	
D.7	OI	Was the LCSD RPD within QC limits?				Х		
к/	OI	Matrix spike (MS) and matrix spike duplicate (MSD)	data			v		
1		Were MS/MSD analyzed at the appropriate frequences	ne ms and msD?	<u> </u>		A V		
1		Were MS (and MSD if applicable) % Do within the labor	ratory OC limite?	<u> </u>		A V		
1		Were MS/MSD RPDs within laboratory OC limits?		<u> </u>		A X		
R8	OI	Analytical dunlicate data				Λ		
		Were appropriate analytical duplicates analyzed for each	matrix?	x				
		Were analytical duplicates analyzed at the appropriate fr	equency?	x x				
		Were RPDs or relative standard deviations within the lab	poratory OC limits?	x				
R9	OI	Method quantitation limits (MOLs):						
<u> </u>		Are the MQLs for each method analyte included in the laborator	ry data package?	х				1
		Do the MQLs correspond to the concentration of the lowest non	-zero calibration standard?	х				
		Are unadjusted MQLs and DCSs included in the laboratory data	n package?	1	х			2
R10	OI	Other problems/anomalies						
1		Are all known problems/anomalies/special conditions no	ted in this LRC and ER?	х				
1		Was applicable and available technology used to lower the	he SDL minimize the matrix interference affects	х				
1	on the sample results?							
1		Is the Laboratory NELAC-accredited under the Texas La	aboratory Accreditation Program for the analytes,	х				
	matrices and methods associated with this laboratory data package?							



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Арр	end	ix A (cont'd): Laboratory Review Chec	cklist: Reportable Data					
Labor	atory	Name: Accutest Laboratories New Jersey	LRC Date: 7/2/13					
Proje	ect Na	me:0111C278A/ SC Sediment Sampling, SGTXD16590	Laboratory Job Number: TC32298					
Revie	wer N	Jame: Nicholas Straccione	Prep Batch Number(s):					
$\#^1$	$A^2$	Description				NA 3	NR <sup>4</sup>	ER #5
<b>S</b> 1	OI	Initial calibration (ICAL)						π
-	01	Were response factors and/or relative response factors	for each analyte within QC limits?			Х		
		Were percent RSDs or correlation coefficient criteria n	net?			Х		
		Was the number of standards recommended in the method	hod used for all analytes?			Х		
		Were all points generated between the lowest and high	est standard used to calculate the curve?			Х		
		Are ICAL data available for all instruments used?				X		
52	OI	Has the initial calibration curve been verified using an	appropriate second source standard?			Х		
52	01	Was the CCV analyzed at the method required frequen	v and CCV) and continuing calibration			v		
		Were percent differences for each analyte within the m	ethod-required OC limits?			X		
		Was the ICAL curve verified for each analyte?	emed retailed QC minus			X		
		Was the absolute value of the analyte concentration in	the inorganic CCB < MDL?			х		
S3	0	Mass spectral tuning:						
		Was the appropriate compound for the method used for	r tuning?			х		
		Were ion abundance data within the method-required Q	QC limits?			х		
S4	0	Internal standards (IS):						
		Were IS area counts and retention times within the method-required QC limits?				х		
S5	OI	Raw data (NELAC section 5.5.10)						
		Were the raw data (for example, chromatograms, spect	ral data) reviewed by an analyst?	х				
		Were data associated with manual integrations flagged on the raw data?				х		
S6	0	Dual column confirmation						
		Did dual column confirmation results meet the method-required QC?				х		
S7	0	Tentatively identified compounds (TICs):						
60	т	If TICs were requested, were the mass spectra and TIC	data subject to appropriate checks?			Х		
20	1	Interference Check Sample (ICS) results:						
S9	Ι	Serial dilutions, post digestion spikes, and method o	f standard additions			X		
		Were percent differences, recoveries, and the linearity	within the QC limits specified in the method?			х		
S10	OI	Method detection limit (MDL) studies						
	-	Was a MDL study performed for each reported analyte	?	Х				
		Is the MDL either adjusted or supported by the analysis	s of DCSs?	х				
S11	OI	Proficiency test reports:						
		Was the laboratory's performance acceptable on the app	plicable proficiency tests or evaluation studies?	х				
S12	OI	Standards documentation						
		Are all standards used in the analyses NIST-traceable of	or obtained from other appropriate sources?	х				
S13	OI	Compound/analyte identification procedures						
		Are the procedures for compound/analyte identification	n documented?	х				
S14	OI	Demonstration of analyst competency (DOC)						
		Was DOC conducted consistent with NELAC Chapter	5C or ISO/IEC 4?	х				
		Is documentation of the analyst's competency up-to-da	te and on file?	х				
S15	OI	Verification/validation documentation for methods	(NELAC Chap 5)					
	1	Are all the methods used to generate the data document	ted, verified, and validated, where applicable?	х				
S16	OI	Laboratory standard operating procedures (SOPs):						
		Are laboratory SOPs current and on file for each method	od performed?	х				
				_	_			

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Appendix A (cont'd): Laboratory Review Checklist: Exception Reports						
Laboratory Na	me: Accutest Laboratories New Jersey	LRC Date: 07/2/13				
Project Name:0111C278A/ SC Sediment Sampling, SGTXD16590		Laboratory Job Number: TC32298				
Reviewer Name: Nicholas Straccione		Prep Batch Number(s):				
DESCRIPTION	Ň					
1	MQL is RL					
2	DCS Values not included in Data Report					
3	TC32298-9 for 0.030 mm (Hydrometer): Data ext with hydrometer analysis at short analysis times.	rapolated from higher and lower data points due to possible analytical problem				
	TC32298-7 for 0.030 mm (Hydrometer): Data extrapolated from higher and lower data points due to possible analytical problem with hydrometer analysis at short analysis times.					

1. Items identified by the letter "R" must be included in the laboratory data package submitted in the TRRP-required report(s). Items identified by the letter "S" should be retained and made available upon request for the appropriate retention period. 2. O= organic analyses; I= inorganic analyses (and general chemistry, when applicable);

3. NA = Not Applicable;

4. NR = Not reviewed;

5. ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked on the LRC)

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Misc. Forms
Custody Documents and Other Forms
(Accutest New Jersey)

Includes the following where applicable:

Chain of Custody

**೧** 



2014 EXIDE APAR PAGE 2751 OF 3116



# SUBCONTRACT COC

FED-EX Tracking # 5642 4617 5860

ottle Order C

10165 Harwin, Suite 150 - Houston, TX 77036 - 713-271-4700 fax: 713-271-4770



TC32298: Chain of Custody Page 1 of 2 Accutest New Jersey

ACCUTEST

TC32298

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### 2014 EXIDE APAR PAGE 2752 OF 3116

### Accutest Laboratories Sample Receipt Summary

LABOR	ATORIES				
Accutest Job Number:	TC32298	Client:		Project:	
Date / Time Received:	6/20/2013		Delivery Method:	Airbill #'s:	
Cooler Temps (Initial/A	djusted): <u>#1: (3.</u>	<u>5/3.5); 0</u>			
Cooler Security 1. Custody Seals Present:	Y or N ✓ □	3. COC Pre	esent: V or N Sample Integr	ity - Documentation	Y or N

2. Custody Seals Intact:	☐ 4.Sn XorN	npl Dates/Time OK	<ol> <li>2. Container labeling complete:</li> <li>3. Sample container label / COC agree:</li> </ol>			
1. Temp criteria achieved:     2. Cooler temp verification:     3. Cooler media:     4. No. Coolers:	I of N           Ice (Bag)           1		Sample Integrity - Condition 1. Sample recvd within HT: 2. All containers accounted for: 3. Condition of sample:	⊻ o ⊻ ⊻	or N	
Quality Control _Preservatio 1. Trip Blank present / cooler: 2. Trip Blank listed on COC:	<u>Y</u> or N □ ✓ □ ✓	<u>N/A</u> □	Sample Integrity - Instructions 1. Analysis requested is clear: 2. Bottles received for unspecified tests	<u>Y</u> α	or N	N/A
<ol> <li>Samples preserved properly:</li> <li>VOCs headspace free:</li> </ol>			<ol> <li>Sufficient volume recvd for analysis:</li> <li>Compositing instructions clear:</li> <li>Filtering instructions clear:</li> </ol>			<ul><li>✓</li></ul>

Comments

ACCUTEST

Accutest Laboratories V:732.329.0200 2235 US Highway 130 F: 732.329.3499 Dayton, New Jersey www/accutest.com

# TC32298: Chain of Custody Page 2 of 2



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General Chemistry

QC Data Summaries

(Accutest New Jersey)

Includes the following where applicable:

- Method Blank and Blank Spike Summaries
- Duplicate Summaries
- Matrix Spike Summaries
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#### DUPLICATE RESULTS SUMMARY GENERAL CHEMISTRY

#### Login Number: TC32298 Account: ALGC - Accutest Laboratories Gulf Coast, Inc. Project: SGTXD: 0111C278A/ SC Sediment Sampling

Analyte	Batch ID	QC Sample	Units	Original Result	DUP Result	RPD	QC Limits
% Gravel	GP72913/GN87455	TC32298-10	olo	5.4	6.5	18.5	0-77%
% Sand	GP72913/GN87455	TC32298-10	8	29.9	35.2	16.3	0-31%
% Silt, Clay, Colloids	GP72913/GN87455	TC32298-10	8	64.8	58.3	10.6	0-36%
0.0015 mm (Hydrometer)	GP72913/GN87455	TC32298-10	8	31.0	28.0	10.2	0-61%
0.005 mm (Hydrometer)	GP72913/GN87455	TC32298-10	8	44.0	40.0	9.5	0-87%
0.030 mm (Hydrometer)	GP72913/GN87455	TC32298-10	8	59.0	53.0	10.7	0-50%
0.375 Inch Sieve	GP72913/GN87455	TC32298-10	8	97.3	99.0	1.7	0-27%
0.75 Inch Sieve	GP72913/GN87455	TC32298-10	8	100	100	0.0	0-21%
1.5 Inch Sieve	GP72913/GN87455	TC32298-10	8	100	100	0.0	0-20%
3 Inch Sieve	GP72913/GN87455	TC32298-10	8	100	100	0.0	0-20%
No.10 Sieve (2.00 mm)	GP72913/GN87455	TC32298-10	8	85.6	77.0	10.7	0-18%
No.100 Sieve (0.15 mm)	GP72913/GN87455	TC32298-10	8	67.2	60.4	10.7	0-32%
No.16 Sieve (1.18 mm)	GP72913/GN87455	TC32298-10	8	81.3	73.2	10.5	0-21%
No.200 Sieve (0.075 mm)	GP72913/GN87455	TC32298-10	8	64.8	58.3	10.5	0-27%
No.30 Sieve (0.60 mm)	GP72913/GN87455	TC32298-10	8	77.0	69.4	10.4	0-27%
No.4 Sieve (4.75 mm)	GP72913/GN87455	TC32298-10	8	94.6	93.5	1.2	0-17%
No.50 Sieve (0.30 mm)	GP72913/GN87455	TC32298-10	8	73.5	66.1	10.6	0-25%
No.8 Sieve (2.36 mm)	GP72913/GN87455	TC32298-10	00	87.7	79.7	9.5	0-18%

Associated Samples: Batch GP72913: TC32298-1, TC32298-2, TC32298-3, TC32298-4, TC32298-5, TC32298-6, TC32298-7, TC32298-8, TC32298-9, TC32298-10

(\*) Outside of QC limits



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e-Hardcopy 2.0 Automated Report

07/06/13

## Technical Report for

Southwest Geoscience

0111C278A/ SC Sediment Sampling

Accutest Job Number: TC32707



Sampling Date: 06/19/13

Report to:

Southwest Geoscience 2351 W. Northwest Highway Suite 3321 Dallas, TX 75220 jason.minter@southwestgeoscience.com; rusty.simpson@southwestgeoscience.com

ATTN: Jason Minter

Total number of pages in report: 31





Test results contained within this data package meet the requirements of the National Environmental Laboratory Accreditation Conference and/or state specific certification programs as applicable.

Client Service contact: Sylvia Garza 713-271-4700

Certifications: TX (T104704220-13-10) AR (12-029-0) AZ (AZ0769) FL (E87628) KS (E-10366) LA (85695/04004) OK (2012-059)

This report shall not be reproduced, except in its entirety, without the written approval of Accutest Laboratories. Test results relate only to samples analyzed.

Gulf Coast • 10165 Harwin Drive • Suite 150 • Houston, TX 77036 • tel: 713-271-4700 • fax: 713-271-4770 • http://www.accutest.com



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## Sample Summary

Southwest Geoscience

**Job No:** TC32707

0111C278A/ SC Sediment Sampling

Sample Number	Collected Date	Time By	Received	Matr Code	ix Type	Client Sample ID
TC32707-1	06/19/13	11:58	06/22/13	SO	Soil	SC-SED-41R
TC32707-2	06/19/13	12:22	06/22/13	SO	Soil	SC-SED-42R
TC32707-3	06/19/13	12:48	06/22/13	SO	Soil	SC-SED-43R
TC32707-4	06/19/13	14:18	06/22/13	SO	Soil	SC-SED-44
TC32707-5	06/19/13	14:50	06/22/13	SO	Soil	SC-SED-45
TC32707-6	06/19/13	15:08	06/22/13	SO	Soil	SC-SED-46
				~ ~	~	22 APR 15
TC32707-7	06/19/13	15:48	06/22/13	SO	Soil	SC-SED-47
				~ ~	~	20 0PP 10
TC32707-8	06/19/13	16:11	06/22/13	SO	Soil	SC-SED-48

Soil samples reported on a dry weight basis unless otherwise indicated on result page.





### SAMPLE DELIVERY GROUP CASE NARRATIVE

Client:	Southwest Geoscience	Job No	TC32707
Site:	0111C278A/ SC Sediment Sampling	Report Date	7/5/2013 4:22:16 PM

8 Samples were collected on 06/19/2013 and were received intact at Accutest on 06/22/2013 and properly preserved in 1 cooler at 4 Deg C These Samples received an Accutest job number of TC32707. A listing of the Laboratory Sample ID, Client Sample ID and dates of collection are presented in the Results Summary Section of this report.

Except as noted below, all method specified calibrations and quality control performance criteria were met for this job. For more information, please refer to QC summary pages.

#### Wet Chemistry By Method ASTM D422-63

	Matrix	SO	Batch ID:	N:GP73021
--	--------	----	-----------	-----------

Analysis performed at Accutest Laboratories, Dayton, NJ.

Accutest Laboratories Gulf Coast (ALGC) certifies that this report meets the project requirements for analytical data produced for the samples as received at ALGC and as stated on the COC. ALGC certifies that the data meets the Data QualityObjectives for precision, accuracy and completeness as specified in the ALGC Quality Manual except as noted above. This report is to be used in its entirety. ALGC is not responsible for any assumptions of data quality if partial data packages are used

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## **CASE NARRATIVE / CONFORMANCE SUMMARY**

Client:	Accutest Laboratories Gulf Coast, Inc.	Job No	TC32707
Site:	SGTXD: 0111C278A/ SC Sediment Sampling	Report Date	7/5/2013 11:11:54 AM

On 06/25/2013, 8 Sample(s), 0 Trip Blank(s) and 0 Field Blank(s) were received at Accutest Laboratories at a temperature of 3 C. Samples were intact and chemically preserved, unless noted below. An Accutest Job Number of TC32707 was assigned to the project. Laboratory sample ID, client sample ID and dates of sample collection are detailed in the report's Results Summary Section.

Specified quality control criteria were achieved for this job except as noted below. For more information, please refer to the analytical results and QC summary pages.

#### Wet Chemistry By Method ASTM D422-63

	Matrix: SO	Batch ID:	GP73021
-	Sample(s) TC32707-1DUP were	e used as the QC samples t	for % Gravel, % Sand, % Silt, Clay, Colloids, 0.0015 mm
	(Hydrometer), 0.005 mm (Hydro	meter), 0.030 mm (Hydro	meter), 0.375 Inch Sieve, 0.75 inch sieve, 1.5 Inch Sieve, 3 inch sieve,

(Hydrometer), 0.005 mm (Hydrometer), 0.030 mm (Hydrometer), 0.375 Inch Sieve, 0.75 inch sieve, 1.5 Inch Sieve, 3 inch sieve, No.10 Sieve (2.00 mm), No.100 Sieve (0.15 mm), No.16 Sieve (1.18 mm), No.200 Sieve (0.075 mm), No.30 Sieve (0.60 mm), No.4 Sieve (4.75 mm), No.50 Sieve (0.30 mm), No.8 Sieve (2.36 mm).

Accutest certifies that data reported for samples received, listed on the associated custody chain or analytical task order, were produced to specifications meeting Accutest's Quality System precision, accuracy and completeness objectives except as noted.

Estimated non-standard method measurement uncertainty data is available on request, based on quality control bias and implicit for standard methods. Acceptable uncertainty requires tested parameter quality control data to meet method criteria.

Accutest Laboratories is not responsible for data quality assumptions if partial reports are used and recommends that this report be used in its entirety. Data release is authorized by Accutest Laboratories indicated via signature on the report cover



Page 1 of 1



Job Number:	TC32707
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/19/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method			
TC32707-1 SC-SED-41R								
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63			
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63			
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63			
0.375 Inch Sieve <sup>a</sup>	98.3			%	ASTM D422-63			
No.4 Sieve (4.75 mm) <sup>a</sup>	83.5			%	ASTM D422-63			
No.8 Sieve (2.36 mm) <sup>a</sup>	66.7			%	ASTM D422-63			
No.10 Sieve (2.00 mm) <sup>a</sup>	62.7			%	ASTM D422-63			
No.16 Sieve (1.18 mm) <sup>a</sup>	54.2			%	ASTM D422-63			
No.30 Sieve (0.60 mm) <sup>a</sup>	44.6			%	ASTM D422-63			
No.50 Sieve (0.30 mm) <sup>a</sup>	39.2			%	ASTM D422-63			
No. 100 Sieve (0. 15 mm) <sup>a</sup>	36.0			%	ASTM D422-63			
No.200 Sieve (0.075 mm) <sup>a</sup>	34.1			%	ASTM D422-63			
0.030 mm (Hydrometer) <sup>a</sup>	28			%	ASTM D422-63			
0.005 mm (Hydrometer) <sup>a</sup>	20			%	ASTM D422-63			
0.0015 mm (Hydrometer) <sup>a</sup>	11			%	ASTM D422-63			
% Gravel <sup>a</sup>	16.5			%	ASTM D422-63			
% Sand <sup>a</sup>	49.4			%	ASTM D422-63			
% Silt, Clay, Colloids <sup>a</sup>	34.1			%	ASTM D422-63			
TC32707-2 SC-SED-42R								
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63			
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63			
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63			
0.375 Inch Sieve <sup>a</sup>	93.1			%	ASTM D422-63			
No.4 Sieve (4.75 mm) <sup>a</sup>	76.3			%	ASTM D422-63			
No.8 Sieve (2.36 mm) <sup>a</sup>	55.6			%	ASTM D422-63			
No.10 Sieve (2.00 mm) <sup>a</sup>	51.2			%	ASTM D422-63			
No.16 Sieve (1.18 mm) <sup>a</sup>	39.8			%	ASTM D422-63			
No.30 Sieve (0.60 mm) <sup>a</sup>	29.7			%	ASTM D422-63			
No.50 Sieve (0.30 mm) <sup>a</sup>	24.0			%	ASTM D422-63			
No.100 Sieve (0.15 mm) <sup>a</sup>	19.8			%	ASTM D422-63			
No.200 Sieve (0.075 mm) <sup>a</sup>	18.5			%	ASTM D422-63			
0.030 mm (Hydrometer) <sup>a</sup>	15			%	ASTM D422-63			
0.005 mm (Hydrometer) <sup>a</sup>	10			%	ASTM D422-63			
0.0015 mm (Hydrometer) <sup>a</sup>	7.0			%	ASTM D422-63			
% Gravel <sup>a</sup>	23.7			%	ASTM D422-63			
% Sand <sup>a</sup>	57.8			%	ASTM D422-63			
% Silt, Clay, Colloids <sup>a</sup>	18.5			%	ASTM D422-63			
TC32707-3 SC-SED-43R								
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63			

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Job Number:	TC32707
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/19/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	96.0			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	68.1			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	58.6			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	31.3			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	10.7			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	6.8			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	6.3			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	6.0			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	1.8			%	ASTM D422-63
% Gravel <sup>a</sup>	4.0			%	ASTM D422-63
% Sand <sup>a</sup>	90.0			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	6.0			%	ASTM D422-63
TC32707-4 SC-SED-44					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	95.1			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	83.6			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	66.9			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	63.3			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	54.7			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	44.5			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	40.5			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	37.9			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	36.2			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	29			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	22			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	17			%	ASTM D422-63
% Gravel <sup>a</sup>	16.4			%	ASTM D422-63
% Sand <sup>a</sup>	47.4			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	36.2			%	ASTM D422-63
TC32707-5 SC-SED-45					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.8			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	90.6			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	65.3			%	ASTM D422-63

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Job Number:	TC32707
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/19/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method
No.10 Sieve (2.00 mm) <sup>a</sup>	58.1			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	47.2			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	38.3			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	35.5			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	34.0			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	32.5			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	25			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	18			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	13			%	ASTM D422-63
% Gravel <sup>a</sup>	9.4			%	ASTM D422-63
% Sand <sup>a</sup>	58.1			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	32.5			%	ASTM D422-63
TC32707-6 SC-SED-46					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	97.2			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	78.6			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	43.6			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	36.2			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	21.9			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	15.2			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	13.7			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	12.4			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	11.5			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	8.0			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	6.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	4.8			%	ASTM D422-63
% Gravel <sup>a</sup>	21.4			%	ASTM D422-63
% Sand <sup>a</sup>	67.0			%	ASTM D422-63
% Silt, Clay, Colloids a	11.5			%	ASTM D422-63
TC32707-7 SC-SED-47					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	95.8			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	82.1			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	59.2			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	54.4			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	43.3			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	27.7			%	ASTM D422-63

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Job Number:	TC32707
Account:	Southwest Geoscience
Project:	0111C278A/ SC Sediment Sampling
Collected:	06/19/13

Lab Sample ID Client Sample ID Analyte	Result/ Qual	MQL	SDL	Units	Method
No.50 Sieve (0.30 mm) <sup>a</sup>	17.1			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	12.1			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	10.8			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	5.0			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	2.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	1.6			%	ASTM D422-63
% Gravel <sup>a</sup>	17.9			%	ASTM D422-63
% Sand <sup>a</sup>	71.3			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	10.8			%	ASTM D422-63
TC32707-8 SC-SED-48					
3 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100			%	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.5			%	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	81.8			%	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	51.1			%	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	44.6			%	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	28.2			%	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	17.8			%	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	14.5			%	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	12.5			%	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	11.7			%	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	7.0			%	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	5.0			%	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	4.0			%	ASTM D422-63
% Gravel <sup>a</sup>	18.2			%	ASTM D422-63
% Sand <sup>a</sup>	70.2			%	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	11.7			%	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



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Sample Results

Report of Analysis

**Section 4** 

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TC32707

	<b>Report of Analysis</b>			Page 1
Client Sample ID:	SC-SED-41R			
Lab Sample ID:	TC32707-1	Date Sampled:	06/19/13	
Matrix:	SO - Soil	Date Received:	06/22/13	
		<b>Percent Solids:</b>	n/a	
Project:	0111C278A/ SC Sediment Sampling			
General Chemistry				

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve a	and Hydrometer	r Testing	)				
3 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.3		%	1	07/02/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	83.5		%	1	07/02/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	66.7		%	1	07/02/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	62.7		%	1	07/02/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	54.2		%	1	07/02/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	44.6		%	1	07/02/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	39.2		%	1	07/02/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	36.0		%	1	07/02/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	34.1		%	1	07/02/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	28		%	1	07/02/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	20		%	1	07/02/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	11		%	1	07/02/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	16.5		%	1	07/02/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	49.4		%	1	07/02/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	34.1		%	1	07/02/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



Page 1 of 1

# Client Sample ID: SC-SED-42R Lab Sample ID: TC32707-2 Date Sampled: 06/19/13 Matrix: SO - Soil Date Received: 06/22/13 Project: 0111C278A/ SC Sediment Sampling Date Sampled: 0/// General Chemistry Value Value Value

**Report of Analysis** 

Result	RL	Units	DF	Analyzed	By	Method
and Hydrometer	r Testing	)				
100		%	1	07/02/13	ANJ	ASTM D422-63
100		%	1	07/02/13	ANJ	ASTM D422-63
100		%	1	07/02/13	ANJ	ASTM D422-63
93.1		%	1	07/02/13	ANJ	ASTM D422-63
76.3		%	1	07/02/13	ANJ	ASTM D422-63
55.6		%	1	07/02/13	ANJ	ASTM D422-63
51.2		%	1	07/02/13	ANJ	ASTM D422-63
39.8		%	1	07/02/13	ANJ	ASTM D422-63
29.7		%	1	07/02/13	ANJ	ASTM D422-63
24.0		%	1	07/02/13	ANJ	ASTM D422-63
19.8		%	1	07/02/13	ANJ	ASTM D422-63
18.5		%	1	07/02/13	ANJ	ASTM D422-63
15		%	1	07/02/13	ANJ	ASTM D422-63
10		%	1	07/02/13	ANJ	ASTM D422-63
7.0		%	1	07/02/13	ANJ	ASTM D422-63
23.7		%	1	07/02/13	ANJ	ASTM D422-63
57.8		%	1	07/02/13	ANJ	ASTM D422-63
18.5		%	1	07/02/13	ANJ	ASTM D422-63
	Result 100 100 100 93.1 76.3 55.6 51.2 39.8 29.7 24.0 19.8 18.5 15 10 7.0 23.7 57.8 18.5	Result         RL           nd Hydrometer         Testing           100         100           100         93.1           76.3         55.6           51.2         39.8           29.7         24.0           19.8         18.5           15         10           7.0         23.7           57.8         18.5	ResultRLUnits100%100%100%100%100%93.1%76.3%55.6%51.2%39.8%29.7%24.0%19.8%15%15%10%7.0%23.7%57.8%18.5%	ResultRLUnitsDF100%1100%1100%1100%193.1%176.3%155.6%151.2%139.8%129.7%119.8%115.5%117.0%118.5%123.7%157.8%118.5%1	ResultRLUnitsDFAnalyzed100%107/02/13100%107/02/13100%107/02/1393.1%107/02/1376.3%107/02/1355.6%107/02/1351.2%107/02/1339.8%107/02/1329.7%107/02/1324.0%107/02/1315.5%107/02/1316.5%107/02/1317.0%107/02/1323.7%107/02/1357.8%107/02/1318.5%107/02/1318.5%107/02/1318.5%107/02/1318.5%107/02/1318.5%107/02/1318.5%107/02/1318.5%107/02/13	ResultRLUnitsDFAnalyzedBy100%107/02/13ANJ100%107/02/13ANJ100%107/02/13ANJ100%107/02/13ANJ93.1%107/02/13ANJ76.3%107/02/13ANJ55.6%107/02/13ANJ51.2%107/02/13ANJ39.8%107/02/13ANJ29.7%107/02/13ANJ19.8%107/02/13ANJ15.5%107/02/13ANJ16.5%107/02/13ANJ17.0%107/02/13ANJ23.7%107/02/13ANJ57.8%107/02/13ANJ18.5%107/02/13ANJ18.5%107/02/13ANJ18.5%107/02/13ANJ18.5%107/02/13ANJ18.5%107/02/13ANJ18.5%107/02/13ANJ18.5%107/02/13ANJ18.5%107/02/13ANJ

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



TC32707



	<b>Report of Analysis</b>			Page
Client Sample ID:	SC-SED-43R			
Lab Sample ID:	TC32707-3	Date Sampled:	06/19/13	
Matrix:	SO - Soil	Date Received:	06/22/13	
		<b>Percent Solids:</b>	n/a	
Project:	0111C278A/ SC Sediment Sampling			
General Chemistry	,			

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydrome	ter Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	96.0		%	1	07/02/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	68.1		%	1	07/02/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	58.6		%	1	07/02/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	31.3		%	1	07/02/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	10.7		%	1	07/02/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	6.8		%	1	07/02/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	6.3		%	1	07/02/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	6.0		%	1	07/02/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	1.8		%	1	07/02/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	< 0.59	0.59	%	1	07/02/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	< 0.59	0.59	%	1	07/02/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	4.0		%	1	07/02/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	90.0		%	1	07/02/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	6.0		%	1	07/02/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



## Client Sample ID: SC-SED-44 Lab Sample ID: TC32707-4 Date Sampled: 06/19/13 Matrix: SO - Soil Date Received: 06/22/13 Project: 0111C278A/ SC Sediment Sampling Date Sampled: 0/22/13 General Chemistry Lab Sample ID: National State State

**Report of Analysis** 

Analyte Result RL Units DF Analyzed Bv Method Particle Size Analysis (Sieve and Hydrometer Testing) 3 Inch Sieve <sup>a</sup> % 1 07/02/13 100 ANJ ASTM D422-63 1.5 Inch Sieve a 100 % 1 07/02/13 ANJ ASTM D422-63 0.75 Inch Sieve a 100 % 07/02/13 1 ANJ ASTM D422-63 0.375 Inch Sieve a 95.1 % 1 07/02/13 ANJ ASTM D422-63 No.4 Sieve (4.75 mm) a 83.6 % 1 07/02/13 ANJ ASTM D422-63 No.8 Sieve (2.36 mm) a 66.9 % 1 07/02/13 ANJ ASTM D422-63 No.10 Sieve (2.00 mm) a % 07/02/13 63.3 1 ANJ ASTM D422-63 No.16 Sieve (1.18 mm) a 54.7 % 1 07/02/13 ANJ ASTM D422-63 No.30 Sieve (0.60 mm) a 44.5 % 1 07/02/13 ANJ ASTM D422-63 No.50 Sieve (0.30 mm) a 40.5 % 1 07/02/13 ANJ ASTM D422-63 No.100 Sieve (0.15 mm) a 37.9 % 1 07/02/13 ANJ ASTM D422-63 No.200 Sieve (0.075 mm) a 36.2 1 07/02/13 % ANJ ASTM D422-63 0.030 mm (Hydrometer) a 29 % 1 07/02/13 ANJ ASTM D422-63 0.005 mm (Hydrometer) <sup>a</sup> 22 % 1 07/02/13 ANJ ASTM D422-63 0.0015 mm (Hydrometer) <sup>a</sup> 17 % 1 07/02/13 ANJ ASTM D422-63 % Gravel <sup>a</sup> 16.4 % 1 07/02/13 ANJ ASTM D422-63 47.4 % Sand <sup>a</sup> % 1 07/02/13 ANJ ASTM D422-63 % Silt, Clay, Colloids a 36.2 % 1 07/02/13 ANJ ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.





# Client Sample ID: SC-SED-45 Lab Sample ID: TC32707-5 Matrix: SO - Soil Project: 0111C278A/ SC Sediment Sampling

**Report of Analysis** 

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydron	neter Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.8		%	1	07/02/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	90.6		%	1	07/02/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	65.3		%	1	07/02/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	58.1		%	1	07/02/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	47.2		%	1	07/02/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	38.3		%	1	07/02/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	35.5		%	1	07/02/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	34.0		%	1	07/02/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	32.5		%	1	07/02/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	25		%	1	07/02/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	18		%	1	07/02/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	13		%	1	07/02/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	9.4		%	1	07/02/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	58.1		%	1	07/02/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	32.5		%	1	07/02/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.





4.5

4



Project:	0111C278A/ SC Sediment Sampling			
		Percent Solids:	n/a	
Matrix:	SO - Soil	Date Received:	06/22/13	
Lab Sample ID:	TC32707-6	Date Sampled:	06/19/13	
Client Sample ID:	SC-SED-46			

**Report of Analysis** 

#### Analyte Result RL Units DF Analyzed By Method Particle Size Analysis (Sieve and Hydrometer Testing) 3 Inch Sieve <sup>a</sup> 07/02/13 100 % 1 ANJ ASTM D422-63 1.5 Inch Sieve a 100 % 1 07/02/13 ANJ ASTM D422-63 0.75 Inch Sieve a 100 % 07/02/13 1 ANJ ASTM D422-63 0.375 Inch Sieve a 97.2 % 1 07/02/13 ASTM D422-63 ANJ No.4 Sieve (4.75 mm) a 78.6 % 1 07/02/13 ANJ ASTM D422-63 No.8 Sieve (2.36 mm) a 43.6 % 1 07/02/13 ANJ ASTM D422-63 No.10 Sieve (2.00 mm) a 36.2 % 07/02/13 1 ANJ ASTM D422-63 No.16 Sieve (1.18 mm) a 21.9 % 1 07/02/13 ANJ ASTM D422-63 No.30 Sieve (0.60 mm) a 15.2 % 1 07/02/13 ANJ ASTM D422-63 No.50 Sieve (0.30 mm) a 13.7 % 1 07/02/13 ANJ ASTM D422-63 No.100 Sieve (0.15 mm) a 12.4 % 1 07/02/13 ANJ ASTM D422-63 No.200 Sieve (0.075 mm) a 07/02/13 11.5 % 1 ANJ ASTM D422-63 0.030 mm (Hydrometer) a 8.0 % 1 07/02/13 ANJ ASTM D422-63 0.005 mm (Hydrometer) <sup>a</sup> 6.0 % 1 07/02/13 ANJ ASTM D422-63 0.0015 mm (Hydrometer) <sup>a</sup> 4.8 % 1 07/02/13 ANJ ASTM D422-63 % Gravel <sup>a</sup> 21.4 % 1 07/02/13 ANJ ASTM D422-63

%

%

1

1

07/02/13

07/02/13

ANJ

ANJ

ASTM D422-63

ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.

67.0

11.5



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% Sand <sup>a</sup>

% Silt, Clay, Colloids a

Project:	0111C278A/ SC Sediment Sampling	Percent Solids:	n/a	
Matrix:	SO - Soil	Date Received:	06/22/13	
Client Sample ID: Lab Sample ID:	SC-SED-47 TC32707-7	Date Sampled:	06/19/13	

## **Report of Analysis**

General	Chemistry
---------	-----------

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydromet	er Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	95.8		%	1	07/02/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	82.1		%	1	07/02/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	59.2		%	1	07/02/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	54.4		%	1	07/02/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	43.3		%	1	07/02/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	27.7		%	1	07/02/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	17.1		%	1	07/02/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	12.1		%	1	07/02/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	10.8		%	1	07/02/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	5.0		%	1	07/02/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	2.0		%	1	07/02/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	1.6		%	1	07/02/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	17.9		%	1	07/02/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	71.3		%	1	07/02/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	10.8		%	1	07/02/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



Page 1 of 1

# Client Sample ID: SC-SED-48 Lab Sample ID: TC32707-8 Matrix: SO - Soil Project: 0111C278A/ SC Sediment Sampling

**Report of Analysis** 

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Particle Size Analysis (Sieve	and Hydrom	neter Testi	ng)				
3 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
1.5 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.75 Inch Sieve <sup>a</sup>	100		%	1	07/02/13	ANJ	ASTM D422-63
0.375 Inch Sieve <sup>a</sup>	98.5		%	1	07/02/13	ANJ	ASTM D422-63
No.4 Sieve (4.75 mm) <sup>a</sup>	81.8		%	1	07/02/13	ANJ	ASTM D422-63
No.8 Sieve (2.36 mm) <sup>a</sup>	51.1		%	1	07/02/13	ANJ	ASTM D422-63
No.10 Sieve (2.00 mm) <sup>a</sup>	44.6		%	1	07/02/13	ANJ	ASTM D422-63
No.16 Sieve (1.18 mm) <sup>a</sup>	28.2		%	1	07/02/13	ANJ	ASTM D422-63
No.30 Sieve (0.60 mm) <sup>a</sup>	17.8		%	1	07/02/13	ANJ	ASTM D422-63
No.50 Sieve (0.30 mm) <sup>a</sup>	14.5		%	1	07/02/13	ANJ	ASTM D422-63
No.100 Sieve (0.15 mm) <sup>a</sup>	12.5		%	1	07/02/13	ANJ	ASTM D422-63
No.200 Sieve (0.075 mm) <sup>a</sup>	11.7		%	1	07/02/13	ANJ	ASTM D422-63
0.030 mm (Hydrometer) <sup>a</sup>	7.0		%	1	07/02/13	ANJ	ASTM D422-63
0.005 mm (Hydrometer) <sup>a</sup>	5.0		%	1	07/02/13	ANJ	ASTM D422-63
0.0015 mm (Hydrometer) <sup>a</sup>	4.0		%	1	07/02/13	ANJ	ASTM D422-63
% Gravel <sup>a</sup>	18.2		%	1	07/02/13	ANJ	ASTM D422-63
% Sand <sup>a</sup>	70.2		%	1	07/02/13	ANJ	ASTM D422-63
% Silt, Clay, Colloids <sup>a</sup>	11.7		%	1	07/02/13	ANJ	ASTM D422-63

(a) Analysis performed at Accutest Laboratories, Dayton, NJ.



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Misc. Forms	
Custody Documents and Other Forms	
Includes the following where applicable:	
<ul><li>Chain of Custody</li><li>LRC Form</li></ul>	

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#### 2014 EXIDE APAR PAGE 2774 OF 3116

Couth	IWEST Labor	aton: Area	ITEST			ANA Rec		3	77	77		DDY RECC se only ate:
GEOS	CIENCE Addre	iss it in	0/ 1/	Tr				///		/ / ,	////	
	geologic Consultants	10010	···/	<i></i>			Š)	' / /			Temp. c	of coolers
Office Location	guns 1 jo Conta	ct:					E					3 4
	Phone	9:					42				Page_	of
Project Manager 4	PO/SC	D#:		$\sim$			3	'	'//	/ /		
JASON MINTESE	Sample	ers Signature	E B	E.	Q		, The last					
Proj. No.	Project Name	SE		De of Con	toinore	с.						
0111C 278 A	SC SEDIMENT	Sampling	Norty		lidilleis			/ / /	'			
Matrix Date Time	C G o r Identifying Marks of Sa m a	umple(s) tra tra	VOA	A/G 2	50 P/O	, i	'					
5 6/19/13 1150	P b	0 2 4 2	5	1 µ. r	ml	1 a					Lab Sample ID	Lab Use Only)
1 1 108	1 SC-SED- 41R				×	×						
1200	SC = SED = YZR										2	
1248	SC - SED - 43F	2				+					3	
1918	DC-SED-YY										4	
1930	JE- 560- 45						_				5	
1508	SC - SED - Y6	n 1		-							6	
S 6/19/12 1/11	V SC- SED-47					-V	_				7	
11113 1011	P SC-SED=YP				*	×					8	
NE	DH				-							
Turn around time	mal 25% Rush 50% Ru	sh 0 100% Rush		)		_						
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Religguished by (Signature)	- 06-20-13 1333 Date: Timo:	/ Yater	X		6-20	-91	3.33					
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Heimiquisned av (Signature)	Date: Time:	Received by: (Signa	ature)		Date:	10 10	Time:	TO	TP æ	BLANK	INCLUDED	
Matrix WW - Wastewat	er W - Water S - Soil	SD - Solid I - Ligu		ANX Page	512	<u>12   1</u>	215					

SOUTHWEST GEOSCIENCE • 2351 W. Northwest Hwy., Suite 3321 • Dallas, Texas 75220 • Office: 214-350-5469 • Fax 214-350-2914

TC32707: Chain of Custody Page 1 of 3



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#### Accutest Laboratories Sample Receipt Summary

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Accutest Job N	lumber:	TC32707	Client:	SOUTHWEST GEOSCIENCE	Project:	SC SEDIMENT SAMPLING
Date / Time Re	ceived:	6/22/2013		Delivery Method:	Airbill #'s:	563713601272
No. Coolers:	1	Therm ID:	IR6;		Temp Adjus	stment Factor: 0;
Coolor Tomps	(Initial/A	division $\#1\cdot(A/A)$				

Cooler Temps (Initial/Adjusted): <u>#</u>

Cooler Security Y	or N				Υc	or N	Sample Integrity - Documentation	Y	or	Ν	
1. Custody Seals Present:		] 3.	COC Present	t: 💽	/		1. Sample labels present on bottles:	$\checkmark$			
2. Custody Seals Intact:		] 4. Sr	npl Dates/Tim	e OK	/		2. Container labeling complete:	$\checkmark$			
Cooler Temperature	Y	or N					3. Sample container label / COC agree:	$\checkmark$			
1. Temp criteria achieved:	$\checkmark$						Sample Integrity - Condition	Y	or	Ν	
2. Cooler temp verification:							1. Sample recvd within HT:	$\checkmark$			
3. Cooler media:	lo	ce (Bag)					2. All containers accounted for:	$\checkmark$			
Quality Control Preservation	Y	or N	N/A	w	ΓВ	STB	3. Condition of sample:		Intact		
1. Trip Blank present / cooler:			$\checkmark$				Sample Integrity - Instructions	Y	or	N	N/A
2. Trip Blank listed on COC:			$\checkmark$				1. Analysis requested is clear:	$\checkmark$			
3. Samples preserved properly:	✓						2. Bottles received for unspecified tests			✓	
4. VOCs headspace free:			$\checkmark$				3. Sufficient volume recvd for analysis:	$\checkmark$			
							4. Compositing instructions clear:				$\checkmark$
							5. Filtering instructions clear:				$\checkmark$
Comments											

Accutest Laboratories V:713.271.4700

10165 Harwin Drive F: 713.271.4770

Houston, TX 77036 www/accutest.com

## TC32707: Chain of Custody Page 2 of 3



#### 2014 EXIDE APAR PAGE 2776 OF 3116



#### Sample Receipt Log

Page 2 of 2

Job #: TC32707

Date / Time Received: 6/22/2013 10:15:00 AM

Initials: EC

Client: SOUTHWEST GEOSCIENCE

Cooler #	Sample ID:	Vol	Bot #	Location	Pres	рН	Therm ID	Initial Temp	Therm CF	Corrected Temp
1	TC32707-1	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR6	4	0	4
1	TC32707-2	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR6	4	0	4
1	TC32707-3	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR6	4	0	4
1	TC32707-4	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR6	4	0	4
1	TC32707-5	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR6	4	0	4
1	TC32707-6	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR6	4	0	4
1	TC32707-7	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR6	4	0	4
1	TC32707-8	8oz	1	SUB	N/P	Note #2 - Preservative check not applicable.	IR6	4	0	4

TC32707: Chain of Custody Page 3 of 3



#### Laboratory Data Package Cover Page Appendix A

This signature page, the laboratory review sheeklist, and the following reportable date

TC32707 This data package consists of

· ·	11113 310	griature page, the laboratory revie	w checkist, and the following reportable data.
Ū.	R1	Field chain-of-custody docum	nentation;
Ē	R2	Sample identification cross-re	eference;
	R3	Test reports (analytical data s	sheets) for each environmental sample that includes:
		a)	Items consistent with NELAC 5.13 or ISO/IEC 17025 Section 5.10
		b)	dilution factors,
		c)	preparation methods,
		d)	cleanup methods, and
		e)	if required for the project, tentatively identified compounds (TICs).
Ģ	R4	Surrogate recovery data inclu	iding:
		a)	Calculated recovery (%R), and
		b)	The laboratory's surrogate QC limits.
Ū.	R5	Test reports/summary forms	for blank samples;
Ū.	R6	Test reports/summary forms	for laboratory control samples (LCSs) including:
		a)	LCS spiking amounts,
		b)	Calculated %R for each analyte, and
		c)	The laboratory's LCS QC limits.
Ū.	R7	Test reports for project matrix	spike/matrix spike duplicates (MS/MSDs) including:
		a)	Samples associated with the MS/MSD clearly identified,
		b)	MS/MSD spiking amounts,
		c)	Concentration of each MS/MSD analyte measured in the parent and
		d)	Calculated %Rs and relative percent differences (RPDs), and
		e)	The laboratory's MS/MSD QC limits
Ū.	R8	Laboratory analytical duplicat	e (if applicable) recovery and precision:
		a)	The amount of analyte measured in the duplicate,
		b)	The calculated RPD, and
		c)	The laboratory's QC limits for analytical duplicates.
Ļ	R9	List of method quantitation lin	nits (MQLs) and detectability check sample results for each analyte for each
Ģ	R10	Other problems or anomalies	

The Exception Report for each "No" or "Not Reviewed (NR)" item in Laboratory Review Checklist and for each analyte, matrix, and method for which the laboratory does not hold NELAC accreditation under the Texas Laboratory Accreditation Program.

Release Statement: I am responsible for the release of this laboratory data package. This laboratory is NELAC accredited under the Texas Laboratory Accreditation Program for all the methods, analytes, and matrices reported in this data package except as noted in the Exception Report. This data package has been reviewed by the laboratory and is complete and technically compliant with the requirements of the methods used, except where noted by the laboratory in the attached exception reports. By my signature below, I affirm to the best of my knowledge, all problems/anomalies, observed by the laboratory as having the potential to affect the quality of the data, have been identified by the laboratory in the Laboratory Review Checklist, and no information or data have been knowingly withheld.

Check, if applicable: This laboratory meets an exception under 30 TAC&25.6 and was last inspection by

[X] TCEQ or [] \_\_\_\_\_\_ on April 2011. Any findings affecting the data in this laboratory data package are noted in the Exception Reports herein. The official signing the cover page of the report in which these data are used is responsible for releasing this data package and is by signature affirming the above release statement is true.

QA Manager

[]

Name (Printed) Richard Rodriguez Signature

Official Title (printed)

Laboratory Director

Date

7/5/2013

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	L/	<b>ABORATORY REVIEW C</b>	HECKLIST: REPORTABLE	DAT	Α		
Laboratory	Name:	Accutest Gulf Coast	LRC Date:	7/5/	/2013		
		0111C278A/ SC Sediment					
Project Nar	me:	Sampling	Laboratory Project Number:	TC	32707		
Reviewer <sup>1</sup>	Name:	Richard Rodriguez	Prep Batch Number(s):	VEOL			- ا د ח <sup>45</sup>
#				TEO	NOINA	INK	
		Did samples meet the laboratory's sta	andard conditions of sample acceptability			1	1
		upon receipt?		X			
		Were all departures from standard co	onditions described in an exception report?	Х			
R2	OI	Sample and quality control (QC) id	entification				
		Are all field sample ID numbers cross	s-referenced to the laboratory ID numbers?	X			
		Are all laboratory ID numbers cross-re	eferenced to the corresponding QC data?	Х			
R3	OI	Test reports					
		Were samples prepared and analyze	d within holding times?		Х		
		Other than those results <mql, th="" were<=""><th>all other raw values bracketed by calibration</th><th></th><th>x</th><th></th><th></th></mql,>	all other raw values bracketed by calibration		x		
		standards?			~		
		Were calculations checked by a peer	or supervisor?		X		+
		Were all analyte identifications check	ted by a peer or supervisor?		X		
		Were all results for soil and acdiment	d for all analytes not detected?				
		Were % moisture (or solids) reported	for all soil and sediment samples?	$\left  \right $		-	+
		Were bulk soils/solids samples for vo	platile analysis extracted with methanol per		^		
		SW846 Method 5035?			X		
		If required for the project, are TIC's re	eported?		Х		
R4	0	Surrogate recovery data					
		Were surrogates added prior to extra	ction?		X		
	0	Were surrogate percent recoveries in	all samples within the laboratory QC limits?		<u> </u>		
R5	0	lest reports/summary forms for bl	ank samples			1	-
		Were blanks analyzed at the appropri	iate frequency?		X		+
		Were method blanks taken through th	he entire analytical process, including				
		preparation and, if applicable, cleanu	p procedures?		X		
		Were blank concentrations <mql?< th=""><th></th><th></th><th>Х</th><th></th><th></th></mql?<>			Х		
R6	OI	Laboratory control samples (LCS):				1	
		Were all COCs included in the LCS?	And a state of the st		X		<u> </u>
		was each LCS taken through the ent	tire analytical procedure, including prep and		X		
		Were I C.Ss analyzed at required free	uencv?		X		+
		Were LCS (and LCSD, if applicable)	%Rs within the laboratory QC limits?		X		
		Does the detectablility check sample	data document the laboratory's capability to		X		
		detect the COCs at the MDL used to	calculate the SDLs?		×		
		Was the LCSD RPD within QC limits	?		Х		
R7	01	Matrix spike (MS) and matrix spike	e duplicate (MSD) data		-	1	
		Were the project/method specified an	nalytes included in the MS and MSD?		X		
		Were MS/MSD analyzed at the appro	Priate frequency?		X		+
		Were the MS/MSD RPDs within Jabo	ratory OC limits?		×		
R8	0	Analytical duplicate data				-	
	•.	Were appropriate analytical duplicate	es analyzed for each matrix?		X	1	
		Were analytical duplicates analyzed a	at the appropriate frequency?		X		
		Were RPDs or relative standard devia	ations within the laboratory QC limits?		Х		
R9	OI	Method quantitation limits (MQLs):					
		Are the MQLs for each method analyt	te included in the laboratory data package?		X		
		Do the MQLs correspond to the conc	entration of the lowest non-zero calibration		X		<u> </u>
B10	0	Are unadjusted MQLs and DUSS Incl	nueu in the laboratory data package?			L	
K IV		Are all known problems/anomalies/sn	pecial conditions noted in this LRC and ER2		X		
		Was applicable and available technol	logy used to lower the SDL to minimize the		X	1	+
		Is the laboratory NELAC-accredited u	Inder the Texas Laboratory Accreditation				$\vdash$
		Program for the analytes, matrices, and	nd methods associated with this laboratory	x			3
		data package?	· · · · · ·				



Laboratory	Name:	Accutest Gulf Coast	LRC Date:	7/5/20	13		
Project Na	me:	0111C278A/ SC Sediment Sampl	Laboratory Project Number:	TC327	07		
Reviewer	Name:	Richard Rodriguez	Prep Batch Number(s):				
# <sup>1</sup>	A <sup>2</sup>	DESCRIPTION		YES NO	$NA^3$	NR⁴	ER # <sup>5</sup>
S1	OI	Initial calibration (ICAL)					
		Were response factors and/or relative	e response factors for each analyte within QC		Y		
		limits?			^		
		Were percent RSDs or correlation co	efficient criteria met?		Х		
		Was the number of standards recom	mended in the method used for all analytes?		Х		
		Were all points generated between th	e lowest and highest standard used to		v		
		calculate the curve?			^		
		Are ICAL data available for all instrum	nents used?		Х		
		Has the initial calibration curve been	verified using an appropriate second source		v		
		standard?			^		
S2	01	Initial and continuing calibration ve	erification (ICCV AND CCV) and continuing				
		Was the CCV analyzed at the method	d-required frequency?		X		
		Were percent differences for each an	alyte within the method-required QC limits?		X		
		Was the ICAL curve verified for each	analyte?		X	_	
		Was the absolute value of the analyte	e concentration in the inorganic CCB <mdl?< th=""><th></th><th>X</th><th></th><th></th></mdl?<>		X		
S3	0	Mass spectral tuning					
		Was the appropriate compound for th	ne method used for tunina?		X		
		Were ion abundance data within the	method-required QC limits?		X		
S4	0	Internal standards (IS)			1		
		Were IS area counts and retention tin	nes within the method-required QC limits?		X		
<b>S</b> 5	0	Raw data (NELAC Section 5.5.10)			1		
		Were the raw data (for example, chro	matograms, spectral data) reviewed by an		1 1	1	
		analyst?			X		
		Were data associated with manual in	tegrations flagged on the raw data?		X		
56	0	Dual column confirmation					
	- <b>-</b>	Did dual column confirmation results	meet the method-required QC?		X	-	
57	0	Tentatively identified compounds	(TICs):				
	<b>–</b>	If TICs were requested, were the mas	s spectra and TIC data subject to appropriate		1 1	1	
		checks?			Х		
S8		Interference Check Sample (ICS)	esults		1 1		
		Were percent recoveries within method	od QC limits?		I X I		
<b>S</b> 9	1	Serial dilutions, post digestion spi	kes, and method of standard additions				
		Were percent differences, recoveries	and the linearity within the QC limits				
		specified in the method?	,		X		
S10	0	Method detection limit (MDL) studi	es				
		Was a MDL study performed for each	reported analyte?		I X I		
		Is the MDL either adjusted or support	ed by the analysis of DCSs?		X		
S11	0	Proficiency test reports			1		
		Was the laboratory's performance ac	ceptable on the applicable proficiency tests or		11		
		evaluation studies?			X		
S12	0	Standards documentation					
		Are all standards used in the analyse	s NIST-traceable or obtained from other		11		
		appropriate source?			X		
S13	0	Compound/analyte identification p	rocedures				
		Are the procedures for compound/an	alvte identification documented?		X		
S14	0	Demonstration of analyst compete	ncy (DOC)				
	- <u>-</u>	Was DOC conducted consistent with	NELAC Chapter 5?		X		
		Is documentation of the analyst's com	npetency up-to-date and on file?		X	-+	
S15	0	Verification/validation documentat	ion for methods (NELAC Chapter 5)				
<u> </u>	- <u> </u>	Are all the methods used to generate	the data documentated, verified, and				
		validated where applicable?			X		
S16	0	Laboratory standard operating pro	ocedures (SOPs)				
		Are laboratory SOPs current and on f	ile for each method performed?		XI		



	LABOR	RATORY REVIEW CHEC	KLIST (continued): Exceptio	n Reports				
Laboratory	Name:	Accutest Gulf Coast	LRC Date:	7/5/2013				
Project Na	me:	0111C278A/ SC Sediment Sampl	Laboratory Project Number:	TC32707				
Reviewer	Name:	Richard Rodriguez	Prep Batch Number(s):					
ER# <sup>1</sup>	Descriptio	on						
	For reporting purposes, the MQL is defined in the report as the RL. The unadjusted MQL/RL is reported in the method							
1	blank. The	SDL is defined in the report as the MI	DL.					
	For reporting	ng purposes, the method blank repres	ents the unadjusted MQL. The DCS is on file i	n the laboratory and is not				
2	included in	the laboratory data package.						
	The labora	tory is NELAC-accredited under the T	exas Laboratory Accreditation Program for the	analytes, matrices, and				
3	methods a	ssociated with this laboratory data pac	kage for analytes that are listed in the Texas F	elds of Accreditation.				

1ER# = Exception Report identification number (an Exception Report should be completed for an item if "NR" or "No" is checked on





Misc. Forms	
Custody Documents and Other Forms	
(Accutest New Jersey)	
	-

Includes the following where applicable:

• Chain of Custody

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2014 EXIDE APAR PAGE 2782 OF 3116

## TC32707: Chain of Custody Page 1 of 2 Accutest New Jersey



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#### 2014 EXIDE APAR PAGE 2783 OF 3116

#### Accutest Laboratories Sample Receipt Summary

LABOR	ATORIES			
Accutest Job Number:	TC32707	Client:		Project:
Date / Time Received:	6/25/2013		Delivery Method:	Airbill #'s:
Cooler Temps (Initial/Ad	ljusted): <u>#1: (3/3);</u>	0		

Cooler Security         1. Custody Seals Present:         2. Custody Seals Intact:         Cooler Temperature	Y or N ✓ □ 3. COC Present: ✓ □ 4. Smpl Dates/Time OK <u>Y or N</u>	Y         or         N           ✓         □         □           ✓         □         □	Sample Integrity - Documentation 1. Sample labels present on bottles: 2. Container labeling complete: 3. Sample container label / COC agree:	Yor ✓ ✓	<u>N</u>	
<ol> <li>Temp criteria achieved:</li> <li>Cooler temp verification:</li> <li>Cooler media:</li> <li>No. Coolers:</li> </ol>	☑         □           Bar Therm		Sample Integrity - Condition 1. Sample recvd within HT: 2. All containers accounted for: 3. Condition of sample:	Y or ✓ ✓ Inta	<u>N</u>	
Quality Control Preservati           1. Trip Blank present / cooler:           2. Trip Blank listed on COC:           3. Samples preserved propert           4. VOCs headspace free:	io <u>Y or N N/A</u> . V		<ol> <li>Sample Integrity - Instructions</li> <li>Analysis requested is clear:</li> <li>Bottles received for unspecified tests</li> <li>Sufficient volume recvd for analysis:</li> <li>Compositing instructions clear:</li> <li>Filtering instructions clear:</li> </ol>	<u>Y</u> or ☑ ☑ □	N	N/A V

Comments

ACCUTEST

Accutest Laboratories V:732.329.0200 2235 US Highway 130 F: 732.329.3499 Dayton, New Jersey www/accutest.com

## TC32707: Chain of Custody Page 2 of 2

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General Chemistry

QC Data Summaries

(Accutest New Jersey)

Includes the following where applicable:

- Method Blank and Blank Spike Summaries
- Duplicate Summaries
- Matrix Spike Summaries

#### 2014 EXIDE APAR PAGE 2785 OF 3116

#### DUPLICATE RESULTS SUMMARY GENERAL CHEMISTRY

#### Login Number: TC32707 Account: ALGC - Accutest Laboratories Gulf Coast, Inc. Project: SGTXD: 0111C278A/ SC Sediment Sampling

Analyte	Batch ID	QC Sample	Units	Original Result	DUP Result	RPD	QC Limits
% Gravel	GP73021/GN87590	TC32707-1	00	16.5	15.1	9.0	0-77%
% Sand	GP73021/GN87590	TC32707-1	%	49.4	49.6	0.5	0-31%
% Silt, Clay, Colloids	GP73021/GN87590	TC32707-1	%	34.1	35.3	3.4	0-36%
0.0015 mm (Hydrometer)	GP73021/GN87590	TC32707-1	%	11	13	16.7	0-61%
0.005 mm (Hydrometer)	GP73021/GN87590	TC32707-1	%	20	22	9.5	0-87%
0.030 mm (Hydrometer)	GP73021/GN87590	TC32707-1	%	28	30	6.7	0-50%
0.375 Inch Sieve	GP73021/GN87590	TC32707-1	8	98.3	97.4	1.0	0-27%
0.75 Inch Sieve	GP73021/GN87590	TC32707-1	8	100	100	0.0	0-21%
1.5 Inch Sieve	GP73021/GN87590	TC32707-1	%	100	100	0.0	0-20%
3 Inch Sieve	GP73021/GN87590	TC32707-1	%	100	100	0.0	0-20%
No.10 Sieve (2.00 mm)	GP73021/GN87590	TC32707-1	%	62.7	63.2	0.8	0-18%
No.100 Sieve (0.15 mm)	GP73021/GN87590	TC32707-1	8	36.0	37.1	3.1	0-32%
No.16 Sieve (1.18 mm)	GP73021/GN87590	TC32707-1	%	54.2	55.1	1.6	0-21%
No.200 Sieve (0.075 mm)	GP73021/GN87590	TC32707-1	%	34.1	35.3	3.4	0-27%
No.30 Sieve (0.60 mm)	GP73021/GN87590	TC32707-1	8	44.6	45.4	1.8	0-27%
No.4 Sieve (4.75 mm)	GP73021/GN87590	TC32707-1	%	83.5	84.9	1.7	0-17%
No.50 Sieve (0.30 mm)	GP73021/GN87590	TC32707-1	8	39.2	40.2	2.3	0-25%
No.8 Sieve (2.36 mm)	GP73021/GN87590	TC32707-1	alo	66.7	67.2	0.8	0-18%

Associated Samples: Batch GP73021: TC32707-1, TC32707-2, TC32707-3, TC32707-4, TC32707-5, TC32707-6, TC32707-7, TC32707-8 (\*) Outside of QC limits



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## APPENDIX F

Limited Site Investigation: Sediment Sampling of Stewart Creek, prepared by SWG dated March 27, 2013 (excerpted)

#### LIMITED SITE INVESTIGATION Sediment Sampling of Stewart Creek

Property:

Stewart Creek BNSF Railroad Bridge to Stonebrook Parkway Frisco, Texas

March 27, 2013 Project No. 0111278

Prepared for:

City of Frisco C/O Russell & Rodriguez, L.L.P. 1633 Williams Drive Building 2, Suite 200 Georgetown, TX 78628

Prepared by:



2351 W. Northwest Hwy., Suite 3321 Dallas, Texas 75220 Ph: (214) 350-5469 Fax: (214) 350-2914



2351 W. Northwest Hwy., Suite 3321 Dallas, Texas 75220 Ph: (214) 350-5469 Fax: (214) 350-2914

March 27, 2013

City of Frisco c/o Russell & Rodriguez, L.L.P. 1633 Williams Drive Building 2, Suite 200 Georgetown, TX 78628 Attn : Mr. Kerry Russell

Re: Limited Site Investigation Sediment Sampling of Stewart Creek BNSF Railroad Bridge to Stonebrook Parkway Frisco, Texas SWG Project No. 0111278

Dear Mr. Russell:

SWG is pleased to submit this Limited Site Investigation (LSI) report for the above-referenced Site. This investigation was performed in accordance with SWG's Proposal Number 01111316 dated September 21, 2011.

We appreciate the opportunity to perform these services for the City of Frisco, c/o Russell & Rodriguez, L.L.P. Please contact either of the undersigned at (214) 350-5469 if you have questions regarding the information provided in the report.

Sincerely, SOUTHWEST GEOSCIENCE

Prepared by:

Jason T. Minter, P.G. Manager, Environmental Field Services

Enclosure







#### TABLE OF CONTENTS

Page No.

1.0	INTRODUCTION	1
2.0	FIELD ACTIVITIES	2
3.0	LABORATORY ANALYTICAL METHODS	3
4.0	DATA EVALUATION	3
5.0	FINDINGS AND RECOMMENDATIONS	4

#### LIST OF APPENDICES

Appendix A:	Figure 1- Topographic Map
	Figure 2 - Site Map
Appendix B:	Photographs
Appendix C:	Table
Appendix D:	Laboratory Data Reports and Chain-of-Custody Documentation


#### LIMITED SITE INVESTIGATION

Sediment Sampling of Stewart Creek BNSF Railroad Bridge to Stonebrook Parkway Frisco, Texas SWG Project No. 0111278 March 27, 2013

# 1.0 INTRODUCTION

# 1.1 Site Description

SWG has completed a Limited Site Investigation (LSI) for sediment sampling activities along Stewart Creek, at and along the proposed Grand Park project, from the eastern edge at the BNSF railroad bridge to Stonebrook Parkway in Frisco, Texas.

A topographic map is included as Figure 1, and a Site Map is included as Figure 2, Appendix A.

#### 1.2 Scope of Work

SWG conducted sediment sampling activities in Stewart Creek, from the eastern edge at the BNSF railroad bridge to Stonebrook Parkway in Frisco, Texas. The proposed scope of work was based on the request of the City of Frisco for sediment sampling and analysis along the proposed Grand Park project as shown on the attached Figure 1. This investigation was requested to evaluate chemicals of concern in sediment in the vicinity of the Grand Park project.

The objective of the proposed scope of services was to evaluate arsenic, cadmium, lead, selenium and sulfate concentrations along Stewart Creek in sediment samples collected from 30 sampling locations based on the layout of the proposed Grand Park project. This scope of work was performed in accordance with SWG's Proposal Number 01111316 dated September 21, 2011.

#### 1.3 Standard of Care

SWG's services were performed in accordance with standards customarily provided by a firm rendering the same or similar services in the area during the same time period. SWG makes no warranties, express or implied, as to the services performed hereunder. Additionally, SWG does not warrant the work of third parties supplying information used in the report (e.g. laboratories, regulatory agencies or other third parties). This scope of services was performed in accordance with the scope of work agreed with the client, as detailed in our proposal.

#### 1.4 Additional Scope Limitations

Findings, conclusions and recommendations resulting from these services are based upon information derived from the on-site activities and other services performed under this scope of work and it should be noted that this information is subject to change over time. Certain indicators of the presence of hazardous substances, petroleum products, or other constituents may have been latent, inaccessible, unobservable, or not present during these services, and SWG cannot represent that the site contains no hazardous substances, toxic materials, Limited Site Investigation Sediment Sampling of Stewart Creek BNSF Railroad Bridge to Stonebrook Parkway SWG Project No. 0111278 March 27, 2013



petroleum products, or other latent conditions beyond those identified during this LSI. Environmental conditions at other areas or portions of the Site may vary from those encountered at actual sample locations. SWG's findings, and recommendations are based solely upon data available to SWG at the time of these services.

# 1.5 Reliance

This report has been prepared for the exclusive use of the City of Frisco, and any authorization for use or reliance by any other party (except a governmental entity having jurisdiction over the site) is prohibited without the express written authorization of the City of Frisco and SWG. Any unauthorized distribution or reuse is at the client's sole risk. Notwithstanding the foregoing, reliance by authorized parties will be subject to the terms, conditions and limitations stated in the proposal, LSI report, and SWG's Agreement. The limitation of liability defined in the agreement is the aggregate limit of SWG's liability to the client and all relying parties unless otherwise agreed in writing.

# 2.0 FIELD ACTIVITIES

As part of this LSI, sediment samples were collected from 30 total sampling locations based on the layout of the proposed Grand Park project, as shown on Figure 1. Sample collection activities were divided into two phases. The first phase was performed between the BNSF railroad bridge and the Dallas North Tollway. The second phase of sediment sampling was performed west of the Dallas North Tollway, along the proposed area of the Grand Park project. The sediment sampling activities were concentrated in depositional areas along Stewart Creek and conducted in general accordance with the Texas Commission on Environmental Quality (TCEQ) *Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods (RG-415)*, dated December 2003.

# 2.1 Sediment Sampling

SWG's LSI field activities were conducted from November 17, 2011 to November 18, 2011 by Mr. Tommy Kim, Mr. John Koehnen and Mr. Jason Minter, P.G., SWG environmental professionals. As part of the approved scope of work, Eleven (11) sediment samples were collected between the BNSF railroad bridge and the Dallas North Tollway bridge. Nineteen (19) sediment samples were collected between the Dallas North Tollway and Stonebrook Parkway. The sediment sample locations were designated SC-SED-1 (west of the BNSF railroad bridge) through SC-SED-30 (north of Stonebrook Parkway).

Sample locations were targeted in areas of soft sediment deposition/accumulation within the depositional features and documented using field GPS equipment. At each location, sediment samples were collected from the 0.0 to 0.5 foot depth interval; however, finer grained bed sediments were sampled preferentially over coarser grained bed sediments.

Figure 1 presents the general boundaries and topography of the Site on the USGS topographic quadrangle map of Frisco, Texas (Appendix A). A Site Map is included as Figure 2 (Appendix A).

Sediment samples were collected using a decontaminated split core sampler. Sampling equipment was cleaned using an Alconox<sup>®</sup> wash and potable water rinse prior to the beginning of the project and before collecting each sediment sample.

Limited Site Investigation Sediment Sampling of Stewart Creek BNSF Railroad Bridge to Stonebrook Parkway SWG Project No. 0111278 March 27, 2013



Battery chips were observed in the creek channel in two locations north of Stonebrook Parkway in the vicinity of SC SED-30 and SC SED-26. Additionally, potential slag was observed in the creek channel in the vicinity of the Dallas North Tollway bridge. Representative photographs of sediment sample locations including photographs of battery chips and potential slag are included as Appendix B.

# 2.2 Sediment Sampling Program

Sediment samples were collected and placed in laboratory prepared glassware, sealed with custody tape and placed on ice in a cooler which was secured with a custody seal. The sample coolers and completed chain-of-custody forms were relinquished to ERMI's analytical laboratory in Allen, Texas for normal turnaround.

# 3.0 LABORATORY ANALYTICAL METHODS

The sediment samples were analyzed for arsenic, cadmium, lead and selenium utilizing EPA Method SW-846#6010B and sulfate utilizing EPA Method 300.0.

Laboratory results are summarized in the tables included in Appendix B. The executed chainof-custody form and laboratory data sheets are provided in Appendix C.

# 4.0 DATA EVALUATION

SWG compared the arsenic, cadmium, lead and selenium concentrations detected in the sediment samples to the freshwater sediment benchmarks and second effects levels for sediment referenced in the TCEQ guidance document *Update to Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas RG-263 (Revised)*, dated January 2006. Based on SWG's review, the TCEQ has not established ecological benchmarks or second effects levels for selenium or sulfate.

#### <u>Arsenic</u>

The arsenic concentrations detected in the sediment samples ranged from 8.10 mg/Kg in SC-SED-18 to 47.2 mg/Kg in SC-SED-8. Arsenic concentrations detected in sediment at each location with the exception of SC-SED-18 exceeded the TCEQ ecological benchmark for sediment of 9.79 mg/Kg. SC-SED-8 exceeded the TCEQ second effects level for arsenic of 33 mg/Kg.

#### <u>Cadmium</u>

The cadmium concentrations detected in the sediment samples ranged from 0.43 mg/Kg in SC-SED-18 to 4.16 mg/Kg in SC-SED-9. Cadmium concentrations detected in sediment at eighteen locations exceeded the TCEQ ecological benchmark for sediment of 0.99 mg/Kg; however, none of the detected sediment concentrations exceeded the TCEQ second effects level for cadmium of 4.98 mg/Kg.

#### <u>Lead</u>

The lead concentrations detected in the sediment samples ranged from 20.5 mg/Kg in SC-SED-18 to 397 mg/Kg in SC-SED-5. The lead concentrations at seventeen locations exceeded the TCEQ ecological benchmark for sediment of 35.8 mg/Kg. Lead concentrations at SC-SED-5, SC-SED-6 and SC-SED-9 also exceeded the TCEQ second effects level for lead of 128 mg/Kg.

Limited Site Investigation Sediment Sampling of Stewart Creek BNSF Railroad Bridge to Stonebrook Parkway SWG Project No. 0111278 March 27, 2013



#### <u>Selenium</u>

Selenium concentrations were not detected above the laboratory sample detection limits (SDLs). The TCEQ has not established an ecological benchmark or a second effects level for selenium in sediment.

#### <u>Sulfate</u>

The sulfate concentrations detected in the sediment samples ranged from 31.0 mg/Kg in SC-SED-21 to 241 mg/Kg in SC-SED-5. The TCEQ has not established an ecological benchmark or a second effects level for sulfate in sediment.

#### 5.0 FINDINGS AND RECOMMENDATIONS

The objective of the proposed scope of services was to evaluate arsenic, cadmium, lead, selenium and sulfate concentrations along Stewart Creek in sediment samples collected from 30 sampling locations based on the layout of the proposed Grand Park project. The scope of work was performed in accordance with SWG's Proposal Number 01111316 dated September 21, 2011.

The findings and recommendations of this investigation are as follows:

- As part of the approved scope of work, Eleven (11) sediment samples were collected between the BNSF railroad bridge and the Dallas North Tollway. Nineteen (19) sediment samples were collected between the Dallas North Tollway and Stonebrook Parkway.
- Sample locations were targeted in areas of soft sediment deposition/accumulation within the stream bed and documented using field GPS equipment. At each location, sediment samples were collected from the 0.0 to 0.5 foot depth interval; however, finer grained bed sediments were sampled preferentially over coarser grained bed sediments.
- The laboratory analytical results indicate that arsenic, cadmium, lead and sulfate concentrations were detected in each of the samples collected. Selenium concentrations were not detected above laboratory SDLs.
- Based on the results of SWG's LSI, additional assessment is necessary to further evaluate the arsenic, cadmium and lead concentrations above the TCEQ ecological benchmarks and/or second effects levels for sediment and to further evaluate the presence of battery chips and potential slag observed during field activities.



APPENDIX A

Figures



SWG Project No. 0111278



Figure 1 Topographic Map Frisco & Hebron Texas Quadrangle Contour Interval = 10 Feet 1981





APPENDIX B

Photographs



1.) Photo of Stewart Creek in the vicinity of sediment sample SC-SED 4.

November 18, 2011



2.) Photo of Stewart Creek in the vicinity of sediment sample SC-SED 7.

November 17, 2011

Southwest



3.) Photo of Stewart Creek in the vicinity of sediment sample SC-SED 13.

November 18, 2011



4.) Photo of Stewart Creek in the vicinity of sediment sample SC-SED 19.

November 18, 2011

Southwest



5.) Photo of Stewart Creek in the vicinity of sediment sample SC-SED 23.

November 18, 2011



6.) Photo of battery chips under water on top of sediment in Stewart Creek.

November 18, 2011

Southwest



7.) Photo of Stewart Creek in the vicinity of sediment sample SC-SED 28.

November 18, 2011



8.) Representative photos of battery chips on a gravel deposit in Stewart Creek.

November 18, 2011





9.) Photo of potential slag observed near the Dallas North Tollway Bridge.

November 18, 2011





APPENDIX C

Table

TABLE 1									
METALS and SULFATE SEDIMENT ANALYTICAL RESULTS									
Stewart Creek East and West of the Dallas North Tollway									
Frisco, Texas									
Sample I.D.	Sample Date	Depth (feet)	Arsenic (mg/Kg)	Cadmium	Lead (mg/Kg)	Selenium	Sulfate		
TRRP Ecologica	al Benchmarks	for Sediment	9.79	0.99	35.8	NE	NE		
TCEQ Second Effects Levels for Sediment			33	4.98	128	NE	NE		
TRRP Human Health Sediment Protective			110	1,100	500	2,700	NE		
			44.0	0.04	20.0	4.00	20.0		
SC-SED-1	11/18/11	0-0.5	11.9	0.61	38.2	<1.09	39.3		
SC-SED-2	11/18/11	0-0.5	11.2	0.75	46.9	<1.15	87.8		
SC-SED-3	11/18/11	0-0.5	18.6	2.01	63.8	<1.06	85.5		
SC-SED-4	11/18/11	0-0.5	12.0	0.95	39.1	<1.09	09.8		
SC-SED-5		0-0.5	14.4	0.90	397	<1.20	Z41		
SC-SED-6		0-0.5	10.2	1.05	307	<1.08	55.0		
SC-SED-7		0-0.5	10.1	0.04	30.0 25.0	<1.07	50.Z		
SC-SED-0	11/17/11	0-0.5	<b>47.2</b>	0.90	30.2	<1.10	JZ.7		
SC-SED-9		0-0.5	20.0	4.10	102	<1.00	43.1		
SC-SED-10	11/17/11	0-0.5	12.3	0.72	22.0	<1.01	40.0		
SC SED 12	11/12/11	0-0.5	29.4	0.70	40.0 56.7	<1.02	172		
SC-SED-12	11/18/11	0-0.5	31.1	0.73	33.7	<1.20	58.3		
SC-SED-14	11/18/11	0-0.5	12.7	0.04	27.7	<0.97	/8.2		
SC-SED-15	11/18/11	0-0.5	12.7	1.54	27.7	<1.01	58.0		
SC-SED-16	11/18/11	0-0.5	14.6	1 49	59.0	<1.01	35.6		
SC-SED-17	11/18/11	0-0.5	18.3	1.10	43.1	<0.97	40.2		
SC-SED-18	11/18/11	0-0.5	8 10	0.43	20.5	<0.91	190		
SC-SED-19	11/18/11	0-0.5	19.5	1.47	37.6	<1.18	93.0		
SC-SED-20	11/18/11	0-0.5	17.4	1.07	38.5	<1.03	54.2		
SC-SED-21	11/18/11	0-0.5	18.0	2.19	49.5	<0.96	31.0		
SC-SED-22	11/18/11	0-0.5	19.2	2.01	53.2	<0.93	78.5		
SC-SED-23	11/18/11	0-0.5	16.1	3.69	34.2	<1.15	190		
SC-SED-24	11/18/11	0-0.5	32.1	2.00	49.5	<1.03	39.8		
SC-SED-25	11/18/11	0-0.5	15.1	1.03	21.6	<1.07	45.0		
SC-SED-26	11/17/11	0-0.5	16.5	0.87	30.1	<1.07	66.3		
SC-SED-27	11/17/11	0-0.5	14.3	1.09	31.8	<1.00	54.1		
SC-SED-28	11/18/11	0-0.5	14.1	1.23	29.0	<0.96	63.0		
SC-SED-29	11/18/11	0-0.5	18.2	1.75	35.9	<1.00	37.2		
SC-SED-30	11/18/11	0-0.5	18.5	2.41	31.3	<0.98	58.9		

mg/Kg - milligrams/Kilogram

(j) - Denotes an estimated value between the laboratory sample detection limit (SDL) and the laboratory method detection limit (MDL).

Shading indicates a concentration above the TRRP Ecological Benchmark for Sediment

Bold and shading indicates a concentration above the TCEQ Second Effects Level

Benchmarks obtained from the TCEQ guidance document Update to Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas RG-263 (Revised), dated January 2006.

< - Not detected above laboratory SDL.

N/A - Not Applicable

NE - Not Established



# APPENDIX G

Interim Report: Visual Survey of Stewart Creek, prepared by SWG dated May 14, 2013

# INTERIM REPORT

Visual Survey of Stewart Creek

Property:

Stewart Creek F.M. 423 to BNSF Railroad Bridge Frisco, Texas

> May 14, 2013 Project No. 0111C278A

> > Prepared for:

City of Frisco c/o Russell & Rodriguez, L.L.P. 1633 Williams Drive Building 2, Suite 200 Georgetown, TX 78628

Prepared by:



2351 W. Northwest Hwy., Suite 3321 Dallas, Texas 75220 Ph: (214) 350-5469 Fax: (214) 350-2914



2351 W. Northwest Hwy., Suite 3321 Dallas, Texas 75220 Ph: (214) 350-5469 Fax: (214) 350-2914

May 14, 2013

City of Frisco c/o Russell & Rodriguez, L.L.P. 1633 Williams Drive Building 2, Suite 200 Georgetown, TX 78628 Attn : Mr. Kerry Russell

Re: Interim Report Visual Survey of Stewart Creek F.M. 423 to BNSF Railroad Bridge Frisco, Texas SWG Project No. 0111C278A

Dear Mr. Russell:

SWG is pleased to submit this interim report documenting the information collected during SWG's walking survey in Stewart Creek from March 28, 2013 to April 19, 2013. SWG's scope of work is being conducted in accordance with SWG's Proposal Number P0113C1098 dated March 26, 2013 (hereinafter, the "proposal").

Please note that this interim report documents SWG's observations in Stewart Creek. Since SWG's field activities are ongoing, this interim report does not represent a final report for the scope of services outlined in SWG's proposal.

We appreciate the opportunity to perform these services for the City of Frisco, c/o Russell & Rodriguez, L.L.P. Please contact either of the undersigned at (214) 350-5469 if you have questions regarding the information provided in the report.

Sincerely, SOUTHWEST GEOSCIENCE

Prepared by:

Jason T. Minter, P.G. Manager, Environmental Field Services

Enclosure



Reviewed by:

Rusty L. Simpson, P.G., C.P.G. Principal PROF

Environmental & Hydrogeologic Consultants



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Appendix B:	Key Map and Photographs				
Appendix C:	Limited Site Investigation – Sediment Sampling of Stewart Creek				
	Dated March 27, 2013				



#### **INTERIM REPORT**

Visual Survey of Stewart Creek F.M. 423 to BNSF Railroad Bridge Frisco, Texas SWG Project No. 0111C278A May 14, 2013

#### 1.0 INTRODUCTION

#### 1.1 Site Description and Background

SWG has conducted a walking survey to identify and document the potential presence of visible battery chips and slag in Stewart Creek from Lake Lewisville east of F.M 423 to the western edge of the Burlington Northern Santa Fe (BNSF) railroad bridge in Frisco, Texas.

Based on property access limitations, SWG's walking survey excluded a portion of Stewart Creek located west of Legacy Drive and north of a high voltage utility easement located approximately 3,300 feet south of Stonebrook Parkway.

According the U.S. Army Corps of Engineers (USACE) website for Lewisville Lake (http://www.swf-wc.usace.army.mil/lewisville/Realestate/Feeland/index.asp), "{a}s a general rule, land around Lewisville Lake at an elevation of or below 535 feet is owned in fee by the U.S. Government." SWG's field activities included a visual survey of a segment of Stewart Creek in land potentially owned by the U.S. Federal Government generally terminating approximately 1.4 miles east of F.M 423.

Figure 1 presents the general boundaries and topography of the assessment area on the USGS topographic quadrangle maps of Frisco, Lewisville East and Hebron, Texas (Appendix A). For reference, the general location of the 535 feet above mean sea level contour line is depicted on Figure 1.

Several regulated facilities are located upstream and along the portion of Stewart Creek currently under evaluation. The following sections provide a brief overview of relevant regulatory history and potential sources of impact to Stewart Creek.

#### FORMER EXIDE TECHNOLOGIES, INC. FACILITY

The Former Exide Technologies, Inc. facility (Exide) is located east and upstream of the limit of SWG's current assessment area. Two tributaries of Stewart Creek flow through the former Exide facility, and portions of both of the natural channels of the tributaries have been altered in the past. Regulatory file reviews previously conducted by SWG for the former Exide facility have indicated that several remediation efforts have been implemented in Stewart Creek within the boundaries of the former Exide facility. These efforts were conducted in response to the documented presence of industrial impacts in Stewart Creek including the presence of slag and battery chips and elevated lead and cadmium concentrations in samples collected within and near the creek. In 1986 two dredging events were conducted to remove lead and cadmium impacted sediments from the creek channel. In 1999, 2,800 feet of Stewart Creek from old 5<sup>th</sup> Street going westward was remediated. The established cleanup levels for Stewart Creek were 91 mg/Kg (lead) and 4.23 mg/Kg (cadmium). The Texas Natural Resource Conservation Commission (TNRCC), predecessor to the Texas Commission on Environmental Quality (TCEQ),



approved the proposed cleanup levels in a letter dated August 31, 1999. The 1999 efforts included removal of visible blast furnace slag wastes from the bed and banks of Stewart Creek. The soils were then mechanically removed to a depth of approximately one-foot from the channel and banks of Stewart Creek. Deeper excavations of two to three feet were required in areas of denser slag. The excavated soils were screened to recover broken slag before placing in stockpiles (approximately 200 cubic yards per stockpile). The recovered slag was recycled at the former Exide facility by processing the slag for lead recovery through the on-site blast furnace. The remediation activities were conducted within the creek channel in 300- to 500-foot segments. Following the removal of impacted materials, three discrete verification samples were collected from each 100-foot interval along the creek to confirm that the cleanup levels were met. Areas that did not meet the criteria were excavated deeper and re-sampled until the verification samples determined that cleanup levels were achieved. The channel was then backfilled with clean on-site and imported soils as necessary to re-establish the grade of the creek bottom. A total of 9,823 cubic yards of excavated materials were disposed of as Class 2 Non-Hazardous waste. Of these, approximately 1,062 cubic yards required treatment to meet Class 2 Non-Hazardous waste classification criteria. A total of approximately 634 cubic vards of the excavated materials met the re-use criteria. A total of 521.3 tons of slag was recovered for use in the blast furnace.

The former Exide facility is currently undergoing investigation and assessment activities.

#### FORMER STEWART CREEK WASTEWATER TREATMENT PLANT (VCP No. 2122)

The former Stewart Creek Wastewater Treatment Plant (FSCWWTP) facility is located immediately adjacent to the west of the BNSF railroad, which is west of the former Exide facility. The FSCWWTP property boundary crosses Stewart Creek to the north with a small portion of the creek bank on the north side being a part of the overall property. The FSCWWTP was an active wastewater treatment plant from 1979 until 1999 and received wastewater from the City of Frisco including the former Exide facility. In addition, waste treatment activities were also conducted on the FSCWWTP site by GNB (a historical business name that was a predecessor to Exide) in the past. SWG was contracted by the City of Frisco to conduct investigation activities on the FSCWWTP facility beginning in 2005. In 2008, the FSCWWTP facility was entered into the TCEQ Voluntary Cleanup Program (VCP 2122). Under an agreement between the City of Frisco and Exide Technologies, Inc., Exide continued the remaining investigation and remediation efforts at the FCSCWWTP facility under review by the TCEQ VCP. An Affected Property Assessment Report (APAR) (containing a Screening Level Ecological Risk Assessment (SLERA) report) and Response Action Completion Report (RACR) were submitted to the TCEQ on April 1, 2013.

Based on the findings of the APAR and SLERA, sediment samples collected from the portion of Stewart Creek nearest the FSCWWTP indicated lead and cadmium concentrations in exceedance of the TCEQ Second Effects Levels for Ecological Receptors. The SLERA recommended "additional evaluation to address potential localized effects in sediment hot spot areas."

#### MUSEUM OF THE AMERICAN RAILROAD FACILITY (SWR#T2966)

The City of Frisco Museum of the American Railroad (MARR) site consists of an approximate 12acre property that is located southwest of Cotton Gin Road and the BNSF railroad in Frisco, Texas. The site was historically an undeveloped parcel of land and is located northwest of the



former Exide plant. The southern boundary of the property abuts the FSCWWTP site, which is bisected by Stewart Creek further south of the site. Historical activities, including the potential construction of a full or partial road bed, apparently used "battery chips" for surface paving. Based on historical information pertaining to the discovery and remediation of battery chips from other areas within the City of Frisco, the suspected source of the battery chips is the former Exide (formerly GNB) battery recycling facility located southeast of the MARR facility. The battery chips likely resulted from the reclamation and recycling of lead acid batteries as part of the operations at the former Exide facility. The exact volume or timing of the placement or use of the battery chips is not documented, although battery chips are evident on the ground surface in several areas along the southern and eastern portions of the site, as well as in the southeastern portions of the site.

A Self Implementation Notice (SIN) was filed on September 28, 2011 to accommodate the expeditious assessment and removal of concentrated areas of battery chips along the former road, as well as associated soil impacts above applicable cleanup goals that may have occurred as a result of their placement on the site. An additional assessment of aerial photographs was conducted in which a historical road was observed trending along the southern and southeastern portion of the site, from Cotton Gin Road, and ultimately crossing over Stewart Creek. The presence of the potential historical road is significant as it is possible that the road was partially built up with battery chips, which were noted in the area of the potential historical road. A series of trenches were excavated to evaluate the potential presence of concentrated areas of battery chips along the former road observed in the historical aerials. While battery chips were observed in several trenches, some of which were observed at a specific depth (i.e., between 12 to 18 inches below grade surface), the results did not indicate the presence of concentrated battery chips along the entire road, and an area of focused assessment and corrective action efforts was established.

Based on the soil analytical results, only two chemicals of concern exceed their residential assessment levels (RALs) (arsenic and lead). Elevated levels of lead (up to 2,150 mg/Kg) were observed in the surface soils above the site-specific RAL of 250 mg/Kg in two locations. Arsenic was detected at levels slightly above the RAL of 24 mg/Kg in two areas; however, the representative concentration of arsenic within a one-eighth acre grid area was less than 24 mg/Kg based on additional sampling of grid locations and a statistical analysis.

Response actions were completed in 2011, resulting in a Remedy A, residential closure from the TCEQ. No further investigation or remediation was required by TCEQ in the MARR track area, or within Stewart Creek.

#### CITY OF FRISCO GRAND PARK AND GRAND LAKE PROJECT

In 2011, the City of Frisco contacted SWG regarding a planned development located west of the Dallas North Tollway and north of Stonebrook Parkway. Based on the above-referenced documented impacts and the potential presence of battery chips and slag in the proposed park area, the City of Frisco requested sediment sampling from the portion of Stewart Creek located within the proposed Grand Park Area. The conceptual development in 2011 included a series of lakes that were planned for construction by widening Stewart Creek in selected areas from the BNSF railroad bridge to Stonebrook Parkway. The following summarizes the results of SWG's investigation in 2011:



#### Limited Site Investigation – Sediment Sampling of Stewart Creek

SWG completed a Limited Site Investigation (LSI) for sediment sampling activities along Stewart Creek, at and along the proposed Grand Park project, from the eastern edge at the BNSF railroad bridge to Stonebrook Parkway in Frisco, Texas.

The objective of the LSI was to evaluate arsenic, cadmium, lead, selenium and sulfate concentrations along Stewart Creek in sediment samples collected from 30 sampling locations based on the layout of the proposed Grand Park project.

The findings and recommendations of the LSI were as follows:

- As part of the approved scope of work, eleven (11) sediment samples were collected between the BNSF railroad bridge and the Dallas North Tollway. Nineteen (19) sediment samples were collected between the Dallas North Tollway and Stonebrook Parkway.
- Sample locations were targeted in areas of soft sediment deposition/accumulation within the stream bed and documented using field GPS equipment. At each location, sediment samples were collected from the 0.0 to 0.5 foot depth interval; however, finer grained bed sediments were sampled preferentially over coarser grained bed sediments.
- The laboratory analytical results indicate that arsenic, cadmium, lead and sulfate concentrations were detected in each of the samples collected. Selenium concentrations were not detected above laboratory sample detection limits (SDLs).
- Based on the results of SWG's LSI, additional assessment is necessary to further evaluate the arsenic, cadmium and lead concentrations above the TCEQ ecological benchmarks and/or second effects levels for sediment and to further evaluate the presence of battery chips and potential slag observed during field activities.

SWG'S LSI is included with this report as Appendix C.

Figure 1 presents the general boundaries and topography of the assessment area on the USGS topographic quadrangle map of Frisco, Lewisville East and Hebron, Texas (Appendix A). A map depicting the sediment sampling points and analytical results previous sediment sampling activities is included as Figure 2 (Appendix A), and a map depicting the northern sediment sample points and analytical results during SWG's previous sediment sampling activities is included as Figure 3 (Appendix A).

#### 1.2 Scope of Work

SWG conducted a walking survey of Stewart Creek, from Lewisville Lake east of F.M. 423 to the western edge of the BNSF railroad bridge in Frisco, Texas. The proposed scope of work was based on the request of the City of Frisco to identify and document the presence of visible battery chips and slag in Stewart Creek. This scope of work was conducted in accordance with SWG's Proposal Number P0113C1098 dated March 26, 2013.

It should be noted that the information contained in this interim report is based on the results of



ongoing field activities to complete the scope of services outlined in SWG's proposal. Subsequent to the completion of the walking survey, SWG will conduct additional sediment sampling activities between F.M. 423 and Stonebrook Parkway to supplement the existing sediment sample results. Since SWG's field activities are ongoing, this interim report does not represent a final report for the scope of services outlined in SWG's proposal.

# 1.3 Standard of Care

SWG's services were performed in accordance with standards customarily provided by a firm rendering the same or similar services in the area during the same time period. SWG makes no warranties, express or implied, as to the services performed hereunder. Additionally, SWG does not warrant the work of third parties supplying information used in the report (e.g. laboratories, regulatory agencies or other third parties). This scope of services was performed in accordance with the scope of work agreed with the client, as detailed in our proposal.

# 1.4 Additional Scope Limitations

Findings, conclusions and recommendations resulting from these services are based upon information derived from the on-site activities and other services performed under this scope of work and it should be noted that this information is subject to change over time. Certain indicators of the presence of hazardous substances, petroleum products, or other constituents may have been latent, inaccessible, unobservable, or not present during these services, and SWG cannot represent that the site contains no hazardous substances, toxic materials, petroleum products, or other latent conditions beyond those identified during SWG's performance of the scope of work outlined in the proposal. Environmental conditions at other areas or portions of the Site may vary from those encountered at actual sample locations. SWG's findings and recommendations are based solely upon data available to SWG at the time of these services.

# 1.5 Reliance

This report has been prepared for the exclusive use of the City of Frisco, and any authorization for use or reliance by any other party (except a governmental entity having jurisdiction over the site) is prohibited without the express written authorization of the City of Frisco and SWG. Any unauthorized distribution or reuse is at the client's sole risk. Notwithstanding the foregoing, reliance by authorized parties will be subject to the terms, conditions and limitations stated in the proposal, interim report, and SWG's Agreement. The limitation of liability defined in the agreement is the aggregate limit of SWG's liability to the client and all relying parties unless otherwise agreed in writing.

# 2.0 FIELD ACTIVITIES

# 2.1 Walking Survey

SWG's walking survey was conducted from March 28, 2013 to April 19, 2013 by Mr. Tommy Kim and Mr. Jason Minter, P.G., SWG environmental professionals.

SWG's walking survey was initiated near Lewisville Lake east of F.M. 423 and progressed upstream, terminating at the BNSF railroad bridge east of Dallas North Tollway. The walking survey was conducted over several separate days due to weather events. In addition, due to



access restrictions, SWG's walking survey excluded a portion of Stewart Creek located west of Legacy Drive and north of a high voltage utility easement located approximately 3,300 feet south of Stonebrook Parkway.

The walking survey was limited to the creek channel, banks and potential erosional features along the bank where battery chips may have been placed historically as fill or road base material.

SWG's survey team utilized GPS equipment and digital cameras to document the potential presence of visible battery chips and slag in the channel sediments in and along the banks of Stewart Creek. The survey team walked through the creek and along the banks during relatively low (clear) water conditions to evaluate the presence of battery chips or potential slag within the creek and on banks. GPS coordinates were collected for individual pieces of battery chips or slag when encountered. If concentrated areas of battery chips or slag were encountered, the survey team recorded the locations in the GPS equipment. Select photographs of SWG's field observations along with a key map depicting the assessment area and the locations where the photographs were collected are provided as Appendix B.

# Stewart Creek from Lewisville Lake to Stonebrook Parkway

SWG began the walking survey east of F.M. 423 near Lewisville Lake. The creek appeared to have been channelized in the area and was relatively deep. SWG evaluated the banks of the creek for approximately 1,200 feet until the survey team could enter the creek.

The first occurrence of potential slag material was observed in sediment approximately 3,200 feet east of F.M. 423. The material was black, vesicular and approximately 1 inch in diameter. A photograph of the suspected slag material is provided in a photograph corresponding to point 2 on the key map in Appendix B. The next occurrence of potential slag material was not observed in the creek sediments until approximately 1.25 miles east of F.M. 423 and 1,550 feet south of Lebanon Road; however, it should also be noted that this portion of the creek exhibited thicker sediment deposition than the upstream areas. Photographs of the suspected slag material in this area are presented at locations 6, 7 and 8 on the key map. Additionally, a 55-gallon steel drum was observed in the creek channel north of the wastewater treatment plant. The drum was not in good condition, and did not have any identifying marks or features to indicate its origin. The drum appeared to be rusted out on the bottom and contained sediment. A photograph of the drum is provided as location 9 on the key map.

The first observed occurrence of a battery chip encountered in Stewart Creek was approximately 1,200 feet east of 4<sup>th</sup> Army Memorial Road, northeast of the North Central Texas Municipal Water District wastewater treatment plant. A potential slag fragment was also observed in the vicinity of the battery chip. SWG's walking survey progressed to the high voltage utility easement representing the southern portion of the excluded area. Battery chips or potential slag material were not encountered in the remaining portions of Stewart Creek from location of the battery chip and potential slag to the utility easement. SWG's survey team exited the creek channel south of the utility easement and walked through City of Frisco property to return to the wastewater treatment plant. Along the way, SWG's survey team observed battery chips at the surface in two separate areas. Photographs of the battery chips are presented at locations 11, 12 and 13 on the key map in Appendix B.

SWG's survey team resumed creek channel observations east of the excluded segment of



Stewart Creek at Legacy Drive. Single occurrences of battery chips were observed in four separate areas and potential slag was observed with the battery chips in two of areas between Legacy Drive and Stonebrook Parkway. Photographs of the battery chips and potential slag are presented at locations 14 through 18 on the key map in Appendix B.

#### Stewart Creek from Stonebrook Parkway to Dallas North Tollway (Grand Park)

Single occurrences of battery chips and potential slag along with concentrated areas of battery chips and potential slag were observed in Stewart Creek north of Stonebrook Parkway on the Grand Park area. For field documentation purposes, areas where three or more occurrences of battery chips or potential slag material were readily observed in a depositional area or bank were designated as concentrated areas.

Four occurrences single battery chips and eight occurrences of concentrated battery chips and/or potential slag material were observed in the creek channel from the Stonebrook Parkway bridge to 750 feet north of Stonebrook Parkway.

Ten occurrences of concentrated battery chips and/or slag and six occurrences of single battery chips were observed from approximately 1,000 feet north of Stonebrook Parkway to approximately 1,900 feet north of Stonebrook Parkway. Within this segment, two areas containing numerous battery chips were encountered in the bank walls of the creek. Photographs of the battery chips observed in the creek bank walls are presented at locations 28 through 34 on the key map in Appendix B.

Two occurrences of concentrated battery chips, seven occurrences of single battery chips and one occurrence of potential slag were observed in a segment beginning approximately 2,130 feet north of Stonebrook Parkway extending north and east approximately 1,250 linear feet. Within this segment, a broken concrete creek crossing was encountered. Battery chips and brick were observed in the base material beneath the concrete surface. Additionally, a battery chip was observed apparently embedded in the concrete at the base of the concrete surface. Photographs of the concrete creek crossing and battery chip observed within the concrete are presented as points 42 and 43 on the key map in Appendix B.

Four occurrences of concentrated battery chips and potential slag material were observed in the Stewart Creek channel in a segment beginning approximately 250 feet west of the Dallas North Tollway bridge and back east to the bridge. A representative photograph of the battery chips observed in this segment is presented as point 49 on the key map in Appendix B.

#### Stewart Creek from Dallas North Tollway to BNSF Railroad Bridge

Two areas of concentrated of battery chips, a battery chip and a piece of potential slag were observed in the creek channel beneath the Dallas North Tollway bridge to approximately 100 feet east of the bridge. Representative photographs of the potential slag and battery chips are presented as points 51 through 53 on the key map.

Concentrated areas of battery chips and potential slag were observed in the final segment surveyed from the Dallas North Tollway bridge approximately 750 feet east of the Dallas North Tollway bridge to the BNSF railroad bridge. Additionally, battery chips were observed along the northern banks of this segment. In the vicinity of the BNSF railroad bridge, numerous occurrences of battery chips (including one battery chip containing a post) and concentrations



of larger potential slag material were observed. Representative photographs of the battery chips and potential slag observed in this segment are presented as points 54 through 57 on the key map in Appendix B.

# 2.2 Sediment Sampling

Subsequent to the completion of the walking survey, SWG will conduct additional sediment sampling activities between F.M. 423 and Stonebrook Parkway to supplement the existing sediment sample results.

Sediment samples will be collected from Stewart Creek in general accordance with the Texas Commission on Environmental Quality (TCEQ) *Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods (RG-415)*, revised August 2012. Sample locations will be targeted in areas of soft sediment deposition/accumulation within the stream bed and in areas of concentrated battery chips/potential slag based on the results of SWG's visual survey.

The results of SWG's sediment sampling and visual survey activities and will be documented in a final report in accordance with SWG's proposal.

# 3.0 FINDINGS AND RECOMMENDATIONS

The objective of the proposed scope of services was to identify and document the presence of visible battery chips and slag in Stewart Creek from Lewisville Lake east of F.M. 423 to the BNSF railroad bridge. This scope of work was conducted in accordance with SWG's Proposal Number P0113C1098 dated March 26, 2013.

It should be noted that the information contained in this interim report is based on the results of SWG's ongoing field activities to complete the scope of services outlined in SWG's proposal. Subsequent to the completion of the walking survey, SWG will conduct additional sediment sampling activities between F.M. 423 and Stonebrook Parkway to supplement the existing sediment sample results. Since SWG's field activities are ongoing, this interim report does not represent a final report for the scope of services outlined in SWG's proposal.

The findings and recommendations of this investigation are as follows:

- Regulatory file reviews previously conducted by SWG for the former Exide facility have indicated that several remediation efforts have been implemented in Stewart Creek within the boundaries of the former Exide facility. These efforts were conducted in response to the documented presence of industrial impacts in Stewart Creek including the presence of slag and battery chips and elevated lead and cadmium concentrations in samples collected within and near the creek.
- Based on the findings of the APAR and SLERA prepared for the Former Stewart Creek Wastewater Treatment Plant, sediment samples collected from the portion of Stewart Creek nearest the FSCWWTP indicated lead and cadmium concentrations in exceedance of the TCEQ Second Effects Levels for Ecological Receptors. The SLERA recommended "additional evaluation to address potential localized effects in sediment hot spot areas."



- Historical activities at the MARR facility, including the potential construction of a full or partial road bed, apparently used "battery chips" for surface paving. Based on historical information pertaining to the discovery and remediation of battery chips from other areas within the City of Frisco, the suspected source of the battery chips is the former Exide (formerly GNB) battery recycling facility located southeast of the MARR facility.
- Battery chips and potential slag was observed in sediment in Stewart Creek. Frequent occurrences of concentrated battery chips and potential slag material were observed in the Stewart Creek channel in Grand Park from Stonebrook Parkway to the Dallas North Tollway bridge. In the vicinity of the BNSF railroad bridge, numerous occurrences of battery chips (including one battery chip containing a post) and concentrations of larger potential slag material were observed.
- Based on the results of SWG's visual survey, additional assessment is necessary to further evaluate the arsenic, cadmium and lead concentrations above the TCEQ ecological benchmarks and/or second effects levels for sediment and to further evaluate the presence of battery chips and potential slag observed during field activities.
- Following completion of SWG's investigation, and submittal of a final report to the City of Frisco, it is recommended that the City of Frisco, Exide, TCEQ, EPA, and USACE collaborate to determine how to best remediate the waste and contaminated environmental media.



APPENDIX A

Figures

2014 EXIDE APAR PAGE 2819 OF 3116



Stewart Creek Sediment Sampling Frisco, Collin County, Texas

Southwest

SWG Project No. 0111C278A

Figure 1 Topographic Map Frisco, Lewisville East and Hebron Texas Quadrangles Contour Interval = 10 Feet 1981







APPENDIX B

Key Map and Photographs

2014 EXIDE APAR PAGE 2823 OF 3116



Stewart Creek Sediment Sampling Frisco, Collin County, Texas

Southwest

SWG Project No. 0111C278A









4. View of the creek.

2. Potential slag.





5. View of creek and sediment.

6. Potential slag.

3. Representative view of creek channel and sediment.







7. Potential slag.

8. Potential slag.

9. Abandoned corroded drum containing sediment.



10. General view of depositional area in the creek.



11. Battery chips located under trees near a residential neighborhood. This area contained multiple battery chips.








16. View of a battery chip located in the creek.





18. Battery chip.

17. Potential slag.











19. Battery chip.

20. Battery chips.







22. Battery chip.

23. Battery chips.







28. Area of battery chips along the wall.



29. Close up view of battery chip in the creek bank wall.









31. Battery chip in the wall.

32. Battery chips on the creek bank wall.

33. Battery chip on a creek bank wall.







36. Battery chips.

35. Potential slag.







40. Battery chip.

41. Battery chip.



43. View of a battery chip embedded in the concrete surface of the bridge.

44. Battery chips in the creek.





46. Battery chip and potential slag under water in the creek.





47. Battery chip.

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49. Battery chips.

50. Typical view of the creek and depositional areas.







52. Battery chip.

53. Battery chip.





55. Potential slag.

56. Battery post.

57. Potential slag.





# APPENDIX H

Memorandum - Background Surface Soil Concentrations for Metals in Frisco, TX -ToxStrategies, Inc., Dated March 3, 2014



Innovative solutions Sound science

J. Andrew Tachovsky, P.E. Toxstrategies, Inc. 9390 Research Blvd #250 Austin, TX 78759

Kerry Russell Russell & Rodriguez, LLP 1633 Williams Drive Building 2, Suite 200 Georgetown, TX 78628

March 3, 2014

### Memorandum re: Background surface soil concentrations for metals in Frisco, TX

Attached is a description of the analyses performed by ToxStrategies to estimate background soils concentrations based on sampling conducted in Frisco, TX. Results are provided in the associated tables. If you have any questions about the analysis, please do not hesitate to contact me at (512) 791-7576, or by email at atachovsky@toxstrategies.com.

Sincerely,

J ardrew Tachavslay

J. Andrew Tachovsky, P.E. Numerical Analysis Practice Leader

# Background surface soil concentrations for metals in Frisco, TX

#### 1.0 Background

Soil sampling was conducted to characterize background concentrations for the eight Resource Conservation and Recovery Act (RCRA) metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) in surface and near-surface soil within the City of Frisco, TX. For the purposes of this study, background is defined as naturally occurring soil concentrations that are not impacted by human activities such as farming, construction, or industrial activities; in particular outside of the suspected range of potential effects of the former Exide Technologies, Inc. facility located at 7471 South 5<sup>th</sup> street, Frisco, TX.

To this end, Southwest Geosciences (SWG) collected soil samples from relatively undisturbed areas in City of Frisco (or City of Frisco affiliate) owned property to the northeast, north and northwest of the former Exide facility, at least 3.0 miles in distance from the former facility. The following 7 locations were targeted for the analysis:

- Property near the southwest corner of US Highway 380 and the Dallas North Tollway (owned by Frisco Economic Development)
- Northwest Community Park located on the northeast quadrant of Panther Creek Parkway and Teel Parkway
- Northeast Community Park located on the northeast quadrant of Honey Grove Drive and Tyler Drive
- Near the intersection of Eldorado Parkway and Independence Parkway
- Near the intersection of Rolater Drive and Independence Parkway
- Near the south end of Teel Boulevard north of Stewart Creek
- Proposed City Park north of Lebanon Road near B.F. Phillips Community Park

Ten discrete cores were collected at each undisturbed area, two depths from each core (0-1 ft and 1-2 ft) for a total of 20 samples per undisturbed area. As the focus of this analysis is background soil concentrations in surface soils, only samples from 0-1 foot depth were used. Based on the analytical results, ToxStrategies proposed to conduct the following three steps to determine background concentrations for each of the 8 RCRA metals:

- 1. Evaluate the samples from each undisturbed area for outliers relative to the site mean
- 2. Evaluate the data across the 7 undisturbed areas to determine if the data are suitable for aggregation
- 3. Calculation of statistics and intervals given the findings in Step 2

#### 2.0 Evaluation of results

Soil sampling analysis results were provided to ToxStrategies by SWG in July 2013. These data were processed and evaluated according to the steps indicated above.

#### 2.1 Evaluation of outliers

As mentioned above, sampling locations were selected, to the extent practical, in areas that were not impacted by farming, construction, and industry. However, perfect site history was not available for each sample location. It was possible that soil may have been impacted by human activities, replaced with soil from another location, or amended with soil or additives (e.g., fertilizers) to achieve certain characteristics. As such, an evaluation of outliers was conducted. Any samples that were identified as outliers were eliminated from background soil concentration calculations.

The Bonferroni-adjusted outlier test was conducted to establish whether any samples within each site are outliers relative to the site mean. Due to the skewed nature of the data, a lower alpha (0.001) was used as a criterion. Smoothed density plots and distributional metrics (e.g., skewness, kurtosis) were examined as additional evidence of outliers. The results of this evaluation indicated that there were no outliers for arsenic, chromium, mercury, selenium or silver. There was one outlier for barium (sample C-1, 251 mg/kg), three outliers for cadmium (samples E-5, 1.7 mg/kg, E-10, 1.3 mg/kg, and E-8, 1.1 mg/kg), and two outliers for lead (samples E-5, 30 mg/kg and E-10, 24.6 mg/kg). In all cases, outliers were samples with concentrations that were much higher than the expected range given the distribution of samples. Table 1 below shows the Bonferroni-adjusted p values for the outlier test and the associated sample in parenthesis; a p-value below 0.001 indicates the presence of an outlier.

Chemical	Bonferroni p value(s)
Arsenic	0.059
Barium	6.5 E-06 (C-1)
	1.6 E-13 (E-5)
Cadmium	1.1 E-07 (E-10)
	1.0 E-07 (E-8)
Chromium	0.075
Lond	7.1 E-07 (E-5)
Leau	4.2 E-06 (E-10)
Mercury	0.011
Selenium	NA*
Silver	NA*

 Table 1: Outlier test results

\* 50% below detection limits

2.2 Evaluation of homogeneity and normality/lognormality

Data were evaluated across the 7 undisturbed areas to determine if the data are suitable for aggregation. The log-rank test was used to evaluate the differences in Kaplan-Meier (KM) estimated cumulative density functions (CDFs) across the 7 undisturbed areas to determine if there are general differences in the CDFs from area to area. Standard variance homogeneity tests were conducted using the KM estimates of mean and variance at each site. The results of the tests indicate statistically different means and variances among the different undisturbed areas for arsenic, cadmium, chromium, mercury, selenium, and silver. For barium and lead the means were statistically different, while the variances were similar. The results of this test indicate that the sampled areas are generally heterogeneous in nature.

We conducted the Shapiro-Wilk test of normality on the samples for each chemical to assess whether the samples were normally distributed, and on the log transformed samples to assess whether the samples were lognormally distributed. Although the lognormal was a reasonably good fit for arsenic and mercury, in general neither the normal or the lognormal distributions characterized these data. The results are shown in Table 2 below, where higher p values (i.e., closer to 1) indicate better fit.

Chemical	Test of normality	Test of lognormality
Arsenic	0.35	0.64
Barium	0.0001	0.0005
Cadmium	0.002	0.00008
Chromium	0.0005	0.03
Lead	0.001	0.064
Mercury	0.02	0.794
Selenium	NA*	NA*
Silver	NA*	NA*

Table 2: Normal and lognormal fit test results

\* 50% below detection limits

Overall, the results indicate that the data do not generally fit classic distributions and are not homogenous. Accordingly, if they are to be aggregated, they should be aggregated using non-parametric methods without implicit distributional assumptions (normal or lognormal). Because the data are statistically heterogeneous, the appropriateness of aggregating them rests on a determination of whether the samples can be deemed to be reasonably representative of the background in this geographic area. If they are representative, then they can be aggregated to provide a composite assessment of the background even though they demonstrate heterogeneity and lack of fit to standard distributions.

### 2.3 Calculation of statistics and intervals

Standard formulas for computing prediction limits are widely known (e.g., Luko and Neubauer, 2011 which describes ASTM methodology) and are usually based on normal

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or lognormal distribution assumptions. Those formulas are not applicable in this context for two reasons. First, the concentrations of compounds across the background samples are highly skewed and are significantly non-normal according to the Shapiro-Wilk test (Shapiro & Wilk, 1965). Second, many compounds had significant numbers of samples below detection limits. These two factors necessitated the use of non-parametric Kaplan-Meier estimation as the basis for assessing the distribution of background samples.

We calculated prediction limits and associated tolerance limits via non-parametric Kaplan-Meier estimation, as implemented in the survival library within the R statistical software environment (R Core Team, 2013). For the purposes of this evaluation, the following definitions were used to be consistent with the EPA (Schumacher et al., EPA, 2007):

- Confidence Interval: the proportion of samples of a given size that may be expected to contain the true mean. That is, for a 95 % confidence interval, if many samples are collected and the confidence interval computed, in the long run about 95 % of these intervals would contain the true mean.
- Prediction Limit: The limit (based upon historical data) below which a newly and independently obtained site observation of the predicted variable (often labeled as a future observation) falls with a given probability (or confidence coefficient).
- Tolerance Limit: A confidence limit on a percentile of the population rather than a confidence limit on the mean. For example, a 95 percent one-sided TL for 95 percent coverage represents the value below which 95 percent of the population values are expected to fall with 95 percent confidence. In other words, a 95% UTL with coverage coefficient 95% represents a 95% upper confidence limit for the 95th percentile.

Table 3 shows the mean and median (50<sup>th</sup> percentile) estimates of central tendency, and the 75%, 95%, and 99% upper prediction limits. A single new sample of each compound obtained under similar circumstances would be expected to fall below the listed prediction limit values with the stated level of confidence. In this case, the UPL corresponds to the percentile points on the non-parametric distribution estimated via Kaplan-Meier rather than those same points on an assumed normal (or lognormal) distribution with a given mean (or log mean) and standard deviation (or log standard deviation) estimated from the data, but their meaning and use is exactly the same.

Statistic	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
Number of samples	70	70	70	70	70	70	70	70
Number of detects	70	70	64	70	70	70	30	28
Min	3.6	77	0.0	15.7	6.8	0.005	0.21	0.096
Max	11.4	251	1.7	56.4	30.0	0.033	3.50	1.500
Mean	6.7	124.5	0.3	27.9	11.5	0.0	0.9	0.2

Table 3:	Summary	statistics	and	interval	calculations
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95% UCL on the mean	7.1	131.7	0.4	29.7	12.4	0.0	1.1	0.3
Median	6.4	120	0.3	27.4	11.1	0.013	0.11	0.150
95% UTL on the								
median	6.8	129	0.3	28.7	11.9	0.015	0.97	0.270
75 <sup>th</sup> percentile (75%								
UPL)	7.6	137	0.3	30.8	12.8	0.016	1.90	0.360
95% UTL on 75 <sup>th</sup>								
percentile	8.6	161	0.4	32.7	13.7	0.019	2.10	0.440
95 <sup>th</sup> percentile (95%								
UPL)	9.5	179	0.5	48.5	17.0	0.021	3.00	0.870
95% UTL on 95 <sup>th</sup>	**	**	**	**	**	**	**	**
percentile								
99 <sup>th</sup> percentile (95%								
UPL)	11.4	251	1.7	56.4	30.0	0.033	3.50	1.500
95% UTL on 99 <sup>th</sup>	**	**	**	**	**	**	**	**
percentile								

\*\* Could not be estimated from the data

The 95% upper confidence limit on the mean is shown, as are the 95% tolerance limits on the percentile-based prediction limit values. These values reflect the uncertainty associated with the mean value itself and/or with the prediction limit values themselves. Note that mathematically a tolerance limit is identical to a confidence limit (this can be seen in the EPA's definition of tolerance limit), but the EPA makes a labeling distinction between the two and we have followed the EPA's nomenclature. There were insufficient data to allow the calculation of tolerance limits in association with the 95% and 99% prediction limit values.

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APPENDIX I

Reference Material

# Evaluation of Arsenic Contamination in Texas

Report Prepared for Texas Commission on Environmental Quality Austin, Texas

August 2005

Prepared by Bureau of Economic Geology Scott W. Tinker, Director John A. and Katherine G. Jackson School of Geosciences The University of Texas at Austin Austin, Texas 78713-8924 2014 EXIDE APAR PAGE 2843 OF 3116

FINAL REPORT – August 2005

# Evaluation of Arsenic Contamination in Texas

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## ACRONYMS

DO	Dissolved Oxygen
Fm., Fms.	Formation(s)
GLF	Geophysical Log Facility
MCL	Maximum Contaminant Limit
NLCD NURE NWIS	National Land Cover Data National Uranium Resource Evaluation National Water Information System
PWS	Public Water Supply
TDS TCEQ TOC TWDB	Total Dissolved Solids Texas Commision on Environmental Quality Total Organic Carbon Texas Water Development Board
	•

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## **EXECUTIVE SUMMARY**

Lowering the Federal standard for arsenic in drinking water from 50 ug/L to 10 ug/L, results in much more widespread arsenic contamination in groundwater in Texas. The objectives of this study were to (1) determine the distribution of arsenic in Texas groundwater; (2) assess the potential of past application of arsenical pesticides as a source of arsenic in groundwater in the southern High Plains and southwestern Gulf Coast; (3) evaluate the role of phosphate fertilizers in mobilizing arsenic; and (4) assess geologic sources of arsenic in Texas. The study focused on geographic areas of domestic drinking water wells affected by high arsenic levels.

The Bureau of Economic Geology (BEG) conducted a number of tasks to accomplish the above objectives. (1) Groundwater arsenic concentrations in surrounding states were reviewed and research related to elevated arsenic studies in the US was evaluated. (2) Potential anthropogenic sources of arsenic, such as arsenical pesticides in the southern High Plains and the southwestern Gulf Coast, were examined using GIS overlay analyses and soil sampling. (3) Potential geologic sources of elevated arsenic concentrations in groundwater were evaluated in the southern High Plains and southwestern Gulf Coast using relationships between arsenic concentrations and different geologic units. Relationships between arsenic concentrations and other ions, particularly oxyanions, were evaluated using existing databases (TWDB, NURE, and TCEQ) to assess sources of arsenic. The impact of different redox conditions on the distribution of arsenic was examined. Limited additional groundwater sampling was conducted in Duval County in the Gulf Coast.

Arsenic contamination is widespread in surrounding states, particularly New Mexico where 16% of wells exceed the MCL (10 ug/L). Arsenic contamination is focused in the Middle Rio Grande Basin and is attributed to desorption of arsenic from iron oxyhydroxides. Only 5% of wells in Oklahoma had arsenic levels exceeding the MCL. Contamination is found primarily in central Okalhoma in Permian formations where arsenic is found in iron oxide coatings and is desorbed under high pH. Arsenic contamination in Arkansas represented 8% of the wells and is found in alluvial aquifers in eastern Arkansas. Arsenic is associated with iron oxide coatings and is released by reductive dissolution of iron oxides. Arsenic contamination in Louisiana is limited.

Groundwater arsenic contamination is widespread in Texas. Approximately 6% of wells exceed the MCL of 10 ug/L. Contamination is focused in the southern High Plains (32% of wells exceed than the MCL) and the southwestern Gulf Coast (29% of wells exceed than the MCL).

#### **Southern High Plains**

The southern High Plains (SHP) was subdivided into two areas: a northern area (SHP-N) characterized by low total dissolved solids (TDS < 500 mg/L) and a southern area (SHP-S) characterized by high TDS (> 500 mg/L). Arsenic contamination is much greater in the SHP-S region (51% of wells > 10 ug/L) than in the SHP-N region (7% of wells > 10 ug/L). Regional analyses of groundwater arsenic concentrations do not support a surfical source of arsenic contamination. Arsenic concentrations are not correlated with land use, i.e. percent cultivated land within a 500 m buffer of each well. Correlations between arsenic concentrations and normalized county areas planted with cotton are low ( $r^2$ =0.09, SHP-S). Arsenic concentrations do not vary systematically with distance from cotton gins. Arsenic concentrations were not correlated with nitrate concentrations. Although arsenic concentrations decrease with increasing clay content throughout the southern High Plains, there is no systematic variation with clay content within the SHP-N and SHP-S regions. The lack of correlation between arsenic concentrations do not correlate with aquifer saturated thickness.

Unsaturated zone studies were conducted to assess the potential for arsenical pesticides to provide a source of arsenic to groundwater. Results of drilling and sampling 18 boreholes in the

southern High Plains indicate that the distribution of arsenic is not related to the distribution of cotton production and application of arsenical pesticides. High arsenic concentrations in a rangeland profile (peak 77 ug/kg) indicate that background levels of water soluble arsenic are high in soils. Arsenic levels in cultivated areas are variable. Some profiles have highest arsenic levels near the surface which are correlated with nitrate and phosphate that may suggest a fertilizer or arsenical pesticide source. These data indicate that arsenic related to arsenical pesticides is probably restricted to the near surface zone. Other profiles have peak concentrations in the middle of the profile or at depth. Chloride profiles provide information on historical water flux conditions. High chloride concentrations at depth in many profiles in cultivated areas indicate low rates of water movement. It is unlikely that arsenical pesticides associated with cotton production would have reached the water table. The unsaturated zone data indicate a widespread source of water soluble arsenic in soils in the southern High Plains that may contribute to groundwater arsenic contamination.

Groundwater arsenic contamination occurs in generally oxidizing conditions in the High Plains and arsenic is expected to be in the form of arsenate. Groundwater arsenic concentrations were compared with concentrations of other ions to evaluate potential arsenic sources. Correlations between arsenic and other constituents (vanadium,  $r^2$  0.65; fluoride  $r^2$ 0.30; molybdenum  $r^2$  0.18; boron  $r^2$  0.17; selenium  $r^2$  0.14) suggest a geologic rather than an anthropogenic source. Arsenic concentrations are related to geologic units and are highest in the Ogallala aquifer and much lower in the Dockum aquifer. Arsenic concentrations in the Edwards Trinity (High Plains) aguifer are highest in the area where it is underlain by the Ogallala and much lower elsewhere. Potential sources of arsenic include volcanic ash beds in the Ogallala, black shales in the Cretaceous (Kiamichi Shale), and saline lakes. Analysis of existing geophysical logs indicates that high gamma zones, representative of volcanic ash beds, are restricted primarily to the southwestern area of the southern High Plains and are not collocated with most of the high groundwater arsenic concentrations. Arsenic concentrations are not related to distance from saline lakes, indicating this is not the only source of arsenic in the region. Additional studies will be required to assess geologic sources, including geophysical logging and stratified water sampling.

#### Southwestern Gulf Coast

Groundwater arsenic concentrations are much higher in the southwestern area of the Gulf Coast (29 percent of wells exceed the MCL) than elsewhere in the Gulf Coast (3.5 percent of wells exceed the MCL).

It is more difficult to evaluate surface sources of arsenic in the Gulf Coast than in the High Plains because aquifers in the Gulf Coast are confined except in the narrow outcrop areas. GIS analysis indicates that groundwater arsenic concentrations are not related to cotton production. Some counties with high levels of arsenic contamination do not have any cotton production (Live Oak and Duval Counties). Results of drilling and sampling 10 boreholes in the unsaturated zone indicate that arsenic concentrations are highest in a rangeland site where gin waste was ploughed into the field (1854 ug/kg at 1.3 m depth). Restriction of elevated arsenic related to gin waste to the upper  $\sim 2 \text{ m}$  soil zone suggests that this is an unlikely source of groundwater arsenic. High chloride concentrations below the arsenic peak indicate that there is little water movement below this zone. High arsenic concentrations in the shallow subsurface and correlation with nitrate suggests fertilizer or arsenical pesticide sources for another profile. High arsenic concentrations were found throughout an irrigated profile. The remaining profiles had low arsenic levels (< 10 ug/kg) that showed no systematic variation with land use or with depth.

Redox conditions range from mildly oxidizing to reducing in the Gulf Coast. Although arsenic concentrations are not related to dissolved oxygen, high arsenic concentrations do not occur at low redox potentials  $\sim$  -100 mV). However, conditions are not reducing enough to immobilize arsenic in sulfides. High arsenic concentrations occur along the Rio Grande valley, in

the few counties west and southwest of Corpus Christi, and along the Catahoula Formation outcrop extending into the north eastern Gulf Coast. Correlations between arsenic and other constituents (vanadium,  $r^2 0.43$ ; molybdenum  $r^2 0.36$ ; boron  $r^2 0.12$ ) suggest a geologic rather than an anthropogenic source. Arsenic concentrations are highest in the Jasper aquifer (48 percent > 10 ug/L) which immediately overlies the Catahoula Formation and are much less in younger stratigraphic aquifers (Evangeline aquifer; 21 percent > 10 ug/L and Chicot aquifer; 27 percent > 10 ug/L). Therefore, volcanic ashes associated with or reworked from the Catahoula Fm. are the most likely source of high arsenic concentrations in the southwestern Gulf Coast aquifer. Correlations between arsenic and other oxyanions typically associated with volcanism (molybdenum, vanadium) as well as the general decrease in arsenic contamination away from this formation strongly support this hypothesis.

This study represents an initial assessment of arsenic contamination in the southern High Plains and southwestern Gulf Coast and has resulted in a number of questions that may be addressed in future studies. The widespread distribution of water soluble arsenic in soils in both regions should be evaluated to determine if arsenic in rangeland and in deeper portions of cultivated profiles is related to volcanic ashes. Gamma logs should be conducted in boreholes to determine if there are high gamma levels that would indicate ashes. Water from leaching the soils should be analyzed for oxyanions and fluoride to assess relationships between soluble arsenic and these ions. Arsenic speciation should be conducted on selected samples to determine whether there are any organic arsenicals in the water. Playa water and saline lake water should be sampled to determine arsenic levels in these potential sources. Groundwater sampling should be conducted in different geologic units to assess potential correlations with arsenic contamination. Geophysical logging and multilevel sampling of groundwater should be conducted to determine if arsenic concentrations are stratified and if arsenic contamination can be linked to specific geologic units.

## INTRODUCTION

The reduction in the arsenic Maximum Contaminant Level from 50 to 10 ug/L has resulted in widespread groundwater contamination with arsenic in the state. The objectives of this study were to determine the distribution of arsenic in Texas groundwater; assess the potential of past application of arsenical pesticides as a source of arsenic in groundwater in the Southern High Plains and Southern Gulf Coast; evaluate the role of phosphate fertilizers in mobilizing arsenic in areas of arsenical pesticide application and high groundwater arsenic concentrations; evaluate geologic sources of arsenic in Texas, and, target geographic areas of domestic drinking water wells potentially affected by high arsenic levels. To accomplish the above objectives, the following tasks were conducted:

**Task A**: Review of elevated arsenic concentrations (> 10 ug/L) in surrounding states and evaluation of research related to elevated arsenic (concentrations > 10 ppb) in groundwater nationwide.

Task B: Develop a quality assurance project plan for water quality and soil sampling and analyses

**Task C**: Evaluate potential anthropogenic sources of arsenic, such as arsenical pesticides in the Southern High Plains and the Southern Gulf Coast using GIS overlay analyses and soil sampling. The ability of phosphate fertilizers to mobilize arsenic from arsenical pesticide applications will also be evaluated where information on phosphate fertilizer application can be obtained.

**Task D**: Assess potential geologic sources of elevated arsenic concentrations in groundwater in Texas using relationships between arsenic concentrations and different geologic units. Relationships between arsenic concentrations and other ions, particularly oxyanions and uranium, were evaluated using existing databases to determine geologic rather than anthropogenic sources of arsenic. The impact of different redox conditions on the distribution of arsenic was also examined. Limited additional groundwater sampling was conducted in the southwestern Gulf Coast.

## **GENERAL BACKGROUND**

On January 22, 2001 EPA adopted a new standard for arsenic in drinking water at 10 ug/L. replacing the old standard of 50 ug/L (Occupational Safety and Health Administration (OSHA) formally determined in 1978 that arsenic is a human carcinogen). The rule became effective on February 22, 2002. The date by which systems must comply with the new 10 ug/L standard is January 23, 2006. The health risks of inorganic arsenic in humans based on chronic exposure usually in drinking water include cancers and other effects. Studies have found the skin to be the area most susceptible to chronic arsenic exposure with skin lesions being common and the first indications of arsenic poisoning (Yoshida et al., 2004). Skin cancer effects from arsenic exposure include: hyperpigmentation, darkening of skin color usually occurring in patches, and keratosis, small raised warty lesions usually on the palms and soles (from a study in India by Mazumder et al., 1998), skin malignancies in Taiwan (Tseng et al., 1968 and Wu et al., 1989), and other skin lesions (in Chile by Borgono et al., 1977, Japan by Tsuda et al., 1995, Bangladesh by Tondel et al., 1999, and China by Guo et al., 2001). However, a study in the U.S. showed no relation between skin lesions and arsenic exposure for low (<0.40 mg/l) concentrations (Valentine et al., 1992). Lung cancer is also related to arsenic exposure as shown from studies in Taiwan (Chiou et al., 1995 and Wu et al., 1989), Japan (Tsuda et al., 1995), Argentina (Hopenhayn-Rich et al., 1998), and Chile (Smith et al., 1998). Bladder cancer is also related to arsenic exposure as shown by studies in Taiwan (Chiang et al., 1993, Guo et al., 1994, and Wu et al., 1989), Argentina (Hopenhayn-Rich et al., 1996), Finland (Kurttio et al., 1999) and Chile (Smith et al., 1998). However, studies with lower (0.5 - 160 ug/l; average of 5.0 ug/l) arsenic concentrations show no significant relationship with bladder cancer (US, Bates et al., 1995; Belgium (Buchet and Lison, 1998). In contrast, a study in Finland showed that bladder cancer can be caused by exposure to relatively low (1.0 ug/l) arsenic concentrations (Kurttio et al., 1999). Liver cancers in Japan (Tsuda et al., 1995) and Taiwan (Wu et al., 1989), kidney cancers in Argentina (Hopenhayn-Rich et al., 1998) and Taiwan (Wu et al., 1989) and urinary tract and uterine cancers in Japan (Tsuda et al., 1995), and prostate (in Taiwan Wu et al., 1989) have all shown relations to chronic arsenic exposure. Other effects of arsenic poisoning include: vascular disease including blackfoot (Chen et al., 1995; Lewis et al., 1999 in the U.S.; Chiou et al., 1997; Wu et al., 1989 in Taiwan), diabetes mellitus (Lai et al., 1994; Rahman et al., 1998 in Bangladesh) and hypertension, respiratory disease, and gastroenteritis (Rahman et al., 1999a, 1999b). Neurological effects have also been cited for effects of chronic arsenic exposure (Abernathy et al., 2003, Yoshida et al., 2004).

Arsenic is an element that occurs naturally in air, water, soil, and rocks, Arsenic minerals include realgar (AsS), orpiment (As<sub>2</sub>S<sub>3</sub>), arsenopyrite (FeAsS), and arsenian pyrite. The geochemistry of arsenic is dominated by the strong interaction of most arsenic compounds with soil particles, particularly iron oxides (and to a lesser degree aluminum and manganese oxides). The fully deprotonated arsenate AsO<sub>4</sub><sup>-3</sup> is the expected form of arsenic in most soils under aerobic conditions only at high pH (Figure 1). At more neutral and acid pH's, the HAsO<sub>4</sub><sup>-2</sup> and  $H_2AsO_4^-$  forms, respectively, are dominant. The general understanding of arsenic mobility in soil and aquifers is that it increases with increasing pH and phosphate concentration and with decreasing clay and iron oxide content. As pH increases, the negative charge of the arsenate ion increases making it less likely to sorb on negatively charged soil particles. Phosphates have a chemical structure similar to arsenates and sorb to soils more than arsenate in some conditions. Other structurally similar oxyanions, sulfate and selenate, are weak sorbers. Under less oxidizing conditions, arsenite H<sub>3</sub>AsO<sub>3</sub> is most stable. The lack of charge renders this ion less likely to sorb to soil particles and more mobile. Its pH stability spread ranges from very acid to alkaline. Under even more reducing conditions, arsenide is the stable ionic form of arsenic. Arsenic metal -As(0)- rarely occurs. Methylated arsenic compounds are generally present at low aqueous concentrations (<1 ug/L), if at all, except maybe when there is an abundance of organic matter (Welch et al., 2000). Methylated arsenic compounds are stable in both oxic and anoxic environments (Stollenwerk, 2003). As(V) and As(III) minerals are fairly soluble and do not control arsenic solubility in oxiding and mildly reducing conditions except maybe if barium is present (Henry et al., 1982a, p.21). In reducing conditions, As precipitates as arsenopyrite (FeAsS) but more commonly in solid solution with pyrite (arsenian pyrite).

Arsenic in groundwater can originate from anthropogenic or natural sources. Anthropogenic sources of arsenic include: industrial effluents (copper smelters), herbicides, insecticides, defoliants, animal feed amendment (promote growth), wood preservatives, and industrial wastes (glass production, paints, drugs, dyes, lead batteries, and metal alloys and semiconductors (Lederer and Fensterheim, 1983; Loebenstein, 1994). Agricultural usages were dominant until ~1980 when wood preservatives became the main avenue for arsenic consumption. Inorganic arsenic has been used in a wide variety of agricultural practices. Lead arsenate (PbHAsO<sub>4</sub>) was used as the main insecticide in fruit orchards prior to the use of DDT (DichloroDiphenylTrichloroethane) in the late 1940s (Shepard, 1951) and resulted in soil contamination (100 mg/kg As in soil) in Washington (Davenport and Peryea, 1991; Welch, 2000). Background arsenic in soil is < 10 mg/kg (Wauchope, 1983; Shacklette and Borengen, 1984). Adsorption generally restricts downward movement of arsenical pesticides; however, phosphate fertilizer has been found to mobilize arsenical pesticides to greater depths (Peryea, 1991; Peryea and Kammereck, 1997). Although elevated groundwater arsenic concentrations are associated with the use of arsenical pesticides in many areas (Hudak, 2000), studies indicate that groundwater contamination in some of these areas is related to natural geologic sources rather than anthropogenic sources (Carter et al., 1998). High arsenic concentrations in groundwater in the southern High Plains in Texas have been attributed to cotton gin waste (Aurelius, 1988). Arsenic is also used as a feed amendment for poultry and swine; however, little information is available on the fate of arsenic from this process (Welch, 2000). Elevated arsenic concentrations are also found in many contaminated sites. Arsenic is the contaminant of concern in ~ 30 percent of 1191 Superfund Sites (Welch, 2000). Disposal sites can result in locally very high concentrations of arsenic in groundwater (e.g. <2.5 g/L in Texas; Welch, 2000). Plants producing arsenical pesticides often have locally high arsenic concentrations. Studies associated with arsenic contamination from smelter emissions indicate that contamination is restricted to the soil zone (e.g. Tacoma Smelter Plume, Washington). In addition to providing a source of arsenic, anthropogenic activities may also release arsenic from natural sources. For example, organic carbon leaching from a landfill site in Maine resulted in release of arsenic from iron oxyhydroxides through reductive dissolution (Stollenwerk and Colman, 2003).

Natural sources of arsenic include (Welch et al., 2000): geothermal waters (T ≥50°C), iron oxides, sulfide minerals, and evapotranspirative concentration. The sources of arsenic in groundwater in the US have been summarized by Welch (2000). The dominant cause of widespread high groundwater arsenic concentrations (> 10 ug/L) in the US is release from iron oxides, particularly in Arizona (Robertson, 1989), South Dakota (Carter et al., 1998) and Minnesota (Kanivetsky, 2000). Sulfide sources predominate in New England, Michigan, Illinois, and Wisconsin (Ayotte et al., 2003; Schreiber et al., 2000, 2003). Geothermal sources are important in California and Wyoming (Ball et al., 1998; Wilkie and Hering, 1998). Evapotranspiration is listed as an important process in generating groundwater with high arsenic concentrations in arid regions of California and Nevada (Swartz et al., 1996; Welch and Lico, 1998). The natural arsenic content in soils varies with the composition of the parent material and could be as high as 20 to 30 mg/kg but averages 5 - 6 mg/kg (Yan-Chu, 1994). Arsenic concentrations vary among rock types (1.8 ppm, igneous, 1.0 ppm, sandstone; 9 ppm, shale; and 1.8 ppm, carbonate) (Hem, 1985; table 10). Most is sorbed to soil particles because of the strong attraction between positively charged arsenate and generally negatively charged soil particles.

Major sources of arsenic and processes releasing arsenic to groundwater were summarized by Smedley and Kinniburgh (2002) (Table 1). The processes include mixing of upwelling geothermal water with shallow groundwater, reductive desorption and dissolution of iron oxides in reducing environments and desorption from iron oxides in oxidizing environments, and pyrite oxidation. The most widespread process resulting in elevated groundwater arsenic concentrations is dissolution or desorption of arsenic from iron oxyhydroxides under reducing conditions. Extremely widespread high arsenic concentrations in Bangladesh are attributed to this process. Reducing conditions in this area are attributed to rapid burial of young sediments. Dissolution or desorption of iron oxyhydroxides is also the dominant process resulting in mobilizing arsenic in groundwater in the US (Welch et al., 2000). Desorption of arsenic under oxidizing conditions generally occurs under high pH. Dissolution of sulfide minerals is also an important process for releasing arsenic and occurs in New England, Michigan, Illinois, and the central valley in California (Welch, 2000). Various lines of evidence are used to distinguish different processes releasing arsenic to groundwater, including source location in geologic units, relationships among different ions, and pH and Eh conditions.
## Task A: Review

# Subtask A1: Review Elevated Arsenic Concentrations (>10 ppb) in Groundwater in Surrounding States

Many of the states surrounding Texas, including New Mexico, Oklahoma, Arkansas, and Louisiana, have a significant number of freshwater aquifer wells that produce water with arsenic concentrations that exceed the new EPA national standard of 10 ug/L. The following summarizes the status of arsenic contamination in surrounding states (Figure 4 and Figure 5), including the most likely sources of arsenic and processes affecting arsenic concentrations.

## A1-1 New Mexico

**Data Source**: United States Geological Survey (USGS) National Water Information System (NWIS) database; National Uranium Resource Evaluation (NURE) database; New Mexico Bureau of Geology and Mineral Resources

**Range of arsenic concentrations**: <0.1 to 1,100 ug/L (1,100 groundwater wells analyzed)

784 wells (70.6%) had arsenic concentrations <5 ug/L

326 wells (29.4%) had arsenic concentrations ≥5 ug/L

180 wells (16.2%) had arsenic concentrations >10 ug/L

### Aquifers:

Middle Rio Grande Basin:

Recent (post-Santa Fe Group) flood-plain, channel, and basin-fill deposition of Pleistocene – Holocene age.

Santa Fe Group: unconsolidated – moderately consolidated basin-fill sediments (Oligocene– middle Pleistocene age) (≤40 m thick)

#### Sources of arsenic:

Middle Rio Grande Basin

Silicic volcanic rocks in the Jemez Mountains that have had contact with geothermal water (north of Albuquerque)

Deep (thousands of feet) mineralized groundwater mixing with shallow groundwater. Upwelling occurs along faults. This source is supported by correlations between arsenic and chloride, SO<sub>4</sub>, Na, Ba, and <sup>14</sup>C age.

Socorro Basin: Thermal springs

### Geochemical Controls on Arsenic Mobilization (Middle Rio Grande Basin):

<u>Reductive dissolution of iron oxides</u> is an unlikely source of arsenic because the aquifer is predominantly oxidizing as shown by the presence of dissolved oxygen and nitrate. In Albuquerque As is present as As(V) in 90% of public water supply wells sampled.

<u>Dissolution of sulfide minerals</u> is not a likely source of arsenic because sulfides are not common in the Santa Fe Group aquifer (Stanton et al., 2001).

<u>Desorption of As from Iron Oxyhydroxides</u> under high pH may cause high As concentrations west of Albuquerque. Arsenic concentrations <20 ug/L have pH values <8.5, whereas As concentrations  $\geq$ 20 ug/L have pH values  $\geq$ 8.5.

**References**: Bexfield (2002), Bexfield et al. (2003), Brandvold (1999), Brandvold (2001), and Brandvold (2002).

## A1-2 Oklahoma

**Data Source:** United States Geological Survey (USGS) National Water Information System (NWIS) database; National Uranium Resource Evaluation (NURE) database; Association of Central Oklahoma Governments (ACOG)

Range of arsenic concentrations: <0.5 to 4,000 ug/L (5,299 groundwater wells analyzed)

4,715 wells (89.0%) had arsenic concentrations < 5 ug/L

584 wells (11.0%) had arsenic concentrations  $\geq$  5 ug/L

268 wells (5.1%) had arsenic concentrations > 10 ug/L

### Aquifers:

Central Oklahoma Aquifer:

Alluvium and terrace deposits (Quaternary age) along streams (0 – 30 m thick).

Garber Sandstone and Wellington Formation of Permian age fine-grained sandstone interbedded with siltstone and mudstone (355 – 490 m thick).

Chase, Council Grove, and Admire Groups Permian-age fine-grained sandstone, shale, and thin limestone (170 – 290 m thick).

The Permian units dip to the west and become confined by the Hennessey Group in the west.

#### Sources of arsenic:

Central Oklahoma Aquifer

Red iron oxide grain coatings (high As, Cr, Se, and U)

Yellow-brown goethite-cemented sandstone (high As)

#### Geochemical Controls on Arsenic Mobilization (Central Oklahoma Aquifer):

Oxidizing redox conditions required to mobilize As and other elements (> 1 mg/L DO). Arsenic, Cr, and Se desorb from iron oxide coatings of mineral grains at higher pH; dissolved concentrations increase with increased pH.

**References:** Christenson and Havens (1998), Christenson et al. (1998), Mosier (1998), and Schlottmann et al. (1998).

## A1-3 Arkansas

**Data Source:** United States Geological Survey (USGS) National Water Information System (NWIS) database; Arkansas Department of Environmental Quality

**Range of arsenic concentrations**: <0.5 to 80 ug/L (515 groundwater wells analyzed)

440 wells (85.4%) had arsenic concentrations < 5 ug/L

75 wells (14.6%) had arsenic concentrations  $\geq$  5 ug/L

42 wells (8.2%) had arsenic concentrations > 10 ug/L

### Aquifers:

Alluvial Aquifer of Eastern Arkansas (Bayou Bartholomew Watershed)

Upland terrace deposits and flat-lying delta deposits.

Arsenic concentrations exceeded MCL in 21 of 118 wells sampled. All high arsenic concentrations were in the delta portion of the watershed.

#### Sources of arsenic:

Iron oxides coatings in the delta deposits

**Geochemical Controls on Arsenic Mobilization:** 

<u>Reductive dissolution of iron oxides</u> is the most likely release mechanism for arsenic. Low arsenic concentrations in water with TDS  $\leq$ 175 mg/L; elevated As, Fe, Mn, total phosphorus, and low NO<sub>3</sub> in water with TDS  $\geq$ 175 and  $\leq$  350 mg/L.

High TOC indicates that carbon as organic carbon is available and is reduced along the flow path (TDS  $\geq$ 175 mg/L). Development of reducing conditions results in release of As from iron or manganese oxyhydroxides (FeOOH, MnOOH), along with Fe and Mn. At higher TDS ( $\geq$  350 mg/L), As concentrations decrease and the decrease is attributed to mixing with low-As water or precipitation with As containing Fe sulfides.

**References:** Kresse and Fazio (2003)

## A1-4 Louisiana

**Data Source:** United States Geological Survey (USGS) National Water Information System (NWIS) database

**Range of arsenic concentrations**: <0.5 to 200 ug/L (428 groundwater wells analyzed)

410 wells (95.8%) had arsenic concentrations < 5 ug/L

18 wells (4.2%) had arsenic concentrations  $\geq$  5 ug/L

11 wells (2.6%) had arsenic concentrations > 10 ug/L

Information on sources and distribution of elevated arsenic in groundwater in Louisiana is limited. A local source from cattle dips is cited in Cow Island.

## Subtask A2: Evaluate Research Related to Elevated Arsenic in Groundwater Conducted by EPA, the U.S. Geological Survey, and Other Agencies that is Relevant to Texas

Groundwater arsenic contamination is widely distributed throughout the United States, particularly in the western United States. The new EPA Maximum Contaminant Level of 10 ug/L has resulted in many public water supply systems not being in compliance with the regulations. A survey of ~ 30,000 arsenic analyses in groundwater indicated that about 10% exceeded 10 ug/L (Welch et al., 2000). Known sources of arsenic in the United States include iron oxide coatings, sulfide minerals, geothermal waters, and evaporite deposits. Processes releasing arsenic include dissolution or desorption of iron oxides under reducing conditions or desorption under high pH under oxidizing conditions. Pyrite oxidation can also release arsenic into groundwater. Understanding the sources and release mechanisms for arsenic in groundwater will provide valuable information to water managers to modify existing water supplies or develop alternative water supplies that comply with the new EPA arsenic regulations.

## A2-1 Distribution of Elevated Arsenic in the United States

Elevated arsenic concentrations in groundwater are widely distributed within the United States, particularly in the western United States, the Great Lakes region, and New England (Ryker, 2001; 2003). Various approaches have been used to show the arsenic distribution in groundwater, including point data and percentiles, to evaluate the degree to which various populations would be impacted by the new EPA regulations. The 75th percentile of arsenic concentration per county (calculated for counties having at least five wells) is shown in Figure 2 and indicates widespread arsenic contamination throughout the western United States, Great Lakes region, and New England.

## A2-2 Research Related to Groundwater Arsenic Contamination

Intensive research is being conducted related to arsenic contamination in groundwater in the US and globally. Most research is related to source attribution, mobilization processes, treatment options and other topics. Within the US, widespread research is conducted by government agencies such as the USGS and EPA and many other groups. The USGS has formed an arsenic studies group (http://wwwbrr.cr.usgs.gov/Arsenic/ ). Reviews of the status of arsenic contamination have been conducted by USGS researchers (Welch et al., 2000; Welch and Stollenwerk, 2000). The USGS has conducted arsenic studies in many states throughout the US, including California (Fuji and Swain, 1995), Nevada (Welch and Lico, 1998); Dakota (Berkas and Komar, 1996), Oklahoma (Schlottmann et al., 1998), New Mexico (Bexfield et al., 2003), and New Jersey (Ayotte et al., 2003). The general approaches used by USGS researchers in evaluating arsenic contamination ranges form reconnaissance mapping, relating arsenic to geologic or anthropogenic sources, and evaluation of mobilization mechanisms. Borehole geophysical applications related to arsenic studies are described in Paillet and Williams (2001). Detailed core sampling, X-ray diffraction analyses, sequential leaching, and arsenic speciation studies were conducted on core from the Middle Rio Grande Basin to understand the source and mobilization mechanisms related to arsenic contamination at this site (Stanton et al., 2001; Stanton and Cole, 2002). Assessing vertical stratification of arsenic concentrations in groundwater is being evaluated using depth dependent sampling techniques in production wells (Izbicki et al., 1999). Groundwater velocity distributions have been determined using dye tracing techniques to determine flow contributions from different depths. Depth dependent sampling and dye tracing are used to isolate zones with high arsenic in California and Oklahoma (Izbicki and Christenson, pers. comm. 2004). Once elevated groundwater arsenic concentrations have been determined, they may be related to particular geologic sources through geophysics and evaluation of cores and cuttings. This approach to determining vertical stratification of arsenic concentrations is of particular interest to groundwater managers because it may allow them to isolate sources and reduce groundwater arsenic contamination without the need for costly treatment options.

Research at EPA covers a wide range of topics including drinking water standards, exposure research, risk assement, remediation, and treatment technologies. A total of \$20 million was pledged for research and development of more cost effective technologies and technical assistance and training to operators of small systems to reduce compliance costs (<u>http://www.epa.gov/ORD/NRMRL/arsenic/</u>). Research topics included cost evaluation of arsenic control technologies, studies to modify treatment methods to reduce residuals, and verification testing of package drinking water treatment technologies for small systems.

## Task A: Conclusions

The above analysis of elevated arsenic concentrations in states surrounding Texas provides an indication of the level of arsenic contamination, the dominant sources of arsenic, and the primary mechanisms releasing arsenic to groundwater. This information is useful for assessing sources and distribution of arsenic in groundwater in Texas.

The status of current understanding of sources and mobilization mechanisms of elevated arsenic in groundwater provides valuable background information for assessing elevated arsenic concentrations in Texas aquifers. The results of the analyses indicate that the dominant sources of arsenic in the US include iron oxide coatings, sulfide minerals, geothermal waters, and evaporite deposits. The dominant mechanisms releasing arsenic to groundwater in the U.S. include dissolution or desorption of iron oxides under reducing or oxidizing conditions. Pyrite oxidation can also release arsenic into groundwater. Understanding the sources and release mechanisms for arsenic in groundwater is essential for predicting the distribution of elevated arsenic in groundwater in Texas.

# Task B: Quality Assurance Project Plan (QAPP) for Water Quality and Soil Sampling and Analyses

A Quality Assurance Project Plan (QAPP) was approved on May 16, 2005 to govern the collection of samples in the field, and analysis of samples in the lab by the Lower Colorado River Authority (LCRA). In accordance with the QAPP, The Bureau of Economic Geology (BEG) conducted soil core collection in the field, core processing, and water extraction for total dissolved arsenic and anion analysis. Collection of soil cores began in the Southern High Plains on May 22, 2005 and continued through June 4, 2005. During this time, 18 soil cores were collected. Collection of soil cores began in the Southwestern Gulf Coast on June 15, 2005 and continued through June 22, 2005. During this time, 10 soil cores were collected. Soil cores were processed, and water extracts were prepared at the UT BEG Core Research Facility in Austin, TX from June 22, 2005 through July 19, 2005.

Soil samples and water extracts were sent to the LCRA for analysis. LCRA analyzed the water extract for total dissolved arsenic using EPA Method 200.8 (ICP-MS). Soil samples were digested by the LCRA and analyzed for total (acid leachable) arsenic using EPA Method 6020 rev. 0. Analytical reports were provided as MS Excel spreadsheets, and formal reports were provided as pdf files. All standard operating procedures (SOPs) used by LCRA were included in the QAPP.

The QAPP was then amended on June 15, 2005 to include The University of Texas at Austin, Environmental and Water Resources Engineering Program (UT-EWRE) in the Civil Engineering Department. The first samples analyzed by UT-EWRE were sent on June 27, 2005. UT EWRE analyzed water extracts prepared by UT BEG for anions by ion chromatograph (IC) according to EPA Method 300.0. Water extracts were analyzed for dissolved arsenic by graphite furnace atomic absorption spectroscopy (GFAA) according to EPA Method 300.0. A refined analysis was also conducted on selected water extracts for dissolved arsenic using hydride generating graphite furnace atomic absorption spectroscopy (HG-GFAA), to achieve lower detection limits. HG-GFAA was based on EPA Method 300.0 and the work of Korte and Fernando (1991). All SOPs used by UT were included in the QAPP as amended on June 15, 2005.

# Task C: Evaluation of Potential Anthropogenic Sources of Arsenic in the Southern High Plains and Southwestern Gulf Coast Regions

There are several potential anthropogenic sources of arsenic in the High Plains and Gulf Coast. These two areas were chosen for study because they show high arsenic aqueous concentrations relative to the rest of Texas (Figure 6). Both regions have almost a century-old tradition of cotton growing. The cotton industry used arsenical products as pesticides (first half of 20th century), harvest-aid desiccants (from late 50's to late 80's in High Plains), and currently organo-arsenicals (particularly in the Gulf Coast region). Related activities, such as waste piles near cotton gins or on fields, gin waste spread on fields, or gin waste used for winterizing wells, can also lead to contamination, as well as atmospheric deposition when gin wastes were burned. There is also anecdotal evidence that isolated arsenic contamination cases may include old cattle dipping pits, especially within the Chicot aquifer in Kenedy County (Vickers, pers. comm., 2005).

Other anthropogenic sources of arsenic are also possible. Phosphate fertilizers, in addition to possibly mobilizing arsenic, can also contain arsenic because of their similar chemistry (Campos, 2002). Arsenic concentration in synthetic and natural phosphate fertilizers can be as high as 13 mg/kg. Campos (2002) argued that arsenic traces in overused fertilizers were sufficient to increase aqueous arsenic concentrations to more than 100 ug/L in Brazil. Direct anthropogenic contamination by oil field brines is unlikely except locally. Contamination by uranium mining in south Texas will be addressed under Task D. This section devoted to Task C will exclusively deal with arsenic related to cotton industry.

# Subtask C1: Compilation of Arsenic Data from Existing Sources (TWDB, TCEQ, NURE, USGS) for Domestic and Public Water Supply Systems.

## C1-1 Description of Data Sources

Arsenic concentrations in groundwater were compiled from the following databases:

- 1) Texas Water Development Board (TWDB) database available at http://www.twdb.state.tx.us/DATA/waterwell/well\_info.asp
- 2) Texas Commission on Environmental Quality (TCEQ) Public Water System (PWS) database not publicly available (<u>http://www.tceq.state.tx.us/</u>)
- 3) National Uranium Resource Evaluation (NURE) database available for the State of Texas at <u>http://pubs.usgs.gov/of/1997/ofr-97-0492/state/nure\_tx.htm</u>
- 4) U.S. Geological Survey (USGS) National Water Information System (NWIS) database available at: <u>http://waterdata.usgs.gov/nwis/</u>
- 5) Miscellaneous small databases

The Texas Water Development Board conducts ambient groundwater monitoring. All the major and selected minor aquifers are sampled on a 5-yr rotating basis. Water quality data are available for 55,000 ground-water sites (wells, springs), resulting in a total of 104,000 analyses, each analysis being done for major anions and cations. The earliest water chemistry data available is from the late 19th century. Groundwater quality information includes state well number, date of sampling event, time, collection remarks, reliability of sampling method remarks, collecting agency, indication of whether the sample is balanced or unbalanced, lab-calculated pH, phenol and total alkalinity, hardness, specific conductance, sodium adsorption ratio (SAR), total dissolved solids, and major anions and cations (Ca, Mg, K, Na, Sr, SO<sub>4</sub><sup>-2</sup>, HCO<sub>3</sub><sup>-1</sup>, CO<sub>3</sub><sup>-2</sup>, Cl<sup>-1</sup>, F<sup>-1</sup>, NO<sub>3</sub><sup>-1</sup>, SiO<sub>2</sub>). In some instances, analyses are performed for infrequent constituents (metals), organics, nutrients, and radioactive constituents. Approximately 500,000 infrequent constituent analyses (each corresponding to one single constituent) have been

entered in the database. Additional well information is provided in the database, including well depth, main aquifer, and groundwater level. The TWDB database includes some but not all the water quality data in the USGS database. The database is provided as a Microsoft Access file and can be downloaded from the TWDB website.

The TCEQ PWS database includes water quality data for all public water systems in the state. Water sources of public water systems include surface water, groundwater, and/or mixed sources. Water chemistry data in the PWS database represent the water entry points, which may represent a blend of groundwater from different wells, or groundwater and surface water, or surface water. For this study, we are only interested in raw groundwater chemistry data; therefore, we selected water quality samples that can be associated with a single well and included raw and entry point data. The database obtained from TCEQ is a subset of the larger PWS database that includes only inorganic chemical constituents of concern, including arsenic. The list of constituents in this modified database: specific conductance, TDS, alkalinity, total hardness, pH, Al, An, Be, N, NH<sub>3</sub>, As, Ba, Ca, Cd, Cl, Cr, Cu, Fl, Fe, Pb, Mg, Mn, Hg, Ni, NO<sub>3</sub>, NO<sub>2</sub>, K, Se, Ag, Na, SO<sub>4</sub>, Th, Zn, gross alpha, U, Rd, radium 226 and radium 228, gross beta, tritium, gross alpha, and Sr90. Additional well information in the database includes well depth. screened interval, aquifer designation, and geology. Well depth is available for most of the wells, but screen depth and geologic descriptions are not available for all the wells in the database. TCEQ PWS has limited spatial coverage because it excludes rural areas. The database is provided as a Microsoft Access file.

The National Uranium Resource Evaluation (NURE) database hydrogeochemical and stream sediment reconnaissance includes data from stream sediments, soils, groundwater, and surface water over the entire United States. The reconnaissance survey began in 1975 and ended in 1980 under the responsibility of four DOE national laboratories: Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Oak Ridge Gaseous Diffusion Plant (ORGDP), and Savannah River Laboratory (SRL) (Smith, 2001; USGS, 2004). The purpose of the program was to explore for undiscovered uranium. This database provides chemical data for Ag, Al, As, Au, B, Ba, Be, Bi, Br, Ca, Cd, Ce, Cl-, Co, Cr, Cs, Cu, Cy, Eu, F, Fe, Ga, He, Hf, Hg, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Pt, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Th, Ti, U, V, W, Y, Yb, Zn, Zr, PO<sub>4</sub> (phosphate), NO<sub>3</sub> (nitrate), SO<sub>4</sub> (sulfate), methane, ethane, propane, and butane in samples of stream sediment, spring sediment, lake or pond sediment, soil, rock, well water, stream water, and spring water. In addition, the database provides location and descriptive information for each sample. The NURE database covers only the eastern half of the southern High Plains, and there were gaps in the southwestern Gulf Coast as well. The database is provided as text files that were consolidated and imported into Microsoft Access and Excel.

The USGS database includes water quality data for selected areas of Texas, mostly in the Houston area. It contains data on major ions and trace metals, as well as additional well information. The database is provided as downloadable text files. A report recently published on perchlorate in the High Plains by Texas Tech University (Jackson et al., 2004) contains approximately an additional 40 arsenic analyses from private wells.

Geophysical logs were also obtained from the Geophysical Log Facility (GLF) at the Bureau of Economic Geology (BEG). The GLF is a repository for geophysical data received from private donations, BEG research projects, and the Railroad Commission of Texas (RRC), which by law receives a copy of geophysical logs from every new, deepened, or plugged well drilled in Texas. These data are available for public viewing and copying, and include wireline electric logs, well records, and scout tickets from hundreds of thousands of wells located in Texas.

### C1-2 Database Analysis

In the High Plains study area, the main aquifers are the Ogallala aquifer and the underlying Edwards Trinity (High Plains) aquifer. These aquifers are sometimes difficult to differentiate and are often grouped as the High Plains aquifer where they are thought to be hydraulically connected. In addition, because individual wells can be screened in both aquifers, water quality samples may carry mixed signatures. We examined and analyzed data from the NURE and TWDB databases, as well as the TCEQ PWS, USGS, and Texas Tech databases. Typically, only the most recent analysis was used. Some wells were sampled multiple times within the past 15 years; one well has time series of five samples, and 23 wells have time series of four samples. The limited data available on temporal trends suggest that there is no systematic variation in arsenic concentrations over time (Figure 7a).

The lack of aguifer data for the NURE database is more of an issue for the southwestern Gulf Coast samples than the High Plains samples because the Gulf Coast comprises multiple aquifers. Aquifer subunits of the Gulf Coast aquifers are, from oldest to youngest, the Jasper, Evangeline, and Chicot aguifers. It is sometimes difficult to reconcile well depth and aguifer. The TWDB has a list of seven- to eight-character aguifer codes for most of the water-bearing units in Texas (Nordstrom and Quincy, 1999). These codes were defined using either rock- or hydrostratigraphic unit names. Of the wells sampled for arsenic by TWDB, each of the three aquifer subunits of the Gulf Coast aquifer (Jasper, Evangeline, and Chicot) contains as many as eight different aquifer codes. Geologic and hydrologic units that compose the Gulf Coast aquifer vary in name and character and are not consistently identified from one area to another. For example, two wells near La Gloria, Texas, in Starr County that were drilled one year apart, have the same total depth, and are separated horizontally by only 50 m. One of the wells has an aguifer designation 1220KVL (Oakville), which is in the Jasper aguifer, whereas the other well is labeled 121EVGL, which is in the Evangeline aguifer. Even with this degree of variability in aguifer code assignment to wells, there are clear trends between arsenic concentration in wells in the Gulf Coast and aquifer unit.

Data were analyzed without consideration for the specific aguifer within the Gulf Coast or by subdividing the database into three units corresponding to the three main Gulf Coast aquifers. In the latter case, wells designated as Gulf Coast Aguifer were excluded. All wells in Jackson County, for which there are TWDB infrequently analyzed constituents, have been given the undifferentiated Gulf Coast Aquifer designation are not included in plots discriminating among units. Wells identified as being completed in the Fleming Fm. were also excluded because this unit is lumped with the Oakville rock stratigraphic unit and included in either the Jasper or Evangeline aquifers in south Texas. In northeast Texas the Fleming Fm. is included in the Jasper aquifer, the Burkeville confining unit, or the Evangeline aquifer. Eight of the nine samples analyzed for arsenic in wells with the 122FLMG (Fleming) aquifer code were below detection limits, so excluding this unit does not affect the statistics to be presented later. The conventional hydrostratigraphic unit defined for the Catahoula Fm. is the Catahoula confining system (Baker, 1979). However, in the southwestern Gulf Coast there are numerous domestic and public water supply wells completed in a unit with the TWDB aguifer code designation 122CTHL. These wells were included in the Jasper aquifer subunit of the Gulf Coast aquifers. Also excluded from the well statistics by layers are wells completed in both the Chicot and Evangeline aquifers.

Analysis of Gulf Coast data focused on the most recent samples. Wells were sampled multiple times during the past 15 years. Only wells with most of the samples  $>10\mu$ g were retained. One well was sampled 13 times, 26 wells were sampled 5 times, and 100 wells were sampled at least 4 times. There is no systematic trend in the time series data (Figure 7b).

Detection limits are variable. The TWDB database, for arsenic data, listed detection limits include 0.5, 1, 1.5, 2, 4, 5, 10, or even 20 ug/L in a few instances. The NURE database has

more consistent detection limit at 1 or 0.5 ug/L. An analysis of variance revealed that both TWDB and NURE databases (data above detection limits) in the southwestern Gulf Coast belong to the same population at a 5% significance level. The lack of coverage of the NURE database in the southern High Plains precludes such an analysis.

## C1-3 Spatial Distribution of Arsenic

Groundwater arsenic concentrations in Texas are highest in the southern High Plains and southwestern Gulf Coast (Figure 6). The map of arsenic concentrations is mainly based on data from the TWDB database because this database includes water quality from many of the TCEQ PWS wells and from the USGS NWIS database. The NURE database consists of samples from an earlier time period (1976 to 1980) and was only used in this report for analytes where little or no information was available from other databases.

The most striking feature of arsenic distribution in the southern High Plains is the contrast in groundwater concentrations between the northern and southern sections of this aquifer. Arsenic concentrations are much higher in an area south and east of a line that extends from Lubbock, Texas, to Clovis, New Mexico. The limit between the northern and southern sections of the southern High Plains was operationally defined as the 500 mg/L TDS line. Approximately 50 percent of the 609 samples in the southern section sampled during the past five years exceed the EPA recommended maximum contaminant level (MCL) of 10 ug/L (~2 percent > 50 ug/L), whereas the percentage of samples exceeding the MCL in the northern section is 7% (Figure 9, Table 2). Only 20 percent of samples exceed the MCL throughout the High Plains in the Texas Panhandle. The area of high arsenic concentrations generally coincides with high total dissolved solids.

Similarly to the High Plains aquifer, the Gulf Coast aquifers offer a contrast in arsenic concentration between the southwestern and northeastern sections. Throughout much of the report, these two sections are compared. The contrast is more diffuse than that in the High Plains and broadly corresponds to the geologic feature called the San Marcos Arch (see geology section). The southwestern section of the Gulf Coast aquifer is operationally defined as limited by and including De Witt, Victoria, and Calhoun counties. Approximately 13 percent of the 1,120 samples in the Gulf Coast aquifer sampled during the past five years have arsenic concentrations > 10 ug/L (2.1 percent > 50 ug/L) (Figure 9, Table 3). Arsenic concentrations were greater in the southwestern Gulf Coast (29 percent > 10 ug/L; 6 percent > 50 ug/L) than in the northeastern Gulf Coast (3.5 percent > 10 ug/ and none > 50 ug/L).

# Subtask C2. Evaluation of Arsenical Pesticides for Cotton Production as a Potential Source of Groundwater Arsenic

In the High Plains, groundwater arsenic contamination has been attributed to arsenical product application on cotton (Hudak, 2000; Welch et al., 2000; Nativ, 1988, p.43; Nativ and Guttierez, 1988, p.14; Lee, 2005), particularly in areas of shallow groundwater. Hudak (2000) suggested that arsenic contamination is of anthropogenic origin in selected counties in the High Plains. He based his conclusion on the following:

- higher arsenic levels in areas of shallower water table depths,
- presence of other agricultural chemicals in groundwater (such as nitrate),
- downward cross-formational flow eliminating deep sources of arsenic,
- and low dissolved arsenic concentrations in potentially arsenic-rich horizons in deeper formations (e.g., Dockum Fm.).

Nativ (1988) and Nativ and Guttierez (1988) attributed the source to arsenical products on the basis of a general spatial relationship between high groundwater arsenic concentrations, shallow water table depths, and use of arsenical pesticides. Lee (2005) observed, using kriging techniques, that areas having the most arsenic lack higher concentrations in other oxyanions and concluded that in the High Plains the origin of the arsenic contamination must be anthropogenic. Welch et al. (2000) also noted the general spatial overlap between high groundwater arsenic concentrations in the United States and use of arsenical pesticides. In the Gulf Coast aquifer, arsenic contamination has generally been attributed to abundant volcanic ash fall or reworked volcanic material and possibly the presence of a uranium mining province.

## C2-1 Arsenic as an Industrial Product

Nearly all of the world's supply of arsenic has been and is recovered as a byproduct of copper, lead, and zinc production. Most of the arsenic currently consumed in the United States is imported. Since the mid-1920's arsenic consumption has mostly oscillated between 15,000 and 30,000 metric tons per year (Figure 10). The U.S. production, concentrated in the western states, essentially ended in 1985 because of the high cost required to reduce atmospheric emissions to meet environmental regulations (Loebenstein, 1994). OSHA formally determined in 1978 that arsenic is a human carcinogen. Smelters released arsenic both locally in tailings and other waste dumps and also in the atmosphere. Those releases are not believed to have impacted Texas, although the Asarco smelter operating in El Paso produced arsenic for sale from 1938 to 1949 (Loebenstein, 1994).

Over the last 100 years, arsenic compounds have had several major industrial uses (Table 4) as a component of animal feed (to promote growth), herbicides, pesticides, lead batteries, metal alloys, semiconductors, wood preservatives, and glass manufacturing (Loebenstein, 1994; Lederer and Fensterheim, 1983). Agricultural usages were dominant until ~1980, when wood preservatives became the main avenue for arsenic consumption (Figure 10). Table 5 shows a rough timeline of arsenic usage. Arsenic trioxide [As<sub>2</sub>O<sub>3</sub>], or white arsenic, is the most common base product for arsenic derivatives. It has a valence of 3, whereas most of its commercial derivatives have a valence of 5. Inorganic arsenical products, such as lead or calcium arsenate or sodium arsenite, were used as herbicides and insecticides in the first half of the 20th century and until they were banned by EPA in 1988 for such usage. Calcium arsenate was specifically used to fight a cotton pest, the boll weevil. Sodium arsenite was used in sheep and cattle dips. Another inorganic arsenical product, arsenic acid, was massively used as a desiccant in Texas from ~1965 to 1992, when it was banned by EPA. Beginning in 1977 and still in use today (<1,000 tons elemental As consumed in the U.S.), organo-arsenical compounds such as monosodium methyl arsonate (MSMA), disodium methyl arsonate (DSMA), and

cacodylic acid have been used as herbicides. MSMA represents the bulk of organo-arsenical compounds used in the cotton industry.

## C.2-2 Arsenic Use in the Cotton Industry

The historical centers of cotton production in Texas are the Blackland Prairie of central and east Texas, where cotton production exploded after the Civil War. A major shift in cotton production occurred at the beginning of the 20th century when irrigation techniques made cotton growth possible in north and west Texas and in south Texas. In the past three decades between 20 and 30 percent of the total land surface in the southern High Plains has been dedicated to cotton, of which ~50 percent is irrigated.

A cotton production cycle (Table 6) starts with preparation measures including spraying of herbicides at the end of the winter to control weed growth. It is followed by further pre-plant steps such as application of herbicides and pesticides, irrigation, if appropriate, and treatment with a fertilizer. In April/May, planting occurs, followed by a new application of herbicides to control weed species growing alongside cotton and by fertilizer treatment to support growth. Later in the season, insecticides are also applied. Both irrigation and precipitation events fall mainly in the May-to-September time range (Figure 11 and Figure 12). Harvest-aid products (boll-openers, defoliants, and desiccants) are applied in late summer/fall to facilitate harvesting. The operational details of the harvest depend on the cotton variety and climate. Cotton from taller varieties is machine-picked after being treated with a defoliant (e.g., thidiazuron, dimethipin), whereas shorter varieties, usually grown in dry plains of Texas and Oklahoma, are machine-stripped and treated with desiccants (previously, arsenic acid; currently, organic desiccants, e.g., paraquat). Machine stripping collects more plant material that is dropped to the ground after processing, whereas machine picking is more discriminatory and leaves plants erect (EPA, 2005). Harvesting is done from mid/late summer in the southwestern Gulf Coast to late fall in the northern Panhandle (EPA, 2005). Table 6 presents a basic picture of cotton agricultural practices. Many variations, depending on climate (temperature, precipitation), irrigation status, local practices, and cotton variety, exist. Application rates gathered from multiple references are summarized in Table 7.

#### Early Arsenic Use: Ca Arsenate - Insecticide

The cotton industry has been using arsenical compounds for more than a century. Before DDT and other more efficient organic insecticides were introduced in the late 1940's, the most widespread insecticides were metal arsenates. Calcium arsenate  $[Ca_3(AsO_4)_2]$  was used in the early fight against boll weevil, while lead arsenate [PbHAsO<sub>4</sub>] was used in orchards across the United States. Inorganic arsenic compounds were banned from insecticide and herbicide use by EPA in 1988. Aurelius (1988) reported anecdotal evidence of calcium arsenate insecticide use near Knott, Howard County, Texas, from the 1930's to the 1960's. The application rate was described as 10-15 lb/acre (equivalent to 420-630 mg/m<sup>2</sup> elemental As).

### The Main Arsenic Compound: Arsenic Acid - Desiccant

Arsenic acid  $[H_3AsO_4]$  became a popular defoliant in the 1960's after becoming commercially available in 1956 (Miller and Bailey, 1979) and until it was banned by EPA in 1992. Arsenic acid was produced and marketed at the Pennwalt Corporation facility (now Elf Atochem) in Bryan, Texas, and also marketed at Volunteer Purchasing Group (VPG) in Boham, Texas. Arsenic acid is commercially available as a powder but more commonly as a liquid. Commercial formulations contain 6.22 lb of elemental arsenic per gallon (Warrick et al, 1992). However, field application rates are measured in pints/acre. Typical dosage for cotton desiccation is 2-3 pints/acre (equivalent to 175-260 mg/m<sup>2</sup> elemental As) that could be delivered in variable water dilution (Warrick et al., 1992). Miller and Bailey (1979) recommended an approximate dosage of 3 pints of arsenic acid per acre, whereas Aurelius (1988) reported an application rate of 2.94-4.42 lb/acre of arsenic acid in an area around Knott, Howard County.

Arsenic acid was generally sprayed from a ground-based vehicle or from an airplane. In the process, the desiccant was deposited on the lint of the open bolls, as well as on the plant foliage and stems and on the ground. Past agricultural practices required most of the plant material to remain on the field or be reused as compost because burning of waste had been banned earlier. Arsenic acid spraying occurs toward the end of the heavy rain period (Figure 12) and certainly after irrigation.

#### Current Arsenic Uses: Organo-arsenicals - Herbicides

Arsenic-based herbicides, such as MSMA and DSMA, are still being applied, although at a smaller application rate than arsenic acid, often in conjunction with other herbicides to control weed growth in cotton fields. Jordan et al. (1997) and Bridges et al. (2002) cited dosages of 1.7 kg/ha (78 mg/m<sup>2</sup> elemental As) and 0.6-0.8 kg/ha (27-37 mg/m<sup>2</sup> elemental As), typically applied before planting or after emergence, early in the growing season. Baumann (1998) indicated that commercial formulations of MSMA consist of 4 or 6 lb of elemental arsenic per gallon, whereas DSMA is often marketed in a 3.6 lb/gal formulation. Baumann (1988) suggested an application rate of 1.33 qt/acre of MSMA at 6 lb/gal (equivalent to 100 mg/m<sup>2</sup> of elemental arsenic) and 4 qt/acre of DMSA at 3.6 lb/gal (equivalent to 165 mg/m<sup>2</sup> of elemental arsenic).

Texas cotton growers currently make little use of organo-arsenical herbicides (only a few percent of the total acreage is treated with organo-arsenical herbicides), but it can be locally important, such as in central/east and south Texas, where pressure from weeds is highest (Abernathy in Lederer and Fensterheim, 1983, p. 57). Organo-arsenical herbicides are used mainly in the southeastern United States. Gianessi and Marcelli (2000) reported that in 1992 and 1997, approximately 3% and 5% of the total cotton acreage was treated with 0.76 lb/a (39 mg/m<sup>2</sup> elemental As) and 1.14 lb/acre (59 mg/m<sup>2</sup> elemental As) of MSMA, respectively. DSMA was used on 1% of the acreage at a dosage of 2 lb/acre (91 mg/m2 elemental As) in 1992. No DSMA use was reported in 1997. The year 1997 is the most recent year for which comprehensive data are available. Data are reported on a state-wide basis. However, Thelin and Gianessi (2000) detailed a simple method to distribute state pesticide data to the county level by using U.S. Department of Agriculture crop statistics available at that level. This approach merely assumes that crop management practices are similar across a given state and that pesticide consumption is distributed proportionally to cotton production. A study by Coupe et al. (1998) in northwest Mississippi suggested that those cotton pesticides are not present in surface waters, despite the fact that MSMA is the most widely used pesticide.

## C2-3 Arsenic Concentrations in Soil in Agricultural Settings

After repeated applications, soil arsenic loading reaches a balance between additions and removal processes (leaching, volatilization, biomobilization). An order-of-magnitude mass balance helps in understanding the total arsenic loading of a cotton tract and suggests that most of the arsenic is trapped in the soil (very little is needed to contaminate water resources; 50 ug/L As in a saturated thickness of 30 m with 25% porosity translates into ~0.4 mg/m<sup>2</sup> elemental arsenic). Assuming no crop rotation and 25 years of arsenic acid treatment at 200 mg/m<sup>2</sup>, 1 square meter of the parcel would have received ~200 mg x 25 = 5,000 mg/m<sup>2</sup> of elemental arsenic. If the arsenic is generally evenly distributed to a depth of 3 m, as suggested by soil sampling in Aurelius (1988, Table 4), and assuming a dry soil density of 2, typical soil arsenic concentrations would be ~1 mg/kg. This value is consistent with previous observations (e.g., Aurelius, 1988, Table 4). Background arsenic concentrations in soil are in the 0.1 to 40 mg/kg range but typically about 5 mg/kg.

Arsenic loading of crops is variable (Table 7) and is a function of both the crop and the climate. A typical application rate in the High Plains would be 200 mg/m<sup>2</sup> elemental arsenic. Lead arsenate for orchards was applied at a much higher rate than arsenic acid on cotton fields. Welch et al. (2000) mentioned that annual loading in orchards could be as high as 490kg/ha of lead arsenate (11 g/m<sup>2</sup> As) and could lead to soil concentration as high as 100 mg/kg. Davenport and Peryea (1991) cited a loading rate of 80 kg/ha (8 g/m<sup>2</sup> As). Peryea and Creger (1994) stated that arsenic soil concentration in apple orchards in Washington State could be as high as ~360 mg/kg. However, contamination was limited to the topsoil (< 40 cm). Peryea and Davenport (1994) also referenced two other studies in the northeast with the same conclusion. Arsenic contamination was limited to the top soil. On the other hand, evidence of leaching was also presented. They stated that arsenic mobility is related to soil texture. Arsenic is more mobile in coarse sand because of a relative lack of substances that would retard arsenic such as iron oxides, clay particles, organic matter, or calcite.

## C2-4 Relationship between Cotton Distribution and Groundwater Arsenic Contamination Based on GIS Analysis

## C2-4.1 Southern High Plains

Groundwater well information was separated into two groups based on the spatial distribution of groundwater quality in the Southern High Plains. The concentration of total dissolved solids (TDS) displays a distinct transition from the northern region (SHP-N) where TDS is generally < 500 mg/L to the southern region (SHP-S) where TDS is generally > 500 mg/L. Median arsenic concentration for wells in the SHP-N region is 4.5 ug/L whereas it is 11.2 ug/L in the SHP-S region. GIS analysis was performed separately on the two regions.

#### General Land Use

Groundwater arsenic concentrations were evaluated relative to general land use categories in the vicinity of each well in the southern High Plains according to the National Land Cover Data (NLCD; satellite imagery from ~1992; Vogelmann *et al.* 2001). Cultivated land use categories (crops, pasture, fallow) account for 61% of the area while rangeland categories (shrubland, grassland) account for 38% (Figure 15). Urban areas were excluded because they constitute only 1% of the area. For each well, percentages of cultivated and rangeland categories within a 500 m radius were calculated for each region. The distributions of arsenic concentrations were determined for 25<sup>th</sup> percentile intervals of cultivated (Figure 16) and rangeland category percentages. An arsenic source associated with agricultural chemicals should indicate a trend toward higher arsenic concentrations with increasing percentage of rangeland land use. The results indicate no significant trends for any percentile for either category or region.

### Cotton-Producing Areas

Groundwater arsenic concentrations were evaluated relative to the distribution of cotton which should be related to arsenical pesticides. The fraction of county area planted with cotton in the Southern High Plains varies from negligible south of Amarillo to one-fourth to almost half of the county in the 9-county area centered on Lubbock county and in Gaines and Dawson counties (Figure 13). Values shown are based on median annual planted cotton acreage for the period 1970 to 1995 (from the National Agricultural Statistics Service, NASS, database), corresponding to the main period of arsenical product usage. There seems to be a spatial match between high arsenic concentrations and cotton production although other Panhandle counties with relatively high cotton production outside of the High Plains aquifer (Hall, Childress, and Cottle counties) do not have arsenic in groundwater (Figure 6). This is also true for the cotton-producing counties northwest of Abilene. Arsenic concentrations were plotted versus median

cotton production in each county (Figure 14). Spatial average arsenic values were estimated for each county using GIS and groundwater well data. Normalized areas planted with cotton were calculated using National Agricultural Statistics Service (NASS) median planted cotton acreages for the 1970 to 1995 period divided by aquifer outcrop area within each county. Three counties (Bailey, Lamb, and Lubbock) were omitted because they straddle the demarcation line between the SHP-N and SHP-S regions. Comparison of arsenic concentrations with higher resolution cotton production data would be more appropriate; however, this information is not available. The results indicate no significant correlation between cotton production and groundwater arsenic concentrations at the county scale

#### Cotton Gins

Cotton gins are distributed across the southern High Plains but are not as numerous in the high-arsenic region (Figure 17). Arsenic concentrations in wells within 1,000 m of cotton gin locations were compared with concentrations in wells at distances greater than 1,000 m for both regions (Figure 18). Within each region, F-tests were used to determine if the variances are significantly different between each population, and two sample student's t-tests were used to determine if population means are significantly different ( $\alpha$ =0.05) (Table 8). Log values were used because concentration distributions are skewed toward high values. Results for the SHP-S region indicate that no significant difference between arsenic concentration variance (p=0.002) or log<sub>10</sub> mean values (p=0.987) for wells closer than and farther than 1,000 m from cotton gins. Results for the SHP-N region are inconclusive because of the small number of wells located within 1,000 m of gins.

#### Soil Texture

If groundwater arsenic contamination is attributed to surficial sources, one might expect arsenic contamination in areas of coarser soil because infiltration and recharge should be higher. Soil texture distribution (Figure 19) was obtained primarily from Soil Survey Geographic (SSURGO) Database county soil survey data. SSURGO soil texture data are not available for Martin, Howard, or Dickens counties where data are available from State Soil Geographic (STATSGO) database (USDA, 1994). Soils are in general coarser in the SHP-S region. Soil clay content increases where the Blackwater Draw Fm. is present, primarily in the SHP-N region. Groundwater arsenic concentrations in each well were plotted against percent clay content within 500 m of each well. Results indicate that within each region there is no correlation between groundwater arsenic concentrations and soil clay content. There is only a slight correlation across regions, with lower clay contents and higher arsenic concentrations in the SHP-S region.

#### Depth to Water Table

Higher groundwater arsenic concentrations would be expected in areas of shallow water tables if land surface applications of arsenic are the dominant source of arsenic. Predevelopment depth to water in the SHP-S region is generally less than 30 m (100 ft) (Figure 21). There is no correlation between arsenic concentrations and depth to water within regions (Figure 22).

#### Saturated Thickness

Higher groundwater arsenic concentrations would be expected in areas of smaller saturated thickness if land surface applications of arsenic are the dominant source of arsenic because dilution would be less important. Predevelopment saturated thickness is in general much smaller in the SHP-S region than in the SHP-N region (Figure 23). Except in Gaines County, saturated thickness is less than ~30 m (100 ft) in most of the SHP-S region. There is no correlation between predevelopment saturated thickness and arsenic concentration in either the SHP-S or SHP-N regions (Figure 24).

#### Nitrate Concentrations

Arsenical pesticide applications may be related to fertilizer applications; therefore, correlations between groundwater arsenic and nitrate concentrations may reflect an arsenical pesticide source. Groundwater arsenic concentrations are not correlated with nitrate concentrations (Figure 26).

## C2-4.2 Southwestern Gulf Coast

Cotton production is generally much lower in the southwestern Gulf Coast. The lack of a relationship between cotton production and arsenic concentrations is obvious because some counties with no cotton production have high arsenic concentrations (Live Oak and Duval Counties) whereas some coastal cotton-producing counties have little arsenic contamination (Willacy and Kleberg Counties). Therefore, it is unlikely that cotton production can explain the distribution of arsenic contamination in the Gulf Coast. Similarly, no high phosphate concentrations accompany arsenic hot spots (may possibly be affected by the high detection limit for phosphate of 1 ppm) (Figure 54g). Groundwater arsenic concentrations are not correlated with nitrate concentrations (Figure 56k). An anthropogenic agricultural origin for arsenic contamination in the southwestern Gulf Coast is unlikely, except maybe locally.

# Subtasks C3/5: Relationship between Cotton Distribution and Groundwater Arsenic Contamination Based on Unsaturated Zone Sampling

This section describes the results of field studies to assess relationships between cotton distribution and elevated arsenic concentrations in groundwater (subtask C3), the impact of phosphate fertilizer on arsenic transport (subtask C4), and the effect of different soil types on arsenic transport (subtask C5). Arsenic from pesticide applications may follow one of two pathways to groundwater in the High Plains—either direct downward movement through soils in cotton areas or through surface-water movement to playas and downward beneath playas. Extensive research in the southern High Plains indicates that playas are the main source of recharge to the Ogallala aquifer (Wood and Sanford, 1985; Scanlon and Goldsmith, 1987).

Boreholes were drilled and soil samples were collected and analyzed for various parameters, including arsenic concentrations (Table 9), to evaluate relationships between land use (cotton distribution) and arsenic concentrations in the unsaturated zone. Field studies were conducted in the southern High Plains and southwestern Gulf Coast. These two areas are described separately. In both areas, information on land cover was obtained from the National Land Cover Data (NLCD; satellite imagery, 1992; Vogelmann *et al.* 2001). Irrigated areas were identified using the NLCD imagery classification results of Qi *et al.* (2002).

## C3/5-1 Site Descriptions

## C3/5-1.1 Southern High Plains

Locations of drilling sites were chosen relative to land use and distributed across the southern High Plains (Figure 30a). Information on land cover was obtained from the National Land Cover Data (NLCD; satellite imagery, 1992; Vogelmann *et al.* 2001). Irrigated areas were identified using the NLCD imagery classification results of Qi *et al.* (2002). Approximately 38% of land in the SHP is rangeland and 61% is cultivated and 23% of cultivated land is irrigated. Cotton production accounts for approximately 38% of all cultivated areas and for 23% of the entire Texas SHP area. From 1968 through 2004, cotton production in the Texas SHP accounted for an average of 17% of US production, ranging from 9% to 23%.

A total of 18 boreholes were drilled in the Southern High Plains: 2 in rangeland, 2 in irrigated, 1 in a playa, and 13 in dryland settings (Figure 30a). Boreholes are in Andrews, Terry, Lamb, Bailey, Gaines, Howard, Dawson, and Martin counties. Boreholes drilled in rangeland settings in Andrews County were used to provide baseline information on arsenic concentrations in soils relative to cultivated areas. A total of 15 borehholes were drilled in areas cultivated with cotton in Bailey, Dawson, Gaines, Howard, Lamb, Martin, and Terry Counties. Two of these boreholes were in irrigated sites in Terry County. One borehole was drilled in a playa surrounded by irrigated cotton fields in Terry County to test the conceptual model that downward arsenic movement occurs in response to focused recharge in playas from runoff from irrigated cotton fields.

Boreholes were also drilled in areas of different soil texture based on STATSGO and/or SSURGO data to evaluate the impact of soil texture on arsenic concentrations (Figure 19). The soil data from these databases only represents the upper 1.5 to 1.8 m of the profile but were used as a preliminary indicators of soil type. Soil clay content at the rangeland and cultivated sites averaged 25% and ranged from 18 to 33%, and was 48% at the playa site.

### C3/5-1.2 Southwestern Gulf Coast

Locations of drilling sites were chosen relative to landuse and distributed across the southwestern Gulf Coast. A total of 10 boreholes were drilled: 5 in rangeland, 1 in irrigated, and 3 in dryland locations. Boreholes are located in Kenedy, Duval, Hidalgo, Starr, and Nueces

counties. The smaller borehole total depth in the Gulf Coast can be attributed to generally higher clay content and drier soil conditions relative to the southern High Plains. Boreholes were also drilled in areas of different soil texture based on STATSGO and/or SSURGO data to evaluate the impact of soil texture on arsenic concentrations. Boreholes in coastal counties are located in predominantly clay rich sediments whereas those in inland counties are in sandier soils.

## C3/5-2 Methods

## C3/5-2.1 Methods (Southern High Plains)

A total of 18 boreholes were drilled with a 6620DT rig (Geoprobe, Salina, KS) without any drilling fluid in the southern High Plains (Figure 30a, Table 9). Continuous cores were obtained using a core tube (1.22 m long, 29 mm inside diameter) from the ground surface to depths ranging from 3.1 to 12.7 m (average 7.6 m). Boreholes were drilled until auger refusal. Core sample tubes were cut in various length sections and capped and sealed to prevent evaporative loss. Sample tubes were stored on ice in the field and in a refrigerator in the laboratory. Core samples were used for laboratory measurement of water content, matric potential, anions, and arsenic concentrations.

In addition to borehole drilling, noninvasive measurements of near-surface apparent electrical conductivity ( $EC_a$ ) were performed at 17 borehole locations using a downhole EM39 instrument (Geonics, Mississaugua, ON). The EM39 has a nominal measurement radius of 0.75 m and provides high resolution measurements of  $EC_a$ . The instrument signal response is a function of several soil parameters, including texture (clay content), water content, and salinity.

Soil samples were analyzed for pressure head (to determine direction of flow). The term pressure head is generally equivalent to the term matric potential, which refers to the potential energy associated with the soil matrix. Matric potentials  $\geq$  -8 m were measured in the laboratory with tensiometers (Model T5, UMH, Munich) whereas matric potentials  $\leq$  -8 m were measured in the laboratory with a dewpoint potentiameter (Model WP4-T, Decagon Devices Inc., Pullman, WA).

Chemical parameters included arsenic concentrations and anions (chloride, sulfate, nitrate + nitrite, bromide, and phosphate) in water leached from 288 unsaturated zone soil samples. The distribution of arsenic in the unsaturated zone provides information on potential transport of arsenic from surface arsenical pesticide applications to underlying aquifers and may also be related to natural arsenic in the soil zone that could provide a source for groundwater contamination. Chloride concentrations were used to estimate the rate of water movement through the unsaturated zone using the chloride mass balance approach (App. 1). Nitrate + nitrite concentrations in the unsaturated zone were used to evaluate transport of nitrogen fertilizers. Soils were air dried. Approximately 40 mL of double deionized water (>18.2 Mohm) was added to about 25 g of soil. The mixture was placed in a reciprocal shaker for 4 hr, centrifuged at 7000 rpm for 20 minutes, and the supernatant was filtered to 0.2 um. Approximately 10 mL was acidified with nitric acid (reagent grade) to pH < 2 for arsenic analysis using graphite furnace atomic absorption spectroscopy and 20 mL was used for anion analysis using ion chromatography at the University of Texas Environmental and Water Resources Engineering Analytical Services Center. Soil samples were oven dried at 105°C for 48 hr to determine gravimetric water content.

Arsenic concentrations are represented as ug/kg by multiplying the arsenic concentrations in the supernatant by the ratio of the volume of DI water to the weight of dried soil (extraction ratio). Arsenic concentrations can also be represented as ug/L of pore water by dividing the concentrations in the supernatant by the gravimetric water content (Figure 32). The latter representation may not be reliable because the leaching process may have removed more arsenic than would generally be present in soil pore water. Arsenic concentrations are discussed primarily in terms of ug/kg of soil. The concentrations from the leaching process indicate that there is soluble arsenic or water extractable arsenic in the soil and may overestimate actual arsenic concentrations in soil pore water.

### C3/5-2.2 Methods (Southwestern Gulf Coast)

A total of 10 boreholes was drilled in the southwestern Gulf Coast in areas of different land use (rangeland, cotton, other crops) under dryland (rainfed) and irrigated conditions (Figure 30b, Table 9). Borehole depths ranged from 0.9 to 7.3 m (average 4.3 m). In addition, downhole electromagnetic induction was used to evaluate stratification. Soil sample analyses for a total of 107 samples were similar to those described for the southern High Plains.

## C3/5-3 Results

## C3/5-3.1 Results (Southern High Plains)

Arsenic concentrations in soils are quite variable, with median arsenic concentrations in individual profiles ranging from 2.6 to 23 ug/kg (Figure 31, Table 9). There is no systematic variation in arsenic concentrations with land use (Figure 31, Table 9). Arsenic concentrations in rangeland were expected to be low and to represent background levels for arsenic in cultivated areas; however, arsenic concentrations in rangeland were high ( $\leq$  77 ug/kg at 6.4 m depth; Figure 31). The second borehole drilled in rangeland had low arsenic levels; however, it was only 3 m deep. Arsenic concentrations in areas of cotton production were quite variable with peak values in different boreholes ranging from 17 - 62 ug/kg. These concentrations are generally slightly lower than those in the rangeland setting (Figure 31). Arsenic concentrations in irrigated cotton settings were similar to those in dryland cotton settings. There is more variation in arsenic profiles within irrigated sites than between irrigated and dryland sites (Figure 31). There is no systematic variation in arsenic concentrations with depth in the cultivated profiles. Some profiles have peak concentrations at the surface (Figure 31 T4, D1, H2, M1, M2, M3, M4) whereas others have peak concentrations toward the center of the profile (T3, T1, L1, B1, B2, G2, H1). The playa profile has the highest peak arsenic concentration (204 ug/kg) at a depth of 2.8 m and arsenic concentrations decreased with depth to values of 0.6 - 7.1 ug/kg.

Total arsenic concentrations in soils were compared with water soluble or water extractable arsenic in selected soil samples that represented a range of soluble arsenic concentrations. Total arsenic concentrations ranged form 0.7 to 4.0 mg/kg (Table 9) which are similar to global average values of soil arsenic estimated by Shacklette and Boerngen (1984) and Hem (1985). The lack of a strong relationship between total and water soluble arsenic is consistent with what is generally reported in the literature and indicates that arsenic solubility is not the controlling process in arsenic mobility.

Arsenic concentrations were evaluated relative to concentrations of other anions to assess sources and transport mechanisms of arsenic. Arsenic is highly correlated with phosphate ( $r^2$ =0.73) in the T4 irrigated site. The restriction of arsenic to the upper ~ 1 m and correlation with arsenic suggests an arsenical pesticide source for arsenic at this site. High correlations between arsenate and nitrate in D1, M3, and M4 dryland cotton sites and highest arsenic concentrations near the surface suggest arsenical pesticide sources for arsenic in the near surface zone.

Many dryland cotton profiles have low chloride concentrations in the shallow subsurface and increasing chloride concentrations at depth (T1, L1, B1, B2, G1, G2). Low chloride concentrations are attributed to leaching of chloride related to higher downward water fluxes beneath cultivated areas. The increase in chloride at depth is attributed to the transition from rangeland to dryland agriculture. High chloride at depth is associated with high sulfates in some profiles, particurarly L1 and H2. Increases in sulfate are shallower than chloride increases in some profiles. Low correlations between arsenic and chloride in these profiles indicates that arsenic levels are independent of water fluxes in the system. Some profiles in dryland settings have low chloride concentrations throughout the profile (H1, D1, M1, M3) which may result from the profiles not being deep enough to show the transition from rangeland to cultivated agriculture.

#### Relationship between Arsenic Concentrations and Soil Type

Soil texture based on SSURGO and STATSGO was variable for boreholes drilled in the Southern High Plains. However, while clay content ranged from 18 to 48%, most (14 of 18 boreholes) were between 20 and 29%. There is no systematic variation in arsenic concentrations with clay content based on SSURGO/STATSGO data. Soil texture data are not available for individual boreholes; however, soil water content is often highly correlated with soil texture; therefore, water content was used as a proxy for soil texture. Correlations between arsenic concentrations and water content for individual profiles were generally low ( $r^2$ <0.2), with the exception of D1 ( $r^2$ =0.5). The low correlations suggest that arsenic concentrations may not be related to soil texture, assuming that soil water content is a reliable proxy for soil texture.

#### C3/5-3.2 Results (southwestern Gulf Coast)

Arsenic concentrations in soils are guite variable, with median concentrations for individual profiles ranging from 3.3 to 102 ug/kg (Figure 33 and Figure 34). Some of the profiles are too shallow to evaluate arsenic distribution in the profile (DU1, DU2, DU3, HI1). The highest arsenic concentration (1,854 ug/kg) was found in a pasture area where cotton gin waste had been ploughed into the soil (HI1). The high arsenic peak occurs at a depth of 1.3 m. High arsenic concentrations are restricted to the upper~ 2 m where chloride concentrations are low as shown by the negative correlation between arsenic and chloride (r=-0.78). This profile indicates that contamination related to gin waste application is restricted to the shallow soil profile. High chloride concentrations below the arsenic peak indicate that there is little water movement at depth; therefore, chloride is not leached. High arsenic concentrations in the ST3 profile are also restricted to the shallow subsurface and are highly correlated with nitrate which may indicate a fertilizer source for arsenic. Although the H12 profile is shallow (1 m), high arsenic concentrations near the surface correlate with high nitrate and phosphate and may suggest a fertilizer source. The profile with the second highest arsenic level is DU1. Arsenic concentrations are high throughout the profile. Median arsenic levels in all the remaining profiles are < 10 ug/kg and show no systematic variation with land use.

## C3/5-4 Modeling Analyses

### C3/5-4.1 Modeling of Arsenic Behavior in the Unsaturated Zone

#### The Modeling Tool

Modeling studies were performed with the USGS PHREEQC geochemical code (Parkhurst and Appelo, 1999). The code has pseudo-1D transport capabilities. Advection (and diffusion) can be modeled when the water moves from cell to cell in a piston flow fashion. Each cell contains 1 kg of water by default. Each cell can have its own reactive surface minerals and initial water composition. In an advection step ("shift" in PHREEQC terminology), water moves from a cell to the one downstream and equilibrates with the minerals and surfaces present in that cell. Comments on the thermodynamic database used in the modeling are given in Appendix I.

#### **Conceptual Model and Assumptions**

This section details a modeling exercise describing the competing behavior of phosphate and arsenic in a generic unsaturated zone considered typical of the southern High Plains. The model illustrates the behavior of arsenic and phosphate as they are transported downward by advection. It consists in loading the soil with arsenical products and with (or without) phosphates by following the historical pattern in monthly time steps for the duration of arsenical products use (~35 years). Rainfall and possibly irrigation water will leach sorbed arsenic and phosphate from the upper topsoil levels where they have deposited or have been incorporated to the uncontaminated subsoil. There, they can also sorb.

We made the following assumptions:

- 1) all anthropogenic arsenic is available to be leached
- 2) oxidizing conditions exist and As(V) only is present
- 3) all oxide-sorbing minerals (amorphous iron oxide, ferrihydrite, green rust, goethite, hematite, amorphous aluminum oxide, gibbsite, boehmite, diaspore) are lumped into one category and modeled as amorphous iron oxide (Fe(OH)<sub>3</sub>). Iron oxide weight fraction is estimated at 0.5 percent, and its specific surface area is assumed to be 300 m<sup>2</sup>/g (see Appendix I).
- 4) unsaturated zone average porosity is 40 percent; water saturation is 50 percent
- 5) local chemical equilibrium is reached (no kinetics)
- 6) diffusion is neglected; only advection is considered
- 7) organo-arsenicals have a minor role and can be neglected
- 8) water movement is only downward

The model contains 150 cells, each ~0.1 m long in the vertical direction. Initially all cells are at chemical equilibrium with the resident water and, as appropriate, typical phosphate loading (see below). Arsenic is then added to the first cell in an amount consistent with its historical use pattern, and the arsenic front slowly moves downward with the infiltrating water. After a period of ~35 years, no arsenic is added to the top cell, only phosphate, as appropriate. It is recognized that some, if not all, of that water will evapotranspirate back into the atmosphere. However, assuming only downward water movement is conservative relative to the location of the arsenic pulse.

#### Soil Information

High Plains soils are mostly derived from the Blackwater Draw eolian deposits (Holliday, 1989). Wood and Sanford (1995) suggested that a porosity of 40 percent and a bulk density of 1.60 g/cm<sup>3</sup> are reasonable values following hundreds of measurements in multiple studies by different authors. Measurements made for this study support the bulk density value of ~1.6 g/cm<sup>3</sup>. The same measurements also produced an average water content by weight of ~11 percent, that is, a volumetric water content of approximately 20 percent. Bryant (1977) measured an average total porosity of ~43 percent on a few sites across the High Plains. He indicated that ~36 percent is microporosity and ~7 percent is macroporosity.

Playa soils consist mainly of smectite clays. Soils in the shallow subsurface of a playa in Andrews County consisted of clay (>50%) (Lipan soil down to a depth of 2 m) transitioning to fine sand of the Blackwater Draw Fm (Allen et al., 1972). The clay minerals are mainly illite (>50% in coarse clay fraction), interstratified illite-montmorillonite and montmorillonite (>50% in fine clay fraction), roughly in equal proportions. Kaolinite is generally present in small quantities (<10%). The upland areas (Arvana soils) are shallower (~1m) with a lower clay content (down to ~20%) but otherwise little different in terms of composition (maybe slightly higher illite fraction). The cation exchange capacity (CEC) of playa and upland soils was estimated at ~15-35 and 10-15 meq/100g of soil, respectively (Allen et al., 1972, their Tables 11 and 12). The organic carbon content decreases from 1% to 0.05% across the soil profile of the playa floor, whereas it did not reach 0.5% in the upland areas. The upland areas had a deep calichified horizon which was absent in the playa soils. Films of manganese and iron oxides are often present in the C horizon. Another study of eight upland areas (Bryant, 1977, his Table 2) determined that clay

fraction varies between 15 and 35% with little silt-size material. CEC was in the range 5-20 meq/100g of soil, and pH was generally between 6.5 and 7.8, typically increasing with depth. Higher pH values were associated with free calcium carbonate. Organic carbon was generally below 0.5%. All sampled soils showed calcic enrichment in the B and/or C horizons.

Given the geochemistry of arsenic (see Appendix I), it is important to understand the nature, amount, location and surface properties of iron oxides and hydroxides in the unsaturated zone. The modeler must provide sorption site density and specific surface area exposed to water. The first parameter is extracted from the literature, whereas the second must be provided by study of grain mineralogy.

#### Water Composition

The input pore water composition is taken from a variety of sources. This study collected only anion data (chloride, sulfate, nitrate/nitrite, phosphates, and bromide). Bryant (1977) presented results for soluble cations (calcium, magnesium, potassium, and sodium), whereas Jackson et al. (2004) in a recent perchlorate study in the High Plains published both anion and cation data. Not all those analyses are fully consistent. Nevertheless, a representative analysis can be built. The average TDS should be in the 400-500 mg/L. Calcium and magnesium should be approximately equal at ~2 milliequivalent per liter (meq/L) each. Sodium would be present at a concentration of ~1 meq/L, whereas potassium would be much lower at 0.1-0.2 meq/L. Anions are dominated by bicarbonate. Bicarbonate is not analyzed but can be backcalculated through electrical balance. Chloride and sulfate should both be below 0.5 meq/L. This is also consistent with recharge water composition presented in Fryar et al. (2001). The biggest discrepancy among all the analyses is the amount of sulfate relative to chloride. Jackson et al. (2004) also reported high fluoride concentrations. To simplify the model and avoid dealing with issues such as rainwater dissolving soil elements, the infiltration is assumed to have the pore water composition from the start.

#### **Chemical Loadings**

Compilation of chemical loading for arsenic (Table 7) suggests a range of 175-260 mg As/m<sup>2</sup> for cotton-producing areas. A worst-case scenario of application of 260 mg/m<sup>2</sup>/year (3.45 mmol/yr/m<sup>2</sup>) is assumed starting in 1956 until 1992 (37 years). This amounts to an arsenic soil concentration over 0.305 m of 260x38/(1x1x0.305x1000)/0.6/2.65 ~ 20.4 mg/kg with a porosity of 40 percent (50 years of Ca arsenate at 500 mg/kg would be an additional 117 mg/kg over 0.305 m) consistent with current observations. Phosphate application is done in different formulations but assumed to be all orthophosphates. We assume also a rate of 20 lb P<sub>2</sub>O<sub>5</sub>/ac, that is, 0.454 kg/lb / (4047 m<sup>2</sup>/ac)=2243 mg/m<sup>2</sup> x (62 of P / 142 of P<sub>2</sub>O<sub>5</sub>) = 980 mg P/m<sup>2</sup> = 32 mmol P/m<sup>2</sup>. With a footprint of 0.059 m<sup>2</sup> (see below), the monthly loading becomes 0.0169 mmol As/liter/month and 0.157 mmol P/liter/month.

#### Infiltration Rates

As mentioned above, PHREEQC default option computes geochemical changes relative to the 1 kg (that is, we assume, occupies 1 liter) of water in a cell. The cell can be shaped according to the user's understanding of the system. The key question to be addressed in this section is how much soil surface area is in contact with 1 liter of water. If we use a vertical dimension of 0.305 m for a cell, given that the volume/volume water content of the soil is 20 percent, a square cell would have a dimension *a* so that  $a^2 = 0.3048/0.2/1000=0.00152 \text{ m}^2$ , that is, *a* = 4 cm. Rainfall in Lubbock is ~18" (14" in Midland). We assume that half of it infiltrates (most of it will go back up as ET). This translates into 8" x 2.54 cm/inch = 0.203m, /0.2 taking into account water content, that is, 1.016 m<sup>3</sup>/m<sup>2</sup>, that is, 0.085m<sup>3</sup>/m<sup>2</sup>/month. It follows that, on average, the wetting front will move by 0.085 m each month. We eventually choose this as the cell vertical dimension. Given that the volume/volume water content of the soil is 20 percent, a square cell would have a dimension *a* so that  $a^2$  (in m) = 0.001/0.085/0.2=0.059 m<sup>2</sup>, that is, a=24 cm.

## C3/5-4.2 Modeling Results

Even using conservative numbers for arsenic and phosphate loadings, as well as infiltration rates, iron oxides strongly retard both arsenic and phosphates. Despite total arsenic concentration in the 30-50 mg/kg, aqueous concentrations remain low (more than 99% of the arsenic is sorbed to iron oxides). Figure 35a (presence of phosphates) shows a rapid increase of aqueous arsenic in water to a maximum of ~1,200 ug/L. In contrast, Figure 36a (no phosphates) displays a much slower increase in arsenic aqueous concentration and a much lower maximum concentration at ~300 ug/L. In both cases, arsenic concentrations in water slowly decrease starting at the end of the application period (37 years). The tail is longer in the no-phosphate case because there is a larger reservoir of arsenic. A couple of meters away from that first cell, the impact of phosphate competition is more dramatic. Figure 36b and c (no phosphate) show that arsenic aqueous concentrations are extremely low, on the order of 1 ug/L, whereas Figure 35b and c (with phosphates) displays a lower concentration than in the first cell but still much higher than in the no-phosphate case.

Vertical profiles (Figure 37) include the same information as breakthrough curves. The cases with and without phosphates are plotted side by side. Arsenic aqueous concentration increases in the loading period (first 37 years), then the pulse moves downward very slowly in the phosphate case. In the no-phosphate case, the arsenic bulge does not move from the first cell (upper meter). In both cases, arsenic aqueous concentrations are below 10 ug/L at a depth of 15 m. Note that this modeling is generic in nature and that specific conclusions for a given site cannot be reached unless site-specific data are used.

## Task C: Conclusions on Anthropogenic Origin of Arsenic Contamination

### **Southern High Plains**

The southern High Plains was subdivided based on differences in TDS into a northern area (SHP-N: TDS < 500 mg/L) and a southern area (SHP-S: TDS > 500 mg/L). Arsenic contamination is much higher in the SHP-S region (51% of wells > 10 ug/L) than in the SHP-N region (7% of wells > 10 ug/L).

Regional analysis of groundwater does not support a surficial source of arsenic. The lack of correlation between groundwater arsenic concentrations and land use, distance from cotton gins, soil texture, water table depth, and aquifer saturated thickness suggests that anthropogenic surface sources are not dominant. Low correlation between groundwater arsenic and nitrate (r2 = 0.05) in the SHP-S region suggests that fertilizer is not a dominant source.

Results of drilling and sampling 18 boreholes in the southern High Plains indicate that the distribution of arsenic contamination is not related to cotton production or application of arsenical pesticides. High arsenic concentrations in rangeland profiles where arsenical pesticides have never been applied, indicate that there are other sources of soluble arsenic in the soils. Elevated arsenic concentrations in near surface soils related to nitrate and phosphate concentrations may reflect a fertilizer or arsenical pesticide source. Other profiles have peak arsenic concentrations at depth that cannot be explained by arsenical pesticides. The unsaturated studies indicate a widespread natural source of water soluble arsenic in the southern High Plains that may contribute to groundwater arsenic contamination.

#### Southwestern Gulf Coast

Groundwater arsenic concentrations are much higher in the southwestern area of the Gulf Coast (29 percent of wells exceed the MCL) than elsewhere in the Gulf Coast (3.5 percent of wells exceed the MCL).

It is more difficult to evaluate surface sources of arsenic in the Gulf Coast than in the High Plains because aquifers in the Gulf Coast are confined except in narrow outcrop areas. No indicator points toward an anthropogenic origin of the arsenic contamination in the southwestern Gulf Coast. GIS analysis indicates that groundwater arsenic concentrations are not related to cotton production. Some counties with the highest arsenic contamination do not have any cotton production (Live Oak and Duval Counties). Results of drilling and sampling 10 boreholes in the unsaturated zone indicate that arsenic concentrations are highest in a rangeland site where gin waste was ploughed into the field (≤1854 ug/kg at 1.2 m depth). Restriction of elevated arsenic related to gin waste to the upper ~ 2 m soil zone suggests that this is an unlikely source of groundwater arsenic. High chloride concentrations below the arsenic peak indicate that there is little water movement below this zone. High arsenic concentrations in the shallow subsurface and correlation with nitrate suggests fertilizer or arsenical pesticide sources for another profile. High arsenic concentrations were found throughout an irrigated profile. The remaining profiles had low arsenic levels (< 10 ug/kg) that showed no systematic variation with land use or with depth.

## Task D: Evaluate Geologic Sources of Arsenic Occurrence in Groundwater

This section describes deliverables for subtasks described in Task D. Elevated arsenic concentrations in groundwater may be related to natural geologic sources. Geologic sources are evaluated separately for the southern High Plains and southwestern Gulf Coast because the geology of each region is markedly different.

# Subtask D1. Compare Arsenic Concentrations in Groundwater with the Distribution of Different Hydrogeologic Units.

## D1-1 Arsenic in Nature

Typical whole-rock arsenic content is approximately 2 mg/kg with higher concentrations in shales based on global average values reported by Hem (1985) (Table 11). Shales generally accumulate more trace metals than other sedimentary rocks because of their slow accumulation and the properties of clay minerals. For example, elevated levels of trace metals in Cretaceous marine shales are attributed to extensive volcanic activity during Cretaceous time (Presser, 1994). Volcanic rocks are also generally enriched relative to their intrusive counterparts. Soil concentrations often reflect concentrations in the parent material. Table 12, gives average abundance of selected elements in soils (Shacklette and Boerngen, 1984). The geometric average arsenic concentration in soils is  $\sim 7 \text{ mg/kg}$  (range 0.1 – 100 mg/kg) based on data from Shacklette and Boerngen (1984) (Table 12). Global average arsenic concentrations in soils of 5 - 6 mg/kg were also reported by Yan-Chu (1994). An average arsenic concentration in soil of 5 - 10 mg/kg was cited by Smedley and Kinniburgh (2002). Most arsenic is adsorbed onto soil particles because of the strong attraction between positively charged arsenic ions, particularly arsenates and generally negatively charged clays and iron oxides. Rock degradation products, such as iron and other metal oxides and clays, are more abundant in soils and scavenge arsenic compounds. This explains the average slightly higher arsenic concentrations in soils than in rock. Soils contaminated by agricultural products have arsenic concentrations as high as ~100 mg/kg (Peryea and Kammereck, 1997) or 366-732 mg/kg (Smedley and Kinniburgh, 2002). Table 14 presents typical concentrations in groundwater. They range from 1 to 50 ug/L, two to three orders of magnitude less than in an average soild phase. Welch et al. (2000) presented a summary figure reproduced in Table 15.

Henry and Kapadia (1980) studied concentrations of As, U, Se, and Mo in soils in the southwestern Gulf Coast area both in background samples and in the vicinity of mines. Table 13 presents baseline concentration for trace elements in the southwestern Gulf Coast and elsewhere in the United States. Most soils in south Texas have Mo, As, and Se concentrations similar to those of natural soils elsewhere. However, sampling of mined and mineralized areas shows much higher concentrations. The average arsenic concentration for the Catahoula Fm. is lower than the world average, despite the fact that the Catahoula Fm. is mainly composed of volcanic degradation products.

## D1-2 Geology of the Analysis Areas

## D1-2.1 Geology of the High Plains

The major aquifer in the Texas Panhandle is the High Plains aquifer. The Texas Panhandle includes part of the central High Plains aquifer and the southern High Plains aquifer. The main geologic unit that makes up the High Plains aquifer is the Ogallala Fm., which is late Tertiary (Miocene-Pliocene, about 4-12 Ma) in age (Nativ, 1988). The Ogallala Fm. consists of coarse fluvial sandstone and conglomerate, that were deposited in paleovalleys in a mid-Tertiary erosional surface with eolian sands in intervening upland areas (Gustavson and Holliday, 1985). The Ogallala Fm. is generally thicker in the northern region (100-200 m Dallam – Hartley

counties) and thins to ~ 30 m in the south (Ector-Midland counties). The thickest deposits are found in paleovalleys ( $\leq 250$  m, e.g. Carson County) that trend to the southeast. Paleovalley fills are separated by interfluvial upland areas where the Ogallala is much thinner and sediments are finer grained. The Ogallala Fm. has been partially eroded locally in the southern High Plains where groundwater discharges at the surface as saline lakes (Figure 38). The top of the Ogallala Fm. is marked by a resistant calcite layer termed the "caprock" caliche.

The Ogallala Fm. is overlain by Quarternary-age (Pleistocene-Holocene) eolian, fluvial, and lacustrine sediments called the Blackwater Draw Fm. (Holliday, 1989). The texture of the formation ranges from sands and gravels along riverbeds and mostly clay in playa floors.

The Ogallala Fm. is underlain by lower Cretaceous (Comanchean) strata in the southern High Plains (Figure 39). The top of the Cretaceous sediments is marked by an erosional surface that represents the end of the Laramide orogeny. Nonuniform erosion resulted in topographic relief on the Cretaceous beneath the Ogallala Fm. Cretaceous strata are absent beneath the thick Ogallala paleovalley fill deposits because they were removed by erosion. The Cretaceous sediments were deposited in a subsiding shelf environment and consist of (1) the Trinity Group (basal sandy, permeable Antlers Fm.), (2) Fredericksburg Group (limy to shaly formations including the Walnut, Comanche Peak, and Edwards Fm., as well as the Kiamichi Fm.), and (3) the Washita Group (low-permeability, shaly sediments of Duck Creek Fm.) (Nativ, 1988). The sequence results in two main aquifer units: the Antlers Sandstone (also termed the Triinty or Paluxy sandstone, ~ 15 m thick) and the Edwards Limestone (~ 30 m thick). The term Edwards Trinity (High Plains) Aquifer is generally used to describe these units (Ashworth, 1991). The limestone decreases in thickness to the northwest and transitions into the Kiamichi Fm. and Duck Creek Fm. (predominantly shale).

The Ogallala Fm. is underlain by the Triassic Dockum Group in much of the southern High Plains. The Dockum Group is exposed along the margins of the High Plains (~150 m thick). The uppermost sediments consist of red mudstones (termed red beds) that generally form an aquitard. Underlying units (Trujillo Sandstone [Upper Dockum] and Santa Rosa Sandstone [lower Dockum]) are aquifers. Water quality in the Dockum is generally poor (Dutton and Simpkins, 1986, Figure 10b). The sediments of the Dockum were deposited in a continental fluvio-lacustrine environment that included streams, deltas, lakes, and mud flats (McGowen et al., 1977) and included alternating arid and humid climatic conditions. The Triassic rocks are thickest in the Midland Basin ( $\leq 600$  m).

The Ogallala Fm. is directly underlain by Permian rocks in the northeastern Texas Panhandle. The Permian is also present across all of the area. The top of the upper Permian consists of sediments deposited in tidal flats and sabkha environments of a shallow hypersaline sea in arid conditions. The filling of paleovalleys during Ogallala times approximately reproduces long-lasting structural features. In the late Paleozoic, three main basins trending W-E/NW-SE existed in the Texas Panhandle from north to south: the Anadarko, Palo Duro, and Midland basins. They are defined by the presence of structural highs: the Amarillo Uplift between the Anadarko and Palo Duro basins and the Matador Arch between the Palo Duro and Midland basins. Since Permian time, the region has been tectonically stable. The area has been tilted and warped, but deep-seated faults are rare (Bachman and Johnson, 1973). Subsidence due to salt dissolution (halite, NaCl, and anhydrite, CaSO<sub>4</sub>) has been and still is common in the geological history of the area. The maximum cumulative evaporite thickness of the Salado and Castile Fms. of Permian age is ~ 600 m and is centered across the Texas-New Mexico state line along the current Pecos River valley in the Delaware basin. The cumulative thickness decreases toward the northeast across the Central Basin Platform to negligible values northeast of the Lubbock area (Bachman and Johnson, 1973, their Figure 3). Sinkholes of Triassic age are known (Bachman and Johnson, 1973, p. 10).

## D1-2.2 Geology of the Southwestern Gulf Coast

During the Cretaceous, sediments deposited from shallow inland seas formed broad continental shelves that covered most of Texas. In the Tertiary (starting 65 million years ago), the Rocky Mountains to the west started rising, and large river systems flowed toward the Gulf of Mexico, carrying abundant sediment, similar to today's Mississippi River, Most of Texas. particularly west Texas, was also uplifted, generating a local sediment source, including erosional detritus from the multiple Tertiary volcanic centers in West Texas and Mexico. Six major progradational events occurred where sedimentation built out into the Gulf Coast Basin. These progradational sequences include the most recent Vicksburg-Catahoula-Frio, Oakville-Fleming, and Plio-Pleistocene sand-rich wedges. A general stratigraphic column is presented in Figure 40. Hydrostratigraphic units do not necessarily correspond to stratigraphic units. The former are defined in terms of flow (i.e., in terms of "shales" vs. "sands"), whereas the latter are defined in terms of age. Three main aguifers define the Gulf Coast aguifer: the Jasper, Evangeline, and Chicot aguifers that broadly include the Oakville Sandstone, the Goliad Sand, and Quaternary units, respectively. The Fleming Fm. is a confining unit between the Jasper and Evangeline aquifers and is named the Burkeville confining unit. A more accurate model would take into account the fact that the top of the Catahoula Fm. is sometimes included in the Jasper as the top of the Fleming Fm. is included in the Evangeline aguifer.

The component geologic units of the Gulf Coast aquifers are, from oldest to youngest, (1) Catahoula Fm., (2) Oakville Sandstone/Fleming Fm., (3) Goliad Fm., (4) Pleistocene formations: Willis Fm., Lissie Fm., and Beaumont Fm., and (5) Quaternary terrace deposits and alluvium (Doering, 1935; Baker, 1979) (Figure 41 and Figure 42). Rocks of the Jackson Group and Frio Fm. underlie the Gulf Coast aquifer formations and are pertinent to this study because they contain volcanic deposits, which are associated with uranium deposits and presumably arsenic concentrations in groundwater. The geologic units range in age from Eocene (Jackson Group) to Recent (Figure 40). Stratigraphic relationships and definitions are inconsistent and sometimes ambiguous for this group of Tertiary rocks, which are discussed below from oldest to youngest.

<u>Jackson Group</u> – Eargle (1959) defined four component formations of the Jackson Group and noted that the uppermost Whitsett Fm. consists of bentonitic clay and tuff at the top and sandstone at the base. Lignite is also present in some horizons of the Jackson Group. It generally behaves as a confining unit between the Yegua and Jasper aquifers. Uranium deposits have been found in the uppermost portions of the Whitsett Fm., where it is unconformably overlain by Catahoula Tuff Fm. Uranium deposits occur in Jackson Group rocks in Karnes County as oxidized deposits near the outcrop and as deeper (25 – 30 m), unoxidized, roll-front-type deposits (Eargle et. al., 1975). Fluvial sand to gray-green clay sedimentary deposits "yield variable amounts of highly mineralized water" from upper Jackson Group rocks (Adidas, 1991). Fewer than half a dozen wells on the western edge of the Gulf Coast aquifers in Webb County penetrate upper Jackson Group rocks, and arsenic concentrations in these wells were below detection limits. <u>Frio Clay</u> – This formation, of the Jackson Group, should not be confused with the Frio Fm. (Figure 40), downdip expression of the Catahoula Fm. (Baker, 1979).

<u>Catahoula (Gueydan) Formation</u> = Catahoula Confining System – The Catahoula Fm. has different lithology and provenance in the southwestern Gulf Coast than it does in the northeastern Gulf Coast. Several authors suggest the Catahoula Fm. in the southwest should be referred to as the Gueydan Fm. (McBride et. al., 1968; and Parker, et. al., 1988), which is the name originally given to it by Bailey (1924). Baker (1979) noted that this unit is referred to as Catahoula Tuff in the southwest and Catahoula Sandstone to the northeast of the Colorado River, where it contains more sand and less volcanic material than in the southwest. In the southwestern counties of Duval and McMullen, the Gueydan Fm. reaches a thickness of ~ 300 m and contains the coarsest volcanic material of any Gulf Coast Tertiary unit (McBride, et. al., 1968). In this region the Catahoula Fm. lies unconformably on either the Frio Fm. or Whitsett Fm. of the Jackson Group. In the southwest the Catahoula/Gueydan formations are unconformably overlain by either the Oakville Fm. or the Goliad Fm., whereas in the northeast they are overlain by the Fleming Fm. (Aronow et. al., 1987 and Shelby et. al., 1992).

McBride et al. (1968) describe cross-bedding in Gueydan strata that suggests deposition of the coarser grained volcaniclastics by streams flowing down a NW-SE-oriented paleoslope in Duval and Karnes counties. Farther north in Fayette County paleocurrent data suggest more of an east to west flow direction. Sediments in the lower Catahoula Fm. are predominantly gray tuff, whereas pink tuffaceous clay is more common in the upper strata, suggesting a change to more humid climatic conditions during deposition. Volcanic conglomerates and sandstone are most common in mid levels of the unit. Bentonite and opalized clay layers and alteration products of volcanic glass (zeolites, Ca-montmorillonite, opal, and chalcedony) are present throughout the formation and indicate syndepositional alteration of tuffaceous beds. Widespread areas of calichification indicate long periods of exposure to soil-forming conditions at the surface (McBride et al., 1968).

Galloway (1977) described the Catahoula Fm. as being deposited by two separate fluvial systems, Gueydan in the southwest and Chita-Corrigan in the northeast parts of the Gulf Coast. The Gueydan bedload fluvial system was deposited in the Rio Grande embayment and is dominated by plagioclase and volcanic rock fragments from a distal western source. The Chita-Corrigan mixed-load fluvial system was deposited in the Houston Embayment and is dominated by quartz-rich material from mixed sedimentary terranes. Both depositional systems contain volcanic ash; however, Galloway (1977) cites differences in alteration clay minerals as evidence that Gueydan deposition occurred in an arid environment, whereas the depositional environment of Chita-Corrigan was more humid.

<u>Oakville Sandstone/Fleming Formation</u> – These two units are commonly grouped because they are both composed of varying amounts of interbedded sand and clay. In the central part of the Gulf Coast (Brazos River to central Duval County) they are easily recognized as stratigraphically adjacent units because the Oakville is sand-rich and the Fleming is more clayrich. To the northeast of the Brazos River, the two units are indistinguishable. Baker (1979, 1986) assigned the Miocene Oakville/Fleming geologic units to the Jasper aquifer, which has been best characterized along the northeastern Texas Gulf Coast, north of the Brazos River. Galloway et al. (1982) described the Oakville in the southwest Gulf Coast as a sand-rich fluvial system overlying the Catahoula Fm. They associated the Oakville Sandstone with the Jasper aquifer and stated that the Evangeline aquifer includes most of the Fleming Fm.

<u>Goliad Formation</u> – The Goliad Fm. is only present at surface as far as Lavaca County, just south of the Colorado River as seen on the Seguin GAT sheet (Proctor et. al., 1974) and is absent farther to the northeast (not present on the Beaumont GAT sheet (Shelby et. al., 1992). The Goliad Fm. was deposited during the Pliocene or as recently as 5 Ma. Hoel (1982) mapped the Pliocene Goliad Fm. in detail for her Master's thesis research at UT Austin. She found the Goliad Fm. to be genetically and compositionally similar to the underlying Oakville and Catahoula formations as they exist in the southwest Gulf Coast. Hoel (1982) also stated that preliminary exploration shows potential for the Goliad Fm. to have economically mineable uranium deposits similar to those found in the underlying Oakville Sandstone. Hoel (1982) noted a distinct change in character of the Goliad Fm. along a line perpendicular to the coast, just north of the Nueces River roughly coincident with the San Patricio-Refugio county line. Southwest of this line the Goliad Fm. was deposited by rivers carrying bed load or very coarse sediments containing a large proportion of orthoclase and plagioclase feldspar crystals and volcanic rock fragments from a "distant western source." Northeast of this line the rivers carried finer grained sediments composed primarily of calc-lithic particles presumably derived from Edwards Plateau rocks of central Texas.

The Evangeline aquifer is composed of water-bearing zones primarily within the Goliad Sand and secondarily in underlying portions of the Fleming Fm. (Ryder and Ardis, 1991) The Goliad Sand is only identified as an aquifer unit in the TWDB well database within and to the south and west of Lavaca and Jackson counties. However, the Evangeline aquifer is present throughout the Gulf Coast aquifer in the northeast into Louisiana. Clearly there is a difference in the geologic units that compose the Evangeline aquifer in the southwest and northeast sections of the Gulf Coast aquifer. According to Baker (1979), the Evangeline aquifer was originally only defined as far west as Austin, Brazoria, Fort Bend, and Washington counties in Texas. He stated that extending the Evangeline farther west is speculative; however, in 1976 the USGS decided to extend the Evangeline to the Rio Grande.

<u>Pleistocene and Recent Alluvial Deposits</u> – Since Pleistocene time, packages of fluvial sediments representing successively younger progradational cycles have been deposited along the Texas Gulf Coast (Blum, 1992). The fluvial sediments range in texture from gravel to clay and are commonly poorly indurated. Decreasing dip of the strata toward the coast through time reflects changes in relative uplift of inland areas (southern Rocky Mountains, Great Plains, and the Edwards Plateau) and subsidence in the Gulf of Mexico (Doering, 1935; Blum, 1992). The older portions of this depositional sequence are coarser grained and dip 3 to 7 m per mile (Willis Sand), whereas the younger units are finer grained and dip only approximately 2×10<sup>-4</sup> (1 ft/mi) (Beaumont Fm.) (Doering, 1935). Major Pleistocene to Recent formations along the Texas Gulf Coast, listed from oldest to youngest, include Willis Fm., Lissie Fm., Beaumont Fm., and Quaternary terrace deposits and alluvium (Doering, 1935; Baker, 1979). These units plus Quaternary alluvial deposits are all assigned to the Chicot aquifer.

Northeast of the Colorado River, Miocene- to Pliocene-age Fleming Fm. clay is unconformably overlain by the Willis Sand, which is in turn unconformably overlain by the sand and clay of the Lissie Fm. South of the Colorado River, the Pliocene-age Goliad Fm. is overlain by the Lissie Fm., which consists of sand, silt, clay, and minor amounts of gravel. The Lissie Fm. is overlain by clay, silt, and fine-grained sand of the Pleistocene-age Beaumont Fm. throughout the Texas Gulf Coast. Although the Beaumont Fm. as a whole is much finer grained than directly underlying formations, it contains localized sand channel deposits. The base of the Pleistocene (thought to be Willis Fm. in the northeast Gulf Coast and Lissie Fm. in southwest Gulf Coast) is very difficult to identify on geophysical logs (Baker, 1979). Because of this the bottom of the Chicot aquifer, which has in the past been defined as the base of the Pleistocene, is ambiguously defined and is often lumped together with the Evangeline aquifer.

The structural map of the Gulf Coast area (Figure 43) shows the abundance of growth faults that strike parallel to the Gulf of Mexico. Each major progradation package has a series of growth faults associated with it. An interesting feature of the map is that the Wilcox fault zone impacts the Catahoula Fm. and Oakville Sandstone close to their outcrop area in the southwestern Gulf Coast but there is no major fault associated with the outcrop of the same formations farther north and in East Texas.

## D1-3 Arsenic Distribution

### D1-3.1 Arsenic Distribution in the High Plains Aquifers

High arsenic concentrations seem mostly to overlap Cretaceous subcrops. However, there are also localized pockets of higher concentrations farther north, in particular, on the escarpment, south of the Palo Duro Canyon (Figure 44a). In order to better visualize arsenic distribution in the High Plains, a probability map that highlights areas having high arsenic concentrations was constructed (Figure 44b). It is based on the strong correlation between

fluoride and arsenic, and it possibly enhances the distribution visualization because fluoride data are more abundant. High arsenic concentrations (>50 ug/L) are mostly restricted to the eastern side of the southern High Plains in Lynn, Terry, Dawson, and Martin Counties. Intermediate arsenic concentrations are present in most or all of Lubbock, Yoakum, Terry, Lynn, Gaines, Dawson, Martin, and Howard Counties, as well as on the Ogallala footprint of Ector, Midland, and Glasscock Counties and in the eastern half of Andrews County. Some counties farther north (Bailey and Hockley Counties) and located along the escarpment (Randall, Briscoe, and Floyd Counties) also show intermediate arsenic values. Low arsenic values are present across most of the northern section of the southern High Plains and in the Texas section of the central High Plains. In the center of the arsenic-contaminated area, in Dawson and eastern Gaines Counties, few samples show arsenic <10 ug/L. The western section of the southern High Plains shows an apparent general decrease in arsenic concentrations (western side of Yoakum, Gaines, and Andrews Counties). There is a lack of arsenic analyses in the Ogallala across the New Mexico state line to confirm whether the trend continues. The Cenozoic-Pecos Alluvium aguifer (TWDB major aguifer) which is similar in origin and age to the Ogallala aquifer also contains higher arsenic concentrations.

Arsenic concentration in aquifers underlying the Ogallala aquifer and next to it are displayed in Figure 45. The TWDB database includes, in the footprint of the High Plains aquifer, water samples whose source well could also be screened mostly in the Cretaceous and/or in a few instances in the Triassic Dockum. There is a total of 177 such samples (out of a total of 6,433). There are several data points with As>10 ug/L in Andrews, Terry, and Dawson counties. This is consistent with the Nativ and Guttierez (1988) study of the Cretaceous aquifers that found only one out of eight samples with As>10 ug/L (in Terry County).

Analyses for arsenic in the Dockum Fm. are mainly from the outcrop area (outside of the Ogallala footprint) and that portion of the aquifer having a TDS <5,000 mg/L (sometimes within the Ogallala footprint). Only 10% of the ~200 Dockum data points are above the 10 ug/L threshold (with a maximum of 26 ug/L). Arsenic concentrations >10 ug/L in the Dockum aquifer are more uniformly distributed than in the Ogallala aquifer, but no sample is > 50 ug/L. The currently available samples do not suggest that arsenic would be more abundant downdip in the center of the basin.

High arsenic values in the Edwards-Trinity aquifer are clearly spatially associated with the underlying Ogallala Fm.. There are no high arsenic concentrations outside of the Ogallala footprint. The Cenozoic Pecos Alluvium aquifer presents an interesting pattern, the Monument Draw Trough, on the east, contains several samples >10 ug/L, whereas the Pecos Trough, on the West, contains only background values.

### D1-3.2 Arsenic Distribution in the Gulf Coast Aquifers

Similarly to the High Plains aquifer, the Gulf Coast aquifers offer a contrast in arsenic concentrations between the southwestern and northeastern sections. Approximately 13 percent of the 1,120 samples in the Gulf Coast aquifer sampled during the past five years have arsenic concentrations > 10 ug/L (2.1 percent > 50 ug/L) (Figure 9, Table 3). Arsenic concentrations were greater in the southwestern Gulf Coast (29 percent > 10 ug/L; 6 percent > 50 ug/L) than in the northeastern Gulf Coast (3.5 percent > 10 ug/ and none > 50 ug/L).

From a spatial standpoint, high arsenic concentrations are present along the Rio Grande valley, in the few counties west and southwest of Corpus Christi, as well as along the Catahoula outcrop extending into the northeastern Gulf Coast region (Figure 46). The highest arsenic concentrations (>50 ug/L) are located mostly along the Catahoula Fm. outcrop, as well as in Jim Hogg, Webb, and Duval Counties on one side and Karnes County on the other side. Elevated arsenic concentrations occur in both the outcrop and confined sections of the Gulf Coast aquifers. The highest arsenic concentrations are in the Jasper aquifer, stratigraphically located

next to and above the Catahoula Fm (48 percent of wells > 10 ug/L; 20 percent of wells > 50 ug/L). The Chicot aquifer, which is the youngest and stratigraphically most distant from the Catahoula Fm. displays much lower levels of arsenic contamination (27 percent of wells > 10 ug/L). The intermediate Evangeline aquifer has 21 percent of wells > 10 ug/L. A few isolated high arsenic sample points across the whole Gulf Coast may or may not be of local anthropogenic origin. Intermediate concentrations (10 – 50 ug/L) are more widespread and exist across all counties south of the San Antonio River. They are also present sporadically in the northeastern Gulf Coast (Brazoria and Galveston Counties). However, numerous concentrations <10 ug/L are also present within the areas of high concentrations. This is characteristic of arsenic hot spots across the world (Smedley and Kinniburgh, 2002).

## Subtask D2. Evaluate Geologic Sources of Arsenic by Comparing Groundwater Arsenic Concentrations with Concentrations of Other Ions Using Existing Databases.

## **D2-1** General Geochemistry

## **D2-1.2 Geochemistry of High Plains Aquifer**

The High Plains aquifer is generally unconfined, saturating the lower section of the Ogallala Fm. Rain water is concentrated by evapotranspiration in interplaya areas and flushed periodically to the playas during higher intensity events (Fryar et al., 2001; Wood and Sanford, 1995a). Playas are the main recharge features in the Texas High Plains (Scanlon and Goldsmith, 1987; Scanlon et al., 1994; Mullican et al., 1997). The imprints of calcite dissolution and ion exchange are added on the downward path to the water table or within the aquifer. The water has a resulting calcium bicarbonate or calcium/magnesium bicarbonate character with a pH in the 7-8 range and is oxidizing. Nativ (1988, Figure 25) showed that south and west of Lubbock, the water has higher TDS and has evolved into a mixed anion-mixed cation type (Ca-Mg-Na-HCO<sub>3</sub>-CI).

Groundwater is at equilibrium with calcite, as defined by a saturation index between -0.3 and 0.3, in about 60% of the samples with an additional 40% slightly supersaturated with a saturation index mostly between 0.3 and 1 (Figure 47). It has also exchanged some Ca and Mg ions for Na ions. Groundwater has also received minor contributions from the weathering of aluminosilicates. Fryar et al. (2001) studied chemical evolution of the groundwater along a few flow paths east of Amarillo in the southern part of the Central High Plains aquifer. Supported by inverse geochemical modeling, they suggested that most of the controlling chemical reactions occur while the water is moving through the unsaturated zone and that mixing is the major process occurring in the saturated zone.

The evolution of groundwater chemistry is sometimes more complex when interactions with underlying formation waters occur. Permian evaporite dissolution results in high TDS in groundwater just south of the Canadian River, as suggested by high chloride and sulfate, as well as isotopic studies (Mehta et al., 2000). McMahon (2001) also explained variations from low-TDS calcium bicarbonate water composition at a few locations by upward flow of Permian brines farther north on the Oklahoma-Kansas state line. Several explanations have been proposed for the regional increase in salinity in the southern High Plains, west and south of Lubbock. The spatial association of higher groundwater salinity and saline lakes (Figure 38) where groundwater discharges and evaporates led Wood and Sanford (1995b) to the conclusion that an oft-repeated cycle of wind deflation, particle deposition and dissolution, and discharge and evaporation caused the increase in TDS. Nativ (1988, p. 38) and Nativ and Guttierez (1988) suggested that the increase in sodium and chloride in both the Ogallala aguifer and the underlying Cretaceous aquifers implies a connection between them, particularly on the paleodivides. Isotopic studies also supported that hypothesis (Nativ and Guttierez, 1988). Nativ (1988), Nativ and Guttierez (1988), and Hopkins (1993) presented data suggesting that groundwater south and west of Lubbock results from the mixing of typical recharging water (as seen north of this NW-SE line) and of Cretaceous water. Studies north of Lubbock by McMahon et al. (2004b), in an area where the TDS is <500 mg/L (e.g., Figure 24 of Nativ, 1988) but close to Cretaceous subcrops, suggest that deeper water in the Ogallala aquifer resulted from mixing of Ogallala with about 20 percent Cretaceous waters. The conclusion was supported by an upward vertical hydraulic gradient in nested wells (p.14-15), consistent with the map presented in Nativ (1988), sulfur isotopes (p.19), and inverse modeling of geochemical reactions along flow paths (p. 28). Formation brines from leaking oil and gas wells, abundant in this area, have

also been suggested as a source for the higher TDS (Nativ, 1988). Several authors (Figure 8 of McMahon et al., 2004b; Nativ 1988) have noted that TDS close to the water table can be higher than in deeper sections of the aquifer as a result of downward transport of anthropogenic contaminants (mainly fertilizers).

A striking feature of the spatial distribution of TDS is its sharp increase west and south of Lubbock along the southern edge of the Clovis-Plainview paleovalley (e.g., Figure 12 sketches in Seni, 1980) and also noted by Hopkins (1993). The TDS distribution is affected by the NW-SE direction omnipresent in the High Plains. Seni (1980, p. 23) described a 15- to 30-m buried Cretaceous escarpment. This paleovalley approximately follows the Paleozoic Palo Duro Basin. High Plains aquifer pH distribution is uneven. The southern area southwest of Lubbock where most of the highest arsenic concentrations are located generally has a lower pH than the rest of the Ogallala aquifer (**Figure 48**a and b and Figure 49m).

Detailed petrology and mineralogy analyses of the Ogallala and Blackwater Draw Fms. are presented in Avakian (1988). These analyses are based on cores of 14 wells drilled in five counties in a transect from Lamb to Dickens counties. McMahon et al. (2004b, p. 9-14) evaluated petrology and mineralogy from cores of two wells drilled in Hale and Castro Counties. Both formations have very similar mineralogy. Quartz is by far the most common framework mineral. McMahon et al. (2004b) stated that feldspar, especially K-feldspar (85 percent of all feldspar grains), is minor detrital grains (~5-10%), whereas Avakian (1988) noted that both Kfelspar and plagioclase make up from 5 to sometimes 50 percent of the framework grains. Clay minerals (illite ~ mixed layer illite-smectite > kaolinite) are ubiquitous, although in minor proportion in siltstones, sandstones, and conglomerates. The authigenic fibrous clay mineral attapulgite is widely distributed, albeit always in minor proportions (Avakian, 1988, p. 20). Calcite is locally an important authigenic cementing mineral. Rock fragments are also locally abundant. Through study of numerous thin sections, Avakian (1988) noticed that authigenic iron oxides and hydroxides are common and disseminated throughout the rock (grains <0.01 mm, Avakian, 1988, p. 36). The iron oxides coat the abundant guartz grains. McMahon et al. (2004b) also reported that in southeast Hale County, guartz is sometimes coated by clay and/or Fe-Mn oxides. In addition, detrital iron oxides (magnetite and hematite) make up most of the accessory minerals (up to a few percent of the framework minerals) (Avakian, 1988, p. 17). Magnetite is more abundant in the upper sections of the Ogallala Fm., whereas hematite is concentrated in the lower portions. Biotite is also described but is easily weathered. Both magnetite and biotite contain reducing Fe(II).

## D2-1.2 Geochemistry of Gulf Coast Aquifers

<u>Oakville Sandstone / Jasper Aquifer</u>: The Oakville sandstone / Jasper aquifer is typical of Gulf Coast aquifers. A thin oxidizing recharge zone is located updip in the formation outcrop, whereas waters slowly become more reducing downdip. In the southwestern Gulf Coast area, the Oakville sandstone is between 100 and 200 m thick in the outcrop (Smith et al, 1982), consists of sandy deposits from several major fluvial systems, and grades downdip into finer deposits. Axes of higher transmissivity such as George West in Live Oak County include most of the uranium mines. TDS in the Oakville are generally in the brackish range (>1,000 mg/L) because of the impact of fault discharge (Smith et al., 1982, p.10) except in the outcrop area and initially along high-transmissivity zones. High concentrations of sulfate and chloride are associated with those faults (Figure 43, Wilcox Fault Zone, and Figure 2 of Henry et al., 1982a). Sulfate could also originate from dissolution of evaporites locally present in playa-floodplain facies (Henry et al., 1982a). In the northeastern Gulf Coast, the same aquifer does not show such high TDS and remains mostly below 1,000 mg/L (Henry et al., 1982a). Hydrochemical facies evolution ranges from calcium bicarbonate in the recharge zone to sodium bicarbonate chloride farther downdip with a strong sulfate component (Smith et al., 1982, p.13-14) in the

southwestern Gulf Coast, whereas in the northeastern Gulf Coast, the hydrogeochemical composition is in the sodium bicarbonate range.

In the southwestern Gulf Coast, geochemical evolution reflects the impact of both Ca/Na cation exchange on clay and fault discharge, possibly from different depths. Following a pattern similar to that of TDS, Eh conditions vary from strongly oxidizing in the recharge area (470 mV) to reducing farther downdip (-170 mV), with variations due to conductivity changes and proximity to faults. The decrease is not progressive but moves through plateaus at ~400, ~50 and ~-100 mV (Henry et al., 1980; Galloway, 1982, p. 21 and his Figure 18). Values of pH increase more or less regularly from ~7 to 8.

Smith et al. (1982, their Figures 19 and 21 to 23) presented spatial distribution of uranium, molybdenum, selenium, and arsenic with inferred isopleths. All ions increase from the northeast to the southwestern Gulf Coast. Galloway (1982, his Figure 18) presented a typical downflow evolution with uranium and selenium decreasing downdip while Mo stays high.

The Oakville sands consist of quartz-poor litharenites or feldspathic litharenites (classification of Folk, 1974) (Galloway et al., 1982, p. 23). Galloway (1982, p. 2-3) and Galloway et al. (1982, p. 24) suggested that sediments were deposited in an arid environment in a typical redbed system with hematitic alteration. Whole-rock analysis suggests that iron oxides are common in the subsurface (2% in Table 1 of Galloway, 1982). Diagenetic calcite cement is also abundant. Fine-grained sediments within the formation mainly consist of montmorillonite and illite. Galloway et al. (1982, p.23) suggested that montmorillonite is derived from older strata rather than an alteration product of ash material.

<u>Catahoula Formation</u>. The Catahoula Fm. comprises two large fluvial systems: the Gueydan system southwest of the San Marcos Arch and the Chita-Corrigan system to the northeast. The Gueydan system was deposited under semiarid conditions, and sediments show a strong volcanic influence, including numerous occurrences of airborne volcanic ash (Galloway, 1977). Thickness ranges from 60 to 300 m (Galloway, 1977, p.3). Fant Tuff, Soledad Conglomerate, and Chusa Tuff are members of the Catahoula Fm. The petrologic composition of the Gueydan system consists of a mixture of feldspar plagioclase, quartz, and volcanic fragments in subequal proportions (feldspathic litharenite or lithic arkose according to Folk's classification, 1974) in sandy intervals. They also contain up to 4% magnetite/ilmenite (Galloway, 1977, p.23). The dominant clay mineral in the clayey petrofacies is montmorillonite, most likely derived from alteration of volcanic ash rather than reworking of older units.

Subsequent diagenesis decreased the permeability of the sand as a result of clay coating and calcite cement. Clayey facies have low permeability, although before alteration they may have had much higher permeability, allowing leaching of uranium and other trace metals very soon after the depositional event. Current trace metal concentrations in the Catahoula Fm. rocks do not show any particular enrichment, suggesting that leaching occurred early after deposition.

Within the Catahoula Fm., the Chita-Corrigan system of central and northeastern Gulf Coast has lower TDS than its southwestern counterpart, the Gueydan system. The Chita-Corrigan system also has a more typical hydrochemical evolution, albeit complex, starting with calcium bicarbonate waters, then increasing in sodium by ion exchange and chloride. The Catahoula Fm. in the southwest has relatively high TDS, attributed to the impact of deep water, except in sandy lobes following major depositional sandy channels (Galloway and Kaiser, 1980, p.25). Current water composition of the Catahoula Fm. is dominated by sodium bicarbonate chloride (Galloway and Kaiser, 1980, p.19). High chloride content in the shallow subsurface suggests the long-term influence of deep brines mixing with recharging waters. The formation pH varies from neutral to alkaline with values locally >10 in ash beds (Galloway and Kaiser, 1980, p. 27).

## D2-2 Crossplot Analyses

Groundwater arsenic concentrations were plotted against a variety of variables to better understand sources and mobilization mechanisms of arsenic. Crossplots include arsenic vs. oxyanions (B, Mo, Se, V) and other trace elements (F, U, perchlorate), arsenic vs. environmental parameters (pH, alkalinity, TDS/conductivity), arsenic versus major ions (sulfate, chloride, bicarbonate) and minor ions (silica, nitrate, iron). Other environmental parameters such as dissolved oxygen/Eh, well depth, water table depth, and aquifer saturated thickness were also plotted or are discussed in other sections.

### D2-2.1 Arsenic and Covariates (southern High Plains)

Arsenic distribution in the southern High Plains was already discussed in a previous section. There is a clear spatial association between arsenic and other oxyanions (B, Mo, Se, V), as well as with fluoride. Table 16 presents a summary of the correlations displayed in Figure 50. The highest correlation is with vanadium (r2=0.65) followed by fluoride (r2=0.30) then by molybdenum (r2=0.18), boron (r2=0.17) and selenium (r2=0.14). Arsenic concentration also increases with that of major anions (chloride, sulfate, bicarbonate) but only when the whole High Plains data set is considered. Correlations are low when applied to only the SHP-S region (presented r2 values are only computed for SHP-S).

All of the more than 800 analyses for beryllium presented in the TWDB database for the area south and southwest of Lubbock are less than the detection limit of 1 ug/L. However, this does not preclude a relationship with arsenic because beryllium concentrations are typically lower than 1 ug/L.

A recent perchlorate study (Jackson et al., 2004) found that perchlorate correlates with Cl, Br, F, SO<sub>4</sub>, K, and Mg but not with NO<sub>3</sub>, Na, or Ca. Potential sources for perchlorate include anthropogenic fertilizers and natural sources (possibly in association with evaporites). Other sources such as industrial sources from explosives (unlikely given the spread of the contamination in a largely agricultural area) or in-situ generation by redox reactions (lightning strikes on buried metallic objects, cathodic protections for oil wells) were eliminated. Highperchlorate waters are concentrated in the upper half of the aquifer. However, the only other local aquifer with perchlorate > 4 ug/L is the underlying Dockum aquifer.

### D2-2.2 Arsenic and Covariates (southwestern Gulf Coast)

High arsenic concentrations are present along the Rio Grande valley, in the few counties west and southwest of Corpus Christi, as well as along the Catahoula outcrop extending into the northeastern Gulf Coast (**Figure 54**a). In the southwestern Gulf Coast, the Jasper aquifer contains the most samples larger than 10 ug/L (47.5 percent > 10 ug/L; 20 percent > 50 ug/L), whereas the Evangeline and Chicot aquifers contain 21 percent > 10 ug/L and 27 percent > 10 ug/L (**Figure 53**). Molybdenum (**Figure 54**b) and vanadium (**Figure 54**d) follow the same pattern. However, Se (**Figure 54**c) is mainly present along the Rio Grande valley and much less in those counties west and southwest of Corpus Christi. Uranium is also high along the Catahoula outcrop, west and southwest of Corpus Christi, and along the Rio Grande (**Figure 54**g). There is a clear spatial association on the regional level between As, Mo, Se, V, and U. This regional association is less clear on cross-plots for reasons to be detailed later (Table 17 and **Figure 55** and Figure 56).

Similarly to the High Plains area, arsenic concentration has been plotted against a variety of variables to understand its behavior. Plots were made for two databases: TWDB and NURE. The NURE database has incomplete spatial coverage and produces noisy crossplots, but most samples were analyzed for major, minor, and trace elements. It also provides total well depth but gives no information about the sampled aquifer. Coverage by the TWDB database is more uniform and does includes aquifer information, but samples were more rarely analyzed for trace

elements. Cross-plots were built by using data from the same samples (same well, same date). Data from the same well with, for example, arsenic concentration in year 1 and Mo concentration in year 2 were not retained. In addition, two cross-plots per element (for Mo, Se, V, and B) are displayed for the TWDB database. One set of cross-plots represents those data points where both As and the companion ion were above detection limits. The other set includes all data points, regardless of detection limits. The latter was used to assess concentrations of one ion when arsenic concentrations in the southwestern and northeastern Gulf Coast. When appropriate and as noted, some of the figures include the whole Texas Gulf Coast, whereas in other instances, only the southwestern Gulf Coast samples were used. In addition, most plots do not discriminate between the different units of the Gulf Coast aquifers (Jasper, Evangeline, and Chicot aquifers). The highest correlations as strong as in the High Plains aquifer.

Molybdenum (Figure 55a and Figure 56a and b) and vanadium (Figure 55c and Figure 56e and f) still correlate relatively strongly with arsenic, whereas selenium (Figure 55b and Figure 56c and d) seems independent of arsenic. Nevertheless As, Mo, Se, and V, as well as U, are spatially associated at the regional scale, pointing to a regional origin of the arsenic contamination (volcanic ash?). Ions of those five elements do not always behave similarly in the subsurface, explaining the discrepancies in the details. Fluoride has, for the most part, concentrations below the MCL of 4 ppm (Figure 54f) and seems to be correlated with arsenic (Figure 56i). In addition, silica (Figure 55f and Figure 56i), bicarbonate (Figure 55h and Figure 56j), and sulfate (Figure 55i and Figure 56j) do not seem to controlarsenic distribution. A weak correlation with TDS (Figure 54h and Figure 56l) suggests that longer residence time or mixing with more saline waters may explain part of the high arsenic concentrations. Redox conditions do not seem to impact arsenic distribution, as noted by several authors, as long as they are not too reducing and the sulfur activity is low (Figure 69). High arsenic concentrations seem to be present in an optimal depth range, particularly in the Jasper aquifer (Figure 57).

## D2-3 General Mechanisms of Arsenic Release

A review of the global distribution of arsenic contamination provided by Smedley and Kinniburgh (2002) indicates that there are several potential release mechanisms (Welch et al., 2000; Smedley and Kinniburgh, 2002):

- 1) dissolution of arsenic-bearing minerals,
- 2) mixing with geothermally influenced water, and
- 3) desorption from iron oxides.

Oxidation and dissolution of arsenic-bearing minerals such as arsenic-rich pyrite or arsenopyrite can lead to high arsenic concentrations. It also leads to low pH and favors the production of iron oxides that can mitigate the impact of arsenic release. Lowering of the water table can bring those sulfides to oxidizing conditions. Magnetite ( $Fe_3O_4$ ) and ilmenite ( $FeTiO_3$ ) can also contain arsenic and vanadium (Smedley et al., 2002, p. 280; Smedley and Kinninburgh, 2002, their Table 3) and other trace elements. Geothermal waters can bring arsenic to the shallow subsurface. This case can be generalized by adding mixing from deeper formations lacking geothermal character.

Desorption from iron oxides is commonly invoked to explain high arsenic concentrations in water. It could occur because the oxides themselves are being dissolved (reductive dissolution, most likely biomediated), as suggested in Bangladesh (Smedley and Kinniburgh, 2002). Kresse and Fazio (2003) suggested that As contamination in an alluvial aquifer in Arkansas is related to reductive dissolution of iron oxides rather than anthropogenic soil arsenic compounds. This hypothesis is supported by spatial correlations between As, Fe, nitrate, and ammonium ions and by the presence of abundant organic matter (Kresse and Fazio, 2003, p.18). Alternatively,

desorption can be due to a change in environmental conditions such as an increase in pH, competition from introduced oxyanions (e.g., phosphates), or mutual competition by other sorbates. Crystallized iron oxides, such as hematite, do not sorb as much arsenic as less ordered and hydrated species (ferrihydrite, goethite). Yet iron oxides typically precipitate under the latter form in conditions expected in a shallow aquifer and then age into the former (see Appendix I). There are indications that the process involves destruction of the mineral structure and reprecipitation of hematite, whose crystallographic structure can accommodate more arsenic. More generally, as described in Appendix I, arsenic sorption on iron oxides could be impacted by phosphates, carbonates (Appelo et al., 2002), organic matter (Redman et al., 2002), and maybe silica (Dixit and Hering, 2003).

Dissolution of silicates and carbonates generally leads to an increase in pH. Alteration of silicates raises pH because it consumes protons (Smedley and Kinniburgh, 2002; Sracek et al., 2004). This is particularly true in the presence of plagioclase because plagioclase feldspars are less stable than potassium feldspars. When the degradation product is kaolinite, the reaction is written as:

 $2NaAlSi_{3}O_{8} + H_{2}O + 2H^{+} = Al_{2}Si_{2}O5(OH)_{4} + 2Na^{+} + 4SiO_{2}$  $CaAl_{2}Si_{2}O_{8} + H_{2}O + 2H^{+} = Al_{2}Si_{2}O5(OH)_{4} + Ca^{+2}$ 

Silica is also generated, along with clay minerals, in the alteration of plagioclases. Silica can compete with arsenic for sorption sites. Calcite dissolution by carbonic acid consumes  $H^+$  and also raises pH

 $CaCO_3 + H^+ + HCO_3^- = Ca^{+2} + 2HCO_3^-$ 

Increase in  $CO_2$  pressure in the presence of calcite will raise pH. An increase in  $CO_2$  pressure can result from biological activity. Mixing with higher-pH waters can also raise pH with no need for extrinsic arsenic. Ion exchange, which typically consumes Ca, also impacts pH.

Hydrodynamic factors are also important to consider for all of the three general mechanisms. The rate of arsenic release relative to the flushing rate of the aquifer impacts arsenic concentration (Table 1 and Smedley and Kinninburgh, 2002, p. 556). Arsenic released at a high rate into an aquifer can be quickly flushed from the system with the overall arsenic aqueous concentration remaining low. Alternatively, stagnant or very slow moving water may have high arsenic concentrations even if the release rate is low.

## **D2-4 Potential Natural Sources of Arsenic**

### D2-4.1 Potential Natural Sources of Arsenic in the High Plains

Elevated arsenic concentrations in the High Plains have been attributed to various natural sources, including Permian brines (McMahon, 2001), upward or lateral flow from Cretaceous subcrops (Nativ, 1988), volcanic ash of variable origin, and saline lakes. Understanding arsenic behavior in the High Plains aquifer requires knowledge of the source and mobilization mechanism, and ensuring an accurate mass balance of arsenic. Any hypothesis should include an explanation for the sharp contrast between northern and southern areas of the Texas High Plains. Considering the High Plains aquifer as an open system, the origin of arsenic in the formation may be intrinsic to the aquifer system (volcanic ash layers, detrital minerals, evaporative concentration) or extrinsic through water originating from underlying formations (Cretaceous, Dockum, Permian) and/or from the Rocky Mountain area.

Arsenic accumulation may still be active (arsenic is added to the system) or relict (no mass of arsenic is added to the formation). In the latter case, arsenic will be flushed progressively out of the formation. The overall young age of the Ogallala water (less than 10,000 years, Figure 12 of McMahon et al., 2004b) suggests that flushing may still be active today. Additional data by Dutton (1995) confirm the relatively young age of the Ogallala water. He reports a percent
modern carbon (pmc) of 40.3±13.8 in the southern High Plains in six wells in Randall, Swisher, and Floyd counties in the north section of the southern High Plains. This translates into an average age of ~7,300 years. Isotopic analyses also suggest that Ogallala water was recharged under the current warm and dry climate that followed the last glaciation about ~10.000 years ago. By contrast a similar analysis of the confined Dockum aquifer yielded an age of 25,000 to 50,000 years.

A crude computation sheds light on the arsenic mass balance. If the Ogallala sediments are 5 millions years (Ma) old on average, a total of at least  $5 \times 10^6$  yr /  $1 \times 10^4$  yr = 500 pore volumes has flowed through them. For an average arsenic groundwater concentration of 20 ug/L, this represents a mass of  $0.02 \times 500 = 10$  mg/L of water. Assuming a porosity of n = 0.2, this translates into depleting the rock of  $10 \times n/(1-n)/2.65 \sim 1$  mg/kg. This simple calculation can be linearly scaled by the sediment age (10 Ma translates into 2 mg/kg), arsenic aqueous concentration (50 ug/L translates into 2.5 mg/kg), or the average water residence time (5,000 years translates into 2 mg/kg). This most likely represents only a fraction of the whole rock amount of arsenic, although the world-wide average arsenic concentration for sandstone is ~ 1 mg/kg (Table 11).

Most of the arsenic is likely to be associated with a solid phase, either part of the mineral structure (in pyrite, arsenopyrite, and other minerals), or sorbed to a mineral or organic surface. Iron and manganese oxides are common in the formation and can sorb and scavenge most of the arsenic. A change in environmental conditions may not change the total mass of arsenic in the formation but will change the balance between sorbed and dissolved fractions, as well as possibly the redox state of the arsenic. A change from reducing to oxidizing conditions will mobilize arsenic contained in sulfides. Conversely a change from oxidizing to reducing conditions can desorb arsenic from the iron oxides that are being dissolved (reductive dissolution). A raise in pH with no change in redox conditions will also mobilize sorbed arsenic. Addition of new competing ions could have the same results without a change in either pH or Eh.

## Volcanic Ash Layers of Ogallala Age

Rhyolitic ash layers have been described within the Ogallala and Blackwater Draw Fms. (Table 18). Those ash layers are collectively described as Pearlette ash. Pliocene and Pleistocene ash falls in the United States originated from three main centers: the Yellowstone area in Idaho and Wyoming, the Long Valley-Glass Mountain area in California, and the Jerez Mountain area in New Mexico (Izett, 1981). Some events, such as the Lava Creek B or Huckleberry Ridge event, blanketed most of the western United States, including the Texas Panhandle (event name is related to the location where the ashfall was studied and generally not to the source). Ash layers of similar age have been recognized in the Blackwater Draw Fm. (Frye and Leonard, 1957, p.22). Gustavson et al. (1991) mentioned Lava Creek B, dated at 0.62 Ma, and Huckleberry Ridge (2.2 Ma) volcanic ash layers present on terraces of the Pecos and Canadian River valleys, north and east of the southern High Plain aguifer, respectively. Gustavson (1996, p. 46) also noted the Guaje ash (1.4 Ma) present in Crosby County. Izett (1981) also cited the Mount Blanco event (2.3 Ma). Ash-bed thickness is on the order of 0.3 m (e.g., Figure 5 in Gustavson et al., 1991). Cepeda (2001) suggested that there are at least 10 volcanic beds in the Ogallala and Blackwater Draw Fms. originating from the Yellowstone area in the past 12 million years and varying in thickness from 0.3 to 1.5 m. He described a 1-meterthick ash bed in the northern Panhandle in Potter County. Hanan et al. (1998) found expression of those ashfalls in Gulf of Mexico turbiditic sediments.

Volcanic ash, some with high U content and As by inference, is not uncommon in Pliocene and Pleistocene sediments. Because the source of the ash was hundreds to thousands of miles away in most cases and blanketed most of the Texas Panhandle, it still leaves open the question of the presence of As only in the southern section of the southern High Plains. Assuming that the whole Texas High Plains aquifer had been subjected to the same conditions, one would expect higher concentrations in the north than in the south because volcanic sources are mostly in the northwest United States. A preliminary study performed for this work and presented in Appendix III suggests that ash bed relicts (Figure 58) may be more abundant in the southern region of the southern High Plains. However, a simple mass balance calculation suggests that the mass of arsenic available may not be sufficient to explain the current elevated arsenic concentrations.

#### Desorption from Iron Oxide Coatings

Most of the Ogallala sediments originated from the ancestral Rocky Mountains before the Pecos River valley cut this supply source (~4 Ma ago). Intense calichification and eolian mobilization and deposition were the two mains processes affecting the High Plains after this event. Ogallala sediments are rich in secondary iron oxides, and it is conceivable that arsenic was incorporated during mineral growth or sorbed at a later time to the oxide surfaces. The arsenic would have originated in the Rocky Mountains area or in now-eroded local Cretaceous rocks, would have been transported either in losing surface streams or in groundwater, and would have been immobilized in the Ogallala sediments. Only the area south of the southern High Plains aquifer would have been contaminated by arsenic because only the most recent alluvial fan moved sediments from farther west arsenic-rich areas such as Colorado uranium deposits (also rich in arsenic) and other volcanic rocks.

#### Saline Lakes

A total of ~ 40 saline lakes having total concentration as high as 430 g/L have been described in the southern High Plains (Wood and Jones, 1990) (**Figure 38**). They vary in size from less than 1 km<sup>2</sup> to tens of square kilometers. They are different from the ~25,000 playas that dot the Texas Panhandle. Playas are generally smaller and have a circular shape (< 1 km of diameter, Osterkamp and Wood, 1987) and are venues for recharge to the aquifer (Scanlon and Goldsmith, 1987; Scanlon et al., 1994; Mullican et al., 1997). They are also more abundant toward the north of the panhandle. Saline lakes discharge groundwater, are oftentimes elongated in shape, and are restricted to the southwest of Lubbock. Wood and Jones (1990) dismissed the hypothesis of migrating brines as the source of the high salinity on the basis of chemical ratios, particularly Br/Cl. They presented convincing evidence that groundwater discharge and runoff water feed the lakes. Most of the lake bottoms are lower than the Ogallala-Cretaceous contact, and the discharging groundwater is mainly from the Cretaceous aquifer. Some of the lake water is also recycled as it infiltrates through the lake bottom and is mixed with groundwater discharging into the lake, possibly generating saline springs (Wood and Jones, 1990).

The spatial association of higher groundwater salinity and saline lakes where groundwater discharges and evaporates led Wood and Sanford (1995b) to the conclusion that an off-repeated cycle of wind deflation, particle deposition and dissolution, and discharge and evaporation caused the high TDS in the south section of the southern High Plains aquifer. There is no question that the TDS is locally impacted by the saline lakes (e.g., study of Double Lake by Wood and Sanford 1995b). However, the problem of the origin of the large spatial distribution of higher TDS remains. A crossplot of chloride vs. arsenic in the south of the southern High Plains show no correlation between the conservative solute and arsenic, as would be expected (Figure 50j)

Arsenic would be passively concentrated in the brine and transported along with other particle constituents. Wood (2002) suggested a similar mechanism to explain the relatively high uranium concentrations in the sand dunes associated with the lakes. Gypsum, halite, and sodium sulfate are present in the lake bottom, as are clays (Parry and Reeves, 1968). Arsenic

would most likely be transported with the clay fraction. In that case, arsenic behavior should be similar to anthropogenic arsenic. A similar hypothesis of atmospheric deposition with saline lakes as source was postulated for perchlorate contamination occurring roughly in the same regional area of the southern High Plains. Perchlorate is known to form or integrate evaporites. However, no perchlorate was detected within the saline lakes (Jackson et al., 2004, p. 140).

This hypothesis, however, cannot explain elevated arsenic concentrations in areas without saline lakes such as Yoakum and most of Gaines and Terry Counties unless currently buried saline lakes have been recurrent during the Ogallala depositional history.

#### Cretaceous Subcrops:

Cretaceous subcrops in the Panhandle consist of mainly marine shales in their upper section overlying a lower section dominated by limestones (Nativ and Gutteriez, 1988). Walnut, Comanche Peak, and Edwards limestones, as well as the Trinity/Paluxy/Antlers sandstones farther down in the section, are aquifers (Figure 39). Figure 39 displays two somewhat similar interpretations of cores and well logs mapping the extent of the Cretaceous. The largest Cretaceous subcrop in the interpretation by Nativ (1988) has been used by the TWDB as the outline of the High Plains Edwards-Trinity minor aquifer. Interpretation by Brandt (1953) is consistent with that of Nativ (1988) in that most of the Cretaceous, except maybe some Antlers (Paluxy) remnants, is missing in the southernmost main depositional axis of the Ogallala Fm. The Ogallala aquifer overlies the shaly upper section of the Cretaceous profile when present, that is, mostly on the northern limit of the Cretaceous subcrop. Both shale formations (Kiamichi shale and Duck Creek shale of the Frederickburg and Washita groups) are described as yellow-brown to dark-gray color with thin intercalations of limestone and sandstone. The maximum cumulative observed thickness of the shale section is 45 m (148 ft). The Kiamichi Shale Fm. crops out in some localities in Lynn, Terry, Hockley, Lamb, and Bailey counties (Brandt, 1953).

Kiamichi shale could be a source of arsenic because Cretaceous times are known for higher than average volcanic activity and because clay minerals scavenge and accumulate trace metals, especially if they are organic matter rich such as black shales (Guilbert and Park, 1980, p. 702-703). Selenium contamination in the Central Valley in California is thought to originate in the Moreno Shale cropping out in the nearby Coastal Range (Presser, 1994). The Kiamichi Fm. is described as a black shale between the Hill Country in Central Texas and the Red River in the east Texas Basin (Neeley, 1994). However, Sidwell (1936) described the Kiamichi shale in the Panhandle as composed of quartz primarily. Some pyrite is also present. He did not describe any feldspar (actually specified as absent) or clay minerals. However, Brandt (1953, Table 3) gave a normative composition with 17% Al<sub>2</sub>O<sub>3</sub> showing the presence of clays (more likely than feldspar at that grain size). This is corroborated by Kessinger (1967), who indicated influx of a quartz mud in Kiamichi sediments but also the presence of dark-gray shale with a paucity of fossils, reflecting a reducing environment and analogous to the black shale accumulation to the East. Bishop (1967) published a detailed stratigraphy of the Kiamichi Fm. but with little information about its facies in the Texas Panhandle. Eargle (1956) reported 10 ppm uranium in the Kiamichi Clay Fm. at King Mountain in Upton Country, south of the High Plains. A large segment of the Kiamichi Fm. is slightly radioactive in that area. No arsenic analysis was made.

There are two possible scenarios to account for a Cretaceous origin of the arsenic: current cross-formational flow and/or paleo-accumulation following erosion of the Cretaceous material. Nativ and Gutteriez (1988) and McMahon (2001) described potential areas of upward flow in association with Cretaceous subcrops by mapping and comparing heads in both the Ogallala and the Cretaceous aquifers. Upward flow would be present in the larger northern subcrop. Blandford and Blazer (2004), using a model recently constructed for the regional Groundwater Availability Model (GAM) groundwater studies (Blandford et al., 2003), suggested that cross-

formational flow is downward, at least in the smaller southern subcrop (**Figure 39**). In addition, along paleovalleys Cretaceous subcrops are at higher elevation than the bottom of the Ogallala sediments, making cross-formational flow possible without head difference in the vertical direction. The second scenario does not involve current hydrogeology but would rely on iron oxide coatings that would have been enriched during the erosion of some arsenic-rich layers. This scenario is similar to the one described above with the Rocky Mountains as a source, except that the source is more local. The lack of good spatial fit between the elevated arsenic concentrations and the Cretaceous subcrops suggests that, although some of the contamination may be genetically linked to them, other elements are at play. The lack of arsenic in the Edwards-Trinity Plateau aquifer (Figure 45b) demonstrates than there is no intrinsic arsenic source in the Cretaceous water-bearing formations (Antlers and Edwards Fms).

#### **Dockum Formation:**

Analyses for arsenic in the Dockum Fm. are mainly from the outcrop area (outside of the Ogallala footprint) and that portion of the aquifer having a TDS <5,000 mg/L (sometimes within the Ogallala footprint). Only 10% of the ~200 Dockum data points are above the 10 ug/L threshold (with a maximum of 26 ug/L). Distribution of arsenic concentrations >10 ug/L in the Dockum aquifer seems more even than in the Ogallala aquifer. However, water-bearing beds in the Dockum are mostly in the lower section of the formation, although some local sandy layers exist within the red beds forming most of the upper section. Red beds are mostly made of clays and silts and have very low permeability. It would not be easy to leak water to the High Plains aquifer. In addition, heads in the Dockum are lower than that of the High Plains aquifer (Bradley and Kalaswad, 2003). The currently available data do not suggest that arsenic would be more abundant downdip in the center of the basin underneath the region with elevated arsenic concentrations or that this area.

#### Permian and Older Formation Brines

There are few available analyses of arsenic concentration in Permian rocks and brines. A request to oil and gas vendors of geochemical data was unsuccessful because very few formation waters are analyzed for arsenic. Parkhurst et al. (1995) studied the Central Oklahoma aquifer developed on rocks of Permian age and described high concentrations of arsenic, molybdenum, selenium, and vanadium. Trace analyses performed on 220 samples yielded 90th percentile and maximum values for As (8 and 110 ug/L), Mo (7.5 and 80 ug/L), Se (20 and 190 ug/L), and V (91 and 560 ug/L) (their Table 1). Those values can be considered low, given the generally high TDS of the formations. In addition, high uranium concentrations are also known to occur in the aquifer. In their study of perchlorate distribution in the High Plains, Jackson et al. (2004) suggested that perchlorate could diffuse from the Permian evaporites to overlying aquifers through fractures. Permian heads do not reach the elevation of the High Plains aquifer. Permian Fms are not considered viable arsenic sources for the Ogallala contamination.

## D2-4.2 Potential Natural Sources of Arsenic in the Gulf Coast

In the southwestern Gulf Coast, arsenic contamination has been attributed to the presence of the uranium mining province and of abundant ashfall or reworked volcanic materials. Other felsic rocks also contain high uranium concentrations. Volcanic ash, however, fully degrades in a short time, maximizing release of trace elements. Numerous abandoned and reclaimed open pits and solution mining operations (some active as of August 2005) are in the same general area as the high arsenic concentrations (Figure 59). Worldwide, arsenic is often associated with uranium. A genetic link is often made (e.g., Nugent et al., 1994), although no specific mechanism is invoked. It could then be due to direct natural contamination through economical but also substandard uranium accumulations or possibly anthropogenic contamination through mining operations and tailings.

### Volcanic Ash / Uranium Deposits

Numerous small uranium deposits were exploited from the 1950's to the early 1990's in the southwestern Gulf Coast. Those deposits are thought to be genetically linked to the arsenic anomalies. Appendix II contains a more detailed description of the uranium province. The deposits are all geographically associated with the Oligocene Catahoula Fm., as well as the upper section of the underlying Eocene Jackson group and the overlying Miocene Oakville sandstone (Henry et al., 1982b, p. 6). A few deposits have also been exploited in the Pliocene Goliad sands. The main mining and exploration area encompassed a large section of the southwestern Gulf Coast from the Mexican border to San Marcos Arch, although uranium showings have been described as far as the northeastern Gulf Coast (Ledger, 1981). The strong relationship of most uranium deposits with high transmissivity sands suggests a genetic connection. The deposits are strata-bound and belong to the epigenetic type (Figure 22 of Galloway, 1982) where multiple influx stages of reducing fluids into the aguifer or products thereof reacted with the uranium-bearing oxidizing waters. The mineralization consists mainly of a matrix of iron sulfides (1-2%) cementing the sandstone silicic clasts with interstitial grains of uranium minerals. The deposits initially exploited resulted from the surface oxidation of the original deposits. RRC (Nugent et al., 1994) did a study of the impoundment waters lying in the excavations before reclamation and of the soil/spoils. Soil/spoil arsenic grade is ≤ 300 ppm (single outlier), but the average value is ~20 ppm (their Table 16). All arsenic aqueous concentrations were less than 30 ug/L, despite TDS being above 1,000 mg/L. The water pH was between 7.6 and 8.2. All selenium aqueous concentrations were below the detection limit of 6 ug/L. Uranium and molybdenum concentrations were often in the hundreds of micrograms per liter (their Appendix A.6). The source of the impoundment water is both runoff and groundwater. The RRC observation is consistent with conclusions by Brandenberger et al. (2004), who found that mine tailings have little impact on the regional surface water quality. Henry et al. (1982a) also stated that the chemical composition of the water matches that of the regional aguifer except in the middle of the ore body. Adidas (1991) studied the impact of local uranium mines on the water quality of the small town of Bruni in Webb County and found no relationship.

Deposits were exploited mainly in open pits, very rarely in underground mines. In a later phase, the exploitation shifted to solution mining, particularly for deeper, reduced deposits. Alkaline-leach mining where sodium or ammonium bicarbonate is injected with oxidants ( $O_2$ ,  $H_2O_2$ ,  $NaClO_3$ ) to solubilize uranium as uranyl-carbonate complexes (Henry et al., 1982b, p. 13) was employed at many locations. At such high pH, most of the sorbed oxyanions are released into the fluid stream despite the oxidation of pyrite into iron oxides. Aquifer contamination could be a problem if hydraulic control is not mastered. Another process at low pH, the acid leach method, seldom used in the southwestern Gulf Coast, would solubilize uranium but not as much the oxyanions. Kingsville Dome uranium mine is active as of 2005. Deposits have formed with and without organic matter. In the latter case,  $H_2S$  from underlying hydrocarbon accumulations or Cretaceous brines flowing up along faults is thought to be the reducing material (Goldhaber et al., 1978) directly or indirectly through pyrite formation before encountering uranium-rich waters. However, brines did not transport uranium to the district (and very likely not As) but only provided reducing material.

Henry et al. (1982a, p.46) stated that higher concentrations of trace elements were to be expected in the Oakville sandstone. It has been postulated that solutions genetically connected to the mineralizations were more concentrated than current groundwater. The most likely reason is the lack of current source. The likely sources, ash layers in the Catahoula, Fleming, and possibly Oakville Fms., had been depleted, although some authors (e.g., Ledger, 1984) argue that leaching is still ongoing. Actual concentrations in oxidizing waters may reflect equilibrium between adsorbed and dissolved phases rather than dissolution from the source. Henry et al.

(1982a, p. 46) did not try to model the chemistry of adsorption of uranium and other trace elements including arsenic.

Galloway et al. (1982) hypothesized that the current position of the redox front is apparently updip of what is was during mineralization owing to additional H<sub>2</sub>S. They identified three distinct redox zones within the Oakville aquifer: An upper oxidizing zone with Eh>200mV extends to ~ 250 m depth. A farther downdip intermediate zone has Eh between 300 and -40 mV and low but detectable H<sub>2</sub>S, and a lower zone has Eh<-40 mV. The third zone is located in deeper sections of the aquifer but also closer to the surface along fault traces. In deposits where the redox gradient is sharp, uranium, molybdenum, selenium, arsenic, and vanadium minerals are found next to each other. However, where the redox gradient is low, more separation is expected with molybdenum and arsenic precipitating farther dowdip and vanadium even farther.; It follows that arsenic, molybdenum and vanadium aqueous concentrations can stay high if conditions are not too reducing.

Granite and volcanic ash derived from high-silica igneous systems are the sources of uranium in sedimentary mineral deposits (Finch, 1967). Some early workers thought there were nearby volcanic sources of uranium in south Texas (e.g. Bailey, 1924, 1926). More recent workers (McBride et al., 1968; and Parker, et al., 1988) have discounted this idea and shown there to be three possible distant sources of volcanic material: (1) the Trans-Pecos Volcanic Field located in the Big Bend region of Texas and adjacent Chihuahua, Mexico. (2) the Sierra Madre Occidental of central Mexico, and (3) Cretaceous intrusive rocks near Uvalde, Texas.

Volcanic activity in the Trans-Pecos Volcanic Field began approximately 35 to 40 million years ago (Ma), or during middle to late Eocene, coincident with deposition of the upper Jackson Group units. A period of active caldera-forming volcanism occurred between 38 and 32 Ma (late Eocene to early Oligocene), resulting in generation of large amounts of volcanic air-fall and ash-flow deposits know as ignimbrites (Henry et. al, 1986). This volcanic activity may have been ongoing during deposition of the Catahoula Fm. Between 34 and 23 Ma, explosive volcanic activity from large caldera complexes in central Mexico produced huge volumes of rhyolitic ignimbrite (McDowell and Claubaugh; 1979). Volcanic material in the Goliad Fm. is probably reworked volcanic debris from the Catahoula Fm. because it is much younger than the period during which rhyolitic volcanism was active in Trans-Pecos Texas and central Mexico.

Parker et al. (1988) confirmed through petrologic analysis that volcanic clasts found in coarse-grained Gueydan deposits in northwestern Duval County were transported from the Trans-Pecos Volcanic Field. They showed these clasts to be distinct from Cretaceous-age intrusive igneous rocks near Uvalde, Texas. The dominant clasts identified were mafic trachyte and basalt, but high-silica devitrified rhyolite and welded ash-flow tuff clasts were also noted (Parker et al., 1988). Welded ash-flow tuff is composed of volcanic glass shards that became sintered soon after deposition and is therefore capable of being transported without disintegrating. Southwest to northeast high-altitude wind patterns have most likely persisted in southern North America since the beginning of the Tertiary Period (McBride, 1968) and could easily have transported ash from central Mexico and Trans-Pecos Texas into the Gulf Coast Plain of Texas.

It is informative to understand why the Catahoula Fm. did not yield economic uranium deposits in east Texas where it is also present (100-200 meters thick as opposed to 300 m thick south of the San Marcos Arch, Ledger, 1981, p.5). This lack of uranium deposits is associated with lower arsenic concentrations in groundwater. Farther away from the emission centers in west Texas, ashfall deposits are common in the Catahoula Fm. of the northeastern Gulf Coast. However, this region is missing the stream-transported volcanoclastics abundant in the southwestern Gulf Coast. The key observation relates to the degree of degradation of the glassy material whose alteration mobilizes and solubilizes uranium. Glass shards are pervasively altered in the southwestern Gulf Coast (Ledger,

1981; Ledger et al., 1984). Galloway and Kaiser (1980) expressed the somewhat contradictory opinion that uranium in the northeastern Gulf Coast was leached and diluted because of the more humid climate and was then unable to precipitate except maybe downdip. The more humid conditions in Catahoula times were inferred by Galloway (1977) because of the relatively abundant kaolinite in the northeastern Gulf Coast, but Ledger et al. (1984) stated that it could be detrital and not authigenic. However, Ledger et al. (1984) also described numerous montmorillonite beds resulting from the degradation of ashfall layers in the northeastern Gulf Coast. Uranium solutions could also have been diluted as a result of the large volume of sandstones of nonvolcanic origin. Another factor to take into account is the possible lack of a reducing agent in the northeastern Gulf Coast. Several other workers (McBride et. al., 1982; Hoel, 1982) have also suggested that great differences in climate between the southwestern and northeastern Gulf Coast could have influenced the nature of depositional environments. For example, the Goliad Fm. is thought to have been deposited as a primary red-bed sequence (syn-depositionally-oxidized) as a result of the arid conditions. Even though there are air-fall tuff deposits (ash) all along the Texas Gulf Coast, there is a greater thickness of sediments containing volcanic material in the southwestern Gulf Coast. Not only would this have provided a greater thickness of sediments from which to leach uranium, arsenic, and other elements contained in volcanic aerosols, these larger and more interconnected sediment packages would also have allowed more extensive groundwater circulation patterns to have developed.

Arsenic contamination may originate from leaching of volcanic ash and volcaniclastic layers. Arsenic contamination can also be the product of erosion and solubilization of a myriad of small uranium/arsenic accumulations. Similarly to what was presented in the High Plains section, it could also be mobilized from the iron oxides.

#### Other Natural Potential Sources

Additional potential sources include upwelling of highly mineralized water from salt domes. However, the spatial mismatch between salt dome distribution and areas of high arsenic concentration (Figure 54a and Figure 60), as well as the lack of correlation between chloride and arsenic concentrations, precludes such an association.

## D2-5 Modeling Arsenic Behavior in the Saturated Zone

### Conceptual Model and Assumptions

This section describes a modeling exercise shedding light on arsenic behavior in the southern Ogallala aquifer. We used a statistical approach by considering the ~6,000 TWDB major ion analyses of the southern High Plains. A concentration of 15 ug/L arsenic is then assumed in the presence of trace elements competing for sorption sites. The model equilibrates this imposed aqueous arsenic and trace element concentrations with iron oxides. In a second step, the pH is raised or lowered by a half pH unit, and the resulting aqueous arsenic concentration is noted.

In contrast to experiments, where almost everything can be controlled, modeling of field data is challenging. Little is known about the sorbing minerals, except in the most general sense, and much less is known of their effectiveness, in particular relative to their reactive surface area. The general environment such as geological setting, hydrologic conditions, water chemistry, particle mineralogy, and subsurface microbiology should be considered. The key point is to capture the first-order processes by the modeling, even if, because of the complexity, not everything is included. We made the following assumptions:

- 1) oxidizing conditions and presence of As(V) only
- 2) closed system
- 3) all oxide sorbing minerals (amorphous iron oxide, ferrihydrite, green rust, goethite, hematite, amorphous aluminum oxide, gibbsite, boehmite, diaspore) are lumped into one

category and modeled as amorphous iron oxide (Fe(OH)<sub>3</sub>). Iron oxide weight fraction is estimated at 0.5 percent, and its specific surface area is assumed 300  $m^2/g$ .

4) aquifer average porosity is 15 percent.

We now successively examine these assumptions. Dissolved oxygen data suggest that conditions are mostly oxidizing and have been so for a long time. It is then reasonable to assume that arsenic is mostly under As(V). Because, the amount of arsenic and other anions sorbed is dependent on the mineral-specific area, it is important to understand the mineralogy of the iron oxides (nature, location, grain size, coatings, etc.). EPA, in its help manual for superfund sites (1996, Part 5, Table 44), proposes a low, medium, and high value for iron oxide content of 0.01, 0.31, and 1.1 weight percent (Fe<sub>2</sub>O<sub>3</sub>), respectively. The iron oxide and hydroxide (FeOx) content in the Ogallala aguifer seems to be higher than the average of U.S. aquifers. It is estimated at 0.5 percent from Avakian's work (1988). Since it is finely disseminated mostly as coating on framework grains, a specific surface area for FeOx of 300  $m^2/q$  is used. Dzombak and Morel (1990) recommended a value of 600  $m^2/q$  for amorphous iron oxide specific surface area. Welch and Lico (1988) also opted for 600 m<sup>2</sup>/g. However, this value applies to fresh oxide aqueous suspensions used in laboratory experiments. In the subsurface, unless ferric iron is actively precipitating, specific surface areas are probably smaller because of aging. Crosby et al. (1983) determined that ~ 10% of initially amorphous iron oxide had been transformed into goethite in 2 weeks. Fuller at al. (1996) mentioned that sorption decreased by 20% on a ferrihydrite after six days, presumably owing to goethite transformation. In addition, despite the internal porosity of the natural iron oxide coating, it is likely that contact between aqueous solution and mineral surface is not as good as in a suspension. For modeling purposes, we assume that there is no gas exchange-in particular, that carbon dioxide partial pressure is fixed by carbonate concentration. Blandford et al. (2003) attributed a specific yield of 15 percent to the Ogallala aguifer in agreement with other sources cited in the report, whereas Nativ (1988) mentioned an average value of 16.1 percent (it ranges from 7.2 to 19.5 percent) measured from cores. The value of 15 percent is retained in this document for porosity.

In addition, because other chemical elements could compete for the same absorption sites, it is important to add their approximate concentrations. The following values were chosen from the average calculated from the TWDB database: boron (0.61 mg/L), molybdenum (0.012 mg/L), phosphate (0.05 mg/L), selenium (0.036 mg/L), and vanadium (0.081 mg/L). Uranium average concentration was extracted from the NURE database at 0.013 mg/L. Fluoride average is approximately 3 ppm, but it is provided with the major elements and thus varies in each run. Litke (2001, Table 7) reported median phosphate concentrations ranging from less than 0.01 to 0.09 mg/L in other areas of the High Plains aquifer, as well as a median of 0.009 mg/L for arsenic, 0.318 mg/L for boron, 0.021 mg/L for dissolved iron, and 0.011 mg/L for selenium in the southern High Plains aquifer, in agreement with the values used here. Carbonate ions and silica were not assumed to sorb on iron oxides.

The choice of thermodynamic data impacts the modeling results (see Appendix I, Section I-3). A modified version of the database IInI.dat is used in the simulations. All surface species listed in the wateq4f.dat database and not listed in the IInI.dat database were copied to the latter. In addition, data for vanadate and molybdate, copied from Chapter 10 of Dzombak and Morel (1990), were added. Because of numerical instabilities during the run, the fluoroarsenate species,  $AsO_3F^{-2}$  and  $HAsO_3F^{-1}$ , were also deleted from the database. Modeling studies by Smedley et al. (2002, p. 269) suggested that they are minor, even with high arsenic and fluoride concentrations. Sorption reaction constants of some species, such as borate, have higher uncertainties than that of arsenic.

#### Modeling Results

With the assumptions of an arsenic aqueous concentration of 15 ug/L, an iron oxide content of 0.5 percent, and a surface area of 300  $m^2/g$ , most of the arsenic is sorbed to the iron oxides

(>99 percent). With the knowledge of arsenic sorption decreasing with pH, it was expected that aqueous arsenic concentrations would increase with increasing pH and decrease with decreasing pH. This, however, did not fully occur during the modeling. About 50 percent of the samples showed an increase in arsenic aqueous concentration (total arsenic constant) with decreasing pH (Figure 61a), whereas about 60 percent of the samples showed a decrease in arsenic concentration with increasing pH (Figure 61b). This behavior could be due to the presence of other trace elements competing for sorption sites. Figure 62a demonstrates that although other trace elements do have a negative impact on arsenic sorption, it is minor. The origin of this behavior is the competition of magnesium. Runs that do not allow magnesium to sorb onto iron oxide surfaces show the expected behavior of increasing arsenic aqueous concentration with increasing pH (Figure 61c). Because the reaction constant of magnesium sorption on iron oxides is not accurately known (Dzombak and Morel, 1990, Table 10.5) and to ensure that those results are not an artifact due to the lack of accuracy, sensitivity runs on the value of the reaction constant were performed (a value of logK of -5.6 was used in addition to the baseline value of -4.6). Figure 62 suggests that this behavior is real although less pronounced with a lower magnesium sorption strength (logK=-5.6). The number of samples whose arsenic aqueous concentration decreases with increasing pH is smaller with logK=-5.6 (below the horizontal line at 15 ug/L) than with logK=-4.6 (to the left of the vertical line at 15 ug/L) (Figure 62b). Conversely, a decrease in pH leads to more samples with an increase in arsenic aqueous concentration, assuming a logK=-5.6, than the baseline logK=-4.6 (Figure 62c). This behavior does not occur in most experimental work on arsenic sorption because workers tend to simplify the object of their studies by using conservative salts (NaCl or NaClO<sub>4</sub>).

Two observations corroborate the impact of magnesium on the High Plains aquifer. Highest arsenic concentrations do not correlate with the highest pH values but rather with more neutral pH values (Figure 50m). There is also a negative correlation between the ratio Ca/Mg and arsenic (Figure 52) supplemented by a satisfying spatial correlation between high arsenic concentrations and low Ca/Mg ratios (Figure 63). This working hypothesis needs more work to be developed and integrated within the history of the High Plains aquifer.

# Subtask D3. Assess the Redox Conditions of Groundwater with and without High Arsenic Concentrations Using Existing Databases.

Redox conditions can be assessed by measuring dissolved oxygen concentration if conditions are at least somewhat oxidizing. Direct measurement of the redox potential can also be done with a redox meter. A third method to estimate redox conditions is to analyze redox couples appropriate to the anticipated Eh level (nitrate/nitrite; sulfate/sulfide).

## D3-1 Redox Conditions in the Southern High Plains Aquifer

Redox conditions in the High Plains aquifer are in general oxidizing. Numerous anecdotal measurements support this statement. The TWDB database stores Eh measurements, whereas the NURE database provides information on dissolved oxygen. The median of 1,152 NURE measurements taken in the footprint of the southern High Plains and east of a north-south line going through Lubbock is 7.9 ug/L (Figure 64a). The average is 7.3 ug/L, the 10th percentile is 3.3 ug/L, and the minimum is ~0 ug/L. At the aquifer temperature, water can hold ~10 mg/L of dissolved oxygen at equilibrium with water vapor-saturated air (Langmuir, 1997, p. 16-17). Measurement of dissolved oxygen can be considered accurate down to a concentration of 0.1 ppm. TWDB Eh measurements (Figure 64c) show a bimodal distribution with a larger mode at ~125 mV and a much smaller one at ~-125 mV. Dissolved oxygen is theoretically related to Eh and pH through the following reaction:

 $2H_2O = 4H^+ + O_2(aq) + 4e^- \log 10\{K\} = -86.08$  (from wateq4f.dat database)

Eh (mV) = 59.2(21.52 -pH + 0.25log{ $[O_2(aq)]/1000/32$ } at 25°C ( $O_2(aq)$  in mg/L)

which runs parallel to the water stability lines in (pH, Eh) diagrams. This equation is dominated by the pH term unless oxygen concentrations are low (not measurable). A pH of 7.5 then yields an Eh of 778 mV (DO = 10 mg/L) and 748 (DO = 0.1 mg/L). Those values are much higher than the measured values. In addition, frequency of negative Eh values in the TWDB database is higher than frequency of low dissolved oxygen values (<0.5 ppm). This can be explained by a difference in the spatial coverage of the sampling, by the well-known difficulties in measuring accurately low DO values and Eh values, or by the presence of true reducing conditions. Additional explanations are given in the section on recent sampling in Duval County. Arsenic concentrations show no obvious relationship with redox potential or dissolved oxygen ((Figure 64b and d).

Dissolved oxygen shows no obvious trend with depth (Figure 65) but is plotted against the only available well depth information: total well depth, a rough proxy for screened depth. Those dissolved oxygen numbers are similar to those provided in the multistate study of the High Plains aquifer (Table 7 of Litke, 2001). McMahon et al. (2004b, p.17, Appendix 1) multilevel well shows that conditions can be locally mildly reducing. The multilevel wells in Castro and Hale Counties described in McMahon et al. (2004b) match the area of lower dissolved oxygen as recorded by the NURE project (Figure 66). Areas of low dissolved oxygen in Figure 66 in Hale, Moore, and Huchinson Counties generally correspond to areas having large saturated thickness. Reducing conditions are more likely to exist at the bottom of the aquifer, and vertical mixing due to heavy pumping may homogenize the water column more than it was under pristine conditions.

## D3-2 Redox Conditions in the Gulf Coast

Redox conditions of the southwestern Gulf Coast aquifers are weakly oxidizing (Figure 67) to reducing. Henry et al., 1980 and Galloway, 1982 stated that in the Oakville sandstone, Eh conditions range from strongly oxidizing in the recharge area (470 mV) to reducing farther downdip (-170 mV) with variations due to conductivity changes and fault proximity. The decrease is not progressive but moves through plateaus at ~400, ~50 and ~-100 mV (Henry et

al., 1980; Galloway, 1982, p.21 and his Figure 18). The Catahoula Fm. is overall reducing in the downdip area.

Arsenic concentrations do not correlate with dissolved oxygen (Figure 68), but there are no high concentrations at low redox potential (~-100 mV) (Figure 69).

The median of 1,725 dissolved oxygen NURE measurements irregularly distributed across the area of interest is 3.9 mg/L. The average is 4.4 mg/L, the 10th percentile is 1.5 mg/L, and the minimum is ~0 mg/L. The trend with increasing depth seems to be a slow decrease in dissolved oxygen (Figure 70). Henry et al. (1982a) with a few sampling lines approximately parallel to groundwater flow lines showed that the redox conditions from oxidizing at the outcrop of the Oakville sandstone become progressively reducing (Figure 72). The gradient is a function of the depositional systems. Large channel sand bodies maintain their oxidizing character farther downdip, as seen with the few data points that maintain a higher Eh than most data points.

# Subtask D4. Conduct Additional Groundwater Sampling Where Feasible and Necessary to Evaluate Geologic Sources

## D4-1 Data Analysis

BEG provided equipment to the TWDB regular sampling team to perform additional measurements in selected wells in Duval County (southwestern Gulf Coast). Some of the same wells had already been sampled through the years for major ions and arsenic and other trace elements. The new analyses are consistent with previous sampling events (Figure 73). In addition to routine chemical analyses, groundwater was also analyzed for redox pairs: sulfate/sulfide, nitrate/ammonia. An assessment of redox conditions of the 33 samples can be made by comparing dissolved oxygen data and that of the two redox pairs. All measurements were made in the field. Ammonia and dissolved oxygen were measured on all samples, whereas sulfide was measured only on those samples having a dissolved oxygen content of less than 1 mg/L. The maximum amount of oxygen dissolved in a water at 28°C (average temperature in Duval County aquifer according to measurements in the TWDB database) is slightly less than 8 mg/L. Four samples report a D.O value between 7 and 8, and two samples have a D.O value higher than 10 mg/L (most likely because they were sampled from windmills). Those six samples are fully oxygenated, but four of them also contain a significant amount of ammonia (none was analyzed for sulfide). Six samples have D.O. values below 1 mg/L, and they all contain sulfide between 20 and 60 ug/L. Another test of the accuracy of the data can be performed by comparing iron concentrations measured in both the field and the laboratory (Figure 74a). In the presence of oxygen and at a neutral-alkaline pH, ferrous iron would be quickly oxidized, leaving only a few micrograms per liter of dissolved ferric iron (Figure 12.4 of Langmuir, 1997). This is the first instance of thermodynamic disequilibrium. There might be a slight trend in increasing iron with decreasing dissolved iron (Figure 74b). Sulfide and ammonia concentrations show no correlation (Figure 74c).

In order to calculate the theoretical Eh associated with those measurements, PHREEQC runs were done with the 33 chemical analyses as input and the Eh computed at equilibrium. As expected, all Eh values involving dissolved oxygen (including those D.O<1 mg/L) are between 600 and 700 mV, whereas the nitrate/ammonia redox couple yields Eh values from 270 to 390 mV and the sulfate/sulfide couple Eh values range from -120 to -40 mV. Measurements of low DO values are notoriously unreliable, and the presence of sulfide, typically quickly oxidized, is evidence of reducing conditions.

## D4-2 Data Interpretation

Dissolved oxygen decreases with depth as expected (Figure 74d) and similarly to the rest of the Gulf Coast (Figure 70). On the contrary, ammonia and sulfide do not show a trend with depth. Henry et al. (1980) suggested that  $H_2S$  is still leaking from the Wilcox Fault zone, preventing the system from reaching equilibrium.

Henry et al. (1980) and Galloway (1982, p. 21 and his Figure 18) have shown that Eh decreases downdip through plateaus at ~400, ~50, and ~-100 mV (Section D1-1.2). The -100 mV plateau corresponds to the sulfide stability domain, and its presence in the Gulf Coast aquifers is again verifed in this sampling campaign. The Eh = ~50 mV is controlled by the ferrous-ferric reaction and is not well represented in this sampling event because of a lack of iron speciation in the analyses. The plateau at ~400 mV typically represents oxygenated and oxidizing conditions (Langmuir, 1997, p. 410). Only rarely does groundwater Eh reach values of Eh = 600-700 mV for thermodynamic equilibrium with dissolved oxygen because of extremely slow kinetics and because dissolved oxygen is not the only redox pair controlling Eh (Langmuir,

1997, p.409). From these observations, Henry et al. (1980, p. 17) concluded that measured Eh might be the best indicator of the true average redox conditions.

Coexistence of redox pairs in thermodynamic desequilibrium is common in groundwater. Lindberg and Runnels (1994) presented compelling evidence of this (Figure 76). Each vertical band on the figure corresponds to a computed Eh from a given redox pair. The cloud of field-measured Eh spans the whole Eh scale. Redox reactions unless microbially mediated are notoriously slow.

As a conclusion, recent measurements of redox conditions in Duval County are consistent with previous studies. Arsenic behavior (Figure 75) compares well with that of the Gulf Coat as a whole (Figure 68 and Figure 69). Eh values used in Figure 75b are based either on a single redox pair ( $O_2(aq)/H2O$ , ammonia/nitrate, or sulfide/sulfate) or on the average of at most two redox pairs (ammonia/nitrate and sulfide/sulfate or  $O_2(aq)/H2O$  and ammonia/nitrate). Arsenic is soluble until it reaches an Eh value of ~-100 mV, when it precipitates, especially in presence of sulfur.

## Task D: Conclusions on Natural Origin of Arsenic Contamination

## **Southern High Plains**

Arsenic contamination is much greater in the SHP-S region (51% of wells > 10 ug/L) than in the SHP-N region (7% of wells > 10 ug/L). Groundwater arsenic contamination occurs in generally oxidizing conditions in the High Plains and arsenic is expected to be in the form of arsenate. Correlations between arsenic and other constituents (vanadium, r2=0.65; fluoride r2=0.30; molybdenum r2=0.18; boron r2=0.17; selenium r2=0.14) suggests a geologic rather than an anthropogenic source. Arsenic concentrations are related to geologic units and are highest in the Ogallala aquifer and much lower in the Dockum aquifer. Arsenic concentrations in the Edwards Trinity (High Plains) aguifer are highest in the area where it is underlain by the Ogallala aquifer and much lower elsewhere. Potential sources of arsenic include volcanic ash beds in the Ogallala aquifer, black shales in the Cretaceous (Kiamichi Shale), saline lakes, and relict sorption on metal oxice coatings and clays. Analysis of existing geophysical logs indicates that high gamma zones, indicative of volcanic ash beds, are restricted primarily to the southwestern area of the SHP and are not collocated with most of the high groundwater arsenic concentrations. Similarly, the Kiamichi shale and the elevated arsenic concentrations do not fully overlap. Arsenic concentrations are not related to distance from saline lakes, indicating this is not a likely source of arsenic in the region. Additional studies will be required to assess geologic sources, including additional geophysical logging and stratified sampling.

## Southwestern Gulf Coast

Groundwater arsenic concentrations are much higher in the southwestern area of the Gulf Coast (29 percent of wells exceed the MCL) than elsewhere in the Gulf Coast (3.5 percent of wells exceed the MCL). High arsenic concentrations occur along the Rio Grande valley, in the few counties westna dn southwest to of Corpus Christi, and along the Catahoula Formation outcrop extending into the north eastern Gulf Coast. Correlations between arsenic and other constituents (vanadium,  $r^2 0.43$ ;; molybdenum  $r^2 0.36$ ; boron  $r^2 0.12$ ) suggest a geologic rather than an anthropogenic source. Arsenic concentrations are highest in the Jasper aquifer (48 percent > 10 ug/L) which immediately overlies the Catahoula Formation and are much less in younger stratigraphic aquifers (Evangeline aquifer; 21 percent > 10 ug/L and Chicot aquifer, 27 percent > 10 ug/L). Therfore, volcanic ashes associated with or reworked from the Catahoula Fm. are the most likely source of high arsenic concentrations in the southwestern Gulf Coast aquifer. Correlations between arsenic and other oxyanions typically associated with volcanism (molybdenum, vanadium) as well as the general decrease in arsenic contamination away from this formation strongly support this hypothesis.

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## **APPENDIX I: Arsenic Geochemistry**

## I-1 Introduction

Behavior of all chemical elements is dependent upon environmental conditions, mainly represented by pH and redox (Eh) conditions. By definition, a low pH represents an abundance of H<sup>+</sup>, whereas a high pH is characterized by scarce H<sup>+</sup>. Natural water pH values range from 5 to 9. Oxidizing conditions are characterized by a high Eh (>400 mV). They can be associated with acidic, neutral, or alkaline pH values. On the other hand, reducing conditions, characterized by a low (<100 mV) or negative Eh, tend to be associated with neutral to alkaline conditions (this is because reduction reactions often tend to consume H<sup>+</sup>). By definition, trace chemical elements, such as arsenic, do not control pH and Eh. They will be under the chemical form/species directed by thermodynamics to be the most stable under those conditions. As will be seen later, thermodynamics equilibrium is not always reached for kinetics reasons (slow reaction rate).

The geochemistry of arsenic is complex because of the possible coexistence of two or even three redox states (-III, III, V), because of the rich chemistry of organo-arsenicals, and because of the strong interaction of most arsenic compounds with soil particles, particularly iron oxides (and to a lesser degree, aluminum and manganese oxides). The fully deprotonated arsenate AsO<sub>4</sub>-<sup>3</sup> is the expected form of arsenic in most soils under aerobic conditions only at high pH (Figure 1). At more neutral and acid pH levels, the HAsO<sub>4</sub><sup>-2</sup> and H<sub>2</sub>AsO<sub>4</sub><sup>-1</sup> forms, respectively, are dominant. The general understanding of arsenic mobility in soil and aquifers is that it will increase with increasing pH and phosphate concentration and with decreasing clay and iron oxide content. A more thorough discussion of arsenic sorption is presented in Appendix I. As pH increases, the negative charge of the arsenate ion increases, making it less likely to sorb on negatively charged soil particles. Phosphates have a chemical structure very similar to that of arsenates and sorb to soils preferentially under some conditions. Nitrogen also belongs to the same periodic table group (Va) but does not show the same competing behavior as phosphate. Other structurally similar oxyanions, such as sulfate and selenate, are also weak sorbers. Under less oxidizing conditions, the arsenite ion  $H_3AsO_3$  is most stable. The lack of charge renders the ion more mobile and less likely to sorb to soil particles. Its pH stability spread ranges from very acidic to alkaline. The first deprotonated form  $H_2AsO_3^{-1}$  exists at significant concentrations only above a pH of approximately 9 (Table 10). The redox processes seem to be mediated by microorganisms (Welch et al., 2000) and to occur next to mineral surfaces.

Under even more reducing conditions, arsenide is the stable ionic form of arsenic. Arsenic has a complex geochemistry with sulfur, both in solution where several thioarsenic ions can form and in the associated minerals. Arsenic metal -As(0)- rarely occurs. Methylated arsenic compounds are generally present at low aqueous concentrations (<1 ug/L), if at all, except maybe when there is an abundance of organic matter (Welch et al., 2000). If not of anthropogenic origin, their formation from inorganic substrates, however, is not thermodynamically favored (Pierce and Moore, 1980) and requires the intervention of organisms (arsenic is often metabolized to render it less toxic). Methylated arsenic compounds are stable in both oxic and reducing environments (Stollenwerk, 2003). The standard Eh of the couple As(V)/As(III) is close to 0 at pH=7, that is, between the Fe<sup>2+</sup>/Fe<sup>3+</sup> and SO<sub>4</sub>-<sup>2</sup>/H<sub>2</sub>S couples (Figure 77).

As(V) and As(III) minerals are fairly soluble and do not control arsenic solubility in oxidizing and mildly reducing conditions, except maybe if barium is present (Henry et al., 1982a, p. 21). This is in contrast to other companion oxyanions not as mobile under reducing conditions, except vanadium. In reducing conditions, As precipitates as arsenopyrite (FeAsS) but more commonly in solid solution with pyrite. Realgar (AsS) and orpiment (As<sub>2</sub>S<sub>3</sub>) require a high sulfur activity and are unlikely in the southwestern Gulf Coast and High Plains. There are more than 500 As-containing minerals, but because of their relatively high solubility, arsenate minerals are typically confined to mining districts, particularly those containing copper, lead, and zinc. The most common arsenate mineral is probably scorodite (FeAsO<sub>4</sub>.2H<sub>2</sub>O). However, scorodite is stable only under a small range of acidic pH values. More generally, during the mineral-forming process, arsenate ion associates itself most frequently with trace metals. Notable minerals include  $Zn_2(AsO_4)(OH)$  (adamite) and  $Co_3(AsO_4)_2.8H_2O$  (erythrite), Arsenate can also substitute for phosphate in apatite and other phosphate minerals (e.g.,  $Ca_5(AsO_4)_3CI$  or  $Ca_5(AsO_4)_3OH$ ) A thermodynamic database distributed with the geochemical modeling code PHREEQC gives a reaction constant of logK = -17.81 for  $Ca_3(AsO4)_2$ , used as an insecticide in the early 1900's. Assuming a reasonable molar concentration in calcium of 2 mmol/L, the lowest arsenic concentration at which precipitation might occur is 2 mg/L.

Distribution coefficient  $K_d$  (L/kg),  $K_d = C_s/C_w$ , where  $C_s$  (mg/kg) and  $C_w$  (mg/L) are concentrations in solid and water, respectively, is a common way to quantify how much arsenic is sorbed to a soil. As discussed later, it is not the best way to model arsenic distribution between solid particles and aqueous phase. Total concentration  $C_T$  and water concentration are then related by

$$C_T = C_w \left( K_d + \frac{\theta_w}{\rho_b} \right)$$

where  $\theta_w$  and  $\rho_b$  are water content and bulk dry density, respectively. Distribution coefficient data for arsenic were computed and gathered by EPA (EPA, 1996, Part 2, p. 40). The coefficient, in the average conditions assumed by EPA, varies linearly from 25 to 31 L/kg for pH values from 4.9 to 8, respectively. For an average porosity of 25 percent and a water saturation of 50 percent, this translates into an additional 9 L/kg to the  $K_d$  for the concentration ratio. Distribution coefficients for specific minerals are listed in Smedley and Kinniburgh (2002, Table 6).

Phosphorus commonly exists under only one valence state, P(V), in natural conditions. Orthophosphate ( $PO_4^{-3}$ ) is the final dissociation product of phosphoric acid ( $H_3PO_4$ ). The most common ionic form of phosphate in natural conditions is  $H_2PO_4^{-1}$ . Condensed forms of phosphates, including polyphosphates, are not stable in water and degrade to phosphate. Phosphate sorbs strongly to oxides, as well as to organic and clay phases. Polyphosphates are strong metal ligands. Phosphate concentration is controlled by apatite (complex calcium phosphate). Fertilizers can increase phosphate concentration in water by several orders of magnitude.

## I-2 Oxyanions and Other Related lons

In many geochemical environments, arsenic is regionally associated with selenium, molybdenum, vanadium, and uranium (Smedley and Kinninburgh, 2002 and, e.g., for Texas, Lee, 2005). There is a well-dcumented association of uranium deposits with those trace elements (e.g., Guilbert and Park, 1986, p.912). It can be seen in the roll-front uranium deposits of the western United States (Wyoming, Colorado, Texas). Volcanic ash is the accepted mineralization source. Uranium and other trace elements are leached by oxidizing and ~neutral pH water and transported downgradient and/or downdip by migrating groundwater until reducing environments are encountered. All those elements share the property of being soluble in oxidizing conditions and insoluble in reducing conditions. Other trace elements, such as iron and manganese, have the opposite characteristics. Reduced Fe(II) is soluble, whereas Fe(III) precipitates as iron oxide in oxidizing conditions (~neutral and alkaline pH levels). Similarly, manganese Mn<sup>+2</sup> is soluble for a larger pH range at reduced Eh. Other light volatile elements, such as fluoride, boron, and beryllium, are also typically found with acidic (rhyolitic) volcanism

and are frequently associated with those oxyanions. They accumulate in the acidic volcanic melt because they do not enter the structure of feldspars and other higher temperature minerals. They typically end up as accessory minerals in intrusive rocks unless they are released during volcanic events. The next few paragraphs give a short review of the behavior of these elements (Se, Mo, V, U, F, B, Be) as well as that of phosphate. Table 10 displays the pH range of stability for the different oxyanions. The pKa is the pH at which the concentrations of the protonated and deprotonated forms are equal.

Selenium has a chemistry similar to that of sulfur, existing naturally in four redox states VI, IV, 0, and –II, with selenate, selenite, and selenide ions occurring in Eh-pH conditions largely parallel to those of arsenic. In oxic conditions, the selenate ion,  $SeO_4^{-2}$ , is the dominant species across all natural pH levels. In slightly reducing conditions, the selenite ion exists from the fully deprotonated form,  $SeO_3^{-2}$ , at alkaline pH levels to the neutral  $H_2SeO_3$  at acid pH values and the  $HSeO_3^{-1}$  form at neutral pH. However, there are several differences with arsenic. The selenate ion is a weak sorber, and its behavior more closely resembles that of sulfate than that of arsenate ion (White and Dubrovsky, 1994). Organo-selenium compounds and possibly native selenium are also more widespread. The standard Eh values for redox couples Se(VI)/Se(IV) and Se(VI)/Se(-II) are ~450 and ~-100 mV, respectively (Figure 77). All selenate and selenite minerals are highly soluble. Native selenium or more likely ferroselite (pyrite with some Se substituted for S) can precipitate at high Eh (~100 mV) at neutral pH. However, kinetics issues may keep selenium in solution even at reducing Eh levels (Henry et al., 1982a, p. 21). No controlling minerals for selenium solubility have been observed in the Gulf Coast.

Molybdenum exists naturally in two redox states: Mo(VI) and Mo(IV). The molybdate ion Mo (VI) ( $MoO_4^{-2}$ ) is stable across all natural pH levels but the most acidic. Mo(IV) is present mainly in molybdenite  $MoS_2$ . Molybdate ion sorbed onto iron oxides and is displaced by arsenate and phosphate. The only common molybdenum mineral is molybdenite ( $MoS_2$ ). Ilsemannite ( $Mo_3O_8$ ) has also been described in the southwestern Gulf Coast. It typically forms a low pH for the Mo concentrations considered in this study. Molybdenite typically forms at Eh lower than -200 mV (Henry et al., 1982a, p. 18). Both minerals are insoluble but do not control the Mo chemistry in the southwestern Gulf Coast because pH is generally neutral to alkaline and reducing conditions so low are rare.

The geochemistry of uranium is complicated in the details but can be summarized by the following. Uranium(VI) in oxidizing conditions exists as the soluble positively charged uranyl  $UO_2^{++}$ . Solubility is higher at acid pH levels, decreases at neutral pH, and increases slightly at alkaline pH. However, the uranyl ion, to the contrary of oxyanions, can easily form aqueous complexes, including with hydroxyl, fluoride, carbonate, and phosphate ligands. Hence, in the presence of carbonates, uranium solubility is considerably enhanced in the form of uranyl-carbonate ( $UO_2CO_3$ ) and other higher order carbonate complexes: uranyl-di- and uranyl-tricarbonates ( $UO_2(CO_3)_2^{-2}$  and  $UO_2(CO_3)_3^{-4}$ ). Adsorption of uranium is in inverse proportion to its solubility and is highest at neutral pH (De Soto, 1978, p. 11). Uranium(IV) is the other commonly found redox state. In that state, however, uranium has low solubility and precipitates as uraninite,  $UO_2$ , coffinite,  $USiO_4.nH_2O$  (if  $SiO_2>60$  mg/L, Henry et al., 1982a, p.18), or related minerals. In the southwestern Gulf Coast, there is no mineral controlling uranium solubility in oxidizing conditions. However, uranite and coffinite are the controlling minerals if the Eh drops below 0-100 mV.

Vanadium naturally exists in three different redox states: V(III), V(IV), and V(V). V(III) is present only in extremely reducing environments and most likely precipitates as V(OH)<sub>3</sub> or VO(OH) (Wanty and Goldhaber, 1992). V(IV) generally forms vanadyl cations VO<sup>+2</sup> (low pH) and VO(OH)<sup>+1</sup> (higher pH). V(V), in the form of vanadate  $-H_2VO_4^{-1}$  and  $HVO_4^{-2}$ , sometimes written as  $VO_2(OH)_2^{-1}$  and  $VO_3(OH)^{-2}$ -, is expected to be prevalent in well-oxygenated systems, but both V(IV) and V(V) are often present together. Vanadyl ions are strongly sorbed by organic

and oxide phases. Vanadate ions form strong inner-sphere complexes with iron oxides (Peacock and Sherman, 2004). Although vanadate minerals have been described in the south Texas uranium province, no reduced vanadium minerals have been found. Vanadium sulfides are rare, and reduced vanadium generally integrates crystal structure of other minerals such as titaniferous magnetite. Both minerals are unlikely in the southwestern Gulf Coast, and no mineral is controlling vanadium concentration.

Phosphorus commonly exists under only one valence state, P(V), in natural conditions. Orthophosphate ( $PO_4^{-3}$ ) is the final dissociation product of phosphoric acid ( $H_3PO_4$ ). The most common ionic form of phosphate in natural conditions is  $H_2PO_4^{-1}$ . Condensed forms of phosphates, including polyphosphates, are not stable in water and degrade to phosphate. Phosphate sorbs strongly to oxides, as well as to organic and clay phases. Polyphosphates are strong metal ligands. Phosphate concentration is controlled by apatite (complex calcium phosphate). Fertilizers can increase phosphate concentration in water by several orders of magnitude.

Fluorine exists naturally in solution under one valence,  $F^-$ , the fluoride ion. Fluoride tends to make complexes and ion pairs with trace elements. It can also sorb significantly to oxides, especially aluminum oxides, and clays (Hem, 1985, p. 121). Its concentration is controlled by calcium, as fluorite (CaF<sub>2</sub>) is the most common fluorine mineral. Apatite can also contain a significant amount of fluorine. Fluorine accumulates in felsic rocks, as well as in sedimentary rocks with the order shale>carbonate>sandstone (Hitchon et al., 1999).

Borate is the only natural form of boron in solution. Orthoboric acid,  $H_3BO_3$ , has a pKa of ~9.2 and occupies most of the Eh-pH diagram (Hitchon et al., 1999). Boron is an essential constituent of tourmaline, an accessory mineral highly resistant to weathering. Boron is a frequent component of volcanic gases. Borate can sorb to clays and metal oxides, but minerals controlling its solubility precipitate only in a saline lake type of environment. Beryllium is a rather rare element occurring typically at concentrations <1 ug/L and is found naturally as Be(II) and related aqueous complexes.

**Figure 77** presents the redox ladder or the order in which the trace elements would precipitate in given conditions, assuming instantaneous reactions. At ~neutral pH, the precipitation order is selenium (0,-II)  $\approx$  uranium (IV)> molybdenum (IV) > arsenic (-II) > vanadium (III). Molybdenum and arsenic solubility at low pH are a strong function of sulfur activity. More genrally the order can be altered depending on other ions present in the solution.

#### I-2 Surface Complexation

The geochemistry of arsenic is largely impacted by sorption on particles also called surface complexation. Chemists usually make a distinction between weak sorption (or physisorption or outer complex sorption) and strong sorption (or chemisorption or inner complex sorption). The latter involves true chemical bonds between the sorbate and the sorbent, whereas the former entails electrostatic interactions. Surface complexation can be modeled with empirically derived isotherms for a given set of experimental conditions. Arsenic sorption on goethite has been fitted to experimental data with a Langmuir isotherm (Pierce and Moore, 1980) and with a Freundlich isotherm. However, experimental isotherms are not as general as theoretically derived surface complexation models and are not as suitable to predict adsorption behavior outside of the range of experimental data. The double-layer model presented in Dzombak and Morel (1980) and implemented in several geochemical codes, including the U.S. Geological Survey PHREEQC numerical code, is widely used. An understanding of transport of arsenic in porous media necessitates a thorough knowledge of the sorbing materials exposed to fluid flow.

## I-2.1 Release Mechanisms

It has been known for a long time that aqueous ions interact with soil or aquifer particles, particularly organic matter, clays, and metal oxides. Soil particles and, in particular, metal oxides have pH-dependent surface charges. A surface includes broken bonds that readily interact with water molecules generating strongly binding OH-type groups. These groups are amphoteric. At lower pH levels, the OH<sub>2</sub><sup>+</sup> group is dominant, whereas at relatively higher pH, the group O<sup>-</sup> is the dominant form. In between, there is a pH where both groups are numerically balanced, leading to a globally neutral surface at the ZPC (Zero-Point of Charge; also called isoelectric point; terminology depends on the method used to measure it). Anion sorption decreases past the ZPC of the surface. ZPCs are generally in the 2-5 pH range for silicates, including most clays, leading to mostly negatively charged surfaces in the subsurface. In contrast, iron oxides have a ZPC in the 7-9 range, positioning them as strong anions sorbents except for the highest natural pH. An example describing surface hydrolysis reactions that was extracted from the PHREEQC database follows:

Hfo-OH + H<sup>+</sup> = Hfo-OH<sub>2</sub><sup>+</sup>  $\log(K_1) = pK_{a1} = 7.29$ Hfo-OH = Hfo-O<sup>-</sup> + H<sup>+</sup>  $\log(K_2) = -pK_{a2} = -8.93$ 

 $pH_{ZPC}=0.5(pK_{a1}+pK_{a2})=8.11$ 

These pKas are intrinsic values that do not account for electrostatic interactions (this is automatically done in the code). Note that ZPCs can be complexly affected by other ions present in the solutions and that ZPC values usually given strictly apply for minerals in pristine conditions with no sorbing ions besides  $H^+$ . ZPCs can be shifted by background ions. For example, Appelo et al. (2002) suggested that carbonate sorption on ferrihydrite moves the ZPC of oxides to lower values. The same observation was made experimentally by Lumsdom and Evans (1994) on pristine goethite in a pure N<sub>2</sub> environment where the theoretical ZPC of ~9.5 can be shifted to values <8 in simpler operational conditions.

Carbonates also have a ZPC in the high pH range. They, however, lack significant specific surface area. Iron oxides, on the other hand, are characterized by high specific surface areas, as high as that of clays, especially if they are amorphous or small grained. Hydrated ferric oxides "Hfo" are very high specific area iron oxides and are particularly active just after genesis and precipitation. The same group includes amorphous iron oxides and other ill-defined species such as ferrihydrite ( $\sim$ Fe<sub>5</sub>HO<sub>8</sub>.4H<sub>2</sub>O). They age to goethite and other FeOOH oxides with a lower specific surface. Hematite (Fe<sub>2</sub>O<sub>3</sub>) is typically more crystalline and has a specific surface lower by a factor of ~10. Experiments tend to prove that the "fresher" and the more hydrated the oxide, the higher the As sorption (Smedley and Kinniburgh, 2002). This aspect of arsenic chemistry is well exploited in some water treatment plants where arsenic removal is handled by first oxidizing any As(III) to As(V), more likely to sorb, and by the introduction of ferric salts that evolves into fresh high specific surface area ferric hydroxides scavenging arsenate ions during the coagulation/flocculation/filtration treatment. An alternative is activated alumina. Direct adsorption on oxides or activated carbon is also used.

Several theories tackle the surface-ion interactions, including some developed by Dzombak and Morel (1990) (diffuse double-layer surface complexation model). They suggested that the chemistry of adsorption on iron oxide surfaces is ultimately adequately modeled by an acid-base model whose reaction constant is corrected by local electrostatic factors. The model input, as implemented in PHREEQC, requires the mass of oxide per unit mass of water, the specific surface area of the oxide, and the density of active sites. Dzombak and Morel (1990) estimated adsorption site density at 0.2 mole/mole of iron (the so-called weak sites Hfo\_w). An additional less numerous set of sites was deemed necessary to fit their experimental data for cations (the so-called strong sites Hfo\_s). Their density was estimated at 0.005 mole/mole of iron. They also suggested a typical specific surface area of 600 m<sup>2</sup>/g of Hfo, defined as FeOOH; this translates

into ~53x10<sup>3</sup> m<sup>2</sup>/mole of Fe. Dixit and Hering (2003) suggested a similar site density for all iron oxides; they would differ only by their specific surface area and by their intrinsic reaction constant. For a stoichiometric formula of FeOOH and a specific surface area of 600 m<sup>2</sup>/g, a site density of 0.2 and 0.005 mol/mol Fe for weak and strong sites, respectively, translates into a site density of 3.84 umol/m<sup>2</sup>. Stollenwerk (1995) found that the average site density of ~50 aquifer cores was 3.33 umol/m<sup>2</sup>, in agreement with recommendation by Dzombak and Morel (1990). The sorption sites were attached to coatings of Fe and Al oxides on quartz and feldspar grains.

In aqueous systems where arsenic anions are the main sorbates, arsenite sorption does not display large variations in the normal pH range and is slightly higher for neutral pH and maybe alkaline pH. Sorption drops beyond the first pKa of H<sub>3</sub>AsO<sub>3</sub> at ~9.2. Arsenate anions sorb most effectively at pH below 7, and then the fraction sorbed decreases to small values (Manning and Goldberg, 1996; Figure 1 of Wilkie and Hering, 1996, who experimented with [As]~100 mg/L). At higher As concentrations (1000's of ppm), work by Raven et al. (1998) suggest that this general model still holds, although arsenite is now more sorbed than arsenate.

Aluminum oxides follow the same general model of high arsenate sorption at pH<7, progressively decreasing as the pH becomes more alkaline (experiments by Halter and Pfeifer, 2001, with [As]~ppm's). However, at equivalent surface area, they sorb more arsenate than iron oxides, particularly at higher pH because of their higher ZPC (~9.5 for amorphous aluminum hydroxides; Manning and Golberg, 1996). In a modeling exercise with their own Al data and Fe data from Dzombak and Morel (1990), Halter and Pfeifer (2001) found that iron oxides sorbed more than Al oxides only at pH<4. They also suggested that  $\alpha$ -Al<sub>2</sub>0<sub>3</sub> (corundum) is a good proxy for arsenic sorption on clays because of the similarity of their mineralogical structure. Lin and Wu (2001) looked at sorption of both arsenite and arsenate on activated alumina across the pH range and also found that the general model is similar to that of sorption on iron oxides.

Manganese oxides have a low ZPC (around 2-3) and are negatively charged in most natural conditions. They sorb little arsenate but some arsenite (because the molecule is not charged). More complex mechanisms are involved, in particular arsenite oxidation and manganese reduction. Silica (SiO<sub>2</sub>) ZPC is around 2. Silica has been described as barely sorbing arsenic (Stollenwerk, 2003). Carbonates have also been observed sorbing arsenic (Stollenwerk, 2003). Calcite has a ZPC of approximately 9, suggesting positive charges on the surface. On the other hand, their specific surface area is low.

Clay charges are thought to be due to substitution of  $AI^{+3}$  for tetrahedral  $Si^{+4}$  or  $Mg^{+2}$  for octahedral  $AI^{+3}$ , creating a pH-independent deficit of negative charges, typically covered by metal cations. Clays can also sorb anions, especially at the edges of their planar structure where hydroxyl groups can be found (Sposito, 1984). However, because clay ZPCs are typically less than 5, substantial sorption on clays is expected only in acidic conditions. In any case, studies by Roddick-Lanzilotta (2002) suggested that kaolinite does not sorb much As, and when it does, the latter is easily washed off. Wenzel et al (2001) suggested that arsenic sorption on clay follows the following model: As[mg/kg]=12.2exp(0.0057xCEC[mmol\_c/kg]) [mmol\_c = mmol of charge = milliequivalent].

Although organic matter binds metals strongly, it does not seem to play a large role in arsenic inorganic processes. Organic matter is often negatively charged and does not interact readily with anions. Soluble organic molecules may enhance or interfere with As sorption. Bowell (1994) found that fulvic acids compete with arsenates for sorption sites on iron oxides.

The amounts sorbed to different media can be reconstructed by doing a sequential extraction of arsenic on the samples. Within the limits of the extraction techniques, Wenzel et al. (2001) determined that the median fractions of arsenic for 20 Austrian As-contaminated soils in the following states—within the solid phase, sorbed onto well-crystallized hydrous Fe and Al

oxides, sorbed onto amorphous and poorly crystallized hydrous Fe and Al oxides, and more lightly sorbed and readily labile (likely weak physisorption on oxides and clays)—were 17.5%, ~29%, ~42%, and ~10%, respectively. The arsenic concentration ranged from 96 to 2,183 mg/kg with a median of 259 mg/kg. The mean soil composition was ~18% clay and 0.053% carbon on a mass basis. The mean Cation Exchange Capacity (CEC) is 184 mmol<sub>o</sub>/kg. The average iron and aluminum oxide fraction is 0.5% Fe and 0.2% Mn on a mass basis. Despite abundant clay, most of the arsenic is sorbed on the metal oxides.

### I-2.2 Competition in Surface Complexation

In natural waters, many types of ions coexist, several possibly competing for the same absorption sites. The final coverage of the surface depends essentially on two parameters: the relative abundance of each ion and their relative attraction to the surface. More generally, sorption phenomena follow the general chemistry principle of mass action. Equilibrium results of competing sorbates is function of the sorption strength of the individual sorbates but also of the sorbate ratio. For example, at some pH levels, arsenates sorb more strongly than phosphates on iron oxides but phosphate concentration is much higher, resulting in most sites being occupied by phosphate anions. Those competing aspects are captured by the modeling software.

Common anions in the subsurface are sulfates and (bi)carbonates, to which can be added nitrates and phosphates in agricultural areas. Other common aqueous species, such as silica, can also impact arsenic absorption. Trace elements, in particular those forming oxyanions (Mo, Se, V), can also compete for the same sites and may locally affect the As-soluble fraction. Many other aqueous components present in groundwater have been suggested to have some effect on arsenic sorption on soil particles; dissolved organic matter has been described as having some negative impact on As sorption on hematite (Redman et al., 2002), especially for As(III). Some chemical elements, such as calcium, may increase the sorbing capacity of soil particles because they create additional positive charges (cationic bridges) favorable to As sorption. In most studies, nitrates and sulfates had no impact on arsenic sorption. Nitrate (Meng et al., 2000, table 1) and sulfates form weak outer sphere complexes.

Manning and Goldberg (1996) and Hiemstra and Van Riemsdijk (1999) looked at the complexity of oxyanion interactions in surface complexation. Both arsenate and phosphate ions behave very similarly relative to sorption on iron oxides. In an agricultural context, phosphates are applied in the form of polyphosphates and progressively degrade to orthophosphates. They can then be adsorbed by plants and also be sorbed by oxides. Introduced in a clean medium in the same molar concentration, it appears that Al-based groups (gibbsite, kaolinite) preferentially sorb phosphates, whereas iron and manganese oxides preferentially sorb arsenates (Violenta et al., 2002; Manning and Goldberg, 1996). Welch et al. (2000) mentioned several instances where phosphate fertilizers displaced sorbed arsenic from soils. Peryea and Davenport (1991) and Peryea and Kammereck (1997) did columns studies on impact of phosphates on arsenic-contaminated soils. They found that arsenic desorbed by phosphate would move downward but sorb again on deeper subsoil.

Carbonate ions have also been suspected of displacing arsenate but at a much smaller scale (Goh and Lin, 2005), although Meng et al. (2000) found that carbonate has no effect on arsenic sorption. Carbonate sorption on HFO was investigated by Appelo et al. (2002). They suggested that sorption of carbonate ions by iron oxides is more widespread than commonly recognized. Swedlund and Webster (1999) found that silica adsorption on ferrihydrite does compete for adsorption sites with arsenate, and not so much for arsenite, especially at high alkaline pH (>9), where arsenate adsorption is at the lowest and silica adsorption at its highest. Meng et al. (2000) also found silica to negatively impact arsenic adsorption.

## **I-3 Kinetics**

Thermodynamics can only suggest what spontaneous reactions are permissible. It does not provide information on how fast a reaction will proceed. This is the realm of mainly experimentbased kinetics. According to Raven et al. (1998), who experimented with arsenic aqueous concentrations on the order of 50 to a few hundred ppm, adsorption on fresh ferrihydrite is completed within a few hours. They found that arsenite sorption is faster at higher arsenic concentrations, but arsenate is faster at low concentrations and low pH. Lombi et al. (1999), experimenting with natural soils and [As]~100 mg/L, suggested that the equilibrium was reached in 5 days and also that arsenite sorbs faster.

Sorption kinetics are important in the presence of competing sorbates because one can sorb faster and occupy more sites than it should relative to equilibrium. It will then take time for it to desorb and reach true equilibrium. Desorption kinetics is generally slower than adsorption ("aging"), that is, sorption is not fully reversible or slower than adsorption, as observed in many contaminated sites. Lomdi et al. (1999) noted that in an extraction sequence after 1, 10, and 30 days, less and less As was released by the weak extractants, suggesting that the bonds were getting stronger.

Redox reactions are generally microbially mediated. Redox kinetics for As(III) to As(V) can take a few days, whereas As(V) to As(III) can take a few weeks/months. Stollenwerk noted that As(III) tends to be metastable in an oxic environment and that oxidation to As(V) could take years in the presence of only atmospheric oxygen. Other inorganic oxidants (Fe<sup>3+</sup>, Mn), however, increase the rate of oxidation. In reducing environments, reduction of As(V) to As(III) is faster. Manganese oxide can mediate oxidation of As(III) to As(V) (Tournassat et al., 2002; Manning et al, 2002). This transformation has not been observed for goethite (Wilkie and Hering, 1996, p. 104). Manning and Goldberg (1996) suggested that kaolinite and illite have catalytic abilities in redox reactions of As(III) to As(V).

## I-4 Geochemical Data

All geochemical numerical modeling is strongly dependent on the conceptual model, but also, in a less obvious fashion, on the thermodynamic database used for the simulations. The PHREEQC modeling software (Parkhurst and Appelo, 1999) is included with three thermodynamic databases: wateq4f, minteq, and EQ3/6. Arsenic inorganic aqueous species are few. Unlike most metals, oxyanions do not form complexes in solution with ions such as Cl<sup>-</sup>,  $SO_4^{-2}$ , OH<sup>-</sup>,  $CO_3^{-1}$  or  $HCO_3^{-1}$  common in typical natural water conditions (F<sup>-</sup> may be an exception). In strongly reducing environments, combinations with sulfur at different redox states add complexity to the arsenic aqueous chemistry. Homogeneous aqueous reaction constants are reasonably well known and consistent in the different databases, as well as with the published literature. In contrast, if, overall, adsorption studies are in general gualitative agreement (but not always), they are somewhat conflicting in their result on the pH having the highest adsorption and on the value of the intrinsic reaction constant. The generalized double-layer model used to fit experimental data simplifies very complex processes and does not capture all aspects, even if experimentally understood. Experiments are done at different temperatures, at different ionic strengths, at different arsenic and other sorbate concentrations, and using diversely prepared sorbents.

The wate4f database has been recently updated (Nordstrom and Archer, 2002) and contains thermodynamic data for  $H_3AsO_4$ ,  $H_3AsO_3$  and derived anions, as well as ions  $H_4AsO_3^+$  ( $H_nAsO_4^{n-3}$ , n=0 to 4;  $H_nAsO_3^{n-3}$ , n=0 to 4). Data for required solid phases, such as hydrated calcium arsenate, are also given, as well as sorption data on iron oxides for arsenate, arsenite, and phosphates. The EQ3/6 and Minteq databases show similar but slightly different information (Table 19). None of the databases provides information on organo-arsenicals.

# APPENDIX II: The Uranium Province of South Texas and Other Uranium Showings

## Uranium Province of South Texas

The Gulf Coast hosts numerous uranium deposits, particularly in Live Oak, Karnes, and Duval counties. Their grade ranges from 0.04 to 0.30 percent  $U_2O_3$  with individual deposits containing 500-10,000 tons  $U_2O_3$  (Reynolds and Goldhaber, 1983; Finch, 1996) for a cumulative resource of ~100,000 tons  $U_2O_3$  (Finch, 1996), of which one third has been produced (Finch, 1997). They are found in the Whitsett Fm. of the Jackson Group of late Eocene age, in the Oligocene Catahoula tuffs, and in the Miocene Oakville sandstone, as well as in the Pliocene Goliad sands (Henry et al., 1982b, p. 6 and Figure 78)

Mineralization consists of iron sulfides (pyrite and marcasite in variable proportions) at 1-2% weight (Fishman et al., 1982; Goldhaber and Reynolds, 1977). Uranium is found in the form of oxide (uraninite,  $UO_2$ ) or silicate (coffinite,  $USiO_4.nH_2O$ ). In association with the mineralization, selenium, molybdenum, and arsenic are also found. The Lamprecht deposit (Live Oak County) yields hundreds to thousands of ppm of uranium and a few hundreds of ppm of selenium in the mineralized section. Native selenium has been observed in the nearby Felder mine (Eargle et al., 1975). No arsenic or vanadium is associated with this deposit. When deposits are brought to the surface by erosion, as in the Karnes County area, oxidized ore comprises iron oxides, uranyl calcium phosphate and vanadate (Eargle et al., 1975), uranium silicates (boltwoodite, weeksite, uranophane), and some uranium oxides (schoepite).

The origin of the deposits has been described in many publications, including Hobday and Galloway (1999), Guilbert and Park (1986), Galloway (1982), Galloway et al. (1982), and Galloway and Kaiser (1980). The deposits result from the movement of oxidizing waters carrying uranium and other oxyanions into a reducing environment. The reducing conditions were created by carbonaceous material (Fisher et al., 1970, p.257), authigenic sulfide, dissolved H<sub>2</sub>S and/or CH<sub>4</sub> leakage along contemporaneous growth faults from underlying hydrocarbon accumulations, and/or previous pyrite mineralization, also thought to have been created by earlier H<sub>2</sub>S leakage, as demonstrated by sulfur isotope studies (Goldhaber et al., 1978) or Mesozoic sulfidic water leakage (Galloway, 1982). Leakage of H<sub>2</sub>S is still active, as shown by the odor in some mines (Eargle et al., 1975). Hydrogen sulfide leakage seems to be the trap for most deposits in the Oakville sandstone, whereas organic matter in lignite seems to have played a larger role in the late Eocene deposits (Ilger et al., 1987) and Catahoula deposits (Galloway, 1977, p. 45). Reductants intrinsic to the depositional system, e.g., organic matter or primary pyrite, are more likely present in finer grained facies. In that case, mineralization will occur near permeability contrasts. Conversely, an exogen reductant will be transported through the most permeable zones where the mineralization will also be found (Hobday and Galloway, 1999).

Oxidizing waters flowing downdip along permeable sandstone layers create the well-known roll-front morphology where a tongue of oxidized water progressively invades the reduced section of the aquifer. The mineralization occurs at the generally sharp interface. However, the detailed depositional history can be more complex. In some Gulf Coast deposits, a later phase of resulfidization, probably corresponding to another discharge from a fault, can alter the previously oxidized zone and mask the previous morphology. The mineralization can also be exposed to surficial conditions. The sulfides are then oxidized and trace elements remobilized.

Some deposits show a chromatographic separation of trace metals relative to their position on the redox ladder. Selenium typically precipitates first at higher Eh than uranium; thus, higher selenium concentrations occur behind the front, whereas molybdenum precipitates ahead of the uranium mineralization because molybdenite (MoS<sub>2</sub>) requires a lower Eh to form (Galloway,
1982, his Figure 12; see core analyses in Fishman et al., 1982). At the Lamprecht deposit (Live Oak County), the gradation occurs in 100-200 m.

The host formations include the basal sands of the Miocene Oakville Fm. and the Catahoula tuffs (=Gueydan) and the upper section of the underlying Jackson Group of Eocene age (e.g., Whitsett Fm.). Some deposits are also found in the Pliocene Goliad Fm. (Finch, 1996). One controlling factor for mineralization in the Eocene Whitsett Fm. of the Jackson Group is whether the Frio Clay, a downdip marine clay facies, is present to separate the Catahoula and Whitsett units. The fact that, where present, the Jackson is typically not mineralized suggests that the mineralization is at least Oligocene and that the Whitsett was merely used as a high-transmissivity conduit (Figure 21 of Galloway et al., 1979).

The source of uranium and other trace elements is volcanic ash (Galloway and Kaiser. 1980). Ash layers are thought to have contained 10-15 ppm of uranium, about half of which was leached during pedogenesis or later (Ledger et al., 1984). The volcanic rocks at the emission centers in west Texas also contained uranium concentration at 5-6 ppm (Ledger et al., 1984), about twice the average concentration for igneous rocks. Uranium could be sorbed onto glass shards and crystals. It is then readily leached. This process is thought to be minor. Uranium may also be disseminated in the groundmass and is then released at a later time during devitrification and recrystalization (De Soto, 1978, p.66). Volcanic ash has a high specific surface area favorable for leaching. Leaching releases trace elements under oxidizing mildly alkaline conditions in a dry climate. Uranium solubilization is most effective in the thick, aerated unsaturated zone (Hobday and Galloway, 1999). The evidence of this statement lies in the reduced uranium content of most acidic ash layers in the Gulf area relative to their counterparts elsewhere. It is also supported by an increase in the thorium/uranium ratio because thorium does not leach as easily (Dickinson, 1976). Some ash layers preserved in reducing lacustrine environments also show higher uranium content. Ash can be directly deposited aerially. It can also be reworked and deposited as tuffaceous material in an aqueous environment shortly after aerial emplacement. Most layers are currently degraded to clays and zeolites. Ledger et al. (1984) also suggested that uranium leaching continues far later than pedogenesis. In particular, leaching of uranium from volcaniclastics in the southwestern Gulf Coast is still occurring, especially during calichification and its typical higher pH and carbonate concentration.

Mineralization of layers older than the Catahoula Fm. could be explained by local ash beds of the same age or by leaching of uranium from the Catahoula Fm. during pedogenesis by recharging waters. Uranium in younger formations could result from general cross-formational flow or reworking of older accumulations. Galloway et al. (1982) contrasted the Oakville sands in this region and concluded that the generally higher TDS and uranium mineralization of South Texas is due to the higher fault density in the south, allowing more reducing material, as well as deep brines, to invade the aquifer. Galloway and Kaiser (1980, p. 18-19) also suggested that in the Catahoula Fm. of East Texas, more abundant recharge may dilute uranium concentration in groundwater, limiting downdip accumulations. The higher precipitation regime can also increase rejected recharge, in effect, shunting the accumulation engine (Galloway, 1977, p. 48). The uranium-rich solution would then be discharged to the ocean through stream base flow. Had the precipitation been lower in Gueydan times, deep recharge would have been too small to generate economic accumulations.

In addition, despite important lignite deposits earlier in the stratigraphic section, no economical uranium accumulation is associated with them. Large low-grade uranium deposits are associated with lignite in the western United States. The source for these deposits seems to be interbedded volcanic tuffs.

#### Uranium Showings in the Texas Panhandle:

Minor production (~1 ton  $U_2O_3$ ) is recorded from Triassic sandstones of the Texas Panhandle and Tertiary rocks of the Hagan Basin in New Mexico (Finch, 1997). Finch (1975) stated that uranium anomalies have been found across the stratigraphic section from the Dockum to the Pleistocene. The Trujillo sandstone in the Dockum Group has yielded 800 tons of ore near the town of Post in Garza County, southeast of Lubbock on the Llano Estacado. McGowen et al. (1979) displayed a map of grab samples from a campaign in the Dockum. Most samples having concentrations >10 ppm are in Garza County, and some are in the Palo Duro Canyon area. A single occurrence of uranium-vanadates minerals in the Edwards limestone of Upton County has also been reported (Eargle, 1956).

McGowen at al. (1977) compiled gamma-ray information from Dockum cores outside of the outcrop areas. They noticed numerous anomalies (their Figures 43 to 47) but mainly in the Midland basin, not on the Central platform. They postulated (p. 69) that a positive structural feature was oxidizing and maybe periodically recharging basinward sandstone aquifers during the Triassic Period. The anomalies are diffuse over large areas and were attributed to the presence of uranium. Contemporary sources for Triassic volcanites have been described east, south, and west of the current outline of the formation (McGowen at al., 1977, p. 77). In addition, the age of the mineralization has not been well constrained. Another hypothesis is leaching of Cretaceous volcanites or shales before deposition of the Ogallala Fm. Ash layers of Ogalalla age are also a possible source, according to McGowen at al. (1977). The Dockum section of the Delaware Basin on the western side of the Central Platform does not exhibit any anomaly (McGowen at al., 1977, p. 69). McGowen et al. (1977, p. 78) concluded their study by stating that the uranium concentration in the Dockum is most likely derived from leaching of Ogallala ash layers and downward flow, especially in the valley fills where the Ogallala is the thickest.

#### Uranium Showings in Central and East Texas

There are some uranium mineralization or radioactivity anomalies in the Catahoula Fm. of Central and East Texas (Galloway, 1977, Plate III; Ledger, 1981).

# APPENDIX III: Evaluation of Geophysical Logs to Determine Potential Sources of Contaminants in the High Plains

#### Introduction

A preliminary survey of geophysical well logs recorded in the Ogallala Formation in the Southern High Plains indicated potential occurrences of locally extensive, anomalously radioactive shale beds. These beds were interpreted to record local accumulations of volcanicash-rich shales, probably in lacustrine (lake) environments. Volcanic ash contains potassium-40 (a radioactive isotope that decays to argon), as well as uranium. Radioactive decay of these and associated isotopes allows volcanic ash to be used for geologic-age-dating. Volcanic ash has been observed in the Ogallala section in Potter County, Texas (Capeda, 2001) and Nebraska (Rose and others, 2003). Younger volcanic ashes also occur. There is a 10-my record of volcanic ash in the High Plains, the source of which has been suggested to be in the Yellowstone area of northern Wyoming (Izett, 1977). It was observed during this investigation that greater numbers of these beds occurred in the southern parts of the study area than in the north and that, coincidentally, greater relative numbers of water wells with elevated arsenic levels also occurred in the south. Volcanic materials have been shown to be a natural source for arsenic. Therefore, it was decided to further investigate the apparent correspondences between groundwater arsenic concentrations and presumed volcanic ash distribution in the Ogallala of the Southern High Plains.

#### Data and Methods

Over 700 geophysical well logs procured from the well log library of the Bureau of Economic Geology and the Surface Casing Unit of the Texas Commission on Environmental Quality were reviewed. These logs represented geologic sections from 21 counties (**Figure 58**). Approximately 250 of these logs had gamma ray responses recorded for sufficiently thick portions of the Ogallala for the purposes of evaluating presence or absence of elevated gamma ray values. The criteria for usefulness of a given well log were 1) an anomalously elevated gamma ray value was generally defined as one that exceeded 100 API units; 2) that logging began within 8 m (25 ft) of the ground surface for logs that showed no anomalously elevated gamma ray values; and 3) that logging began within 30 m (100 ft) of the surface for logs that did show anomalously elevated values.

The gamma-ray value criterion was applied somewhat subjectively because it was obvious that not all of the well logs had been calibrated to the same standards. All logs were not of the same vintage. In the end a gamma ray value was deemed to be anomalous if it exceeded values for other shale beds in the upper 300 m (1000 ft) of geologic section, which also included Cretaceous and Triassic strata. Also, ash-rich beds less than 2 ft thick may not have produced gamma-ray-log responses that achieved full expression of their actual radioactivity. The second criterion assured that most of the Ogallala was measured prior to judging it free of volcanic beds. Most of the Ogallala is overlain by varying thicknesses of overburden, including the Blackwater Draw Formation and other alluvial material. The third criterion recognized that it was important only that a volcanic bed was observed in the Ogallala, not that it occurred in any predefined part of the section.

An attempt was made to provide as spatially consistent data coverage as was possible. Some counties have hundreds of hydrocarbon-prospective boreholes while others have few. The distribution of well data that was collected should be adequate to detect local concentrations of volcanic ash of such extent as to justify further investigation to determine the boundaries of the deposits.

#### **Results**

The presence of anomalously elevated gamma ray values for strata within the Ogallala Formation was observed in logs from approximately 110 of the 250 locations for which data were gathered (Figure 58). The most areally extensive occurrences are in Andrews, Gaines, and Yoakum Counties, based on contour mapping of data that was classified according to bed thickness. Three bed-thickness classes were defined: greater than 5 ft thick, 1-5 ft thick, and 0 ft thick (no ash bed present). Contour mapping, in this instance, suggests lateral continuity of the geologic setting between data points. For example, if two data points show indications of the presence of an ash bed then any point between them (if data were available for the point) would also show presence of an ash bed. There is no implication that individual ash beds are laterally continuous between locations, although this is more likely between closer-spaced data locations. In other words: contours envelop areas within which ash beds are expected to have been deposited, but not necessarily at the same time in all places within the contour envelope. If ash beds are a source of arsenic, then the areas within contour envelopes are suggested to mark areas within which potential arsenic sources occur.

Groundwater arsenic generally is more concentrated in the southern than in the northern parts of the Southern High Plains (Figure 44). There appears to be some association between estimated accumulations of interpreted volcanic ash and occurrences of elevated arsenic beneath them and down hydraulic gradient toward the southeast. These associations may indicate that arsenic-bearing constituents may have been extracted from ash deposits and are being transported by groundwater advection. Sparcity of volcanic-ash indicators (elevated gamma-ray responses) in more northern areas and coincident overall with lower levels of arsenic is strongly suggestive that the volcanic deposits and elevated groundwater-arsenic in the south are interrelated. The following section will test this hypothesis.

#### Mass Balance Computation

In order to assess the possibility of arsenic leaching from Ogallala-age ash beds, a crude mass balance was performed. The total mass of arsenic currently contained in the southern region of the southern High Plains is 1.2×10<sup>6</sup> kg. This calculation assumes an average saturated thickness of 15 m with a porosity of 0.15 and an average arsenic concentration of 20 ug/L over an approximate area of 25,000 km<sup>2</sup>. If the reasonable value of 500 for the number of pore volumes that went through the aquifer in the past 5 millions years, and the assumption that the average arsenic concentration has stayed constant since sediment deposition are used. approximately  $0.57 \times 10^9$  kg of arsenic have exited the aquifer through seeps and springs on the escarpment. The footprint of the operationally-defined ash beds (mainly in Gaines and Yoakum counties) is approximately 4,900 km<sup>2</sup>. The beds are assumed continuous with an average thickness of 1 m. A total volume for the ash beds of 4.9×10<sup>9</sup> m<sup>3</sup> follows. Assuming a arsenic content of 6 mg/kg and that half of it is leached, the total mass released is 0.033×10<sup>9</sup> kg. This mass falls short by one order of magnitude of the amount required. It can however be almost matched if one assumes that the arsenic was leached when the ash covered the whole area (most of it would have washed away to the Gulf of Mexico and only relicts remained within the Ogallala Fm.) and that upgradient areas in New Mexico also provided arsenic.

#### Conclusions

The apparent association between distribution of groundwater arsenic and anomalously elevated radioactivity in Ogallala Fm. is intriguing and merits additional investigation. More stratigraphic and hydrochemical data should be analyzed than was allowed within the scope of this work. Hundreds of additional well-logs are available that may allow more detailed stratigraphic and geographic mapping of interpreted volcanic ash deposits. A lower cutoff of gamma ray values for inclusion in the thickness map would more completely capture the geographical extent of lake deposits that contain ash material at presumably lower

concentrations than were mapped for this survey. Stratigraphically controlled hydrochemical surveys may allow precise identification of Ogallala strata that convey arsenic-bearing groundwater. Use of stable isotopes may clarify the actual geologic source of arsenic, which conceivably could be Cretaceous (Edwards-Trinity aquifer) or Triassic (Dockum aquifer) strata.

## **APPENDIX IV: Soil Sampling Results**

The following tables display results from the soil sampling campaign. In Table IV.1, chemical analyses are posted with 2 significant digits. Units are kg/kg for water content and mg/kg for other columns. Analyses from nitrite, nitrate, sulfate, and phosphate represent the ion, not the chemical element. Table IV.2 includes texture analyses for sampled boreholes. In Table IV.3, method 1 indicates a matric potential measurement made with a UMS model T5 Tensiometer; method 2 indicates a water potential measurement made with a Decagon model WP4 psychrometer.

Sample	Bore	Depth	Water							
ID .	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO <sub>3</sub>	SO <sub>4</sub>	PO₄
05-001	A1	0.08	0.020	4.1	1.7	0.0	0.1	0.4	1.7	0.2
05-002	A1	0.38	0.031	4.3	0.8	0.1	0.1	0.5	1.3	3.1
05-003	A1	0.69	0.061	1.8	0.8	0.0	0.2	0.3	0.9	0.2
05-004	A1	0.99	0.076	1.3	1.2	0.0	0.1	0.5	15.9	0.1
05-005	A1	1.30	0.092	2.1	1.3	0.2	0.4	0.5	94.4	1.1
05-006	A1	1.60	0.073	1.5	14.4	0.2	0.3	6.7	104.1	0.2
05-007	A1	2.21	0.032	4.2	19.4	0.1	0.3	0.4	43.6	0.4
05-008	A1	2.97	0.039	3.1	26.6	0.2	0.4	0.7	113.7	0.1
05-009	A2	0.08	0.021	9.7	2.0	8.0	1.1	1.6	6.2	0.5
05-010	A2	0.38	0.046	15.5	0.5	7.1	0.8	0.7	1.8	0.0
05-011	A2	0.69	0.069	19.2	0.4	8.5	0.8	0.9	9.9	0.0
05-012	A2	0.99	0.058	24.5	0.9	8.4	0.8	0.6	27.7	0.0
05-013	A2	1.30	0.039	19.1	0.7	12.4	0.5	0.1	65.0	0.0
05-014	A2	1.60	0.044	19.1	2.8	9.7	0.5	0.0	107.3	0.0
05-015	A2	2.21	0.065	26.0	34.1	7.4	0.4	1.6	205.3	0.1
05-016	A2	2.82	0.061	24.1	30.6	9.1	0.3	1.2	37.3	0.0
05-017	A2	3.43	0.070	33.9	24.2	9.2	0.3	1.2	38.1	0.0
05-018	A2	4.04	0.100	28.6	21.4	10.7	0.5	1.5	37.2	0.0
05-019	A2	4.65	0.066	14.5	13.5	10.1	0.2	1.4	33.9	0.0
05-020	A2	5.26	0.038	16.4	12.0	5.6	0.2	0.0	26.2	0.0
05-021	A2	5.87	0.099	71.9	36.0	6.5	0.1	0.0	91.5	0.0
05-022	A2	6.48	0.066	77.0	31.4	0.2	0.0	0.2	112.1	0.6
05-023	A2	7.09	0.071	36.6	53.0	0.4	0.1	0.1	203.0	0.5
05-024	A2	7.70	0.155	23.0	202.7	1.5	0.3	0.2	523.8	0.3
05-025	A2	8.31	0.136	13.1	180.6	1.6	0.2	0.3	496.7	0.2
05-026	T1	0.08	0.073	3.6	1.0	0.1	0.0	12.7	8.2	0.7
05-027	T1	0.38	0.093	5.8	0.3	0.0	0.2	5.1	10.9	0.5
05-028	T1	0.69	0.109	4.5	0.4	0.1	0.8	1.3	21.0	0.3
05-029	T1	0.99	0.108	3.3	0.7	0.2	0.6	1.4	31.7	0.1
05-030	T1	1.30	0.140	2.1	1.2	0.4	0.4	1.9	86.3	0.0
05-031	T1	1.60	0.140	3.8	1.0	0.3	0.5	4.6	98.4	0.0
05-032	T1	2.21	0.109	4.2	1.4	0.3	0.3	31.2	30.3	0.1
05-033	T1	2.82	0.136	14.0	0.9	0.2	0.4	11.0	42.9	0.1
05-034	T1	3.43	0.130	15.2	0.4	0.3	0.3	3.6	69.6	0.1
05-035	T1	4.04	0.120	14.7	0.5	0.1	0.1	7.4	119.8	0.4

Table IV.1 Chemical analyses of soil core samples

Sample	Bore	Depth	Water							
ID .	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO <sub>3</sub>	SO₄	PO₄
05-036	T1	4.65	0.172	29.0	1.0	0.2	0.3	12.0	236.1	0.1
05-037	T1	5.26	0.131	16.9	1.4	0.0	0.2	8.8	335.3	0.5
05-038	T1	5.87	0.141	17.2	4.6	0.0	0.3	10.8	485.9	0.0
05-039	T1	6.48	0.126	14.4	14.3	0.2	0.1	13.6	401.9	0.1
05-040	T1	7.09	0.083	16.8	19.7	0.2	0.1	12.0	248.8	0.1
05-041	T2	0.08	0.197	3.1	0.9	0.1	0.6	12.8	15.0	0.6
05-042	T2	0.38	0.183	8.1	0.5	0.1	0.2	3.8	5.4	1.2
05-043	T2	0.69	0.211	3.0	0.7	0.1	0.6	12.6	14.6	0.6
05-044	T2	0.99	0.127	20.2	0.5	0.2	0.4	0.9	2.2	7.2
05-045	T2	1.30	0.163	32.6	0.6	0.0	0.1	0.1	1.5	6.6
05-046	T2	1.60	0.184	30.9	0.5	0.2	0.3	0.1	1.9	4.3
05-047	T2	2.21	0.183	64.3	1.1	0.1	0.5	0.1	4.8	2.8
05-048	T2	2.82	0.199	203.5	0.4	0.6	0.5	0.1	7.4	1.0
05-049	T2	3.43	0.226	99.2	0.7	0.1	0.7	0.6	20.5	0.6
05-050	T2	4.04	0.160	78.6	0.4	0.0	0.3	0.3	8.3	1.7
05-051	T2	4.65	0.126	59.3	0.4	0.2	0.2	0.3	6.4	1.8
05-052	T2	5.26	0.117	59.6	0.5	0.1	0.2	0.3	6.6	0.6
05-053	T2	5.87	0.213	0.6	1.0	0.0	0.1	1.0	43.3	0.1
05-054	T2	6.48	0.228	0.7	1.5	0.2	0.2	1.7	12.8	0.1
05-055	T2	7.09	0.204	4.6	1.0	0.2	0.2	1.0	24.6	0.1
05-056	T2	7.70	0.127	4.8	0.6	0.0	0.1	0.4	15.4	0.1
05-057	T2	8.31	0.114	5.7	0.4	0.1	0.1	0.5	18.2	0.1
05-058	T2	8.92	0.099	7.1	0.6	0.1	0.1	0.4	14.8	0.1
05-059	Т3	0.08	0.070	45.0	4.0	0.2	1.9	6.7	6.9	10.5
05-060	Т3	0.38	0.063	18.3	1.9	0.1	0.9	5.2	9.1	1.7
05-061	Т3	0.69	0.104	4.2	2.6	0.3	1.2	1.5	35.7	0.2
05-062	Т3	0.99	0.107	2.8	3.3	0.3	1.1	1.6	235.3	0.1
05-063	Т3	1.30	0.197	4.3	62.3	0.9	1.3	42.7	1127.7	0.0
05-064	Т3	1.60	0.157	2.3	243.7	0.1	0.7	31.8	504.7	0.0
05-065	Т3	2.21	0.147	4.5	116.8	1.1	0.8	21.7	198.7	0.1
05-066	Т3	2.82	0.124	8.0	37.8	0.5	0.5	13.2	78.5	0.0
05-067	Т3	3.43	0.114	24.8	25.0	0.2	0.6	12.3	31.1	0.1
05-068	Т3	4.04	0.103	34.4	21.3	0.2	0.4	11.8	22.6	0.2
05-069	Т3	4.65	0.121	29.4	26.4	0.3	0.5	13.4	11.6	0.1
05-070	Т3	5.26	0.109	35.7	24.7	0.3	0.2	11.5	28.7	0.3
05-071	Т3	5.87	0.128	41.1	20.0	0.2	0.2	8.5	23.1	0.1
05-072	Т3	6.48	0.116	54.4	13.0	0.5	0.2	4.8	20.5	1.3
05-073	Т3	7.09	0.090	62.1	6.1	0.1	0.1	2.1	11.1	0.6
05-074	Т3	7.70	0.136	43.6	7.5	0.4	0.1	2.0	13.8	0.1
05-075	Т3	8.31	0.110	30.0	4.4	0.1	0.0	1.1	13.7	0.1
05-076	Т3	8.92	0.109	16.5	3.4	0.4	0.1	0.8	22.8	0.1
05-077	Т3	9.53	0.092	11.4	2.4	0.3	0.1	0.5	15.5	0.1
05-078	Т3	10.13	0.080	20.1	1.2	0.1	0.1	0.4	30.1	0.1
05-079	Т3	10.74	0.072	8.2	0.8	0.1	0.0	0.3	28.1	-
05-080	Т3	11.35	0.088	17.0	1.1	0.3	0.1	0.4	21.0	0.1
05-081	Т3	11.96	0.087	24.0	1.1	0.2	0.1	0.3	11.6	0.1
05-082	Т3	12.57	0.064	10.4	1.3	0.2	0.1	0.4	13.5	0.1
05-083	T4	0.08	0.054	33.2	46.4	0.1	1.5	8.9	64.1	7.4

Sample	Bore	Depth	Water							
ID .	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO <sub>3</sub>	SO <sub>4</sub>	PO <sub>4</sub>
05-084	T4	0.38	0.042	62.2	2.7	0.0	0.2	1.4	10.0	54.8
05-085	T4	0.69	0.052	2.1	2.2	0.2	0.5	0.8	21.4	0.1
05-086	T4	0.99	0.043	2.1	4.5	0.0	0.4	0.5	23.5	0.2
05-087	T4	1.30	0.101	1.4	4.2	0.0	0.8	0.7	107.2	0.0
05-088	T4	1.60	0.162	0.4	19.1	0.1	0.5	1.1	663.0	0.0
05-089	T4	2.21	0.127	0.5	115.7	0.4	0.3	8.7	368.7	0.0
05-090	T4	2.82	0.158	3.1	375.6	6.8	1.1	19.6	212.7	
05-091	T4	3.43	0.153	2.5	288.3	7.7	0.7	11.4	73.2	0.0
05-092	T4	4.04	0.123	1.7	176.6	4.0	0.5	7.2	86.0	0.0
05-093	T4	4.65	0.147	2.2	97.0	4.2	0.3	5.3	126.3	0.0
05-094	T4	5.26	0.156	3.8	55.7	4.1	0.2	4.5	122.3	0.0
05-095	T4	5.87	0.083	1.7	21.0	3.4	0.1	2.7	63.9	0.0
05-096	T4	6.48	0.107	4.3	23.0	3.7	0.0	3.7	53.5	0.0
05-097	T4	7.09	0.110	2.0	28.2	3.4	0.2	4.6	64.1	0.1
05-098	T4	7.70	0.135	2.3	42.4	5.6	0.2	7.0	73.2	0.0
05-099	T4	8.31	0.147	6.1	60.3	6.2	0.5	8.8	116.2	0.0
05-100	T4	8.92	0.123	3.7	58.4	5.8	0.2	7.1	106.3	0.4
05-101	T4	9.53	0.170	5.5	71.2	6.2	0.1	7.6	156.0	0.3
05-102	T4	10.13	0.115	3.5	36.4	3.7	0.2	4.6	122.9	0.0
05-103	L1	0.08	0.099	6.5	1.7	0.5	0.8	5.1	5.5	0.2
05-104	L1	0.38	0.130	1.3	0.9	0.4	0.7	1.9	21.5	0.0
05-105	L1	0.69	0.124	0.6	0.8	0.3	0.5	0.9	16.7	0.0
05-106	L1	0.99	0.098	1.2	1.1	0.6	0.6	0.6	8.4	0.0
05-107	L1	1.30	0.124	1.3	0.6	0.3	0.5	0.9	24.7	0.1
05-108	L1	1.60	0.118	2.1	0.4	0.4	0.6	0.9	58.6	0.1
05-109	L1	2.21	0.136	9.9	1.6	0.6	0.3	3.4	69.2	0.1
05-110	L1	2.82	0.115	15.9	2.7	0.8	0.3	10.2	56.2	0.1
05-111	L1	3.43	0.201	37.1	7.6	0.9	0.4	5.4	141.4	0.1
05-113	L1	4.65	0.156	28.8	55.8	0.7	0.3	22.5	390.5	0.1
05-114	L1	5.26	0.119	12.6	75.3	0.4	0.2	20.1	409.4	0.1
05-115	L1	5.87	0.128	9.9	114.5	0.5	0.3	18.0	738.4	0.1
05-116	L1	6.48	0.089	7.3	127.3	0.7	0.1	7.3	319.1	0.1
05-117	L1	7.09	0.084	5.6	154.4	0.6	0.1	3.2	321.1	0.1
05-118	L1	7.70	0.099	18.9	181.2	0.8	0.2	1.5	270.3	0.1
05-119	L1	8.31	0.101	17.7	212.2	0.8	0.2	0.8	279.7	0.1
05-120	L1	8.53	0.078	5.5	163.3	0.5	0.2	0.4	220.4	0.0
05-121	B1	0.08	0.119	4.2	0.6	0.4	0.9	8.7	3.4	0.2
05-122	B1	0.38	0.119	0.7	0.4	0.1	0.5	2.2	1.4	0.6
05-123	B1	0.69	0.121	1.0	0.3	0.8	1.0	1.1	4.2	0.0
05-124	B1	0.99	0.112	1.6	0.4	0.3	1.3	1.0	7.6	0.1
05-125	B1	1.30	0.112	2.3	0.2	0.1	0.8	1.0	18.3	0.1
05-126	B1	1.60	0.122	3.5	0.3	0.2	0.8	0.8	25.3	0.0
05-127	B1	2.21	0.109	3.8	0.4	0.2	0.4	0.5	33.5	0.6
05-128	B1	2.82	0.093	7.6	0.5	0.1	0.3	0.8	26.1	0.1
05-129	B1	3.43	0.106	4.1	1.7	0.3	0.6	5.3	40.2	0.1
05-130	B1	4.04	0.141	11.0	0.7	0.1	0.3	4.6	79.7	0.1
05-131	B1	4.65	0.126	12.1	0.4	0.0	0.2	0.7	138.0	0.1
05-132	B1	5.26	0.136	7.2	0.4	0.1	0.3	0.7	438.2	0.1

Sample	Bore	Depth	Water							
ID .	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO <sub>3</sub>	SO <sub>4</sub>	PO <sub>4</sub>
05-133	B1	5.87	0.127	5.9	0.5	0.1	0.2	0.6	460.8	0.1
05-134	B1	6.48	0.107	19.4	0.6	0.0	0.1	0.5	384.6	0.3
05-135	B1	7.09	0.128	16.1	1.5	0.0	0.1	0.8	502.4	0.2
05-136	B1	7.70	0.120	17.4	4.0	0.1	0.2	1.2	529.9	0.4
05-137	B1	8.31	0.105	10.6	11.8	0.1	0.2	2.5	507.8	0.2
05-138	B1	8.92	0.096	15.5	32.6	0.2	0.2	4.4	447.2	0.2
05-139	B1	9.53	0.084	7.2	51.2	0.2	0.1	4.7	376.2	0.2
05-140	B1	10.13	0.088	4.5	96.2	0.5	0.1	5.4	407.0	0.2
05-141	B1	10.74	0.083	4.8	110.9	0.5	0.2	4.0	333.6	0.2
05-142	B1	11.35	0.100	3.9	164.0	0.7	0.1	2.9	331.1	0.0
05-143	B2	0.08	0.097	4.5	2.4	4.5	1.1	15.4	6.3	0.3
05-144	B2	0.38	0.155	1.6	0.9	4.0	0.1	1.5	6.0	0.1
05-145	B2	0.69	0.121	0.8	1.0	10.2	0.4	1.7	27.2	0.0
05-146	B2	0.99	0.127	0.8	0.8	7.6	0.6	1.3	47.3	0.0
05-147	B2	1.30	0.129	3.6	0.7	8.0	0.4	0.8	25.8	0.0
05-148	B2	1.60	0.127	6.9	0.6	8.8	0.5	0.7	25.0	0.0
05-149	B2	2.21	0.123	17.4	0.3	13.5	0.4	0.1	45.8	0.0
05-150	B2	2.82	0.131	13.5	7.2	8.8	0.4	0.6	224.6	0.1
05-151	B2	3.43	0.145	14.4	19.0	7.6	0.2	0.7	418.5	0.0
05-152	B2	4.04	0.166	18.2	86.2	4.1	0.4	4.4	346.9	0.0
05-153	B2	4.80	0.136	10.8	42.3	7.9	0.3	0.9	521.2	0.6
05-154	B2	5.26	0.109	10.0	45.9	6.7	0.3	0.9	365.6	0.0
05-155	B2	5.87	0.087	8.1	120.6	2.7	0.5	3.4	235.1	0.0
05-156	B2	6.17	0.068	3.4	93.6	2.3	0.3	3.0	167.4	0.0
05-157	G1	0.08	0.064	6.2	6.5	0.2	1.5	18.4	28.4	0.7
05-158	G1	0.38	0.085	4.6	0.9	0.1	1.0	6.4	3.7	0.4
05-159	G1	0.69	0.101	2.4	1.0	0.3	0.6	0.9	5.8	1.2
05-160	G1	0.99	0.102	2.7	1.9	0.2	0.4	0.9	9.4	0.0
05-161	G1	1.30	0.492	14.2	9.2	0.6	1.5	2.6	71.7	0.3
05-162	G1	1.60	0.155	9.9	3.9	0.3	0.4	2.7	57.2	1.0
05-163	G1	2.21	0.180	10.4	51.4	1.2	0.5		130.5	0.2
05-164	G1	2.82	0.123	6.9	84.1	0.5	0.0	3.0	332.9	0.2
05-165	G1	3.43	0.168	8.9	149.9	0.9	0.2	6.2	602.8	0.2
05-166	G1	4.04	0.201	17.7	191.1	1.3	0.3	10.4	712.9	0.0
05-167	G1	4.65	0.153	17.2	88.2	0.7	0.5	4.8	381.5	0.3
05-168	G1	4.95	0.162	15.9	88.2	0.6	0.4	4.5	364.0	0.0
05-169	G2	0.08	0.101	5.6	0.7	0.3	0.1	1.7	3.5	2.3
05-170	G2	0.38	0.052	5.9	0.5	0.4	0.0	1.0	1.5	1.0
05-171	G2	0.69	0.084	2.2	0.3	0.5	0.1	0.8	3.4	0.3
05-172	G2	0.99	0.102	2.2	0.4	3.0	0.4	0.5	15.1	0.1
05-173	G2	1.30	0.072	1.1	0.3	3.7	0.4	0.4	17.8	0.1
05-174	G2	1.60	0.084	1.6	0.3	2.6	0.4	0.6	31.4	0.1
05-175	G2	2.21	0.111	3.7	1.4	0.9	0.7	25.6	12.5	0.1
05-176	G2	2.82	0.126	7.9	1.1	4.2	0.3	12.5	15.8	0.1
05-177	G2	3.43	0.060	6.8	0.4	5.9	0.2	3.7	22.2	0.0
05-178	G2	4.04	0.079	9.9	0.4	5.4	0.2	2.6	26.2	0.0
05-179	G2	4.65	0.084	13.7	0.4	7.4	0.2	2.0	13.1	0.1
05-180	G2	5.26	0.156	23.3	0.5	10.3	0.2	2.1	20.2	0.1

Sample	Bore	Depth	Water							
ID	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO₃	SO <sub>4</sub>	PO <sub>4</sub>
05-181	G2	5.87	0.103	23.0	0.5	8.5	0.2	1.5	19.6	0.1
05-182	G2	6.48	0.090	37.2	0.5	8.2	0.2	1.4	27.1	0.2
05-183	G2	7.09	0.079	14.3	0.5	6.4	0.0	1.3	162.2	0.1
05-184	G2	7.70	0.066	9.6	0.6	4.2	0.0	2.0	3035.2	0.0
05-185	G2	8.31	0.102	8.0	1.6	3.1	0.1	4.7	2530.1	0.1
05-186	G2	8.92	0.125	9.3	2.7	0.6	0.2	5.3	485.8	0.0
05-187	G2	9.53	0.135	3.3	35.5	0.1	0.1	15.0	514.9	0.0
05-188	G2	10.13	0.200	8.8	145.1	0.4	0.3	12.3	664.5	0.0
05-189	G2	10.74	0.178	5.8	137.0	0.3	0.2	8.6	471.4	0.0
05-190	H1	0.08	0.071	39.2	1.2	1.6	0.6	4.6	4.6	1.2
05-191	H1	0.38	0.114	11.3	0.1	6.3	0.6	1.8	2.3	0.1
05-192	H1	0.69	0.132	5.5	0.2	6.9	0.5	1.4	8.3	0.0
05-193	H1	0.99	0.129	4.5	0.4	6.2	0.4	1.6	25.2	0.0
05-194	H1	1.30	0.123	5.1	0.2	6.5	0.5	1.5	39.4	0.0
05-195	H1	1.60	0.122	4.9	0.2	0.1	0.4	3.0	25.3	0.1
05-196	H1	2.21	0.119	6.1	1.3	0.3	0.2	30.2	17.2	0.1
05-197	H1	2.97	0.124	18.9	1.1	0.2	0.3	18.6	28.1	0.1
05-198	H1	3.43	0.171	49.9	0.6	0.2	0.2	5.4	36.7	0.3
05-199	H1	4.04	0.127	74.5	0.8	0.1	0.2	1.6	28.6	0.2
05-200	H1	4.65	0.116	76.8	0.4		0.1	1.0	58.8	0.2
05-201	H1	5.26	0.149	34.4	0.5	0.2	0.2	1.5	83.1	0.2
05-202	H1	5.87	0.160	22.3	0.7	0.3	0.4	1.7	112.8	0.2
05-203	H1	6.17	0.130	52.7	0.8	0.1	0.6	1.0	78.0	0.2
05-204	H2	0.08	0.107	34.8	0.4	0.3	1.3	3.2	11.7	0.3
05-205	H2	0.38	0.156	3.2	1.1	0.1	1.0	5.2	60.0	0.1
05-206	H2	0.69	0.115	3.8	6.0	0.6	0.5	43.9	76.8	0.1
05-207	H2	0.99	0.153	4.1	51.3	0.6	0.5	92.5	158.3	0.1
05-208	H2	1.30	0.152	6.3	185.3	0.8	0.2	96.7	313.2	0.1
05-209	H2	1.60	0.146	10.9	288.0	1.7	0.5	64.6	402.2	0.1
05-210	H2	2.21	0.089	10.5	258.8	1.0	0.3	25.6	280.2	0.1
05-211	H2	2.82	0.069	0.0	203.6	0.8	0.1	8.1	206.6	0.0
05-212	H2	3.43	0.072	0.8	185.7	0.7	0.2	3.5	203.0	0.1
05-213	H2	4.04	0.069	0.8	184.7	0.6	0.3	2.2	154.6	0.1
05-214	H2	4.65	0.071	0.9	196.9	0.8	0.1	1.9	115.2	0.1
05-215	H2	5.26	0.071	0.6	213.7	0.8	0.1	1.8	96.2	0.1
05-216	H2	5.87	0.078	1.9	265.8	0.9	0.1	1.9	109.9	0.1
05-217	H2	6.48	0.076	2.4	274.5	0.9	0.1	1.9	116.1	0.0
05-218	H2	7.09	0.068	3.9	224.3	0.8	0.1	1.7	117.5	0.0
05-219	H2	7.70	0.071	3.9	263.0	1.1	0.1	2.0	122.5	0.1
05-220	H2	8.31	0.031	2.2	121.6	0.4	0.0	1.0	63.0	0.0
05-221	D1	0.08	0.060	35.9	1.0		1.5	6.7	7.2	1.6
05-222	D1	0.38	0.083	34.8	0.2		0.2	4.0	2.6	1.1
05-223	D1	0.69	0.134	7.4	0.4		0.7	2.3	3.5	0.1
05-224	D1	0.99	0.118	8.3	0.2		0.6	3.1	5.2	0.8
05-225	D1	1.30	0.132	5.0	0.1		0.5	1.5	5.3	0.0
05-226	D1	1.60	0.134	4.2	0.1		0.5	0.9	4.2	0.0
05-227	D1	2.21	0.144	2.8	0.5		0.3	0.9	20.5	0.0
05-228	D1	2.82	0.106	23.0	1.2		0.3	2.4	42.5	0.0

Sample	Bore	Depth	Water							
ID .	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO₃	SO <sub>4</sub>	$PO_4$
05-229	D1	3.43	0.170	7.7	0.5		0.1	2.3	24.1	0.0
05-230	D1	4.04	0.065	9.3	0.4		0.2	1.0	25.5	0.0
05-231	M1	0.08	0.055	32.8	0.2		0.5	3.4	1.9	1.1
05-232	M1	0.38	0.086	2.4	0.2	8.0	0.4	1.4	1.5	0.1
05-233	M1	0.69	0.081	2.4	0.1	5.2	0.1	0.8	0.7	0.1
05-234	M1	0.99	0.154	0.1	0.2	6.3	0.2	0.7	1.0	0.0
05-235	M1	1.30	0.205	3.2	0.2	9.4	0.7	1.4	12.0	0.0
05-236	M1	1.60	0.168	4.4	0.2	8.7	0.7	3.0	20.6	0.0
05-237	M1	2.21	0.133	8.4	0.3	8.5	0.2	2.3	6.7	0.0
05-238	M1	2.82	0.125	17.8	0.3	8.4	0.2	2.1	4.4	0.0
05-239	M1	3.43	0.134	13.4	0.8		0.5	3.5	7.1	0.0
05-240	M1	4.04	0.128	13.9	1.2	7.7	0.2	2.7	7.1	0.0
05-241	M1	4.65	0.123	27.4	0.7	8.4	0.2	2.4	7.0	0.1
05-242	M1	5.26	0.119	16.8	0.5	8.0	0.2	1.4	6.9	0.0
05-243	M1	5.87	0.114	15.6	0.4	8.0	0.1	1.5	18.4	0.0
05-244	M1	6.48	0.147	29.6	0.5	8.3	0.3	1.1	11.6	0.0
05-245	M1	7.09	0.131	22.8	0.5	8.3	0.3	1.4	30.5	0.0
05-246	M1	7.54	0.090	22.5	0.4	8.9	0.2	1.1	17.1	0.0
05-247	M2	0.08	0.125	29.6	2.0	0.2	4.4	13.1	10.1	2.3
05-248	M2	0.38	0.081	10.1	0.3	0.2	1.6	1.4	3.4	0.2
05-249	M2	0.69	0.087	9.8	0.3	0.3	1.6	1.1	13.7	0.2
05-250	M2	0.99	0.067	7.8	0.6	0.4	12	1.3	20.6	0.1
05-251	M2	1.30	0.079	4.2	0.2	0.2	0.9	0.5	41.6	•••
05-252	M2	1.60	0.077	6.8	0.7	0.2	0.9	1.0	36.1	0.1
05-253	M2	2.21	0.117	17.0	8.8	0.6	0.7	20.4	48.6	0.1
05-254	M2	2.82	0.102	3.4	5.6	0.4	0.3	16.0	84.4	0.1
05-255	M2	3.43	0.102	5.2	1.0	0.2	0.6	2.4	200.2	0.7
05-256	M2	4.04	0.088	11.7	6.3	0.1	0.3	1.3	212.3	1.1
05-257	M2	4.65	0.100	9.9	34.3	0.3	0.1	4.0	305.5	0.2
05-258	M2	5.26	0.074	6.6	36.9	0.2	0.1	3.7	186.5	0.2
05-259	M2	5.87	0.091	6.5	50.1	0.3	0.2	4.8	234.0	0.2
05-260	M2	6.48	0.079	8.0	75.1	0.5	0.2	6.7	162.8	0.2
05-261	M2	7.09	0.097	12.1	124.3	0.9	0.2	9.2	136.9	1.2
05-262	M2	7.70	0.077	13.6	111.8	0.7	0.1	6.4	65.9	0.2
05-263	M2	8.31	0.083	18.4	148.3	0.8	0.2	6.0	45.7	1.3
05-264	M2	8.92	0.105	22.6	192.5	1.1	0.3	5.8	64.6	0.2
05-265	M3	0.08	0.170	35.4	0.8		2.2	18.5	8.6	1.4
05-266	M3	0.38	0.101	34.0	0.2		0.8	2.0	2.0	0.1
05-267	M3	0.69	0.112	13.7	0.1		0.9	1.4	2.1	0.0
05-268	M3	0.99	0.148	6.0	0.3		0.6	1.2	4,7	5.7
05-269	M3	1.30	0.137	6.6	0.2	8.2	0.5	0.8	8.0	0.1
05-270	M3	1.60	0.117	7.2	3.7	8.7	0.4	0.7	2.8	0.1
05-271	M3	2.21	0.188	8.2	0.2	11.0	0.4	0.9	20.9	0.1
05-272	M3	2.82	0.172	11.0	0.2	10.9	0.2	0.9	3.2	0.1
05-273	M3	3.43	0.138	9.2	0.7	10.2	0.2	0.8	6.6	0.0
05-274	M3	4.04	0.155	97	0.5	90	0.3	0.8	22.4	0.0
05-275	M3	4 65	0 173	8.0	0.7	8.6	0.3	0.7	10.0	0.0
05-276	M3	5.26	0.153	8.7	0.2	8.0	0.2	0.6	8.9	0.0

Sample	Bore	Depth	Water							
ID	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO <sub>3</sub>	SO <sub>4</sub>	PO <sub>4</sub>
05-277	M3	5.87	0.112	5.7	0.1	7.5	0.2	0.5	17.6	0.0
05-278	M3	6.48	0.116	6.1	0.2	10.4	0.3	0.1	14.0	0.0
05-279	M4	0.08	0.092	20.1	1.0	0.1	1.2	11.8	5.5	0.8
05-280	M4	0.38	0.081	14.1	1.2	0.2	1.0	3.4	1.8	0.0
05-281	M4	0.69	0.136	3.7	0.3	0.2	1.2	1.4	6.1	0.1
05-282	M4	0.99	0.065	4.3	0.5	0.4	1.2	1.6	22.0	0.1
05-283	M4	1.30	0.084	3.4	1.3	0.1	0.9	1.9	25.6	0.1
05-284	M4	1.60	0.088	4.9	0.7	0.1	0.9	0.9	34.2	0.1
05-285	M4	2.21	0.110	2.8	1.0	0.1	0.2	1.0	43.0	0.8
05-286	M4	2.82	0.072	5.6	0.9	0.1	0.3	1.5	51.0	0.1
05-287	M4	3.43	0.137	6.7	8.0	0.3	0.3	11.9	70.2	0.2
05-288	M4	4.04	0.113	10.1	31.2	0.5	0.3	9.9	48.8	0.3
05-289	M4	4.50	0.080	10.2	51.6	0.5	0.3	4.9	48.2	0.5
05-290	DU1	0.08	0.093	0.7	43.7	2.1	0.0	0.2	43.4	0.0
05-291	DU1	0.38	0.086	72.3	38.5	2.8	0.0	0.3	27.7	0.1
05-292	DU1	0.69	0.074	63.3	32.8	2.3	0.1	0.2	18.0	0.1
05-293	DU1	0.99	0.013	81.6	2.7	2.6	0.1	0.7	1.7	3.4
05-294	DU1	1.30	0.128	99.9	146.8	12.6	0.3	0.4	28.9	0.3
05-295	DU1	1.60	0.132	123.7	106.5	12.9	0.2	0.3	35.3	0.2
05-296	DU1	2.21	0.116	49.9	164.5	11.9	0.3	0.3	29.8	0.2
05-297	DU1	2.82	0.125	122.7	86.9	13.7	0.3	0.5	102.2	0.1
05-298	DU1	3.43	0.127	96.4	88.3		0.3		159.1	0.2
05-299	DU2	0.08	0.052	4.6	16.6	10.7	2.3	2.9	9.3	0.3
05-300	DU2	0.38	0.062	5.4	7.5	9.3	0.5	1.6	7.8	0.1
05-301	DU2	0.69	0.071	5.0	7.7	8.5	0.4	1.0	3.7	0.0
05-302	DU2	0.99	0.079	4.5	7.1	7.5	0.2	0.9	9.3	0.1
05-303	DU2	1.30	0.077	2.9	11.9		0.4		31.5	0.1
05-304	DU2	1.60	0.061	4.4	8.7	7.5	0.1		56.3	0.0
05-305	DU2	2.21	0.133	17.9	398.5	8.5	0.8	0.3	159.7	0.0
05-306	DU2	2.82	0.142	68.8	360.3		1.6		347.1	0.0
05-307	DU3	0.08	0.039	5.9	7.2		2.3	10.2	12.5	0.2
05-308	DU3	0.38	0.072	3.6	7.0	8.4	1.5	2.8	15.1	0.1
05-309	DU3	0.69	0.073	3.7	8.0		1.3	6.8	28.4	0.0
05-310	DU3	0.99	0.067	4.4	12.5	7.2	1.3	2.1	43.2	0.0
05-311	DU3	1.30	0.061	3.4	44.1		0.9	4.6	65.1	0.0
05-312	DU3	1.60	0.052	2.8	24.0	6.2	0.7	11.9	17.3	0.0
05-313	DU3	2.21	0.058	3.0	31.2		0.3	31.3	14.4	0.0
05-314	HI1	0.08	0.024	138.1	14.1		2.1	5.8	8.3	18.4
05-315	HI1	0.38	0.039	301.2	6.1	7.5	0.1	1.4	2.8	23.4
05-316	HI1	0.69	0.054	719.2	9.7	11.1	0.2	1.4	8.4	14.9
05-317	HI1	0.99	0.058	613.0	5.6	13.4	0.2	1.7	9.0	46.6
05-318	HI1	1.30	0.071	1854.1	5.4	14.6	1.0	1.9	24.5	47.4
05-319	HI1	1.60	0.067	748.2	6.5	15.3	0.9	2.0	20.6	17.7
05-320	HI1	2.21	0.071	8.1	32.8		0.5	0.5	789.2	0.2
05-321	HI1	2.82	0.075	10.7	99.0		0.3	3.3	3103.3	0.1
05-322	HI1	3.43	0.089	11.9	281.1		0.3	21.1	2764.4	0.0
05-323	HI1	4.04	0.095	13.3	442.6		0.2	34.9	1699.1	0.1
05-324	HI1	4.65	0.104	27.2	540.4		0.1	36.4	504.3	0.7

Sample	Bore	Depth	Water							
ID .	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO₃	SO <sub>4</sub>	PO <sub>4</sub>
05-325	HI1	5.11	0.105	65.3	533.5		0.3	23.1	350.0	2.1
05-326	HI2	0.08	0.017	5.6	3.9	9.0	0.3	1.6	4.4	3.7
05-327	HI2	0.38	0.045	3.5	4.1	9.1	0.1	0.9	3.1	1.4
05-328	HI2	0.69	0.087	2.0	1.4	5.8	0.1	0.5	1.4	0.3
05-343	KE1	0.08	0.021	3.9	9.5	0.0	0.7	12.1	9.2	1.4
05-344	KE1	0.38	0.007	4.0	0.7	0.0	0.1	0.7	1.5	0.4
05-345	KE1	0.69	0.016	8.2	1.1	0.1	0.2	0.9	2.4	0.6
05-346	KE1	0.99	0.017	12.6	1.7	0.1	0.2	0.3	5.4	0.1
05-347	KE1	1.30	0.023	11.3	4.9	0.0	0.2	0.2	5.0	0.1
05-348	KE1	1.60	0.095	7.9	1.5	0.0	0.2	0.2	3.3	0.0
05-349	KE1	2.21	0.064	29.8	0.4	0.0	0.2	0.1	2.0	0.1
05-350	KE1	2.82	0.062	7.3	2.2	0.1	0.2	0.1	5.2	0.1
05-351	KE1	3.43	0.017	12.3	1.2	0.0	0.2	0.1	1.9	0.4
05-352	KE1	4.04	0.013	1.2	0.8	0.0	0.1	0.1	2.2	0.2
05-353	KE1	4.65	0.030	5.3	3.6	0.1	0.2	0.1	6.0	0.7
05-354	KE1	5.26	0.023	12.7	0.8	0.0	0.1	0.2	2.7	0.7
05-355	ST1	0.08	0.018	8.3	5.7		0.4	• • =	6.6	14.7
05-356	ST1	0.38	0.034	2.0	3.2	0.0	0.2	2.0	6.2	1.0
05-357	ST1	0.69	0.033	1.9	2.2	0.0	0.2	0.5	1.6	0.5
05-358	ST1	0.99	0.034	12.4	0.7	0.0	0.0	0.0	2.6	1.1
05-359	ST1	1.30	0.036	7.3	0.8	0.1	0.3	0.8	5.5	0.5
05-360	ST1	1.60	0.035	7.9	2.1	0.0	0.3	0.2	2.4	0.4
05-361	ST1	2.21	0.043	11.6	0.6	0.0	0.4	0.2	2.9	0.3
05-362	ST1	2.82	0.072	13.1	9.6	0.8	0.3	0.2	30.4	0.4
05-363	ST1	3.43	0.091	16.6	27.7	0.1	0.1	0.4	19.6	0.4
05-364	ST2	0.08	0.052	13.7	5.8	7.0	1.2	13.1	8.7	0.4
05-365	ST2	0.38	0.084	10.4	2.0		0.3	2.8	10.1	0.1
05-366	ST2	0.69	0.096	8.8	0.5		0.3	3.0	26.2	0.1
05-367	ST2	0.99	0.094	7.9	0.5		0.3	2.6	55.4	0.1
05-368	ST2	1.30	0.093	8.3	1.6		0.4	4.3	114.4	0.0
05-369	ST2	1.60	0.099	6.9	36.9	5.7	0.3	33.7	226.5	0.0
05-370	ST2	2.21	0.107	4.9	330.4		0.8	43.7	160.2	0.0
05-371	ST2	2.82	0.124	8.2	633.3		1.3	7.8	177.7	0.5
05-372	ST2	3.43	0.120	14.9	796.8		1.8	5.5	229.9	0.0
05-373	ST2	4.00	0.129	23.9	926.1		0.5	4.1	248.4	0.0
05-374	ST2	4.65	0.137	48.3	1462.5		0.0	6.2	358.2	0.0
05-375	ST2	5.26	0.118	136.6	1093.2		0.1	4.4	4328.6	0.0
05-376	ST3	0.08	0.008	4.9	9.0	3.2	0.4	4.0	8.2	8.4
05-377	ST3	0.38	0.011	3.3	2.4	2.6	0.1	1.2	6.0	0.7
05-378	ST3	0.69	0.011	2.1	1.0	2.2	0.0	0.4	2.6	0.3
05-379	ST3	0.99	0.010	1.9	1.0	2.0	0.0	0.4	2.5	0.3
05-380	ST3	1.30	0.010	2.4	2.3	4.4	0.1	0.1	4.0	0.6
05-381	ST3	1.60	0.011	1.4	0.5	2.2	0.0	0.2	3.0	0.3
05-382	ST3	2.21	0.009	1.1	0.1	1.9	0.0	0.2	1.7	0.2
05-383	ST3	2.82	0.060		54	11	0.0	0.8	23.4	0.1
05-384	ST3	3.43	0.099	8.0	29.9	13.4	0.1	3.3	93.9	0.2
05-385	ST3	4.04	0.086	7.2	25.4	2.9	0.1	3.1	55.5	0.2
05-386	ST3	4.65	0.094	18.5	31.8	3.0	0.1	2.6	59.6	0.3

Sample	Bore	Depth	Water							
ID	hole	(m)	Content	As	CI	Br	NO <sub>2</sub>	NO <sub>3</sub>	SO <sub>4</sub>	PO <sub>4</sub>
05-387	ST3	5.26	0.102	24.5	39.3	5.6	0.1	5.9	67.5	0.1
05-400	NU1	0.08	0.157	75.7	34.3	2.8	0.0	53.0	18.8	2.1
05-401	NU1	0.38	0.196	30.4	181.2	0.8	0.9	18.4	36.2	0.2
05-402	NU1	0.69	0.222	8.6	1029.1	0.3	3.9	43.0	236.3	0.2
05-403	NU1	0.99	0.234	11.0	1580.7	0.2	5.3	45.2	4424.6	0.1
05-404	NU1	1.30	0.229	12.0	1931.2	0.1	6.0	25.7	4537.1	0.0
05-405	NU1	1.60	0.227	14.3	1852.9	0.1	5.7	16.2	4367.9	0.1
05-406	NU1	1.91	0.214	14.2	1898.4	0.1	5.5	9.9	4374.1	0.1
05-407	NU1	2.21	0.220	14.3	2181.6	0.0	6.1	7.6	1651.9	0.3
05-408	NU1	2.51	0.254	12.6	2958.2	0.0	8.1	4.2	723.0	0.3
05-409	NU1	2.82	0.291	11.9	3512.6	0.0	9.6	4.2	770.7	0.1
05-410	NU1	3.12	0.252	9.4	3069.2	0.0	8.3	3.5	634.8	0.0
05-411	NU1	3.73	0.225	8.0	2885.4	0.1	7.7	3.0	563.2	0.0
05-412	NU1	4.04	0.215	5.0	3017.1	0.0	7.9	1.1	460.9	0.1
05-413	NU1	4.34	0.203	4.7	2704.4	0.0	6.8	0.7	423.9	0.1
05-414	NU1	4.65	0.215	6.0	2749.2	0.0	7.7	2.5	480.2	0.1
05-415	NU1	4.95	0.215	3.6	2751.4	0.0	6.9	1.5	430.7	0.0
05-416	NU1	5.26	0.186	2.2	1673.8	0.0	4.5	1.4	316.5	0.0
05-417	NU1	5.56	0.146	3.0	1425.9	0.1	3.6	1.8	359.9	0.0
05-418	NU1	5.87	0.147	3.5	1238.7	0.0	3.0	2.0	421.0	0.0
05-419	NU1	6.17	0.157	1.9	1329.7	0.0	3.2	2.5	417.4	1.3
05-420	NU1	6.48	0.148	1.6	1336.3	0.0	3.2	2.3	388.0	0.1
05-421	NU1	6.78	0.204	1.3	2020.0	0.0	4.8	2.9	573.1	0.2
05-422	NU1	7.09	0.232	0.7	2757.5	0.0	7.2	3.3	566.4	0.0

Sample ID	Borehole	Sand (%)	Silt (%)	Clay (%)
05-001	A1	84.5	5.6	9.9
05-003	A1	69.4	7.7	22.9
05-005	A1	52.7	27.5	19.9
05-007	A1	64.4	20.4	15.2
05-008	A1	57.1	24.3	18.6
05-009	A2	80.5	10.4	9.0
05-010	A2	72.7	10.7	16.6
05-011	A2	62.3	12.7	25.0
05-012	A2	66.8	10.4	22.8
05-013	A2	76.8	7.2	16.1
05-014	A2	78.3	6.9	14.8
05-015	A2	76.9	6.2	16.9
05-016	A2	62.5	15.2	22.3
05-017	A2	58.6	15.3	26.1
05-018	A2	71.6	15.3	13.1
05-019	A2	74.3	12.6	13.1
05-020	A2	74.1	13.7	12.2
05-021	A2	82.0	8.9	9.1
05-022	A2	84.4	6.5	9.1
05-023	A2	74.2	13.1	12.7
05-024	A2	69.0	15.9	15.1
05-025	A2	62.1	18.9	19.0
05-026	T1	76.5	5.7	17.8
05-028	T1	65.6	9.8	24.7
05-031	T1	43.7	22.7	33.6
05-032	T1	42.8	27.9	29.3
05-033	T1	52.5	18.3	29.3
05-035	T1	42.4	28.3	29.3
05-036	T1	40.3	22.0	37.8
05-037	T1	41.1	20.3	38.6
05-038	T1	42.0	17.8	40.3
05-040	T1	76.4	5.2	18.4
05-041	T2	16.9	20.7	62.4
05-043	T2	21.5	23.7	54.7
05-044	T2	61.9	9.7	28.4
05-046	T2	42.4	15.7	41.9
05-048	T2	34.8	23.2	42.0
05-049	T2	22.8	24.7	52.5
05-050	T2	57.7	8.0	34.3
05-052	T2	77.4	5.0	17.6
05-053	T2	37.5	11.0	51.5
05-055	T2	23.5	51.1	25.5
05-056	T2	44.5	34.4	21.1
05-058	T2	55.4	24.8	19.8
05-059	T3	80.8	4.2	15.0
05-061	T3	66.2	10.9	22.9

Table IV.2	Texture	analysis	for	borehole	samples

Sample ID	Borehole	Sand (%)	Silt (%)	Clay (%)
		12 T		20 6
05-003	T2	43.7	20.0	29.0
05-003	13 T2	51.1 63.0	0.1	27.0
05-007	13 T2	70.0	9.1	21.9
05-069	13 T2	70.9	2.0	20.3
05-071	13 T2	70.0	1.9	27.0
05-073	13 T2	76.9	1.8	21.3
05-075	13	<u> </u>	11.5	10.7
05-077		53.4	26.0	20.7
05-079	13 T2	50.3 74.7	25.9	17.8
05-081	13 T2	71.7	13.9	14.4
05-082	13	70.6	18.4	11.0
05-083		83.5	2.8	13.8
05-086		78.1	5.3	10.0
05-088		54.9	10.9	34.2
05-090	14	53.6	24.1	22.3
05-092	14	64.4	14.9	20.6
05-094	14	65.5	6.1	28.3
05-096	14	61.7	22.3	16.0
05-097	14	43.5	34.8	21.7
05-099	14	55.2	27.2	17.6
05-101	14	58.8	25.3	15.9
05-102	14	55.4	29.5	15.0
05-103	L1	68.0	13.0	19.0
05-106	L1	70.3	8.4	21.3
05-107	L1	52.3	20.4	27.4
05-109	L1	46.1	24.0	29.9
05-111	L1	30.9	31.8	37.4
05-113	L1	48.0	18.1	33.9
05-115	L1	39.3	25.8	34.8
05-117	L1	59.3	16.6	24.1
05-118	L1	74.9	6.3	18.8
05-120	L1	72.4	12.6	15.0
05-123	B1	62.7	9.3	28.0
05-125	B1	59.0	14.2	26.7
05-126	B1	59.0	13.8	27.1
05-128	B1	65.4	13.4	21.2
05-131	B1	42.0	24.9	33.1
05-132	B1	45.9	21.9	32.2
05-134	B1	69.8	8.9	21.3
05-135	B1	66.7	11.6	21.7
05-137	B1	50.1	27.5	22.4
05-139	B1	70.9	13.4	15.8
05-141	B1	53.1	25.8	21.1
05-142	B1	52.3	27.8	19.9
05-144	B2	48.0	20.2	31.8
05-145	B2	62.8	15.9	21.3
05-147	B2	52.0	23.4	24.6
05-149	B2	56.9	18.4	24.6

Sample ID	Borehole	Sand (%)	Silt (%)	Clav (%)
05-151	R2	35.2	.32.4	.32.4
05-152	B2	46.7	27.0	26.3
05-153	B2	49.2	19.8	31.0
05-156	B2	64.6	19.3	16.0
05-157	G1	87.7	2.6	9.7
05-159	G1	76.2	5.4	18.4
05-160	G1	81.3	1 1	17.6
05-162	G1	67.2	27	30.1
05-163	G1	40.6	29.0	30.3
05-164	G1	52.1	29.3	18.6
05-166	G1	73.6	15.2	11.2
05-168	G1	69.5	17.2	13.3
05-169	G2	86.3	24	11.3
05-171	G2	72.3	6.4	21.3
05-173	G2	82.6	1.1	16.3
05-175	G2	76.0	1.4	22.6
05-176	G2	72.3	3.9	23.8
05-178	G2	85.2	2.2	12.6
05-179	G2	86.5	2.2	11.3
05-180	G2	90.3	1.3	8.4
05-181	G2	72.1	7.0	20.9
05-183	G2	83.8	2.4	13.8
05-184	G2	87.6	2.7	9.7
05-186	G2	77.3	13.1	9.6
05-189	G2	76.0	17.8	6.2
05-191	H1	66.5	13.1	20.5
05-192	H1	55.9	18.6	25.5
05-194	H1	44.4	23.7	31.9
05-196	H1	41.8	24.1	34.1
05-198	H1	39.3	29.9	30.7
05-199	H1	40.5	29.6	29.8
05-200	H1	45.8	29.2	25.0
05-202	H1	59.7	29.7	10.5
05-203	H1	71.9	19.5	8.6
05-204	H2	62.4	18.1	19.5
05-205	H2	33.3	27.2	39.5
05-207	H2	37.9	36.6	25.5
05-208	H2	48.4	34.8	16.9
05-211	H2	56.2	34.1	9.7
05-214	H2	62.9	29.8	7.3
05-218	H2	59.4	28.2	12.4
05-219	H2	68.9	23.3	7.8
05-223	D1	66.3	13.3	20.4
05-224	D1	68.9	13.2	17.9
05-227	D1	48.8	19.7	31.5
05-228	D1	78.2	12.5	9.3
05-229	D1	68.1	21.3	10.6
05-231	M1	92.4	1.3	6.3

Sample ID	Borehole	Sand (%)	Silt (%)	Clay (%)
05-233	M1	86.0	36	10.4
05-235	M1	23.7	38.6	37.8
05-237	M1	66.5	10.6	22.9
05-239	M1	36.3	30.6	33.1
05-200	M1	68.7	10.5	20.8
05-243	M1	59.7	16.3	20.0
05-240	M1	62.3	22.1	15.6
05-246	M1	58.7	24.9	16.3
05-240	M2	57.9	24.3	21.9
05-249	M2	50.6	16.9	32.5
05-245	M2	45.4	10.0	35.4
05-251	M2	34.5	27.2	38.3
05-255	M2	64.5	20.6	14.9
05-256	M2	72.6	16.3	14.5
05-258	M2	72.0	15.0	12.4
05-260	M2	73.0	13.6	12.7
05-200	M2	72.6	14.9	12.5
05-201	M2	72.0	16.2	13.8
05-202	M2	67.3	16.2	15.8
05-204	M3	66.0	12.8	21.2
05-200	M3	30.2	28.8	32.0
05-200	M3	51.2	20.0	27.8
05-209	Ma	32.3	20.3	42.3
05-271	M3	55.5	14.9	20.6
05-275	M3	63.4	14.5	29.0
05-273	M3	05. <del>4</del> 11 1	33.1	22.5
05-277	M3	44.4	34.3	22.5
05-270	MA	73.8	10.4	15.8
05-273	M4	61.6	20.3	18.1
05-204	M4	45.3	20.0	16.6
05-205	M4		26.6	14.0
05-200	M4	57.0	20.0	14.0
05-207	M4	60.7	27.5	14.7
05-200		54.9	50	30.3
05-230		76.5	5.8	17 0
05-292		89.4	1.0	94
05-295		64 Q	4 9	30.2
05-204		67.8	4.6	27.7
05-290		62.6	14.8	22.1
05-290		69.0	14.6	16.4
05-301		61.3	13.5	25.2
05-303		48.5	20.6	30.9
05-304		48.2	20.0	30.5
05-305		20.2	48.2	31.8
05-306		26.6	40.2	32.6
05-314	HI1	84.4	62	9.4
05-316	HI1	70.4	77	21 9
05-319	HI1	66.4	84	25.1

Sample ID	Borehole	Sand (%)	Silt (%)	Clay (%)
05-321	HI1	58.8	14.4	26.7
05-323	HI1	53.5	20.7	25.8
05-325	HI1	53.7	19.2	27.1
05-326	HI2	82.0	5.8	12.2
05-328	HI2	57.8	6.2	36.0
05-343	KE1	88.2	1.2	10.6
05-345	KE1	90.7	<0.1	9.4
05-347	KE1	85.7	<0.1	14.4
05-348	KE1	80.6	5.5	13.8
05-349	KE1	76.8	4.3	18.9
05-351	KE1	90.7	<0.1	9.4
05-353	KE1	88.2	<0.1	11.9
05-354	KE1	89.5	<0.1	10.6
05-355	ST1	84.5	2.4	13.1
05-357	ST1	81.9	3.7	14.4
05-359	ST1	83.2	4.6	12.2
05-361	ST1	81.9	4.6	13.5
05-363	ST1	78.0	14.4	7.6
05-364	ST2	57.9	25.5	16.6
05-366	ST2	43.9	23.8	32.2
05-368	ST2	35.6	29.2	35.2
05-370	ST2	37.8	27.1	35.2
05-372	ST2	29.4	32.8	37.7
05-375	ST2	66.2	25.8	7.9
05-376	ST3	88.2	2.4	9.4
05-378	ST3	92.6	<0.1	7.5
05-380	ST3	90.1	2.4	7.5
05-382	ST3	95.3	<0.1	5.0
05-384	ST3	77.5	2.5	20.0
05-385	ST3	82.6	2.4	15.0
05-387	ST3	65.8	15.9	18.2
05-400	NU1	19.5	32.0	48.5
05-402	NU1	20.2	22.8	56.9
05-404	NU1	18.2	37.4	44.3
05-406	NU1	26.6	47.3	26.1
05-409	NU1	10.5	22.3	67.2
05-410	NU1	14.4	22.8	62.9
05-412	NU1	20.9	25.7	53.4
05-414	NU1	20.2	25.6	54.2
05-416	NU1	26.9	26.5	46.6
05-418	NU1	42.6	28.1	29.2
05-420	NU1	45.7	26.7	27.6
05-422	NU1	10.5	22.9	66.6

	Depth	Potential	
Borehole	(m)	(-m)	Method
A05-01	0.15	-394	2
A05-01	0.76	-240	2
A05-01	1.37	-65.0	2
A05-01	2.13	-118	2
A05-01	2.90	-214	2
A05-02	0.15	-726	2
A05-02	0.76	-347	2
A05-02	1.37	-366	2
A05-02	2.29	-93.4	2
A05-02	2.90	-125	2
A05-02	3.51	-103	2
A05-02	4.11	-170	2
A05-02	4.88	-198	2
A05-02	5.79	-266	2
A05-02	6.71	-200	2
A05-02	7.62	-107	2
A05-02	8.53	-142	2
B05-01	0.23	-3.39	1
B05-01	1.14	-6.70	1
B05-01	2.67	-6.98	1
B05-01	4.50	-7.93	1
B05-01	7.24	-7.85	1
B05-01	9.68	-8.52	1
B05-01	11.20	-9.11	1
B05-02	0.23	-5.33	1
B05-02	0.53	-6.85	1
B05-02	1.14	-4.92	1
B05-02	1.60	-7.33	1
B05-02	2.36	-6.58	1
B05-02	2.82	-4.15	1
B05-02	4.04	-3.49	1
B05-02	5.11	-7.69	1
D05-01	0.23	-4.76	1
D05-01	0.53	-3.18	1
D05-01	0.84	-2.47	1
D05-01	1.14	-2.37	1
D05-01	1.45	-1.39	1
D05-01	1.75	-0.70	1
D05-01	2.29	-0.10	1
D05-01	2.90	-0.65	1
D05-01	3.58	-2.58	1
DU05-01	0.15	-166	2
DU05-01	0.76	-128	2
DU05-01	1.37	-121	2
DU05-01	2.29	-115	2
DU05-01	2.90	-67.0	2

	Depth	Potential	
Borehole	(m)	(-m)	Method
DU05-01	3.35	-71.1	2
DU05-02	0.15	-335	2
DU05-02	0.76	-209	2
DU05-02	1.37	-200	2
DU05-02	2.29	-128	2
DU05-02	2.74	-228	2
DU05-02	2.90	-301	2
DU05-03	0.15	-876	2
DU05-03	0.76	-429	2
DU05-03	1.37	-241	2
DU05-03	1.83	-276	2
DU05-03	2.44	-274	2
G05-02	0.53	-3.14	1
G05-02	1.14	-4.96	1
G05-02	1.75	-5.04	1
G05-02	2.36	-6.61	1
G05-02	2.97	-4,88	1
G05-02	4 50	-3 72	1
G05-02	5 41	-3 43	1
G05-02	6.63	-4 68	1
G05-02	7 85	-2 67	1
G05-02	9.07	-4.30	1
G05-02	10.29	-0.60	1
H05-01	0.23	-25.4	2
H05-01	0.53	-32.5	2
H05-01	1 14	-4 12	1
H05-01	1.14	-4 50	1
H05-01	2 29	-3.40	1
H05-01	2.23	-62.9	2
H05-01	4 19	-51.8	2
H05-01	6.02	-28.4	2
H05-07	0.02	-20.4	2
H05 02	0.23	-55.0	2
H05-02	1 14	-55.8	2
H05.02	1.14	-55.0	2
H05-02	2.97	-03.0	2
	2.97	-110	2
H05-02	4.19 5.41	200	2
	0.41	-209	2
	0.03 7 0F	-210	2
	0.4C	-230	2
	0.40	-200	2
	0.15	-083	2
	0.76	-413	2
	1.37	-434	2
HIU5-01	2.29	-352	2
HI05-01	2.90	-320	2
HI05-01	3.51	-298	2
HI05-01	4.11	-228	2

	Depth	Potential	
Borehole	(m)	(-m)	Method
HI05-01	5.03	-260	2
HI05-02	0.15	-665	2
HI05-02	0.46	-356	2
HI05-02	0.91	-366	2
KE05-01	0.15	-92.4	2
KE05-01	0.76	-224	2
KE05-01	1.37	-131	2
KE05-01	2.29	-131	2
KE05-01	2.90	-159	2
KE05-01	3.51	-239	2
KE05-01	4.11	-138	2
KE05-01	4.72	-168	2
KE05-01	5.33	-93.4	2
L05-01	0.53	-5.97	1
L05-01	1.14	-5.20	1
L05-01	1.75	-5.22	1
L05-01	2.97	-7.30	1
L05-01	4.19	-7.87	1
1.05-01	6.63	-7.80	1
1.05-01	7 85	-8.03	1
M05-01	0.23	-0.94	1
M05-01	0.53	-1 30	1
M05-01	0.84	-1.43	1
M05-01	1 75	-1.45	1
M05-01	2.36	6.90	1
M05-01	2.30	-0.90	2
M05-01	2.97	-24.4	2
N05-01	4.11	-17.3	2
N05-01	5.33	-11.2	2
M05-01	7.10	-11.2	2
M05-02	0.23	-6.47	1
M05-02	0.53	-130	2
M05-02	1.14	-89.3	2
M05-02	1.68	-58.9	2
M05-02	2.90	-27.4	2
M05-02	3.51	-16.2	2
M05-02	4.11	-35.5	2
M05-02	4.72	-40.6	2
M05-02	5.94	-76.1	2
M05-02	7.16	-85.3	2
M05-02	8.53	-103	2
M05-03	0.23	-7.35	1
M05-03	0.53	-7.49	1
M05-03	0.84	-4.81	1
M05-03	1.14	-4.98	1
M05-03	1.45	-13.7	2
M05-03	1.75	-13.7	2
M05-03	2.29	-18.4	2
M05-03	2.90	-39.4	2

	Depth	Potential	
Borehole	(m)	(-m)	Method
M05-03	3.51	-38.3	2
M05-03	4.11	-19.6	2
M05-03	4.72	-19.6	2
M05-03	5.33	-21.9	2
M05-03	6.25	-19.6	2
M05-04	0.23	-1.90	1
M05-04	0.53	-5.14	1
M05-04	0.76	-8.12	2
M05-04	1.07	-15.2	2
M05-04	1.68	-25.4	2
M05-04	2.29	-25.4	2
M05-04	2.90	-26.4	2
M05-04	3.51	-33.5	2
M05-04	4.42	-50.8	2
ST05-01	0.15	-1046	2
ST05-01	0.76	-318	2
ST05-01	1.37	-268	2
ST05-01	2.29	-91.4	2
ST05-01	2.90	-43.6	2
ST05-01	3.66	-54.8	2
ST05-02	0.15	-247	2
ST05-02	0.76	-109	2
ST05-02	1.37	-115	2
ST05-02	2.29	-117	2
ST05-02	2.90	-117	2
ST05-02	3.51	-163	2
ST05-02	4.04	-182	2
ST05-02	4.72	-157	2
ST05-02	5.33	-180	2
ST05-03	0.15	-758	2
ST05-03	0.76	-518	2
ST05-03	1.37	-464	2
ST05-03	2.29	-263	2
ST05-03	2.90	-56.8	2
ST05-03	3.51	-50.8	2
ST05-03	4.11	-39.6	2
ST05-03	4.72	-43.6	2
ST05-03	5.33	-53.8	2
T05-01	0.15	-2.19	1
T05-01	0.76	-5.37	1
T05-01	1.37	-2.09	1
T05-01	2.29	-5.95	1
T05-01	3.51	-9.34	1
T05-01	4.11	-14.6	2
T05-01	4.72	-29.4	2
T05-01	5.33	-80.0	2
T05-01	5.94	-87.3	2
T05-01	7.01	-69.4	2

	Depth	Potential	
Borehole	(m)	(-m)	Method
T05-02	0.23	-8.00	1
T05-02	1.14	-1.85	1
T05-02	1.75	-3.54	1
T05-02	2.97	-6.21	1
T05-02	4.19	-2.80	1
T05-02	5.41	-1.03	1
T05-02	6.63	-8.67	1
T05-02	7.85	-7.59	1
T05-03	0.15	-3.38	1
T05-03	1.07	-3.49	1
T05-03	2.29	-3.10	1
T05-03	2.74	-7.34	1
T05-03	5.33	-8.25	1
T05-03	6.55	-24.0	2
T05-03	7.16	-7.72	1
T05-03	7.77	-18.3	2
T05-03	8.99	-33.5	2
T05-03	11.43	-33.5	2
T05-04	0.15	-4.33	1
T05-04	1.07	-6.09	1
T05-04	2.13	-2.49	1
T05-04	3.51	-7.05	1
T05-04	5.18	-7.38	1
T05-04	6.40	-6.94	1
T05-04	7.01	-8.82	1
T05-04	8.08	-25.4	2
T05-04	9.60	-25.2	2
T05-04	10.06	-30.5	2



Table 1. Overview of arsenic behavior in the subsurface

SOURCE: Smedley and Kinninburgh, 2002

	Number of Samples	As<10 ug/L	10 <as<50 l<="" th="" ug=""><th>As&gt;50 ug/L</th></as<50>	As>50 ug/L
Central High Plains	668	99.7%	0.3%	0.0%
Southern High Plains (Northern)	477	92.7%	7.3%	0.0%
Southern High Plains (Southern)	609	49.3%	48.4%	2.3%
Southern High Plains	1086	68.3%	30.4%	1.3%
Texas High Plains	1754	80.3%	18.9%	0.8%

Table 2. Arsenic concentration statistics in the High Plains area

# Table 3. Arsenic concentration statistics in the Gulf Coast area

	Number of				
	Samples	As<10 ug/L	10 <as<50 l<="" th="" ug=""><th>As&gt;50 ug/L</th></as<50>	As>50 ug/L	
Gulf Coast Aquifers					
Chicot A.	386	90.9%	8.5%	0.5%	
Evangeline A.	456	90.4%	9.2%	0.4%	
Jasper A.	278	77.3%	15.5%	7.2%	
Combined	1,120	87.3%	10.5%	2.1%	
Southwestern Section of the Gulf Coast Aquifers					
Chicot A.	96	72.9%	25.0%	2.1%	
Evangeline A.	209	79.4%	19.6%	1.0%	
Jasper A.	101	52.5%	27.7%	19.8%	
Combined	406	71.2%	22.9%	5.9%	
Northeastern Section of the Gulf Coast Aquifers					
Chicot A.	290	96.9%	3.1%	0.0%	
Evangeline A.	247	99.6%	0.4%	0.0%	
Jasper A.	177	91.5%	8.5%	0.0%	
Combined	714	96.5%	3.5%	0.0%	

Common Name(s)	Formula (CAS#)	As Redox state	Comments (non exhaustive list of trade names)
Arsenic trioxide or white arsenic	As <sub>2</sub> O <sub>3</sub> (1327-53-3)	Ш	Main base product for arsenical compound manufacturing
Arsenic acid or Orthoarsenic acid	H₃AsO₄ (7778-39-4)	V	(also Dessicant L-10; Hi-Yield Dessicant H-10; Zotox; Desiccant L-10; Hy-Yield H-10; Poly Brand Dessicant; CCA Type C; Chemonite Part A; Crab grass killer)
Sodium Arsenite	NaAsO2 (7784-46-5)	Ш	sodium metaarsenite
Acid lead arsenate	PbHAsO <sub>4</sub> (7784-40-9)	V	
Basic lead arsenate	Pb <sub>4</sub> (PbOH)(AsO <sub>4</sub> ) <sub>3</sub>	V	
Calcium arsenate	Ca <sub>3</sub> (AsO <sub>4</sub> ) <sub>2</sub> (7778-44-1)	V	
MSMA	NaHAsO <sub>3</sub> (CH <sub>3</sub> ) (2163-80-6)	V	monosodium methanearsonate, salt of the monomethylarsonic acid (MMA) (also Bueno6, Ansar6-6, Drexel, Zeneca, Helena)
DSMA	Na <sub>2</sub> AsO <sub>3</sub> (CH <sub>3</sub> ) (144-21-8)	V	disodium methanearsonate, salt of the monomethylarsonic acid (MMA) (also Ansar8100, Drexel, Zeneca)
Cacodylic acid DMA(A)	HAsO <sub>2</sub> (CH <sub>3</sub> ) <sub>2</sub> (75-60-5)	V	dimethylarsinic acid (also Ansar 138, Arsan, Bolls- Eye, Broadside, Check-Mate, Cotton Aide HC, Moncide, Montar, Phytar, Phytar 138, Phytar 600, Rad-E-Cate 25, Dilic, Silvisar 510, Sylvicor)
Chromated Cu Arsenate (CCA)	Complex structure;	Mainly V	comes in 3 types including: CrO <sub>3</sub> .CuO.As <sub>2</sub> O <sub>3</sub>

Tahle 4	Common	arsenical	products	and their	IISA
	COMMUN	aiseilleai	producis		use

### Table 5. Arsenical compound use history

lleano	Start Date	Ban Date	Chemical
Animal feed (poultry)	1930's	N/A	Organic form of As
Herbicide - weed killer	1900's	1988	Pb Arsenate, Cu Acetoarsenite ("Paris green")
- ~specific to cotton	1977	N/A	MSMA, DSMA, cacodylic acid
Insecticide: - Sheep and cattle dips - Boll weevil (cotton pest) - Orchard pests	<1900	1988	Na Arsenite Ca Arsenate Pb Arsenate
Defoliant	First marketed in 1956 ~1965	1992	Arsenic acid
	~1900's		
Wood preservatives	~1975	N/A	Chromated Copper Arsenate

SOURCE: Loebenstein (1994); NOTE: usages not included are lead batteries, metal alloys, semiconductors, glass manufacturing

Table 6. Timeline for High Plains cotton crop

Season / Month		Chemical	Goal	Application Method
Winter	Field plowed after harvest		Limit pest infestation	N/A
Winter		herbicide	Weed control	Spray
Early Spring / Spring	Pre-plant	P, N fertilizer Herbicide (e.g., MSMA) Insecticide	favor rooting weed control pest control	If dry land, applied into soil If irrigated, applied with water
April/May (last planting date: June 1 in counties north of Lubbock, June 5 in the Lubbock region, and June 10 to the south)	Planting			N/A
June	Emergence, early development stages	Herbicide (e.g., MSMA, DSMA) N, P fertilizer	weed control favor growth	Spray dry land = apply into soil irrigated = with water
May - August	Irrigation if available			
Summer	<b>J</b>	Insecticide(s)	Pest control	
Fall	Harvest-aid series Sometimes a light freeze plays the role of dessicant.	boll-opener, defoliant, dessicant (previously arsenic acid)	Facilitate harvest	spray
Fall (before first hard freeze)	Harvest			N/A

NOTE: Phases are shifted earlier by a few weeks for the southwestern Gulf Coast region

Substance	Ap. Rate (mg As/m <sup>2</sup> )	Cited Ap. Rate	Source and comments
Ca Arsenate	420-630	10-15 lbs/ac	Aurelius (1988)
Arsenic acid	260	3 pts/ac	Miller and Bailey (1979)
ibid	170-260	2.94-4.42 lbs/ac	Aurelius (1988)
ibid	175-260	2-3 pts/ac at 6.22 lbs As/gal	Warrick et al. (1992)
MSMA	78	1.7 kg/ha	Jordan et al. (1997) (in Arkansas)
ibid	100	1.33 qts/ac at 6 lbs product/gal	Baumann (1998) (preplant use)
ibid	100	1.33 qts/ac at 6. lbs product/gal	Baumann (1998) (postemergence use)
ibid	39	0.76 lbs/ac	Gianessi and Marcelli (2000) (state average in 1992)
ibid	59	1.14 lbs/ac	Gianessi and Marcelli (2000) (state average in 1997)
ibid	27-37	0.6 – 0.8 kg/ha	Bridges et al. (2002) (in Florida, Georgia)
ibid	100	2 lbs/ac	LSU (2005) (Louisiana) (preplant)
ibid	50-100	1-2 lbs/ac	LSU (2005) (Louisiana) (postemergence)
DSMA	165	4 qts/ac at 3.6 lbs product/gal	Baumann (1998) (postemergence use)
ibid	91	2 lbs/ac	Gianessi and Marcelli (2000) (state average in 1992)
ibid	70-140	1.5-3 lbs/ac	LSU (2005) (Louisiana) (postemergence)
Pb Arsenate	10,590	490 kg/ha (440 lb./acre)	Welch et al. (2000) – general citation for western US, high bound.
ibid	8,000	80 kg/ha As	Davenport and Peryea (1991) – high bound
ibid	1,660	1.1 mmol/kg	Peryea and Kammereck (1997): experiment mimicking field conditions on a soil with a density of 1.35 g/cm3 and to a depth of 14

 Table 7. Elemental arsenic and product application rates (loadings)

L \_\_\_\_\_ | cm. NOTE: Given the diversity of the units used in the references, compiled application rate and dosage values are converted to mg elemental As/m<sup>2</sup> for comparison purposes but also cited as in the original source. Rates are sometimes reported as "active ingredient (a.i)", some other times with no such indication. We assumed all rates are a.i. rates.

Ap. = Application; ac = acre (4046.86 m<sup>2</sup>); pts = pints ( $0.4732x10^{-3} m^{3}$ ); qts = quarts ( $0.9464x10^{-3} m^{3}$ ); lbs = pounds (454,000 mg); ha = hectare (10,000 m<sup>2</sup>); As molar weight = 75 g/mole Unless indicated, rates apply to a Texas location

Table 8. Comparison of arsenic concentrations in wells within and farther than 1000 m from cotton gin locations in the Texas Southern High Plains

Region	Wells	Number	$\mu_0$	ν	P(F<=f)	P(T<=t)
SHP-S	≤ 1000 m	31	1.0775	0.0456	0.002	0.987
	> 1000 m	503	1.0765	0.1069	0.002	
SHP-N	≤ 1000 m	11	0.6920	0.0729	0.007	0.000
	> 1000 m	341	0.6746	0.0544	0.207	0.808

NOTE: Average ( $\mu_0$ ) and variance (v) values are for log<sub>10</sub> arsenic concentrations. For F-tests, the p-value indicates the probability that the compared sample variances are different. For t-tests, the p-value indicates the probability that the compared sample means are the same.

Table 9. Borehole sampling information

Borehole	L atituda	Longitude	County	Setting		Depth	Number of	Arser	nic (ug/	kg)	Arse	enic (ug	j/L)
Dorenoie	Latitude	Longitude	County	Setting	Crop/vegetation	(ft)	Samples	median	min	max	median	min	max
Southern	High Plains	3											
A1	32.3866	-102.7640	Andrews	Rangeland	Shrubs, grasses	10.0	8	2.6	1.3	4.3	54	17	206
A2	32.3804	-102.7979	Andrews	Rangeland	Shrubs, grasses	28.0	17	23	9.7	77	425	97	1162
T2	33.3560	-102.2329	Terry	Playa	Adjacent irrigated cotton	30.5	18	14	0.55	203	115	2.6	1025
Т3	33.2354	-102.2838	Terry	Irrigated	Cotton	41.5	24	19	2.3	62	230	15	687
T4	33.0212	-102.3067	Terry	Irrigated	Cotton	33.5	20	2.4	0.41	62	22	2.6	1490
T1	33.3278	-102.3005	Terry	Dryland	Cotton	23.5	15	14	2.1	29	103	15	203
L1	33.9280	-102.6098	Lamb	Dryland	Cotton	28.3	17	7.3	0.63	37	73	5.0	191
B1	33.9114	-102.6755	Bailey	Dryland	Cotton	36.6	22	5.4	0.68	19	52	5.7	182
B2	34.0051	-102.9440	Bailey	Dryland	Cotton	20.5	14	7.5	0.76	18	67	6.3	142
G1	32.7099	-102.4294	Gaines	Dryland	Cotton	16.5	12	9.4	2.4	18	57	24	113
G2	32.6777	-102.3056	Gaines	Dryland	Cotton	35.5	21	7.9	1.1	37	74	16	415
H1	32.4475	-101.6386	Howard	Dryland	Cotton	20.5	14	21	4.5	77	146	34	662
H2	32.3957	-101.5416	Howard	Dryland	Cotton	28.0	17	3.2	0.05	35	31	0.7	324
D1	32.7072	-102.1747	Dawson	Dryland	Cotton	11.5	10	8.0	2.8	36	63	20	598
M1	32.3844	-102.0458	Martin	Dryland	Cotton	20.5	16	15	0.11	33	123	0.74	598
M2	32.3488	-102.0782	Martin	Dryland	Cotton	27.5	18	9.8	3.4	30	114	34	238
M3	32.1155	-101.7563	Martin	Dryland	Cotton	21.5	14	8.5	5.7	35	59	40	338
M4	32.1305	-101.7563	Martin	Dryland	Cotton	14.5	11	5.6	2.8	20	66	25	218
Southwes	tern Gulf C	oast											
KE1	26.7550	-97.6048	Kenedy	Rangeland	Live Oak, shrubs, grasses	18.0	12	8.0	1.2	30	510	186	753
DU2	27.4581	-98.7189	Duval	Rangeland	Shrubs, grasses	10.0	8	4.8	2.9	69	79	37	486
DU3	27.7999	-98.6301	Duval	Rangeland	Shrubs, grasses	8.0	7	3.6	2.8	5.9	55	50	152
ST1	26.7027	-98.3974	Star	Rangeland	Shrubs, grasses	12.3	9	8.3	1.9	17	206	59	468
HI2	26.5352	-98.1659	Hidalgo	Rangeland	Grasses	3.0	3	3.5	2.0	5.6	79	23	332
HI1	26.5607	-98.1242	Hidalgo	Rangeland	Shrubs, grasses	17.0	12	102	8.1	1854	3168	114	26201
ST3	26.7208	-98.5238	Star	Irrigated	Pasture, grasses	18.0	12	3.3	1.1	24	189	81	586
DU1	27.2934	-98.3157	Duval	Dryland	Peanuts	11.5	9	72	0.69	124	840	7.4	979
ST2	26.4746	-98.7435	Star	Dryland	Corn	17.9	12	9.6	4.9	137	107	46	1156
NU1	27.6726	-97.7076	Nueces	Dryland	Cotton	24.0	23	8.0	0.74	76	36	3.2	483

Oxyanion	Dominant Species / pKa
Arsenate – As(V)	$H_3AsO_4$ <b>2.30</b> $H_2AsO_4^{-1}$ <b>7.16</b> $HAsO_4^{2-1}$ <b>11.65</b> $AsO_4^{3-1}$
Phosphate – P(V)	H <sub>3</sub> PO <sub>4</sub> <b>2.15</b> H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> <b>7.20</b> HPO <sub>4</sub> <sup>2-</sup> <b>12.35</b> PO <sub>4</sub> <sup>3-</sup>
Selenate – Se (VI)	HSeO <sub>4</sub> <sup>-</sup> <b>1.8</b> SeO <sub>4</sub> <sup>-2-</sup>
Molybdate – Mo(VI)	H <sub>2</sub> MoO <sub>4</sub> ~4HMoO <sub>4</sub> <sup>-4</sup> .24 MoO <sub>4</sub> <sup>-2-</sup>
Vanadate – V(V)	$H_{3}VO_{4}$ <b>4</b> $H_{2}VO_{4}^{-}$ <b>8.5</b> $HVO_{4}^{-2-}$
Borate – B(III)	H <sub>3</sub> BO <sub>3</sub> <b>9.24</b> H <sub>2</sub> BO <sub>3</sub> <sup>-</sup>
Arsenite – As(III)	H <sub>3</sub> AsO <sub>3</sub> <b>9.15</b> H <sub>2</sub> AsO <sub>3</sub>
Selenite Se(IV)	$H_2SeO_3$ <b>2.7</b> $HSeO_3^{-1}$ <b>8.54</b> $SeO_3^{-2}$

Table 10. Dominant species and pKa of relevant chemical elements

NOTE: pKa's are approximately located and thus the table represent the spread of a species under varying pH. Data from Dzombak and Morel (1990, Table 10.9) and other sources

Table 11.	Average	abundance of	of arsenic and	other	elements for	or different	rock types	(mg/kg)
								· · · · · / /

Element	Igneous	Sandstone	Shale	Carbonate
Arsenic	1.8	1	9	1.8
Boron	7.5	90	194	16
Fluoride	715	220	560	112
Molybdenum	1.2	0.5	4.2	0.75
Antimony	0.5	0.8	0.1	0.2
Selenium	0.05	0.5	0.6	0.3
Uranium	2.8	1.	4.5	2.2
Vanadium	149	20	101	13

SOURCE: Hem (1985, Table 1)

Table 12. Average abundance of arsenic and other elements in soils in the U.S. (mg/kg)

Element	Geometric Average	Range
Arsenic	7.2	<0.1 - 97
Boron	33	<20 - 300
Fluoride	430	<10 – 3,700
Molybdenum	~1	<3 - 15
Antimony	0.66	<1 – 8.8
Selenium	0.39	< 0.1 – 4.3
Uranium	2.7	0.3 - 11
Vanadium	80	<7 - 500
Source: Checkles	tto and Deernaan	(1004 Tables 1 a)

Source: Shacklette and Boerngen (1984, Tables 1 and 2)

Table 13. Current trace element concentration in southwestern Gulf Coast soils. Arithmetic mean (range) in mg/kg

Formation	Arsenic	Molybdenum	Selenium	Uranium
Whitsett	5.3 (0.6-17)	2.1 (0.2-4.6)	0.18 (0.01-0.90)	
Catahoula	3.4 (0.2-6.9)	0.9 (0.2-4.0)	0.13 (0.01-0.60)	2-3*
Oakville	No Data	0.9 (0.3-2.0)	0.17 (0.01-0.38)	
U.S. average	~5-6	1-2	0.1-0.5	

NOTE: from a total of ~300 samples

Data from Table 4 of Henry and Kapadia (1980) Arithmetic mean + composite range \* from Galloway (1977, p.39) and Galloway and Kaiser (1980, p.14)

	Value or	
Element	Range (ug/L)	Source
Arsenic	1-50 1-50 <10	Hitchon et al. (1999) Welch et al. (2000, Figure 2) Smedley and Kinninburgh (2002, p.525
Boron	50-1000	Hitchon et al. (1999)
Fluoride	10-1,500 <1,000	Hitchon et al. (1999) Hem (1985, p.120)
Molybdenum	~<10 (?) variable	Hem (1985, p.140)
Antimony	~<5	Hem (1985, p.145)
Selenium	0.1-10 <1	Hitchon et al. (1999) Hem (1985, p.145)
Uranium	0.1-10	Hem (1985, p.148)
Vanadium	<10	Hem (1985, p.138)

Table 14. Typical dissolved concentration in groundwater

Table 15. Typical arsenic concentrations in water



SOURCE: Welch et al., 2000

NOTE: Summary statistics for arsenic and pH in groundwater. "AP" (Atlantic Plains) and "IP" (Interior Plains) apply to the Gulf Coast and High Plains areas, respectively.

Covariate	Value	As Source	Parameter Source
Molybdenum	0.180	TWDB	TWDB
Selenium	0.138	TWDB	TWDB
Vanadium	0.653	TWDB	TWDB
Boron	0.170	TWDB	TWDB
Fluoride	0.299	TWDB	TWDB
Silica	0.075	TWDB	TWDB
Iron	0.004	TWDB	TWDB
Bicarbonate	0.056	TWDB	TWDB
Sulfate	0.091	TWDB	TWDB
Chloride	0.058	TWDB	TWDB
Nitrate	0.048	TWDB	TWDB
TDS	0.010	TWDB	TWDB
pH	0.013	TWDB	TWDB
Beryllium	N/A		TWDB – All <dl< td=""></dl<>
Perchlorate	0.100	Jackson et al., 2004	Jackson et al., 2004
Ca/Mg	0.145	NURE	NURE
Ca/Mg	0.101	TWDB	TWDB

Table 16. Summary of regression coefficients between arsenic and other parameters (High Plains)

Covariate	Value	As Source	Parameter Source
Molybdenum	0.033	NURE	NURE
Molybdenum	0.130	TWDB – All >DL	TWDB – All >DL
Molybdenum	0.358	TWDB	TWDB
Selenium	0.020	NURE	NURE
Selenium	0.014	TWDB – All >DL	TWDB – All >DL
Selenium	0.012	TWDB	TWDB
Vanadium	0.386	NURE	NURE
Vanadium	0.381	TWDB – All >DL	TWDB – All >DL
Vanadium	0.432	TWDB	TWDB
Boron	0.120	NURE	NURE
Boron	0.061	TWDB – All >DL	TWDB – All >DL
Boron	0.004	TWDB	TWDB
Fluoride	0.039	TWDB – All >DL	TWDB – All >DL
Uranium	0.088	NURE	TWDB – All <dl< td=""></dl<>
Silica	0.115	NURE	NURE
Silica	0.089	TWDB – All >DL	TWDB – All >DL
Iron	0.024	NURE	NURE
Alkalinity	0.002	NURE	NURE
Bicarbonate	0.001	TWDB – All >DL	TWDB – All >DL
Sulfate	0.034	NURE	NURE
Sulfate	0.138	TWDB – All >DL	TWDB – All >DL
Chloride	0.040	NURE	NURE
Nitrate	0.000	TWDB – All >DL	TWDB – All >DL
Conductivity	0.052	NURE	NURE
TDS	0.049	TWDB – All >DL	TWDB – All >DL
Disolved Oxygen	0.027	NURE	NURE
Disolved Oxygen	0.002	NURE(if As>10ug/L)	NURE (if As>10ug/L)
Redox – All GC	0.003	TWDB	TWDB
Redox – Sth. GC	0.005	TWDB	TWDB
pН	0.078	NURE	NURE
pH	pH 0.189 TWDB – All >DL		TWDB – All >DL

Table 17. Summary of regression coefficients between arsenic and other parameters (southwestern Gulf Coast)

Event Name	Age (Ma)	Approximate Source	U (ppm)	Thickness (ft) in Panhandle	Source
Lava Creek B	0.62	Yellowstone area	6.6	1	lzett (1981)
Guaje	1.4	Jemez Mountains	18		Izett (1981) Age in Gustavson et al. (1991)
Huckleberry Ridge	2.2	Yellowstone area	6.2		Izett (1981)
Mount Blanco	2.3	Pacific Northwest	3.3		Izett (1981)
West Amarillo Creek	~10	Yellowstone area		3	Cepeda (2001)

Table 18. Ashfall events in the Texas Panhandle during Ogallala and Blackwater Draw sediment deposition

## Table 19. pKa for arsenic-based acids at 25°C

Arsenical Compound	рКа	Source
	9.17 – (14.1)	Nordstrom and Archer (2003)
	9.15 – (14.7)	Wateq4f
	9.20 – (11.02)	EQ3/6 (Wolery, 1995)
	9.29 – (12.04)	Minteq
	2.30 - 6.99 - 11.80	Nordstrom and Archer (2003)
Arsenic acid	2.30 - 7.16 - 11.65	Wateq4f
H <sub>3</sub> AsO <sub>4</sub>	2.25 - 6.76 - 11.60	EQ3/6 (Wolery, 1995)
	2.24 -6.96 - 11.50	Minteq
monomethylarsonic acid (MMA)	4 10 9 7	Molenat et al. (1999) and NRC
$H_2AsO_3(CH_3)$	4.19-0.7	(1999, p.29)
dimethylarsinic acid (DMA)	1.78?	Molenat et al. (1999)
$HAsO_2(CH_3)_2$	6.2?	NRC (1999, p.29)







NOTE: Distribution based on 31,350 ground-water samples. The map shows arsenic concentrations found in at least 25% of samples per county SOURCE: Ryker, 2001

Figure 2. Distribution of arsenic concentration in the U.S.


Figure 3. Distribution of groundwater with elevated arsenic concentrations (> 50 ug/L) and primary source or process resulting in high arsenic concentrations



NOTE: Texas Water Development Board, US Geological Survey, National Uranium Resource Evaluation, New Mexico Bureau of Geology and Mineral Resources, Association of Central Oklahoma Governments, and Arkansas Department of Environmental Quality databases Figure 4. Arsenic concentrations in groundwater in Texas and surrounding states



Figure 5. Summary of arsenic concentrations for states surrounding Texas



SOURCE : TWDB and NURE databases Figure 6. Arsenic distribution in groundwater across the state of Texas



NOTE: the analysis =13.2 ug/L in plot (b) within the time series with the highest average is likely a typo

Figure 7. Time series for arsenic analyses (a) south of southern High Plains; (b) southwestern Gulf Coast (both from TWDB database)



NOTE: Total of 477, 609, and 668 samples in the southern and northern section of the southern High Plains and central High Plains, respectively

Figure 8. Arsenic concentration statistics in the High Plains



NOTE: Total of 1,120 and 406 samples for (a) and (b), respectively Figure 9. Arsenic concentration statistics: (a) whole Gulf Coast aquifer; (b) only southwestern section



Source: Loebenstein (1994, Table 2)

NOTE: "others" includes glass manufacturing, alloys, electronics; and USGS commodity data (<u>http://minerals.usgs.gov/minerals/pubs/commodity/arsenic</u>) Figure 10. U.S. consumption of elemental arsenic



Source: National Weather Service

Figure 11. Precipitation monthly average in Lubbock and Midland in the High Plains and Benavides in the southwestern Gulf Coast



Source: Blandford (2003) Note: Irrigated cotton crop accounts for 37 and 26% of the total area of Lubbock and Terry counties Note: data include years 1982, 1983, 1984, 1987, 1992, and 1993 Figure 12. Monthly fraction of total county irrigation in Lubbock and Terry counties



NOTE: Values shown based on median annual planted cotton acreage for the period 1970 to 1995 SOURCE: NASS database





NOTE: SHP-S and SHP-N = Texas southern High Plains southern and northern regions, respectively Figure 14. Average arsenic concentration in groundwater related to area planted to cotton by county in the southern High Plains



Figure 15. Map of land use in the southern High Plains



NOTE: Land use derived from NLCD (1992) (Vogelmann *et al.* 2001) NOTE: SHP-S and SHP-N = Texas southern High Plains southern and northern regions, respectively Figure 16. Distribution of groundwater arsenic concentrations in the southern High Plains in relation to the percentage of cultivated land use within 500 m of well locations



Figure 17. Cotton gin locations in the High Plains



NOTE: SHP-S and SHP-N = Texas southern High Plains southern and northern regions, respectively Figure 18. Relationship between groundwater arsenic concentrations and distance to cotton gins in the High Plains



Figure 19. Soil clay content on the footprint of the southern High Plains aquifer





within 1000 m of well locations for the Texas southern High Plains



Figure 21. Predevelopment depth to water (southern High Plains aquifer)



NOTE: Predevelopment depth to water was estimated from the earliest TWDB database information available in a given area

NOTE: SHP-S and SHP-N = Texas southern High Plains southern and northern regions, respectively Figure 22. Relationship between predevelopment depth to water in the High Plains aquifer and arsenic concentrations in ground water



Figure 23. Predevelopment saturated thickness (southern High Plains aquifer)



NOTE: Predevelopment saturated thickness was estimated from the earliest TWDB database information available in a given area

NOTE: SHP-S and SHP-N = Texas southern High Plains southern and northern regions, respectively Figure 24. Relationship between predevelopment saturated thickness of the High Plains aquifer and arsenic concentrations



Figure 25. Nitrate distribution in the Texas High Plains



NOTE: trendline uses only SHP-S data points Figure 26. Crossplot of As vs. Nitrate (High Plains aquifer)



Figure 27. Cotton gin locations in the southwestern Gulf Coast



Figure 28. Nitrate (a) and phosphate (b) distribution in the Gulf Coast



NOTE: TWDB data (a) Figure 29. Crossplot of As vs. Nitrate (southwestern Gulf Coast)



Figure 30. Drilling sites locations: High Plains (a) and southwestern Gulf Coast (b)



Figure 31. Borehole sample arsenic concentrations in soil in the southern High Plains

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Figure 32. Borehole sample arsenic concentrations in soil water in the southern High Plains

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Figure 33. Borehole sample arsenic concentrations in soil in the southwestern Gulf Coast

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Figure 34. Borehole sample arsenic concentrations in soil water in the southwestern Gulf Coast



Figure 35. Soil modeling results with phosphates: As and P breakthrough curves at selected distances



Figure 36. Soil modeling results without phosphates: As breakthrough curves at selected distances





Figure 37. Soil modeling results with and without phosphates: As and P vertical profiles at selected times





Figure 37. Soil modeling results with and without phosphates: As and P vertical profiles at selected times (continued)



NOTE: Numerals for lakes with unknown lakes are from Wood and Jones (1990)

SOURCE: from Wood and Jones, 1990, and GAT sheets Figure 38. Location of saline lakes in the Texas High Plains



NOTE: Boundaries close to that of Nativ (1988) were adopted by the TWDB as High Plains Edwards-Trinity minor aquifer

SOURCE: (a) Brand et al. (1953) and (b) Nativ (1988) Figure 39. Location of Cretaceous subcrops in the southern High Plains



SOURCE: Chowdhury and Mace, 2003 Figure 40. Stratigraphy and hydrostratigrphy of the Gulf Coast aquifers



Figure 41. Simplified geologic map of the southwestern Gulf Coast region



Figure 42. Cross-section along dip in the Gulf Coast aquifer through Karnes, Goliad, and Refugio Counties



Figure 43. Tectonic map of the Gulf Coast area



Figure 44. Arsenic distribution in the High Plains aquifer (TWDB database): (a) from arsenic data points; (b) inferred from fluoride data points.



NOTE: data include those High Plains wells screening in multiple formations NOTE: only Dockum outcrop and that part of the aquifer with a TDS<5,000 mg/L are shown. Downdip central section is more saline. Dockum Fm. underlies all of the southern High Plains aquifer. SOURCE: aquifer outlines from TWDB GIS coverage of major and minor aquifers Figure 45. Arsenic distribution in the Dockum (a), Edwards Trinity (b), and Cenozoic Pecos Alluvium aquifers (c).



NOTE: data include those High Plains wells screening in multiple formations SOURCE: aquifer outlines from TWDB GIS coverage of major aquifers Figure 45. Arsenic distribution in the Dockum (a), Edwards Trinity (b), and Cenozoic Pecos Alluvium aquifers (c). (continued)



Figure 46. Arsenic distribution in the Gulf Coast aquifers (TWDB and NURE databases)

Distribution of Calcite SI in Texas Section of Ogallala Aquifer (TWDB)



Figure 47. Distribution of calcite saturation index in the southern High Plains aquifer (TWDB data set)



(b)

Figure 48. pH distribution in the High Plains Aquifer: all Texas data points (a); southwestern region of southern High Plains (b). all data points (TWDB database).

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Figure 49. Spatial distribution of As (a), Mo (b), Se (c), V (d), B (e), F (f), U (g), silica (h), Fe (i), chloride (j), sulfate (k), TDS (l), and pH (m) in High Plains aquifers. All plots use only TWDB data except U where NURE data are used.



Figure 49. Spatial distribution of As (a), Mo (b), Se (c), V (d), B (e), F (f), U (g), silica (h), Fe (i), chloride (j), sulfate (k), TDS (l), and pH (m) in High Plains aquifers. All plots use only TWDB data except U where NURE data are used. (continued)



Figure 49. Spatial distribution of As (a), Mo (b), Se (c), V (d), B (e), F (f), U (g), silica (h), Fe (i), chloride (j), sulfate (k), TDS (l), and pH (m) in High Plains aquifers. All plots use only TWDB data except U where NURE data are used. (continued)



Figure 49. Spatial distribution of As (a), Mo (b), Se (c), V (d), B (e), F (f), U (g), silica (h), Fe (i), chloride (j), sulfate (k), TDS (l), and pH (m) in High Plains aquifers. All plots use only TWDB data except U where NURE data are used. (continued)


Arsenic (ug/L) (c) Figure 50. Cross-plots of (a) As vs. Mo, (b) vs. Se, (c) vs. V, (d) vs. B, (e) vs. F, (f) vs. silica, (g) vs. Fe, (h) vs. bicarbonate, (i) vs. sulfate, (j) vs. chloride, (l) vs. TDS and (m) vs. pH (NURE data set), High Plains aquifers.



Figure 50. Cross-plots of (a) As vs. Mo, (b) vs. Se, (c) vs. V, (d) vs. B, (e) vs. F, (f) vs. silica, (g) vs. Fe, (h) vs. bicarbonate, (i) vs. sulfate, (j) vs. chloride, (l) vs. TDS and (m) vs. pH (NURE data set), High Plains aquifers. (continued)



Figure 50. Cross-plots of (a) As vs. Mo, (b) vs. Se, (c) vs. V, (d) vs. B, (e) vs. F, (f) vs. silica, (g) vs. Fe, (h) vs. bicarbonate, (i) vs. sulfate, (j) vs. chloride, (l) vs. TDS and (m) vs. pH (NURE data set), High Plains aquifers. (continued)



Figure 50. Cross-plots of (a) As vs. Mo, (b) vs. Se, (c) vs. V, (d) vs. B, (e) vs. F, (f) vs. silica, (g) vs. Fe, (h) vs. bicarbonate, (i) vs. sulfate, (j) vs. chloride, (l) vs. TDS and (m) vs. pH (NURE data set), High Plains aquifers. (continued)



NOTE: Data set from Public Water Supply well sampling (Jackson et al., 2004) Figure 51. Cross-plot of As vs. perchlorate, southern High Plain aquifers.



Figure 52. Cross-plot of As vs. Ca/Mg ratio, southern High Plains; NURE (a) and TWDB (b) databases



Figure 53. Arsenic spatial distribution by aquifer: all together (a) and, individually, in Chicot, Evangeline, and Jasper aquifers (b).



Figure 54. Spatial distribution of As (a), Mo (b), Se (c), V (d), B (e), F (f), U (g), silica (h), Fe (i), chloride (j), sulfate (k), TDS (l), anf pH (m) in Gulf Coast aquifers. All plots use only TWDB data except As and U where NURE data are also included.



Figure 54. Spatial distribution of As (a), Mo (b), Se (c), V (d), B (e), F (f), U (g), silica (h), Fe (i), chloride (j), sulfate (k), TDS (l), anf pH (m) in Gulf Coast aquifers. All plots use only TWDB data except As and U where NURE data are also included. (continued)



Figure 54. Spatial distribution of As (a), Mo (b), Se (c), V (d), B (e), F (f), U (g), silica (h), Fe (i), chloride (j), sulfate (k), TDS (I), anf pH (m) in Gulf Coast aquifers. All plots use only TWDB data except As and U where NURE data are also included. (continued)



Figure 55. Cross-plots of (a) As vs. Mo, (b) vs. Se, (c) vs. V, (d) vs. B, (e) vs. U, (f) vs. silica, (g) vs. Fe, (h) vs. alkalinity (~bicarbonate), (i) sulfate, (j) vs. chloride, (k) vs. conductivity (~TDS) and (l) vs. pH (NURE data set), southwestern Gulf Coast aquifers.



Figure 55. Cross-plots of (a) As vs. Mo, (b) vs. Se, (c) vs. V, (d) vs. B, (e) vs. U, (f) vs. silica, (g) vs. Fe, (h) vs. alkalinity (~bicarbonate), (i) sulfate, (j) vs. chloride, (k) vs. conductivity (~TDS) and (I) vs. pH (NURE data set), southwestern Gulf Coast aquifers. (continued)



NOTE: Left-hand side plots include only those sample points where both variables are above detection limits; right-hand side plots include all sample points Figure 56. Cross-plots of (a,b) As vs. Mo, (c,d) vs. Se, (e,f) vs. V, (g,h) vs. B, (i) vs. fluoride and silica, (j) vs. bicarbonate and sulfate, (k) vs. nitrate, and (I) vs. TDS and pH (TWDB database), southwestern Gulf Coast aquifers.



NOTE: all plots include only those sample points where both variables are above detection limits except (h) that include all sample points.

Figure 56. Cross-plots of (a,b) As vs. Mo, (c,d) vs. Se, (e,f) vs. V, (g,h) vs. B, (i) vs. fluoride and silica, (j) vs. bicarbonate and sulfate, (k) vs. nitrate, and (I) vs. TDS and pH (TWDB database), southwestern Gulf Coast aquifers. (continued)



Figure 57. Arsenic concentration vs. total well depth in Gulf Coast Aquifers (a), only southwestern Gulf Coast (b)



Figure 58. Thickness map of Ogallala-age ash beds based on geophysical logs



Figure 59. Map of selected uranium mines in the southern Gulf Coast area



NOTE: locations from Lopez (1995), depth information from Halbouty (1979) and Ewing (1990) Figure 60. Map of salt domes along the Gulf Coast





Figure 61. Histograms of arsenic distribution showing modeling results



(c) Figure 62. Crossplot of arsenic concentration with and without including trace elements in the modeling



Figure 63. Spatial distribution of the Ca/Mg ratio in the southern High Plains (TWDB database)



Dissolved Oxygen in Southern Ogallala Aquifer (Eastern Half - NURE)

Figure 64. Distribution of dissolved oxygen (NURE) and redox potential (TWDB) in the southern High Plains aquifer



Figure 65. Depth distribution of dissolved oxygen in the eastern half of the southern High Plains aquifer (NURE data)



Figure 66. Spatial distribution of dissolved oxygen in the eastern half of the southern High Plains aquifer (NURE data)

Dissolved Oxygen in Southern Gulf Coast (NURE)



Figure 67. Histogram of dissolved oxygen in the southwestern Gulf Coast aquifers (NURE data)



NOTE: (a) all samples; (b) only samples with As > 10 ug /L are retained Figure 68. Cross-plots of As vs. dissolved oxygen (NURE data set), southwestern Gulf Coast aquifers:



Figure 69. Redox potential in Gulf Coast aquifers (a) and only southwestern section (b)



NOTE: (a) to a depth of 3,000 ft; (b) to a depth of 1,000 ft Figure 70. Depth distribution of dissolved oxygen in the southwestern Gulf Coast aquifers



Dissolved Oxygen (mg/L)







NOTE: data from Henry et al. (1982a, Table A-1)

Figure 72. Eh evolution along groundwater flowlines in Oakville sandstone of the southwestern Gulf Coast



Figure 73. Time series of arsenic and Vanadium aqueous concentrations in wells recently sampled in Duval County





Figure 75. Cross-plots of As vs. dissolved oxygen (a) and computed redox potential (b) (Duval County)



Figure 76. Literature comparison of measured and computed Eh



NOTE: at  $25^{\circ}$ C, pe = 16.9 Eh (V) or Eh (mV) = 59 pe SOURCE: Parkhurst et al., 1995 Figure 77. Redox ladder for As, Se, U, and V and major redox couples

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	au		E	ande			- 10121	nur ur				
	loce	222.63					P	Sand, gravel, silt, clay.				
	Ho	1	FI	uvial	terrace deposits		00000	Sand, gravel, silt, clay.				
	Pleistocene		PI	eisto Clay, ation	Cene Deweyville Formation, Beaumo Montgomery Formation, Bentley Form , and Pliocene (?) Willis Sand .	ont m-	0000 0000 0000 0000 0000 0000	Sand, gravel, silt, clay.				
	Pliocene		G	oliad	Sand	*		Fine to coarse sand and conglomerate; cal- careous clay; basal medium to coarse sand- stone. Strongly calichified.				
			FI	emir	9 (Logarto) Formation			Calcareous clay and sand.				
	Miocene	2 8 8 A	0	akvill	e Sandstone	*		Calcareous, crossbedded, coarse sand. Some clay and silt and reworked sand and clay pebbles near base.				
-			la mation	rs)	Chusa Tuff			Calcareous tuff: bantonitic claus come erouel				
		- 10	atahou Jan For	e autho	Soledad Conglomerate	*		and varicolored sand near base. Soledad in Duval County, grades into sand				
	Oligocene		) [Gueyo	of som	Fant Tuff		1110	renses in northern Duval and adjacent counties.				
	0		Fr (	io Cla Sout	ay hwest of Karnes County)	*		Light-gray to green clay; local sand-filled chan				
[	20	Jackson	hitsett Formation	Fashing Clay				Chiefly clay; some lignite, sand, Corbicula				
				Tordilla Sandstone, Calliham Sandstone			=	Very fine sand.				
	ene			Dubose			三十	Silt, sand, clay, lignite.				
	Eoo			Deweesville Sandstone				Mostly fine sand; some carbonaceous silt and cla				
				Conquista Clay Dilworth Sandstone			- 4-1	Carbonaceous clay.				
	1000	in l	3				1					

NOTE: Crossed picks indicate units from which uranium has been extracted SOURCE: Galloway et al., 1979 Figure 78. Stratigraphic section in the South Texas uranium province



## Hazardous Materials Control Resources Institute (HMCRI)

Data Table

Table Comparison of OU No. 3 Soil/Sediment Data to Regional Background Data RSR Corporation Superfund Site Operable Unit No. 3

Background Soil Concentrations (mg/kg)

Maximum - Observed OU No. 3 Concentrations (mg/kg)

Chemical	Range	Arithmetic Mean	Standard Deviation	Number of Samples	Arithmetic Mean + 2 Standard Deviations	Surface Soil	Site 1 Sub- surface Soil	Sediment	Surface Soil	Site 3 Sub- surface Soil	Sediment	Surface Soil	Site 4 Sub- surface Soil	Sediment
Alummium	700 - >100,000	72,000		1,247	47,000	32,300	10,800	17,000	29,800	27,900	25,500	25,900	19,000	23,500
		47,000	2.48											
Arsenic	1.1 - 18	6.4	3.3	119	13	7,980	309	224	127	12.8	55.8	252	114	19.6
Barium	150 - 1,000	404	200	119	800	2,330	431	272	934	131	426	2,330	1,060	162
Berllium	N.D 7.0	0.62	1.06	119	2.7	4.3	0.79	2.5	1.6	1.5	2.5	2.8	1.3	2.4
Cadmium b	N.D 11			1,319		637	17.7	43.1	8.4	1.3	9.1	8.7	15.1	0.75
Chromium	3.0 - 150	40	28	119	96	204	40.5	94.1	288	85	66.6	69.1	1,420	41.7
Cobalt	N.D 30	4.9	4.5	119	14	86.1	21.1	12.6	19.8	32.6	64.2	264	25.7	12.6
Copper	3.0 - 30	1.5	8.0	119	31	6,610	484	219	286	37.3	213	395	2,090	71.9
Lead	N.D 30	1.3	8.1	119	29	105,000	6,540	3,940	71,500	320	2,100	6,390	11,500	364
Manganese b	<2.0 - 7,000	550		1,317	340	3,490	3,050	7,630	1,060	680	2,380	970	1,200	1,200
		330	2.77											
Mercury	<0.01 - 0.69	0.064	0.097	119	0.26	2	0.06	0.55	0.61	0.13	1.2	0.86	0.52	0.32
Nickel	N.D 50	12	8.8	119	30	1,180	95.1	49.4	162	12,200	62	62.6	95.8	33.2
Silver b	N.D 5.0			1,319	5.0	3.2	0.24	3.4	1.55	1.25	0.55	4.4	6.2	1.75
Thallium						4.4	1.1	7.95	0.9	2.9	1.25	2.6	5.4	2.55
Vanadium	7.0 - 200	52	37	119	130	64.7	50.2	56.3	72.8	64.7	58.8	52.1	43.7	54.3
Zinc	5.0 - 108	39	22	116	83	4,300	630	2,090	796	116	394	17,500	4,250	276

Source: Dragon. J. and Chasson Andrew, 1991. Elements in North American Soils. Hazardous Materials Control Resources Institute.

aGeometric mean

bSoil of contaminous USA, rather than Texas soils only

cMaximim value