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# Remedial Action Work Plan for OU1

## Volume I

### Settling Defendant: 1500 South Tibbs LLC

1500 S. Tibbs Ave.
Indianapolis, IN 46241

May 16, 2025

| Volume | Location | Description |
|---|---|---|
| Volume I | RAWP | Main Body of Report and Attachments |
| Volume I | RAWP | Certification |
| Volume I | RAWP | Remedial Design Overview |
| Volume II | Appendix A | Remedial Design Drawings |
| Volume III | Appendix B | Remedial Design Specifications |
| Volume III | Appendix C | Remedial Action Construction Schedule |
| Volume III | Appendix D | Site Survey |
| Volume III | Appendix E | Photographic Documentation Plan (PDP) |
| Volume III | Appendix F | Permitting Plan (PP) |
| Volume III | Appendix G | Site-Wide Monitoring Plan (SWMP) |
| Volume III | Appendix H | Field Sampling Plan (FSP) |
| Volume IV | Appendix I | Quality Assurance Project Plan (QAPP) |
| Volume III | Appendix J | Construction Quality Assurance and Control Plan (CQA/CP) |
| Volume III | Appendix K | Transportation and Off-Site Disposal Plan (TODP) |
| Volume III | Appendix L | Emergency Response Plan (ERP) |
| Volume III | Appendix M | Community Impacts Mitigation Plan (CIMP) |
| Volume III | Appendix N | Operation and Maintenance Plan (OMP) |
| Volume III | Appendix O | Operation and Maintenance Manual (OMM) |
| Volume V | Appendix P | Health and Safety Plan (HASP) |

Prepared by: David M. Peterson, PE, PC

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# Remedial Action Work Plan for OU1
# Main Body of Report and Attachments

## Settling Defendant: 1500 South Tibbs LLC

1500 S. Tibbs Ave.
Indianapolis, IN 46241

May 16, 2025

Prepared by: David M. Peterson, PE, PC

# Remedial Action Work Plan

**Remedial Action Work Plan ("RAWP") for OU1**. Settling Defendant shall submit a RAWP for EPA approval that includes a proposed Remedial Action Construction Schedule, an updated health and safety plan that covers activities during the Remedial Action, and plans for satisfying permitting requirements, including obtaining permits for off-site activity and for satisfying substantive requirements of permits for on-site activity.

Table of Contents

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Table of Contents

1.0 Introduction…… 1
1.1 Overview…… 1
1.2 Site Location and Description…… 1
1.3 Site History…… 1
1.4 Objectives…… 2
2.0 Geology and Hydrogeology…… 2
2.1 OU1 and OU5 Shallow Aquifer System…… 2
2.2 OU1 Deep and OU5 Medium Aquifer System…… 2
2.3 OU5 Deep Aquifer System…… 2
2.4 Bedrock System…… 2
2.5 Groundwater Pumping Conditions…… 3
2.6 Hydrogeologic Properties…… 3
3.0 Nature and Extent of Contamination…… 3
4.0 Performance Standards…… 5
4.1 Remedial Action Objectives for Groundwater Contamination…… 5
4.2 Groundwater Exceeding Remedial Goals…… 5
4.3 Groundwater Not Exceeding Remedial Goals…… 6
4.4 Vapor Intrusion Pathway Remedial Goals…… 6
5.0 Applicable or Relevant and Appropriate Requirements…… 7
6.0 OU1 Remediation…… 7
7.0 Contaminant Transport Modeling…… 8
8.0 Biosparge Technical Evaluation…… 8
8.1 Sparge Radius of Influence…… 9
8.2 Fine Grained Layers between Shallow and Deep Zones…… 10
8.3 Modeled Sparge Operation…… 10
8.4 Groundwater Treatment…… 11
8.5 Subsurface Vapor Intrusion Evaluation…… 11
8.5.1 Regulatory Applicability…… 11
8.5.2 Vapor Intrusion Screening…… 12
8.6 Potential to Emit…… 12
8.7 Groundwater Level Monitoring…… 12
8.8 Biosparge Basis of Design…… 13
9.0 Barrier Biosparging Description…… 13
9.1 System Description…… 13
9.2 System Design…… 14
9.3 System Monitoring…… 14
10.0 Biosparge System Startup and Shakedown…… 15
11.0 Cessation of Groundwater Pumping…… 15
12.0 Contingency Plans…… 16
12.1 Groundwater Monitoring…… 17
12.2 Soil Gas Monitoring…… 17
13.0 Remedial Design…… 17
14.0 Remedial Action Implementation…… 18

14.1 Permitting Plan…… 21
14.2 Photographic Documentation Plan…… 22
14.3 Construction Quality Assurance and Quality Control Plan…… 22
14.4 Transportation and Off-Site Disposal Plan…… 23
14.5 Emergency Response Plan…… 23
14.6 Community Impacts Mitigation Plan…… 23
14.7 Health and Safety Plan…… 23
15.0 Remedial Action Operation and Maintenance…… 24
15.1 Operation and Maintenance Plan…… 24
15.2 Operation and Maintenance Manual…… 24
16.0 Remedial Action Monitoring…… 25
16.1 Site-Wide Monitoring Plan…… 25
16.2 Field Sampling Plan…… 25
16.3 Quality Assurance Project Plan…… 25
17.0 Remedial Action Schedule…… 25
18.0 References…… 26
19.0 Supporting Documentation…… 28
20.0 Attachments…… 30

List of Tables

Table 1 OU1 and OU5 Shallow Aquifer Impacts
Table 2 OU1 Deep and OU5 Medium Aquifer Impacts
Table 3 OU5 Deep Aquifer Impacts
Table 4 Groundwater Concentration Trends over the past 3 Years
Table 5 Groundwater Remedial Goals (RGs)
Table 6 OU1 and OU5 Shallow Aquifer Impacts above RGs
Table 7 OU1 Deep and OU5 Medium Aquifer Impacts above RGs
Table 8 OU5 Deep Aquifer Impacts above RGs
Table 8 OU5 Deep Aquifer Impacts above RGs
Table 9 Vapor Screening Levels
Table 10 Summary of OU1 Sparging Pilot Tests
Table 11 Deep Aquifer Sparging Results Summary
Table 12 Shallow Aquifer Sparging Results Summary
Table 13 Benzene and Pyridines Sparging Half-Lives with Radius of Influence
Table 14 Cessation of Groundwater Pumping Monitoring Locations
Table 15 Remediation Action Schedule
Table 16 References

Attachments

A. Drawings
   1. Site Map
   2. Shallow Groundwater Gradient Map
   3. Deep Groundwater Gradient Map
   4. Shallow Groundwater Concentrations
   5. Deep Groundwater Concentrations
   6. Sparge Pilot Test Areas
   7. OU5 Additional Groundwater Monitoring Locations
   8. Operating Unit Location Map
B. Cross Sections
   1. OU1 and OU5 Cross Sections Map
   2. OU1 and OU5 Cross Sections A, B, and C
   3. OU1 and OU5 Cross Sections D and E
   4. OU1 and OU5 Cross Sections F and G
C. Monitoring Well Concentration Trends
D. 2019 Groundwater Modeling Report and EPA Response to Comments
E. Sparging Feasibility Testing Description
F. Biosparge Basis of Design
G. Vapor Intrusion Screening
H. Decision Diagrams
   1. Dissolved Oxygen Monitoring
   2. Cessation of Pumping – Groundwater
   3. Groundwater Monitoring Contingency Plan
   4. Soil Gas Monitoring Contingency Plan
   5. OU5 Groundwater Increase ≥3 Times Prior Result
I. Data Quality Objectives
   1. Biosparge Well Depth and Spacing
   2. Investigation Derived Waste and Surplus Excavated Soil Collection and Characterization
   3. Biosparge Well Performance Testing
   4. Biosparge Pipe Pressure Testing
   5. Proper Biosparge System Operation
   6. Biosparge System Optimization via Dissolved Oxygen Monitoring
   7. Soil Gas Vapor Intrusion Evaluation
   8. Cessation of Groundwater Pumping
   9. OU5 Groundwater Evaluation
   10. Groundwater Vapor Intrusion Evaluation

Appendices (Supporting Documentation)

A. Remedial Design Drawings
B. Remedial Design Specifications
C. Remedial Action Construction Schedule
D. Site Survey
E. Photographic Documentation Plan
F. Permitting Plan
G. Site-Wide Monitoring Plan
H. Field Sampling Plan
I. Quality Assurance Project Plan
J. Construction Quality Assurance and Control Plan
K. Transportation and Off-Site Disposal Plan
L. Emergency Response Plan
M. Community Impacts Mitigation Plan
N. Operation and Maintenance Plan
O. Operation and Maintenance Manual
P. Health and Safety Plan

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# (1) Introduction

## 1.1 Overview

This Remedial Action Work Plan (RAWP) constitutes the Remedial Design (RD) for the implementation of the OU1 sparge system Remedial Action (RA) in accordance with the Consent Decree (CD) for Remedial Design and Remedial Action between the plaintiffs including the United States of America and State of Indiana and the defendant including 1500 South Tibbs LLC (USA 2024). The Statement of Work (SOW) attached to the CD contains many of the prescribed requirements for the RA. The formatting within this RAWP is modeled after formatting prescribed by the USEPA for the Uniform Federal Policy – Quality Assurance Project Plan (QAPP).

## 1.2 Site Location and Description

The Site is located at 1500 South Tibbs Avenue in the southwest quadrant of Indianapolis, Indiana. Minnesota Street divides the 120 acre Site into 2 parcels. The Oak Park property, which occupies approximately 40 acres, is located north of Minnesota Street. The Maywood property, which occupies approximately 80 acres, is located south of Minnesota Street. The southern half of the Maywood property has been leased and has been developed for use as a solar farm. **Attachment A** contains Figure 1 as a site map.

The facility was a chemical manufacturing facility for decades and ceased production in 4Q2023. The majority of the facility buildings are located north of Minnesota Street, on the Oak Park property. Approximately 75% of the Oak Park property is covered by buildings, pavement, and above-ground tank farms formerly used for chemical manufacturing. The northern portion of the Maywood Property contained chemical manufacturing and wastewater treatment processes.

The site is surrounded by a mix of residential, industrial, and commercial properties. Residential neighborhoods are located to the north and east of the Oak Park property. All residences and places of business are connected to the municipal water supply. Commercial and industrial properties are located west, south and southeast of the site.

## 1.3 Site History

Industrial development of the site began in 1921 when the Republic Creosoting Company started a coal tar refinery and a creosote wood treatment operation on the Maywood property. Republic Creosoting Company later became Reilly Tar & Chemical, and then Reilly Industries Inc. During a 2007 merger, the name was changed to Vertellus Specialties Inc. (VSI). In 2016 VSI filed for Chapter 11 bankruptcy and Vertellus Integrated Pyridines LLC (VIP) emerged as the new owner following the corporate restructuring. VIP was later renamed Aurorium Indianapolis LLC in 2023 and then renamed 1500 South Tibbs LLC in 2023.

On-site wood treatment operations occurred from 1921 until 1972. Beginning in 1941, chemical plants were constructed and operated on the Oak Park property. Environmental issues at the site were investigated during the Remedial Investigation (RI) in the late 1980's and early 1990's (ENSR, 1991a and 1991b). The identified issues were related to the management and disposal of creosoting process wastes and substances/wastes associated with the process of manufacturing custom synthesized specialty chemicals.

In 1984, the site was listed on US EPA's National Priorities List (NPL). In 1987, the potentially responsible party (PRP) agreed to conduct an RI/FS. The RI/FS was completed during the early 1990's. Five OUs were established and each has been addressed. OU1 (on-site) and OU5 (off-site) address groundwater. OU2, OU3, and OU4 were remediated, capped, and are subject to long-term inspections and maintenance. OU2 is located on the Oak Park property as the former lime pond. OU2 is also located on the Maywood property as the former railroad trench, former treatment pit, former drainage ditch, and south landfill / former fire pond. OU3 is located on the northern portion of the Maywood property as the kickback area and consists of former solid waste management units near wastewater Tanks 17 and 18, the drum steam-out area, and the south API area. OU4 is located on the Oak Park property and consists of the north process area, hazardous waste storage Tank 66, and the process sewers.

Several Institutional Controls (ICs) are in affect for the site including no use of groundwater, restrictions on the use of the CERCLA areas, fencing around the remedial areas, cover maintenance, and industrial land use restrictions. These ICs have been reviewed and approved by the EPA and Indiana Department of Environmental Management (IDEM) and recorded in a Declaration of Environmental Restrictive Covenant for the Site (Vertellus 2012).

1.4 Objectives

The RAWP objectives are to present and describe the RD and RA resulting from the installation, operation, maintenance, and monitoring of a biosparge system described in the Record of Decision Amendment dated August 2021 (ROD Amendment). The RA will be performed in accordance with this RAWP including supporting RD documents and associated work plans identified as Supporting Documentation.

(2) Geology and Hydrogeology

The Site lies within the White River drainage basin and is located approximately 2.5 miles west of the White River. The Eagle Creek tributary is located approximately 4,000 feet east of the site, flows in a southeasterly direction, and empties into the White River. Topography in the area is relatively flat with a gentle downward slope in an easterly direction. Other surface water bodies in the area include Blue Lake (a former gravel pit) located approximately 2,000 feet east of the Site, another water body located approximately 2,000 feet east of the solar farm, and a surface water impoundment located approximately 800 feet west-southwest of the solar farm.

The sand and gravel deposits that underlie almost all of the White River drainage basin form the principal aquifers in the area. In the vicinity of the Site, shallow, medium, and deep aquifer zones have been identified. The three aquifer zones are not always present or laterally continuous in all areas of OU1 and OU5. For example, the shallow aquifer is present everywhere in OU1 and OU5. The deep OU1 aquifer is laterally continuous with the medium depth aquifer in OU5. Finally, the deep aquifer in OU5 has no lateral equivalent in OU1 for the Site area north of Minnesota Ave. Each of the aquifer zones are described in the following sections and several cross sections are provided in **Attachment B**.

2.1 OU1 and OU5 Shallow Aquifer System

The shallow sand and gravel aquifer is present everywhere in OU1 and OU5 and is typically underlain by finer grained soils. The finer grained soils contain silt and/or clay that can be mixed with sand and/or gravel. Monitoring wells in the shallow aquifer are typically screened in the range of approximately 25-35 feet below ground surface (bgs). Pumping wells PW-1S and PW-2S are screened in the shallow aquifer along with perimeter wells RI-4S, RI-6S, and RI-17S. The ground surface in this area is approximately 700 feet above mean sea level (feet msl).

The lower permeability soils beneath the shallow aquifer are typically present and beginning at an elevation of approximately 670 feet msl in OU1 and OU5 although some anomalies and variations do exist. Instances of continuous sand and gravel formation (i.e. no lower permeability soils) include areas around well locations RI-2, PW-3, RI-6, RI-20, and RI-19.

2.2 OU1 Deep and OU5 Medium Aquifer System

A deep aquifer underlies the shallow aquifer in OU1. The deep aquifer in OU1 is laterally continuous with the aquifer zone identified as the medium aquifer in OU5. Wells in the OU1 deep aquifer and OU5 medium aquifer are generally screened in the range of 40-60 feet bgs. OU1 perimeter wells in the deep zone include RI-4D, RI-5S, RI-6D, and RI-17D. Pumping well PW-1D is also screened in this zone. OU5 wells in this zone include RI-11M, RI-15M and RI-19D.

2.3 OU5 Deep Aquifer System

A deep aquifer underlies the medium aquifer in OU5. Monitoring wells in the OU5 deep aquifer are typically screened in the range of approximately 80 to 110 feet bgs and include wells RI-11D and RI-15D. OU1 perimeter well RI-5D and the OU5 Rolls-Royce production wells are also screened in the deep aquifer.

2.4 Bedrock System

Bedrock underlies the sand and gravel and till deposits and its elevation varies. In the northern portion of OU1, the depth to bedrock varies from approximately 45 feet to 60 feet bgs. In the area of PW-2 and RI-17 the depth to bedrock is approximately 50 feet bgs. Bedrock is approximately 90 to 100 feet bgs in the vicinity of RI-5 and RI-6.

In OU5, bedrock is generally 100 to 120 feet bgs. A rise in the bedrock elevation has been identified in OU5 which pinches out the deep aquifer in the area of RI-19 and former RI-42.

2.5 Groundwater Pumping Conditions

Shallow groundwater level data has been measured while pumping from PW-1S and PW-2S which are in place to provide groundwater containment as required by the OU1 ROD (EPA 1992). **Attachment A** contains Figure 2 that illustrates the groundwater gradient map for the OU1 and OU5 shallow aquifer during 1Q2024 (DMP 2024a). Groundwater levels in the shallow and deep aquifers suggest a slight downward gradient.

Medium and deep groundwater level data has been measured while pumping from PW-1D which is in place to provide groundwater containment as required by the OU1 ROD. In addition, the Rolls-Royce production wells are actively pumped and impact the direction of groundwater flow. **Attachment A** contains Figure 3 that illustrates the groundwater gradient map for the OU1 deep aquifer and OU5 medium and deep aquifers during 1Q2024.

The shallow and medium / deep groundwater gradient maps illustrate that the groundwater flow is multi-directional, both to the northeast as well as to the south / southeast.

Rolls-Royce operates 3 high capacity non-contact cooling water wells located southeast of the Site (PW-1, PW-2, and PW-3). The closest Rolls-Royce well is PW-3, which is located approximately 1,200 feet east of the Site. In the past, Olin Brass also maintained a high capacity well field on the west side of Eagle Creek and south of Minnesota Ave. The Olin Brass well field was located approximately 2,400 feet east of the Site, ceased operation in 2006 to 2007, and the wells were abandoned on March 30, 2007 according IDEM well records (IDNR 2007).

In general, the sand and gravel formations in OU1 are less thick and less permeable than those in OU5. Less water can be pumped from OU1 wells PW-1S, PW-2S, and PW-1D than can be pumped from OU5 Rolls-Royce production wells.

2.6 Hydrogeologic Properties

The distribution of hydraulic conductivity varies across the site. Hydraulic conductivities for Site wells tested during the Remedial Investigation (RI) range from 1 x $10^{-2}$ to 1 x $10^{-3}$ centimeters per second (approximately 28 to 2.8 feet/day) (ENSR, 1991a and 1991b). Later studies performed by August Mack Environmental (AME, 1996) yielded a range of 1.4 x $10^{-2}$ to 1.06 x $10^{-3}$ centimeters per second (approximately 40 to 3.0 feet/day). A study performed by EGC (EGC, 2002) at one location yielded a value of 2.1 x $10^{-2}$ centimeters per second (approximately 60 feet/day).

(3) Nature and Extent of Contamination

OU1 and OU5 have been impacted by benzene, pyridines and ammonia. These compounds have impacted the shallow and deep aquifers on-site in OU1 and the shallow, medium and deep aquifers off-site in OU5 as summarized in the following tables which present concentrations measured in 1Q2024. Non-detect levels are not presented in the tables and only concentrations of ammonia exceeding 1 mg/L (part per million, ppm) are identified. Benzene and pyridines are reported in µg/L (micrograms per liter = parts per billion, ppb). **Attachment C** contains graphs that display the concentration trends at monitoring wells presented in the 2024 Annual Linear Regression Report (DMP 2024b).

OU1 locations identified in the tables include the Perimeter (eastern limit of OU1 along Tibbs Avenue), DAB Plant Area which is in the northern central portion of the Oak Park property, Vinyl Pyridine (VP) Plant which is in the southern central portion of the Oak Park property, Former Railway Trench which is in the central portion of the Maywood property, and the Former Treatment Pit (FTP) Area which is just north of the solar farm on the Maywood property. OU5 locations are identified by direction within OU5.

**Table 1 – OU1 and OU5 Shallow Aquifer Impacts**

| Compound of Concern | OU1 Shallow Aquifer Impact, Well ID and General Location | OU5 Shallow Aquifer Impact, Well ID and General Location |
|---|---|---|
| Benzene | 129 µg/L at RI-18S (VP Plant)<br>24.1 µg/L at RI-25S (DAB Plant Area) | No impacts. |
| Pyridines | 47.7 µg/L at RI-4S (Perimeter)<br>381.8 µg/L at RI-18S (VP Plant)<br>85.1 µg/L at RI-25S (DAB Plant Area) | No impacts. |

| | | |
|---|---|---|
| | 17.8 µg/L at RI-29S (Former Railway Trench)<br>58.2 µg/L at RI-30S (Former Railway Trench)<br>9.6 µg/L at RI-31S (FTP Area)<br>50.5 µg/L at RI-33S (FTP Area) | |
| Ammonia | 15.0 mg/L at PW-2S (Perimeter)<br>7.8 mg/L at RI-4S (Perimeter)<br>4.3 mg/L at RI-6S (Perimeter)<br>6.6 mg/L at RI-17S (Perimeter)<br>8.7 mg/L at RI-18S (VP Plant)<br>5.4 mg/L at RI-25S (DAB Plant Area)<br>3.9 mg/L at RI-28S (Former Railway Trench)<br>4.0 mg/L at RI-29S (Former Railway Trench)<br>1.5 mg/L at RI-30S (Former Railway Trench)<br>2.3 mg/L at RI-35S (FTP Area) | 1.1 mg/L at RI-19S (Central Area)<br>2 mg/L at RI-42S (Central Area) in March 2015; well was paved over when street was resurfaced by others in 2015. |

Detections of benzene, pyridines and ammonia in the shallow aquifer are illustrated in **Attachment A**, Figure 4.

**Table 2 – OU1 Deep and OU5 Medium Aquifer Impacts**

| Compound of Concern | OU1 Deep Aquifer Impact, Well ID and General Location | OU5 Medium Aquifer Impact, Well ID and General Location |
|---|---|---|
| Benzene | 33.4 µg/L at RI-4D (Perimeter)<br>12.5 µg/L at RI-5S (Perimeter)<br>18.1 µg/L at PW-1D (Perimeter) | 34.0 µg/L at RI-15M (Northern Limit) |
| Pyridines | 64.8 µg/L at RI-4D (Perimeter)<br>33.7 µg/L at RI-5S (Perimeter) | No impacts. |
| Ammonia | 14.9 mg/L at RI-4D (Perimeter)<br>8.0 mg/L at RI-5S (Perimeter) | 24.2 mg/L at RI-11M (NE Corner)<br>14.6 mg/L at RI-15M (Northern Limit)<br>2.7 mg/L at RI-19D (Southern Area) |

**Table 3 – OU5 Deep Aquifer Impacts**

| Compound of Concern | OU5 Deep Aquifer Impact, Well ID and General Location |
|---|---|
| Benzene | 6.6 µg/L at RI-15D (Northern Limit) |
| Pyridines | No impacts. |
| Ammonia | 5.9 mg/L at RI-11D (NE Corner)<br>6.0 mg/L at RI-15D (Northern Limit)<br>2.1 mg/L at Rolls Royce PW-3 in March 2022; well is no longer accessible. |

Detections of benzene, pyridines and ammonia in the OU1 deep, OU5 medium, and OU5 deep aquifers are illustrated in **Attachment A**, Figure 5.

Concentrations previously referenced are similar to results over the past three years with the following exceptions.

**Table 4 – Groundwater Concentration Trends over the past 3 Years**

| Well | Operating Unit | Aquifer | Groundwater Concentration Trend over the past 3 Years |
|---|---|---|---|
| RI-18S | OU1 – Source Area | Shallow | B and P spiked at 247 µg/L and 1,316.3 µg/L, respectively, and are decreasing. |
| RI-25S | | | B increased from non-detect and P decreased from 608.4 µg/L. |
| RI-31S | | | P have a decreasing trend from 26.7 µg/L. |
| RI-32S | | | P have a decreasing trend from 94 µg/L. |
| RI-33S | | | P have a decreasing trend from 289 µg/L. |

| | | | |
|---|---|---|---|
| RI-4S | OU1 – Barrier Area | | B and P have a decreasing trend from 22.5 µg/L and 459.2 µg/L, respectively. |
| RI-6S | | | B and P have a decreasing trend from 30.7 µg/L and 25.9 µg/L, respectively. |
| PW-2S | | | Ammonia has a decreasing trend from 23.1 mg/L. |
| RI-4D | | Deep | B and P have a decreasing trend from 553 µg/L and 529 µg/L, respectively. |
| RI-15M | OU5 | Mid-Depth | B has an increasing trend from 26.9 µg/L and P have a decreasing trend from 57.5 µg/L. |
| Note: B = Benzene and P = Pyridines | | | |

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(4) Performance Standards

4.1 Remedial Action Objectives for Groundwater Contamination

The Remedial Action Objectives (RAOs) outlined in the 1992 OU1 Record of Decision (ROD) (EPA 1992) remain in effect and this change to the remedy will continue to achieve the following RAOs:

- Perimeter containment to prevent further off-Site migration of groundwater contaminated by the Site; groundwater must meet Maximum Contaminant Levels (MCLs) at the facility boundary.
- Restore off-Site groundwater in the OU5 area to drinking water quality (MCLs) for future use.

At the Site, MCLs and maximum contaminant level goals are not applicable, but are relevant and appropriate, because the unconfined aquifer below the Site is a Class II aquifer that has been used in the past for drinking water by residents bordering the Site and could potentially be used as a drinking water source in the future. Groundwater cleanup criteria (a.k.a. remedial goals; RGs) from the OU1 ROD include:

**Table 5 – Groundwater Remedial Goals**

| Contaminant of Concern | Remedial Goals (mg/L) | Contaminant of Concern | Remedial Goals (mg/L) |
|---|---|---|---|
| **Volatile Organic Compounds** | | **Pyridines** | |
| Benzene | 0.005 | Pyridine | 0.035 |
| Toluene | 1 | 2-Picoline | 0.035 |
| Ethylbenzene | 0.7 | 3&4-Picoline | 0.035 |
| Xylenes | 10 | 2,6-Lutidine | 0.035 |
| | | 2-Ethylpyridine | 0.035 |
| **Inorganics** | | 2,4- & 2,5-Lutidine | 0.035 |
| Ammonia-Nitrogen | 30 | 2,3-Lutidine | 0.035 |
| Nitrate-Nitrogen | 10 | 3-Ethylpyridine | 0.035 |
| | | 4-Ethylpyridine | 0.035 |
| **Metals** | | 3,5-Lutidine | 0.035 |
| Arsenic | 0.01 | 3,4-Lutidine | 0.035 |
| Lead | 0.015 | 2 Methyl-5-ethylpyridine | 0.035 |
| Chromium | 0.1 | 2 Methyl-3-ethylpyridine | 0.035 |
| | | 3 Ethyl-4-ethylpyridine | 0.035 |

4.2 Groundwater Exceeding Remedial Goals

The following tables identify locations where the RGs were exceeded in 1Q2024.

**Table 6 – OU1 and OU5 Shallow Aquifer Impacts above RGs**

| Compound of Concern | OU1 Shallow Aquifer Impact, Well ID and General Location | OU5 Shallow Aquifer Impact, Well ID and General Location |
|---|---|---|
| Benzene | 129 µg/L at RI-18S (VP Plant)<br>24.1 µg/L at RI-25S (DAB Plant Area) | No impacts. |
| Pyridines | 47.7 µg/L at RI-4S (Perimeter) | No impacts. |

| | | |
|---|---|---|
| | • 47.7 µg/L 3,5-Lutidine<br>381.8 µg/L at RI-18S (VP Plant)<br>• 116 µg/L 3,5-Lutidine<br>• 127 µg/L 3/4 -Picoline<br>• 36.2 µg/L 2,6-Lutidine<br>• 45.6 µg/L 2-Ethyl Pyridine<br>85.1 µg/L at RI-25S (DAB Plant Area)<br>• 54.2 µg/L 2-methyl-3-ethyl Pyridine | |
| Ammonia | No impacts above RGs. | No impacts above RGs. |

**Table 7 – OU1 Deep and OU5 Medium Aquifer Impacts above RGs**

| Compound of Concern | OU1 Deep Aquifer Impact, Well ID and General Location | OU5 Medium Aquifer Impact, Well ID and General Location |
|---|---|---|
| Benzene | 33.4 µg/L at RI-4D (Perimeter)<br>12.5 µg/L at RI-5S (Perimeter)<br>18.1 µg/L at PW-1D (Perimeter) | 34.0 µg/L at RI-15M (Northern Limit) |
| Pyridines | 64.8 µg/L at RI-4D (Perimeter)<br>• 54.9 µg/L 3,5-Lutidine | No impacts above RGs. |
| Ammonia | No impacts above RGs. | No impacts above RGs. |

**Table 8 – OU5 Deep Aquifer Impacts above RGs**

| Compound of Concern | OU5 Deep Aquifer Impact, Well ID and General Location |
|---|---|
| Benzene | 6.6 µg/L at RI-15D (Northern Limit) |
| Pyridines | No impacts. |
| Ammonia | No impacts above RGs. |

4.3 Groundwater Not Exceeding Remedial Goals

Groundwater does not exceed RGs at sampling locations absent from Tables 6, 7 and 8. Groundwater has been sampled for toluene, ethylbenzene, and xylenes and no concentrations have been detected above the RGs in any wells for two decades. The most recent toluene, ethylbenzene, or xylene detections above the RGs were on-site at RI-18S for ethylbenzene in October 1998 and RI-33S for toluene in February 2004; these wells have been non-detect for these parameter over the past ten years. Therefore, groundwater samples will no longer be analyzed for toluene, ethylbenzene, and xylenes.

4.4 Vapor Intrusion Pathway Remedial Goals

Work performed to achieve the groundwater RAOs shall not render the vapor intrusion pathway complete to receptors near the biosparge system that are located on-site nor off-site. Regulatory screening levels published in the Indiana Department of Environmental Management (IDEM) Risk Based Closure Guide (RBCG) dated July 8, 2022 (IDEM 2022), Table 1 effective March 28, 2025 (IDEM 2025) use a total hazard quotient of 1 and target risk level of $10^{-5}$. IDEM screening levels are published using one significant figure. OSWER Publication 9200.2-154 dated June 2015 named Technical Guidance for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (EPA 2015b) allows use of the same hazard quotient of 1 and target risk level of $10^{-5}$ (this is the mid-point of EPA's risk range). USEPA Regional Screening Levels for ambient air dated November 2024 for resident and composite worker (i.e. commercial) use more significant figures. However, EPA recommends using one significant figure as published in the EPA vapor intrusion screening levels (VISL) frequently asked question (FAQ) #11.

**Table 9 – Vapor Screening Levels**

| Compound of Concern | Location | Residential Screening Level ($\mu g/m^3$) | Commercial Screening Level ($\mu g/m^3$) |
|---|---|---|---|
| Benzene | Indoor Air<br>Soil Gas | 4<br>100 | 20<br>500 |
| Pyridines | Laboratory analysis of pyridine vapors is not available at Pace Analytical who analyzes all the pyridine derivatives in groundwater. Pyridine does not have an IDEM nor EPA screening level. Benzene has a vapor pressure 4.6 times higher than pyridine (Lide 1995) and the Henry's Law constant indicates benzene is more than 400 times more removable from groundwater than pyridines (NIST 2000). To the extent any volatilization occurs, benzene is much more likely to be volatilized than pyridines. Therefore, pyridine vapors will not be monitored. | | |
| Ammonia | Indoor Air<br>Soil Gas | 500<br>20,000 | 2,000<br>70,000 |
| | Ammonia was evaluated by the EPA Vapor Intrusion Screening Level (VISL) calculator (EPA 2020a and b). Input values included a target risk of $10^{-5}$, target hazard quotient of 1, residential exposure, chronic RfC, and a groundwater temperature of 20˚C. The resulting target groundwater concentration is 898 mg/L that exceeds existing groundwater concentrations. | | |

Notes:
1. Sub-slab and deep (>5 ft below ground surface) soil gas (collectively "Soil Gas") levels are calculated using an attenuation factor of 0.03.
2. Both the EPA vapor intrusion screening levels (VISLs) and IDEM screening levels (SLs) are identical to one significant figure. While EPA VISLs are published to three significant figures, the EPA VISL frequently asked question (FAQ) #11 states that EPA recommends using one significant figure.

A data quality objective for soil gas vapor intrusion is included in **Attachment I**.

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(5) Applicable or Relevant and Appropriate Requirements

CERCLA specifies that Superfund remedial actions must meet any Federal standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate requirements (ARARs). State requirements may also be ARARs if they are more stringent than Federal requirements. The RAWP must comply with ARARs as identified in the RODs.

(6) OU1 Remediation

Groundwater pumping has been occurring since October 1994 to provide groundwater containment as required in the OU1 ROD (EPA, 1992) and as determined through routine groundwater monitoring. Wells PW-1 and PW-2 started to be pumped in 1994 and PW-3 and PW-4 started to be pumped in 1997. PW-1 and PW-2 were replaced with PW-1S, PW-1D, and PW-2S in 2002 and 2003. PW-3 and PW-4 were deactivated following EPA approval in 2005. PW-4 was restarted in July 2010 to address increasing concentration trends at RI-6 and was deactivated in 2012 with EPA approval after benzene and pyridines trended downward to non-detect and ammonia was lowered below the RG. In 1Q2024, groundwater pumping occurred from PW-1S, PW-1D and PW-2S at 6.2, 42, and 34 gallons per minute (gpm), respectively, after the wells were cleaned.

The groundwater pumping system is operated and pumped groundwater is metered as it is discharged to the combined sewer on-site. Within the sewer, the pumped groundwater combines with site stormwater and sanitary water and flows to the CWA Authority's AWT facilities in accordance with Industrial Discharge Permit #285901. Pumped groundwater from PW-1S and PW-1D combines with on-site stormwater and sanitary water and flows south to the Belmont AWT facility. Pumped groundwater from PW-2S combines with on-site stormwater and sanitary water and flows north to the Southport AWT facility. Sampling of discharged water occurs in accordance with the Industrial Discharge Permit. PW-1S, PW-1D and PW-2S were most recently cleaned in February and March 2024. Operation and maintenance (O&M) of the groundwater pumping system occurs for continuous pumping. O&M includes submersible groundwater pump maintenance, recording groundwater discharge flow totalizer values, sampling, and well cleaning.

(7) Contaminant Transport Modeling

In 2018 and 2019, at the request of the EPA to support an analysis of sparging, work was performed to complete a groundwater model to further develop the understanding of solute migration and containment. The groundwater modeling activities were developed and revised through input from regulating authorities including the EPA, the EPA's consultant Jacobs Engineering Group (Jacobs), and IDEM. A report dated March 5, 2019 and titled Groundwater Modeling Evaluation in Support of Focused Feasibility Study was generated by AECOM that described the groundwater flow modeling, described contaminant transport modeling, discussed the results, and presented conclusions (AECOM 2019). This report is included as **Attachment D** and includes responses to comments provided by the EPA on May 9, 2019.
The groundwater modeling report evaluated groundwater treatment via barrier sparging. This not only considered on-site hydraulic changes (e.g., enhanced and ceased pumping conditions), but also considered off-site changing hydraulic conditions (e.g., pumping and not pumping from Rolls Royce Plant production wells).

Despite dramatic changes to the groundwater extraction rates at Rolls Royce Plant production wells (e.g., continually pumping at peak rates and long-term shut-down), groundwater flow modeling results indicate that groundwater impacts near the eastern limit of OU1 will be treated by barrier sparging. The groundwater flow modeled during barrier sparging indicated that sparge wells will intercept groundwater to aerobically biodegrade benzene and pyridines below the RGs before groundwater migrates to OU5. Groundwater contaminants will be effectively treated near the eastern limit of OU1 between the northern property line and RI-6 area.

Groundwater velocities calculated from the modeling while sparging with consistent pumping at Rolls Royce in the shallow and deep aquifers are 0.133 and 0.135 feet per day, respectively, near Minnesota St. and Tibbs Ave. (near RI-4), and 0.169 and 0.157 feet per day, respectively, near Environmental Rd. and Tibbs Ave. (near RI-6).

Natural attenuation times of contaminants in OU5 rapidly increase with higher starting concentrations. Using data from the groundwater model, the estimated time for the natural attenuation process to occur and result in COC concentrations below the RGs in OU5 is less than 8 years for pyridines, 9 years for ammonia, and 19 years for benzene. These time periods commence with the startup of the biosparging system. The longest estimated time for benzene to naturally attenuate to the RG is in the deep aquifer that emanates near RI-4D.

For reference, the groundwater pumping remedy has been operational for 31 years (since 1994). During that time, dissolved concentrations of benzene and pyridines in groundwater have been substantially reduced.

- Benzene in shallow groundwater was reduced by >98% from in excess of 9,000 µg/L to 129 µg/L.
- Benzene in deep groundwater was reduced by >99% from in excess of 6,000 µg/L to 34 µg/L.
- Pyridines in shallow groundwater were reduced by >95% from in excess of 9,000 µg/L to 382 µg/L.
- Pyridines in deep groundwater were reduced by >98% from in excess of 5,000 µg/L to 65 µg/L.

In addition, the dissolved benzene, pyridines, and ammonia groundwater plumes have been substantially reduced in size as shown in figures 2 through 7 of the OU1 Record of Decision Amendment (EPA 2021).

Although benzene and pyridines have been substantially reduced, they remain above the RGs. Biosparging is being implemented to further reduce these concentrations below the RGs near the eastern limit of OU1 so that RGs can be achieved in OU5 via natural attenuation. During this process, ammonia will also attenuate below the RG in OU5.

(8) Biosparging Technical Evaluation

Sparging has been completed at multiple locations in OU1 between 2008 and 2016. Descriptions of the sparging tests are presented in **Attachment E** and the locations of the sparging tests are illustrated in **Attachment A**, Figure 6. A summary of the sparging test locations and durations is presented in the following table:

| Table 10 – Summary of OU1 Sparging Pilot Tests | | | |
|---|---|---|---|
| **Location** | **Sparge Zone** | **Sparge Well(s)** | **Duration of Test** |
| Former Treatment Pit (FTP) | Shallow Sand | SP-31, SP-32, SP-33, and two others | 2008 pilot, Nov 2010 to Oct 2012, Mar 2013 to June 2013, May 2014 to Sept 2014 |
| VP Plant | Shallow Sand | SP-S | 2012 pilot, Dec 2012 to May 2013 and Oct 2013 to Present |
| VP Plant | Deep Sand | RI-18D | Dec 2012 pilot, May 2013 to Aug 2013, and Oct 2013 to 2016 |
| RI-5 | Deep Sand | SP | Dec 2012 pilot, Feb 2013 to Sept 2014 |
| PW-1 Old | Shallow Sand | PW-1 Old Drop Tube | Jan 2013 to Sept 2014 |
| PW-2 Old | Shallow Sand | PW-2 Old with Packer | Jan 2013 to Sept 2014 |
| PW-4 | Shallow Sand | PW-4 with Packer | Oct 2012 to Feb 2013 |
| RI-6D | Deep Sand | RI-6D and two others | Feb 2013 to Sept 2014 |

Sparging results have been used to develop the basis of design to achieve the RAOs for the barrier sparge system. The basis of design identifies the radius of influence, saturated thickness, permeability of the finer grained sediments between the shallow and deeper groundwater, operation of the sparge system, anticipated subsurface results from sparging, and the biodegradation time within the sparge barrier treatment zone.

8.1 Sparge Radius of Influence

The following table summarizes the results from sparging the deep aquifer:

| Table 11 – Deep Aquifer Sparging Results Summary | | |
|---|---|---|
| **Parameter** | **VP Plant Area** | **RI-5 Area** |
| Sparge Well | RI-18D | SP |
| Screen Interval | 52.5 to 57.5 ft bgs | 53-55 ft bgs |
| Depth to Water | 18 ft bgs | 21 ft bgs |
| Saturated Thickness | 34.5 ft (14.9 psi) | 32 ft (13.9 psi) |
| Sparge Rate | 18 scfm at 18-32 psi | 14-17 scfm at 18-22 psi |
| Monitored Wells (Distance Away) | RI-18S (11 ft), DO-55' (50 ft), DO-20' (100 ft), DO-40' (105 ft) all screened approximately 17-27 ft bgs | RI-5S (45 ft) screened 46-56 ft bgs |
| DO Rise | RI-18S (0.2 to 7.7 mg/L, bubbles), DO-55' (1.45 to 2.85 to 7.6 to 9.8, bubbles), no influence at DO-20' or DO-40' | RI-5S (No changes during short term, long term 0.4 to 1.07 mg/L) |
| ROI/Sat. Th. | Min: 50 ft / 34.5 ft = 1.4<br>Max: <100 ft / 34.5 ft = <2.9 | Max: ≤45 ft / 32 ft = ≤1.4 |
| GW Conc.<br><br>Benzene (µg/L)<br>Pyridines (µg/L)<br>Ammonia (mg/L) | RI-18S; Sep-12, Dec-12, Mar-13, Jun-13, Aug-13, Nov-13, Mar-14, Mar-15<br>B 24000, 7400, 1400, 17, 100, 27, ND, ND<br>P 24220, 1680, 92, 23, 44, 245, 33, ND<br>A 13, 9.6, 10, 6.2, 1.6, 3.7, 1.5, 1 | RI-5S: Mar-13, Aug-13, Mar-14, Mar-15<br>B 370, 330, 170, 18.6<br>P 323, 120, 151, 54.2<br>A 15, 16, 11, 11 |

Based upon these results the estimated ratio of the radius of influence to the saturated thickness is 1.4 in the deep aquifer. Since there were no monitoring points screened deep at similar elevations as the sparge wells, a 1.5 factor of safety has been incorporated so that the ratio of the radius of influence to the saturated thickness is 0.93 (1.4 / 1.5 = 0.93). Consequently, the saturated thickness in the deep aquifer would be multiplied by 0.93 to determine the radius of influence.

The radius of influence from adjacent sparge wells will be overlapped to determine the final well positions. In addition, during a meeting with the EPA at Vertellus on January 21, 2016, it was agreed that 25% more sparge wells would be utilized. Therefore, a saturated thickness of 36 feet will result in a 27 foot radius of influence (overall 36 x 0.75 = 27). Calculations are included in **Attachment F**.

The following table summarizes the results from sparging the shallow aquifer:

| Table 12 – Shallow Aquifer Sparging Results Summary | | |
|---|---|---|
| **Parameter** | **VP Plant Area** | **Former Treatment Pit Area** |
| Sparge Well | SP-S | SP-33 |
| Screen Interval | 30-32 ft bgs | 33.5-35.5 ft bgs |
| Depth to Water | 18 ft bgs | 21 ft bgs |
| Saturated Thickness | 12 ft (6.1 psi) | 12.5 ft (5.4 psi) |
| Sparge Rate | 10 scfm at 12 psi | 15 scfm at 9.5-11.5 psi |
| Monitored Wells (Distance Away) | DO-20' (20 ft), DO-40' (40 ft), DO-55' (55 ft), RI-18S (90 ft) all screened approximately 17-27 ft bgs | RI-33S (20 ft) and RI-32S (50 ft) screened 19-29 ft bgs and 20-30 ft bgs, respectively. |
| DO Rise | DO-20' (5.1 mg/L), DO-40' (8.0 mg/L), DO-55' (2.3 mg/L), RI-18S (0.42 mg/L) | RI-33 (5.4 mg/L), RI-32 (0.52 mg/L) |
| ROI/Sat. Th. | Min: 55 ft / 12 ft = 4.6<br>Max: <90 ft / 12 ft = <7.5 | Min: 20 ft / 12.5 = 1.6<br>Max: <50 ft / 12.5 ft = <4.0 |
| GW Conc.<br><br>Benzene (µg/L)<br>Pyridines (µg/L)<br>Ammonia (mg/L) | RI-18S; Sep-12, Dec-12, Mar-13, Jun-13, Aug-13, Nov-13, Mar-14, Mar-15<br>B 24000, 7400, 1400, 17, 100, 27, ND, ND<br>P 24220, 1680, 92, 23, 44, 245, 33, ND<br>A 13, 9.6, 10, 6.2, 1.6, 3.7, 1.5, 1 | RI-33S: Mar-08, Mar-09, Mar-10, Mar-11, Mar-12, Mar-13, Mar-14<br>B 180, 120, 76, 100, 14, 20, 10<br>P 1014, 2323, 1783, 994, 405, 587, 190<br>A 21, 12, 6.7, 6.2, 2.6, 2.7, 2.5 |

The results from the VP Plant area were used to determine that the estimated ratio of the radius of influence to the saturated thickness is between 4.6 and 7.5. The results from the FTP Area were used to determine that the estimated ratio of the radius of influence to the saturated thickness is between 1.6 and 4.0.

8.2 Fine Grained Layers between Shallow and Deep Zones

Finer grained sediments are located between the shallow aquifer and deep aquifer in the VP Plant area. The shallow aquifer (which also contains gravel) in the vicinity of the VP Plant extends to a depth of approximately 33.5 feet below grade at RI-18. Finer grained sediments were identified at RI-18 between 33.5 and 68.5 feet below grade (see **Attachment F** for the RI-18 boring log). These were described at depth as:

- 33.5 to 38.5 feet: Dense brown-gray clay, trace very coarse sand to very fine gravel.
- 38.5 to 42 feet: Tan-gray very fine sand, trace silt.
- 42 to 53.5 feet: Dense grey-brown clay, little very coarse sand to fine gravel, little very find sand, little silt (till).
- 53.5 to 58 feet: Dark brown silt, some to little clay – less than till above.
- 58 to 59 feet: Tan-gray very coarse sand to very fine gravel, some fine to coarse sand, little to a trace of silt.
- 59 to 63.5 feet: Tan-gray silt, some, to little, clay.
- 63.5 to 68.5 feet: Tan medium brown silt, some, to little, clay, trace very find sand, trace organic matter.

Sparging within and beneath the finer grained sediments at RI-18D, screened 52.5 to 57.5 feet below grade in the deep aquifer, influenced RI-18S and DO-55' that are screened in the shallow sand (<30 feet below grade).

8.3 Modeled Sparge Operation

Most of the pilot test sparging was completed at air flow rates between 14 and 18 scfm. At these flow rates a pressure between 1.2 and 2.1 times the saturated thickness was required. For example, at a saturated thickness of 36 feet, a wellhead pressure between 19 and 33 psi would be required to sparge.

The modeled sparge flow rate is 7.5 scfm. Although lower pressures will be required to sparge less air, the design of the system will employ a factor of safety so that 15 scfm can be sparged at a pressure of up to 3 times the saturated thickness to employ a factor of safety and ensure flow.

8.4 Groundwater Treatment

Aerobic first-order biodegradation of benzene and pyridines was calculated based upon the DO uptake and sparging results from the shallow sand in the VP Plant Area and the Former Treatment Pit.

**Table 13 – Benzene and Pyridines Sparging Half-Lives within Radius of Influence**

| Parameter | VP Plant Area | Former Treatment Pit Area |
|---|---|---|
| Sparge Well | RI-18D | SP-32 |
| Sparge Screen Interval | 52.5 to 57.5 ft bgs | 41-43 ft bgs |
| Depth to Water | 18 ft bgs | 21 ft bgs |
| Monitor Well | RI-18S | RI-32S |
| MW Screen Interval | 14-24 ft bgs | 20-30 ft bgs |
| Groundwater Sampling Results and First-Order Degradation Analysis | Benzene<br>1.4 mg/L on 3/7/13.<br>Start sparging 5/25/13.<br>Progress sparging:<br>0.100 mg/L on 8/27/13<br>Time: 94 days<br>Decay Rate: 0.028/day (Note 1)<br>Half-Life: 25 days | Pyridines<br>2.585 mg/L avg from 1Q98 to 1Q10.<br>Start sparging 3/10/11.<br>Progress sparging:<br>0.019 mg/L on 3/12/12<br>Time: 367 days<br>Decay Rate: 0.013/day<br>Half-Life: 52 days |

Note 1: Benzene decay rate in aerobic environment is below published values between 0.043/day and 0.14/day (equivalent half-life range of 5 to 16 days). This may be due to lower fractional organic content in sand and/or lower concentrations than other sites used for comparison (Rifai 1998).

Based upon the 1Q2020 groundwater results, the highest benzene and pyridine (3,5-Lutidine) concentrations were 0.628 and 0.624 mg/L, respectively, as measured from RI-4D (DMP 2020a). These are much higher than the concentrations measured in 1Q2024 which were 0.0334 and 0.0549 mg/L, respectively. As a result, a concentration factor of safety of more than 10 is included in the treatment zone when compared to 1Q2024 results. Using the calculated first order decay rates in the above table resulting from biosparging, it will take 7.0 and 4.2 half-life reductions (175 and 219 days) to achieve the RGs for benzene and 3,5-Lutidine, respectively, within the biosparge radius of influence. Based upon a conservatively high groundwater velocity of 0.135 feet per day in the deep aquifer near RI-4, this will require a minimum of 22 feet of treatment for benzene and pyridines within the biosparge treatment zone. The radius of influence from adjacent biosparge wells will be overlapped to provide at least 30 feet of groundwater treatment to allow for a factor of safety.

8.5 Subsurface Vapor Intrusion Evaluation

Biosparging will focus on delivering sufficient oxygen to promote aerobic biodegradation of benzene and pyridines. However, it is possible that very low levels of benzene and pyridine may be volatilized during biosparging. Benzene has a vapor pressure 4.6 times higher than pyridine (Lide 1995) and the Henry's Law Constant used to estimate volatilization from groundwater during sparging indicates benzene is more than 400 times more removable from groundwater than pyridines (NIST 2000). Therefore, to the extent any volatilization occurs, benzene is much more likely to be volatilized into the vadose zone than pyridines. In addition, ammonia may be volatilized to soil gas.

8.5.1 Regulatory Applicability

The IDEM air screening levels presented in the IDEM Risk Based Closure Guide (RBCG) dated July 8, 2022 (IDEM 2022), Table 1 effective March 28, 2025 (IDEM 2025) assume a total hazard quotient of 1 and target risk level of $10^{-5}$. The screening levels for benzene and ammonia residential and commercial indoor air concentrations were presented in Table 9 of this plan. In accordance with IDEM guidance, an attenuation factor (AF) of 0.001 is used to calculate the indoor air concentration resulting from the groundwater concentration. The AF reflects the decrease in concentration from groundwater to indoor air.

The EPA guidance that has been considered is the OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air dated June 2015 (EPA 2015b). The EPA guidance references the EPA Regional Screening Level (RSL) Summary Tables, November 2024. Using the target risk of $10^{-5}$ (consistent with IDEM guidance), the benzene residential and commercial indoor air concentrations are 3.6 and

16 µg/m$^3$, respectively. These are the same values published by IDEM since IDEM uses one significant figure (resulting in 4 and 20 µg/m$^3$, respectively). To calculate indoor air levels from groundwater, the EPA recommended generic AF is 0.001, which is also the same as IDEM guidance. The EPA uses the Vapor Intrusion Screening Level (VISL) calculator to assist with evaluating the potential for a completed vapor intrusion pathway.

8.5.2 Vapor Intrusion Screening

A benzene vapor intrusion screening evaluation has been performed for the biosparging system in OU1 using the VISL calculator. VISL calculator inputs and outputs are included in **Attachment G** are accompanied by graphs and a table of recent groundwater concentrations at wells along the eastern limit of OU1 near the planned biosparge system. The dissolved benzene concentration calculated from the VISL calculator is 19.7 µg/L for residential and 85.8 µg/L for commercial. Dissolved benzene levels measured in 1Q2024 at all monitoring wells near the eastern limit of OU1 were less than this value except for RI-4D that contained 33.4 µg/L. Similarly, the dissolved ammonia concentration from the VISL calculator is 898 mg/L for residential and this far exceeds the maximum 15 mg/L ammonia detected in PW-2S.

At RI-4D, the vadose zone is approximately 22 feet thick. Benzene was not detected (<5 µg/L) in shallow groundwater at RI-4S (water above RI-4D). The nearest dwelling is 180 feet away from RI-4D. Any vapors liberated to the vadose zone are anticipated to be diluted and/or biodegrade due to the abundance of oxygen provided by sparging. It has been documented that for dissolved benzene sources that are separated from overlying buildings by more than 6 feet of clean, biologically active soil, the potential threat of vapor intrusion is negligible (EPA 2015c). To confirm the subsurface vapors do not pose a risk, subsurface soil gas monitoring will be performed for benzene and ammonia.

8.6 Potential to Emit

To demonstrate that air emissions from biosparging are exempt from permitting and no vapor control or permit is required, the total potential to emit must be less than 1 ton per year (5.48 pounds per day) per 326 Indiana Administrative Code (IAC) 2-1.1-3 (e)(1)(G) (Indiana 2020). This can be calculated along the eastern limit (perimeter) of OU1 impacts using:

- Soil porosity of 25%.
- Maximum saturated thickness of 40 feet.
- Length of deep aquifer biosparge barrier of 2,750 feet.
- Groundwater velocity of 0.169 feet per day (maximum near RI-6).
- Dissolved benzene maximum level of 0.628 mg/L at RI-4D in 1Q2020 (was 0.0334 mg/L in 1Q2024).

As a maximum potential, it has been assumed that 100% benzene is volatilized (no biodegradation; this is not the case with biosparging), no adsorptive retardation occurs (retardation factor was determined to be 1.36), and lower concentrations do not exist along the treatment barrier (no the case). The resultant calculations presented in **Attachment F** indicate that 0.21 pounds per day of benzene would be emitted. This provides a factor of safety of 26 (5.48 lbs/day / 0.21 lbs/day). Therefore, there is no need to procure an air permit.

8.7 Groundwater Level Monitoring

In the VP Plant Area, water levels were monitored at RI-18S when well RI-18D was sparged at 19.5 scfm. RI-18S is approximately 11 feet away from RI-18D. After sparging RI-18D for 15 minutes the groundwater level in RI-18S rose by 0.14 feet. It was then measured to sequentially decrease and return to within 0.02 feet of the baseline condition after 70 minutes of continued sparging.

Water levels were monitored at RI-5S when well SP was sparged in the RI-5 Area. RI-5S is approximately 45 feet away from well SP. After sparging well SP at approximately 16 scfm for approximately one hour, the water level in RI-5 rose by approximately one foot. Approximately 20 hours after sparging commenced, the water level was measured again and it was a little lower than that measured before sparging started.

These two cases demonstrate that once sparging commences, a temporary short term water level rise (mound) is experienced which then dissipates. The short-term mound may be present for more or less than an hour. Sparging approximately 7.5 scfm instead of 16 to 19.5 scfm should generate less of a short-term groundwater mound and groundwater modeling demonstrates the biosparge barrier will treat groundwater in OU1 before it migrates to OU5.

8.8 Biosparge Basis of Design

Additional information regarding the biosparge basis of design is included in **Attachment F** and provides a narrative description of the following elements, including calculations.

1. Biosparge Treatment Target Zone
2. Biosparge Flow Rate
3. Biosparge Pressure
4. Biosparge Radius of Influence
5. Groundwater Treatment and Biosparge Well Radii of Influence Overlap
6. Sparge Well Spacing
7. Pulsed Biosparge Operation
8. Biosparge Influence Monitoring
9. Ammonia Soil Gas Evaluation
10. Sparge Well Sizing, Depth, and Materials
11. Monitoring Point Sizing and Locations
12. Vapor Monitoring Point Sizing and Locations
13. Monitoring Well Sizing and Locations
14. Separating Site into Two Systems
15. Compressor Size
16. Conveyance Piping Material and Size
17. Groundwater Monitoring Program
18. Soil Gas Monitoring Program
19. System Optimization Plan
20. Remediation Timeline
21. Air Permitting Maximum Potential to Emit
22. RI-18 Boring Log and Well Construction Details

(9) Barrier Biosparging Description

9.1 System Description

Biosparging is an effective technology for the in-situ biodegradation of benzene and pyridines. Biosparging will utilize compressors to inject air into the deep aquifer at the base of contamination near the eastern limit (perimeter) of OU1. Sparged air will disperse within the deep and shallow aquifers resulting in aerobic conditions that promote in-situ biodegradation of benzene and pyridines. Sparging will be completed in a pulsed manner so that varying subsurface flow channels in the saturated zone will provide for optimal delivery of oxygen throughout the treatment zone.

Barrier sparging will treat dissolved levels of benzene and pyridines near the eastern limit of OU1 to prevent groundwater above the RGs from migrating into OU5. The use of multiple sparge points will provide for remediation along the eastern limit of OU1. Nested monitoring points will be installed in the shallow aquifer and deep aquifer to monitor the effectiveness of sparging and supplement data that will be collected from existing wells. Nested monitoring points will be installed within, and downgradient of, the barrier sparge zone (the radius of influence) in OU1.

To supplement the existing monitoring wells in OU5, new nested monitoring wells will be installed at four locations in OU5 (see **Attachment A**, Figure 7). At each location (RI-42R, RI-43, RI-44, and RI-45) a monitoring well will be installed in the shallow (i.e. RI-43S), mid-depth (i.e. RI-43M), and deep (i.e. RI-43D) intervals, assuming that all such intervals are encountered at each location. If the bedrock elevation is higher, then it may only be possible to install monitoring wells in the shallow and mid-depth intervals as was the case with RI-42 and RI-19. Based upon the cross sections provided in **Attachment B**, it is estimated that the shallow, mid-depth, and deep intervals will be at elevations of approximately 700 to 670 feet msl, 670 to 640 feet msl, and 640 to 610 feet msl, respectively. Groundwater monitoring will occur at these locations to track OU5 remedial progress.

The increased number of treatment locations (i.e. sparge points) near the eastern limit of OU1 will treat groundwater below the RGs before it migrates into OU5. Groundwater modeling indicates that it will take approximately 19 years to achieve the

RGs in OU5 following startup of the biosparge system. Biosparging may still be required after that time to treat OU1 groundwater impacts above the RGs, if present.

9.2 System Design

Two compressed air systems will be utilized for sparging 73 sparge wells as shown in **Appendix A** – Remedial Design Drawings. One compressed air system will be installed for the 38 sparge wells north of Minnesota St (Oak Park Property) and one compressed air system will be installed for the 35 sparge wells south of Minnesota St (Maywood Property). Each compressed air system will include two rotary screw air compressors and two receiver tanks. Compressed air combined from both compressors will then flow through a coalescing filter, twin tower heatless desiccant dryer, particulate filter, flowmeter, and regulator a being distributed to the sparge wells. The conditioned compressed air will be distributed to the barrier sparge wells through individual high density polyethylene (HDPE) pipes.

Each sparge well will be equipped with a 1/2 inch diameter flow metering pipe spool consisting of a shut off valve, pressure gauge, flow meter, regulator, pressure gauge, solenoid valve, and discharge valve. HDPE tubing will extend from the discharge valve to the sparge well. The operation of the sparge wells will be controlled by a timer operated by a programmable logic controller (PLC) equipped with a human machine interface (HMI) panel. The operation of each sparge well will be able to be uniquely controlled and adjusted via the PLC/HMI to provide the maximum treatment flexibility. The sparge system is designed to pulse sparge 7.5 scfm of compressed air into each well.

The operational duration and frequency of each sparge well depends upon the saturated thickness. Generally, sparge wells are designed to operate for between 8 and 32 hours to elevated the dissolved oxygen level and then be off for 16 to 24 hours while the dissolved oxygen is consumed. Operational frequencies may be adjusted at startup and during system operation to achieve the RAOs. **Attachment F** contains a table that summarizes the estimated saturated thickness, radius of influence, and other information about the sparge wells.

Two 40 horsepower (Hp) rotary screw air compressors will be utilized for each compressed air system. Although the biosparge compressed air demand for each system ranges between 150 and 157.5 standard cubic feet per minute (scfm), each system will be capable of producing 338 scfm. Each system will be able to accommodate incidental piping leaks, dryer purge air, and provide 120 scfm of excess compressed air to accommodate flow rate changes and/or additional sparge wells.

Each sparge well will be constructed using 2-inch diameter PVC pipe equipped with three feet of 0.010-inch slotted screen at the bottom. The bottom of the screen will be installed at the base of the deep aquifer that varies between approximately 45 and 65 feet below grade. As the sparge wells are being installed and the actual depth of each sparge well is determined, then the spacing to the adjacent sparge well may be adjusted based upon the actual (not theoretical) saturated thickness. In turn, the pulse cycle of each sparge well at 7.5 scfm may also be adjusted.

The PVC sparge well casing will transition to galvanized steel approximately 42 inches below grade and then to HDPE tubing which will extend to the compressed air system. Metal (steel, brass, bronze, aluminum, stainless steel) and rubber hose (rated for compressed air) will be used above grade for compressed air connections to the flow metering piping.

9.3 System Monitoring

Sparge flow rates and pressures will be recorded for each sparge well to document system operation. Groundwater monitoring for dissolved oxygen (DO) will be performed to confirm sparge influence. Sparge flow rate adjustments will be made as necessary to raise the DO within the designed sparge well radius of influence to at least 2.0 mg/L and promote in-situ aerobic biodegradation. Routine maintenance of compressors, filters, and the dryer will be performed as recommended by the manufacturer.

Nested groundwater monitoring points will be used to evaluate and optimize the biosparge system and will be constructed of 2 inch diameter PVC and 0.010-inch slotted PVC screen. A pair of nested groundwater monitoring points will be screened at the top and bottom 10 feet of the groundwater targeted for remediation. A total of 17 pairs of nested groundwater monitoring points will be installed and used for sparge performance monitoring. Eight of these nested groundwater monitoring point pairs will be installed within the designed sparge radius of influence. The remaining nine pairs will be installed downgradient, beyond of the radius of influence, and near the eastern limit of OU1. The locations and construction of the nested groundwater monitoring points are presented in **Appendix A**. Existing wells will also be used for sparge system performance monitoring.

Vapor monitoring points (VMPs) will be installed to monitor subsurface soil gas. Each VMP will be constructed with both shallow and deep screen intervals positioned 6.5 to 8.0 feet below ground surface (ft bgs) and 13 to 15.5 ft bgs, respectively. The deep screen will be set approximately 2 feet above the high groundwater level measured over the past 13 years and the shallow screen will be set approximately midway between the deep screen and ground surface. Each screen interval will be constructed with a ½ -inch diameter, 6-inch long stainless steel screen. Each screen will be connected with ¼-inch Teflon tubing, extended to a steel road box set in concrete, plugged, and labeled as shallow or deep. A total of 24 VMPs will be installed at 12 locations and these will be used for soil gas monitoring. Soil gas monitoring will be completed consistent with federal and state regulatory guidance to evaluate the vapor intrusion pathway. The locations and construction of the nested vapor monitoring points are presented in **Appendix A**.

Monitoring locations, parameters, and frequencies are provided in **Appendix G** (Site-Wide Monitoring Plan). Sampling will be completed in accordance with **Appendix H** (Field Sampling Plan). All sampling will also be completed in accordance with **Appendix I** (Quality Assurance Project Plan) and **Appendix P** (Health and Safety Plan). Biosparge system monitoring will be completed in accordance with **Appendix N** (Operation and Maintenance Plan) and **Appendix O** (Operation and Maintenance Manual).

(10) Biosparge System Startup and Shakedown

The biosparge system startup and shakedown period is anticipated to occur over a period of up to twelve (12) months. During this time, the groundwater pumping system will continue to operate. In order to confirm that the sparge system is operating properly, groundwater monitoring will occur across the entire sparge barrier. Near RI-4, groundwater monitoring will occur with additional temporary groundwater monitoring points (TPs) since RI-4D has historically contained the highest levels of benzene and pyridines near the eastern limit of OU1.

Prior to starting the sparge system, a total of eight (8) TPs will be installed near the biosparge barrier to supplement existing wells and 17 pairs of groundwater monitoring points (notably MP-9S and MP-9D that are in the center of the TPs) as shown in **Appendix A**. Two of these points will be installed in the shallow groundwater zone located between 700 and 670 feet msl and designated with S suffix. Six of these points will be installed in the deep groundwater zone located 670 to 640 feet msl and designed with D suffix. Three groundwater monitoring points (3 x D wells) will be constructed upgradient of the sparge radius of influence, two points will be constructed within the sparge radius of influence (2 x S wells), and three points will be constructed downgradient of the sparge radius of influence (3 x D wells). Construction of the points will be as depicted in **Appendix A**.

Prior to commencing sparging, baseline groundwater and soil gas monitoring will be performed at OU1 and OU5 groundwater monitoring wells, OU1 groundwater monitoring points, OU1 groundwater temporary monitoring points, and OU1 vapor monitoring points that are scheduled to be used to monitor sparge progress in OU1 and the resulting natural attenuation in OU5. Following startup, locations closest to the sparge wells will be monitored more frequently than those further from the sparge wells since it takes time for treated groundwater to migrate from sparge wells to downgradient wells / points. VMPs will also be monitored. Groundwater monitoring parameters include dissolved oxygen, additional field natural attenuation parameters (water level, pH, temperature, conductivity, oxygen reduction potential, and turbidity), benzene, pyridines, and ammonia. Soil gas monitoring will be performed using a photoionization detector (PID) in the field and by collecting soil gas samples for benzene and ammonia analysis at a fixed based laboratory. The sampling schedule is included in **Appendix G**.

(11) Cessation of Groundwater Pumping

During the startup and shakedown period benzene and pyridine levels should decrease below the RGs within the sparge radius of influence. Monitoring performed throughout the sparge barrier at monitoring locations will be used to document the effectiveness of sparging. In-situ dissolved oxygen (DO) monitoring at these monitoring locations will occur more frequently than groundwater sampling to confirm the radius of influence from nearby sparge wells. Such DO monitoring may result in adjustments to sparge flow rates and operational pulse cycles to achieve at least 2 mg/L DO within the radius of influence when the sparge wells are operating.

| Table 14 – Cessation of Groundwater Pumping Monitoring Locations | | | |
|---|---|---|---|
| **Property** | **Monitoring Locations** | **Nearby Sparge Wells** | **Nearby Pumping Well** |
| Oak Park Property (North of Minnesota St. | MP-1S and MP-1D | SP-3 and SP-4 | PW-2S |
| | MP-3S and MP-3D | SP-8 and SP-9 | |
| | MP-5S and MP-5D | SP-19 and SP-20 | |
| | MP-7S and MP-7D | SP-27 and SP-28 | |
| | MP-9S and MP-9D | SP-34 and SP-35 | PW-1S and PW-1D |
| | TP-1D, TP-2D, TP-3D, TP-4S, TP-6S, TP-7D, TP-8D and TP-9D | SP-32, SP-33, SP-34, SP-35, and SP-36 | |
| Maywood Property (South of Minnesota St.) | MP-12S and MP-12D | SP-46 and SP-47 | |
| | MP-14S and MP-14D | SP-57 and SP-58 | |
| | MP-16S and MP-16D | SP-63 and SP-64 | |

Biosparge monitoring at groundwater monitoring locations in the above table for benzene and pyridine will be performed prior to sparging (baseline sampling) and approximately 30, 60, 120, 180, 240, and 300 days after sparging commences (7 events total). Benzene and pyridine groundwater results will be used to calculate the half-lives and compare them to the design half-lives of 25 and 52 days, respectively.

The biosparge system will be deemed to be operating properly for benzene and pyridines in groundwater once either:

- two consecutive calculations (between three data points) demonstrate half-lives less than or equal to the design,
- concentrations are reduced to below the RGs, or
- calculations indicate that the RGs will be achieved within the sparge well radius of influence. Calculations are included in the data quality objective for cessation of groundwater pumping in **Attachment I**.

If the groundwater concentrations of benzene or pyridine are such that the conditions for the cessation of pumping may not be achieved, then operation of the biosparge system shall be adjusted by increasing sparging rates, adjusting the sparging duration, adjusting the sparging frequency (i.e. on and off periods), and/or installing additional sparge wells. Implementing these measure(s) will be made until benzene and pyridines groundwater concentrations indicate the biosparge system is operating properly.

Once the biosparging system is fully operational and achieving the design objectives, including the RAOs, then groundwater pumping may cease with USEPA approval.

The eight temporary groundwater monitoring points (TP-1D, TP-2D, TP-3D, TP-4S, TP-6S, TP-7D, TP-8D, and TP-9D) installed for biosparge performance monitoring may be abandoned with EPA approval in accordance with IDEM well abandonment requirements after groundwater pumping has ceased.

If, after the groundwater pumping has ceased, the concentrations of benzene or pyridine increase such that the RAOs are not achieved, even after adjusting the biosparge system operation, then groundwater pumping shall be returned to operation until the biosparge system has been subsequently deemed to be operating properly.

Decision diagrams for the cessation of pumping groundwater from PW-1S, PW-1D, and PW-2S are included in **Attachment H**.

After groundwater pumping has ceased, the groundwater pumping equipment shall be maintained for future use. This may include removing submersible pumps from wells and storing them on-site. This may also include the future cleaning of wells as needed for future pumping. The Industrial Discharge Permit issued by CWA Authority shall also be maintained for potential future groundwater discharge.

(12) Contingency Plans

Contingency plans for barrier biosparging have been established to address elevated groundwater concentrations and soil gas concentrations.

12.1 Groundwater Monitoring

It is anticipated that biosparging will treat benzene and pyridines concentrations below the RG in OU1 before groundwater migrates into OU5. There are numerous monitoring wells and monitoring points that will be used to confirm that this occurs during operation of the biosparge system. However, if this does not occur, then additional groundwater monitoring actions will be implemented. Such sequential actions include:

1. Confirm that the groundwater data is valid by reviewing sampling methods, field data, and laboratory data. If the data is invalid, then resample.
2. If valid groundwater data exceeds the RG, then modify the sparge system operation by changing sparge flow rates, changing the sparge operational pulse cycle, and/or changing sparge well operation. Operate the sparge wells and monitor the DO to determine if the DO increases to at least 2.0 mg/L within the sparge radius of influence. If this does not occur, then continue to make changes until the DO levels reach at least 2.0 mg/L while sparging.
3. Continue to operate the sparge wells in this manner until treated groundwater has migrated to the groundwater monitoring location(s) and then resample for benzene and pyridines.
4. If the samples indicate that the RG is not achieved, then install and operate additional sparge wells as appropriate based upon monitored data.
5. At any point in this process, when the groundwater achieves the RG, then responsive groundwater sampling will cease, and routine scheduled groundwater sampling will resume.

A decision diagram for the groundwater monitoring contingency plan is included in **Attachment H**.

12.2 Soil Gas Monitoring

If soil gas collected from any of the vapor monitoring points (VMPs) exceeds an applicable screening level, then additional monitoring actions will be implemented. Such sequential actions include:

1. Confirm that the soil gas data is valid by reviewing sampling methods, field data, and laboratory data. If the data is invalid, then resample.
2. If valid soil gas data is above the screening level, and the sparge system can be adjusted, then adjust the sparge system. Adjusting the sparge system may consist of changing the sparge flow rate, sparge well operational cycle, and/or changing active sparge wells. Following the adjustment, then promptly sample the soil gas with rush 72-hour laboratory analysis.
3. If valid soil gas data following sparge adjustments exceeds criteria, or adjustments could not be made to the sparge system, then install pair(s) of shallow and deep VMPs between the elevated soil gas and the receptor. Promptly sample the soil gas in the original VMPs that exceeded the screening level and the new VMPs with rush 72-hour laboratory analysis.
4. If the soil gas in the new VMPs exceeds the screening level, then proceed to sample the receptor, which is presumed to be a dwelling. Sample the sub-slab of the dwelling and the indoor air. The sub-slab sample will be analyzed first with rush 72-hour laboratory analysis, and if it is below the screening level, then the indoor air will not be analyzed. If the sub-slab sample exceeds the screening level, then the indoor air sample will be analyzed with rush 72-hour laboratory analysis.
5. If the indoor air sample exceeds the screening level, then cease sparging near soil gas exceeding the screening level and implement or adjust a sub-slab depressurization (SSD) system. Proceed to Step 4 after sparging ceases. Once the SSD system is implemented, then proceed to Step 4.
6. At any point in this process, when the soil gas or indoor air achieves the screening level, the responsive sampling will cease, and scheduled sampling will resume. If a sub-slab depressurization system has been implemented, then operation, maintenance, and monitoring (indoor air) will proceed as described in the sub-slab depressurization system operation and monitoring plan.

A decision diagram for the soil gas monitoring contingency plan is included in **Attachment H**.

## (13) Remedial Design

The RD is based upon the ROD Amendment, and CD/SOW. **Appendix A** includes Remedial Design drawings and **Appendix B** includes Remedial Design Specifications that provide design and implementation details.

1. Sparge wells are located based upon pilot testing data, calculated benzene and pyridine in-situ biodegradation rates, and factors of safety as previously described.

2. Well and point installation
    a. Installation of 73 sparge wells (SP-1 through SP-73) on-site along the west side of Tibbs Ave. over a distance of approximately 2,750 feet generally between the northern property limit and the solar farm.
    b. Installation of 17 pairs of groundwater monitoring points (MP-1 through MP-17; shallow [S] and deep [D]) on-site to monitor the effectiveness of the sparge system.
    c. Installation of 8 temporary groundwater monitoring points (TP locations) on-site to monitor the effectiveness of the sparge system at startup in the vicinity of RI-4D until the sparge system is proven effective within these points.
    d. Installation of 12 pairs of nested vapor monitoring points (VMP-1 through VMP-12; shallow [S] and deep [D]) on-site in the deep vadose zone to monitor for the presence of benzene and ammonia in soil gas to compare to vapor intrusion screening levels.
    e. Installation of 4 sets of three nested groundwater monitoring wells off-site in OU5 (RI-42R, RI-43, RI-44, and RI-45; shallow [S], mid-depth [M], and deep [D]) to enhance the existing OU5 groundwater monitoring network.
3. Sparge system installation
    a. Trenching between the 38 sparge wells on the Oak Park property to a common location where compressed air will be generated, filtered, and regulated to provide sparge air.
    b. Trenching between 35 sparge wells on the Maywood property to a common location where compressed air will be generated, filtered, and regulated to provide sparge air.
    c. Installing ½-inch HDPE tubing between each sparge well and the compressed air source.
    d. Backfilling trenches with pea gravel around piping. Backfilling above the pea gravel using suitable native material and restoring the surface to match pre-construction conditions.
    e. Installing a 480 VAC, 3 phase, 400 amp power supply with a dedicated meter from AES Indiana to each compressed air source.
    f. Installing compressed air systems on the Oak Park and Maywood properties. Each system will consist of:
        i. Two 40 horsepower (Hp) rotary screw air compressors containing food grade oil to generate a minimum of 360 cubic feet per minute free air delivery (cfm FAD) at 125 pounds per square inch gauge pressure (psig).
        ii. Two 240 gallon receiver tanks.
        iii. One coalescing filter, one twin tower heatless desiccant dryer, one particulate filter, one flowmeter transmitter, two pressure transmitters, and one regulator.
        iv. One oil water separator for condensate generated from automatic drain valves connected to the receiver tanks and coalescing filter.
        v. Individual flow metering pipe spools for each sparge well consisting of a flowmeter, a regulator, pressure gauges, and a solenoid valve.
        vi. One programmable logic controller with human machine interface (PLC/HMI) to control the pulsed operation of the sparge wells, record the overall sparge flow rate and pressures, monitor the operation of the compressors, and notify personnel if alarm conditions are encountered via a cellular telemetry system. This system will also be used for remote monitoring of the biosparge system status.
4. Biosparge system operation
    a. Sparge 7.5 scfm of compressed air in a pulsed manner through each sparge well.
    b. Monitor the dissolved oxygen (DO) to confirm it is ≥2 mg/L within the sparge radius of influence.
    c. Perform monitoring in groundwater monitoring wells, groundwater monitoring points, temporary monitoring points, and vapor monitoring points to compare to Performance Standards.
    d. Make adjustments to the biosparge system, as needed so that the Performance Standards are achieved.
    e. Implement the groundwater monitoring and/or soil gas monitoring contingency plans, if necessary.
    f. Perform operation and maintenance activities as described in **Appendix O**.

(14) Remedial Action Implementation

Implementing the RA includes drilling and installing sparge wells, groundwater monitoring wells, groundwater monitoring points, temporary groundwater monitoring points, and vapor monitoring points. It also includes the construction, startup, and

shake-down of the biosparge system. An overview of the main elements of this work are described in this section and additional details are provided in the appendices.

1. Preparation
    a. Secure encroachment permits and access agreements for monitoring wells to be installed in OU5. No permitting or access agreements are required for drilling and installation in OU1 (on-site).
    b. Contact electrical company to apply for a new metered service at each compressed air generation station.
2. Drilling and installing wells and points
    a. Contact Indiana811 prior to drilling and ensure that all utilities are marked. Utilize a private utility locating company as well.
    b. At least two sonic drill rigs will be used to install sparge wells (SP-), monitoring wells (RI-), groundwater monitoring points (MP-), and temporary monitoring points (TP-).
    c. Sonic drilling or direct push technology (i.e. Geoprobe ®) will be used to install vapor monitoring points.
    d. Hand dig or soft dig to 5 feet below grade at each location. Extend to 7 feet below grade in vicinity of deeper utilities such as sewers or known water pipes.
    e. Continuously log the subsurface geology encountered in deep borings. Shallower borings within 10 feet of a deep boring do not need continuously logging of the geology. Soil cores will be horizontally laid on plastic on the ground and the plastic core wrapping will be cut. The core will be examined by a licensed professional geologist or a geologist under their direction. The geologist will use the Unified Soil Classification System (USCS) to log the soil core and record it on a field form. Soil cores will be containerized in a drum or roll-off box pending lawful off-site disposal. The drum will be covered with a lid and the roll-off box will be covered to prevent storm water from entering the box.
    f. Install wells and points to the target depths unless a thick competent clay or bedrock is encountered.
    g. Install monitoring points prior to installing sparge wells to gain a better understanding of the geology and identify any potential adjustments in sparge well depths.
        i. Where shallow (S) and deep (D) points are installed, the deep points shall be installed prior to the shallow points.
        ii. Install Oak Park property points first using two sonic drilling rigs. One rig will install in order of MP-10S/D, MP-8S/D, MP-5S/D, MP-7S/D, TP-8D, TP-7D, TP-9D, TP-4S, TP-6S, and TP-3D. The second concurrently operating drill rig will install in order of MP-6S/D, MP-4S/D, MP-2S/D, MP-1S/D, MP-3S/D, MP-9S/D, TP-2D, and TP-1D.
        iii. Install Maywood property points second using two sonic drilling rigs. One rig will install in order of MP-11S/D, MP-13S/D, and MP-12S/D. The second concurrently operating drill rig will install in order of MP-15S/D, MP-17S/D, MP-16S/D, and MP-14S/D.
        iv. The drilling order may be modified based upon the geology logged via the USCS as wells are installed. The drilling strategy is to obtain data around the sparge wells prior to installing sparge wells so that depths of the sparge wells can be best estimated in advance. Sparge well depths impact the spacing between sparge wells.
    h. Install vapor monitoring points.
    i. Install groundwater monitoring wells in OU5.
    j. Install all groundwater monitoring wells, groundwater monitoring points, temporary monitoring points, and vapor monitoring points in flush mount road boxes set in concrete aprons as shown in **Appendix A**.
    k. Install sparge wells. These will be completed above ground and secured for sparge well testing with a locked expandable plug.
    l. Test each sparge well with compressed air to confirm that 15 scfm of air can be sparged at ≤3 times the breakthrough pressure.
    m. Redevelop, clean and retest a failed sparge well. If the retest fails, then replace the sparge well.
    n. Decontaminate drilling equipment between each borehole.
    o. Develop each air sparge well, groundwater monitoring well, groundwater monitoring point, and temporary monitoring point using a submersible pump.
    p. All decontamination water and development water shall be collected and contained for off-site disposal in accordance with **Appendix K** (Transportation and Off-Site Disposal Plan) and the data quality objective in **Attachment I**.

q. All soil cores shall be collected and contained for off-site disposal in accordance with **Appendix K** and the data quality objective in **Attachment I**.

3. Sparge system construction
    a. Excavate at each sparge well, cut down each sparge well riser, construct well connection fittings for future access, pressure test sparge piping to be buried, and install metal plates to locate the buried wells in the future. Details are shown in **Appendix A**.
    b. Trench from each sparge well to the compressed air source while excavating approximately 30 inches deep.
    c. Backfill trenches with approximately 14 inches of pea gravel.
    d. Perform pressure testing of all sparge piping to each well and each spare pipe.
    e. Backfill and compact with native materials above the pea gravel (if native materials are suitable for backfilling).
    f. Complete surface construction to match adjacent conditions (i.e. paved surfaces, grass surfaces, gravel surfaces, as appropriate).
    g. Install electrical power supply to each compressed air source location. AES Indiana will be contacted to arrange for a new metered service to each location that provides 400 amp, 480 volt, 3 phase power as described in **Appendix B**.
    h. Install enclosures (i.e. shipping containers) containing compressed air system equipment, energize, and test rotation.
    i. Install enclosures containing header system for piping to each individual sparge well with pipe spools for flow metering, flow regulating, and flow control as shown in **Appendix A**. For equipment within the enclosures, the manufacturer shall:
        i. Pressure test each pipe segment of compressed air system.
        ii. Install 24 VDC control wiring from each sparge well solenoid valve to the PLC/HMI.
        iii. Install 4-20 mA wiring from compressor, flowmeter transmitter, and pressure transmitters to PLC/HMI.
        iv. Program the PLC/HMI for controlling sparge well pulsed operation.
        v. Program the PLC/HMI for alarm monitoring and notifications via the cellular telemetry system.
4. Baseline environmental monitoring
    a. Measure natural attenuation parameters as scheduled in the Site-Wide Monitoring Plan (**Appendix G)** while collecting samples for benzene, pyridine, and ammonia analysis from monitoring wells, groundwater monitoring points, and temporary monitoring points.
    b. Measure *in-situ* dissolved oxygen (DO) levels from monitoring wells near the sparge system, groundwater monitoring points, and temporary monitoring points using a dissolved oxygen meter with a probe that can be deployed within the screen interval of the monitored location.
    c. Collect soil gas samples for benzene and ammonia analyses from the nested vapor monitoring points.
    d. Survey the locations of all sparge wells, groundwater monitoring wells, groundwater monitoring points, temporary groundwater monitoring points, and vapor monitoring points.
    e. Survey the top of casing and ground elevations of groundwater monitoring wells, groundwater monitoring points, and temporary groundwater monitoring points. Survey the ground elevations for vapor monitoring points.
5. Sparge system startup
    a. Check the PLC/HMI for proper sparge pulse durations for each sparge well.
    b. Check the rotation of the compressors and start the system.
    c. Adjust the sparge flow rate to 7.5 scfm for each well by adjusting the regulator for each well and observing the flow rate via the flowmeter.
    d. Measure *in-situ* DO levels from monitoring wells near the sparge system, groundwater monitoring points, and temporary monitoring points using a dissolved oxygen meter with a probe that can be deployed within the screen interval of the monitored location.
    e. Adjust flow rates, sparge pulse durations, and/or operational sparge wells as needed to achieve ≥2 mg/L DO within the sparge radius of influence; process described as a decision diagram in **Attachment H** and as a data quality objective in **Attachment I**.
6. Sparge system operation and maintenance

a. Perform routine operation and maintenance activities on the compressed air system including, but not limited to, oil changeouts and filter changeouts as described in **Appendix O**.

7. Sparge system monitoring
    a. Collect data from the sparge system including sparge flow rates and pressures and documenting them on a data collection form as described in **Appendix O**.
    b. Measure *in-situ* DO levels from monitoring wells near the sparge system, groundwater monitoring points, and temporary monitoring points using a dissolved oxygen meter with a probe that can be deployed within the screen interval of the monitored location.
    c. Measure natural attenuation parameters as scheduled while collecting samples for benzene, pyridine, and ammonia analysis from groundwater monitoring wells, groundwater monitoring points, and temporary groundwater monitoring points.
    d. Collect soil gas samples for benzene and ammonia analyses from vapor monitoring points.
8. Groundwater pumping system monitoring
    a. Monitoring of the existing groundwater pumping system from PW-1S, PW-1D, and PW-2S will continue until the sparge system has been proven to be effective and the shake-down period ends.
    b. Measure the pumping rate and total volume of groundwater pumped from each pumping well.
    c. Measure groundwater levels in surrounding groundwater monitoring locations.
9. Weekly project meetings
    a. Weekly project meetings will occur to review work completed the prior week, work occurring the week of the meeting, and work scheduled to be completed in the next two to four weeks.
    b. Meetings attendees (all will be invited to the meetings):
        i. The Supervising Contractor project manager, field superintendent and/or health and safety officer.
        ii. The Contractor superintendent and health and safety officer.
        iii. Representatives from major subcontractors.
        iv. The Project Coordinator, or their designee, may attend.
        v. Representatives from USEPA and IDEM, or their designees, may attend.
    c. The agenda for each meeting may include any, or all, of the following:
        i. Review minutes of previous meetings, as necessary.
        ii. Review of Work progress and Project schedule.
        iii. Field observations, problems, and decisions.
        iv. Identification of problems impeding planned progress.
        v. Review of submittals schedule and status of submittals.
        vi. Review of off-site fabrication and delivery schedules.
        vii. Maintenance of progress schedule.
        viii. Corrective measures to regain projected schedules.
        ix. Planned progress during succeeding work period.
        x. Coordination of projected progress.
        xi. Maintenance of quality and work standards.
        xii. Effect of proposed changes on progress schedule and coordination.
        xiii. Health and safety report and status.
        xiv. Community issues and minimizing community impacts.
        xv. Other business relating to Work.

14.1 Permitting Plan

The Permitting Plan in **Appendix F** provides details for securing access to install OU5 monitoring wells in the City of Indianapolis right-of-way (ROW). A Consent of Encroachment Application will be prepared for city approval to install the monitoring wells. An Encroachment License application will be prepared for the monitoring wells to remain in the ROW and to use the ROW for access to the monitoring wells for groundwater sampling. These documents will be prepared for three locations including RI-42R, RI-43, and RI-44. At each location three nested monitoring wells are planned to be installed in the shallow, mid-depth, and deep aquifers. 1500 South Tibbs LLC will take the lead on preparing these applications and submitting them to the city. 1500 South Tibbs LLC will also complete applications for hydrant use for the drilling contractor. The drilling contractor will be required to comply with approved applications including traffic control and work zone

establishment, site restoration, procuring a city meter for hydrant use, and paying for water used as part of the drilling contract with 1500 South Tibbs LLC.

An off-site access agreement will be secured with Rolls Royce for the RI-45 location. During that process, it will be determined whether RI-45 is located within the City of Indianapolis ROW or exclusively on Rolls Royce property. If within the City of Indianapolis ROW, then applications will be submitted to the city as they are planned for RI-42R, RI-43, and RI-44.

The Permitting Plan also describes the existing discharge of pumped groundwater to the sanitary sewer that is already authorized by the CWA Authority, Inc. Industrial Discharge Permit #285901 for the term of May 1, 2024 through March 31, 2027. The permit allows for the discharge of stormwater, sanitary water, and groundwater to the combined sewer. This permit will be renewed prior to expiration for the same discharges, even if groundwater pumping has ceased, so that groundwater pumping can resume in the future, if needed.

14.2 Photographic Documentation Plan

The Photographic Documentation Plan in **Appendix E** describes requirements for photographs that will be taken of the Remedial Action to document work progress and completed work. This will include undisturbed areas prior to completing work; drilling, excavation, and construction activities; testing, repairs, and construction compliance activities; waste management containers; and other daily work activities. A minimum of 10 digital photographs will be taken each work day.

Photographs will be organized in electronic file folders by date and chronological order. A database will be maintained for all photos taken during the project and each photo will have a caption describing the work being completed. Daily work activities will be documented in a daily photo log that will consist of representative photos. The photos, database, and daily photo logs will be stored electronically and retained for a period of 5 years.

14.3 Construction Quality Assurance and Quality Control Plan

The Construction Quality Assurance and Quality Control Plan (CQA/CP) in **Appendix J** describes construction activities that will provide confidence that Performance Standards will be met. This addresses logging soil borings for the proper installation of wells and points. It also provides a method for determining the spacing of sparge wells based upon the sparge well depths to ensure that the sparge influence adequately overlaps between sparge wells. Determining the biosparge well depth and spacing is also described in a data quality objective in **Attachment I**.

Sparge well testing and documentation is described where 15 scfm is sparged at ≤3 times the breakthrough pressure prior to connecting sparge wells to compressed air distribution piping. Sparge well testing is also described in a data quality objective in **Attachment I**.

Details are provided for trenches excavated to between 20 and 30 inches below grade, HDPE piping installation between the compressed air source and each sparge well, backfilling with pea gravel above the HDPE piping to 16 inches below grade, and then installing suitable compacted backfill with a surface cap to match existing conditions (grass, paved surface, or gravel). Documentation of the trench depth, HDPE piping location, location of each sparge well, backfilling, and pressure testing is described. Pipe pressure testing is also described in a data quality objective in **Attachment I**

CQA/CP activities will be documented in bound field books and/or using testing forms. Documentation will be scanned and stored electronically. Electronic files will be organized by subject matter including, but not limited to, health and safety tailgate meetings, contractor submittals, data collected from the field, testing results, and as-built data. A full list is provided in **Appendix J**.

Construction deficiencies will be flagged in the field, tagged to note the deficiency, documented, and then the flag will be removed once the deficiency is corrected and the corrective action is documented.

Minor and major project modifications may result from unanticipated field conditions. All modifications require approval from the USEPA prior to implementation. Minor modifications may include relocating a well or point by no more than 10 feet due to the presence of an underground utility, relocating a sparge well, replacing a sparge well, relocating a trench due to subsurface obstruction, alternatively sized equipment so long as the specified compressed air flow is achieved, and minor piping changes. A full list with additional descriptions is provided in **Appendix J**.

Major project modifications may have a significant impact on the project and include relocating a well or point by more than 10 feet due to the presence of an underground utility, relocating sparge wells based upon an impermeable clay or bedrock that results in terminating the sparge well more than 20 feet above the target depth, needing to assess the vapor intrusion pathway and/or implement an active vapor mitigation system prior to starting the biosparging system due to existing soil gas conditions, modifying the remedial design in response to a community concern prior to starting the sparge system, or modifying the remedial design by more than qualifies for a minor modification.

14.4 Transportation and Off-Site Disposal Plan

The Transportation and Off-Site Disposal Plan in **Appendix K** identifies waste materials, including investigation derived waste (IDW), generated during construction and operation and maintenance, characterizes this material, identifies disposal and recycling facilities, describes shipping and plans to minimize impacts to surrounding communities, and describes recordkeeping and manifesting.

Since no historical process operations have occurred in the vicinity of the planned drilling and trenching locations, benzene, pyridine, and ammonia impacts are expected to be low. Similarly, based upon groundwater sampling data, decontamination, development, and purge water are also expected to contain low levels of contamination. All soil and water wastes are planned to be disposed of as non-hazardous waste at nearby facilities.

Representative sampling of soil and water will be performed as required by the disposal facility to generate a waste profile and document the non-hazardous status. If allowed by CWA Authority via their Special Discharge Application, decontamination, development, and purge water may be discharged to the combined sewer. No waste materials will be disposed on-site. The collection and characterization of IDW and surplus excavated soil is also described in a data quality objective in **Attachment I**

14.5 Emergency Response Plan

The Emergency Response Plan in **Appendix L** describes potential emergencies related to the sparge system installation and operation, the chain of command for responding to the emergency(ies), and notification activities. Potential emergencies may result from utility damage, construction equipment failure and possible oil release (i.e. via a hose rupture), power outages, and sparge system equipment failure. Spill kits will be present that will contain sorbent material, containment material, and tools to contain an oil release from construction equipment or a compressor. Based upon recent groundwater concentrations of benzene, pyridines, and ammonia, and that the sparge system will be installed outside of former process areas, none of these chemicals can be released in an amount exceeding a reportable quantity.

14.6 Community Impacts Mitigation Plan

The Community Impacts Mitigation Plan in **Appendix M** describes community involvement activities including public meetings that are planned prior to construction, following construction, after the sparge system shakedown period, and to address issues or complaints. In addition, measures are described that will be taken to reduce air emission impacts, traffic impacts, and impacts from installing OU5 groundwater monitoring wells, as well as restoration actions (utilities, vegetation, sidewalks, and curbing). Groundwater and soil vapor monitoring in Community Areas is described along with communicating monitoring results. A description of the substantial contractors and vendors that will be used to implement the remedial action is also described. The EJ Screen Report prepared by the EPA on January 13, 2023 identified that only 3% of the community members were unemployed.

14.7 Health and Safety Plan

Remedial Action implementation activities will be in compliance with the Health and Safety Plan (HASP) in **Appendix P**, that was prepared per 29 CFR 1910.120 and other applicable federal, state, and local laws, regulations, and statutes.

Wells and points will be installed using a sonic drill rig or direct push technology (DPT; i.e. Geoprobe ®). Prior to use of a sonic drill rig or DPT, each boring location will be marked. Indiana811 will be notified and a private locating company will be utilized to identify utilities near each drilling location. Hand or soft digging techniques will be utilized to 5 feet below grade at each location. This depth will extend to 7 feet below grade in vicinity of deeper utilities such as sewers or known water pipes.

The HASP describes protective measures to be taken during well installation, development, and sampling as well as excavation activities associated with trenching, installing road boxes, and conveyance piping. This includes installing wells

and points a safe distance from overhead utilities. It also addresses working with compressed air and sparging operation and maintenance.

It is anticipated that work will be completed in Level D personal protective equipment (PPE) including a hardhat, safety glasses, protective gloves (leather, nitrile, cotton, or other as required for the task), substantial boots, traffic vest, and hearing protection, when needed. Conditions requiring an upgrade to Level C PPE are identified which would require a NIOSH approved half or full face air purifying respirator, chemical resistant clothing where needed, and/or other protective measures. Air monitoring will be performed during drilling and excavation activities with a 10.6 eV photoionization detector (PID) and if the reading is <1 parts per million (ppm) above background or intermittently 1-5 ppm above background, then Level D PPE will apply. If PID levels are sustained 5 to 50 ppm above background, then Level C PPE will apply. If PID levels are sustained greater than 50 ppm above background then work shall cease in that area pending further investigation and implementation of corrective measures so that work can be completed safely.

Additional health and safety measures and protocols are included in **Appendix P**.

(15) Remedial Action Operation and Maintenance

Remedial Action operation and maintenance (O&M) consists of maintaining the remedies in OU1, OU2, OU3, OU4, and OU5. OU1 and OU5 address on-site and off-site groundwater, respectively. The remedial action in OU1 is biosparging and the remedial action in OU5 is natural attenuation. The remedial actions for OU2, OU3, and OU4 have been completed and ongoing activities include inspections and maintenance of the protective caps (grass, gravel, and paved surfaces).

15.1 Operation and Maintenance Plan

The Operation and Maintenance Plan in **Appendix N** describes the engineering components of each OU and routine environmental inspections, monitoring, and laboratory testing of each OU along with the performance standards. It identifies the activities to be completed for each OU along with the reporting schedule.

Corrective actions are described for each OU in the event there is a failure. Failures for OU1 include a compressor failure and need for a prompt repair or substitute compressor, a broken pipe, valve, or instrumentation and replacement / repair of the break, and a power outage and the need for a generator. If the groundwater and soil gas monitoring does not achieve Performance Standards, then groundwater monitoring and/or soil gas monitoring contingency measures will be taken as previously described.

Failures of an environmental cap for OU2, OU3, or OU4 will result in surficial tar removal and containerization and/or cap maintenance work to repair vegetative, gravel, or paved surfaces in a timely manner.

Hydrogeologic modeling estimated that it will take 19 years for benzene to achieve the RG in OU5 (less time for pyridines; ammonia already meets the RG). An evaluation of the OU5 remedial progress will be made in the Annual Linear Regression report to determine when the RG will be achieved to compare to the estimated 19 years.

The existing Declaration of Environmental Restrictive Covenant dated February 13, 2012 provides on-site groundwater and land-use restrictions that will be evaluated annually to confirm compliance. In addition, the Marion County Health and Hospital Corporation (MCHHC) Code, Chapter 18, dated July 1, 2023 describes the permits, inspections, requirements, and well pumps that are regulated for off-site groundwater use. 1500 South Tibbs LLC is responsible for obtaining timely groundwater usage restrictions with MCHHC for OU5, either through ordinance or individual property restrictions to ensure that there is no potential exposure to site-related groundwater contamination in the OU5 area. Annual inquiries will be made to the MCHHC to provide assurance that use of OU5 groundwater is not occurring. The Institutional Controls Implementation and Assurance Plan (ICIAP) contains additional details regarding the annual evaluation of institutional controls.

15.2 Operation and Maintenance Manual

The Operation and Maintenance Manual in **Appendix O** describes the OU1 biosparging system inspections, operation, and maintenance. Proper biosparge system operation is also described in a data quality objective in **Attachment I.**

The OU1 biosparging system normal operation, startup procedures, routine maintenance activities, and remedy inspection requirements are described. Potential operating problems along with a potential cause and solution are identified for biosparge system troubleshooting.

A description of equipment installed as part of the OU1 biosparge system is provided along with recommended spare parts to be kept on-site. OU1 O&M forms are included to document the system operation, dissolved oxygen levels at surrounding wells, and remote monitoring of the system. Semi-annual inspections of the OU2, OU3, and OU4 environmental caps are described and a semi-annual inspection form is provided. A description of the recording and reporting requirements as well as emergency contact information is also provided.

(16) Remedial Action Monitoring

Remedial Action monitoring consists of collecting groundwater and soil gas / vapor samples and comparing them to Performance Standards to determine remedial progress and completeness / incompleteness of the vapor intrusion pathway to sensitive receptors.

16.1 Site-Wide Monitoring Plan

The Site-Wide Monitoring Plan in **Appendix G** describes the groundwater and soil gas to be monitored and presents a sampling schedule that identifies sampling locations, sampling frequency, sampling parameters, and analytical methods to be employed. Sampling and laboratory data will be validated and data will be presented in quarterly reports. An Annual Linear Regression report will be prepared that evaluates trends in the data, including data prior to the installation of the biosparge system. This data will be presented in a tabular and graphical manner. Evaluating trends in OU5 groundwater data and natural attenuation data is also described in a data quality objective in **Attachment I.**

In the event that groundwater is not meeting the RAOs, then the groundwater monitoring contingency plan will be followed. Similarly, if soil gas exceeds the screening levels, then the soil gas monitoring contingency plan will be followed. These plans have been previously described. Each contingency plan is represented by a decision diagram that identifies the length of time for each step and decision diagrams are included in **Attachment H**.

If groundwater sampling data from OU5 indicates a rise in concentration of benzene, pyridines, or ammonia by more than a factor of three from the prior sampling event, then the EPA will be notified within two business days. If the data proves to be invalid, then resampling will occur promptly with an analytical turnaround time of 72 hours. Validated data will be used to determine if the groundwater to indoor air vapor intrusion exposure pathway may be complete. This process is also represented by a decision diagram in **Attachment H** that references data quality objectives in **Attachment I.**

16.2 Field Sampling Plan

The Field Sampling Plan in **Appendix H** describes the step-by-step process of collecting groundwater and soil gas samples. It identifies sampling equipment and procedures and describes sample handling and analysis including sampling containers, preservatives, and holding times. The management of investigation derived waste (IDW) is also described along with sampling requirements for the final disposition of soil cores (generated from drilling), decontamination water, well development water, and groundwater. The collection and characterization of IDW is also described in a data quality objective in **Attachment I.**

16.3 Quality Assurance Project Plan

The Quality Assurance Project Plan in **Appendix I** follows the EPA Uniform Federal Policy, Project Specific format and contains 37 worksheets for groundwater and soil gas samples. The conceptual site model (Worksheet #10) is accompanied by 11 figures. Attachments include the SWMP and FSP, field standard operating procedures (SOPs), environmental testing SOPs and manuals from Pace Analytical Services, and data validation report templates.

(17) Remedial Action Schedule

The RA schedule is based upon receiving USEPA approval of the RAWP, RD, and supporting work plans by January 21, 2025. A more detailed schedule with a Gantt chart exists within **Appendix C**.

**Table 15 – Remedial Action Schedule**

| Date | Work Description | Party Impacting Schedule |
|---|---|---|
| 05-05-2025 | Receive USEPA approval on RAWP, RD, and work plans. | USEPA and IDEM |
| 05-12-2025 | Start RA administrative work – identify drilling contractors, bidding period, receive and evaluate bids, project contracting and award. | 1500 South Tibbs LLC |
| 05-19-2025 | Start OU5 off-site permitting process and access agreements. | 1500 South Tibbs LLC |
| 08-01-2025 | Pre-project submittals, approvals, Indiana811, private utility locate, and drilling materials procurement concluded. | 1500 South Tibbs LLC and Drilling Contractor |
| 08-06-2025 | On-site pre-construction conference concluded. | USEPA and IDEM<br>1500 South Tibbs LLC<br>Drilling Contractor |
| 08-20-2025 | Mobilization and commence drilling | Drilling Contractor |
| 08-05-2025 | Start RA administrative work – identify trenching, plumbing, and electrical contractors, bidding period, receive and evaluate bids, project contracting and award. | 1500 South Tibbs LLC |
| 10-24-2025 | Pre-project submittals, approvals, Indiana811, private utility locate, and trenching, piping, and electrical materials procurement concluded. | 1500 South Tibbs LLC<br>Excavation, Piping, and Electrical Contractors |
| 10-31-2025 | On-site pre-construction conference concluded. | USEPA and IDEM<br>1500 South Tibbs LLC<br>Excavation, Piping, and Electrical Contractors |
| 11-10-2025 | Mobilize and commence excavation, piping, and electrical work. | Excavation, Piping, and Electrical Contractors |
| 12-12-2025 | Complete drilling with 2 sonic drilling rigs and a Geoprobe®. | Drilling Contractor |
| 10-06-2025 – 01-16-2026 | Perform baseline groundwater monitoring, soil gas monitoring, and reporting. | Supervising Contractor |
| 01-16-2026 | Complete compressed air / sparge system equipment procurement and installation, including electrical power supply. | Equipment Vendor |
| 01-30-2026 | Complete trenching, pipe installation, backfilling, pipe testing, and ground surface restoration. | Excavation and Piping Contractor |
| 02-02-2026 | Sparge system startup | Supervising Contractor |
| 02-03-2027 | Sparge system shake-down period for up to 12 months | Supervising Contractor |
| 02-09-2026 | Pre-final RA inspection. | USEPA and IDEM |
| 03-13-2026 | Pre-final inspection report. | Supervising Contractor |
| 04-03-2026 | Final inspection. | USEPA and IDEM |
| 02-03-2027 | End of shake-down period, turn off groundwater pumps | Supervising Contractor |
| 03-05-2027 | Submit Remedial Action Report | Supervising Contractor |

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## (18) References

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**Table 16 – References**


| Citation | Document |
|---|---|
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| AME 1996 | August Mack Environmental, Inc., January 31, 1996, Focused Feasibility Study for OU5 |
| AME 2010 | August Mack Environmental, Inc., June 30, 2010, Response Letter to May 20, 2010 US EPA Letter |
| AME 2011 | August Mack Environmental, Inc., April 8, 2011, Vertellus Groundwater Modeling Degradation Rate Information |

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|---|---|
| Biovapor 2020 | Interstate Technology & Regulatory Council Petroleum Vapor Intrusion Modeling: https://www.itrcweb.org/PetroleumVI-Guidance/Content/5.%20Modeling.htm United States Environmental Protection Agency Science Inventory: https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=235551 American Petroleum Institute Biovapor Indoor Vapor Intrusion Model: https://www.api.org/oil-and-natural-gas/environment/clean-water/ground-water/vapor-intrusion/biovapor |
| Buscheck 1995 | Buscheck, T.E. and Celia, M.A., 1995, Regression Techniques and Analytical Solutions To Demonstrate Intrinsic Bioremediation. Proceedings of the Battelle In Situ and On-site Bioremediation Symposium. April 24-27, 1995. San Diego, CA. |
| CWA 2017 | CWA Authority, Inc., 2017 (November), Raw Sewage Overflow Control Program Long Term Control Plan Report |
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| DMP 2024a | David M. Peterson, PE, PC, April 15, 2024, 1Q2024 Progress Report |
| DMP 2024b | David M. Peterson, PE, PC, April 25, 2024, Annual Linear Regression Report |
| DMP 2020a | David M. Peterson, PE, PC, April 15, 2020, 1Q2020 Progress Report |
| EGC 2002 | Environmental and Geological Consulting, Inc., June 27, 2002, Subsurface Investigation Near RI-4 |
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| ENSR 1991b | ENSR, 1991, Final CERCLA RI Report and the RCRA RFI Phase III Release Characterization Report |
| EPA 2021 | United States Environmental Protection Agency, August 2021, OU1 Record of Decision Amendment |
| EPA 2020a | United States Environmental Protection Agency, 2020, Vapor Intrusion Screening Level Calculator: https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-level-calculator |
| EPA 2020b | United States Environmental Protection Agency, 2020, EPA On-Line Tools For Site Assessment Calculation, Estimated Henry's Law Constants: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/esthenry.html |
| EPA 2016 | United States Environmental Protection Agency, August 2016, Petroleum Vapor Intrusion (PVI) Screen model and supporting documentation. |
| EPA 2015a | United States Environmental Protection Agency, 2015 (August), Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites, OSWER Directive 9283.1-36 |
| EPA 2015b | United States Environmental Protection Agency, 2015 (June), OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154 |
| EPA 2015c | United States Environmental Protection Agency, 2015 (June), Technical Guide for Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites, EPA 510-R-15-001 |
| EPA 2005 | United States Environmental Protection Agency, 2005, Approval of the Final Soil Closure Sampling for Area A of OU4 |
| EPA 2004 | United States Environmental Protection Agency, 2004 (February), Remediation System Evaluation |
| EPA 2003 | United States Environmental Protection Agency, 2003 (September), Performance Monitoring for MNA Remedies for VOCs in Ground Water, OSWER 9355.4-25. |
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| EPA 1997b | United States Environmental Protection Agency, 1997, Explanation of Significant Differences, Reilly Tar and Chemical Groundwater Operable Unit 2 |
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| EPA 1992 | United States Environmental Protection Agency, 1992, Declaration for the Record of Decision, Reilly Tar and Chemical Groundwater Operable Unit 1 |

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|---|---|
| EPA 1988 | United States Environmental Protection Agency, 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA |
| IDEM 2025 | Indiana Department of Environmental Management, March 28 2025, Risk Based Closure Guide Published Levels in Table 1 (Human Health: Standard Exposure Scenarios) |
| IDEM 2022 | Indiana Department of Environmental Management, July 8, 2022, Risk Based Closure Guide |
| IDEM 2020 | Indiana Department of Environmental Management, September 2020, Vapor Intrusion Investigation Documentation. |
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| Vertellus 2012 | Vertellus Specialties Inc., 2012 (February), Declaration of Environmental Restrictive Covenant (ERC), [subsequently approved by EPA, Department of Justice, and IDEM]. |


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(19) Supporting Documentation

Appendices

| App. | Title | Description | Supporting Documentation (Tables, Forms, and Attachments) |
|---|---|---|---|
| A | Remedial Design Drawings | 35 RD drawings for the installation of the sparge system and groundwater and soil gas monitoring network. | None |
| B | Remedial Design Specifications | Specifications describing the RD installation details. | Table 1 – Drilling Summary<br>Table 2 – Sparge Well Operational Schedule<br>Construction Standards Institute Specifications |
| C | Remedial Action Construction Schedule | Schedule for the RD implementation. | None |
| D | Site Survey | Recent site survey. | None |
| E | Photographic Documentation Plan | Requirements for photographing site activities. | Form 1 – Photographic Documentation Template |
| F | Permitting Plan | Requirements for obtaining OU5 off-site access and encroachment permits to install monitoring wells. | Table 1 – Drilling Summary<br>Att. 1 – CWA Authority Discharge Permit<br>Att. 2 – Consent of Encroachment Application<br>Att. 3 – Encroachment License<br>Att. 4 – Chapter 200 Regulations for ROW |

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|---|---|---|---|
| G | Site-Wide Monitoring Plan (SWMP) | Requirements for Performance Standards, groundwater and soil gas monitoring, reporting, groundwater contingency measures, and soil gas contingency measures. | Table 1 – Site Wide Monitoring Schedule<br>Table 2 – Monitoring Locations and Depths<br>Table 3 – Existing Groundwater Monitoring Changes |
| H | Field Sampling Plan (FSP) | Requirements for groundwater and soil gas monitoring, including step-by-step sampling instructions, and waste management. | Table 1 – Site Wide Monitoring Schedule<br>Table 2 – Monitoring Locations and Depths<br>Att. 1 – Low Flow Groundwater Sampling Log<br>Att. 2 – Example Groundwater Chain of Custodies<br>Att. 3 – Soil Gas Sampling Log<br>Att. 4 – Pace Air Sampling Guidance<br>Att. 5 – Example Soil Gas Chain of Custodies<br>Att. 6 – Sampling Training Form |
| I | Quality Assurance Project Plan (QAPP) | Requirements for Project Specific Uniform Federal Policy - QAPP | Att. 1 – Site Wide Monitoring Plan and Field Sampling Plan<br>Att. 2 – Field Standard Operating Procedures<br>Att. 3 – Pace Laboratory Documentation<br>Att. 4 – Data Validation Examples |
| J | Construction Quality Assurance and Control Plan (CQA/CP) | Requirements for RA construction including responsibilities, installation performance standards, testing, documentation, verification, correcting deficiencies, documentation retention, and project modifications. | Table 1 – Sparge Well Design Parameters<br>Table 2 – Monitoring Locations and Depths<br>Form 1 – Field Boring Log Form<br>Form 2 – Field Well Construction Form<br>Form 3 – Sparge Well Spacing Calculation Form<br>Form 4 – Sparge Well Testing Form<br>Form 5 – Pipe Pressure Testing Form |
| K | Transportation and Off-Site Disposal Plan (TODP) | Requirements for waste management during RA construction and operation and maintenance as well as documentation. | Form 1 – Material Release Form |
| L | Emergency Response Plan (ERP) | Requirements for emergency response and notification during RA construction and operation and maintenance. | None |
| M | Community Impacts Mitigation Plan (CIMP) | Requirements for addressing impacts to the community during RA construction and operation and maintenance. | Att. 1 – EJ Screen Report, 01-13-2023 |
| N | Operation and Maintenance Plan (OMP) | Operation and maintenance requirements for OU1, OU2, OU3, OU4, and OU5 including responsibilities, reporting, and response to equipment, power, and Performance Standard failures. | Att. 1 – Declaration of Restrictive Covenant |

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|---|---|---|---|
| O | Operation and Maintenance Manual (OMM) | Operation and maintenance manual for the sparge system including inspections, startup, troubleshooting, corrective actions, equipment description, reporting, emergency response, and utilities. This also addresses environmental caps for OU2, OU3, and OU4. | Table 1 – Drilling Summary<br>Table 2 – Sparge Well Operational Schedule<br>Form 1 – OU1 Sparge System O&M Form<br>Form 2 – OU1 Sparge System Remote Monitoring Form<br>Form 3 – OU1 Biosparge Well Change of Operation Form<br>Form 4 – OU1 and OU5 Monitoring Locations Annual Inspection Form<br>Form 5 – OU1, OU3, and OU4 Semi-Annual Cover O&M Form<br>Att. 1 – Sparge System Manufacturer Data Sheets |
| P | Health and Safety Plan (HASP) | Requirements for safe execution of work during the construction, operation, and maintenance of the RA. | Att. 1 – Documentation<br>Chemical Descriptions<br>Safety Data Sheets<br>Att. 2 – Forms<br>Air Monitoring Form<br>Site Safety Checklist<br>Daily Tailgate Safety Meeting Form |

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(20) Attachments

Attachments

A. Drawings
   1. Site Map
   2. Shallow Groundwater Gradient Map
   3. Deep Groundwater Gradient Map
   4. Shallow Groundwater Concentrations
   5. Deep Groundwater Concentrations
   6. Sparge Pilot Test Areas
   7. OU5 Additional Groundwater Monitoring Locations
   8. Operating Unit Location Map
B. Cross Sections
   1. OU1 and OU5 Cross Sections Map
   2. OU1 and OU5 Cross Sections A, B, and C
   3. OU1 and OU5 Cross Sections D and E
   4. OU1 and OU5 Cross Sections F and G
C. Monitoring Well Concentration Trends
D. 2019 Groundwater Modeling Report and EPA Response to Comments
E. Sparging Feasibility Testing Description
F. Biosparge Basis of Design
G. Vapor Intrusion Screening
H. Decision Diagrams
   1. Dissolved Oxygen Monitoring
   2. Cessation of Pumping – Groundwater
   3. Groundwater Monitoring Contingency Plan
   4. Soil Gas Monitoring Contingency Plan
   5. OU5 Groundwater Increase ≥3 Times Prior Result
I. Data Quality Objectives
   1. Biosparge Well Depth and Spacing
   2. Investigation Derived Waste and Surplus Excavated Soil Collection and Characterization
   3. Biosparge Well Performance Testing
   4. Biosparge Pipe Pressure Testing
   5. Proper Biosparge System Operation
   6. Biosparge System Optimization via Dissolved Oxygen Monitoring
   7. Soil Gas Vapor Intrusion Evaluation
   8. Cessation of Groundwater Pumping
   9. OU5 Groundwater Evaluation
   10. Groundwater Vapor Intrusion Evaluation

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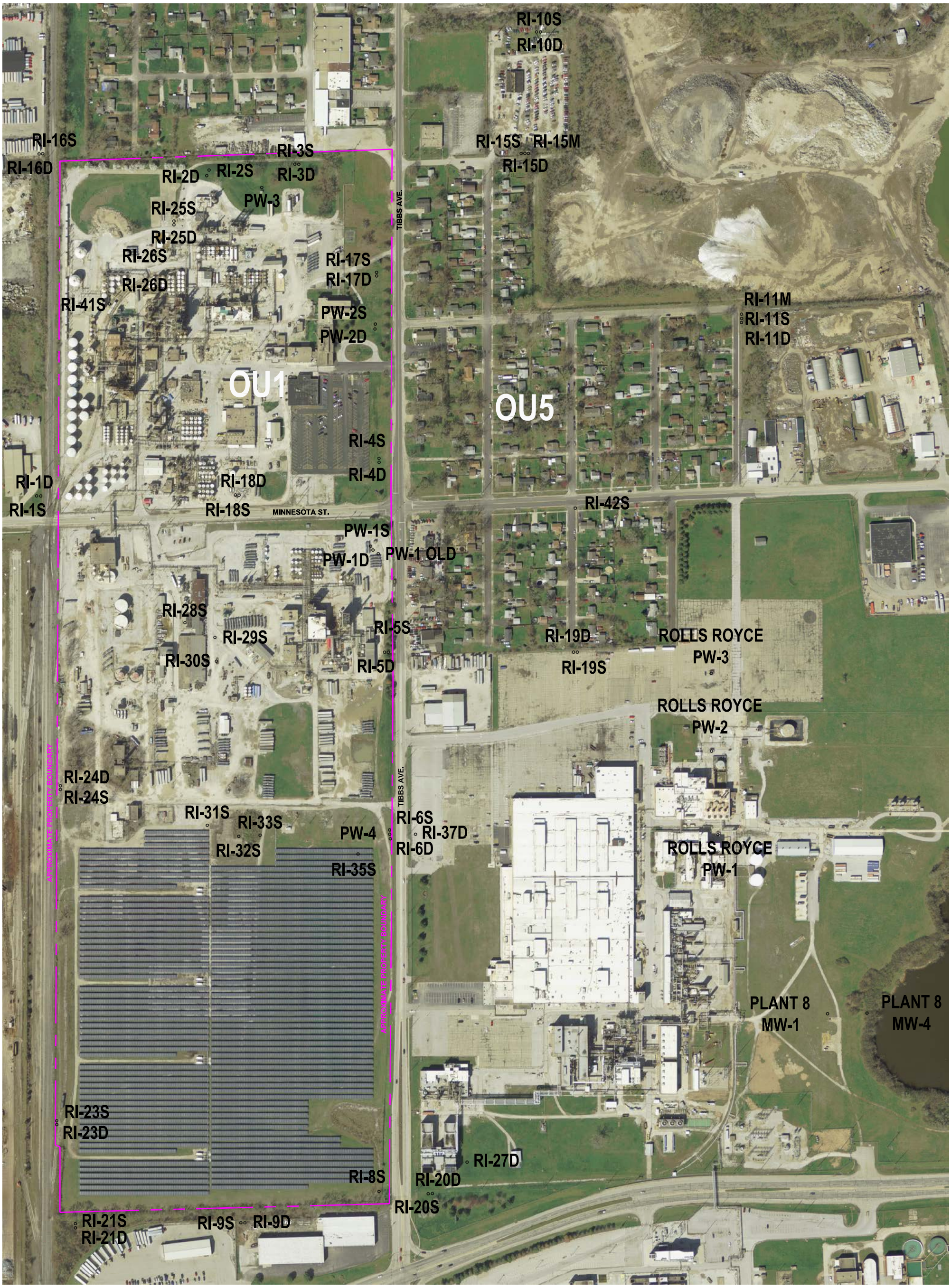
**Attachment A**

**Drawings**

1. Site Map
2. Shallow Groundwater Gradient Map
3. Deep Groundwater Gradient Map
4. Shallow Groundwater Concentrations
5. Deep Groundwater Concentrations
6. Sparge Pilot Test Areas
7. OU5 Additional Groundwater Monitoring Locations
8. Operating Unit Location Map




BEARING

0 350 700

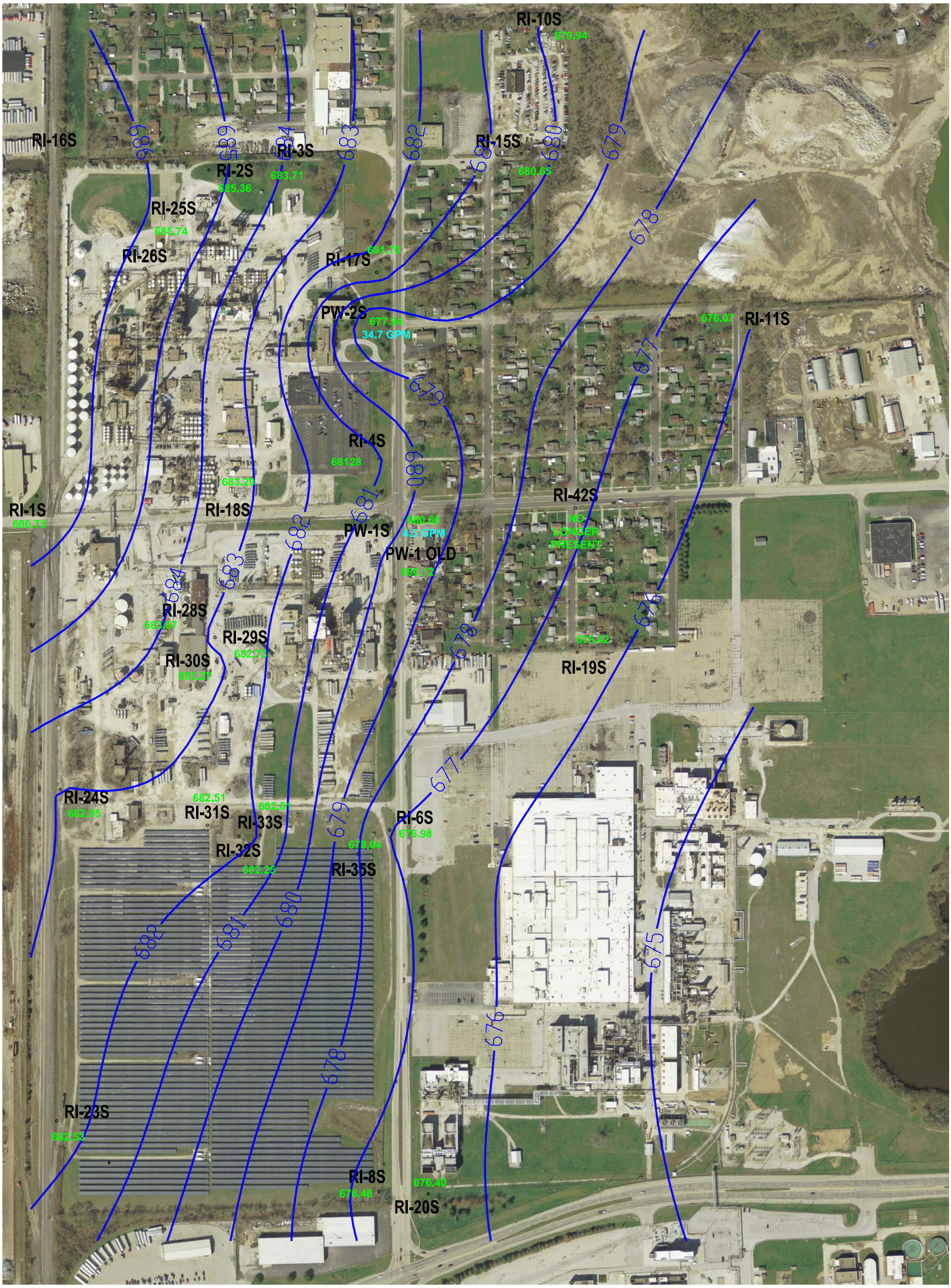
SCALE (FEET)

# REMEDIAL ACTION WORK PLAN

| REV. DATE: | DRAWING DATE: 12–16–2024 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

## SITE MAP

| CLIENT: 1500 SOUTH TIBBS LLC | | | PM: DMP |
|---|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | | DRAWING: 1 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: RAWP | |




BEARING

0 350 700

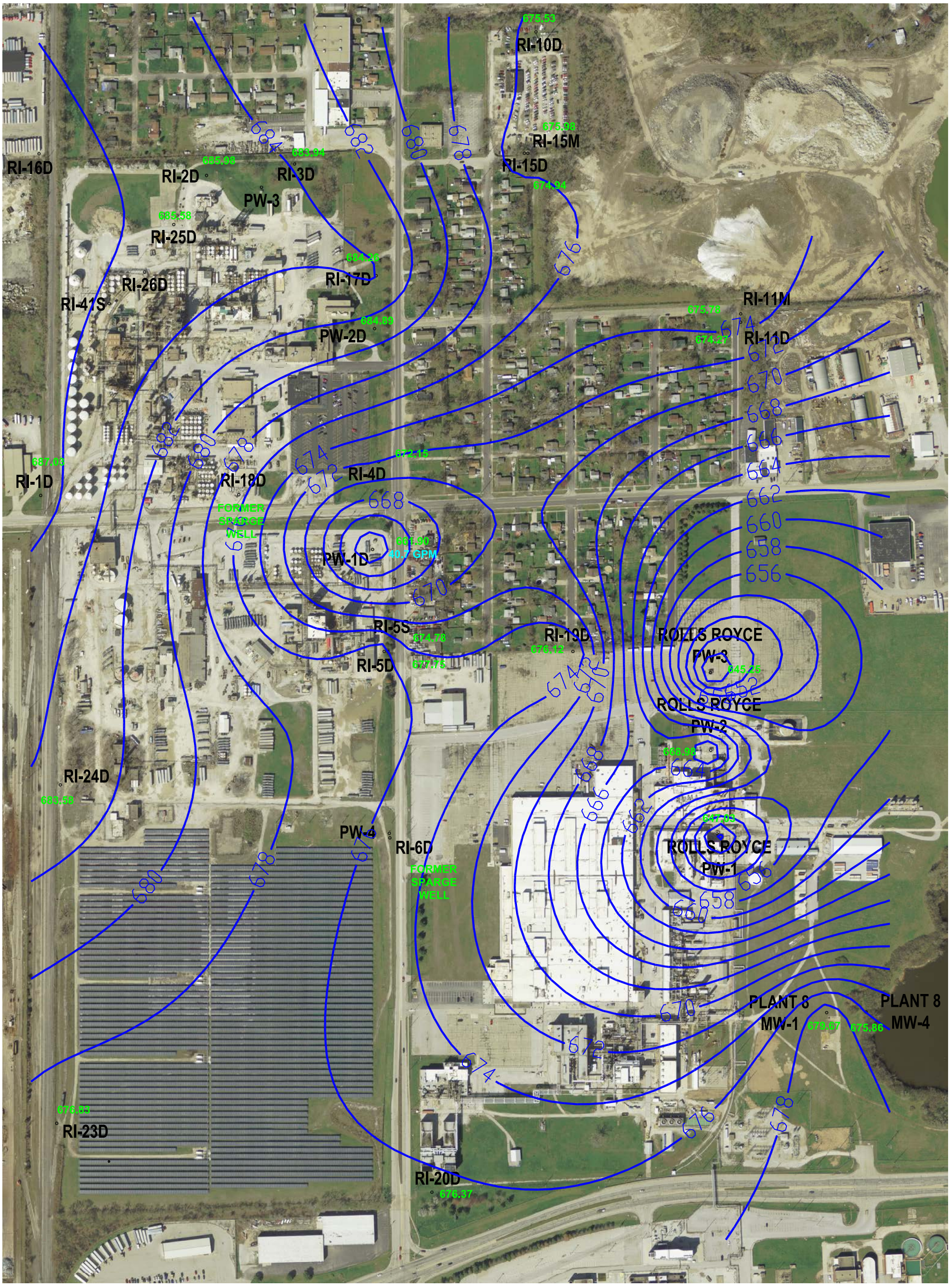
SCALE (FEET)

1Q2024 REPORT

| REV. DATE: | DRAWING DATE: APR. 2024 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

# SHALLOW GROUNDWATER GRADIENT MAP

| CLIENT: 1500 SOUTH TIBBS LLC | | PM: DMP |
|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | DRAWING: 2 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: |




BEARING

0 350 700

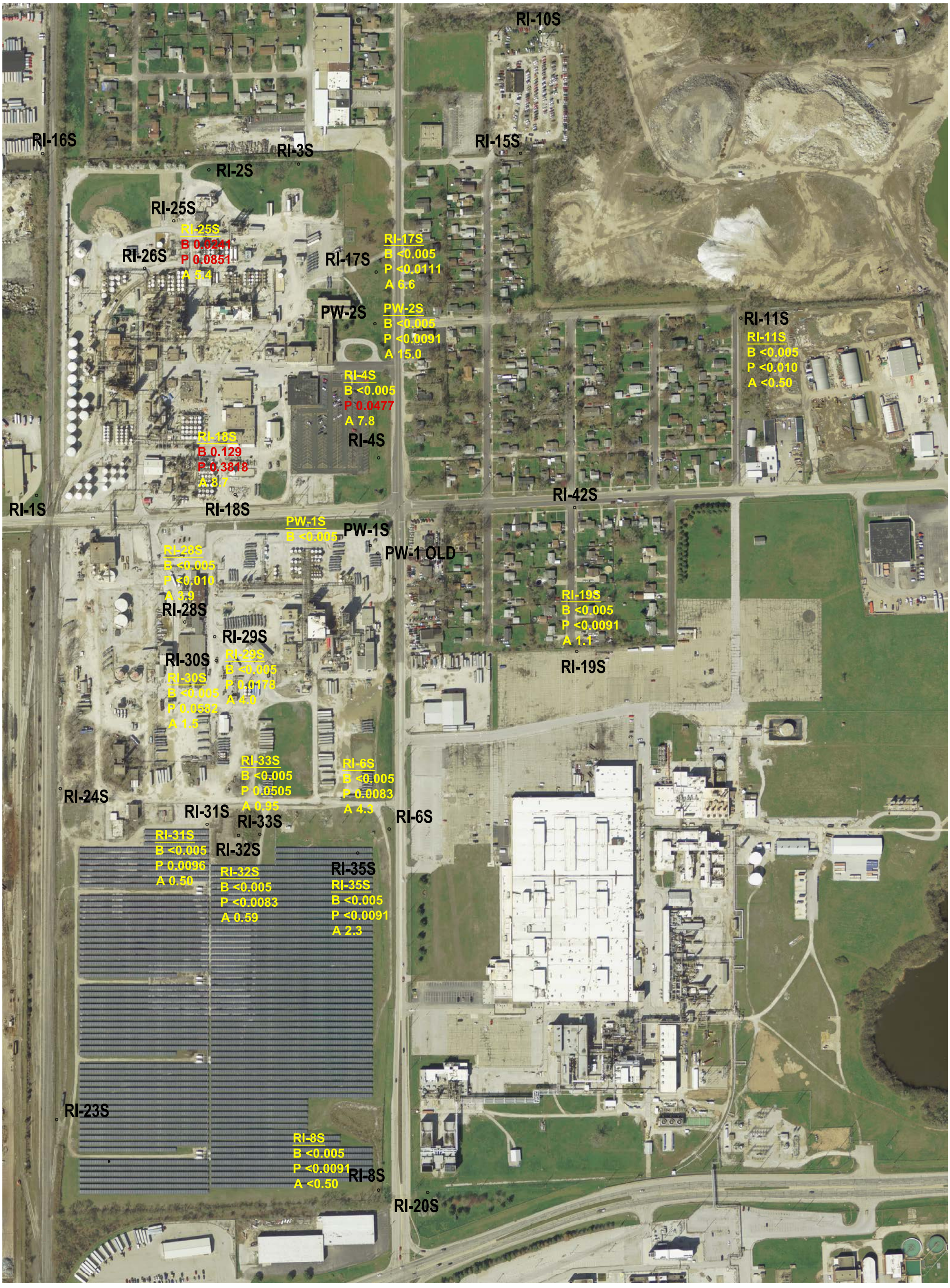
SCALE (FEET)

# 1Q2024 REPORT

| REV. DATE: | DRAWING DATE: APR. 2024 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

## DEEP GROUNDWATER GRADIENT MAP

| CLIENT: | PM: |
|---|---|
| 1500 SOUTH TIBBS LLC | DMP |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | DRAWING: 3 |
| DESIGNED: DMP / DETAILED: DMP / PROJECT NO.: | |




BEARING

0 350 700

SCALE (FEET)

**REMEDIAL GOAL (RG)**
**BENZENE (B) 0.005 MG/L**
**PYRIDINE (P) 0.035/EACH MG/L**
**AMMONIA (A) 30 MG/L**

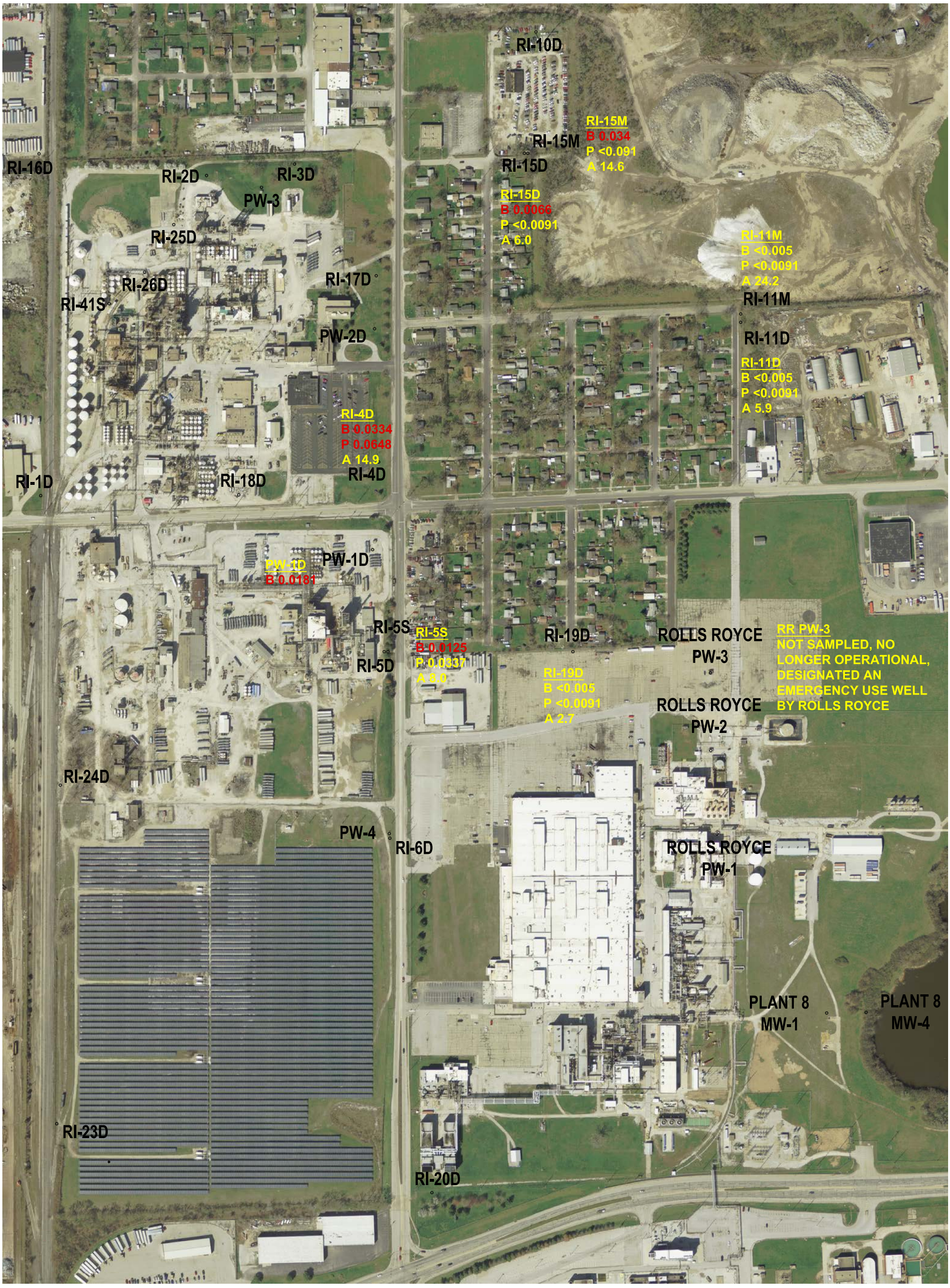
**NOTE: EXCEEDED RG IS RED**

# 1Q2024 REPORT

| REV. DATE: | DRAWING DATE: APR. 2024 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

## SHALLOW GROUNDWATER CONCENTRATIONS

| CLIENT: 1500 SOUTH TIBBS LLC | | PM: DMP |
|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | DRAWING: 4 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: |




BEARING

0 350 700

SCALE (FEET)

**REMEDIAL GOAL (RG)**
**BENZENE (B) 0.005 MG/L**
**PYRIDINE (P) 0.035/EACH MG/L**
**AMMONIA (A) 30 MG/L**

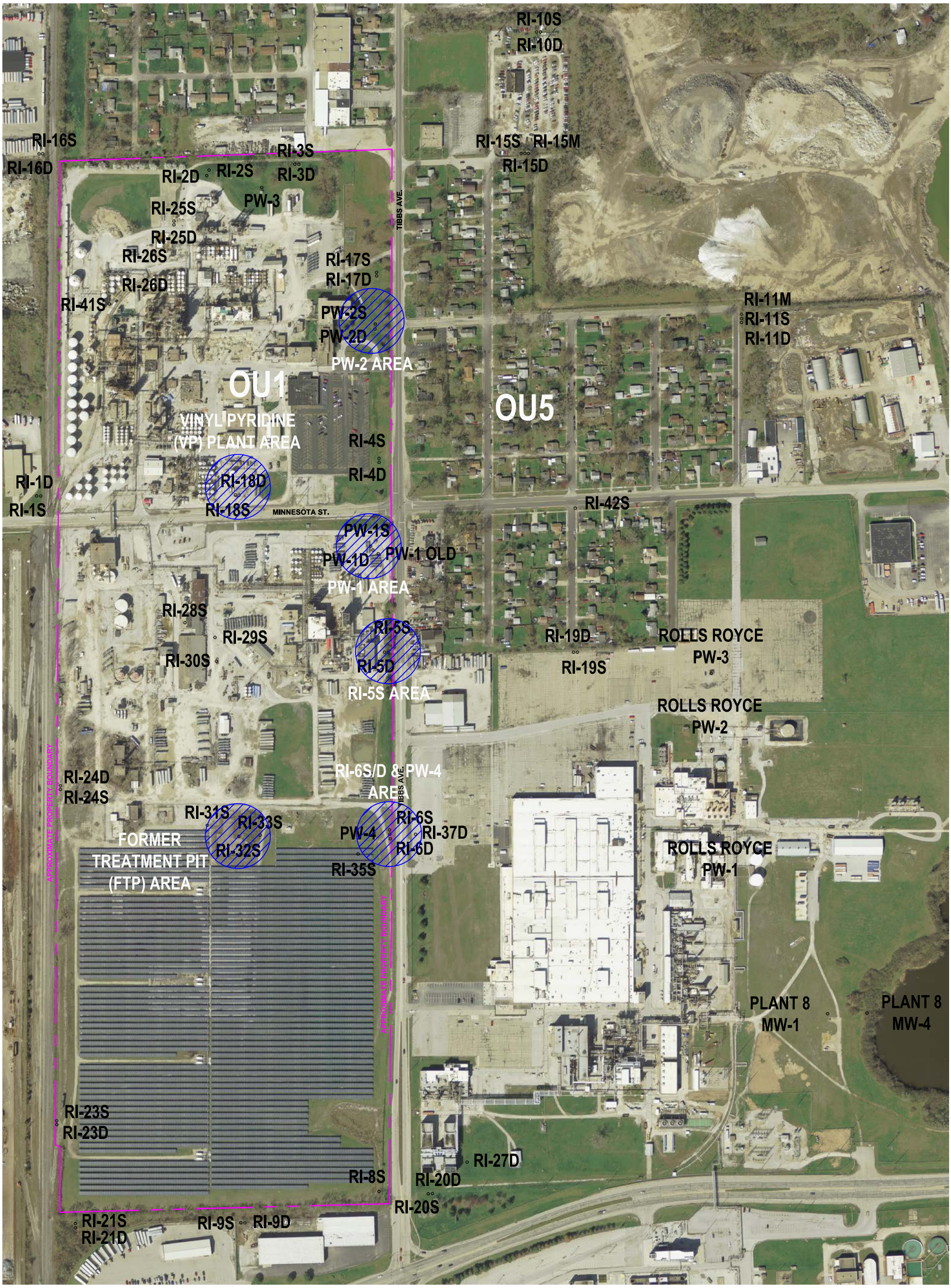
**NOTE: EXCEEDED RG IS RED**

# 1Q2024 REPORT

| REV. DATE: | DRAWING DATE: APR. 2024 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

## DEEP GROUNDWATER CONCENTRATIONS

| CLIENT: | PM: |
|---|---|
| 1500 SOUTH TIBBS LLC | DMP |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | DRAWING: 5 |
| DESIGNED: DMP / DETAILED: DMP / PROJECT NO.: | |




BEARING

0 350 700

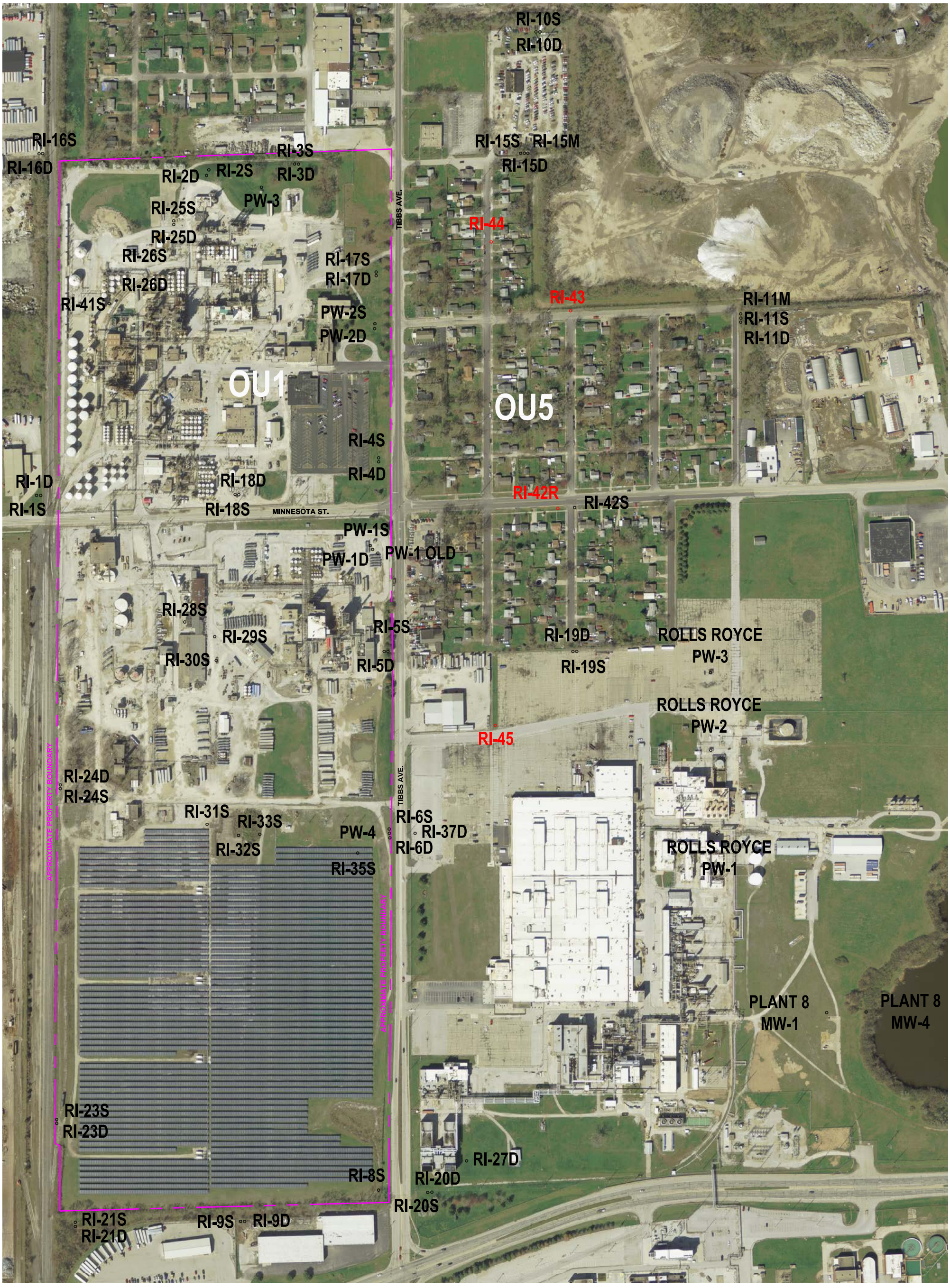
SCALE (FEET)

# REMEDIAL ACTION WORK PLAN

| REV. DATE: | DRAWING DATE: 12–16–2024 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

## SPARGE PILOT TEST AREAS

| CLIENT: 1500 SOUTH TIBBS LLC | | | PM: DMP |
|---|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | | DRAWING: 6 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: RAWP | |




BEARING

0 350 700

SCALE (FEET)

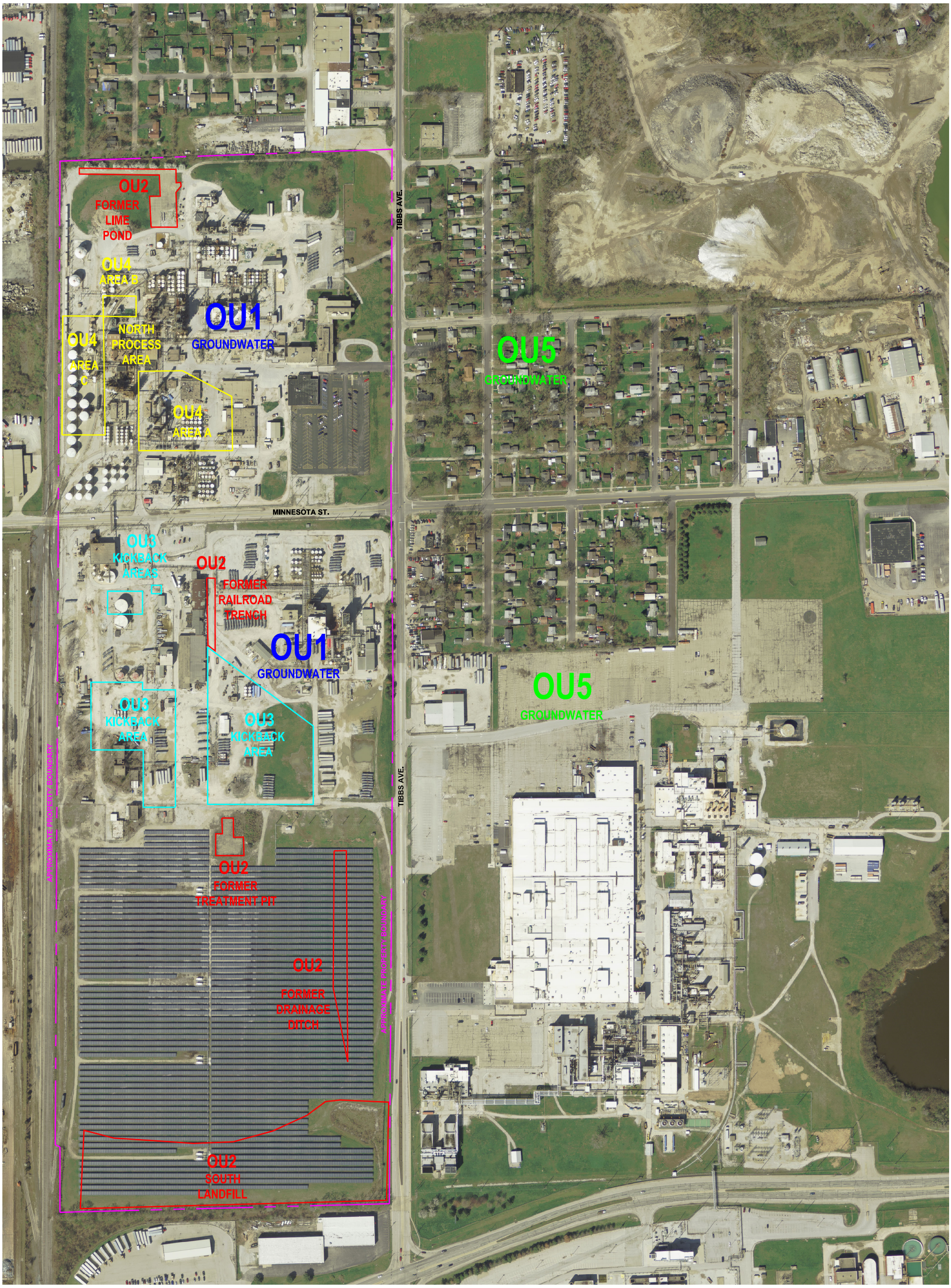
NOTE: AT EACH LOCATION (MW–42R, MW–43, MW–44 AND MW–45) A MONITORING WELL WILL BE INSTALLED IN THE SHALLOW (I.E. MW–43S), MID–DEPTH (I.E. MW–43M), AND DEEP (I.E. MW–43D) INTERVALS, ASSUMING ALL SUCH INTERVALS ARE ENCOUNTERED AT EACH LOCATION. IF THE BEDROCK ELEVATION IS HIGHER, THEN IT MAY ONLY BE POSSIBLE TO INSTALL MOINTORING WELLS IN THE SHALLOW AND/OR MID–DEPTH INTERVALS AS WAS THE CASE WITH MW–42 AND MW–19. IT IS ESTIMATED THAT THE SHALLOW, MID–DEPTH, AND DEEP INTERVALS WILL BE AT ELEVATIONS OF APPROXIMATELY 700 TO 670 FT MSL, 670 TO 640 FT MSL, AND 640 TO 610 FT MSL, RESPECTIVELY.

# REMEDIAL ACTION WORK PLAN

| REV. DATE: | DRAWING DATE: 12–16–2024 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

## OU5 ADDITIONAL MONITORING WELLS

| CLIENT: | PM: |
|---|---|
| 1500 SOUTH TIBBS LLC | DMP |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | DRAWING: 7 |
| DESIGNED: DMP / DETAILED: DMP / PROJECT NO.: RAWP | |




BEARING

0 350 700

SCALE (FEET)

OPERABLE UNITS (1–5)

OU1 – ON–SITE GROUNDWATER
OU2 – CERCLA AREAS
OU3 – KICKBACK AREAS
OU4 – NORTH PROCESS AREAS
OU5 – OFF–SITE GROUNDWATER

DRAWING SOURCES

1. OU2 ROD (SEP 1993), FIGURE 3
2. OU3 AND OU4 ROD (OCT 1996), FIGURE 5
3. ENVIRONMENTAL RESTRICTIVE COVENANT DATED 02–13–2012

REMEDIAL ACTION WORK PLAN

| REV. DATE: | DRAWING DATE: 04–18–2025 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

# OPERATING UNIT LOCATION MAP

| CLIENT: 1500 SOUTH TIBBS LLC | | PM: DMP |
|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | DRAWING: 8 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: ICIAP |

**Attachment B**

**Cross Sections**

1. OU1 and OU5 Cross Sections Map
2. OU1 and OU5 Cross Sections A, B, and C
3. OU1 and OU5 Cross Sections D and E
4. OU1 and OU5 Cross Sections F and G

RI-10S
RI-10D
RI-16S
RI-16D
RI-3S
RI-3D
RI-2D
RI-2S
PW-3
RI-15S
RI-15M
RI-15D
RI-25S
RI-25D
TIBBS AVE.
CROSS SECTION A
RI-26S
RI-26D
RI-17S
RI-17D
RI-41S
PW-2S
PW-2D
RI-11M
RI-11S
RI-11D
OU1
OU5
RI-4S
RI-4D
CROSS SECTION B
RI-1D
RI-18D
RI-42S
RI-1S
RI-18S
MINNESOTA ST.
PW-1S
PW-1D
PW-1 OLD
CROSS SECTION G
CROSS SECTION E
RI-28S
RI-29S
RI-30S
RI-5S
RI-5D
RI-19D
RI-19S
ROLLS ROYCE
PW-3
CROSS SECTION C
CROSS SECTION F
ROLLS ROYCE
PW-2
RI-24D
RI-24S
RI-31S
RI-33S
RI-32S
PW-4
RI-35S
RI-6S
RI-37D
RI-6D
ROLLS ROYCE
PW-1
PLANT 8
MW-1
PLANT 8
MW-4
RI-23S
RI-23D
RI-27D
RI-8S
RI-20D
CROSS SECTION D
RI-20S
RI-21S
RI-21D
RI-9S
RI-9D

BEARING

0 350 700

SCALE (FEET)

DAVID M. PETERSON, PE, PC

PROJECT: VIP FFS

OU1 AND OU5
CROSS SECTIONS

CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC

PM: DMP

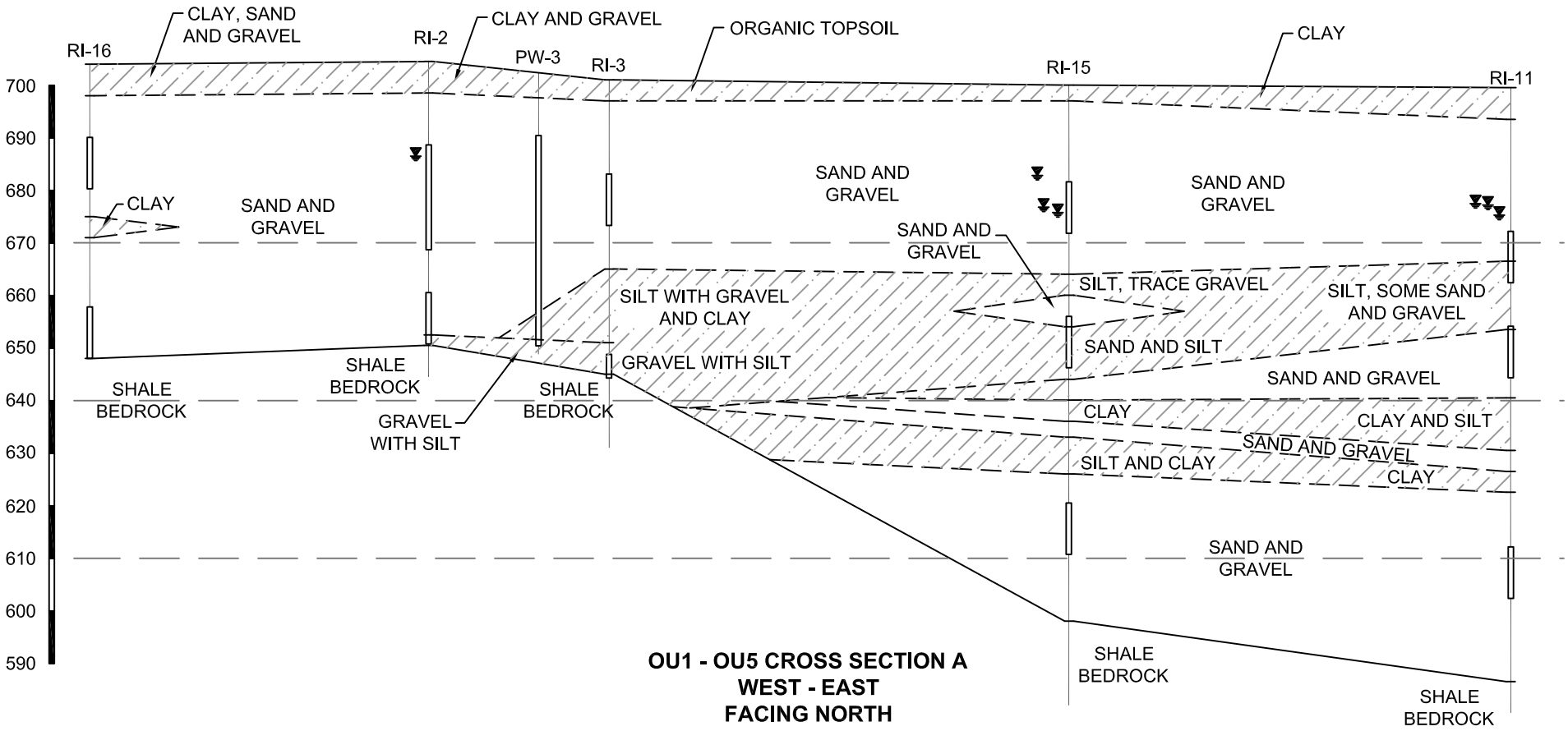
LOCATION: 1500 S. TIBBS AVE INDIANAPOLIS, INDIANA

DRAWING: 1

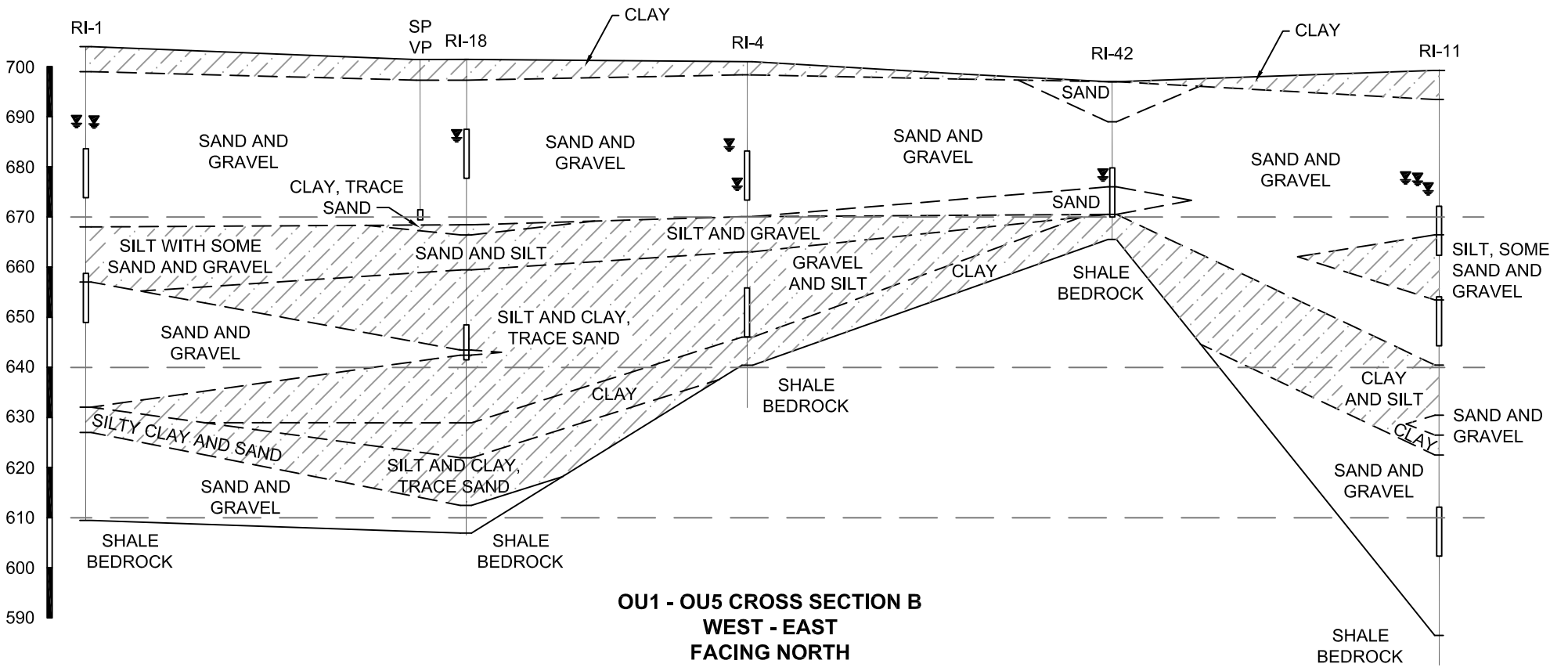
DRAWN BY: DMP

REVIEWED BY: DMP

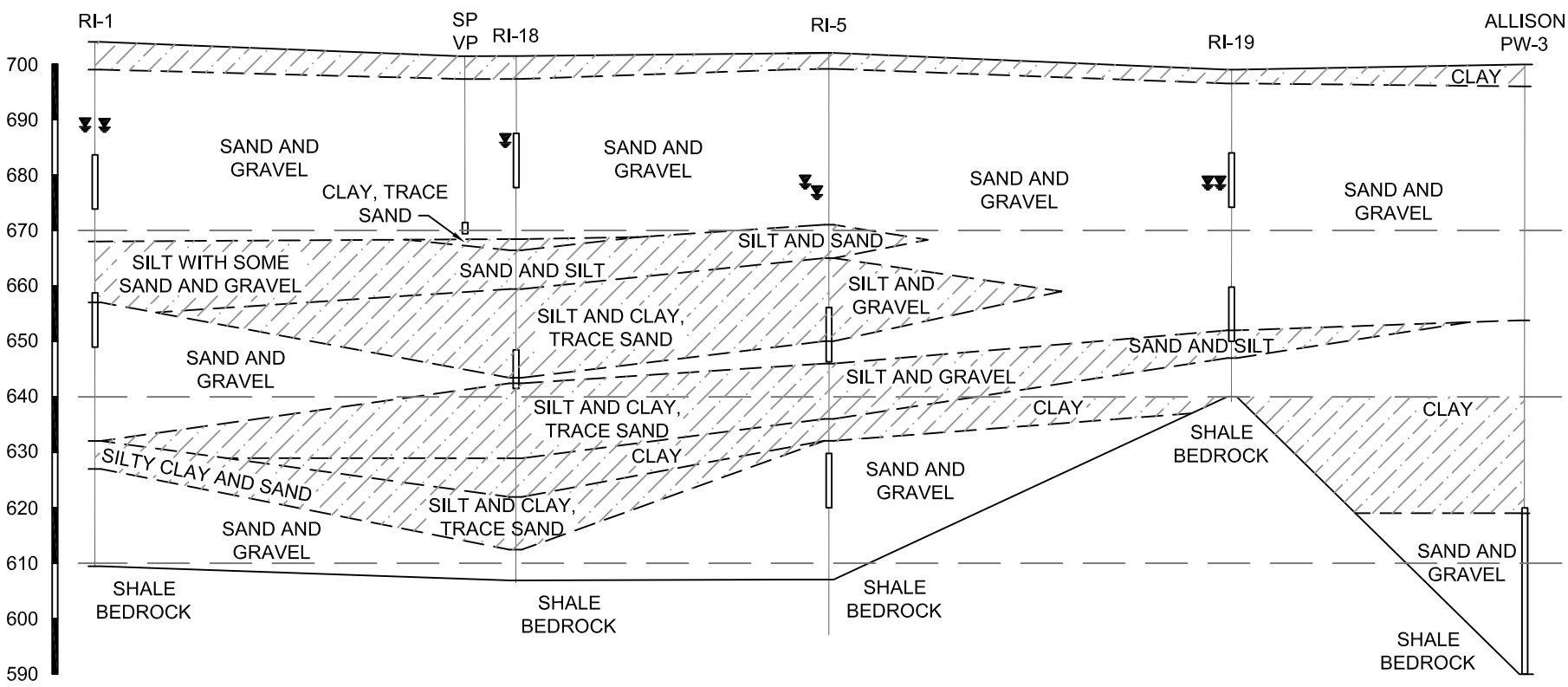
DATE: 02/22/2020




**OU1 - OU5 CROSS SECTION A**
**WEST - EAST**
**FACING NORTH**




**OU1 - OU5 CROSS SECTION B**
**WEST - EAST**
**FACING NORTH**




**OU1 - OU5 CROSS SECTION C**
**WEST - EAST**
**FACING NORTH**

HATCHING LEGEND

- SAND AND GRAVEL
- FINER GRAINED SOIL (PARTLY SILT, SILT, AND CLAY)
- APPROX. GROUNDWATER LEVEL

0 100 200 300 400 500 600 700 800 900 1000

HORIZONTAL SCALE (FEET)

DAVID M. PETERSON, PE, PC

PROJECT: VIP FFS

OU1 AND OU5 CROSS SECTIONS

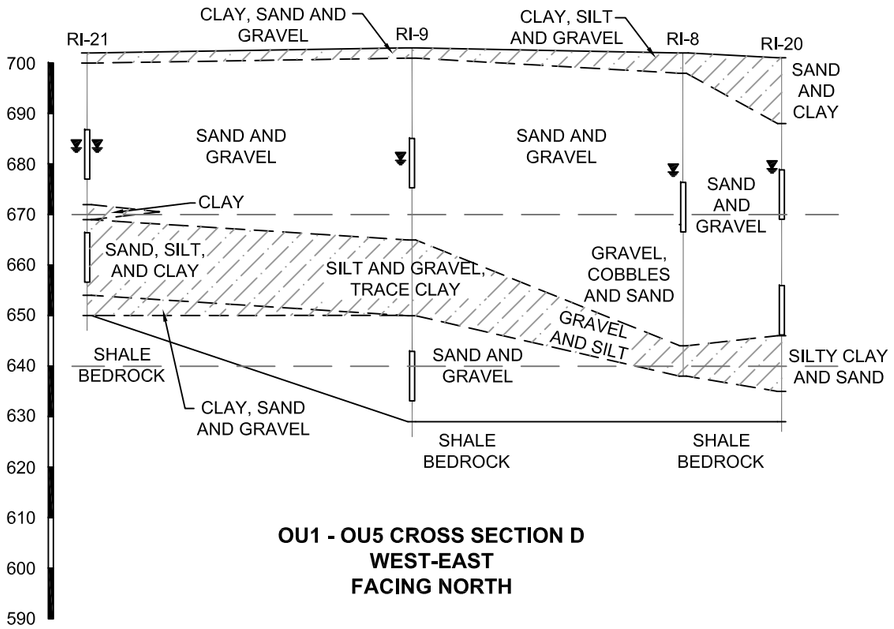
CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC

PM: DMP

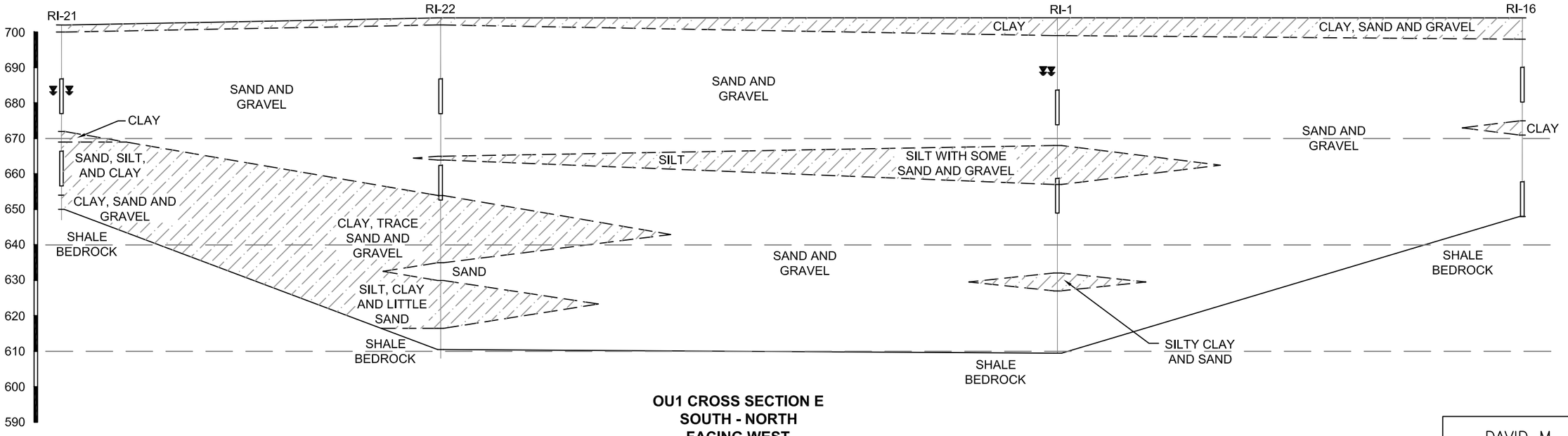
LOCATION: 1500 S. TIBBS AVE INDIANAPOLIS, INDIANA

DRAWING: 2

DRAWN BY: DMP | REVIEWED BY: DMP | DATE: 03/26/2020




**OU1 - OU5 CROSS SECTION D**
**WEST-EAST**
**FACING NORTH**




**OU1 CROSS SECTION E**
**SOUTH - NORTH**
**FACING WEST**

HATCHING LEGEND

- SAND AND GRAVEL
- FINER GRAINED SOIL (PARTLY SILT, SILT, AND CLAY)
- APPROX. GROUNDWATER LEVEL

0 100 200 300 400 500 600 700 800 900 1000

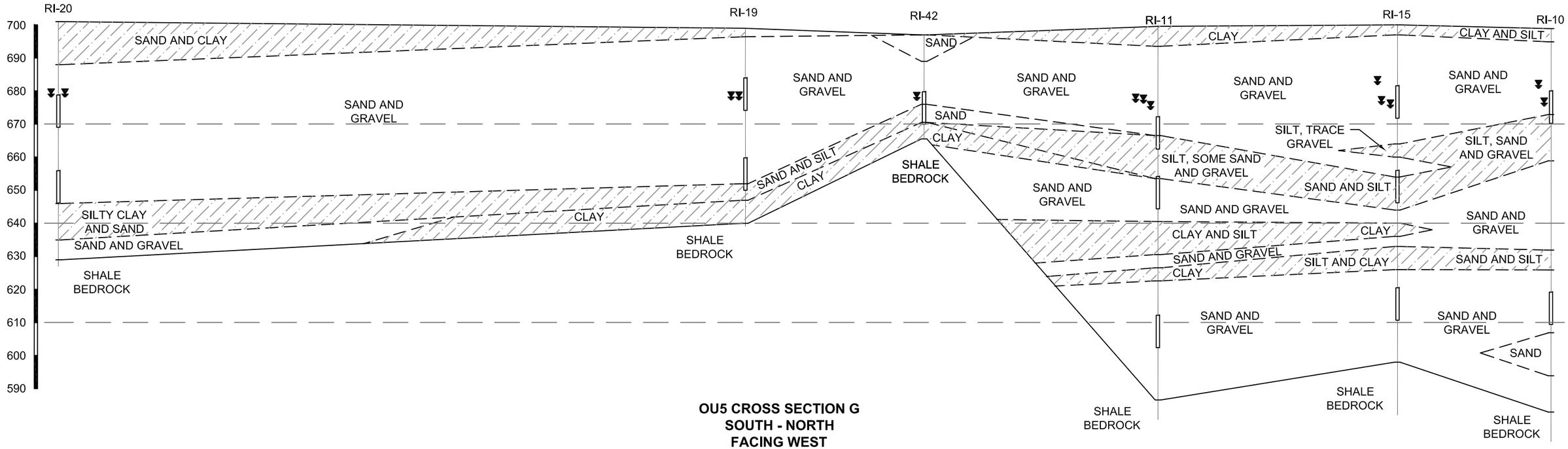
HORIZONTAL SCALE (FEET)

DAVID M. PETERSON, PE, PC

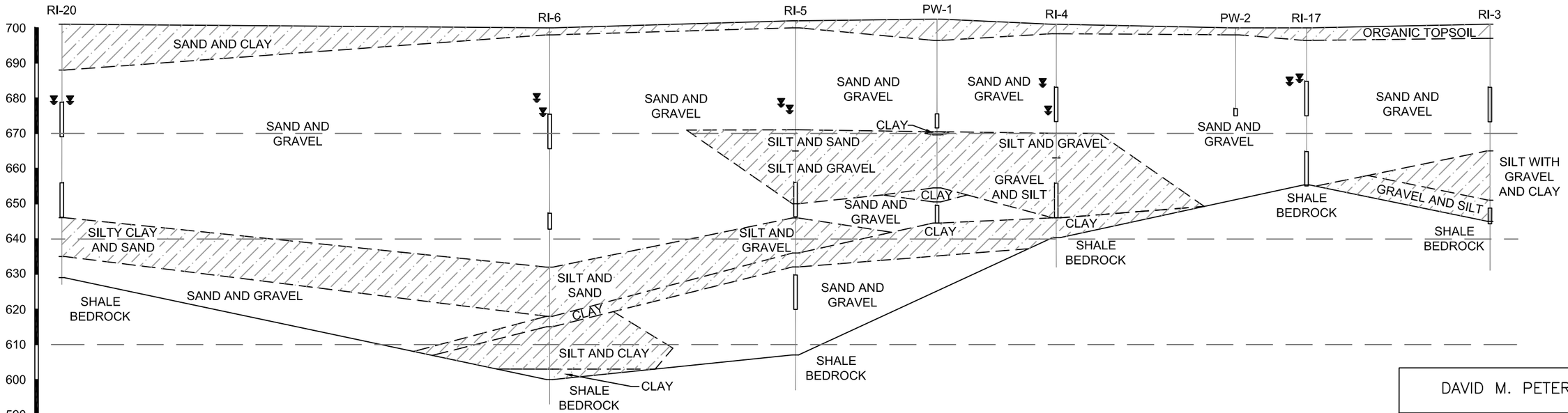
PROJECT: VIP FFS

OU1 AND OU5
CROSS SECTIONS

| CLIENT: | PM: |
|---|---|
| VERTELLUS INTEGRATED PYRIDINES LLC | DMP |
| LOCATION: 1500 S. TIBBS AVE INDIANAPOLIS, INDIANA | DRAWING: 3 |
| DRAWN BY: DMP / REVIEWED BY: DMP / DATE: 03/26/2020 | |




**OU5 CROSS SECTION G**
**SOUTH - NORTH**
**FACING WEST**




**OU1 CROSS SECTION F**
**SOUTH - NORTH**
**FACING WEST**

HATCHING LEGEND

- SAND AND GRAVEL
- FINER GRAINED SOIL (PARTLY SILT, SILT, AND CLAY)
- APPROX. GROUNDWATER LEVEL

0 100 200 300 400 500 600 700 800 900 1000

HORIZONTAL SCALE (FEET)

DAVID M. PETERSON, PE, PC

PROJECT: VIP FFS

OU1 AND OU5
CROSS SECTIONS

CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC

PM: DMP

LOCATION: 1500 S. TIBBS AVE INDIANAPOLIS, INDIANA

DRAWING: 4

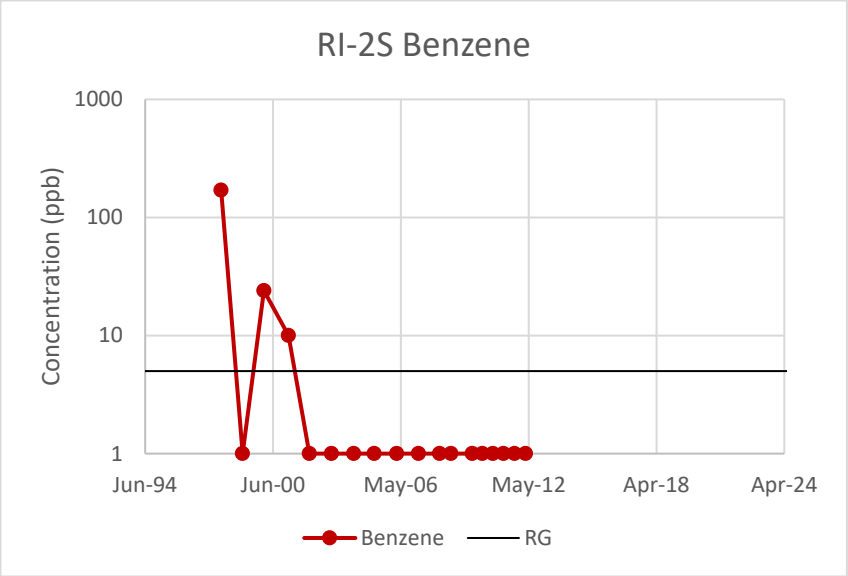
DRAWN BY: DMP | REVIEWED BY: DMP | DATE: 03/26/2020

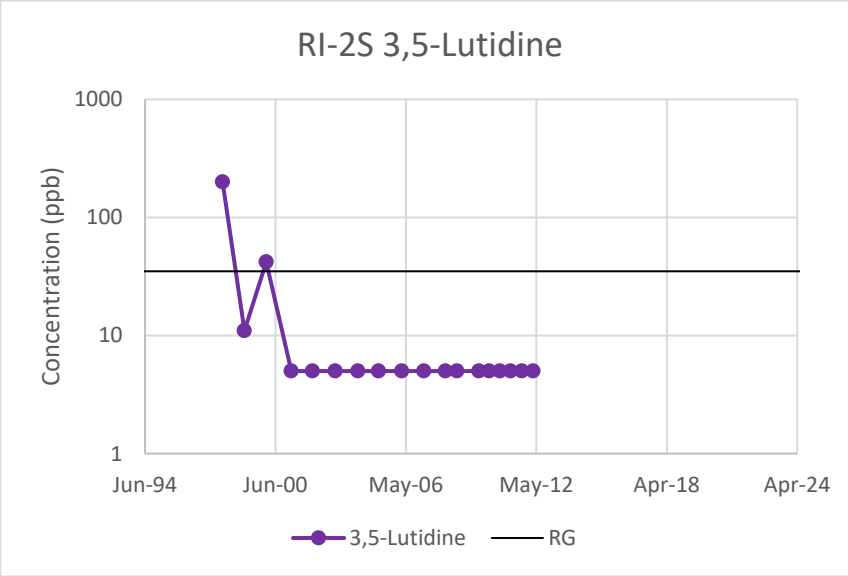
**Attachment C**

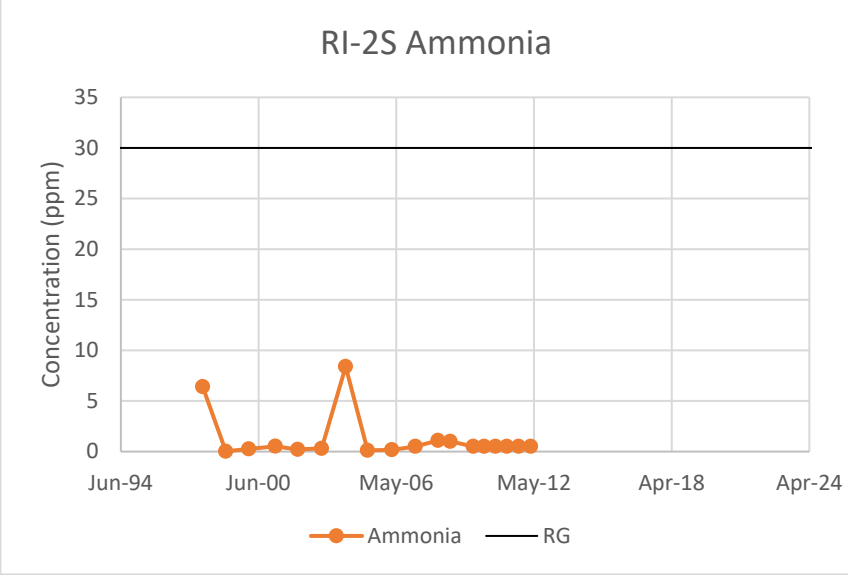
**Monitoring Well Concentration Trends**

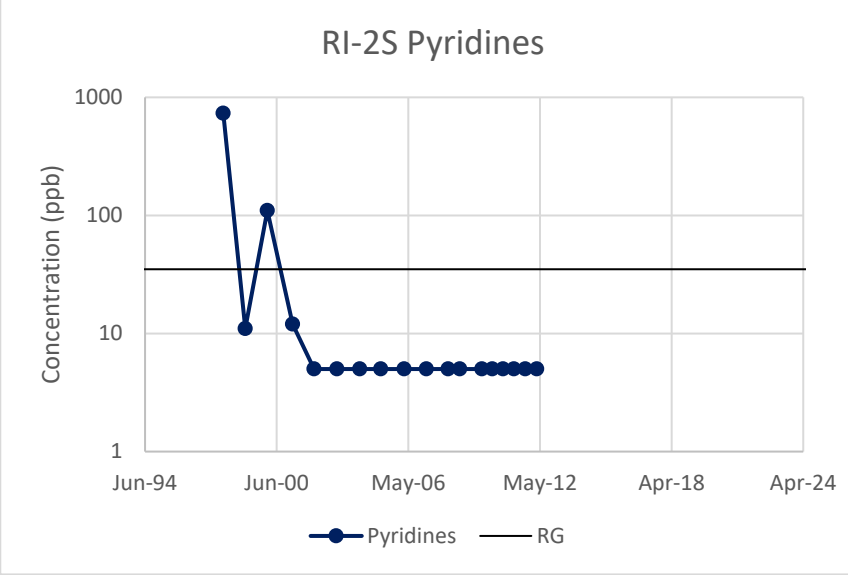
**OU1 WELLS**
**RI-2S GRAPHICAL ANALYSIS**

Note: Benzene, pyridine, and ammonia levels were below the RGs so sampling ceased in 2012.



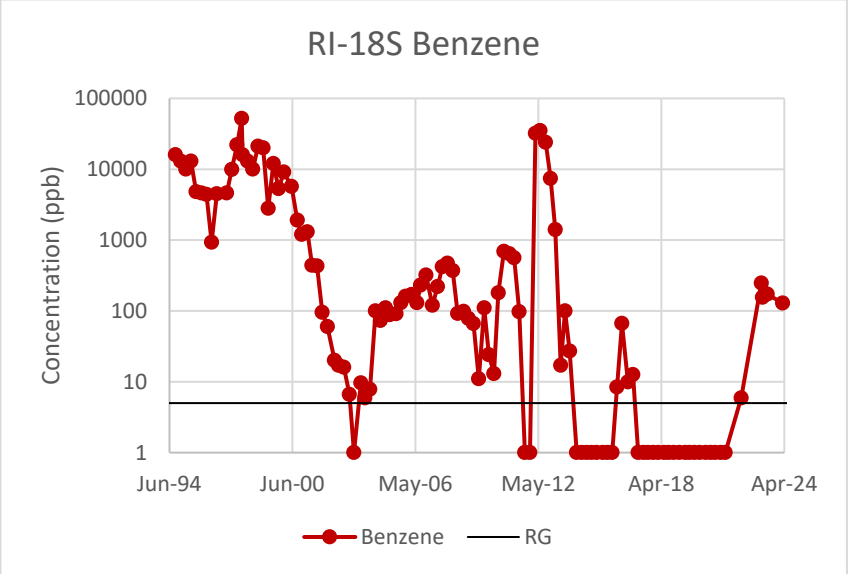



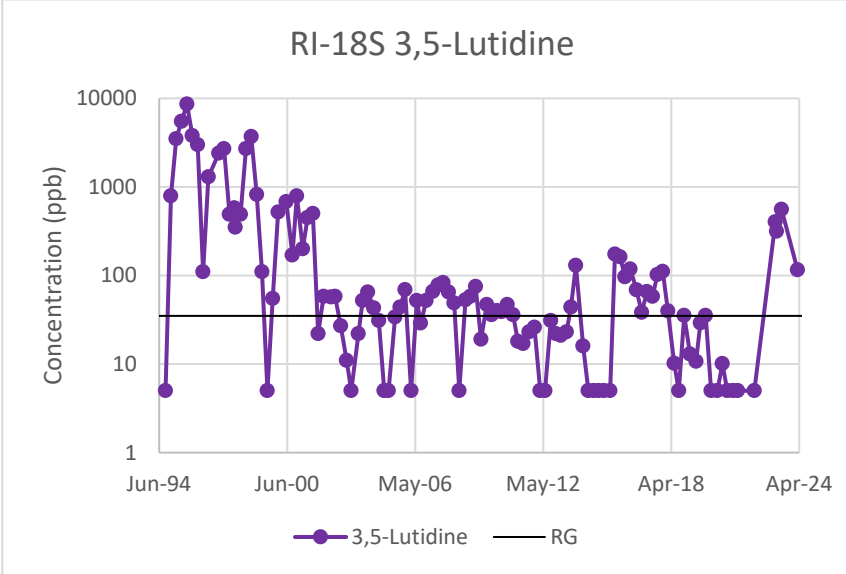



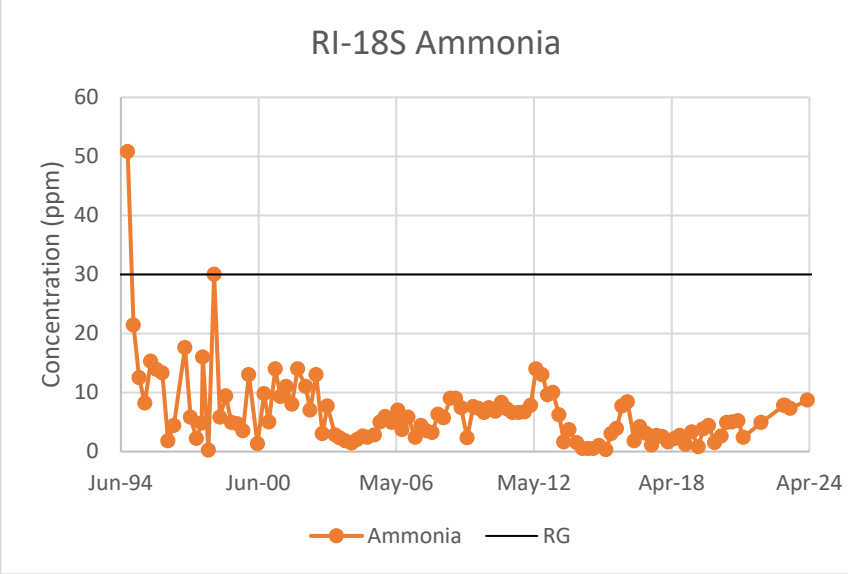



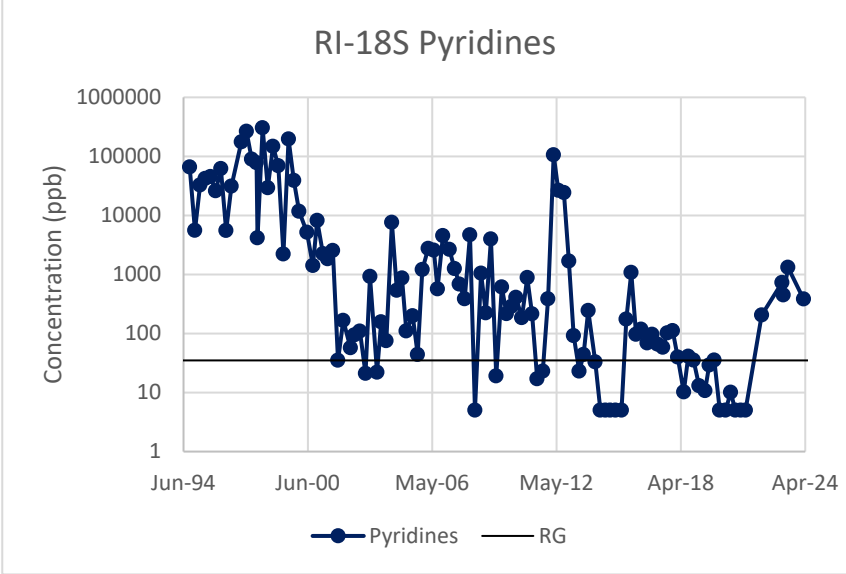
**OU1 WELLS**
**RI-18S GRAPHICAL ANALYSIS**

Note: Benzene and pyridine levels have risen above the RGs. Ammonia levels are below the RGs. Sparging has occurred 2012-2020.



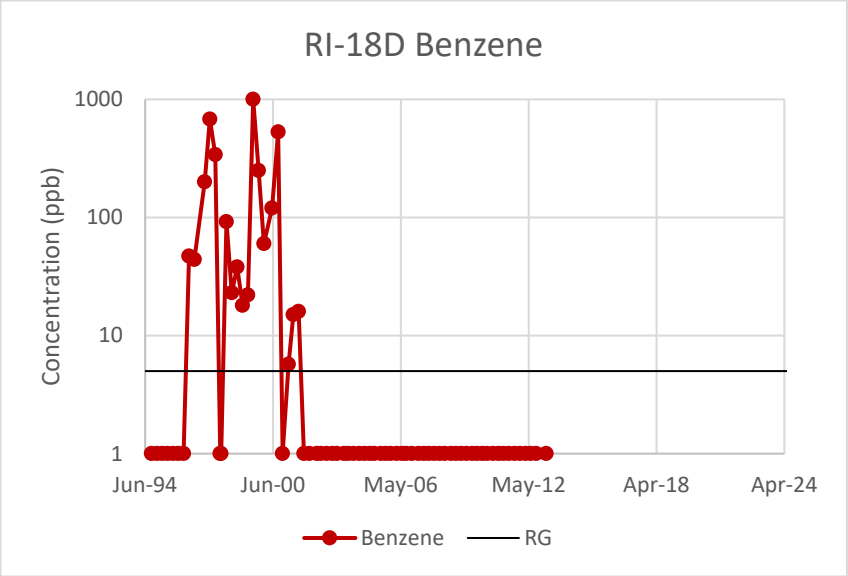



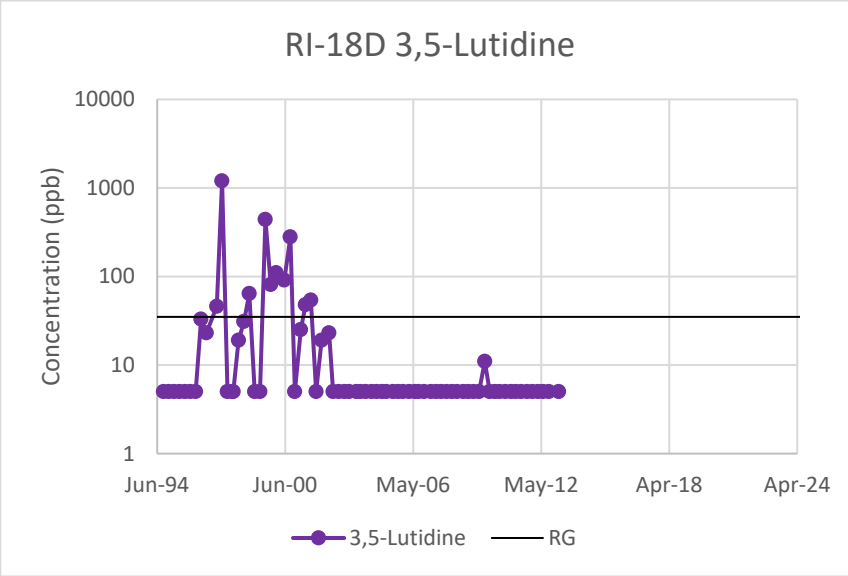



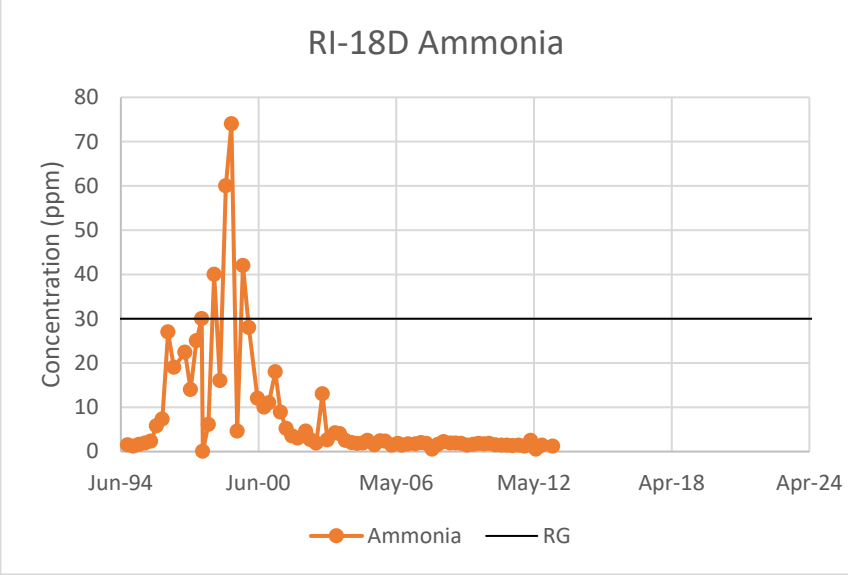



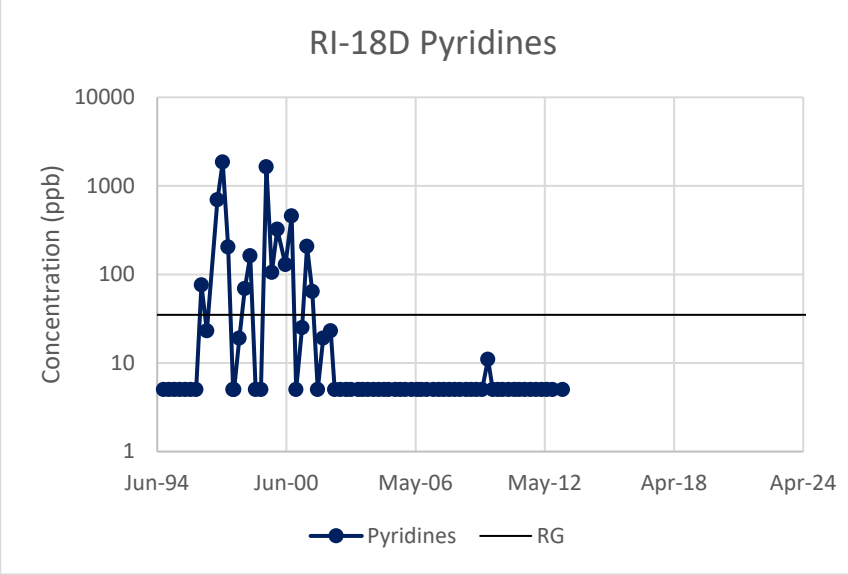
**OU1 WELLS**
**RI-18D GRAPHICAL ANALYSIS**

Note: Benzene and pyridine levels decreased and remained below the RGs; sampling ceased in 2013. Sparging occurred at RI-18D.



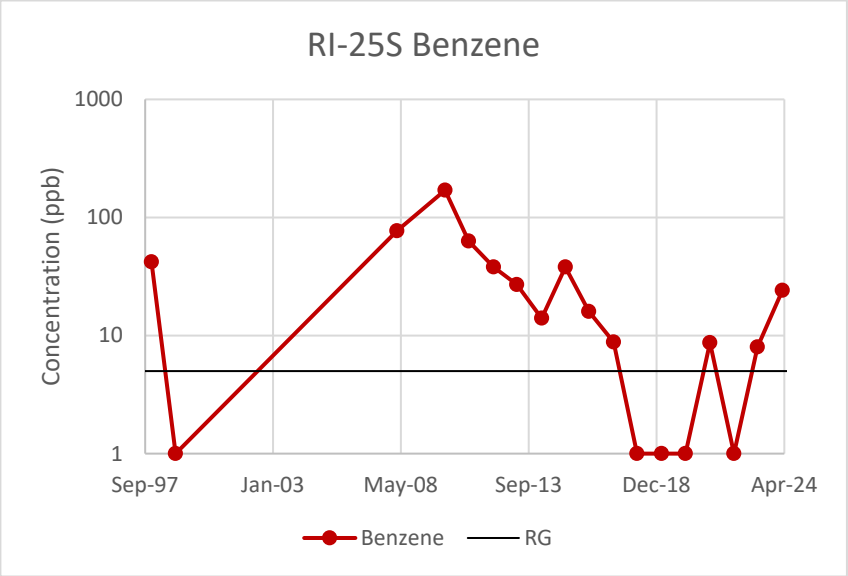



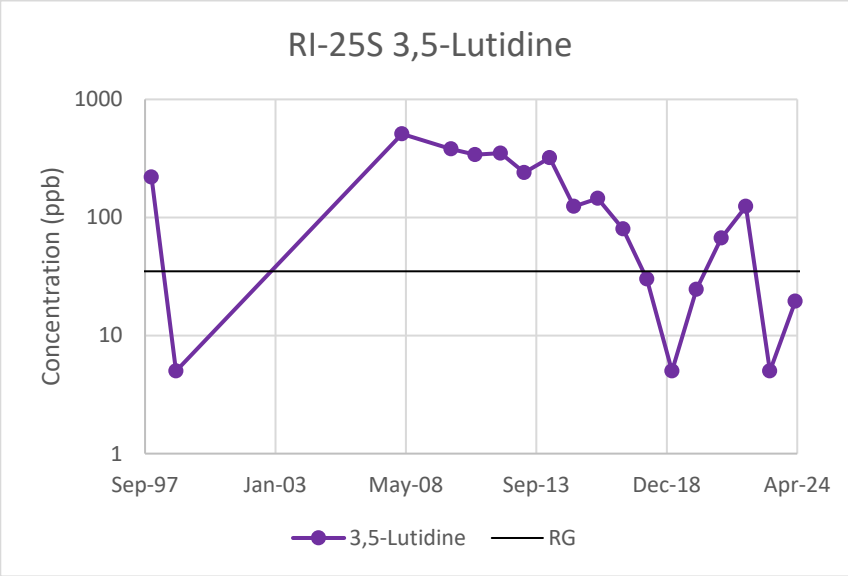



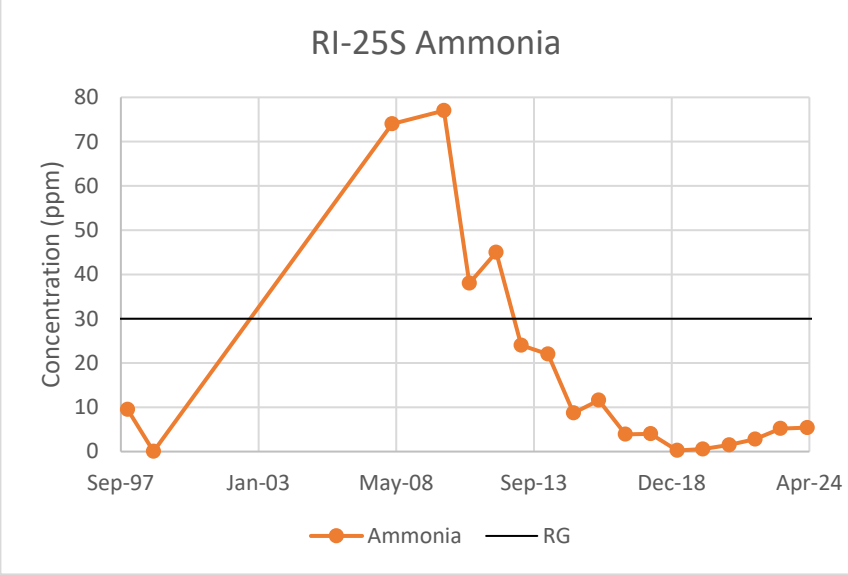



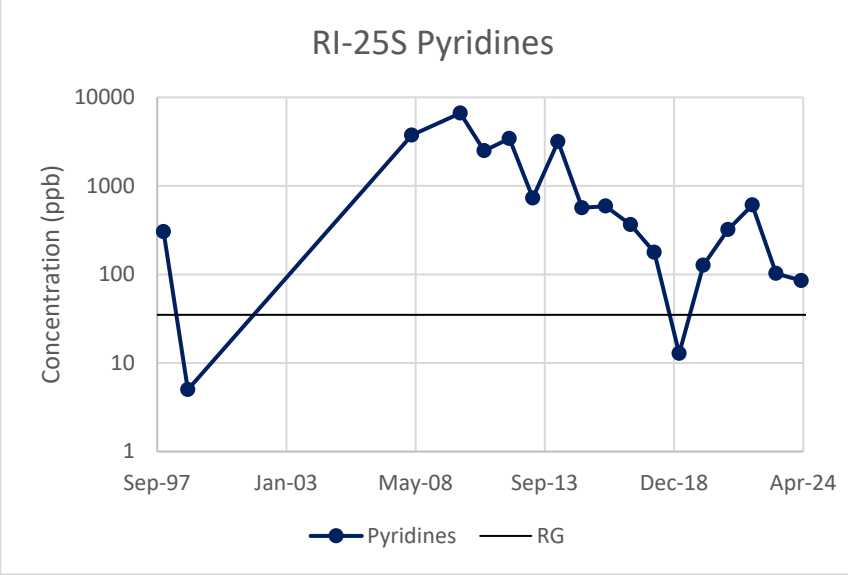
**OU1 WELLS**
**RI-25S GRAPHICAL ANALYSIS**

Note: Benzene and pyridine levels have been fluctuating below and above the RGs. Ammonia levels are below the RG.



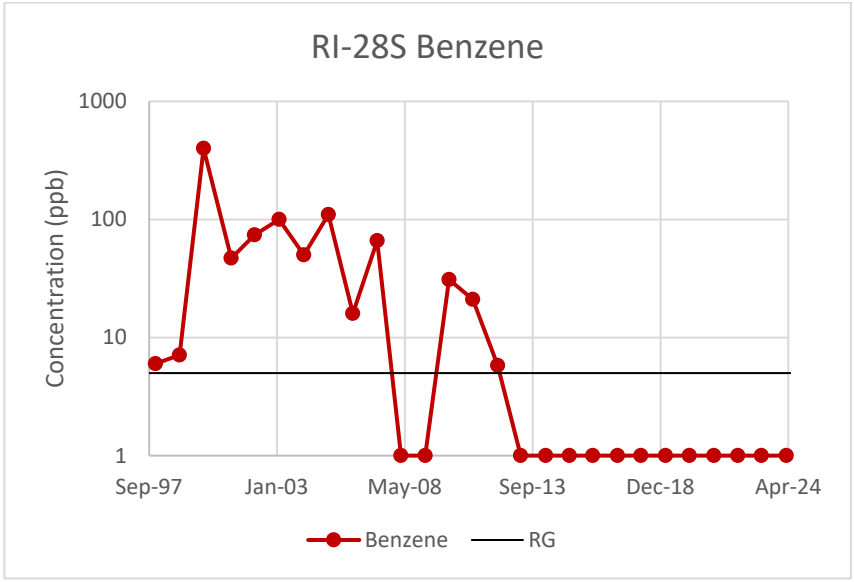



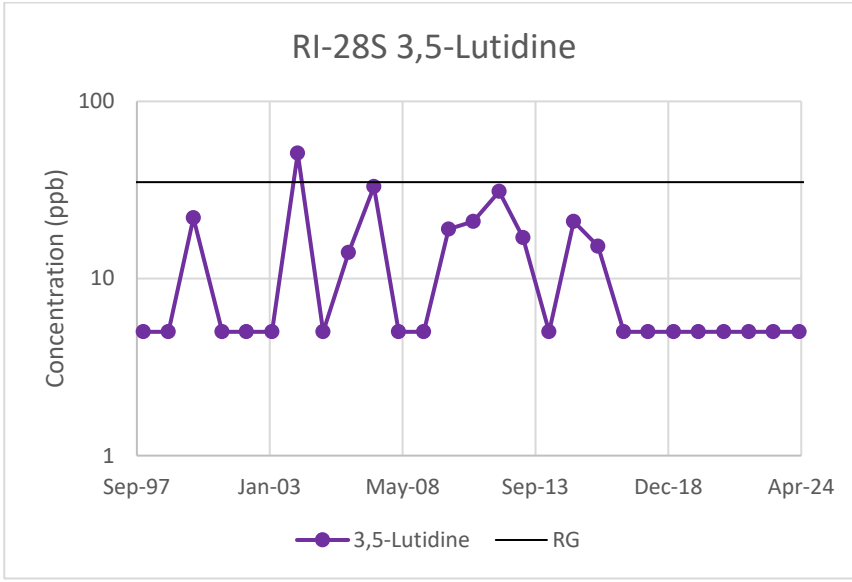



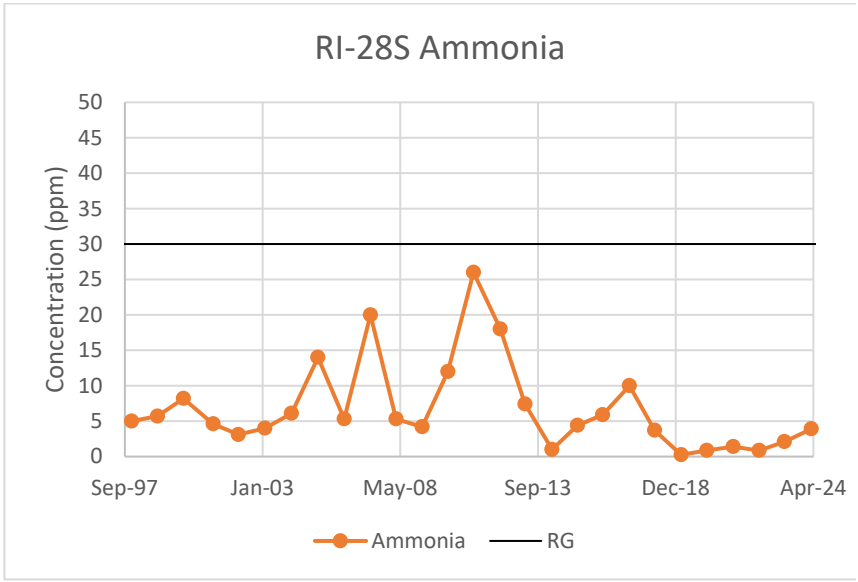



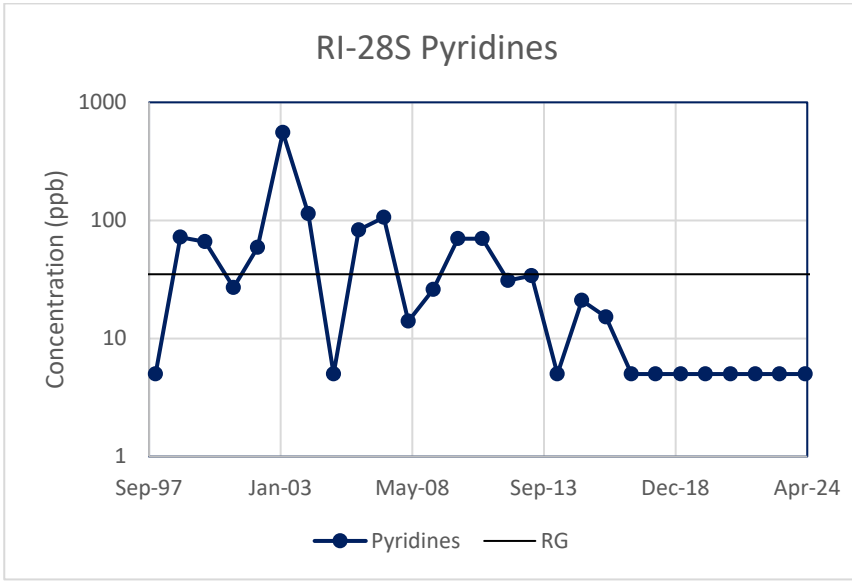
**OU1 WELLS**
**RI-28S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



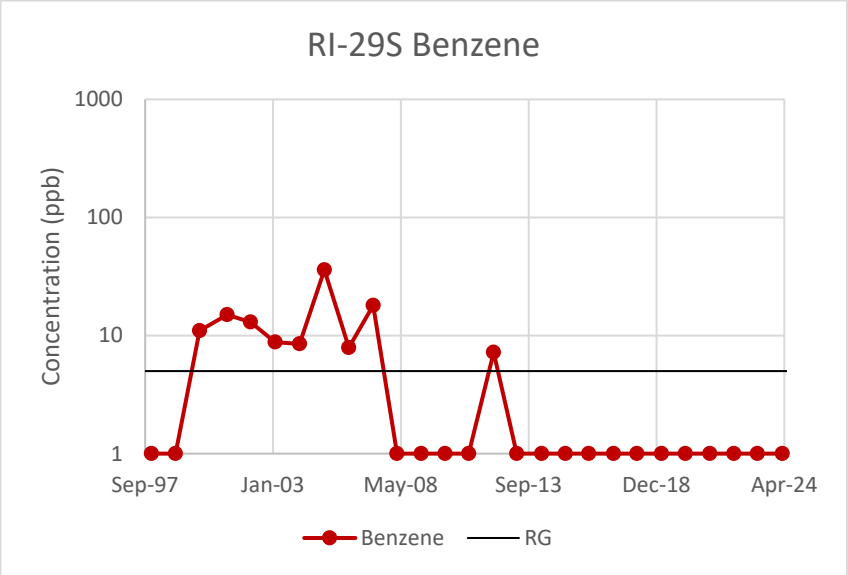



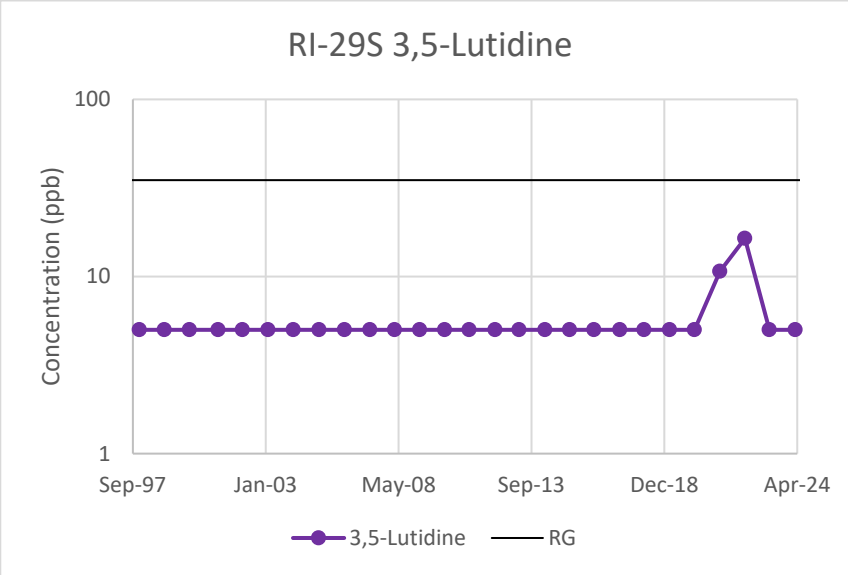



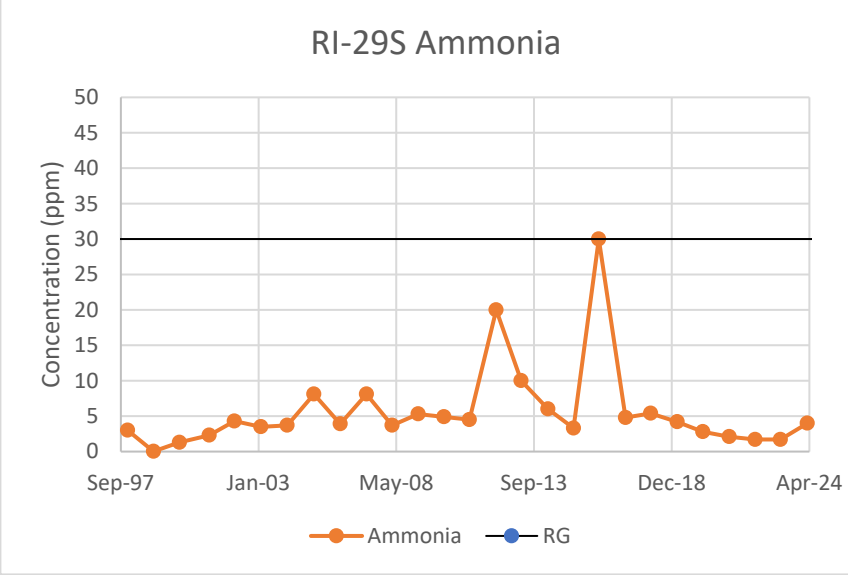



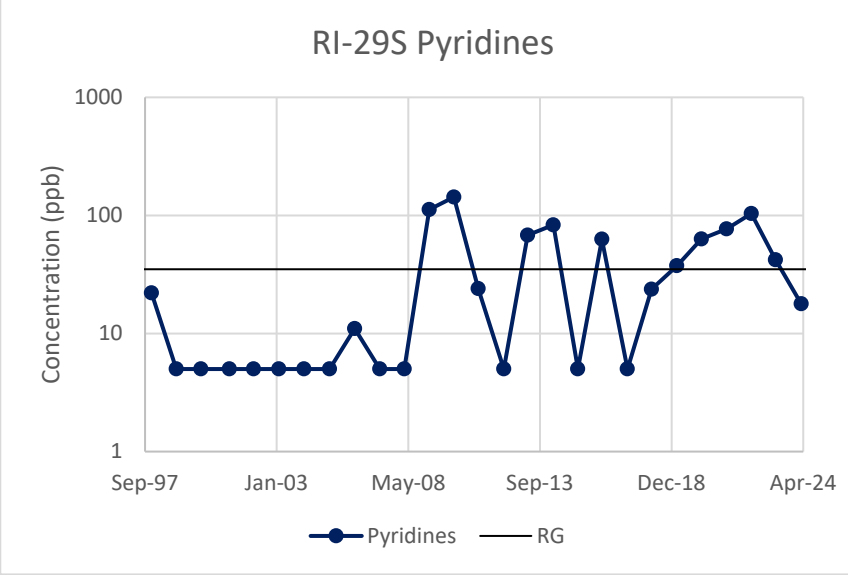
**OU1 WELLS**
**RI-29S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



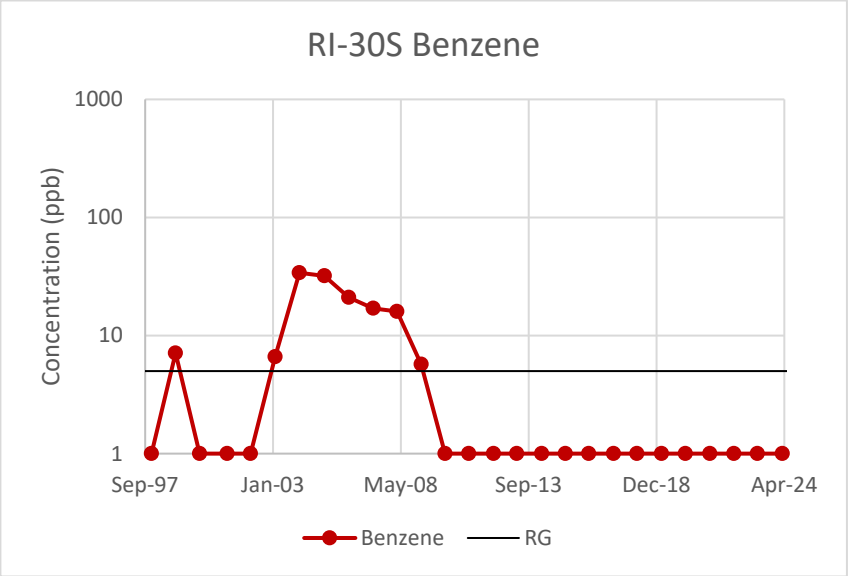



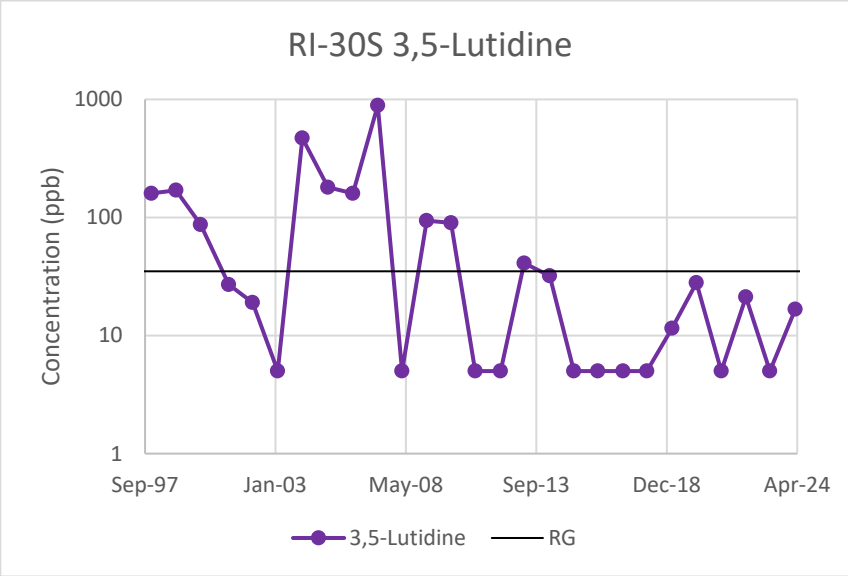



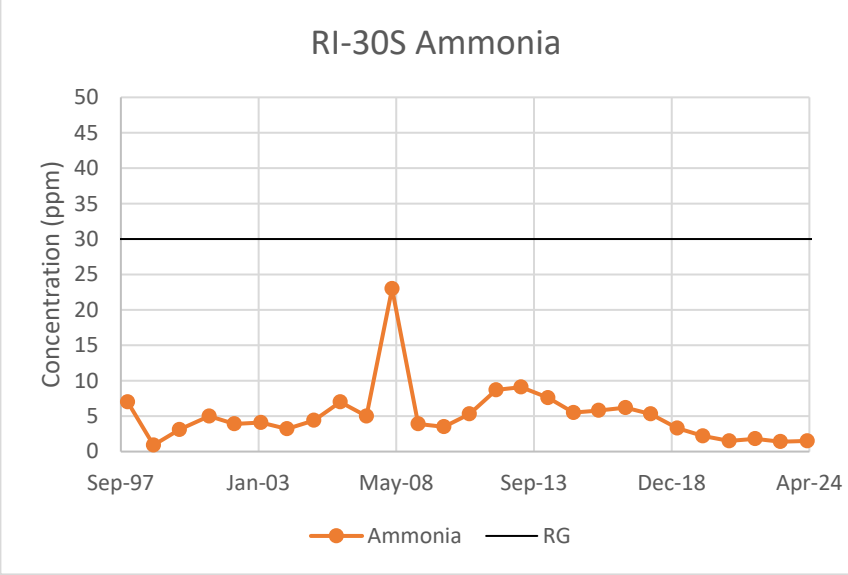



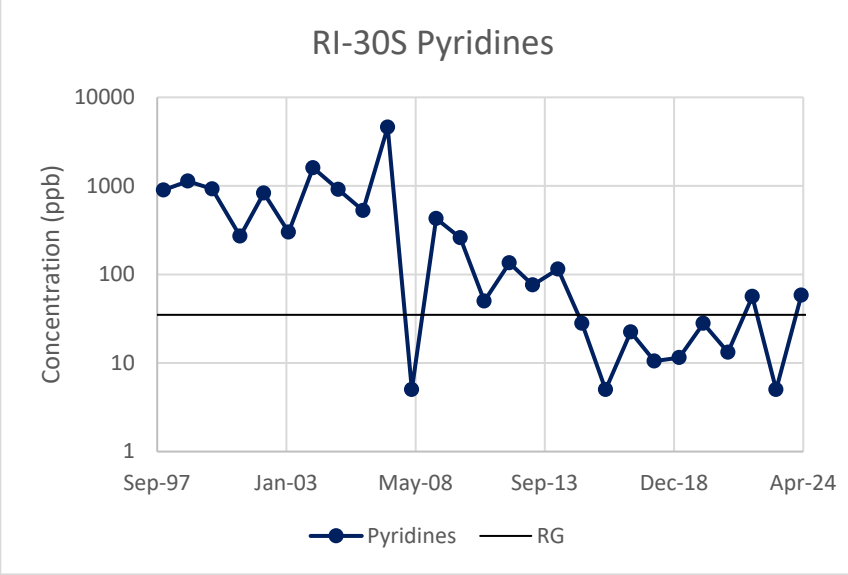
**OU1 WELLS**
**RI-30S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



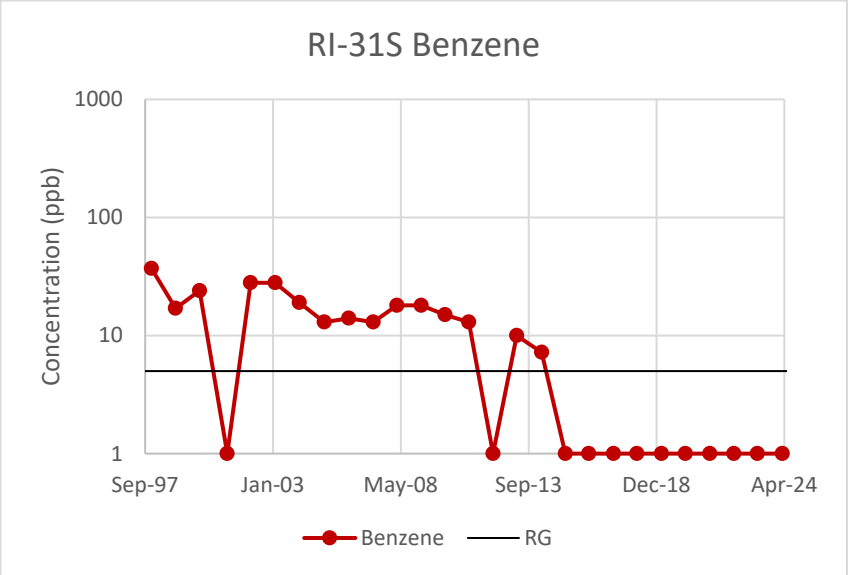



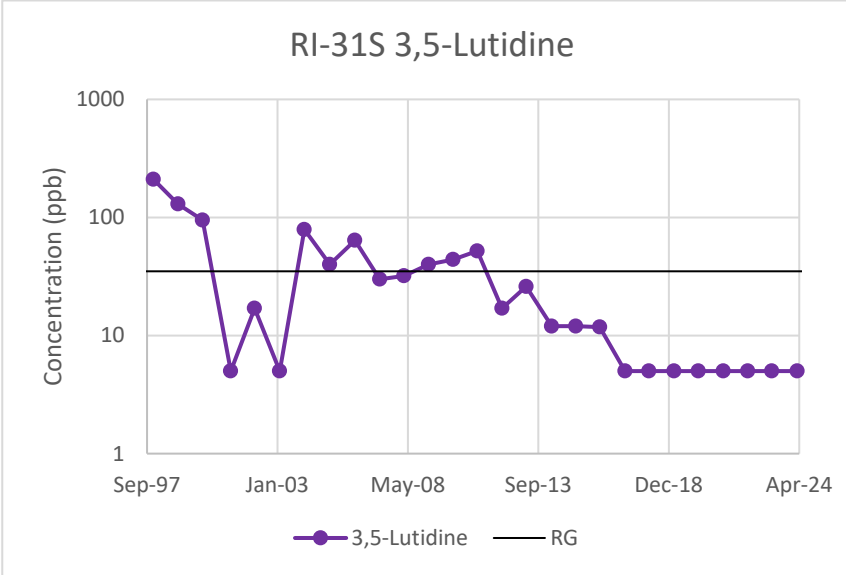



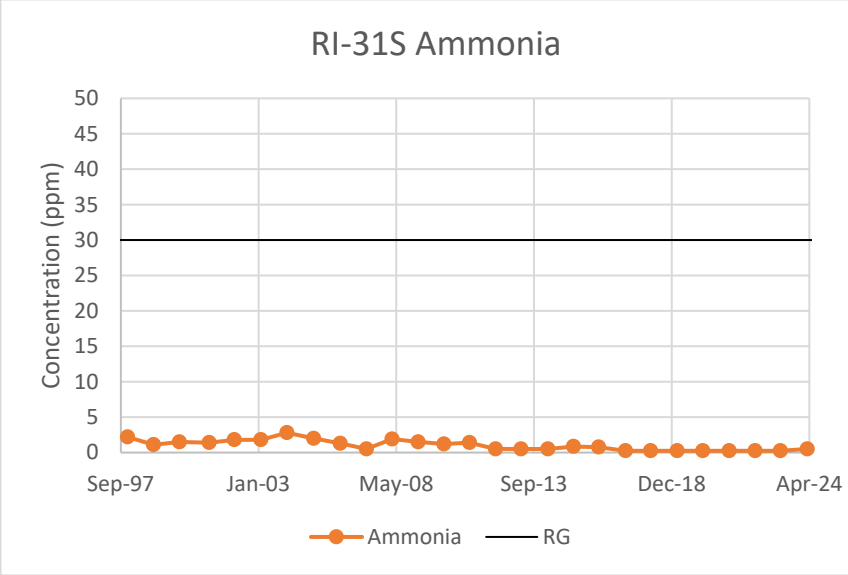



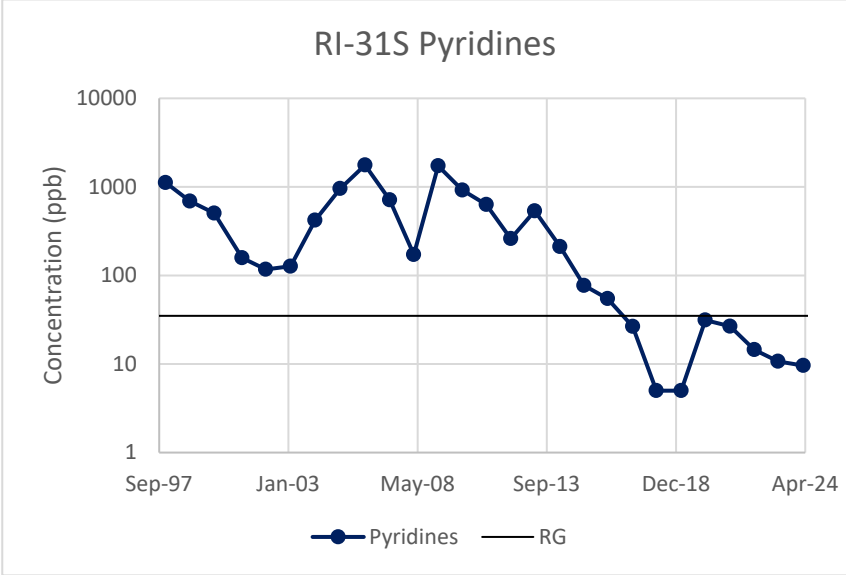
**OU1 WELLS**
**RI-31S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



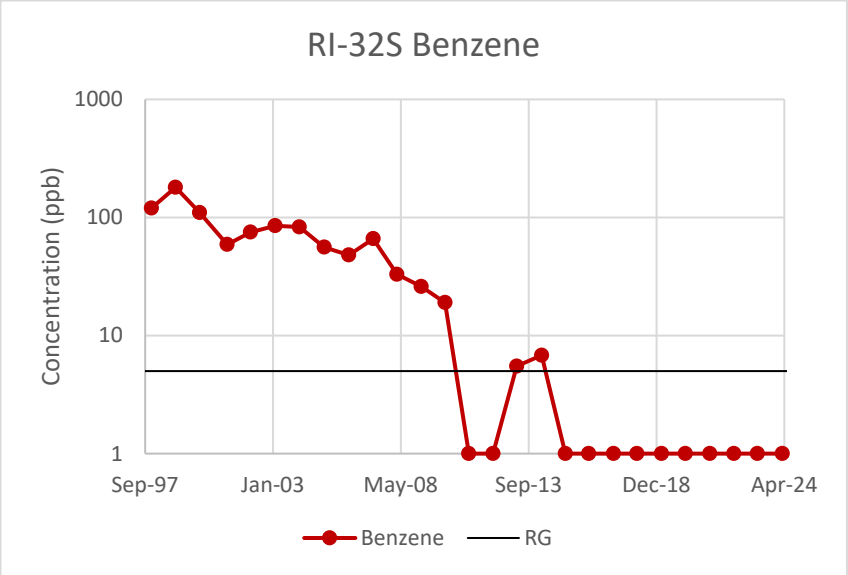



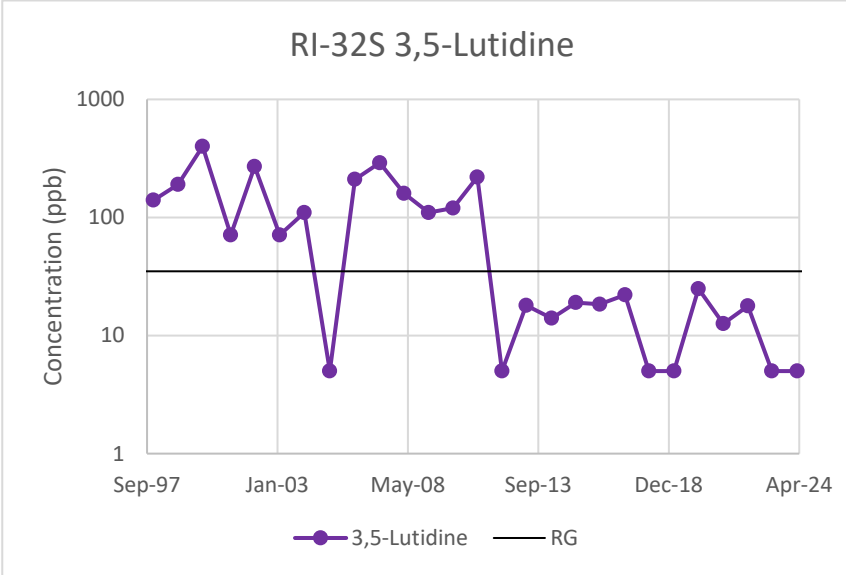



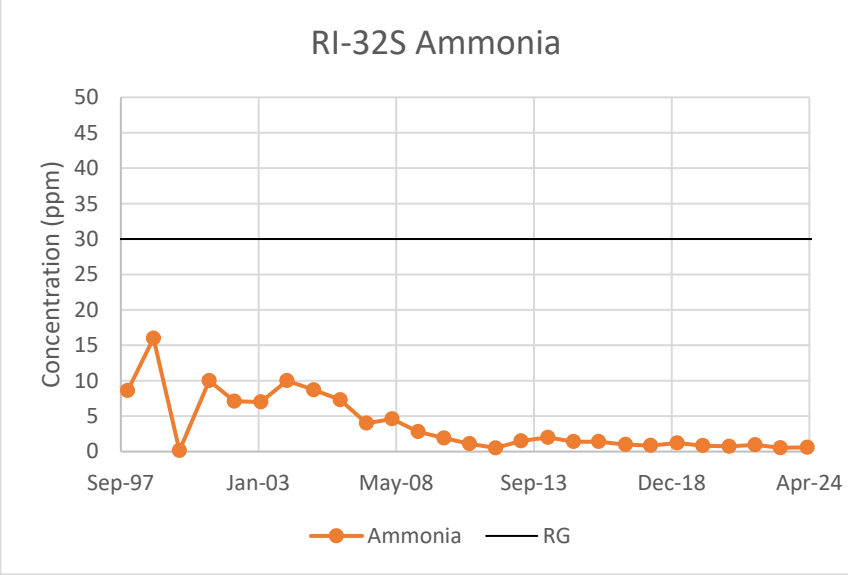



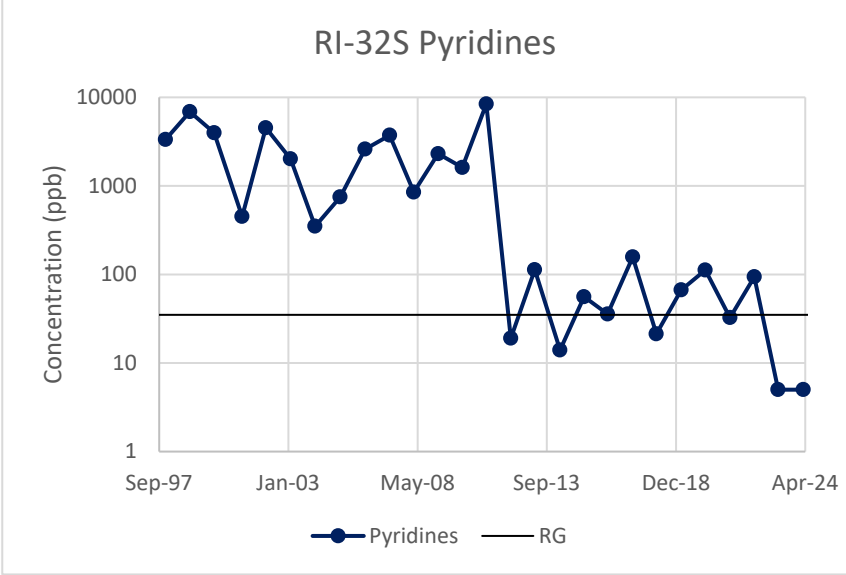
**OU1 WELLS**
**RI-32S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



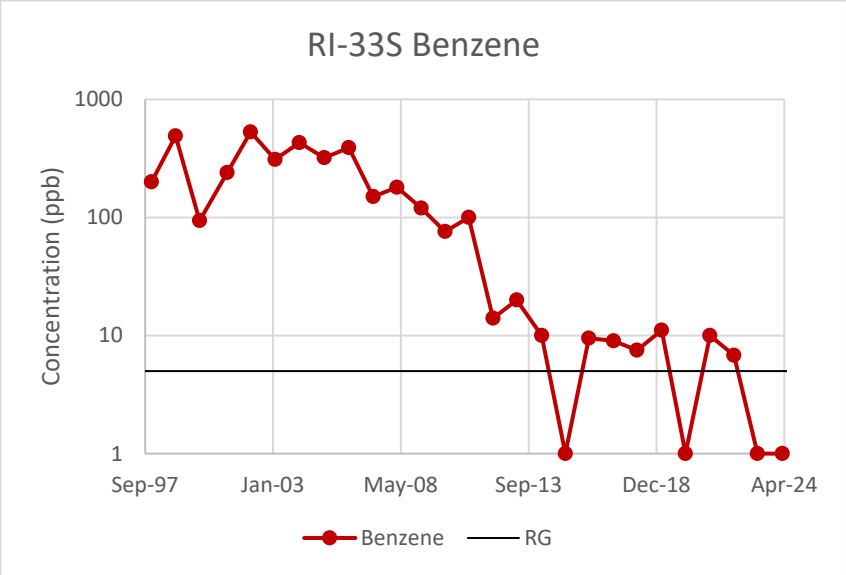



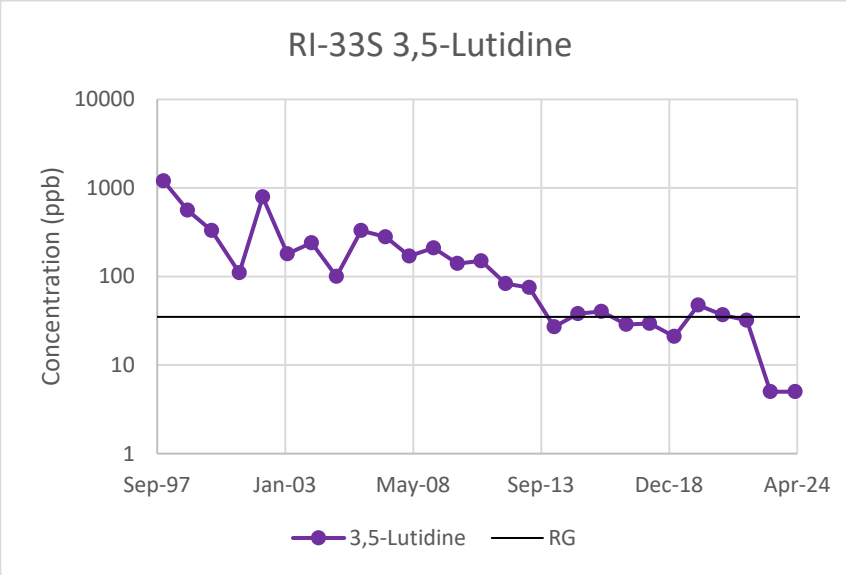



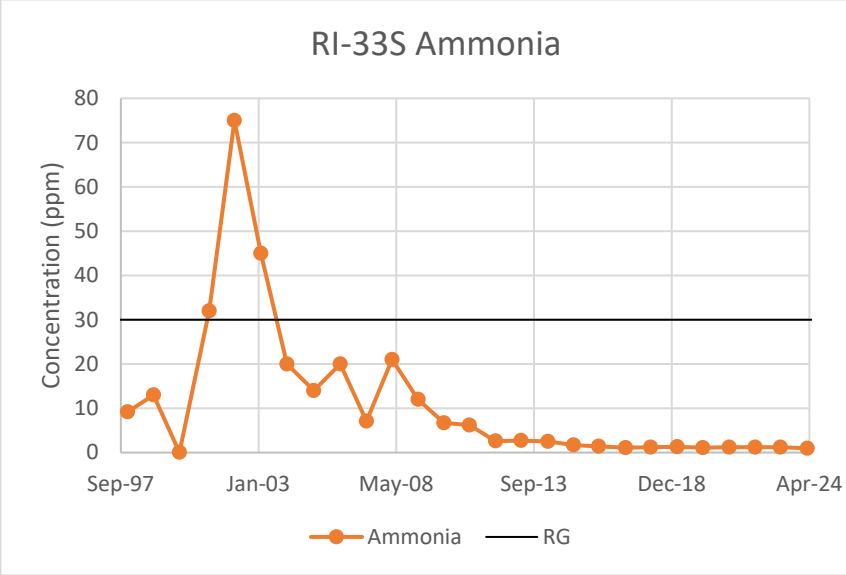



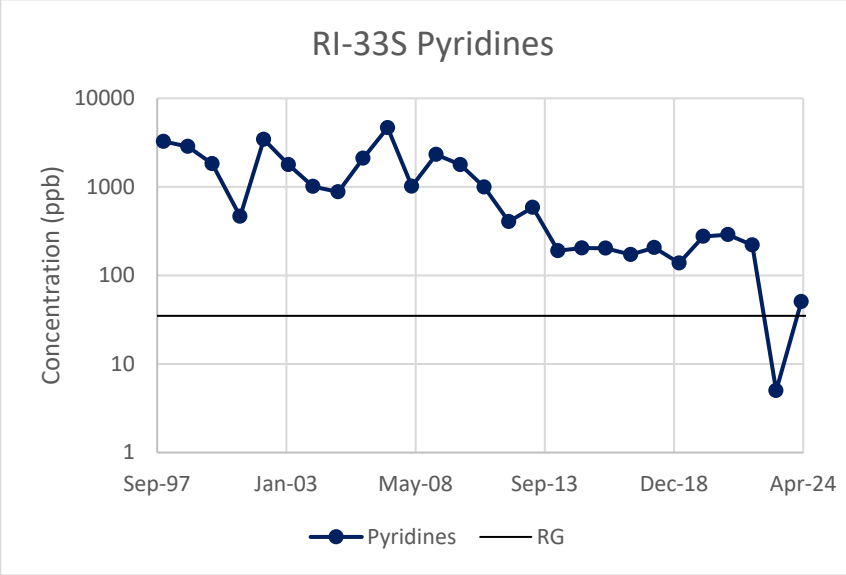
**OU1 WELLS**
**RI-33S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



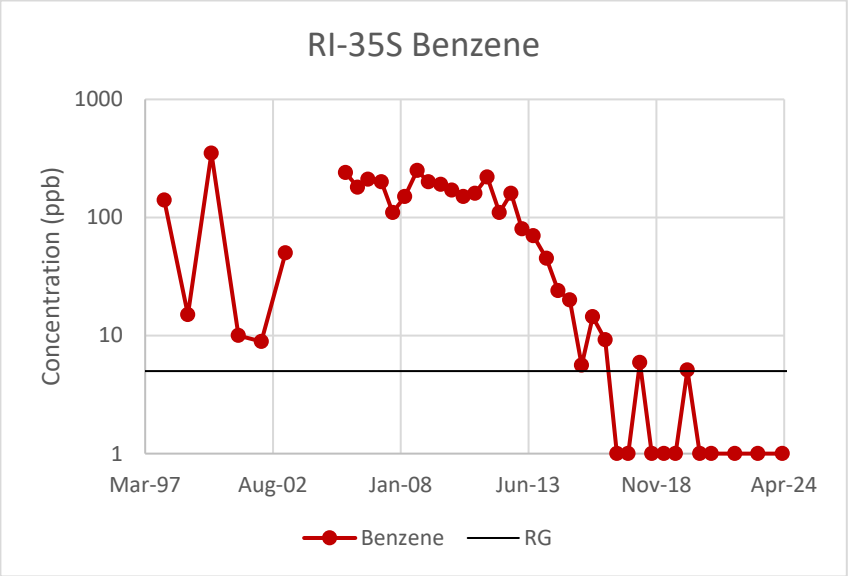



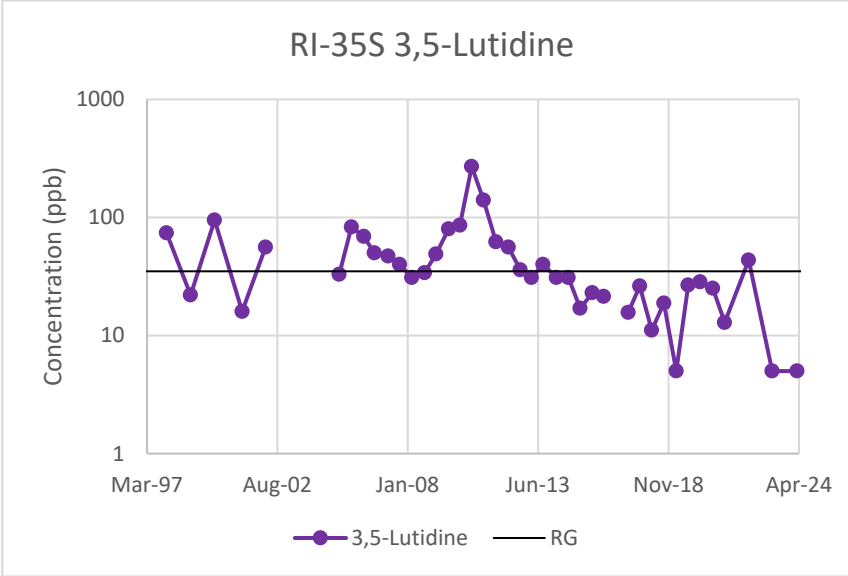



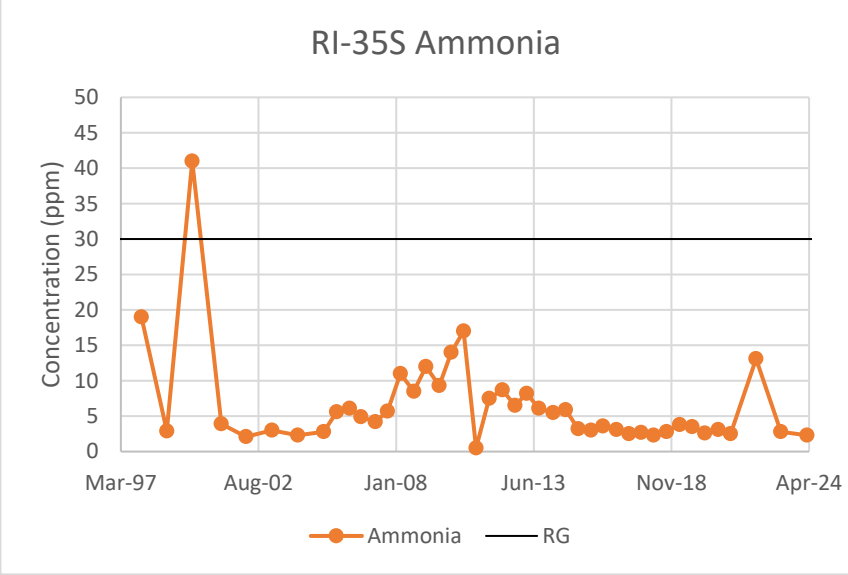



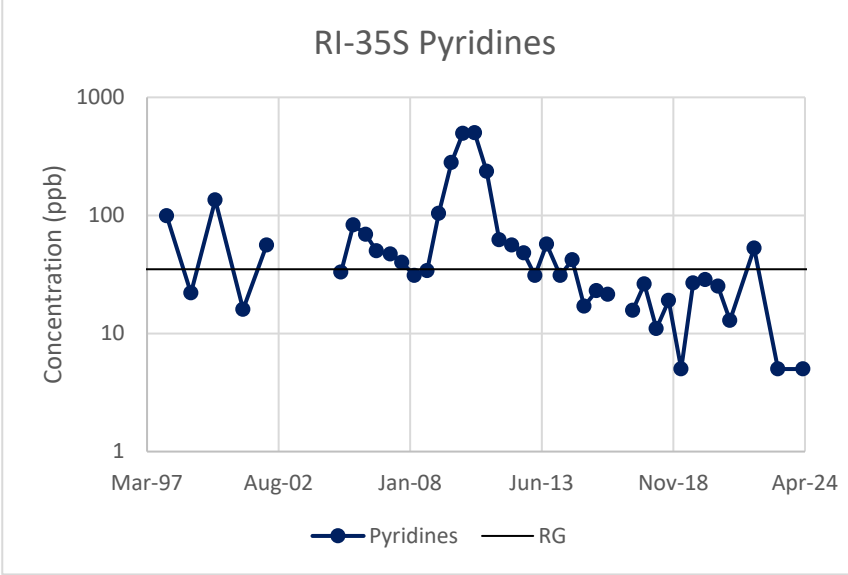
**OU1 WELLS**
**RI-35S GRAPHICAL ANALYSIS**

Note: Benzene and pyridine levels decreased to below the RGs following sparging in the former treatment pit (FTP) area.



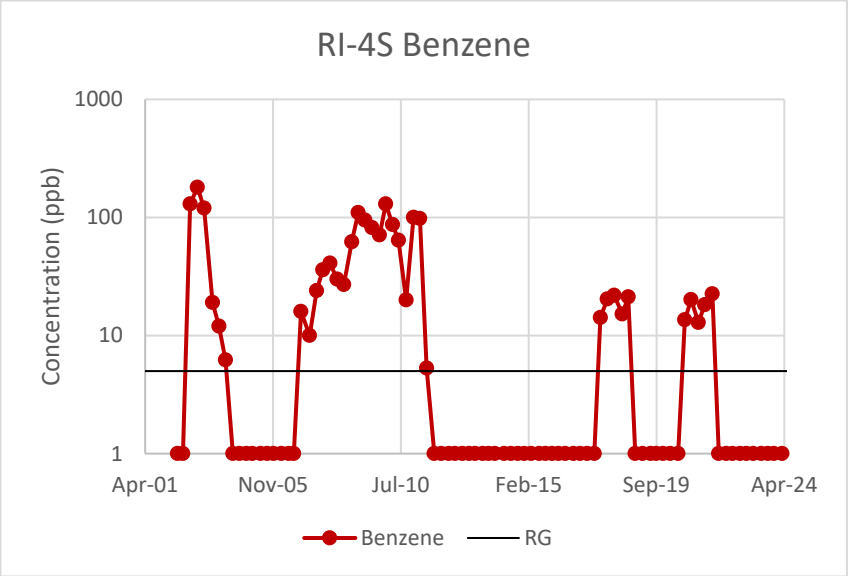



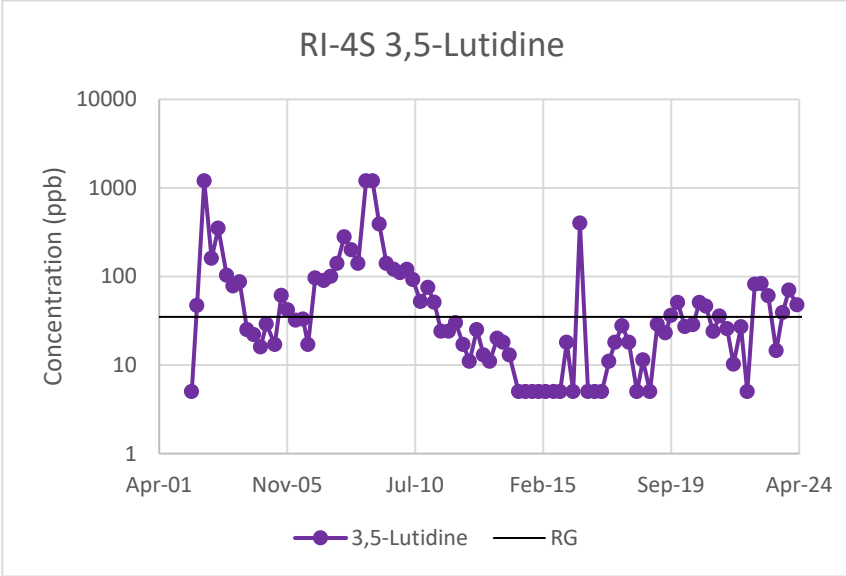



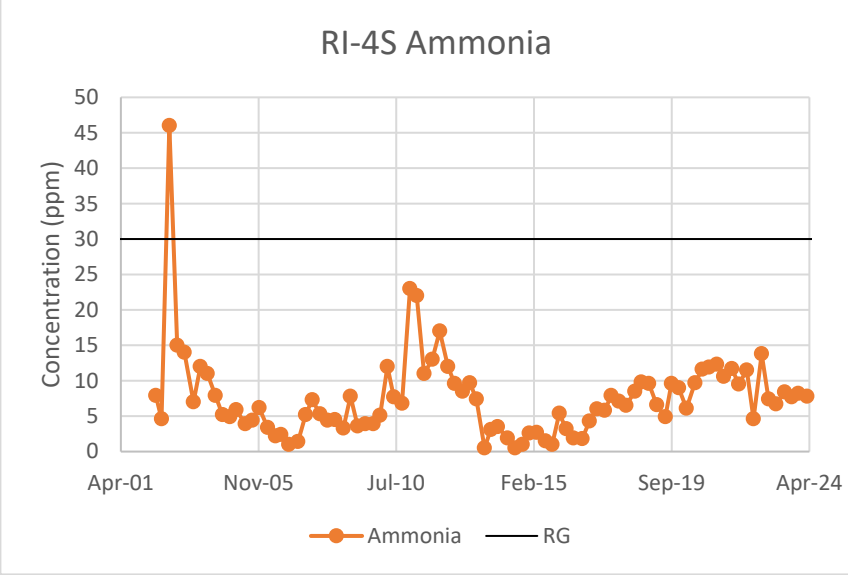



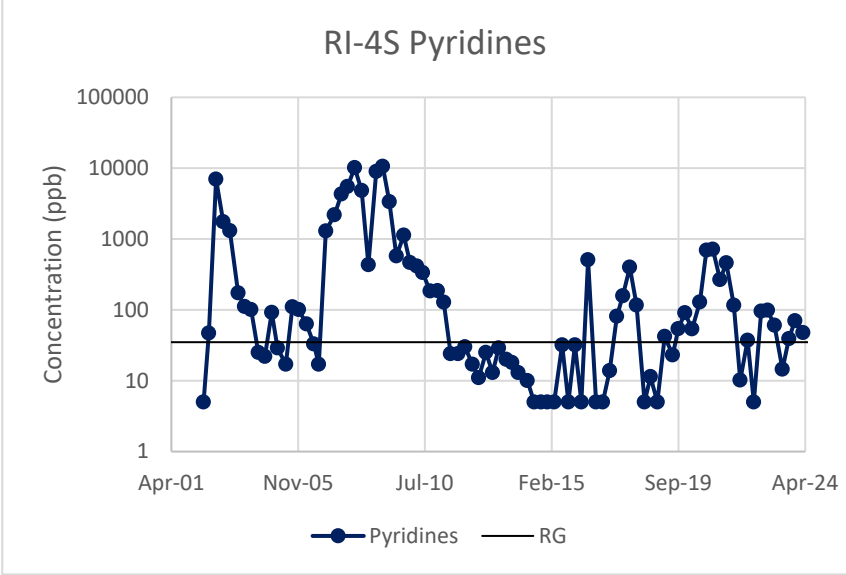
**OU1 PERIMETER WELLS**
**RI-4S GRAPHICAL ANALYSIS**

Note: Benzene and ammonia are below the RGs. Pyridines are above the RG.



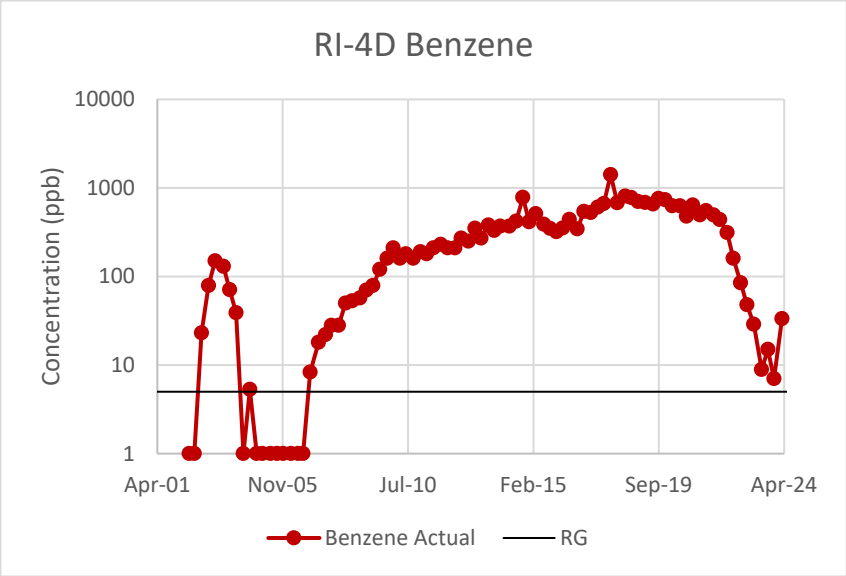



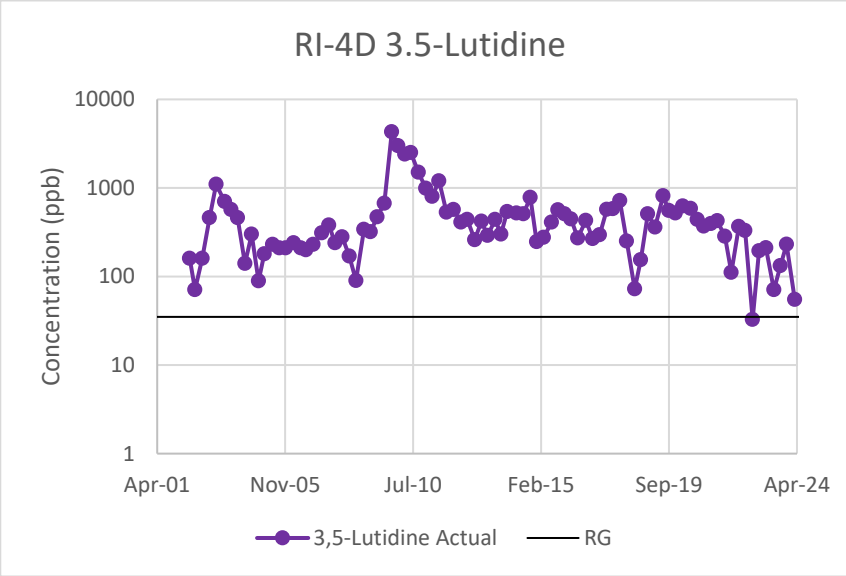



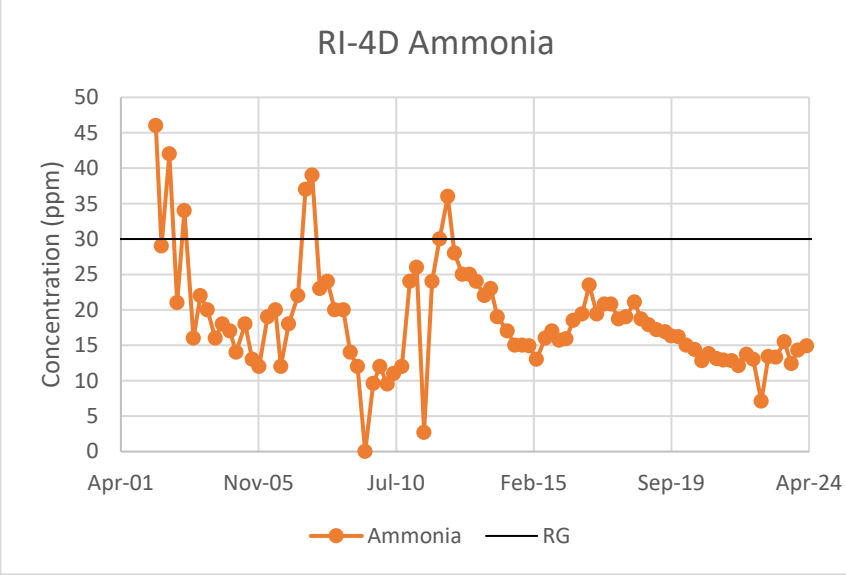



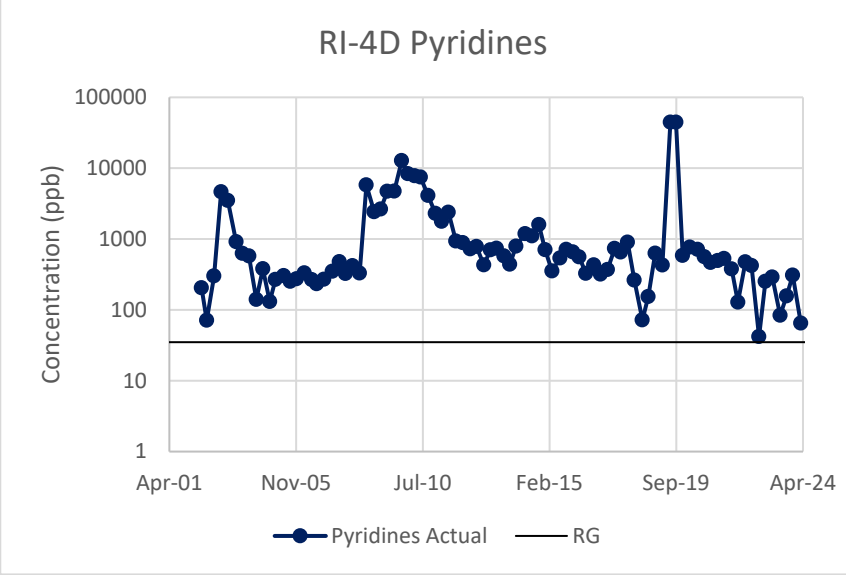
**OU1 PERIMETER WELLS**
**RI-4D GRAPHICAL ANALYSIS**

Note: Benzene and pyridine levels are above the RGs. Ammonia is below the RG.



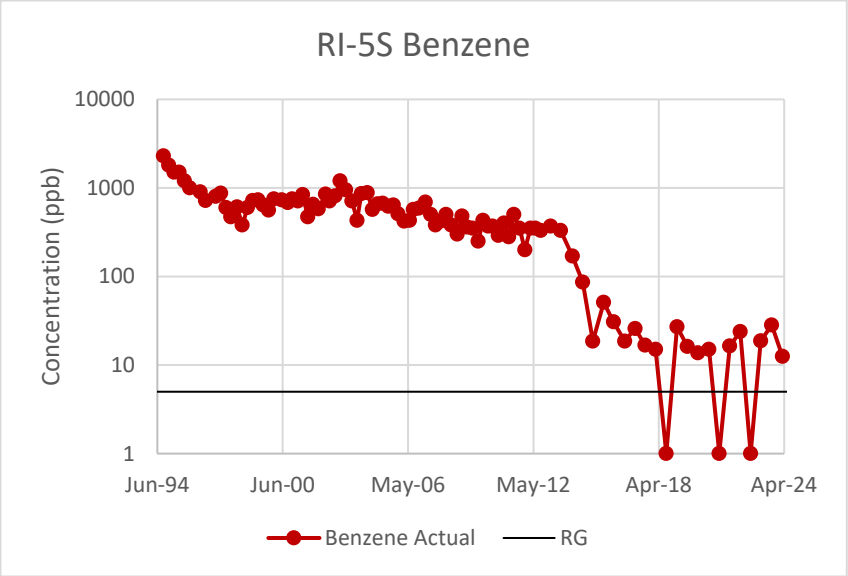



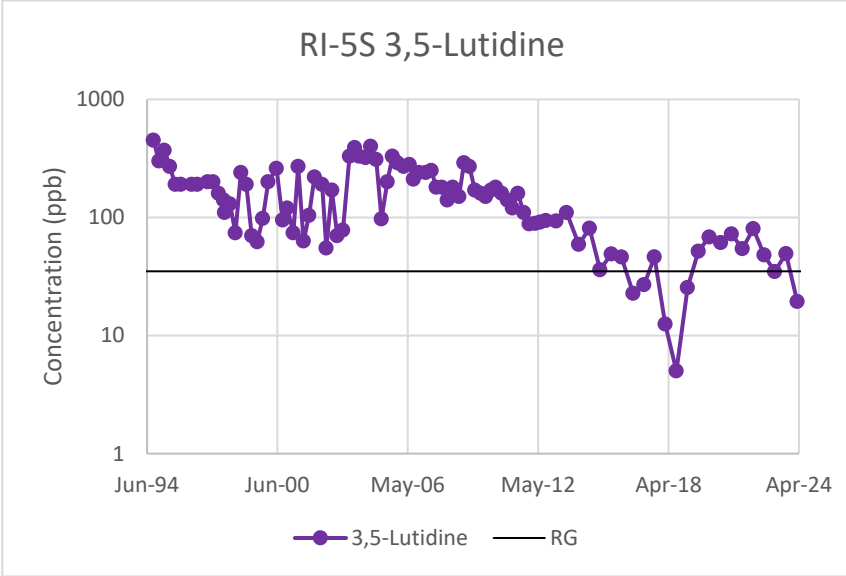



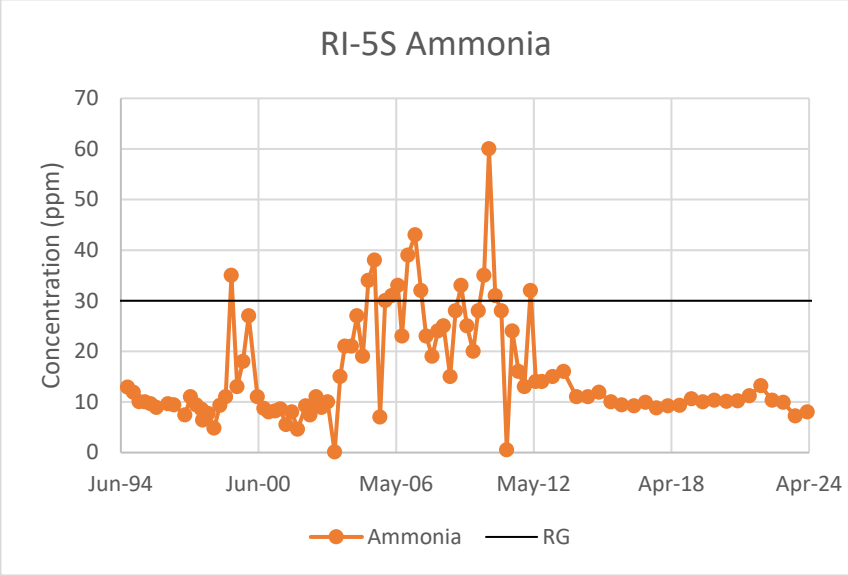



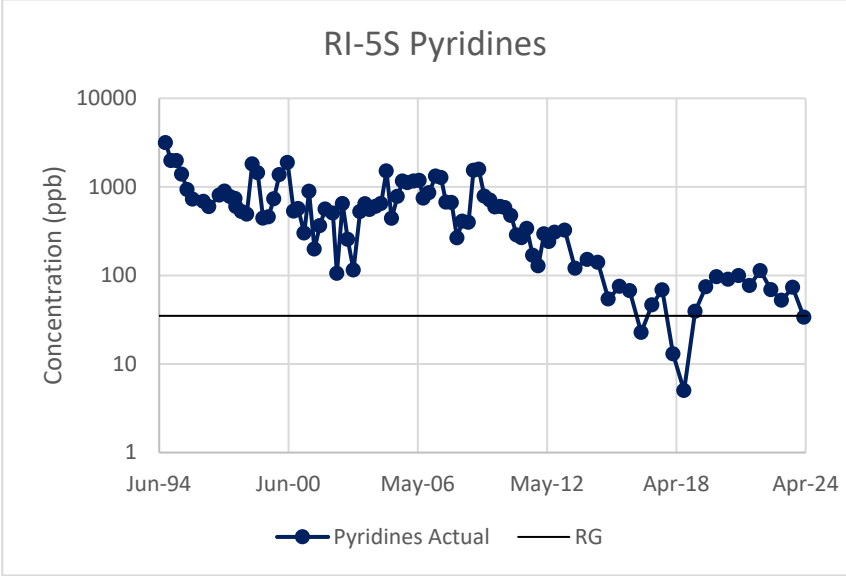
**OU1 PERIMETER WELLS**
**RI-5S GRAPHICAL ANALYSIS**

Note: Benzene and pyridine levels substantially decreased after sparging in this area. Ammonia is below the RG.



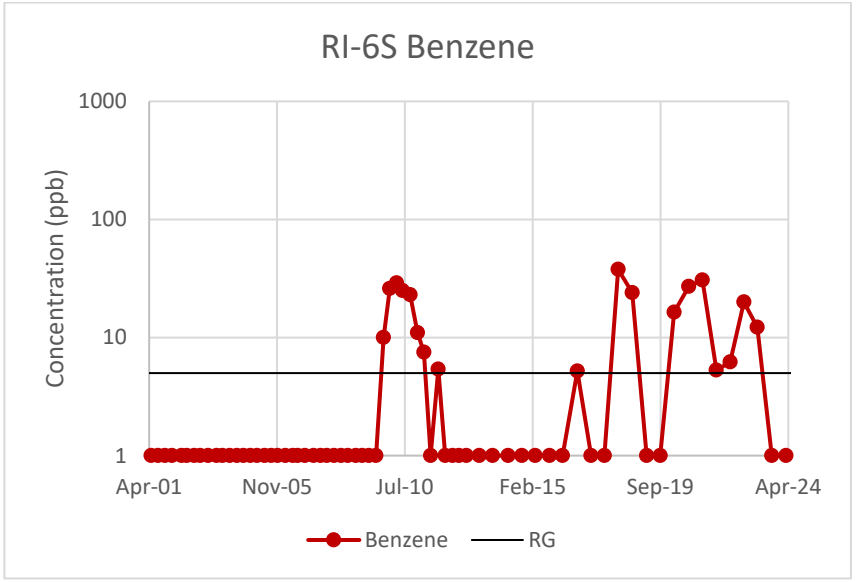



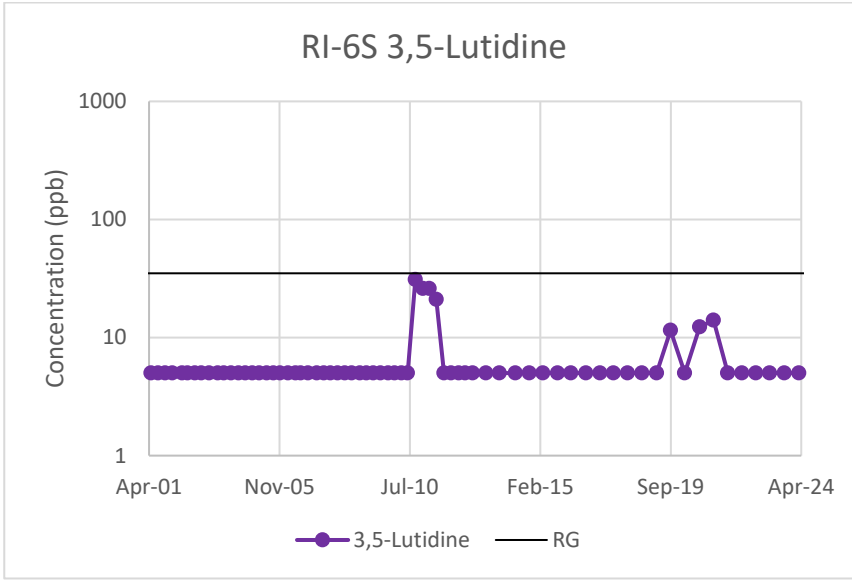



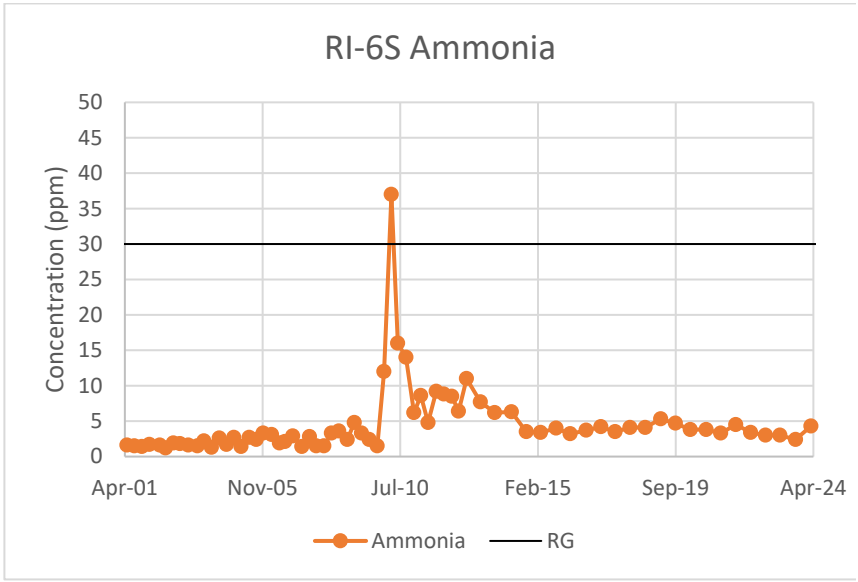



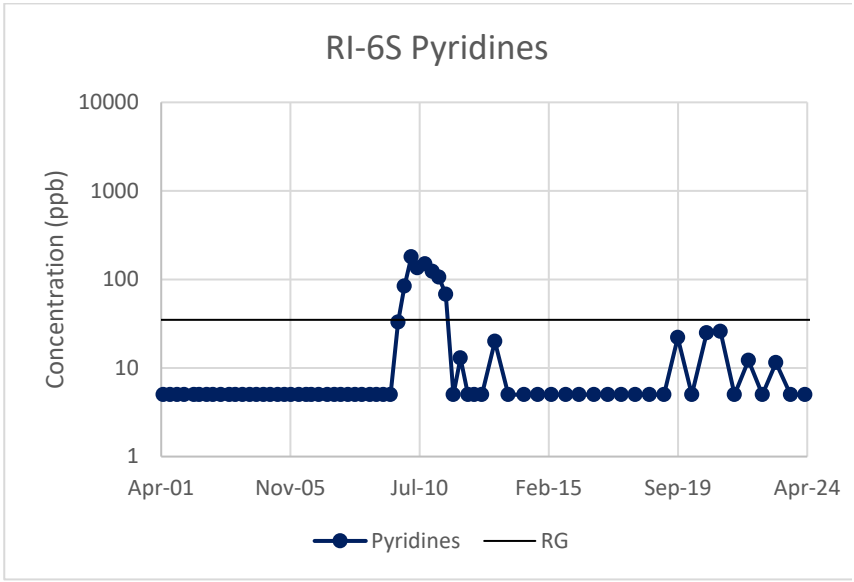
**OU1 PERIMETER WELLS**
**RI-6S GRAPHICAL ANALYSIS**

Note: Ammonia and pyridine levels are below the RGs; benzene increased above the RG.



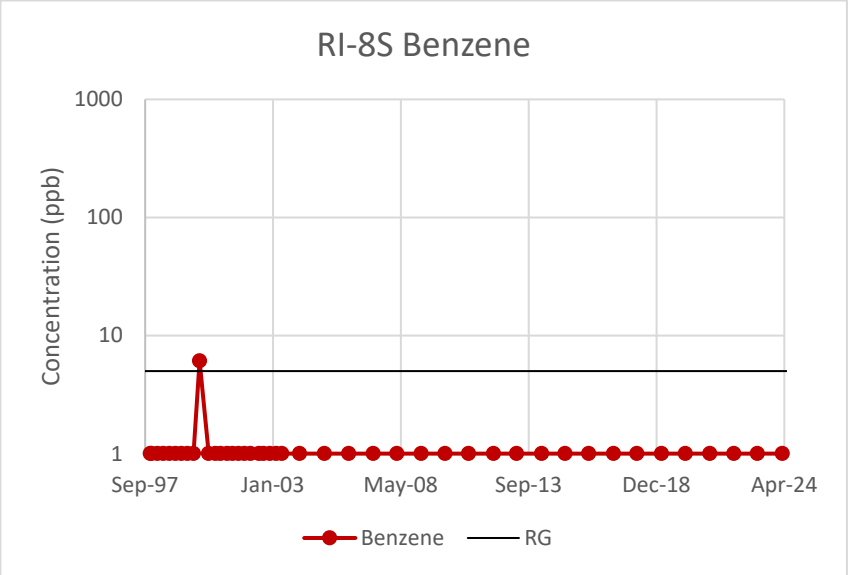



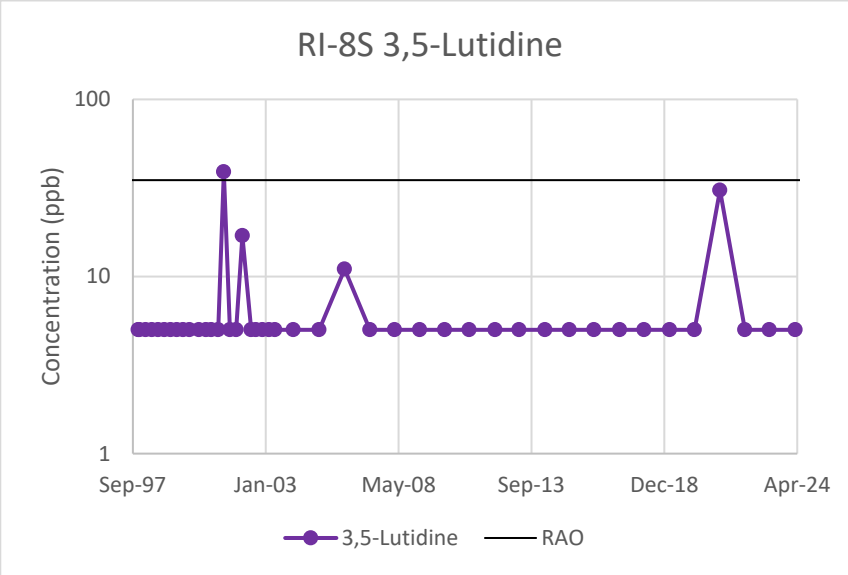



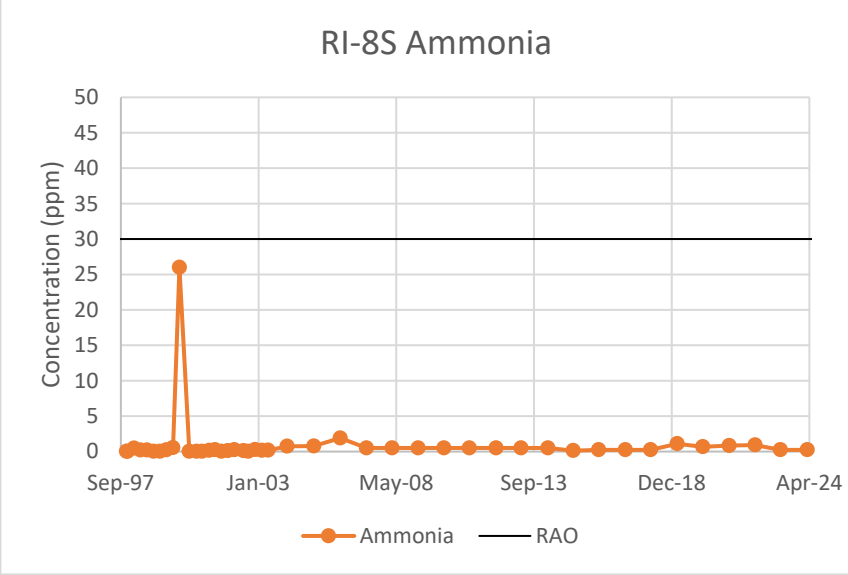



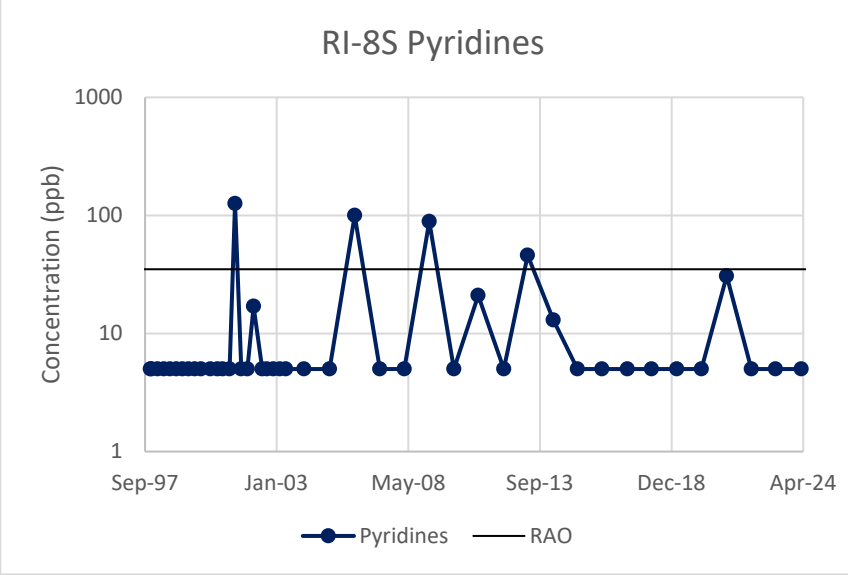
**OU1 PERIMETER WELLS**
**RI-8S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



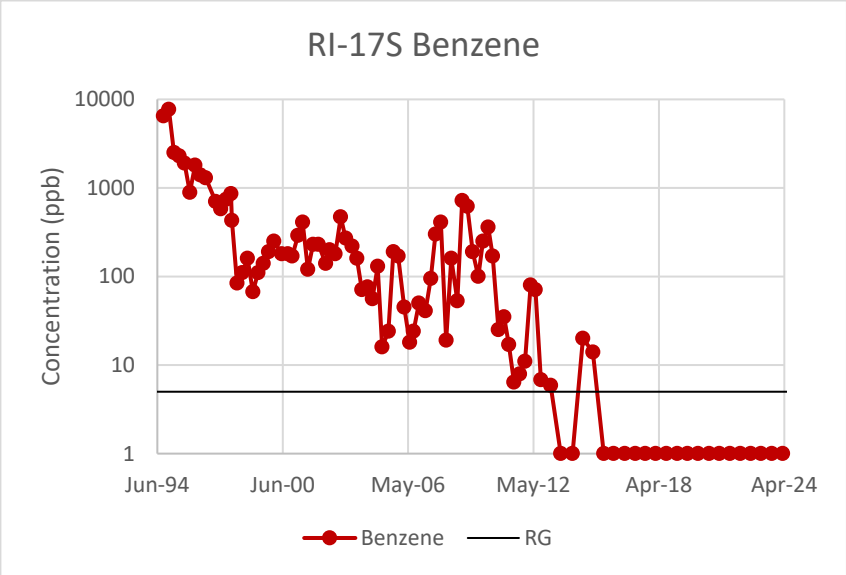



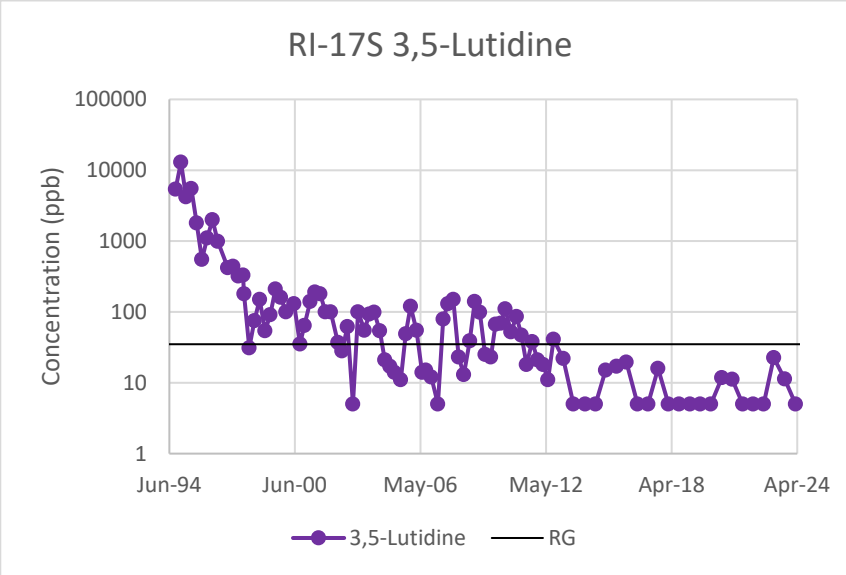



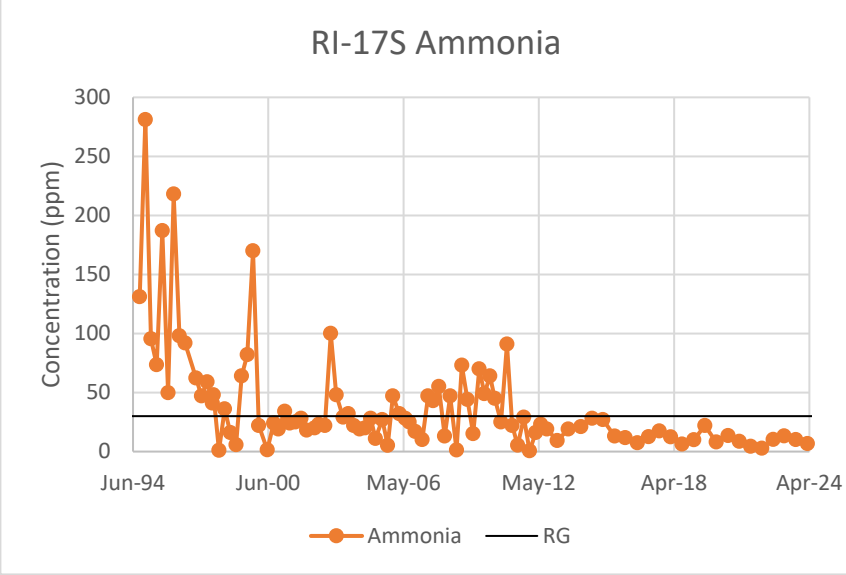



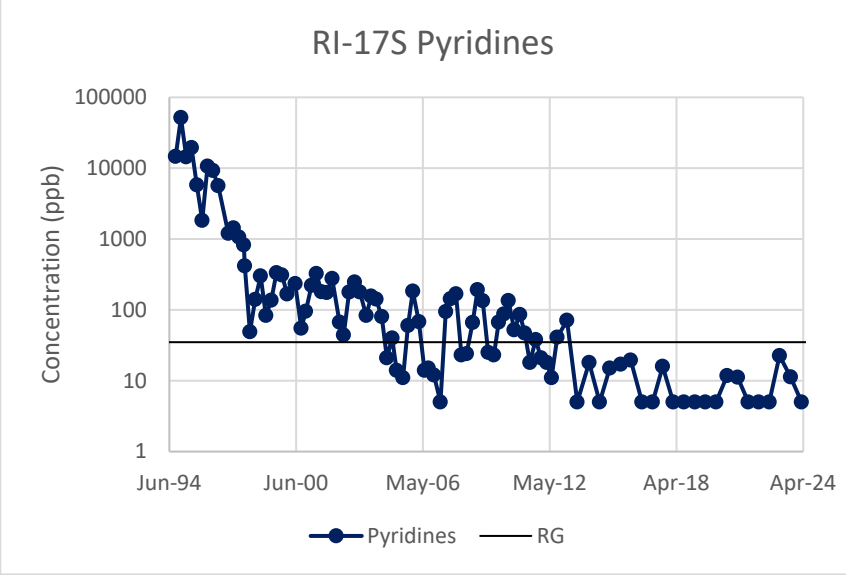
**OU1 PERIMETER WELLS**
**RI-17S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



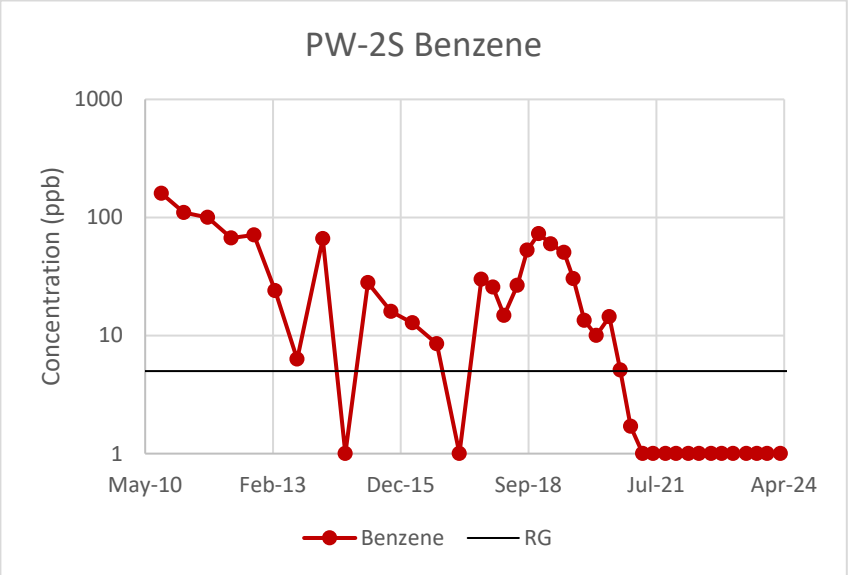



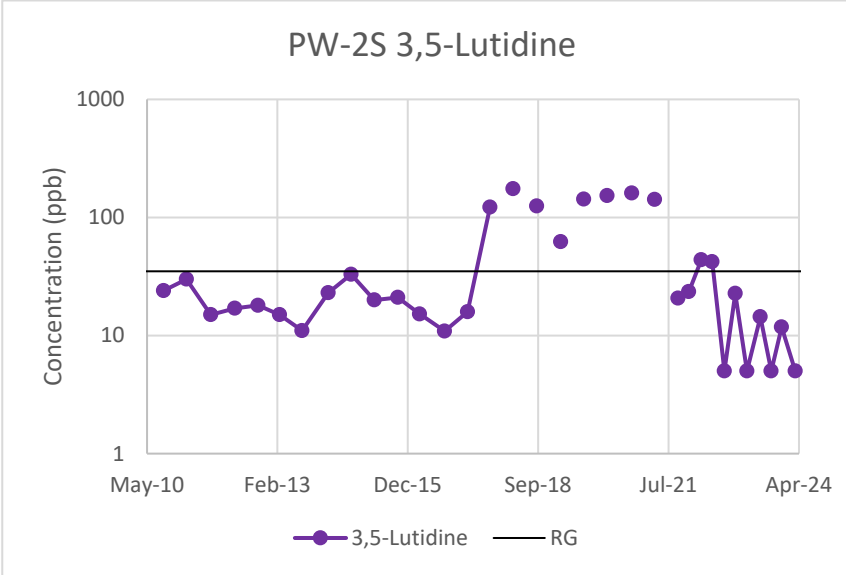



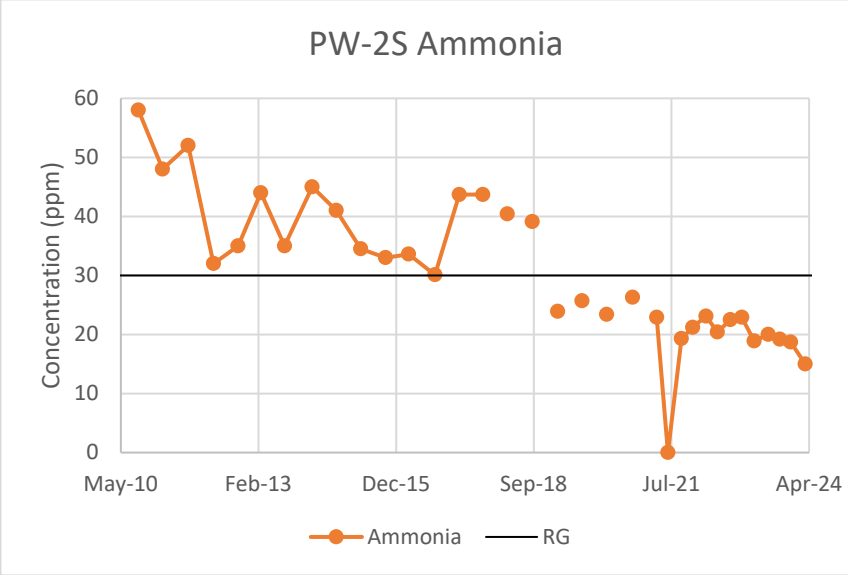



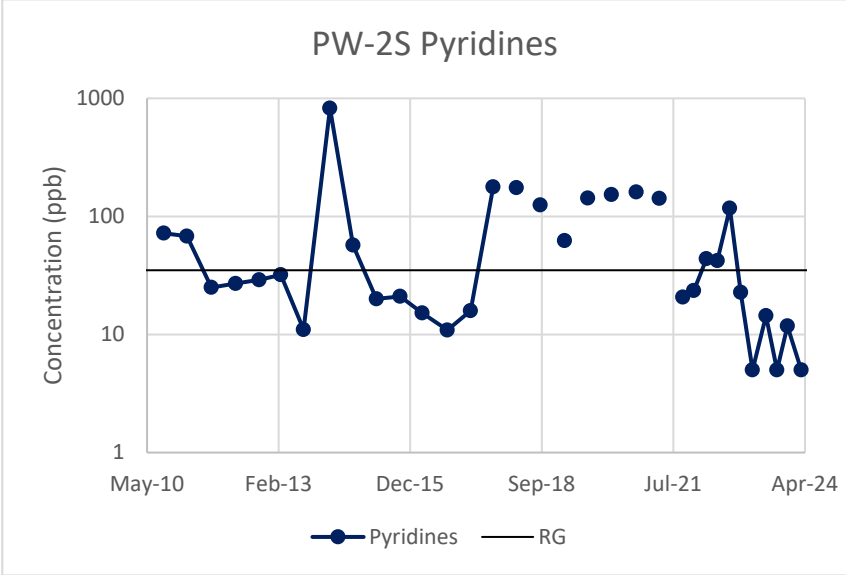
**OU1 PERIMETER WELLS**
**PW-2S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



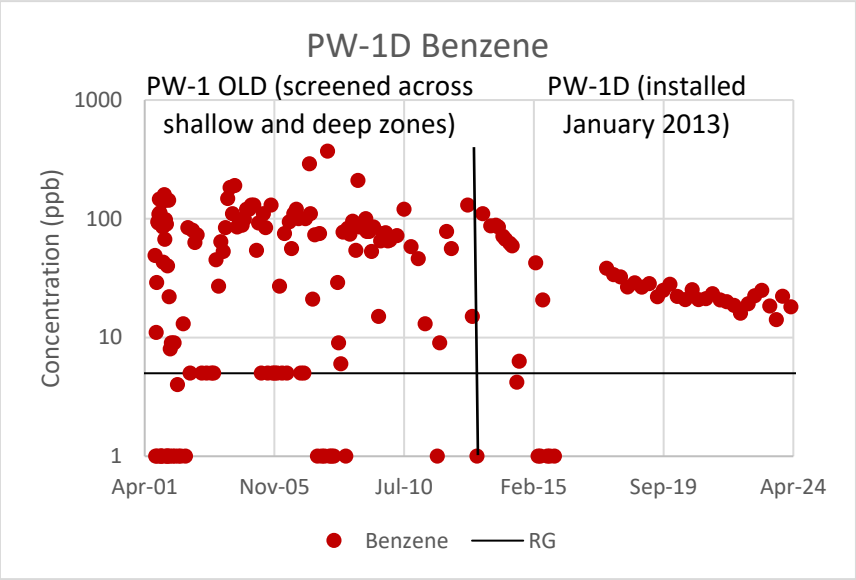



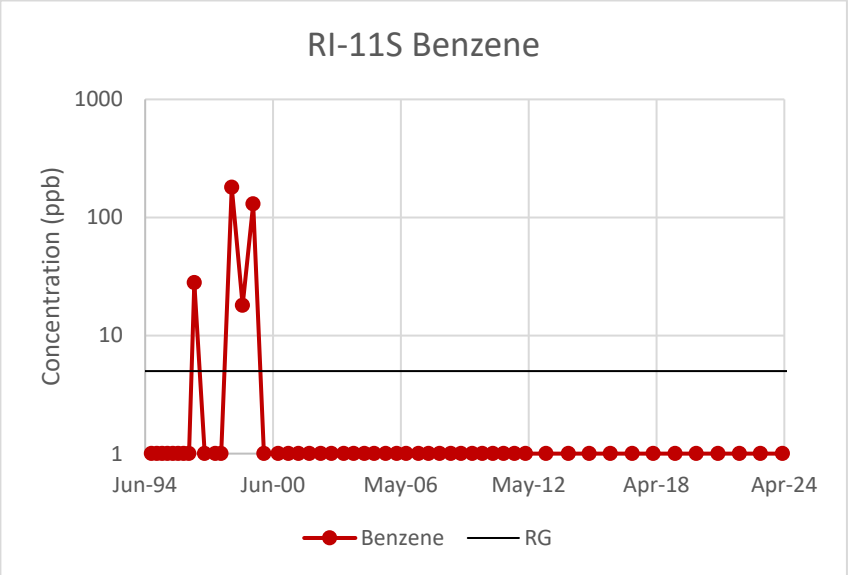
# OU1 PERIMETER WELLS
# PW-1D GRAPHICAL ANALYSIS

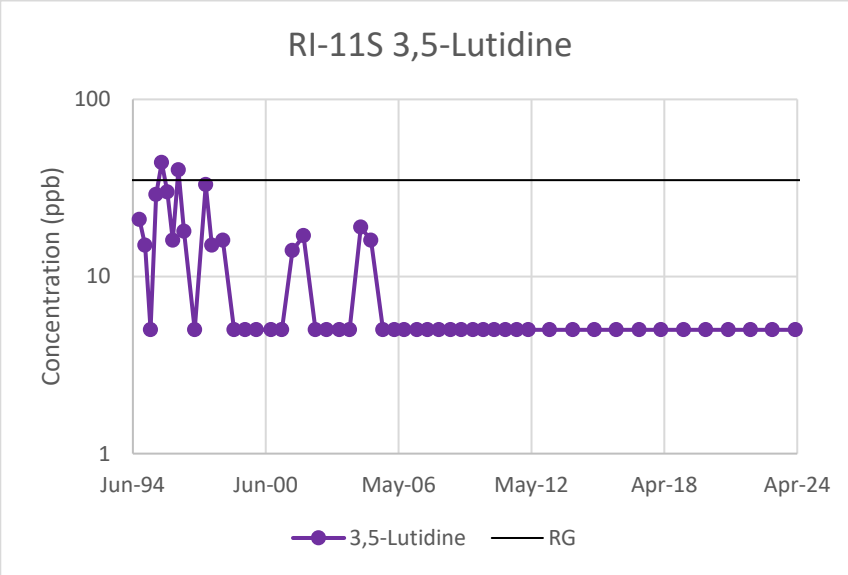
Note: Benzene levels measured for discharge compliance only. PW-1 Old was screened across shallow and deep zones.
PW-1S and PW-1D were installed to replace PW-1 Old in January 2013. PW-1S has been non-detect and PW-1D concentrations are graphed.

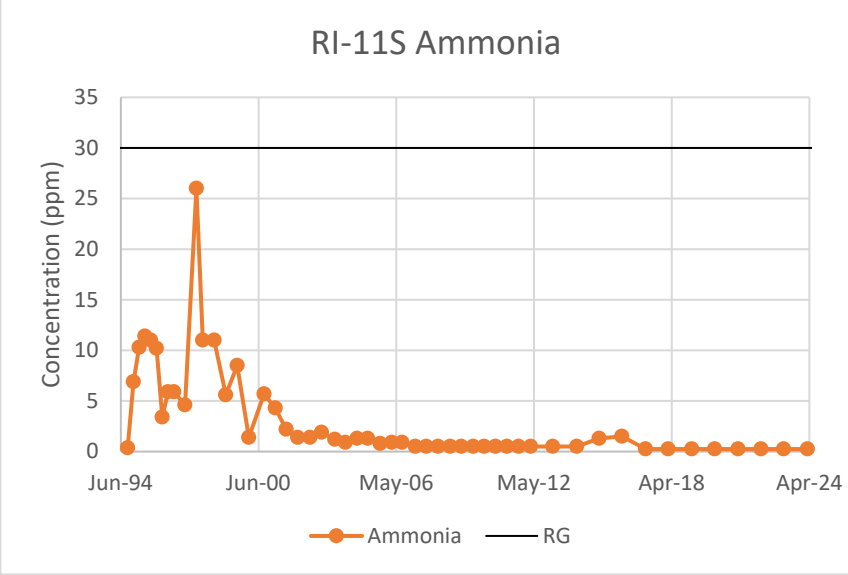


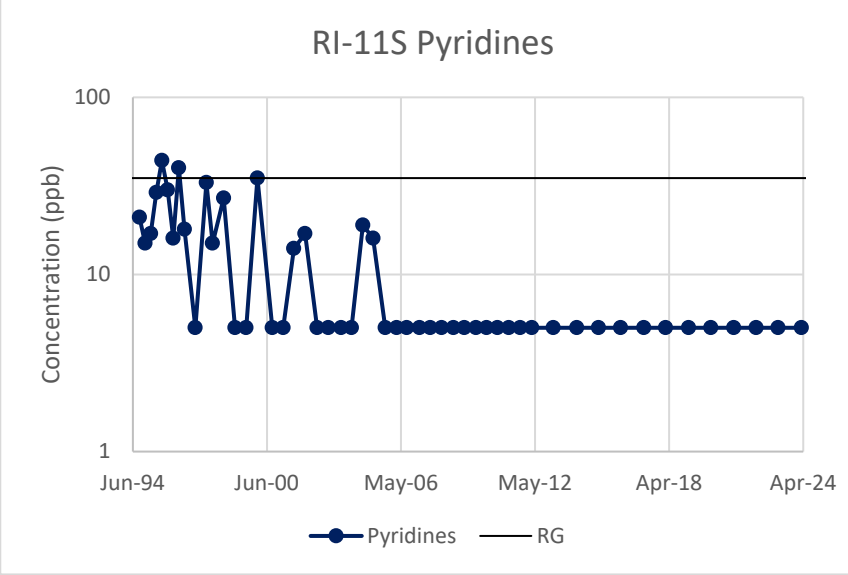
**OU5 WELLS**
**RI-11S GRAPHICAL ANALYSIS**

Note: Note: Benzene, pyridines, and ammonia levels are below the RGs.



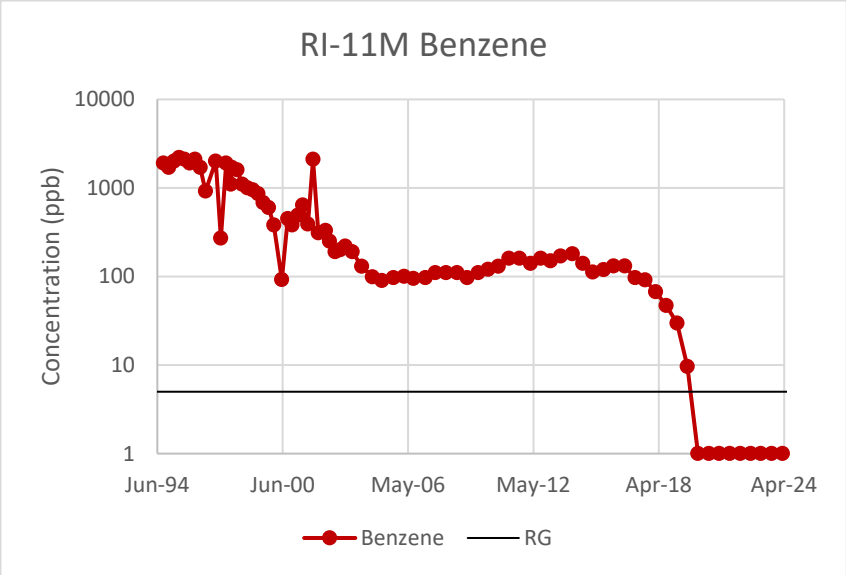



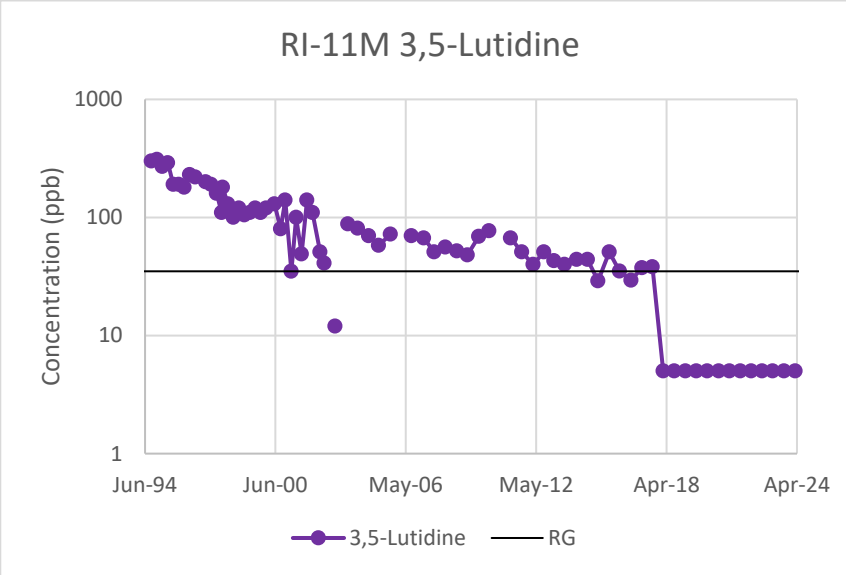



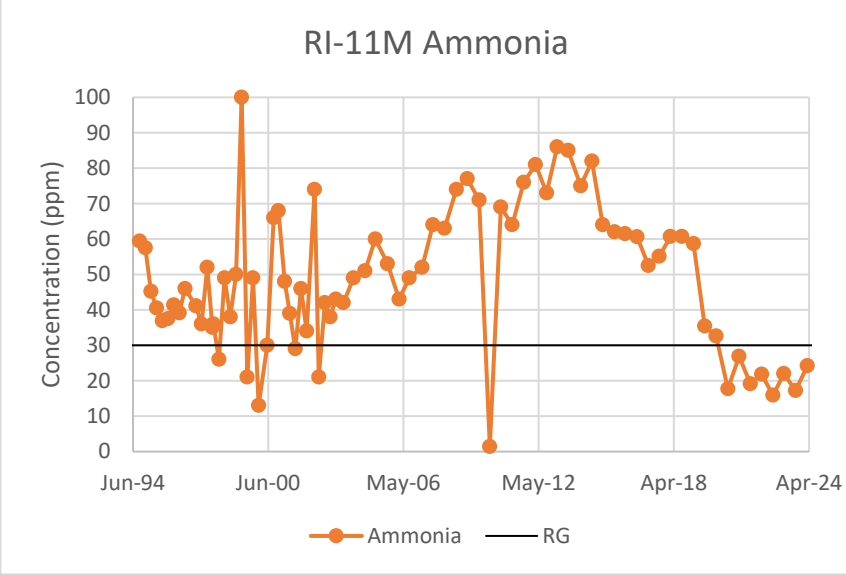



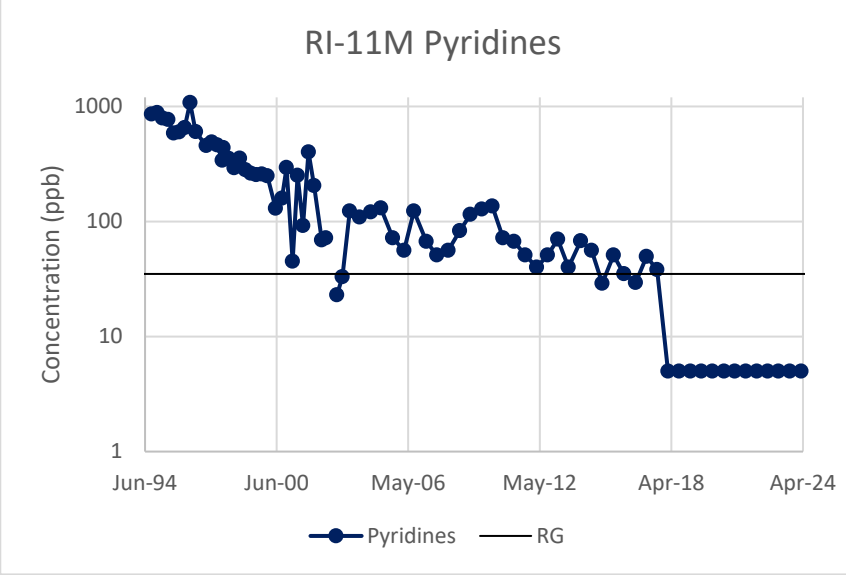
**OU5 WELLS**
**RI-11M GRAPHICAL ANALYSIS**

Note: Note: Benzene, pyridines, and ammonia levels are below the RGs.



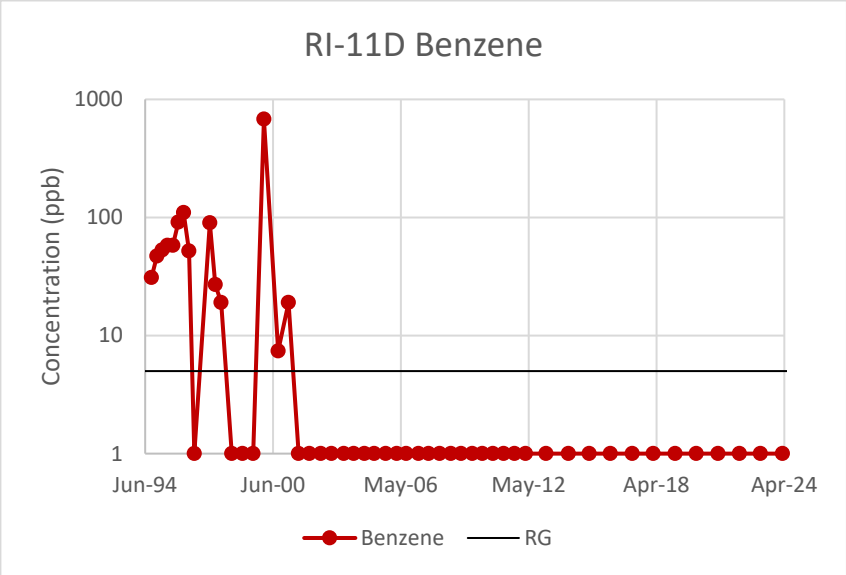



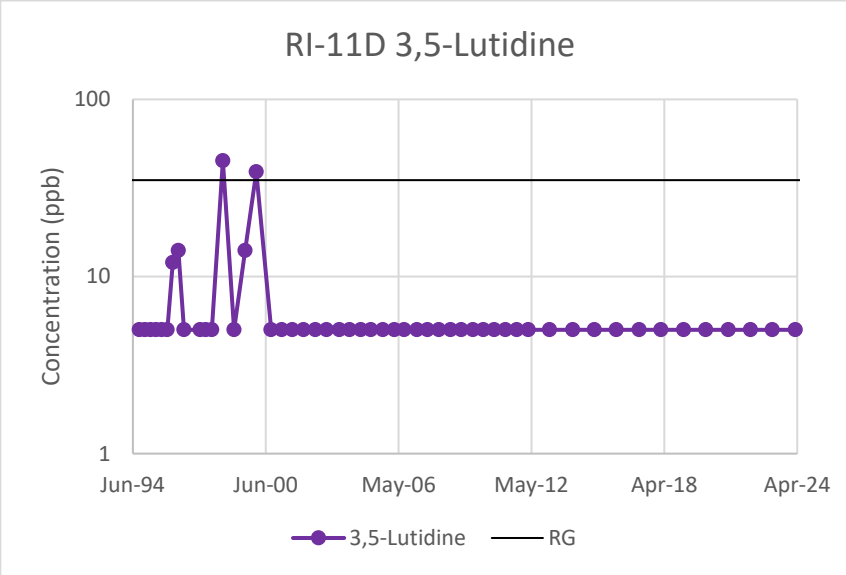



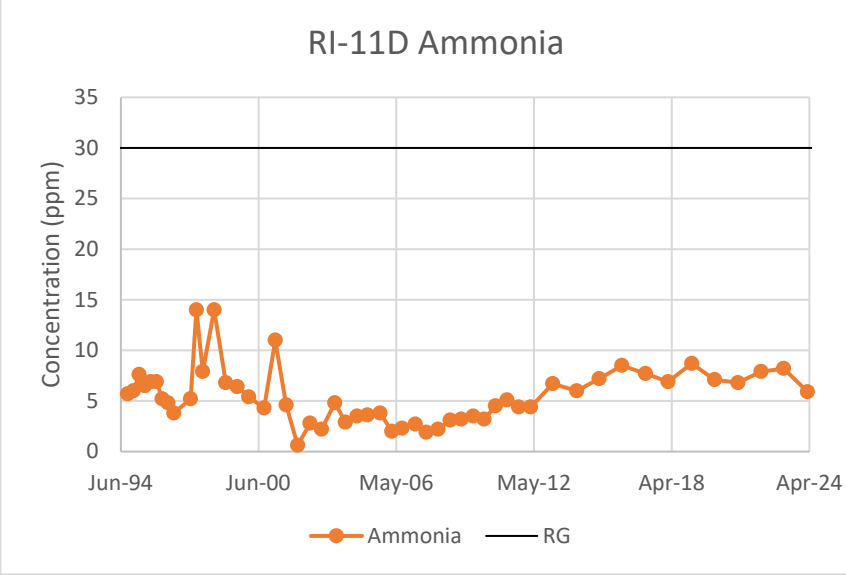



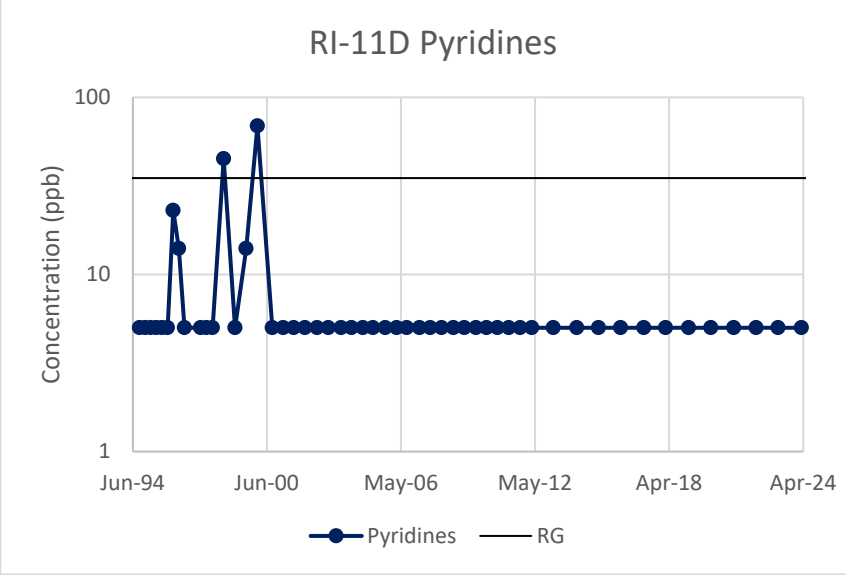
# OU5 WELLS
# RI-11D GRAPHICAL ANALYSIS

Note: Benzene, pyridines, and ammonia levels are below the RGs.



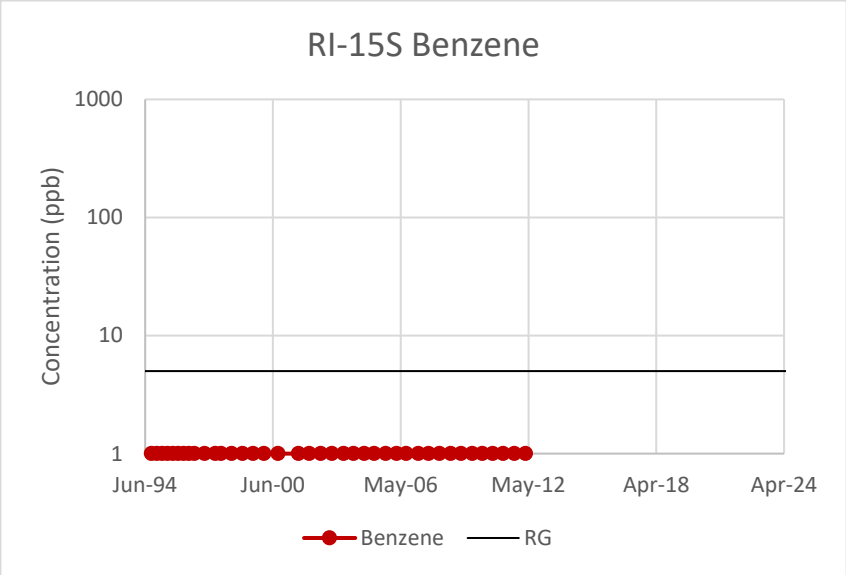



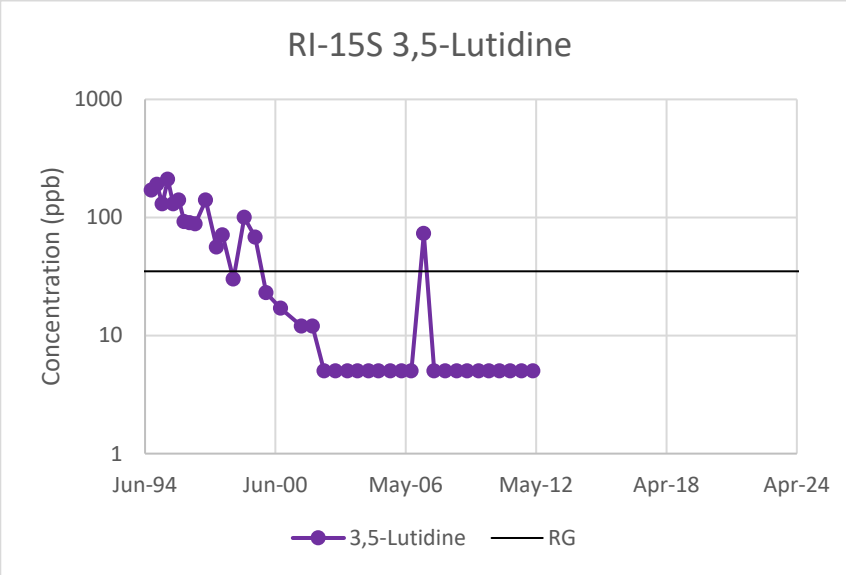



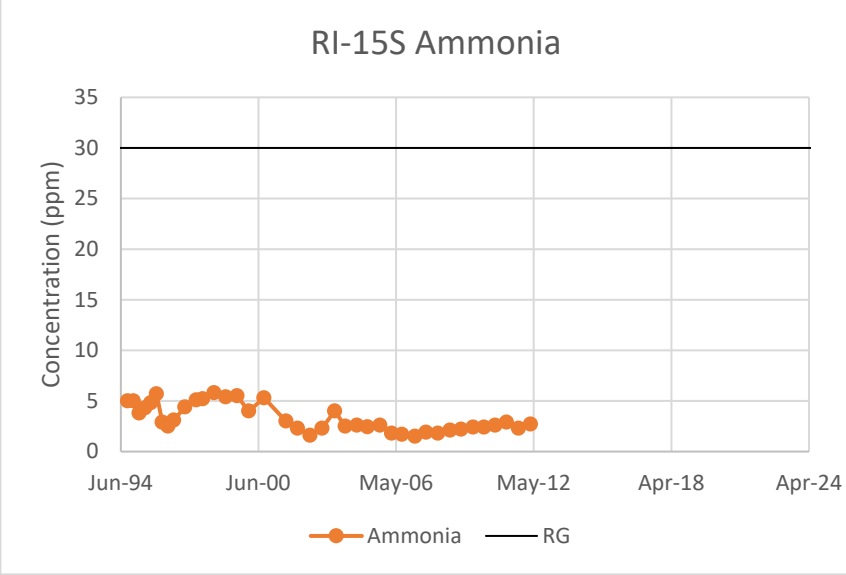



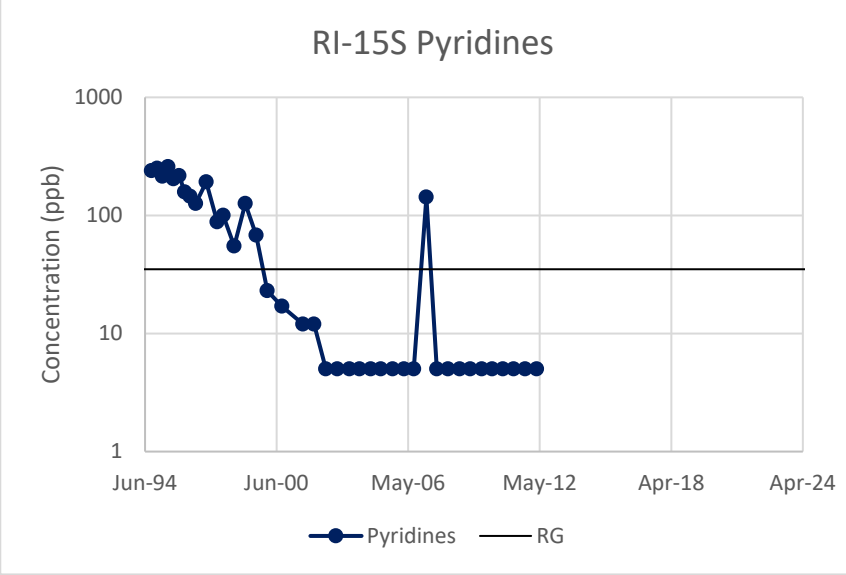
**OU5 WELLS**
**RI-15S GRAPHICAL ANALYSIS**

Note: Sampling ceased in 2012 after levels were consistently below the RGs.



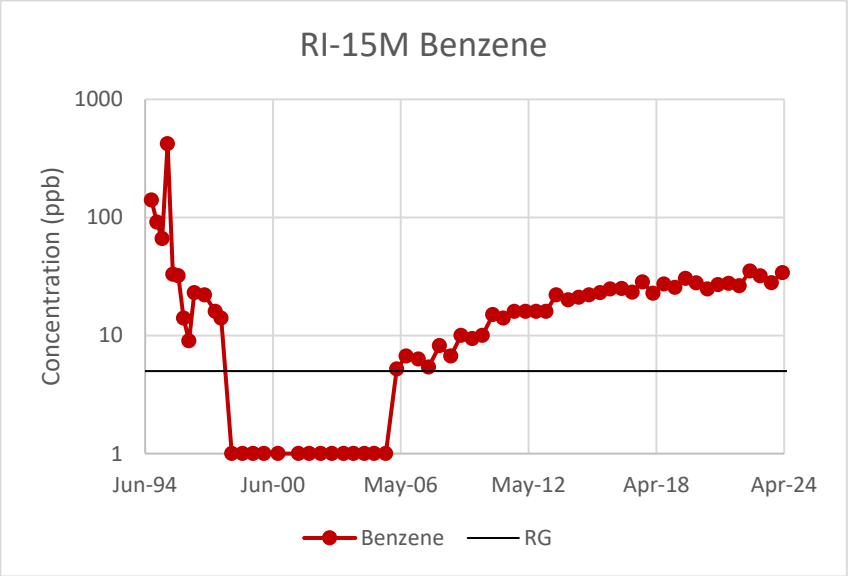



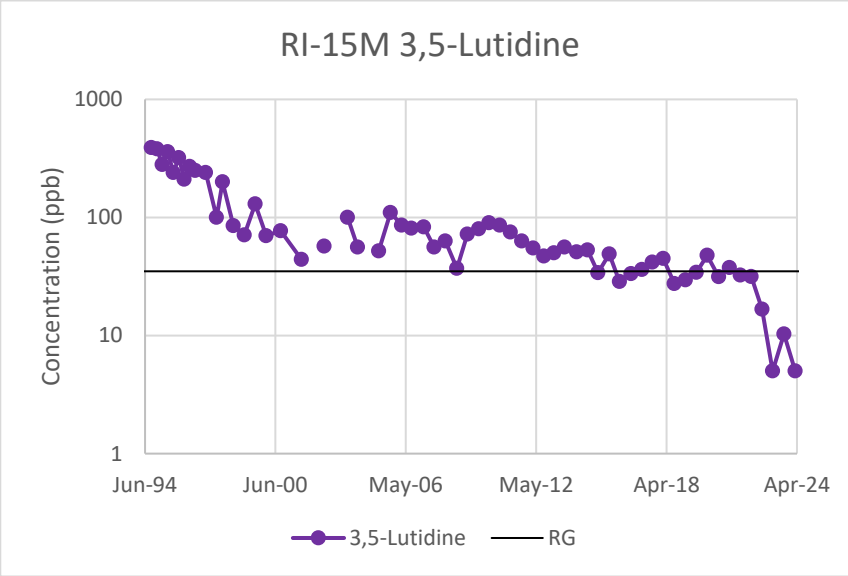



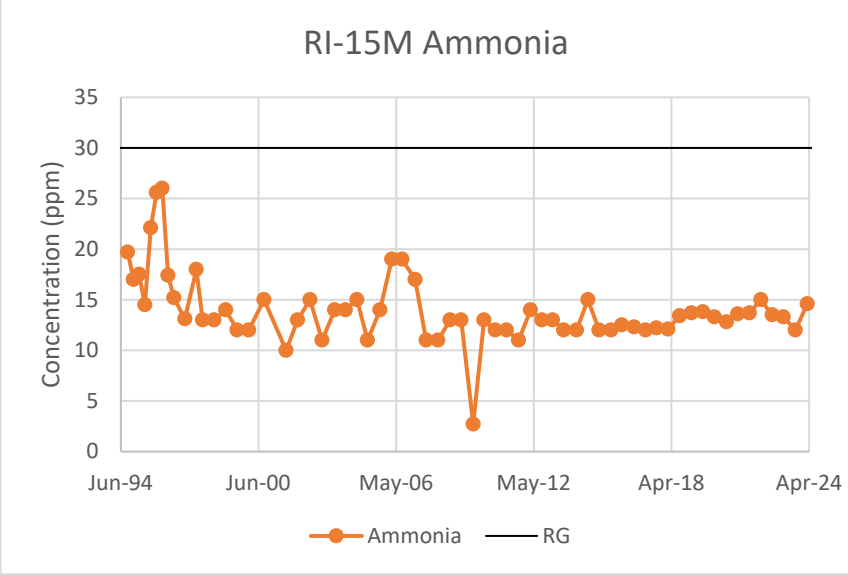



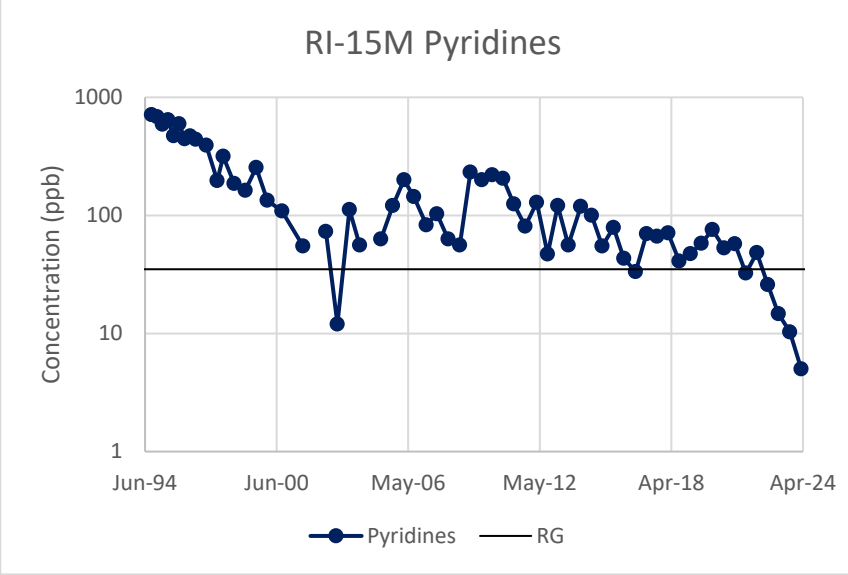
**OU5 WELLS**
**RI-15M GRAPHICAL ANALYSIS**

Note: Benzene is above the RG. Pyridines are below the RG. Ammonia has always been below the RG.



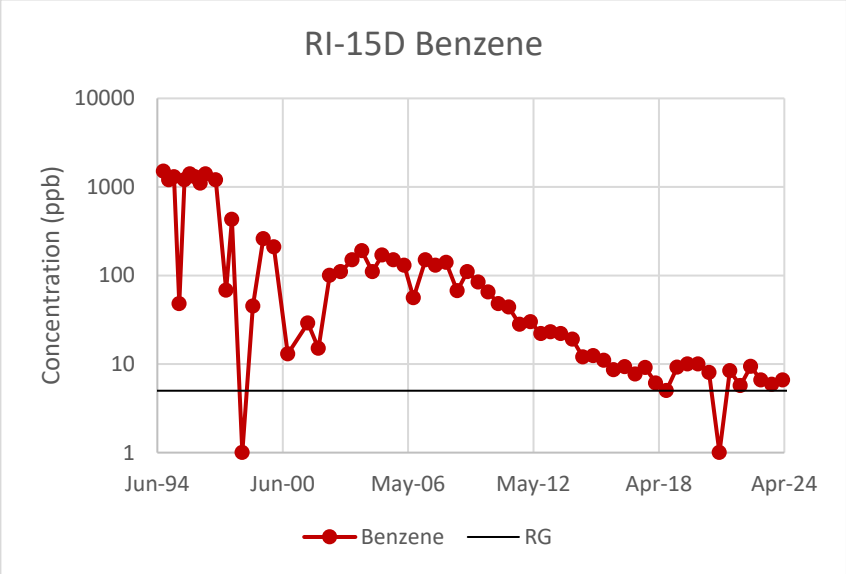



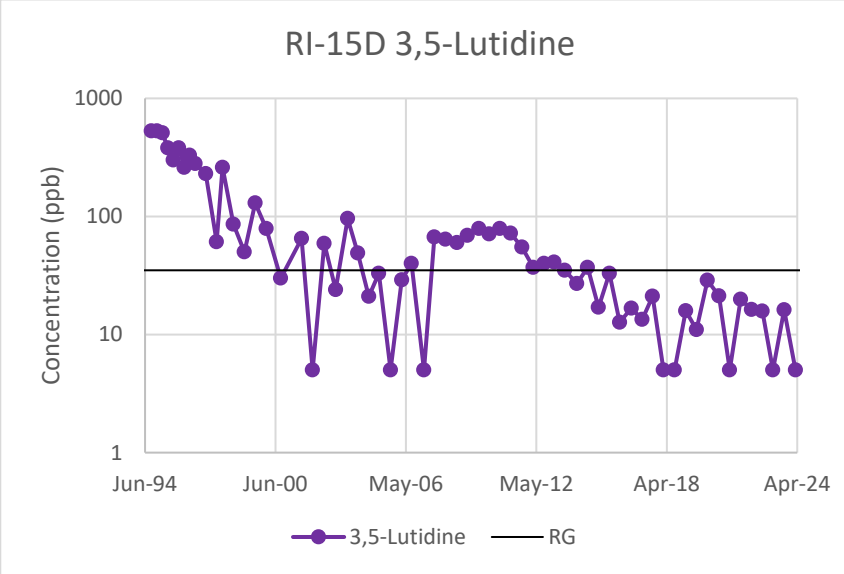



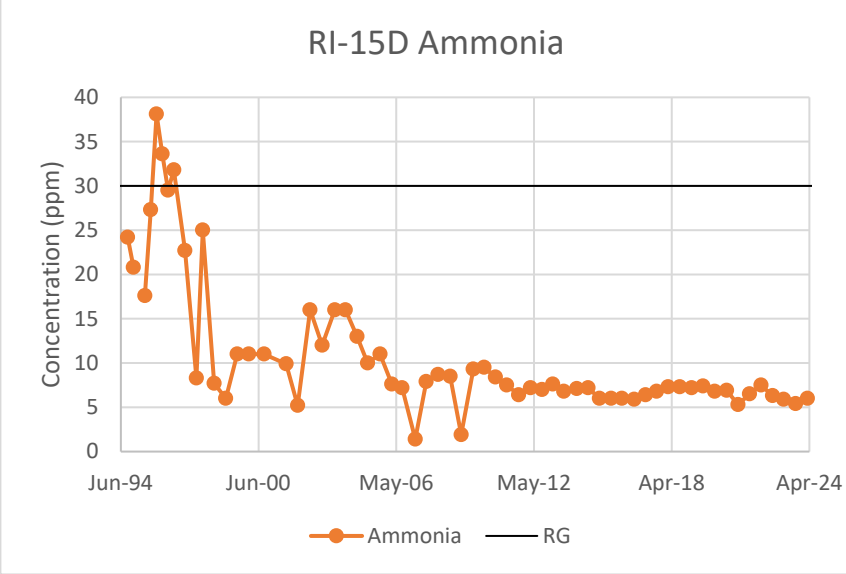



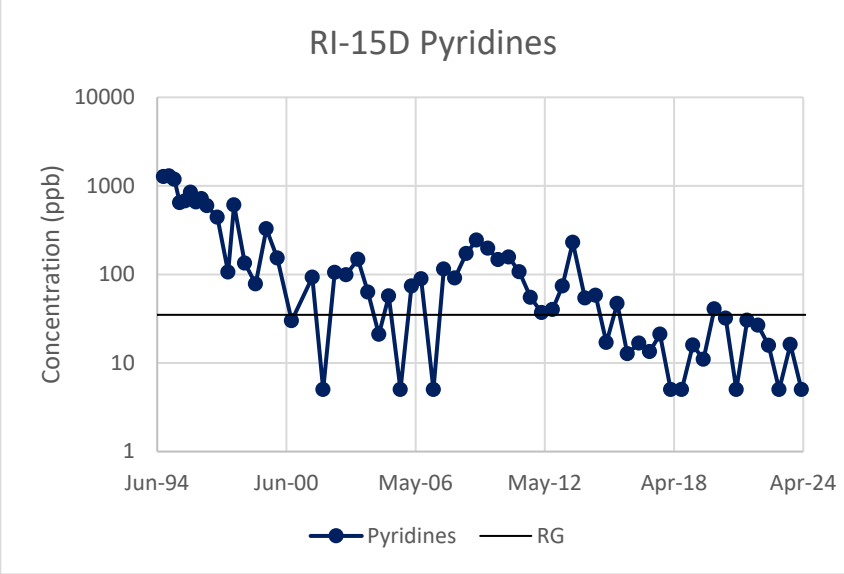
**OU5 WELLS**
**RI-15D GRAPHICAL ANALYSIS**

Note: Benzene and pyridines have generally been decreasing. Pyridines and ammonia are below the RGs.



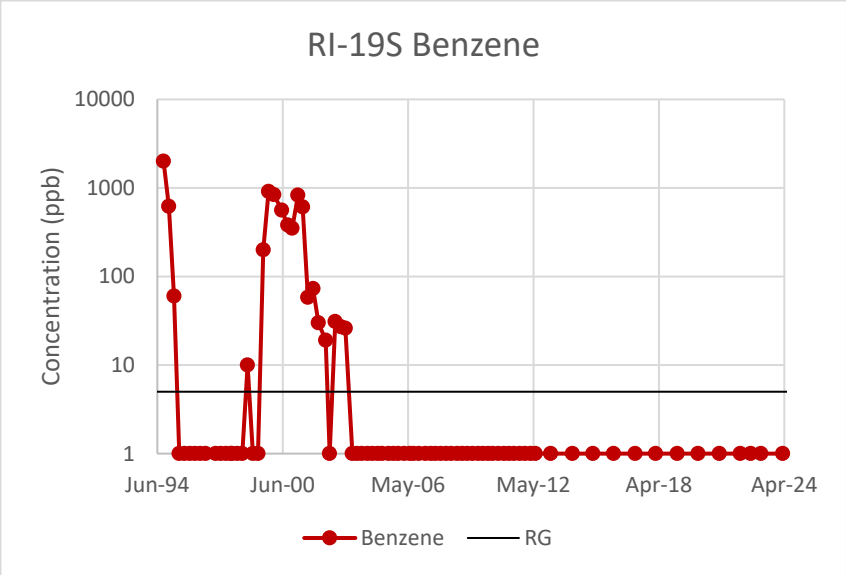



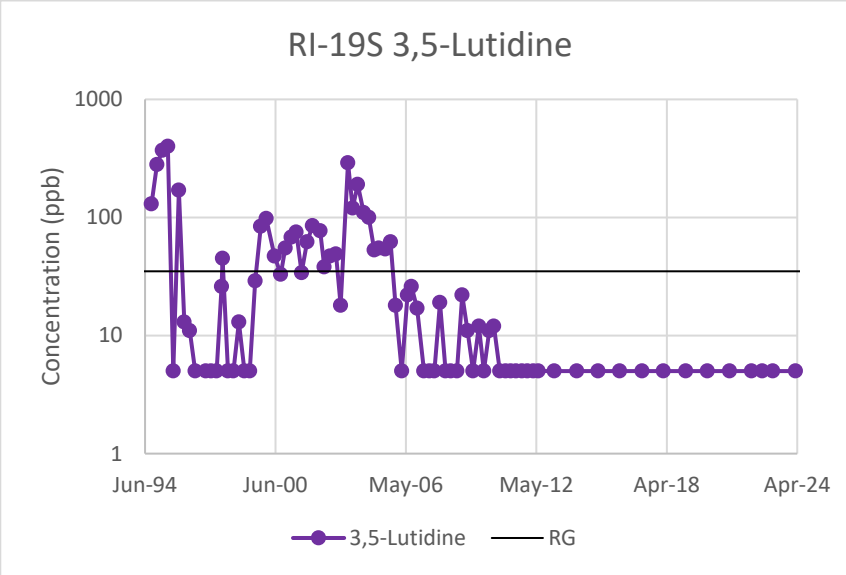



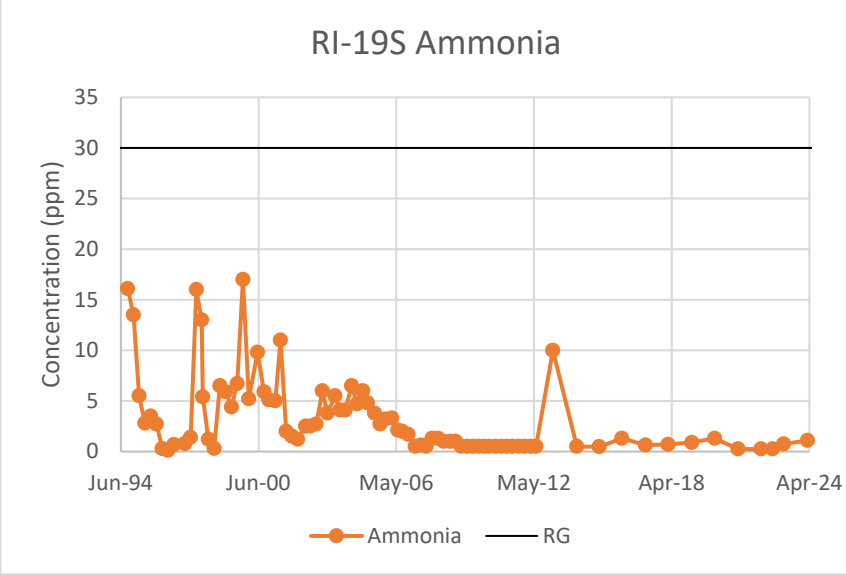



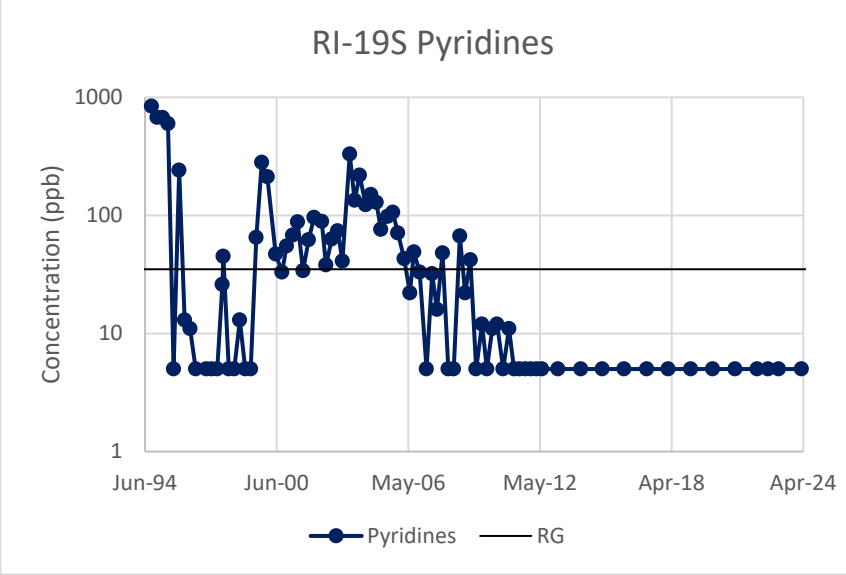
**OU5 WELLS**
**RI-19S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



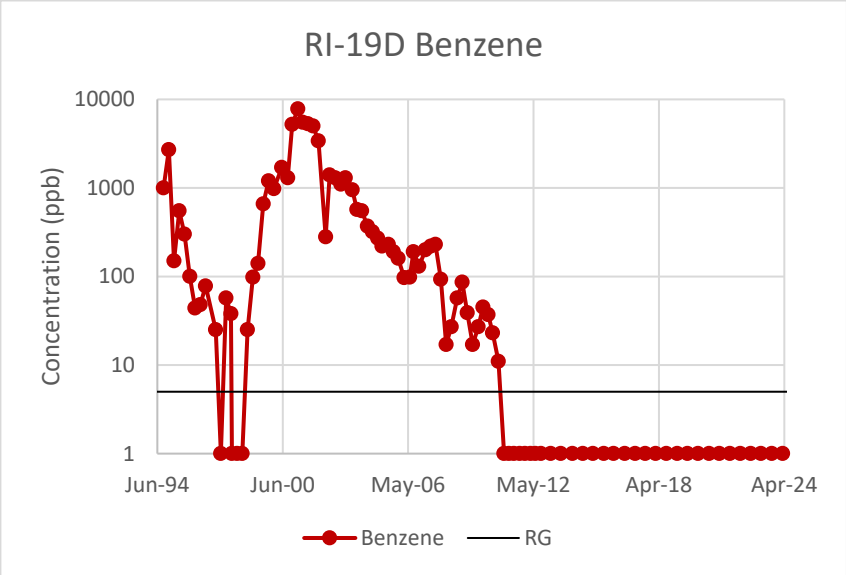



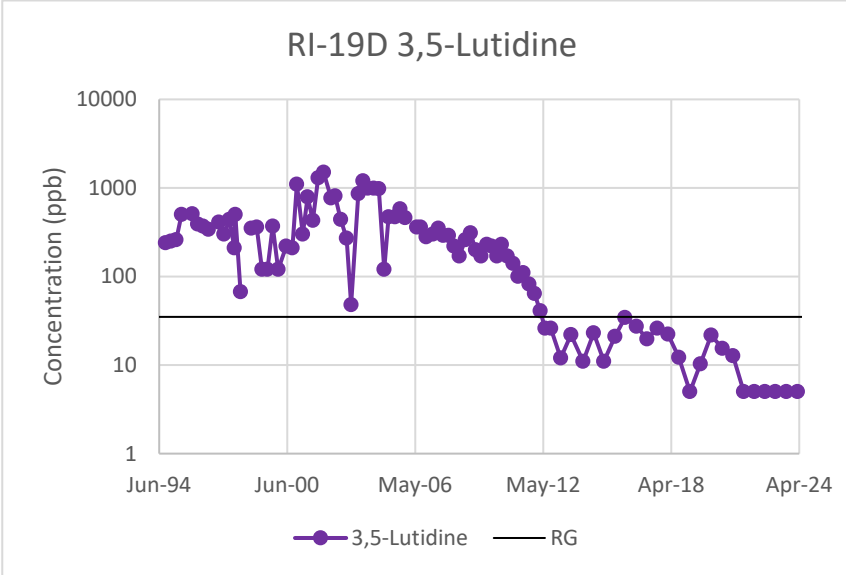



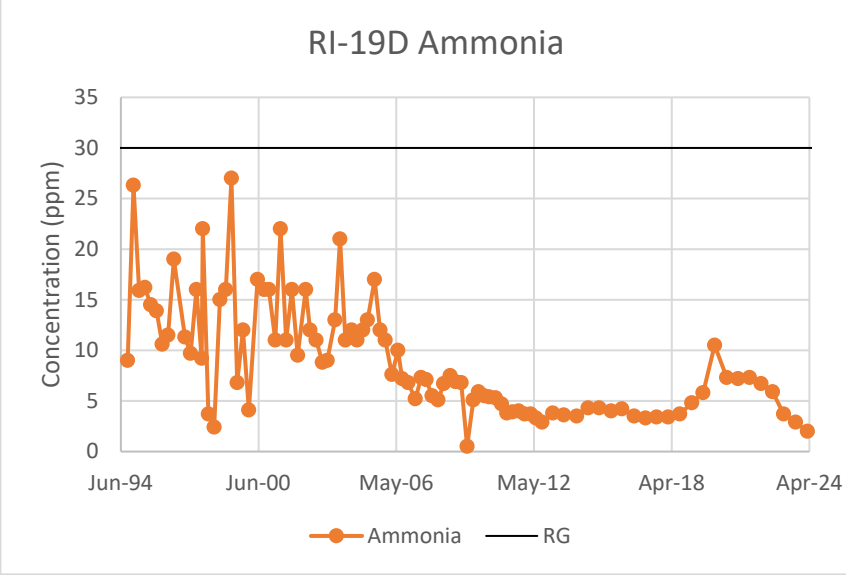



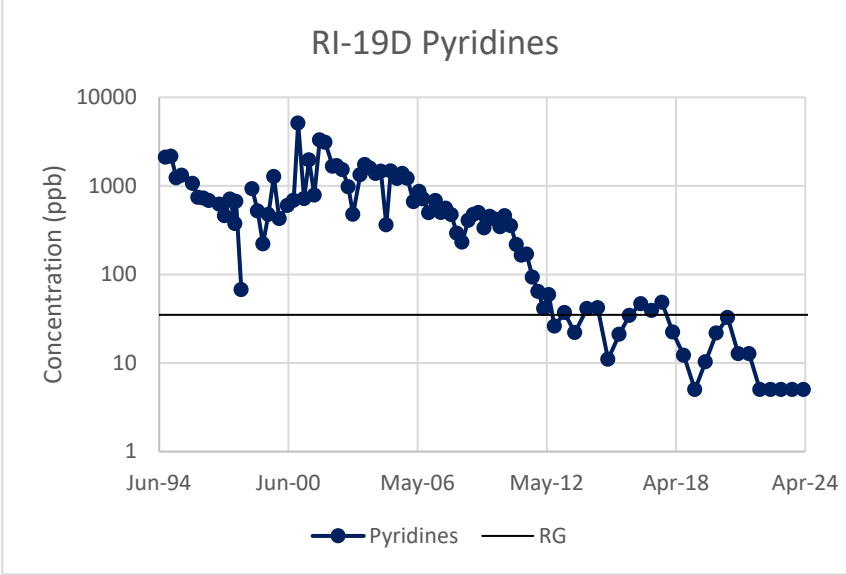
**OU5 WELLS**
**RI-19D GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



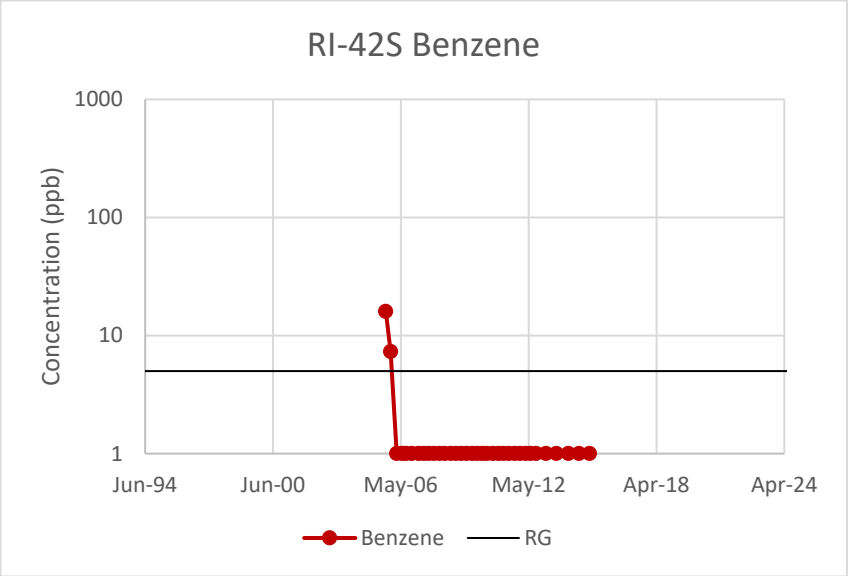



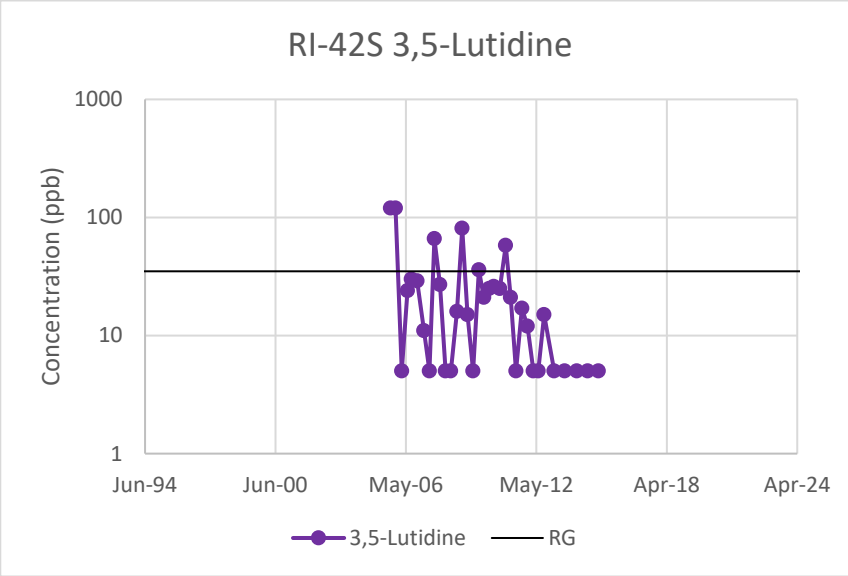



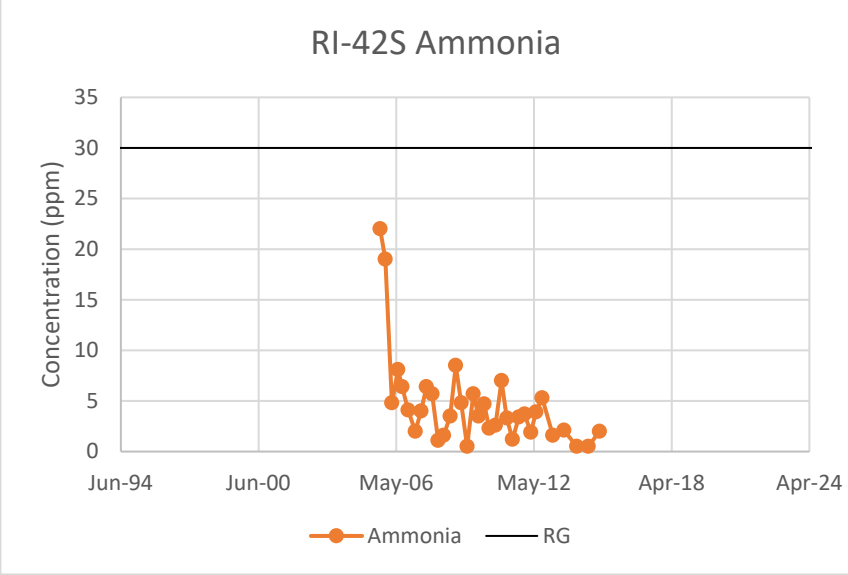



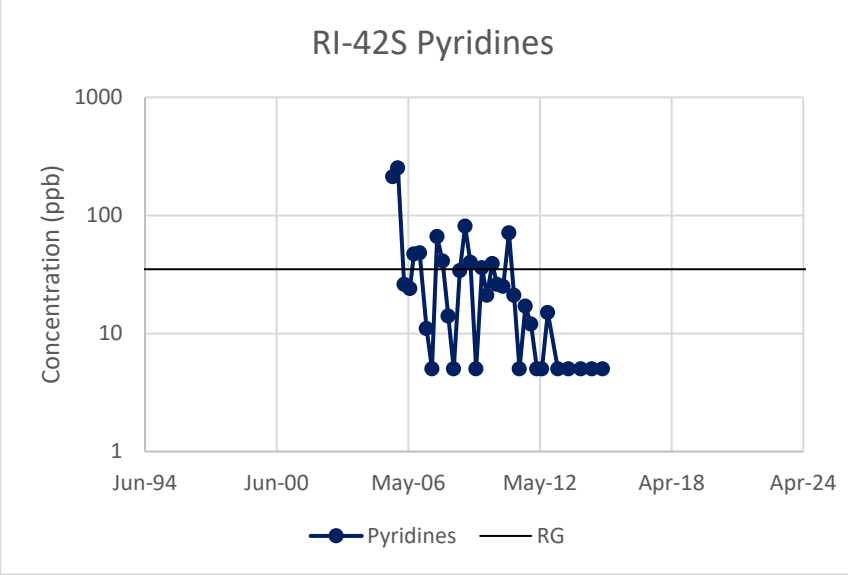
**OU5 WELLS**
**RI-42S GRAPHICAL ANALYSIS**

Note: Benzene, pyridine, and ammonia levels were below the RGs. The well was destroyed by road work.



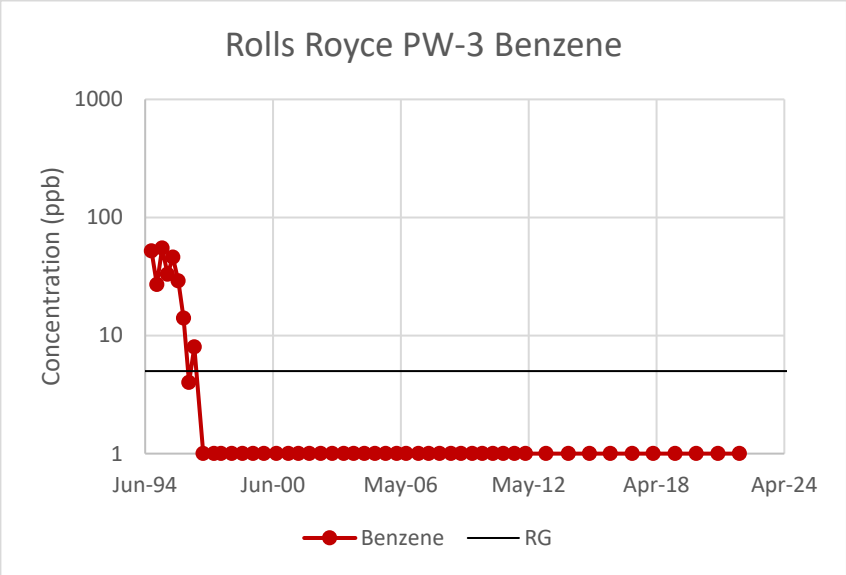



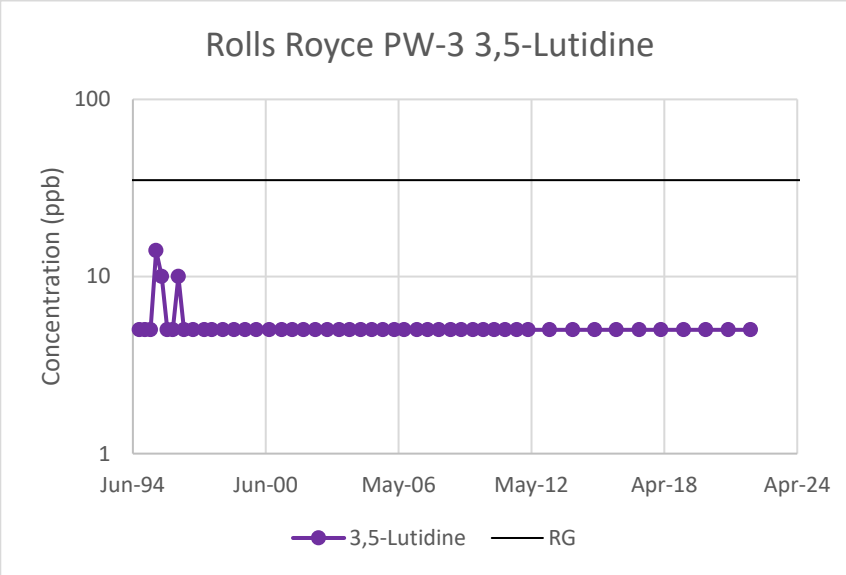



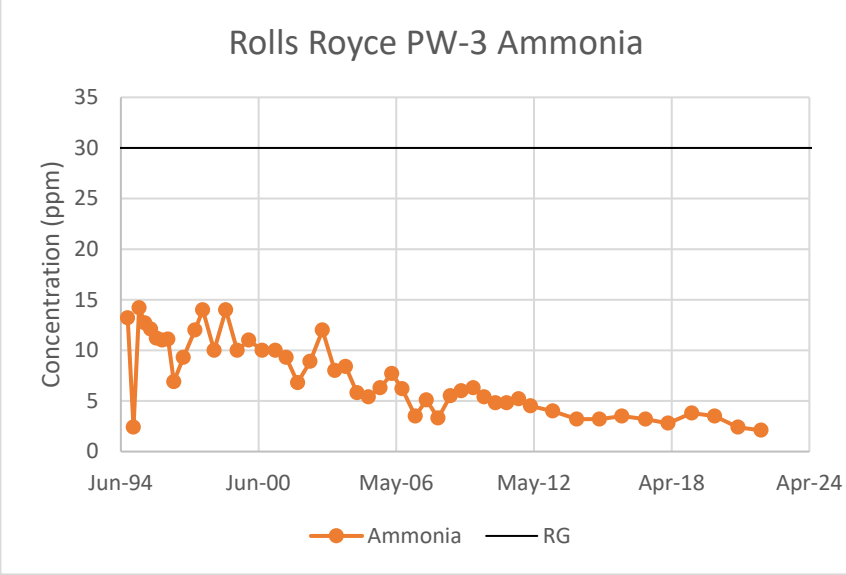



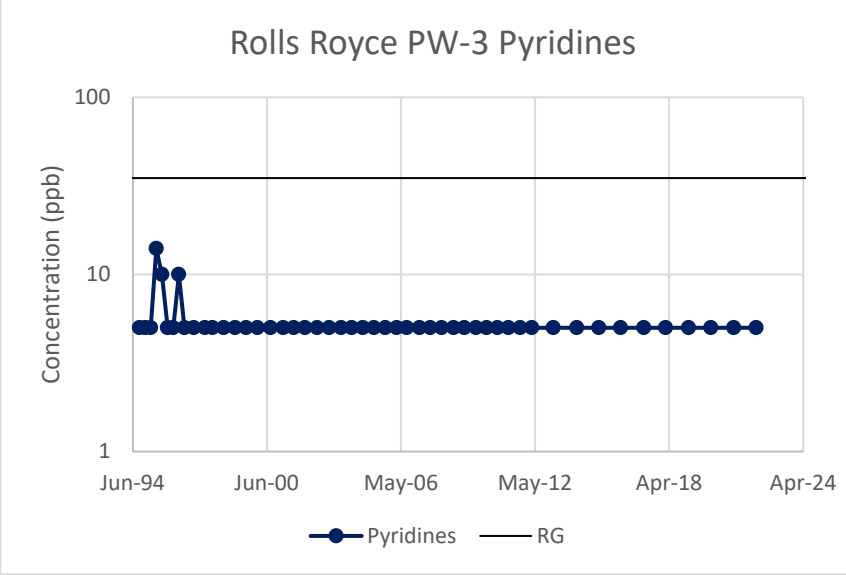
# OU5 WELLS
# ROLLS ROYCE PW-3 GRAPHICAL ANALYSIS

Note: Benzene, pyridine, and ammonia levels have been below the RGs for 25 years.



**Attachment D**

**2019 Groundwater Modeling Report and EPA Response to Comments**

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Milwaukee, Wisconsin 53212

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414.944.6081 fax

# Letter of Transmittal

Attention: Mrs. Tamra Kress Date: September 16, 2019

Project reference: Vertellus Integrated Pyridines, LLC
Project number: 60571463

Mrs. Kress –

AECOM is pleased to provide the finalized version of the Groundwater Modeling Evaluation Technical Report for the Former Reilly Industries, Inc. site located at 1500 S. Tibbs Avenue, Indianapolis, Indiana. The Technical Report, which will be included in the updated Focused Feasibility Study being prepared by Mr. David Peterson, is attached as a bookmarked PDF document. The responses to U.S. EPA comments on the draft modeling report have been prepared in cooperation with and submitted separately by Mr. Peterson. AECOM appreciates the opportunity to assist Vertellus on this important project.

Signature

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AECOM

Prepared for:
Vertellus Integrated Pyridines, LLC

# Groundwater Modeling Evaluation in Support of Focused Feasibility Study

## Former Reilly Industries, Inc.,
## 1500 S. Tibbs Avenue, Indianapolis, Indiana

September 16, 2019

**1.0 Introduction ..... 1-1**
1.1 Purpose ..... 1-1
1.2 Project Location and Background ..... 1-1
1.3 Summary of Groundwater Modeling Activities ..... 1-2

**2.0 Site Characterization ..... 2-1**
2.1 Hydrologic, Physiographic, and Geologic Setting ..... 2-1
2.2 Hydrogeology Framework ..... 2-1

**3.0 Groundwater Flow Modeling ..... 3-1**
3.1 Flow Modeling Method, Code, and Rationale ..... 3-1
3.2 Flow Model Conceptual Model ..... 3-2
3.2.1 Unit Elevations ..... 3-3
3.2.2 Hydraulic Conductivity ..... 3-3
3.2.3 Recharge ..... 3-4
3.2.4 Target Groundwater Levels and Extraction Well Rates ..... 3-5
3.3 Flow Model Calibration ..... 3-6
3.4 Flow Model Sensitivity Analysis ..... 3-6
3.4.1 Flow Model Sensitivity to Hydraulic Conductivity ..... 3-7
3.4.2 Flow Model Sensitivity to Recharge ..... 3-7
3.5 Flow Model Results ..... 3-8
3.5.1 Particle Tracking Analysis ..... 3-8
3.5.2 Groundwater Flow Velocity Analysis ..... 3-9
3.5.3 Analysis of Groundwater Flow of in OU5 ..... 3-10

**4.0 Contaminant Transport Modeling ..... 4-1**
4.1 Transport Modeling Code and Rationale ..... 4-1
4.2 Calibration of 1-D Transport Model ..... 4-2
4.3 Transport Model – Sensitivity Analyses ..... 4-4
4.4 Transport Model – Natural Attenuation Modeling Inputs ..... 4-5
4.5 Transport Model – Natural Attenuation Modeling Results ..... 4-7

**5.0 Discussion of Modeling Results ..... 5-1**
5.1 Flow Model Uncertainty Analysis ..... 5-1
5.2 Conservative Assumptions in Contaminant Transport Models ..... 5-1

**6.0 Conclusions ..... 6-1**
6.1 Groundwater Flow Modeling Conclusions ..... 6-1
6.2 Conclusions from 1-D Natural Attenuation Modeling ..... 6-2

**7.0 References ..... 7-1**

# List of Tables

Table 3-1 Groundwater Flow Modeling Evaluation Matrix
Table 3-2 Hydraulic Conductivity Testing Results
Table 3-3 Predicted vs. Observed Head Calibration Results - Deep Aquifer Model
Table 3-4 Predicted vs. Observed Head Calibration Results - Shallow Aquifer Model
Table 3-5 Summary of Recent Groundwater Withdrawals from Rolls-Royce Plant #8
Table 3-6 Comparison of Average Groundwater Discharge from Outwash
Table 3-7 Groundwater Flow Velocity Assessment in OU1 (Deep Unit)
Table 3-8 Groundwater Flow Velocity Assessment in OU1 (Shallow Unit)
Table 4-1 Recent Concentrations for OU5 Natural Attenuation Evaluation – Deep Hydrostratigraphic Unit
Table 4-2 Recent Concentrations for OU5 Natural Attenuation Evaluation – Shallow Hydrostratigraphic Unit
Table 4-3 Initial Concentration Profiles for 1-D Modeling - Deep Hydrostratigraphic Unit
Table 4-4 Initial Concentration Profiles for 1-D Modeling - Shallow Hydrostratigraphic Units
Table 4-5 Results of Natural Attenuation Analysis in OU5

# List of Figures

Figure 1-1 Site Map
Figure 2-1 Regional Hydrogeological Cross-Section
Figure 2-2 Hydrostratigraphic and Conceptual Model Cross-Section
Figure 2-3 Bedrock Elevation Map
Figure 3-1 Conceptual Site Model - Plan View
Figure 3-2 Bottom Elevation - Deep Unit
Figure 3-3 Bottom Elevation - Shallow Unit
Figure 3-4 Hydraulic Conductivity Distribution - Deep Hydrostatic Unit
Figure 3-5 Hydraulic Conductivity Distribution - Shallow Hydrostatic Unit
Figure 4-1 Calibrated 1-D Model Run: RI-33S to RI-6S (Simulated Concentration vs. Distance Plot)
Figure 4-2 Maximum Observed Concentrations (2016-2018) in OU5 for Natural Attenuation Modeling – Deep Hydrostratigraphic Unit
Figure 4-3 Maximum Observed Concentrations (2016-2018) in OU5 for Natural Attenuation Modeling – Shallow Hydrostratigraphic Unit
Figure 4-4A Natural Attenuation Modeling Results – Benzene
Figure 4-4B Natural Attenuation Modeling Results – Pyridines
Figure 4-4C Natural Attenuation Modeling Results – Ammonia

# List of Appendices

Appendix A Background Information
- A-1 Geologic Cross Sections
- A-2 August-Mack Modeling Information
  - September 2009 Groundwater Levels
  - Qtr1-2018 Groundwater Levels
- A-3 Groundwater Hydrographs
- A-4 Time-Trend Graphs of RI-11 and RI-15 in OU5

Appendix B Groundwater Flow Modeling Results
- B-1 Groundwater Flow Modeling of FFS Scenarios
- B-2 Groundwater Flow Model Sensitivity Analysis – Deep Unit
- B-3 Groundwater Flow Model Sensitivity Analysis – Shallow Unit

Appendix C Contaminant Transport Modeling Results
- C-1 Transport Model Calibration Files
- C-2 Transport Model Sensitivity Analyses
- C-3 Set-Up Files for Transport Model
- C-4 Contaminant Transport Modeling Results

Appendix D Groundwater Flow Analysis in the area of RI-11 and RI-15

# 1.0 Introduction

## 1.1 Purpose

On behalf of Vertellus Integrated Pyridines (VIP), AECOM performed groundwater modeling simulations to bolster the understanding of solute migration and containment at VIP's Tibbs Avenue Indianapolis, Indiana facility (Site) in support of the Focused Feasibility Study (FFS). The groundwater modeling activities for the FFS have been developed and revised through input of regulating authorities, including U.S. Environmental Protection Agency (USEPA), their consultant, Jacobs Engineering Group (Jacobs), and Indiana Department of Environmental Management (IDEM).

## 1.2 Project Location and Background

The 120-acre Site is located at 1500 South Tibbs Avenue in the southwest quadrant of Indianapolis as illustrated in Figure 1-1. The facility is described in the December 1, 2017 FFS [prepared by David M. Peterson (DMP), PE, PC] as follows:

> *The northern portion of the facility – primarily north of Minnesota Street – is an active chemical manufacturing facility. Much of this area is developed by buildings, pavement, and above-ground tank farms. Chemical manufacturing and wastewater treatment also occur in the northern portion of the Site. The site is regulated by a RCRA Treatment, Storage, and Disposal (TSD) Permit and as a large quantity generator by the RCRA program. The southern portion of property has been leased and has been developed for use as a solar farm. The site is surrounded by a mix of residential, industrial, and commercial properties. Residential neighborhoods are located to the north and northeast of the Site. All residences and places of business are connected to the municipal water supply. Commercial and industrial properties are located west, south and southeast of the Site.*

Environmental issues at the Site were investigated during the Remedial Investigation (RI) in the late 1980's and early 1990's (ENSR, 1991). The identified issues were related to the management and disposal of creosoting process wastes and substances/wastes associated with the process of manufacturing custom synthesized specialty chemicals. The RI and Feasibility Study (FS) were completed during the early 1990's. Five OUs were established and each has been addressed. Of the five Operating Units (OUs), OU1 (on-site) and OU5 (off-site) address groundwater and are the subject of the groundwater modeling associated with the FFS.

Groundwater in OU1 and OU5 have been impacted by the following contaminants of concern (COC): benzene, pyridines and ammonia. These compounds have impacted the shallow and deep aquifers on-site in OU1, and the shallow, medium and deep aquifers in OU5. The remedial action objectives (RAOs) established relative to OU1 and OU5, as specified in the Record of Decision (ROD), include:

- Benzene ≤ 0.005 mg/L
- Each Pyridine ≤ 0.035 mg/L
- Ammonia ≤ 30 mg/L

Groundwater pumping has been occurring since 1994 to provide groundwater containment as required in the ROD and continues through on-going verification monitoring. Groundwater pumping occurs along the downgradient boundary of OU1 at PW-1S, PW-1D and PW-2S to maintain a hydraulic barrier to limit potential offsite migration of the COCs. Historical pumping of these wells has exceeded 100 gallons per minute (gpm) (DMP, 2017). The current pumping rate after recent well cleanings in 4Q2018 is 92 gpm. Pumped groundwater is metered and continues to be discharged to the Indianapolis POTW.

Off-site groundwater (OU5) impacted with benzene, pyridine and ammonia (downgradient of OU1) is addressed through Monitored Natural Attenuation (MNA) (DMP, 2017). As outlined in the FFS (DMP, 2017), the OU5 remedy is linked to the remedy for OU1 in that the OU1 remedy (groundwater pumping) was designed to provide engineering controls (groundwater containment) and prevent the additional degradation of groundwater in OU5 (EPA, 1997). MNA has been occurring as concentrations of benzene, pyridines and ammonia have generally decreased. However, MNA rates are slower than anticipated in the ROD. Furthermore, some wells have observed increases in concentration, while others have observed concentrations that exceed RAOs.

Several RAO exceedances of benzene, pyridines, and ammonia still exist in OU5 and the benzene level at RI-15M has been gradually increasing. These monitoring results suggest that the existing pumping system requires further enhancement or change in remedy. Biosparging has been pilot tested and proven to be an effective alternative remedy for benzene and pyridines. A barrier biosparge system could effectively replace the groundwater pumping system to contain benzene and pyridine impacts in OU1 while promoting monitored natural attenuation in OU5.

Groundwater modeling was completed for OU5 by August Mack Environmental, Inc. (AME) in 1996 (AME, 1996). The results of the 1996 groundwater modeling estimated it would take 1.5 to 6 years for MNA to meet RAOs. These cleanup times proved to be too short. Updated groundwater modeling was completed by AME in 2010 (AME, 2010). For this work, AME updated the 1996 groundwater model and evaluated the difference in inputs and results from the updated groundwater model to the 1996 groundwater model. Lastly, as part of the December 2017 FFS submittal (DMP, 2017), hydrogeological modeling was completed to more accurately estimate the duration of remediation under current conditions (groundwater pumping), as well as conditions with a containment (sparge) barrier. Due to the trends of concentrations at RI-11M and RI-15M, the time for benzene to achieve the RAO under current groundwater pumping conditions could not be determined while it was estimated to take 15 years to achieve the RAOs during barrier sparging. Historical groundwater concentrations over several years were utilized to calculate the groundwater velocities, retardation factors, and biodegradation rates (half-lives) in the 2017 FFS; these data are utilized in this groundwater modeling evaluation.

## 1.3 Summary of Groundwater Modeling Activities

Plume containment will be evaluated through three possible remedies, including:

(1) No Action
(2) Enhanced Groundwater Pumping
(3) Barrier Containment (Sparging)

Groundwater flow modeling was performed for each remedy to assess variation in groundwater flow paths, gradients, elevations, and flow velocities. After the groundwater flow paths under each remedy were understood, fate and transport modeling simulations were performed to determine degradation times within the barrier sparge system in OU1 and monitored natural attenuation times in OU5. AECOM conducted groundwater modeling through the use of two primary modeling tools: groundwater *flow* modeling using an analytic element model, and a one-dimensional (1-D) contaminant *transport* model. These tools were used to evaluate both OU1 and OU5 to meet project objectives of evaluating changes in groundwater flow across OU1 and evaluating natural attenuation in OU5.

The set-up of the models, including data inputs, modeling tools and methods, and preliminary results have been provided to USEPA and their representative during AECOM's development of their groundwater models. This interaction was conducted so the groundwater modeling inputs and

methods could be reviewed as the models were being developed and calibrated. USEPA's request to review the groundwater modeling input data was made during our conference call on August 9, 2018 at which their comments (and their representatives) on the groundwater modeling plan were finalized. Correspondence with USEPA regarding model development and reviews are summarized as follows:

- The groundwater modeling plan was originally submitted to USEPA on April 27, 2018 and was consistent with the discussions that occurred upon during our April 12, 2018 meeting. Comments were received from the USEPA on June 11, 2018. Responses to USEPA comments on the groundwater modeling plan were submitted on July 3, 2018.

- The 2010 AME groundwater model was requested to be re-evaluated for use in these modeling exercises. However, the 2010 AME model could not be obtained. Therefore, AECOM proposed closely matching inputs.

- Several meetings were conducted to discuss the Model's conceptual model, inputs, and preliminary results:

    - Aug. 8, 2018 – Conference Call - Topics included GFLOW Model Domain and Boundaries

    - Oct. 2, 20118 – Meeting at AECOM Indianapolis Office - Pre-Calibration Meeting

    - Nov. 27, 2018 – Meeting at AECOM Indianapolis Office - Preliminary Modeling Results

- An email from USEPA on December 19, 2018 indicated that modeling runs should consider monitoring wells and groundwater flow along the north portion of the sparge barrier considering it is now being extended to the northern property line.

# 2.0 Site Characterization

## 2.1 Hydrologic, Physiographic, and Geologic Setting

The Site lies within a relatively flat/low-lying area that is near the boundary of the New Castle Drainageways (to the east) and the Tipton Till Plains (to the west) in central Marion County, Indiana (Gray, 2000). The subsurface unconsolidated glacial deposits are illustrated in the regional cross-section provided in Figure 2-1, and in the local cross-section provided in Figure 2-2. The unconsolidated overburden is dominated by Wisconsin-age sand and gravel glacial outwash deposited in sluiceways and terraces that are deeply incised into pre-Wisconsin age deposits (Brown and Laudick, 2000). The Site lies just east of the boundary between Till Plains and Outwash. The Till Plains consist of sequences of episodic deposition of till-like deposits of overconsolidated silt loam with scattered lenses of sand and silty-sand. The Outwash consists of more-recent detritus washed-out from glacier meltwater streams and deposited in terraces and floodplains adjacent to the ancestral White River and its tributaries.

The hydrologic setting is described in the December 2017 FFS (DMP, 2017) as:

> *The Site is within the White River watershed, as it is located approximately 2.5 miles west of the White River. Eagle Creek tributary is located approximately 4,000 feet east of the site, flows in a southeasterly direction, and discharges into the White River. Topography in the area is relatively flat with a gentle downward slope in an easterly direction. Other surface water bodies in the area include Blue Lake (a former gravel pit) located approximately 2,000 feet east of the Site, another water body located approximately 2,000 feet east of the solar farm, and a surface water impoundment located approximately 800 feet west-southwest of the solar farm.*

The occurrence of bedrock is also described in the December 2017 FFS (DMP, 2017) as:

> *Bedrock underlies the sand and gravel and till deposits and its elevation varies. In the northern portion of the Site, the depth to bedrock varies from about 45 feet to 60 feet bgs. In the area of PW-2S and RI-17 S/D the depth to bedrock is about 50 feet bgs and the lower till unit is thicker, resulting in a thin deep aquifer for this area (cross sections #3 and #7). Bedrock is about 90 feet bgs (cross section #3) in the vicinity of RI-5 S/D (east side of Maywood Property).*
>
> *In OU5, bedrock is generally 100 to 120 feet bgs. A rise in the bedrock elevation has been identified in OU5 which pinches out the deep aquifer in the area of former RI-42. During the installation of RI-42, till and then bedrock was encountered below the shallow aquifer at a depth starting approximately 27 feet bgs (no deep aquifer was identified). This higher elevation bedrock is documented to extend to the south where at well location RI-19 S/D, till and then bedrock was encountered at approximately 55 feet and 60 feet below grade, respectively (cross sections #5 and #6).*

The referenced geologic cross-sections included in the 2017 FFS are also included in Appendix A for convenience. A regional bedrock surface elevation map is illustrated in Figure 2-3 that reflects the variation in the bedrock surface of nearly 75 feet in the vicinity of the Site. The bedrock beneath the Site consists of organic-rich, grey, brown, and black shale of the Devonian and Mississippian New Albany Shale Formation (Brown and Laudick, 2000).

## 2.2 Hydrogeology Framework

The primary aquifers at the Site are a part of the White River Outwash & Tributary Systems. These aquifers consist of thick sequences of glacial outwash sands and gravels that are capped locally by a finer grained clay and silt deposits (Schmidt, 2011). Areas to the west of the Site (upgradient) primarily represent the New Castle /Tipton Aquifer System, which consists primarily of glacial till (i.e., mixed unconsolidated material deposited directly by and underneath glacial ice) with intertill sand and

gravel layers (Schmidt, 2011). This aquifer system has individual sand and gravel units that are commonly 5 to 15 feet thick that yield domestically 10 to 50 gpm, and 70 to 430 gpm for high-capacity wells.

Three specific hydrostratigraphic (aquifer) units have been identified at the Site that form the principal aquifers in the area. These units are conceptually noted in the Regional Cross-Section (Figure 2-1) and illustrated in the local hydrogeologic cross-section in Figure 2-2. The shallow, medium, and deep aquifer zones consist of varying quantities of sand and gravel that thicken (in depth) and coarsen (in grain size) towards the east as evident by the available boring logs, hydraulic conductivity data, and well yield information. The shallow aquifer is present everywhere in OU1 and OU5. The deep OU1 aquifer is laterally continuous with the medium depth aquifer in OU5. However, the deep aquifer in OU5 has no lateral equivalent in OU1 for the Site area north of Minnesota Ave. Each of the aquifer zones (or hydrostratigraphic units) are described below – as included in the December 1, 2017 FFS (DMP, 2017):

***OU1 and OU5 Shallow Aquifer System***

*The shallow aquifer is present everywhere in OU1 and OU5 and typically underlain by a silt rich unit (till) which, because of the silt/clay content, is less permeable and limits the vertical movement of groundwater between the aquifers. Monitoring wells in the shallow aquifer are typically screened in the range of approximately 25-35 feet below ground surface (bgs). Pumping wells PW-1S and PW-2S are screened in the shallow aquifer along with perimeter wells RI-4S, RI-6S, and RI-17S. The ground surface in this area is approximately 700 feet above mean sea level (feet msl).*

*The lower permeability layer beneath the shallow aquifer is typically present and beginning at an elevation of about 670 feet msl (30 feet bgs) in OU1 and OU5 although some anomalies and variations do exist. Two instances of continuous sand and gravel formation (i.e. no separating lower permeability layer) have been identified from drilling and include an area on the north portion of the Site around well locations RI-2 S/D, RI-25 S/D and former production well PW-3, and an area on the Rolls-Royce property around RI-19 S/D.*

***OU1 Deep and OU5 Medium Aquifer System***

*A deep aquifer underlies the shallow aquifer in OU1. The deep aquifer in OU1 is laterally continuous with the aquifer zone identified as the medium aquifer in OU5. Wells in the OU1 deep aquifer and OU5 medium aquifer are generally screened in the range of 40-60 feet bgs. Perimeter wells in the deep zone include RI-4D, RI-5S, RI-6D, and RI-17D. Pumping well PW-1D is also screened in this zone. OU5 wells in this zone include RI-11M, RI-15M and RI-19D.*

***OU5 Deep Aquifer System***

*A deep aquifer underlies the medium aquifer in OU5. Monitoring wells in the OU5 deep aquifer are typically screened in the range of approximately 80 to 110 feet bgs and include wells RI-11D and RI-15D. OU1 perimeter well RI-5D is also screened in the deep aquifer. The Rolls Royce production wells are also screened in the deep aquifer in OU5.*

A Rolls-Royce (RR) engine production facility is located southeast (and downgradient) of VIP's Tibbs Avenue Site. The RR Plant 8 facility has three deep unit production wells (PW-1, PW-2, and PW-3) that together average about 11 million gallons of monthly groundwater withdrawals. Another RR facility is located south of Plant 8 (south of Raymond St.) and has three additional groundwater production wells (PW-4, PW-5, or PW-6). These wells are pumped at similar rates as the Plant 8 extraction wells.

The shallow aquifer is relatively isolated throughout OU1 and OU5, but the medium and deep aquifers can be reasonably grouped together. This is illustrated in the regional and local hydrogeologic cross-sections included as Figure 2-1 and 2-2, respectively. Other geologic cross-sections produced for the

Site (and provided in Appendix A) indicate similar conditions that the medium and deep aquifer units are hydraulically connected and would not be unreasonable to model as a single hydrostratigraphic unit. These two units were modeled as Layer 2 of the 2010 AME groundwater model. This approach to model the medium and deep units together was mimicked in AECOM's flow modeling efforts. This was done not only to be consistent previous modeling conducted for the Site, but because there isn't sufficient information to suggest the middle and deep aquifers are significantly isolated from each other such that they should be represented as unique hydrostratigraphic units.

# 3.0 Groundwater Flow Modeling

Groundwater modeling was performed to establish estimated hydraulic gradients, groundwater elevations, and velocities under the three possible remedy scenarios: 1) No Action Scenario, 2) Enhanced Groundwater Pumping, and 3) Barrier (Sparging) Containment. Under Scenario #1 (no-action) and Scenario #3 (containment barrier), there will be an absence of existing on-site pumping. Thus, the groundwater flow modeling simulations for Scenarios 1 and 3 are identical and are therefore grouped together with the results (of no on-site pumping) being applicable to each scenario. The flow model was also used to develop an enhanced on-site groundwater pumping system (Scenario #2) that could be used to improve the current hydraulic containment.

Each scenario was simulated with off-site changes that are plausible to occur, so that remedial system effectiveness during changed conditions could be evaluated. The changed conditions included varying groundwater extraction rates at Rolls Royce (RR) Plant wells. The RR Plant wells varied from near-average extraction rates in September 2009 (11.2 million gallons) during calibration, to peak-demand monthly extraction rates of 20.5 million gallons that were observed in October 2014, September 2015, and September 2016. The off-site changed conditions analysis also simulated the deactivation of the RR wells, where no groundwater pumping was conducted. A comprehensive matrix of the groundwater flow evaluation is summarized on Table 3-1.

Further changes to off-site conditions were considered with the addition of new production wells within OU5. However, these simulations were not conducted because of the moratorium for the installation of new production wells in the unconsolidated aquifer in the vicinity of OU1 and OU5. This agreement to not model new off-site extraction wells was reached at the November 27, 2018 meeting.

Since the AME 2010 groundwater model had gone through USEPA review already, the new groundwater flow model simulations were set-up using the same datasets. Therefore, the new groundwater flow model was calibrated using the same data as the AME (2010) groundwater model, which was based on using the groundwater levels and pumping rates obtained in September 2009, as well as using the hydraulic conductivity dataset from the original RI. Furthermore, the same recharge dataset was utilized to establish an acceptable range of recharge rates that were used in model calibration.

AME (2010) constructed a two-layer MODFLOW model. The groundwater flow models prepared for this evaluation were constructed in GFLOW (Haitjema Software, 2016) using the analytical element method (AEM). Layer 2 of the AME (2010) model (representing the medium and deep hydrostratigraphic units) was calibrated first. The deep flow model is viewed more critically than the shallow model due to the higher COC concentrations in OU1 and OU5, the thicker outwash in OU5, as well as the potential for higher groundwater flow velocities that are enhanced by the RR groundwater extractions. Set-up and calibration of the shallow aquifer unit followed calibration of the deep model.

The overall goal of these flow modeling simulations in OU1 was the demonstration that groundwater contaminants will be effectively contained utilizing enhancements to the existing groundwater pumping system or through (sparge) barrier containment. The proposed barrier (sparge) system has been demonstrated to be effective during pilot testing (DMP, 2017).

## 3.1 Flow Modeling Method, Code, and Rationale

GFLOW is an efficient stepwise groundwater flow modeling system using the AEM. It models steady-state flow in a single homogeneous or heterogeneous aquifer using the Dupuit-Forchheimer assumption (Strack 1989). The AEM employs superposition of analytic solutions whereby streams

and pumping wells are represented directly by line-sinks and point-sinks rather than by cells in a finite-difference grid (Haitjema 1995). The computational effort of AEM is therefore dependent on the number of surface water bodies represented and the detail for which they are represented (Hunt, 2006). AEM has been used to represent multi-layer models that focus groundwater interactions in shallow formations (Haitjema et al, 2010). While GFLOW supports some local transient and three-dimensional flow modeling, it is particularly suitable for modeling regional horizontal flow.

GFLOW provides for efficient set-up, calibration, and analysis run-times when compared to traditional grid-based or mesh- based modeling platforms. The primary reasons for its usage include:

- Full accounting for regional shallow groundwater flow from sub-regional groundwater divides toward local and regional sinks;
- Utilizing heterogeneities to represent variations in site geology;
- Efficiency in setting-up and calibrating, so resources are used to evaluate various scenarios, since discretization of finite elements or a finite difference grid are not required - and oscillation of cell computations are avoided; and
- Incorporation of current and future groundwater pumping and non-pumping scenarios to evaluate possible changes in groundwater flow patterns from changes to onsite and off-site groundwater withdrawals.

Two separate flow models have been developed that incorporated the hydraulic properties for the sand and gravel deposits within the shallow and deep hydrostratigraphic units. Separate flow models (versus a multilayer contaminant transport model) are justified since the migration of COC flow through the preferred alternative (barrier contaminant) have been demonstrated to meet RAOs in pilot testing (DMP, 2017). Since the sparge barrier system will be effective across both the shallow and deep hydrostratigraphic units, a multilayer model is not necessary to evaluate interaction between the two aquifers. The decision to model each unit separately, rather than to model all the unconsolidated deposits as a single aquifer, was to better simulate on-site pumping in each aquifer more accurately and to mimic previous modeling (AME, 2010).

Several simplifying assumptions were required for the numerical modeling of the groundwater flow system. The following modeling assumptions are based on the conceptual model and standard numerical modeling practices, including: 1) The groundwater flow system is steady state (i.e., no storage in the flow system, specific storage and time were not required as input), and 2) The modeled system is saturated and has hydrogeologic properties representative of the stratigraphic unit in which it is located.

## 3.2 Flow Model Conceptual Model

The site Conceptual Site Model (CSM) was developed in general accordance with ASTM 41 E1689-95 to visualize and represent the geological and hydrogeologic setting of the existing groundwater flow and contaminant transport mechanisms. The reason for this conceptualization of the site was twofold: First, the aquifer model construct condensed large quantities of field data (e.g., local and regional sources, sinks, water levels, pumping and recharge effects) into a concise format that provides a clearer understanding of the fundamental aquifer processes. Second, the aquifer model construct is used as an intermediate step from which the actual conditions present beneath the Site can be applied within the constraints of the numerical model. The CSM is illustrated in plan-view in Figure 3.1. The conceptual cross-sectional view is illustrated in Figure 2-2.

Regional flow conditions (which represent far-field hydraulic boundaries) were utilized to set starting head conditions within the modeling domain. The far-field domain, which is the area outside of the

primary area of concern (i.e., outside of the OU1 and OU5 areas), extends to the upgradient shallow potentiometric divide located west of Interstate I-465, to the downgradient hydrologic boundary that represents the White River. Assigned upgradient heads vary from 770 to 780 ft msl, while heads along the discharge sink varied from 680 ft msl to 658 ft msl as the White River flows through Indianapolis north to south.

The eastern half of the groundwater modeling domain represents the White River and Tributary Outwash Systems. These aquifer systems consist of thick glacial outwash sands and gravels that are generally capped by a layer of clay and silt deposits (Schmidt, 2011). Upgradient areas of the model primarily represent the New Castle /Tipton Aquifer System, which is observed to be up to about 300 feet in thickness and consists of intertill sand and gravel layers (Schmidt, 2011). The Site lies just east of the boundary between the two aquifer systems along a bedrock high that is prominent in Figure 2-1. The varied deposition environments affirm the observed grain size and hydraulic conductivity differences of on-site (OU1) deposits (finer with lower conductivity) versus the sand and gravel deposits in OU5 that tend to be coarser and have higher hydraulic conductivities.

Some aquifer interactions between the shallow and medium/deep aquifers are believed to occur, but significant direct communication is not believed to be widespread. Rather, the shallow and intermediate/deep aquifers are generally separated by lower permeability silty clay materials. Over the past 8 years: RI-4S has averaged of 8.5 feet higher than RI-4D; RI-11S has averaged 0.37 feet higher than RI-11M; RI-15S has averaged 5.6 feet higher than RI-15M; and RI-19S has averaged 0.30 feet higher than RI-19D. Thus, downward gradients exist within the silt clay unit, which are induced by the groundwater extraction activities at the RR Plants in OU5.

The direct hydraulic communication encountered in the vicinity of OU5 monitoring well RI-19 is believed to be isolated. This location is the only area where direct hydraulic communication appears to occur. Inspection of the other geologic cross-sections (Appendix A) indicate the shallow unit is separated from the medium and deep aquifers. However, the till units appear to be leaky. Based on the sparge pilot testing, the till units separating the aquifer units are leaky in that air sparging in the deep unit will migrate up through the till unit and successfully oxygenate the shallow aquifer.

### 3.2.1 Unit Elevations

GFLOW default elevations are set at the start of the modeling construction. The default base elevation of both models was set to 610 feet msl, with an aquifer thickness of 74 feet. However, base elevations where varied in the model based on the structural configuration of the till unit (for the shallow model) and the base of the deep aquifer (for the medium/deep flow model). The structural map for the top of bedrock is illustrated in Figure 2-3, but also illustrated on Site cross-sections included in Appendix A.

Adjustment of base elevations were applied to the model by applying inhomogeneities within the near-field area. Placement of inhomogeneities allowed refinement of the bottom elevation and hydraulic conductivities of the model based on specific site data. For example, the bottom elevation of the deep model ranged from 580 feet msl to 658 feet msl, as illustrated in Figure 3-2. The bottom elevation for the shallow flow model varied from 606 feet msl to 670 feet msl, as illustrated in Figure 3-3. Large areas of the model outside of the near-field areas, did not have significant changes from the set base elevations for either model.

### 3.2.2 Hydraulic Conductivity

As mentioned, inhomogeneity domains allowed for the unique input of aquifer parameters (e.g., hydraulic conductivity, porosity, aquifer base elevations, and recharge) to be entered based on site-specific data. Varying hydraulic conductivity values across the near-field area is an important

component of calibration due to the spatial variation of hydraulic conductivity in the aquifer. However, hydraulic conductivity adjustments were limited to the range of conductivities obtained through field testing conducted during RI activities. A summary of site-specific hydraulic conductivity testing results is summarized on Table 3-2.

The horizontal hydraulic conductivities zonations are illustrated in Figures 3-4 and Figure 3-5, for the deep and shallow models, respectively. As mentioned, hydraulic conductivity values for the site were based primarily on in-situ hydraulic conductivity testing conducted in Site monitoring wells. The RI conductivities ranged from 0.4 to 114 feet/day (ft/d) in the deep unit and 24 to 224 ft/d in the shallow unit. The spatial distributions of hydraulic conductivities are generally consistent with the conceptual understanding of the area in that conductivities are commonly lower in OU1 than in OU5. This is due to the coarser material being deposited in terraces and sluiceways in the thicker sequences of the White River aquifer system versus the transition area where outwash was deposited in linear sluiceways the Site is located (Figure 2-1). As represented on the cross-section in the regional cross-section (Figure 2-1), the topographic high on the bedrock surface located below the Site limited thicker sequences of outwash to be deposited and allowed for more fine-grained materials (including till sequences) to be maintained (and not eroded in the primary White River channel). Thus, the calibrated models resulted in conductivities values in OU1 versus OU5 in both the deep and shallow models.

The range of conductivity inputs varied from 1 to 30 ft/d in OU1, and 20 to 250 ft/d in OU5. The two exceptions in OU5 are the areas around RI-19D and the RR production wells 1, 2, and 3. Monitoring well RI-19D is located in an area with a very high bedrock surface and has high well screen relative to other wells screened in the medium or deep units in OU5. These two factors made it difficult to calibrate to the water level at RI-19D. Changes in conductivity, along with an increase in the base elevation were also adjusted to match observed conditions at this well.

Total porosity was held consistent throughout the model domain. However, changes in porosity did not influence the groundwater flow solution, rather they are only used for calculation of average groundwater flow velocities and representation of particle tracking path-line time tick marks.

### 3.2.3 Recharge

Recharge refers to the volume of infiltrated water that crosses the water table and becomes part of the groundwater system (Anderson and Woessner, 1992). While recharge rates are spatially and temporarily variable, there was a wealth of documented recharge rates that enabled a bracketing of target recharge rates for both flow model units. The AME groundwater modeling efforts (2010) used a global recharge value of 0.00325 feet per day (ft/d) or 14.25 inches per year (in/yr) across their entire model domain. This value was based on the average recharge rates for the outwash aquifer of the White River provided in IDNR (2002) and ATEC (1995). Further assessment of these references indicated recharge rates vary based on lithology.

The ATEC Associates (1995) Phase I Groundwater Hydrology Assessment provided the following summary:

- Leopold (1959) estimated effective recharge into the White River Outwash area to be 11.6 in/yr, and non-outwash areas contributing to Eagle Creek 4.9 in/yr.
- Meyer et al. (1975) calibrated a Marion County groundwater flow model using a uniform effective recharge rate of 13.6 in/yr and 2.0 in/yr in till plains.
- Gillies (1976) calibrated a groundwater flow model of the White River Outwash using a recharge rate of 11.9 in/yr, and 3.7 in/yr in till plains.

- Herring (1976) calculated an average recharge rate of Marion County Outwash Aquifer of 12.6 in/yr, and 2.4 to 5.3 in/yr for the upland till plains
- Smith (1983) simulated reasonable recharge rates of 10 to 15 in/yr in the Outwash, and 3.0 to 5.0 in/yr in till plains (Non-Outwash Areas).

Using these references, the target bracketed recharge rate during calibration for the AECOM models was:

10 to 15 in/yr for Outwash Areas

2 to 5 in/yr for Non-Outwash Areas

During model refinement and calibration, the recharge rate was adjusted and spatially zonated within the pre-defined range of document values to reflect site-specific conditions which may include variations in land cover, surface drainage, lithology to improve calibration. However, the final recharge rates were maintained within the bracketed rates of 3 to 5 in/yr in the till plains (non-outwash areas west of the Site) to 7 to 10 in/yr in outwash which represented the eastern half of the model domain. The intertill recharge rates were within the pre-modeling range of 2 to 5 in/yr, while the outwash recharge was slightly lower than pre-modeling range objective of 10 to 15 in/yr. Local recharge rates were varied somewhat during model calibration but not outside this range. For example, recharge in some zones within the near-field modeling area were adjusted up to 13 to 15 in/yr to account for variations in local lithology, land-use, and land-cover that impact groundwater recharge and subsequently, groundwater levels. Since the Deep Unit is not fully confined, the recharge rates were maintained within this range, but were slightly lower than the Shallow Unit in the till plains.

### 3.2.4 Target Groundwater Levels and Extraction Well Rates

Groundwater levels measured by AME in September 2009 were used as calibration targets. These groundwater levels, which are included in Appendix A-2, were used to be consistent with the already approved 2010 AME groundwater model. Furthermore, groundwater withdrawal rates within the models were also maintained consistent with the AME Model (2010) by using the following September 2009 pumping rates:

| Groundwater Withdrawals Input into GFLOW Models | | | | | | |
|---|---|---|---|---|---|---|
| Extraction Well ID | Unit | Approx. Well Depth | Total Groundwater Withdrawal (Sept. 2009) | | Average Daily Withdrawal (Sept. 2009) | |
| | | (feet) | Million-gallons | gallons | gal/day | $ft^3$/day |
| <u>On-site Wells</u> | | | | | | |
| PW1S | Shallow | 31 | 0.13 | 1,300,000 | 4333.3 | 579.3 |
| PW2 | Deep | 25 | 0.82 | 820,000 | 27333.3 | 3,654.2 |
| PW1D | Deep | 58 | 1.70 | 1,700,000 | 56666.7 | 7,575.8 |
| <u>Off-site Wells</u> | | | | | | |
| RR1 | Deep | 110 | 4.6 | 4,600,000 | 153,333.3 | 20,499.1 |
| RR2 | | 114 | 2.0 | 2,000,000 | 66,666.7 | 8,912.7 |
| RR3 | | 110 | 4.6 | 4,600,000 | 153,333.3 | 20,499.1 |
| PW2A | | 104 | 36.6 | 36,600,000 | 1,220,000.0 | 163,101.6 |

Both the groundwater levels and the extraction rates were compared to recent data to assess potential changes to the assumptions used when the 2010 AME Groundwater Model was developed. Comparisons of recent groundwater levels (Appendix A-2) and extraction rates (Table 3-5), indicate that the 2009 data are within the ranges of recent data results.

## 3.3 Flow Model Calibration

The primary goal of flow model calibration was to establish a site-specific model that simulates steady-state groundwater flow conditions in the deep and shallow aquifers so that changes to present conditions (i.e., termination of on-site pumping) can be accurately evaluated. Calibration was accomplished by inputting local hydrologic and hydrogeologic data, running the flow model, and comparing the computed hydraulic heads with the observed head conditions. The input data were then varied within established data ranges until computed hydraulic heads and fluxes closely compared to observed heads and estimated/calculated fluxes. This iterative procedure was used to calibrate each of the flow models until an average residual error of less than or equal to 1.0 feet was achieved across the monitoring wells chosen to represent the hydrostratigraphic unit. After manual calibration was achieved, a nonlinear parameter estimation program PEST (Doherty, 1998) was used to improve and reduce uncertainty of the manually calibrated the model.

Calibration of the models ensure the constructed models are representative of the actual steady state shallow and deep groundwater flow conditions. Calibration must be evaluated both qualitatively and quantitatively. Potentiometric contour lines must match the conceptual understanding of the aquifer and the regional flow conditions. The shallow unconsolidated aquifer potentiometric surface and conceptual groundwater modeling domain is included in Figure 3-1. The local patterns simulated in the model show a reasonable match with the potentiometric maps provided in the draft FFS (DMP, 2017), particularly north of Minnesota Street, which corresponds to the approximate center of the model domain. However, even in a quantitative evaluation, the fit between model results and reality is subjective (Anderson and Woessner, 1992), but is generally accepted if the absolute error is a small percentage of the observed fluctuations groundwater elevation. For the deep and shallow unit flow models, an absolute residual error of less than 1.0 foot was deemed to be an acceptable calibration considering 1.0 foot was less than 1% of the head decrease of over 100 feet across the model domain. Upgradient heads were greater than 750 ft msl and the groundwater levels at the RR Plant extraction wells are approximately 650 ft msl. The model to predicted head values are tabulated and visually displayed for the Deep and Shallow Units on Table 3-3 and 3-4, respectively. The primary head calibration statistics include the mean absolute difference (residual), root-mean-square difference, and the sum of squared differences. The calculated residual is defined as the difference between the calculated head results and the observed head results.

Estimated groundwater baseflow from the Outwash to the White River was used as a calibration target. The White River and its tributaries are estimated to gain about 42.0 $ft^3$/d per foot of channel length (Meyer et al., 1975). The groundwater model was calibrated to 42.9 $ft^3$/d per foot of channel length or 2.1% of this flux target as summarized in Table 3-6. The flux target has errors associated with it since it is difficult parameter to measure directly, but the comparison to flux estimates has provided a positive independent check to calibrated hydraulic conductivity values.

## 3.4 Flow Model Sensitivity Analysis

A sensitivity analysis was performed on the calibrated flow model's inputs for recharge and hydraulic conductivity to evaluate the uncertainty of the modeling results with respect to the estimates of the input parameters. The sensitivity analyses were accomplished by systematically varying the calibrated values for the chosen input parameter within a predetermined range, while all other parameters are held constant.

The site-wide regional values for both recharge and hydraulic conductivity were varied in the steady-state simulations, along with specific recharge and hydraulic conductivity zonations in OU1 and OU5 areas. The recharge and hydraulic conductivity values were assessed by varying these parameters by +/-50 percent. The impact of the changes in the recharge and hydraulic conductivity values on the model calibration was evaluated by recording the change in the absolute residual mean of the steady-state calibration and evaluating the effects of these changes to the models flow and gradients. A determination of the type of sensitivity analysis response per the ASTM D5611-94 (16) Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application was then performed. There are four types of sensitivity classifications (Type I through IV), which are assigned based on the changes in inputs have on the calibration residuals and model conclusions, and whether they are significant or insignificant. The results of the sensitivity analyses and response classifications are summarized in Appendix B-2 and B-3, for the deep and shallow models. These results are discussed below.

### 3.4.1 Flow Model Sensitivity to Hydraulic Conductivity

Three hydraulic conductivity zones, including the general model, till plains, and outwash values were varied to evaluate the model's sensitivity to these changes.

Deep Model - The change in the regional outwash conductivity (of +/- 50 percent from baseline) did not have significant results on output, due to the limited area exclusive of the general model domain. Variations to the conductivity of the outwash (baseline 250 ft/d) and till (baseline 25 ft/d) showed that changes to these conductivity values caused appreciable changes in the calibration residuals but insignificant changes in the model's conclusions. Deep aquifer hydraulic conductivity zones in both OU1 and OU5 areas were evaluated for sensitivity in nine units individually and all together. Results indicate changes to these conductivity values or zones either individually or all together caused no concern regardless of the value of the input, the models calibration residuals and conclusion remain the same.

Shallow Model - The shallow model's regional conductivity when varied from (+/-) 50 percent from the baseline value of 200 ft/d has the most effect and caused significant changes to both the calibration residuals and the model's conclusions. The sensitivity evaluation of the outwash showed that changes to these conductivity values caused significant changes to the calibration residuals, but insignificant changes to groundwater flow patterns. Finally, the Wisconsin Till sensitivity evaluation showed changes to these conductivity values caused no concern regardless of the value of the input and the models calibration residuals and conclusion remain the same.

### 3.4.2 Flow Model Sensitivity to Recharge

Recharge to the water table is traditionally evaluated based on some percentage of the average annual rainfall in the area and landscape site cover and geomorphology. The site was broken down to include three general aerial zone(s) of recharge in the White River drainage basin, Total Regional (default), Outwash Alluvium, and Wisconsin Till. The total regional recharge zone and Outwash Alluvium zone are considered good for groundwater occurrence and recharge potential.

Deep Model - The deep model's regional recharge when varied from (+/-) 50 percent from the baseline value of 0.0016 ft/day (7 Inch/year), caused significant changes in the calibration residuals but insignificant changes in the model's conclusions. The Outwash Alluvium (baseline 0.0016 ft/day) and Wisconsin Till (baseline 0.00068 ft/day) sensitivity showed changes to the recharge value is of no concern because regardless of the value of the input, the conclusion remains the same. The slight difference in calibration residuals during the regional sensitivity analysis can be attributed the size of this zone and recharge uncertainty in the model domain.

Shallow Model - The shallow model's regional recharge when varied from (+/-) 50 percent from the baseline value of 0.0014 ft/day (7 Inch/year), caused significant changes in the calibration residuals but insignificant changes in the model's conclusions. The Outwash Alluvium (baseline 0.0014 ft/day) and Wisconsin Till (baseline 0.00068 ft/day) sensitivity results show there is no concern because regardless of the value of the input, the conclusion remains the same.

## 3.5 Flow Model Results

Each FFS scenario was simulated using changes to off-site conditions. The groundwater flow monitoring results are included in Appendix B-1 and are summarized on Table 3-1. Variations in input parameters were conducted so that the effectiveness of the remedial system during potentially changed conditions could be evaluated. The changed conditions included varying groundwater extraction rates at Rolls Royce (RR) Plant wells. The RR Plant wells varied from near-average extraction rates in September 2009 (11.2 million gallons) during calibration, to peak-demand monthly extraction rates of 20.5 million gallons that were observed in October 2014, September 2015, and September 2016. The peak demand months are high-lighted on Table 3-5. The off-site changed conditions analysis also simulated the shut-down of the RR wells, where no groundwater pumping was conducted.

### 3.5.1 Particle Tracking Analysis

Scenario 1 – simulates a cessation of the on-site groundwater pumping system, but without the installation of a containment (sparge) barrier. The flow modeling cannot assess the attenuation of the existing (and future) contamination plumes but can provide insight into the flow directions of groundwater in OU1 and OU5. Groundwater flow between Environmental Rd. and Minnesota St. appears to remain unchanged in that flow is ESE towards the RR production wells. This flow direction is mimicked north of Minnesota St. to approximate location of the Plant Office. Immediately north of the Plant Office to northern extent of Site operations, groundwater flow is more pronounced to the SE. These flow directions mimic regional groundwater flow patterns.

Particle tracking for both the current conditions and Scenario 1 (which simulates cessation of site pumping) indicates that groundwater flowing through the site will flow to and discharge at one of the three closest RR production wells (PW-1, PW-2, or PW-3) located at their Plant 8 facilities. The flow-paths are nearly identical for the high pumping case where particles emanating from the site are also captured by RR pumping wells PW-1, PW-2, or PW-3 (but are simply flowing faster). The only case where particles bypass Rolls' Plant 8 production wells PW-1, PW-2, or PW-3 is during simulation of the low-flow case. However, despite the bypass of the Plant 8 production wells, these particles are captured by the RR wells (PW-4, PW-5, or PW-6) that are located south and east of the Plant 8 wells off of Raymond Street.

Scenario 2 – Groundwater modeling was conducted using the current remedy of groundwater pumping while the RR wells are pumping. The groundwater pumping was enhanced with additional pumping wells to provide hydraulic control. Existing wells that were formerly used as pumping wells were input into the model, since they would be the most-likely candidates for additional groundwater extraction (even though they may require refurbishment or replacement).

The enhanced steady-state groundwater pumping is summarized as follows:

**Scenario 2 - Supplemental Pumping Rates for Enhance On-Site Pumping**

| Pumping Well ID | X Coordinate | Y Coordinate | Discharge | | Diameter of Well |
|---|---|---|---|---|---|
| | (ft) | (ft) | ($ft^3/d$) | (gpm) | (ft) |
| Deep Aquifer | | | | | |
| PW-1D (existing) | 173,499 | 1,637,354 | 8500 | 44 | 1 |
| PW-2D (existing) | 173,487 | 1,638,192 | 8500 | 44 | 1 |
| PW-3D (existing) | 173,087 | 1,638,721 | 2850 | 15 | 1 |
| PW-4D (existing) | 173,523 | 1,636,261 | 7200 | 37 | 1 |
| PW-5D (new) | 173,489 | 1,636,737 | 8850 | 46 | 1 |
| Shallow Aquifer | | | | | |
| PW-1S (existing) | 173,490 | 1,637,371 | 579 | 3 | 1 |
| PW-2S (existing) | 173,513 | 1,638,215 | 3654 | 19 | 1 |

The Scenario 2 modeling indicates that the cone of depression from the enhanced groundwater pumping system extends approximately 300 feet off-site into OU5. This is consistent with the simulations provided in the AME Groundwater Modeling memorandum (AME, 2011) as illustrated in Appendix A.

Enhanced groundwater pumping was increased until all of the particle tracks were captured by site pumping wells (existing or simulated). The capture zone extended about 400 feet south of Environmental Road. The remainder of the solar farm flows to RR production wells. Again, the same flow-path results were observed for the high-flow case. The low-flow case differed in that particles from the north portion of the solar farm were captured by site pumping wells, and particles in the southern portion of the solar farm were captured by RR pumping wells located southeast of Plant 8.

Scenario 3 – Barrier sparging has been demonstrated to be effective during pilot testing and, unlike groundwater pumping, treats groundwater at OU1 before it migrates into OU5. The sparge line will extend from approximately 150 feet south of RI-6D to the northern property line. Evaluation of the path lines produced for Scenario 3 (i.e., combined Scenario 1 & 3 simulations) indicates that there is complete coverage along the alignment of proposed containment (sparge) barrier remedy. Therefore, groundwater contaminants will be effectively contained within OU1 by utilizing biosparging to aerobically biodegrade benzene and pyridines.

Particle tracking for Scenario 3 (cessation of site pumping) is identical to Scenario 1, which indicates groundwater flowing through the site will flow to and most-likely discharge at one of the three closest RR production wells (PW-1, PW-2, or PW-3) located at their Plant 8 facilities.

### 3.5.2 Groundwater Flow Velocity Analysis

Groundwater flow modeling was conducted for three possible remedy scenarios, including the (1) No Action Scenario, (2) Enhanced Groundwater Pumping Scenario, and (3) Barrier (Sparge Curtain) Containment Scenario. As mentioned, the groundwater flow modeling simulations for Scenarios 1 and 3 are identical and are therefore grouped together with the results (of no on-site pumping) being applicable to each scenario. The specific groundwater simulations associated with each scenario are

outlined on Table 3-1. A summary of the resulting hydraulic gradients and average groundwater flow velocities are provided on Tables 3-7 and 3-8 for the deep and shallow units, respectively.

Groundwater flow velocities were calculated using the following relationship:

$$v = \frac{K * i}{n_e}$$

$v$ = average groundwater velocity (ft/d)
$K$ = hydraulic conductivity (ft/d)
$n_e$ = effective porosity (%)
$i$ = hydraulic gradient (*Δh/ΔL*); (ft/ft; *unitless*)

Hydraulic gradients were obtained directly from the flow model simulations. The effective porosity obtained through the contaminant transport model calibration to the observed water quality data (18%) were used to assess the predicted average groundwater velocity at two locations across the Site for each of the FFS Scenarios. The calibration of the contaminant transport model and determination of the 18% effective porosity is presented in Section 4.0.

The observed plume migration peaks used to calibrate the contamination transport modeling were also used in the groundwater velocity estimates. Groundwater velocity was calculated to be 0.15 ft/d in the FTP Area and at the VP Plant Area (DMP, 2017). Using this value, the hydraulic conductivity input for both hydraulic gradient sections (across the Site at Environmental Road and at Minnesota St.) could be back-calculated to match that observed groundwater velocity in the Scenario 0 (calibrated scenario). The back-calculated hydraulic conductivity was then used in the average groundwater velocity estimations for Scenarios 1, 2, and 3. For the deep model, the resulting hydraulic conductivities were 2.7 ft/d and 2.5 ft/d across the Site at Environmental Road and at Minnesota St., respectively. For the shallow model, the resulting hydraulic conductivities were 4.5 ft/d and 3.8 ft/d across the same locations. These hydraulic conductivities were slightly lower than the calibrated hydraulic conductivity zonations for both the deep model (4 ft/d) and shallow model (4.9 ft/d) along these flow paths.

The resulting average groundwater velocities for the Deep Unit are what would be expected. For Scenarios #1 and #3 along Environmental Road, the average groundwater velocities bracket the observed value (54.6 ft/d) with velocities ranging from 50.4 ft/d for the low seepage case, to 62.8 ft/d for the high seepage velocity case. Simulations suggest that typical conditions (i.e., consistent off-site pumping) may be slightly greater (57.1 ft/d) than calibrated conditions due to water level changes from termination of on-site pumping. The evaluation of groundwater heads across the Minnesota Avenue transect indicate there is a greater influence from the termination of on-site pumping but indicate slower groundwater velocities overall. It appears only the high seepage case (i.e., increased pumping at RR Plant) will have a higher groundwater velocity (55.8 ft/d) versus calibrated conditions (54.8 ft/d).

The remaining scenarios with no on-site pumping and similar or less groundwater withdrawals at RR Plant will result in lower groundwater velocities. Similar results are observed in the shallow unit. The highest predicted seepage rate will have a groundwater velocity of 71.9 ft/d.

### 3.5.3 Analysis of Groundwater Flow of in OU5

A flow modeling analysis was conducted to evaluate variations in groundwater flow directions off the northeast corner of the Site in the vicinity of monitoring well nests RI-11 and RI-15, and the sand and gravel pit Blue Lake. Blue Lake is located east of the RI-11 well nest as shown in Figure 1-1. The former sand and gravel pit has been filled-in in the area north of the RI-11 nest.

The analysis was conducted to evaluate how groundwater flow directions have changed over the past decade in this area to help explain the increasing benzene concentrations in monitoring well RI-15M. The COC concentrations, including ammonia, 3,5-Lutidine, and total pyridines, are observing steady declines or have stabilized below RAOs (DMP, 2017). Time-trend graphs showing the stability of these parameters at RI-11M and RI-15M are included in Appendix A-4. The benzene concentrations, however, have observed an increase over the past decade. Oddly, the concentrations have increased from concentrations that were less then detection levels (0.005 mg/L) between 1998 and 2005, to concentrations that currently exceed 0.020 mg/L. Prior to that, the highest observed concentrations decreased significantly in the mid-1990's after the installation of the groundwater pumping system. Due to the lack of other COCs besides benzene, it is possible that the increasing benzene concentrations at RI-15M are being caused by an off-site secondary source of the benzene and not related to the heritage benzene plume that was observed at RI-15M from 1994 to 1998.

A series of screen captures provided in Appendix D illustrate steady-state groundwater flow paths at the northeastern corner of the facility (about 300 feet east of RI-15 well nest) and roughly at the RI-11 well nest. Three steady-state simulations were conducted to evaluate groundwater flow directions at these locations based on changes in groundwater extraction taking place in OU1 and OU5 over time, including:

1) Pre-development flow paths (no on-site pumping, no RR production wells; no Olin-Brass production wells)
2) Flow paths observed during historical high periods of groundwater dewatering (with on-site pumping, with RR production wells, and with Olin-Brass production wells)
3) Current conditions (with on-site pumping, with RR production wells; no Olin-Brass production wells)

Under these scenarios, flow vectors continued to indicate a more southerly flow has occurred throughout the history of the Site. The azimuthal flows indicate the following flow vectors over time for each steady-state simulation: 1) E24˚S, 2) E45˚S, and 3) S35˚E. Thus, groundwater flow in the vicinity of RI-15D has changed 31˚to the south based primarily on the continued pumping at RR Plant No. 8 and the cessation of pumping of the Olin-Brass wells. While off-site migration occurred historically in the vicinity of RI-15M (as indicative of COC exceedances), the change in groundwater flow conditions – from the period of time when Olin-Brass wells were pumping, to the cessation of Olin-Brass pumping – does not support the Site as a source of increasing benzene concentrations since current flow conditions indicate a much more southerly flow than in the past.

During the periods of heavy groundwater withdrawals from Olin-Brass, the COC plume was likely pulled into the till deposits underlying the medium sand unit in OU5. However, if the benzene concentrations are back-diffusing from the underlying till back in to the medium aquifer, increases in pyridines would also be expected. Pyridines, however, have observed stabilized concentrations over the past five years after significant decreases were observed from 2009 through 2012 at RI-15M.

# 4.0 Contaminant Transport Modeling

AECOM utilized the GFLOW modeling contours to re-evaluate previously completed contaminant transport modeling included in the FFS for ammonia, benzene, and total pyridines in OU5. Several one-dimensional analytical model simulations were developed to address changes in hydraulic gradients, stratigraphy, and lithology within OU5. Contaminant transport modeling was conducted using the analytic advection-dispersion code POLLUTE (Rowe and Booker, 1990). POLLUTE was developed by the Geotechnical Research Center of the University of Western Ontario (Rowe and Booker, 1990) and is a well-documented code for completing groundwater impact assessments. This contaminant transport code was used primarily to evaluate the length of time until offsite groundwater concentrations reach RAOs.

## 4.1 Transport Modeling Code and Rationale

POLLUTE is a one-dimensional (1-D) semi-analytical program which uses numerical inversion of the Laplace transform to solve the following 1-D dispersion advection equation for porous media:

$$n\frac{\partial c}{\partial t} = nD\frac{\partial^2 c}{\partial^2 z} + nv\frac{\partial\ c}{\partial\ z} - n v_x \frac{\partial c}{\partial x} - \rho K_d \frac{\partial c}{\partial t} - n\lambda c$$

where:

| | | |
|---|---|---|
| c | = concentration at point (x,z) where c = c(*x,z,t*) | [$ML^{-3}$] |
| $D_x$ | = coefficient of hydrodynamic dispersion in x direction | [$L^2T^{-1}$] |
| $\bar{v}_x$ | = groundwater (seepage) velocity in x direction | [$LT^{-2}$] |
| n | = porosity of the soil | [$L^3L^{-3}$] |
| ρ | = dry density of the soil | [$ML^{-3}$] |
| $K_d$ | = distribution/partitioning coefficient | [$L^3M^{-1}$] |
| λ | = decay constant of the contaminant species | [$T^{-1}$] |

This model provides for and assumes:

1) advective, as well as, diffusive transport
2) one-dimensional transport in a horizontal or vertical orientation
3) multiple time and distance solutions to the transport equation
4) retardation of non-conservative constituents
5) a transport solution with no space or time discretization errors
6) Fick's Law applies to solute dispersion within the deposit
7) Sorption of a non-conservative species of contaminant can be modelled as a linear relationship, such that sorption in the advection-dispersion equation is defined as:

$$S = (K_d)\ c$$

where:

| | | |
|---|---|---|
| $K_d$ | = distribution/partitioning coefficient | [$L^3M^{-1}$] |
| c | = concentration of contaminants | [$ML^{-3}$] |

8) Multiple layers with different properties may be specified. It is assumed that there is continuity of concentration and flux at the boundary between two layers assuming there is sufficient diffusion to adequately "move" the contaminant across the layer boundary.

POLLUTE has been widely applied throughout United States, Canada, Europe, Australia and New Zealand. Predicted results from POLLUTE have compared favorably to other numerical transport models and analytical solutions (Rowe and Booker, 1990). POLLUTE was specifically selected for this project for a variety reasons, including:

- Accuracy of solution;
- Extent of verification using comparison to analytic solutions, other numerical models, and observed conditions;
- Ability to independently model molecular diffusion and mechanical dispersion;
- Ability to assess contaminant migration as a function of gradient variations; and
- Ability to obtain an accurate contaminant transport solution without space and time discretization constraints.

As mentioned, the primary objective of the advection/dispersion modeling was to predict the timeframes associated with natural attenuation of legacy contamination within OU5 assuming onsite COC concentrations meet RAOs at the sparge barrier. This was accomplished by making several POLLUTE simulations across OU5, including two cases in the deep hydrostratigraphic unit (Deep Unit - Case 1 and Case 2), and one case in the shallow hydrostratigraphic unit (Shallow Unit - Case 3). The natural attenuation processes have been demonstrated through predicted concentration versus distance plots at yearly intervals.

To adequately express the geology and hydrogeology of the Site within the context of a contaminant transport model, some simplifications to the site geology and hydrogeology were necessary. These assumptions are discussed below:

1. All geologic units and earthen structures are homogeneous and isotropic with respect to all lithologic and hydrologic parameters — Most contaminant transport models are incapable of working with the small-scale changes for these parameters that are seen within many geologic materials. Sensitivity analyses performed over the observed range of values provide an adequate examination of the effects of this variability.
2. The aquifers are of uniform thickness and is laterally extensive.
3. Geologic and hydrologic parameters used are mean values of site-specific data, or mean values taken from the literature for similar materials. Ranges for these values are also taken into consideration — The mean values analyzed provide a reasonable analysis of the site conditions. Transport through a geologic unit with a high variability of hydraulic conductivity, transmissivity, porosity, and other properties will actually produce an "average" movement through the geologic unit.
4. Groundwater Flow - transport of constituents through the local aquifers is assumed to be horizontal.
5. Unforeseen Conditions - Potential changes in heads due to weather, storm water runoff, and other unforeseen flux changes are short duration variations which are considered inconsequential in terms of the modeling simulations.

The transport model was calibrated using historically observed ammonia concentrations. Sensitivity analyses were then completed to assess the changes in results based on variations in modeling input parameters. The goal of the sensitivity analyses was to develop a set of conservative conditions that result in the worst-case length of time for off-site concentrations to continue to exceed their respective ROA performance standards.

## 4.2 Calibration of 1-D Transport Model

Inputs to the contaminant transport model were largely established by matching the observed ammonia concentrations versus time observed at monitoring wells RI-33S, RI-35S and RI-6S, which

are located downgradient from the Former Treatment Pit (FTP) on the Vertellus property as illustrated in the existing sparge figures included in Appendix C-1. Wells RI-33S and RI-6S were used to calibrate the 1-D model since they are positioned parallel to groundwater flow (along the same travel path line), are in the same hydrostratigraphic unit, and had applicable data. Calibration involved using the groundwater (seepage) velocity determined using the ammonia concentration spikes observed in the groundwater data. Since ammonia is soluble in groundwater, the rate of transport of ammonia in groundwater is used as a proxy to determine the groundwater velocity. Key calibration parameters based on observations included: seepage velocity, dry density, effective porosity, and distribution coefficient. The calibrated GFLOW velocity (55 ft/yr) matched well to the average groundwater seepage velocity from the ammonia data (59 ft/yr).

The highest ammonia concentration peak at well RI-33S was observed in February 2002 (Appendix C-1). The related ammonia concentration spike at downgradient well RI-6S was observed just over eight years later in March 2010. These observed concentration spikes provide numerous inputs for use as calibration targets, including:

- Distance between the monitoring wells (477 ft or 145 m),
- Time between the high concentration peaks (8.1 years),
- Resulting average groundwater seepage velocity (58.9 ft/yr or 17.96 m/yr), and
- Concentration targets at each monitoring well (75 mg/L at RI-33S; 37 mg/L at RI-6S).

POLLUTE concentration vs. distance plots were used to adjust unknown inputs to “calibrate” the 1-D model. It was found that the observed concentration profile could be visually matched fairly well when the Year 3 and Year 11 (8-year travel time) simulated spikes in concentration from an upgradient source were used to match observed data at RI-33S and RI-6S, respectively.

Downgradient from RI-33S, the model was divided into five layers that varied from 25.9 to 30.5 m (or 85 ft to 100 ft). While the number and distance of each layer was arbitrary, the resulting horizontal dispersivity (which is based on the scale of flow length) proved to provide a reasonable match to observed concentration data. Within each layer, sublayers were added such that each sublayer represented about 10 feet along the flow path. This allowed for numerous calculations of concentration along the flow path. The output boundary concentration was set as an infinite bottom layer. Both boundary conditions reasonably represent actual site conditions.

Dry density was estimated with known inputs using the following relationship between the porosity and void ratio:

Using the following assumptions,

$n$ = total porosity (25% from RI data)
$G_s$ = specific gravity of sand & gravel outwash (2.65 g/cm3)
$\rho_w$ = density of water (1,000 kg/m^3)

void ratio ($e$) can be calculated, and

$$e = \frac{n}{1-n} = \frac{0.25}{1-0.25} = 0.33$$

used in the calculation of dry density ($\rho_d$):

$$\rho_d = \frac{G_s * \rho_w}{1+e} = \frac{2.65 * 1000}{1+0.33} = 1{,}993\ kg/m^3\ or\ equivalent\ to\ 2.0\ g/cm^3$$

Based on this calculation, a dry density of 2.0 g/cm$^3$ was used in the contaminant transport modeling.

Thus, the final (and significant) 1-D modeling input parameter that was evaluated during the calibration process was effective porosity. Effective porosity was an important component of the 1-D calibration, since the porosity determined from the RI data and used in previous modeling (25%) was scrutinized during the groundwater modeling progress meeting on November 27, 2018. An effective porosity of 18% (i.e., about one-third less than total porosity), was found to match the on-site ammonia data while other parameters were able to be held constant since they were known quantities. Modifications to effective porosity – either higher or lower – resulted in a less accurate model due to the shift from the match of the observed ammonia concentration spikes.

Effective porosities are typically in the range of 20% less than total porosity in medium-grained sands (Walton, 1988). Therefore, the effective porosity of the outwash, which was calibrated to be 18%, is calculated to be nearly 30% less than total porosity. This value is considered to be conservative (lower porosity increases the groundwater velocity) since, some of the effective porosity ratios found in literature for sands are less than 20% of a reduction of total porosity. The output from the 1-D calibrated model is illustrated in Figure 4-1. Inputs used to obtain the 1-D model calibration were evaluated through sensitivity analysis of the calibrated model, which are described in the following section.

## 4.3 Transport Model – Sensitivity Analyses

Prior to advection/dispersion modeling in OU5, sensitivity analyses were completed to assess impact of variables on the concentration and position of spikes within the simulated ammonia plume. The systematic analysis of inputs was used to evaluate how the match to the observed data varied based on changes to input parameters. This process verified that calibrated inputs are appropriate for use in evaluating natural attenuation times in OU5. A summary table of the sensitivity analyses, as well as graphs of changes to modeling inputs are provided in Appendix C-2.

Results of the sensitivity analyses indicate the following:

- Dry density was observed to have low sensitivity at the calibrated seepage velocity. Dry density varied from 1.0 to 3.0 g/cm$^3$ for which there was negligible change in the distance between observed peaks and less than 0.1% change to their respective concentrations. However, it was noted that as seepage velocity increased, dry density became more sensitive.
- Variation of effective porosity has a small impact to the results of the calibration runs. Effective porosity is an independent input parameter within POLLUTE. However, it is also used in the formula to calculate Darcy velocity and horizontal mechanical dispersion as shown in the hand-calculations included in Appendix C-1. Therefore, a modification to effective porosity changes the Darcy velocity value, but horizontal mechanical dispersion value remains the same.
- It was found that a decrease in effective porosity decreases the distance between peaks. However, variation of the effective porosity input by itself is not very sensitive. Changes in Darcy velocity is more sensitive.

  The distance between the simulated peaks of the plume and the simulated concentrations between wells R33S and RI-6S (and the difference of concentrations) vary more – by percentage – to the percentage of change to the input. Since the Darcy velocity (seepage velocity * effective porosity) is the most sensitivity parameter to calibrate to the distance between the peaks and seepage velocity is based on observed data, an effective porosity of 18% appears to be an accurate estimation.
- Distribution coefficients ($K_d$) were found to have a significant impact at the calibrated Darcy velocity. As $K_d$ is increased, the peak concentrations were less, but were broad - occurring

over a longer period of time. The distribution coefficient was maintained at zero for modeling of ammonia, but small inputs of $K_d$ were applied to benzene and total pyridines.

## 4.4 Transport Model – Natural Attenuation Modeling Inputs

Starting concentrations within OU5 were varied off of the highest concentrations observed over the three most recent years of groundwater monitoring from March 2016 through September 2018. The last three years of concentrations of ammonia, benzene, and total pyridines are summarized on Table 4-1 and 4-2 for the deep and shallow hydrostratigraphic units, respectively. This dataset allowed for a conservative estimate of existing concentrations (by using the highest concentrations) while using the most-current (last three years) worth of data. Several additional simulations were then conducted using a percentage change (i.e., +25%, -50%, -75%) from the maximum observed concentrations (2016-2018) to develop the natural attenuation curves.

A summary of the initial concentration profiles that include the interval distance, maximum observed concentration (2016-2018), and percentages from the max concentration are included on Tables 4-3 and 4-4 for the Deep and Shallow hydrostratigraphic units, respectively. In some cases, the highest concentration was observed at an on-site monitoring well, but in other cases, higher concentrations were observed in an OU5 monitoring well. A spatial depiction of the maximum concentrations observed over the past three years (2016-2018) of the deep and shallow hydrostratigraphic units are illustrated on Figures 4-2 and 4-3, respectively.

The two flow paths that were considered for the deep hydrostratigraphic unit include: Run 1) a centrally located flow path that corresponds to the location where the highest concentrations are generally observed in OU1 for benzene and total pyridines and flow in close proximity to monitoring well RI-19D; and Run 2) a northern flow path that considers the northern-most flow path of particles that may be emanating on-site and flow in close proximity to monitoring wells RI-11M/D and R-15M/D. This northern flow path was included as requested by USEPA (in a December 19, 2019 email).

An additional flow path was conducted for the shallow hydrostratigraphic unit (Run 3). Although existing COC concentrations in the shallow hydrostratigraphic unit are already lower than RAOs in OU5, the shallow simulation (Run 3) conservatively considers the migration of existing OU1 COC concentrations. The shallow flow path emanates from just north of the facility entrance and considers the current OU1 exceedances for benzene (0.0528 mg/L at PW-2S) and total pyridines (0.507 mg/L at RI-4S).

Input parameters were kept as consistent as possible to the calibrated model. Layer distances for each path line were adjusted so that the POLLUTE sublayer thickness was similar to the calibrated model (3 to 5 meters) and similar for each path line. Fifteen layers were used to achieve the goal sublayer thickness, which is to stay below the POLLUTE-controlled maximum 200 sublayers. The upgradient boundary condition was set as a constant concentration at the RAO levels. For example, the source water coming from OU1 to OU5 was set at a constant source concentration of 30 mg/L for ammonia. Therefore, the models conservatively assume that dispersion/diffusion was not occurring at concentrations less RAOs. Half-lives for benzene, pyridine, and ammonia were held consistent at 3.5 years, 6 years and 100 years, respectively, to inputs used in the 2017 FFS (DMP, 2017).

Additional POLLUTE inputs summarized on the data input sheets included in Appendix C-3 include: Darcy velocity, hydrodynamic dispersion coefficient, mechanical dispersion coefficient, dispersivity, and the distribution coefficient ($K_d$). These are described below:

Darcy velocity ($V_a$) is defined as:

$$V_a = n_e * v$$

where,
$n_e$ = effective porosity (18%)
v = seepage (groundwater) velocity

It is used to calculate the mass of contaminant transported by advection per unit area per unit time, given by:

$$f = V_a * c = n_e * v * c$$

where,
f = mass flux
c = concentration of the contaminant

POLLUTE requires the input of hydrodynamic dispersion coefficients for each model layer in the horizontal direction. The hydrodynamic dispersion coefficient is calculated by the following formula:

$$D_h = D_m + D_d$$

where,
$D_h$ = the hydrodynamic dispersion coefficient,
$D_m$ = the coefficient of mechanical dispersion, and
$D_d$ = the effective diffusion coefficient

The coefficient of mechanical dispersion is calculated using the following formula:

$$D_m = \alpha\left(\frac{V_a}{n_e}\right)$$

where,
$D_m$ = coefficient of mechanical dispersion,
α = dispersivity,
$V_a$ = Darcy velocity, and
$n_e$ = effective porosity (18%)

Therefore, substitution of the mechanical dispersion coefficient formula yields the following formula for hydrodynamic dispersion:

$$D_h = \alpha\left(\frac{V_a}{n_e}\right) + D_d$$

Horizontal dispersivity was calculated using the guidance provided in Gelhar, et. al., (1992). If the scale is less than 100 meters, one-tenth of the scale is used to determine dispersivity. If the scale is greater than 100 meters, the equation provided by Xu and Eckstein (1995) is used:

Horizontal dispersivity = (0.83*log scale^2.414)

The modeling of ammonia assumed that no attenuation due to sorption or retardation of contaminants occurred (i.e., $K_d$ =0) and the high diffusion coefficient 0.019 $m^2$/yr. The distribution coefficient ($K_d$) of benzene and pyridines (0.036 $cm^3$/g) was calculated based on the observed values (or calculated values of observed data) of Retardation (R), dry density ($\rho_d$), and effective porosity ($n_e$) using the following relationship (Rowe, Quigley, Brachman, and Booker, 1995):

$$R = 1 + (\rho_d * K_d)/n_e$$

where

R = 1.4 (from FFS *DMP, 2017*)

$\rho_d$ = 2.0 g/cm$^3$

$n_e$ = 18%

The $K_d$ for benzene was further evaluated due to the greater availability of retardation references. This information was used to estimate $K_d$ using the following equation:

$$K_d = K_{oc} \times f_{oc}$$

where

$K_{oc}$ = organic carbon partition coefficient

$f_{oc}$ = fraction of organic carbon in soil (as %)

A $K_{oc}$ of 61.7 L/kg was obtained from USEPA documentation (USEPA, 2008). While no organic content was found within historical site reports, a conservative fraction organic content ($f_{oc}$) of 0.06% was developed as a lower interval of available references of alluvial aquifers. As reported in ITRC (2015), alluvial aquifers generally averaged $f_{oc}$'s that were nearly an order of magnitude greater than 0.06%. Thus, the $K_d$ for benzene is considered to be conservative. The distribution coefficients used for each constituent is summarized in the data input tables for each of the simulations (Appendix C-3).

## 4.5 Transport Model – Natural Attenuation Modeling Results

The primary objective of the advection/dispersion modeling was to establish a range of timeframes associated with natural attenuation of legacy contamination within OU5. The timeframes were established by varying starting concentrations throughout the simulated migration path line. The range of starting concentrations were based on the maximum concentrations observed from 2016 to 2018 and offsets from them. The natural attenuation modeling results are summarized in Table 4-4 and graphically depicted on Figures 4-4A, 4-4B, and 4-5C for benzene, pyridines, and ammonia, respectively.

The natural attenuation curves presented on Figures 4-4A and 4-4B are presented on semi-log graphs that highlight the logarithmic trends of how attenuation times increase with increasing starting concentrations. Each simulated case for benzene and pyridine (i.e., Run 1, Run 2, and Run 3) all indicated very similar trends. Thus, the modeling results are scalable so that attenuation times can be used as a tool to evaluate future sampling results. For example, the most recent concentrations, which are labeled on each of the Figures (4-4A – 4-4C), are lower than the highest concentrations observed from 2016-2018. Therefore, natural attenuation times can be evaluated as new (lower) data are collected.

Using the most recent concentrations from September 2018, the estimated time for natural attenuation process to occur and result in COC concentrations below the respective RAO is from less than 8 years for pyridines, about 9 years for ammonia, and 19 years for benzene. The longest estimated time for natural attenuation to reach RAO (19 years) is for benzene in the deep aquifer at the Run 1 location that emanates near RI-4D. The long duration required to attenuate this constituent at this location is primarily due to the high concentration of 0.779 mg/L, which is many times larger than the RAO.

While the attenuation curves for Run 2 and Run 3 for ammonia (Figure 4-4C) do not correlate as well as the benzene and pyridines for the different runs, the general trends are linear. The ammonia attenuation curves vary from the benzene and pyridines curves due to the addition of retardation and decay of the latter.

The Darcy velocity used in POLLUTE simulations (3.13 m/yr) was based on the observed groundwater velocity between wells RI-33S and RI-6S within OU1 (0.15 ft/d or 0.046 m/d) and the calibrated effective porosity value of 18%. The darcy velocity used in the natural attenuation modeling was adjusted slightly (e.g. from 3.02 m/yr to 3.13 m/yr) to better match the concentration spikes observed in RI-6S. Note that the calibrated darcy velocity (3.13 m/yr) was higher than what the observed average linear velocity would have indicated (i.e., 3.02 m/yr). Considering average linear velocity is a field-measured parameter, it would be anticipated that effective porosity be adjusted higher to match the observed data. A higher effective porosity of 18.6% would be required to match the observed data. However, effective porosity was not increased and therefore is considered conservative for transport simulations.

As discussed in Section 3, based on the hydraulic conductivity testing, relative yield from extraction wells, as well as the conceptual site model, the hydraulic conductivity in OU5 is higher than OU1. To assess the possibility of faster solute flow within OU5, a Darcy velocity of 4.7 m/yr (50% higher than the calibrated rate) was used to simulate benzene migration at the Run 1 location. The resulting curve indicates slightly faster attenuation times as illustrated on Figure 4-4A.

# 5.0 Discussion of Modeling Results

## 5.1 Flow Model Uncertainty Analysis

There are uncertainties in the groundwater flow field simulated by a numerical model. These uncertainties are due to the simplifications and assumptions in the design of the model, uncertainty in the boundary conditions and input parameters, as well as the uncertainty of the error range of the calibration to the observed groundwater flow systems.

The uncertainty in the recharge rate is relatively low. Groundwater recharge rates in the White River Basin have been extensively studied and a relatively tight range of recharge rates are available. Some uncertainties exist due to the simplifications and assumptions in the application of recharge, since local recharge rates can vary significantly due to variations in topography, vegetation, soil characteristics, and the extent of development of the land surface.

The uncertainty in the hydraulic conductivity data and zonations in the model are also believed to be relatively low. In-situ hydraulic conductivity tests have been performed in the model area and have been calibrated to in previous models (AME, 2011). In addition, extensive sensitivity analyses were performed with various hydraulic conductivity zones to assess the uncertainty of the hydraulic conductivity zonations used in calibration. Parameter optimization in the model was also performed on various K-zones. PEST was used internally in GFLOW to estimate new sets of parameters by comparing model results to a set of observations. Parameter estimation provided valuable insight into the conceptual model, calibration, and uncertainty of input values. Hydraulic conductivity of select zones were optimized by bracketing RI conductivity values to find a best-fit residual error. By in large, uncertainty of hydraulic conductivity inputs was reduced by an order of magnitude when compared to the AME (2011) model since a lower range of conductivity values were used in the AECOM models (i.e., approximately 1 to 250 ft/d) versus the AME model (0.1 to 250 ft/d).

In general, the uncertainty of the groundwater models is low, since relatively complete datasets of local recharge, site-specific hydraulic conductivity, site-specific groundwater elevations, as well as groundwater discharge rates, were available. The primary source of uncertainty lies within the conceptual geologic model and the understanding of upgradient conditions where White River outwash deposits pinch out and the aquifer units are intertill sand and gravel deposits. However, this uncertainty is not significant, since the outwash units are still predominant at the Site.

## 5.2 Conservative Assumptions in Contaminant Transport Models

The natural attenuation evaluation contained some conservative assumptions. Thus, there are a number of reasons why the length of time the COCs will take to reach RAOs is not believed to be underestimated, as follows:

- Longitudinal dispersivity is low due to the small flow length scale (100 feet) used to calculate dispersivity. This prevented overestimation of dispersivity values.
- Flow paths of 1-D modeling were considered at transects that corresponded to locations where the highest COC concentrations were generally observed.
- The limited flow lengths were considered, so dispersivity values were not over-estimated.
- Constant upgradient source concentrations were set to RAO levels. This conservatively assumed that dispersion/diffusion was not occurring at concentrations less than RAOs.
- Retardation and decay of ammonia were not considered.

# 6.0 Conclusions

## 6.1 Groundwater Flow Modeling Conclusions

The modelled FFS Scenarios not only considered on-site hydraulic changes (e.g., enhanced and ceased pumping conditions), but also considered off-site changed conditions. Despite dramatic changes to the groundwater extraction rates at RR Plant wells (e.g., continually pumping at peak rates and long-term shut-down), flow modeling results indicate that source areas within OU1 will be contained (hydraulically contained through dewatering or treated through biosparge barrier).

**Adaptation to FFS Scenarios**

- FFS Scenario 1 – Groundwater flow between Environmental Rd. and Minnesota St. appears to remain unchanged in that flow is ESE towards the RR production wells. This flow direction is mimicked north of Minnesota St. to approximate location of the Plant Office. Immediately north of the Plant Office to northern extent of Site operations, groundwater flow is more pronounced to the SE.
- FFS Scenario 2 – Simulations of enhanced groundwater pumping using additional OU1 pumping wells required the use of five total extraction wells (PW-1D, PW-2D, PW-3D, PW-4D, and PW-5D) averaging about 37 gpm in each well (or a total of 186 gpm to maintain hydraulic containment. Two additional pumping wells (PW-1S and PW-2S) totaling 22 gpm were required to maintain hydraulic containment in the shallow aquifer. Existing wells that were formerly used as pumping wells were input into the model, since they would be the most-likely candidates for additional groundwater extraction. The Scenario 2 modeling indicates that the cone of depression from the enhanced groundwater pumping system extends approximately 300 feet off-site into OU5, which is consistent with the simulations provided in the AME Groundwater Modeling memorandum (AME, 2011).
- FFS Scenario 3 – Evaluation of the path lines produced for Scenario 3 indicates that there is complete coverage along the alignment of proposed containment (sparge) barrier remedy to aerobically biodegrade benzene and pyridines. Therefore, groundwater contaminants will be effectively contained within OU1.

**Simulated Groundwater Velocities**

Average groundwater velocities indicate that all simulated flow model scenarios bracket the observed value (54.6 ft/d) with velocities ranging from 50.4 ft/d for the low seepage case, to 62.8 ft/d for the high seepage velocity case. Simulations suggest that typical conditions (i.e., consistent off-site pumping) may be slightly greater (57.1 ft/d) than calibrated conditions due to water level changes from termination of on-site pumping. The evaluation of groundwater heads across the Minnesota Avenue transect indicate there is a greater influence from the termination of on-site pumping but indicate slower groundwater velocities overall. It appears only the high seepage case (i.e., increased pumping at RR Plant) will have a higher groundwater velocity (55.8 ft/d) versus calibrated conditions (54.8 ft/d).

The remaining scenarios with no on-site pumping and similar or less groundwater withdrawals at RR Plant will result in lower groundwater velocities. Similar results are observed in the shallow unit. The highest predicted seepage rate will have a groundwater velocity of 71.9 ft/d.

**Analysis of Groundwater Flow of in OU5**

A flow modeling analysis was conducted to evaluate variations in groundwater flow directions off the northeast corner of OU1 in the vicinity of monitoring well nests RI-11 and RI-15. The changes in flow directions indicate the groundwater flow in the vicinity of RI-15D has changed 31˚to the south over the past decade based primarily on the continued pumping at RR Plant No. 8 and the abandonment of the Olin Brass high-capacity wells.

During the periods of heavy groundwater withdrawals from Olin-Brass wells completed in the deep aquifer, the COC plume was likely pulled into the till deposits underlying the medium sand unit in OU5. Upon shutting down these withdrawals, the downward gradient through the underlying till unit would decrease and the existing plume would be maintained within the medium unit. This scenario may explain slight increases in benzene concentrations. However, if the benzene concentrations are being maintain in the medium aquifer rather than being pulled into the underlying till, increases in ammonia and pyridine concentrations would also be expected. Ammonia and pyridines concentrations, however, have been observed to be fairly stable. Pyridine concentrations over the past five years have stabilized after significant decreases were observed from 2009 through 2012 at RI-15M. Due to the change in flow direction and lack of correlation with other COCs, the increasing benzene concentrations at RI-15M do not appear related to the heritage contaminant plume that was observed at RI-15M from 1994 to 1998, but rather from a secondary off-site source.

## 6.2 Conclusions from 1-D Natural Attenuation Modeling

Attenuation times rapidly increase with higher starting concentrations. Each simulated case for benzene and pyridine (i.e., Run 1, Run 2, and Run 3) all indicated very similar trends and can be used to assess attenuation times at different starting concentrations. Using the most recent dataset (September 2018 concentrations), the estimated time for natural attenuation process to occur and result in COC concentrations below their respective RAO is less than 8 years for pyridines, 9 years for ammonia, and 19 years for benzene. The longest estimated time for natural attenuation to reach RAO (19 years) is for benzene in the deep aquifer at the Run 1 location that emanates near RI-4D. The long duration required to attenuate this constituent at this location is primarily due to the high concentration of 0.779 mg/L, which is many times larger than the RAO.

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# Tables


| | |
|---|---|
| Table 3-1 | Groundwater Flow Modeling Evaluation Matrix |
| Table 3-2 | Hydraulic Conductivity Testing Results |
| Table 3-3 | Predicted vs. Observed Head Calibration Results - Deep Aquifer Model |
| Table 3-4 | Predicted vs. Observed Head Calibration Results - Shallow Aquifer Model |
| Table 3-5 | Summary of Recent Groundwater Withdrawals from Rolls-Royce Plant #8 |
| Table 3-6 | Comparison of Average Groundwater Discharge from Outwash |
| Table 3-7 | Groundwater Flow Velocity Assessment in OU1 (Deep Unit) |
| Table 3-8 | Groundwater Flow Velocity Assessment in OU1 (Shallow Unit) |
| Table 4-1 | Recent Concentrations for OU5 Natural Attenuation Evaluation – Deep Hydrostratigraphic Unit |
| Table 4-2 | Recent Concentrations for OU5 Natural Attenuation Evaluation – Shallow Hydrostratigraphic Unit |
| Table 4-3 | Initial Concentration Profiles for 1-D Modeling - Deep Hydrostratigraphic Unit |
| Table 4-4 | Initial Concentration Profiles for 1-D Modeling - Shallow Hydrostratigraphic Units |
| Table 4-5 | Results of Natural Attenuation Analysis in OU5 |

# Table 3-1
## Groundwater Flow Modeling Evaluation Matrix
Former Reilly Tar - Focused Feasibility Study

| Groundwater Flow Modeling Evaluation Matrix | RR Wells (Ave. Pumping Case) | RR Wells (High Pumping Case) | RR Wells (Cease Pumping Case) | Label | Description |
|---|---|---|---|---|---|
| FFS Scenario #1<br>No Action (Cease On-Site Pumping) | X | | | Sc1-3_A | Scenario #1 &#3 Baseline; No On-Site Pumping, Consistent withdrawals at RR Plant 8 |
| | | X | | Sc1-3_B | No On-Site Pumping, Increased Pumping at RR Plant 8 |
| | | | X | Sc1-3_C | No On-Site Pumping, Cease Pumping at RR Plant 8 (Low Seepage Velocity Case) |
| FFS Scenario #2<br>Enhanced On-Site Pumping | X | | | Sc2_A | Scenario #2 Baseline; Enhanced Site Pumping, Consistent withdrawals at RR Plant 8 |
| | | X | | Sc2_B | Enhanced Site Pumping, Increased Pumping at RR Plant 8 (High Seepage Velocity Case) |
| | | | X | Sc2_C | Enhanced Site Pumping, Cease Pumping at RR Plant 8 |
| FFS Scenario #3<br>Sparge Barrier (Cease On-Site Pumping) | X | | | Sc1-3_A | Same as FFS Scenario #1 |
| | | X | | Sc1-3_B | Same as FFS Scenario #1 |
| | | | X | Sc1-3_C | Same as FFS Scenario #1 |

Notes:
An "X" indicates the components that will be included in the groundwater flow simulation.
FFS = Focused Feasibility Study Remedial Alternative
RR = Rolls Royce Plant No. 8 Production Wells

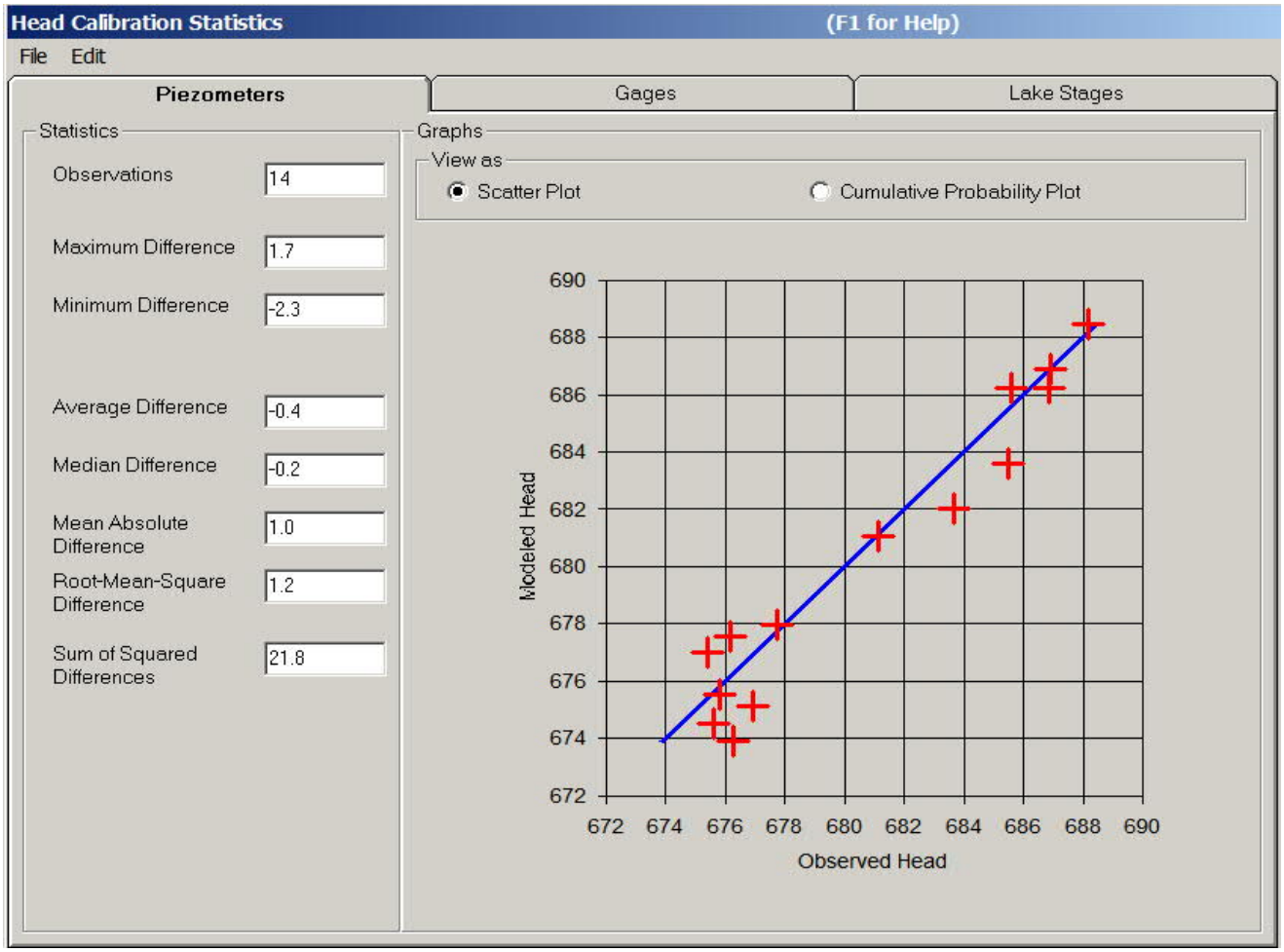
The RR Average Pumping Case are the withdrawal rates from Sept 2009 that were used in the calibration of both the AECOM 2018 model and the August-Mack 2009 groundwater models.
The RR High Pumping Case uses the high monthly withdrawal rates reported from 2015 through 2017.
The RR No-Pumping Case has been included to evaluate groundwater flow directions and seepage velocities to consider a temporary or permanent shutdown of the Plant.

# Table 3-2
# Hydraulic Conductivity Testing Results
Table 3-4 from August-Mack (2010)

| Well I.D. | Hydraulic Conductivity (RI Results - ENSR, 1990) | |
|---|---|---|
| | (cm/sec) | (ft/d) |
| Medium & Deep Unit | | |
| RI-1D | 1.37E-03 | 4 |
| RI-2D | 3.20E-02 | 91 |
| RI-3D | 1.75E-03 | 5 |
| RI-5S | 7.89E-02 | 224 |
| RI-5D | 9.01E-03 | 26 |
| RI-6D | 2.51E-02 | 71 |
| RI-7D | 2.00E-02 | 57 |
| RI-9D | 2.17E-03 | 6 |
| RI-10D | 2.15E-02 | 61 |
| RI-11M | 3.28E-02 | 93 |
| RI-11D | 3.08E-02 | 87 |
| RI-12D | 2.53E-02 | 72 |
| RI-15D | 1.10E-02 | 31 |
| RI-16D | 3.77E-02 | 107 |
| RI-17D | 6.41E-03 | 18 |
| RI-18D | 8.28E-04 | 2 |
| RI-19D | 1.94E-02 | 55 |
| RI-20D | 2.59E-02 | 73 |
| RI-21D | 1.48E-04 | 0.4 |
| RI-22D | 4.02E-02 | 114 |
| Min. | 1.48E-04 | 0.4 |
| Max. | 7.89E-02 | 224 |
| GeoMean: | 1.0E-02 | 29 |
| Shallow Unit | | |
| RI-16S | 6.44E-02 | 183 |
| RI-17S | 2.83E-02 | 80 |
| RI-18S | 8.38E-03 | 24 |
| RI-19S | ND | ND |
| RI-20S | ND | ND |
| RI-21S | 2.83E-02 | 80 |
| RI-22S | ND | ND |
| Min. | 8.38E-03 | 23.8 |
| Max. | 6.44E-02 | 183 |
| GeoMean: | 2.6E-02 | 73 |

# Table 3-3
## Predicted vs. Observed Head Calibration Results
[Deep Aquifer Model]

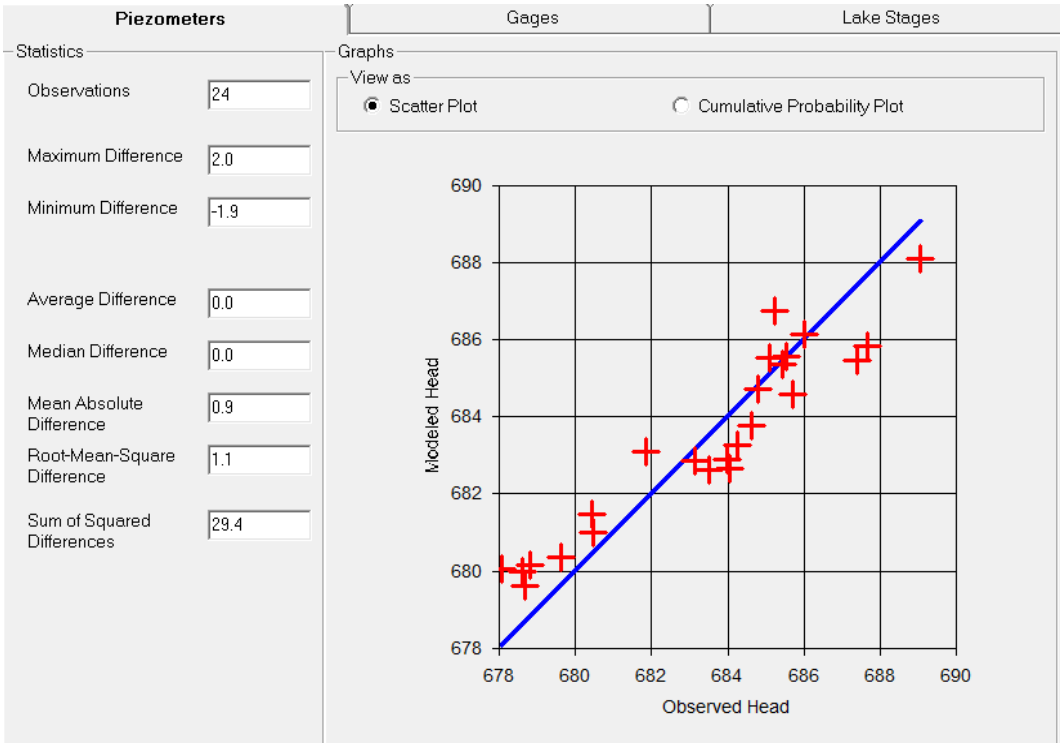
| Calibration Point | Location | | Observed Head | Model Head | Head Difference |
|---|---|---|---|---|---|
| | X (ft) | Y (ft) | (Ft MSL) | (Ft MSL) | (ft) |
| RI-1D | 172,222 | 1,637,556 | 688.16 | 688.45 | 0.293 |
| RI-2D | 172,875 | 1,638,785 | 686.87 | 686.23 | -0.638 |
| RI-3D | 173,213 | 1,638,830 | 685.50 | 683.60 | -1.897 |
| RI-5D | 173,568 | 1,636,959 | 675.82 | 675.52 | -0.302 |
| RI-9D | 173,022 | 1,634,765 | 677.71 | 677.97 | 0.257 |
| RI-10D | 174,157 | 1,639,338 | 676.16 | 677.58 | 1.423 |
| RI-11M | 174,929 | 1,638,254 | 675.58 | 674.54 | -1.039 |
| RI-15M | 174,122 | 1,638,859 | 675.37 | 677.03 | 1.661 |
| RI-18D | 172,978 | 1,637,542 | 683.65 | 682.00 | -1.645 |
| RI-19D | 174,283 | 1,636,956 | 676.24 | 673.92 | -2.323 |
| RI-20D | 173,741 | 1,634,878 | 676.94 | 675.14 | -1.805 |
| RI-21D | 172,371 | 1,634,745 | 681.15 | 681.07 | -0.080 |
| RI-24D | 172,313 | 1,636,443 | 685.61 | 686.22 | 0.611 |
| RI-25D | 172,749 | 1,638,597 | 686.91 | 686.91 | -0.005 |



# Table 3-4
## Predicted vs. Observed Head Calibration Results
[Shallow Aquifer Model]

| Calibration Point | Location | | Observed Head | Model Head | Head Difference |
|---|---|---|---|---|---|
| | X (ft) | Y (ft) | (Ft MSL) | (Ft MSL) | (ft) |
| RI1S | 172,238 | 1,637,556 | 689.06 | 688.11 | -0.95 |
| RI2S | 172,884 | 1,638,807 | 687.39 | 685.48 | -1.91 |
| RI3S | 173,229 | 1,638,829 | 685.71 | 684.57 | -1.14 |
| RI4S | 173,515 | 1,637,705 | 683.50 | 682.62 | -0.88 |
| RI6S | 173,569 | 1,636,267 | 679.61 | 680.34 | 0.73 |
| RI8S | 173,537 | 1,634,886 | 678.80 | 680.16 | 1.36 |
| RI9S | 173,006 | 1,634,765 | 680.42 | 681.48 | 1.06 |
| RI10S | 174,157 | 1,639,338 | 681.87 | 683.10 | 1.23 |
| RI11S | 174,929 | 1,638,237 | 678.08 | 680.06 | 1.98 |
| RI17S | 173,528 | 1,638,419 | 684.04 | 682.67 | -1.37 |
| RI18S | 172,999 | 1,637,559 | 685.54 | 685.55 | 0.01 |
| RI19S | 174,298 | 1,636,956 | 678.60 | 679.99 | 1.39 |
| RI20S | 173,725 | 1,634,877 | 678.67 | 679.61 | 0.94 |
| RI21S | 172,371 | 1,634,761 | 683.15 | 682.86 | -0.29 |
| RI23S | 172,300 | 1,635,157 | 684.78 | 684.70 | -0.08 |
| RI24S | 172,313 | 1,636,429 | 685.25 | 686.76 | 1.51 |
| RI25S | 172,749 | 1,638,611 | 687.68 | 685.83 | -1.85 |
| RI28S | 172,792 | 1,637,070 | 686.02 | 686.13 | 0.11 |
| RI29S | 172,906 | 1,637,013 | 685.10 | 685.53 | 0.43 |
| RI30S | 172,913 | 1,636,921 | 685.44 | 685.36 | -0.08 |
| RI31S | 172,877 | 1,636,292 | 684.61 | 683.78 | -0.83 |
| RI32S | 172,998 | 1,636,249 | 684.24 | 683.26 | -0.98 |
| RI33S | 173,080 | 1,636,254 | 683.98 | 682.88 | -1.10 |
| RI35S | 173,456 | 1,636,182 | 680.45 | 680.99 | 0.54 |

## Head Calibration Statistics



# Table 3-5
## Summary of Recent Groundwater Withdrawals from Rolls-Royce Plant #8
Tibbs Avenue, Indianapolis, Indiana

| Year | Rolls Royce Well ID | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec | Annual Withdrawal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Withdrawals listed in millions of gallons) | | | | | | | | | | | | |
| Sorted By Year | | | | | | | | | | | | | | |
| 2009 | PW-1 | 5.2 | 3.8 | 4.0 | 5.3 | 4.8 | 5.7 | 7.1 | 4.8 | 4.6 | 6.2 | 3.8 | 3.1 | 58.4 |
| | PW-2 | 4.6 | 3.4 | 3.6 | 3.7 | 2.1 | 2.5 | 3.0 | 2.1 | 2.0 | 2.8 | 3.2 | 2.9 | 35.9 |
| | PW-3 | 5.6 | 4.2 | 4.3 | 6.0 | 4.9 | 5.7 | 7.2 | 4.8 | 4.6 | - | 10.2 | 3.4 | 60.9 |
| | | 15.4 | 11.4 | 11.9 | 15.0 | 11.8 | 13.9 | 17.3 | 11.7 | 11.2 | 9.0 | 17.2 | 9.4 | 155.2 |
| 2014 | PW-1 | 4.8 | 3.2 | 3.2 | 4.6 | 4.2 | 4.3 | 4.8 | 4.5 | 3.5 | 6.8 | 4.0 | 4.3 | 52.2 |
| | PW-2 | 4.5 | 3.1 | 2.9 | 4.3 | 3.7 | 3.9 | 4.6 | 4.1 | 3.3 | 6.3 | 3.8 | 4.1 | 48.6 |
| | PW-3 | 5.3 | 3.5 | 3.5 | 5.0 | 4.2 | 4.7 | 5.2 | 4.9 | 3.7 | 7.4 | 4.4 | 4.7 | 56.5 |
| | | 14.6 | 9.8 | 9.6 | 13.9 | 12.1 | 12.9 | 14.6 | 13.5 | 10.5 | 20.5 | 12.2 | 13.1 | 157.3 |
| 2015 | PW-1 | 3.0 | 2.4 | 2.3 | 3.8 | 3.2 | 3.7 | 0.4 | --- | --- | --- | --- | 2.5 | 21.3 |
| | PW-2 | 2.8 | 2.3 | 2.1 | 3.4 | 3.0 | 3.6 | 7.8 | 5.5 | 13.5 | 5.3 | 4.1 | 4.1 | 57.5 |
| | PW-3 | 3.2 | 2.6 | 2.5 | 4.0 | 3.5 | 4.0 | 4.8 | 8.6 | 7.0 | 5.8 | 3.1 | 2.7 | 51.7 |
| | | 9.0 | 7.3 | 6.9 | 11.2 | 9.7 | 11.3 | 13.0 | 14.1 | 20.5 | 11.1 | 7.2 | 9.2 | 130.5 |
| 2016 | PW-1 | 2.4 | 1.9 | 2.2 | 3.8 | 3.2 | 3.7 | 0.4 | --- | --- | --- | --- | 2.5 | 20.1 |
| | PW-2 | 2.3 | 1.7 | 1.9 | 3.4 | 3.0 | 3.6 | 7.8 | 5.5 | 13.5 | --- | 3.1 | 4.0 | 49.9 |
| | PW-3 | 2.6 | 2.1 | 2.3 | 4.0 | 3.5 | 4.0 | 4.8 | 3.1 | 7.0 | --- | 3.1 | 2.7 | 39.1 |
| | | 7.3 | 5.7 | 6.3 | 11.2 | 9.7 | 11.3 | 13.0 | 8.6 | 20.5 | - | 6.2 | 9.2 | 109.1 |
| 2017 | PW-1 | 1.5 | 1.6 | 1.5 | 3.3 | 2.1 | 4.5 | 1.8 | 1.8 | 2.6 | 1.2 | 1.0 | 1.1 | 24.0 |
| | PW-2 | 1.5 | 1.5 | 1.4 | 3.1 | 1.9 | 4.2 | 1.8 | 1.8 | 2.6 | 1.1 | 0.8 | 1.0 | 22.7 |
| | PW-3 | 1.5 | 1.8 | 2.8 | 7.9 | 2.3 | 4.8 | 2.0 | 1.5 | 1.3 | 1.3 | 1.0 | 1.1 | 29.3 |
| | | 4.4 | 4.9 | 5.8 | 14.4 | 6.3 | 13.5 | 5.7 | 5.2 | 6.6 | 3.5 | 2.8 | 3.1 | 76.0 |

Sorted By Pumping Well

| | | (Withdrawals listed in millions of gallons) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PW-1 | 2009 | 5.2 | 3.8 | 4.0 | 5.3 | 4.8 | 5.7 | 7.1 | 4.8 | 4.6 | 6.2 | 3.8 | 3.1 | 58.4 |
| | 2014 | 4.8 | 3.2 | 3.2 | 4.6 | 4.2 | 4.3 | 4.8 | 4.5 | 3.5 | 6.8 | 4.0 | 4.3 | 52.2 |
| | 2015 | 3.0 | 2.4 | 2.3 | 3.8 | 3.2 | 3.7 | 0.4 | --- | --- | --- | --- | 2.5 | 21.3 |
| | 2016 | 2.4 | 1.9 | 2.2 | 3.8 | 3.2 | 3.7 | 0.4 | --- | --- | --- | --- | 2.5 | 20.1 |
| | 2017 | 1.5 | 1.8 | 2.8 | 7.9 | 2.3 | 4.8 | 2.0 | 1.5 | 1.3 | 1.3 | 1.0 | 1.1 | 29.3 |
| PW-2 | 2009 | 4.6 | 3.4 | 3.6 | 3.7 | 2.1 | 2.5 | 3.0 | 2.1 | 2.0 | 2.8 | 3.2 | 2.9 | 35.9 |
| | 2014 | 4.5 | 3.1 | 2.9 | 4.3 | 3.7 | 3.9 | 4.6 | 4.1 | 3.3 | 6.3 | 3.8 | 4.1 | 48.6 |
| | 2015 | 2.8 | 2.3 | 2.1 | 3.4 | 3.0 | 3.6 | 7.8 | 5.5 | 13.5 | 5.3 | 4.1 | 4.1 | 57.5 |
| | 2016 | 2.3 | 1.7 | 1.9 | 3.4 | 3.0 | 3.6 | 7.8 | 5.5 | 13.5 | --- | 3.1 | 4.0 | 49.9 |
| | 2017 | 2.6 | 2.1 | 2.3 | 4.0 | 3.5 | 4.0 | 4.8 | 3.1 | 7.0 | --- | 3.1 | 2.7 | 39.1 |
| PW-3 | 2009 | 5.6 | 4.2 | 4.3 | 6.0 | 4.9 | 5.7 | 7.2 | 4.8 | 4.6 | - | 10.2 | 3.4 | 60.9 |
| | 2014 | 5.3 | 3.5 | 3.5 | 5.0 | 4.2 | 4.7 | 5.2 | 4.9 | 3.7 | 7.4 | 4.4 | 4.7 | 56.5 |
| | 2015 | 3.2 | 2.6 | 2.5 | 4.0 | 3.5 | 4.0 | 4.8 | 8.6 | 7.0 | 5.8 | 3.1 | 2.7 | 51.7 |
| | 2016 | 2.6 | 2.1 | 2.3 | 4.0 | 3.5 | 4.0 | 4.8 | 3.1 | 7.0 | --- | 3.1 | 2.7 | 39.1 |
| | 2017 | 1.5 | 1.8 | 2.8 | 7.9 | 2.3 | 4.8 | 2.0 | 1.5 | 1.3 | 1.3 | 1.0 | 1.1 | 29.3 |

Notes/Abbreviations:

- Data collected from Significant Water Withdrawal Facility database, located at: https://www.in.gov/dnr/water/3595.htm

| | |
|---|---|
| cfpd | Cubic feet per day |
| ft | Feet |
| gals | Gallons |
| gpd | Gallons per day |
| gpm | Gallons per minute |
| in | Inches |

Rolls-Royce Plant Extraction Well Information:

| Well ID | Capacity | Well Log Number | Depth | Diameter |
|---|---|---|---|---|
| | (gpm) | | (ft) | (in) |
| PW-1 | 1500 | 183268 | 110 | 18 |
| PW-2 | 1500 | 173701 | 114 | 18 |
| PW-3 | 1500 | 183278 | 110 | 18 |

# Table 3-6

## Comparison of Average Groundwater Discharge from Outwash

(Modelled vs. Observed)

| Specified Head Line Segment | | Total Segment Length | Percent of Segment Length | Average Discharge per Segment |
|---|---|---|---|---|
| # | Label | (feet) | | ($ft^3$/d per ft of channel length) |
| 1 | White River | 8,773 | 40% | 47.2 |
| 2 | WR2 | 1,978 | 9% | 43.4 |
| 3 | WR3 | 5,975 | 27% | 40.9 |
| 4 | WR4 | 5,150 | 24% | 37.7 |

Total Length: 21,875

Calibrated Model Weighted Average Discharge: 42.9 ($ft^3$/d per ft of channel length)

Average Groundwater Discharge from Outwash to Streams (Meyer et al., 1975): 42.0 ($ft^3$/d per ft of channel length)

Difference in Discharge between Modeled & Reference: 2.1%

Source:

Meyer, William R., Reussow, J.P.; Gillies D.C., and Shampine, W.J., 1975. Availability of Ground-water in Marion County, Indiana: Indiana Dept. of Natural Resources, Division of Water Open-File Report 75-312. Prepared

# Table 3-7
# Groundwater Flow Velocity Assessment in OU1
## (Deep Unit)

| Groundwater Flow Modeling Scenario | Label | Effective Porosity | Hydraulic Gradient and Resulting Groundwater Velocity Across Site at Environmental Rd. & Tibbs Ave. (Distance between point of head levels = 1325 feet) | | | | | | Hydraulic Gradient and Resulting Groundwater Velocity Across Site at Minnesota St. & Tibbs Ave. (Distance between point of head levels = 1274 feet) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Upgradient Head | Downgradient Head | Head Difference | Hydraulic Gradient | Average Groundwater Velocity | | Upgradient Head | Downgradient Head | Head Difference | Hydraulic Gradient | Average Groundwater Velocity | |
| | | | (ft msl) | (ft msl) | (ft) | (ft/ft) | (ft/d) | (ft/yr) | (ft msl) | (ft msl) | (ft) | (ft/ft) | (ft/d) | (ft/yr) |
| Scenario #0 (Calibration Conditions) | Scenario 0 (Calibrated Model) | 18% | 686.49 | 673.18 | 13.31 | 0.010 | 0.150 | 54.6 | 688.38 | 674.60 | 13.78 | 0.011 | 0.150 | 54.8 |
| Scenario #1 & #3 | | | | | | | | | | | | | | |
| Scenario #1 & #3 Baseline; No On-Site Pumping, Consistent withdrawals at RR Plant 8 | Sc1-3_A | 18% | 687.31 | 673.38 | 13.93 | 0.011 | 0.157 | 57.1 | 688.22 | 675.80 | 12.42 | 0.010 | 0.135 | 49.4 |
| No On-Site Pumping, Increased Pumping at RR Plant 8 | Sc1-3_B | 18% | 686.62 | 671.30 | 15.32 | 0.012 | 0.172 | 62.8 | 687.39 | 673.38 | 14.01 | 0.011 | 0.153 | 55.8 |
| No On-Site Pumping, Cease Pumping at RR Plant 8 (Low Seepage Velocity Case) | Sc1-3_C | 18% | 688.25 | 675.95 | 12.3 | 0.009 | 0.138 | 50.4 | 689.72 | 678.79 | 10.93 | 0.009 | 0.119 | 43.5 |
| Scenario #2 | | | | | | | | | | | | | | |
| Scenario #2 Baseline; Enhanced Site Pumping, Consistent withdrawals at RR Plant 8 | Sc2_A | 18% | 686.09 | 670.56 | 15.53 | 0.012 | 0.174 | 63.7 | 687.68 | 672.06 | 15.62 | 0.012 | 0.170 | 62.2 |
| Enhanced Site Pumping, Increased Pumping at RR Plant 8 (High Seepage Velocity Case) | Sc2_B | 18% | 685.44 | 668.38 | 17.06 | 0.013 | 0.192 | 70.0 | 687.03 | 670.83 | 16.2 | 0.013 | 0.177 | 64.5 |
| Enhanced Site Pumping, Cease Pumping at RR Plant 8 | Sc2_C | 18% | 687.01 | 673.23 | 13.78 | 0.010 | 0.155 | 56.5 | 688.53 | 673.84 | 14.69 | 0.012 | 0.160 | 58.5 |

Note:

Groundwater heads were obtained from flow model simulations at the following locations:

Across Site along Env. Rd to Tibbs - Upgradient (X 172,311; Y 1,636,625); Downgradient (X 173,611; Y 1,636,368)

Across Site along Minn. St. to Tibbs - Upgradient (X 172,304; Y 1,637,530); Downgradient (X 173,577; Y 1,637,496)

Groundwater velocity was calculated to be 0.15 ft/d in the FTP Area and at the VP Plant Area based on site data (DMP, 2017). Hydraulic conductivity was adjusted to match that observed groundwater velocity - across the Site at Environmental Road (2.7 ft/d) and at Minnesota Ave. (2.5 ft/d)

# Table 3-8
## Groundwater Flow Velocity Assessment in OU1
## (Shallow Unit)

| Groundwater Flow Modeling Scenario | Label | Effective Porosity | Hydraulic Gradient and Resulting Groundwater Velocity Across Site at Environmental Rd. & Tibbs Ave. (Distance between point of head levels = 1325 feet) | | | | | | Hydraulic Gradient and Resulting Groundwater Velocity Across Site at Minnesota St. & Tibbs Ave. (Distance between point of head levels = 1274 feet) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Upgradient Head | Downgradient Head | Head Difference | Hydraulic Gradient | Average Groundwater Velocity | | Upgradient Head | Downgradient Head | Head Difference | Hydraulic Gradient | Average Groundwater Velocity | |
| | | | (ft msl) | (ft msl) | (ft) | (ft/ft) | (ft/d) | (ft/yr) | (ft msl) | (ft msl) | (ft) | (ft/ft) | (ft/d) | (ft/yr) |
| Scenario #0 (Calibration Conditions) | Scenario 0 (Calibrated Model) | 18% | 689.0 | 681.0 | 8 | 0.006 | 0.150 | 54.8 | 688.3 | 679.3 | 9 | 0.007 | 0.150 | 54.7 |
| Scenario #1 & #3 | | | | | | | | | | | | | | |
| Scenario #1 & #3 Baseline; No On-Site Pumping, Consistent withdrawals at RR Plant 8 | Sc1-3_A | 18% | 685.0 | 676.0 | 9 | 0.007 | 0.169 | 61.6 | 686.5 | 678.5 | 8 | 0.006 | 0.133 | 48.7 |
| No On-Site Pumping, Increased Pumping at RR Plant 8 | Sc1-3_B | 18% | 684.5 | 674.0 | 10.5 | 0.008 | 0.197 | 71.9 | 685.8 | 677.3 | 8.5 | 0.007 | 0.142 | 51.7 |
| No On-Site Pumping, Cease Pumping at RR Plant 8 (Low Seepage Velocity Case) | Sc1-3_C | 18% | 686.0 | 678.0 | 8 | 0.006 | 0.150 | 54.8 | 687.0 | 680.0 | 7 | 0.005 | 0.117 | 42.6 |
| Scenario #2 | | | | | | | | | | | | | | |
| Scenario #2 Baseline; Enhanced Site Pumping, Consistent withdrawals at RR Plant 8 | Sc2_A | 18% | 687.0 | 676.5 | 10.5 | 0.008 | 0.197 | 71.9 | 687.8 | 678.0 | 9.75 | 0.008 | 0.162 | 59.3 |
| Enhanced Site Pumping, Increased Pumping at RR Plant 8 (High Seepage Velocity Case) | Sc2_B | 18% | 686.0 | 674.0 | 12 | 0.009 | 0.225 | 82.2 | 687.0 | 675.0 | 12 | 0.009 | 0.200 | 73.0 |
| Enhanced Site Pumping, Cease Pumping at RR Plant 8 | Sc2_C | 18% | 687.3 | 679.0 | 8.25 | 0.006 | 0.155 | 56.5 | 688.5 | 679.3 | 9.25 | 0.007 | 0.154 | 56.3 |

Note:

Groundwater heads were obtained from flow model simulations using the instant inspection feature that allowed locations to be quickly replicated.

Across Site along Env. Rd to Tibbs - Upgradient (X 172,311; Y 1,636,625); Downgradient (X 173,611; Y 1,636,368)

Across Site along Minn. St. to Tibbs - Upgradient (X 172,304; Y 1,637,530); Downgradient (X 173,577; Y 1,637,496)

Groundwater velocity was calculated to be 0.15 ft/d in the FTP Area and at the VP Plant Area (DMP, 2017). Hydraulic conductivity was adjusted to match that observed groundwater velocity - across the Site at Environmental Road (4.5 ft/d) and at Minnesota Ave. (3.8 ft/d).

# Table 4-1

## Recent Concentrations for OU5 Natural Attenuation Evaluation
Deep Hydrostratigraphic Unit

Maximum concentration over last 3 years of monitoring (Mar. 2016 - Sept. 2018)

| Well | Sample Date | Benzene (ug/L) | Total Pyridines (ug/L) | Ammonia (mg/L) |
|---|---|---|---|---|
| RI-4D | Mar. 2016 through Sept. 2018 | 1410 | 899 | 24 |
| RI-5S | | 31 | 69 | 9.9 |
| RI-11D | | 0.5 | 0 | 8.5 |
| RI-11M | | 131 | 50 | 62 |
| RI15D | | 9 | 21 | 7.3 |
| RI-15M | | 28 | 71 | 13.4 |
| RI-19D | | 5 | 48 | 4.2 |
| RR PW-3 | | 5 | 0 | 3.5 |

Water Quality Monitoring - Concentrations over last 3 years of monitoring (Mar. 2016 through Sept. 2018)

| Well | Sample Date | Benzene (ug/L) | Total Pyridines (ug/L) | Ammonia (mg/L) |
|---|---|---|---|---|
| RI-4D | Mar-16 | 351 | 558 | 15.9 |
| | Jun-16 | 441 | 327 | 18.5 |
| | Sep-16 | 344 | 430 | 19 |
| | Dec-16 | 542 | 318 | 24 |
| | Mar-17 | 527 | 369 | 19.4 |
| | Jun-17 | 606 | 735 | 21.5 |
| | Sep-17 | 664 | 651 | 20.8 |
| | Dec-17 | 1410 | 899 | 18.7 |
| | Mar-18 | 679 | 262 | 19 |
| | Jun-18 | 809 | 72 | 21.1 |
| | Sep-18 | 779 | 154 | 18.7 |
| RI-5S | Mar-16 | 31 | 67 | 9 |
| | Sep-16 | 19 | 23 | 9 |
| | Mar-17 | 26 | 46 | 9.9 |
| | Sep-17 | 17 | 69 | 8.8 |
| | Mar-18 | 15 | 13 | 9.2 |
| | Sep-18 | <5 | <10 | 9.3 |
| RI-11D | Mar-16 | 0.5 | 0 | 8.5 |
| | Mar-17 | 0.5 | 0 | 7.7 |
| | Mar-18 | <5.0 | 0 | 6.9 |
| RI-11M | Mar-16 | 131 | 35 | 62 |
| | Sep-16 | 131 | 29 | 61 |
| | Mar-17 | 97 | 50 | 53 |
| | Sep-17 | 91 | 38 | 55 |
| | Mar-18 | 67 | <10 | 61 |
| | Sep-18 | 47 | <10 | 61 |
| RI-15D | Mar-16 | 9 | 13 | 6.0 |
| | Sep-16 | 9 | 17 | 5.9 |
| | Mar-17 | 8 | 13 | 6.4 |
| | Sep-17 | 9 | 21 | 6.8 |
| | Mar-18 | 6 | 0 | 7.3 |
| | Sep-18 | 5 | 0 | 7.3 |

Notes: Non-detect is indicated by 0.5 ug/L for benzene, 0 for pyridines, 0.5 for ammonia.

# Table 4-1

Water Quality Monitoring - Concentrations over last 3 years of monitoring (Mar. 2016 through Sept. 2018)

| Well | Sample Date | Benzene (ug/L) | Total Pyridines (ug/L) | Ammonia (mg/L) |
|---|---|---|---|---|
| RI-15M | Mar-16 | 25 | 43 | 12.5 |
| | Sep-16 | 25 | 33 | 12.3 |
| | Mar-17 | 23 | 70 | 12 |
| | Sep-17 | 28 | 66 | 12.2 |
| | Mar-18 | 22.7 | 71 | 12.1 |
| | Sep-18 | 27.2 | 41 | 13.4 |
| RI-19D | Mar-16 | 0.5 | 34 | 4.2 |
| | Sep-16 | 0.5 | 47 | 3.5 |
| | Mar-17 | 0.5 | 39 | 3.3 |
| | Sep-17 | <5.0 | 48 | 3.4 |
| | Mar-18 | <5.0 | 22 | 3.4 |
| | Sep-18 | <5.0 | 12 | 3.7 |
| Rolls Royce (Allison) PW3 | Mar-16 | 0.5 | 0 | 3.5 |
| | Mar-17 | 0.5 | 0 | 3.2 |
| | Mar-18 | <5.0 | 0 | 2.8 |

Notes: Non-detect is indicated by 0.5 ug/L for benzene, 0 for pyridines, 0.5 for ammonia.

# Table 4-2

## Recent Concentrations for OU5 Natural Attenuation Evaluation
Shallow Hydrostratigraphic Unit

Maximum concentration over last 3 years of monitoring (Mar. 2016 - Sept. 2018)

| Well | Sample Date | Benzene (ug/L) | Total Pyridines (ug/L) | Ammonia (mg/L) |
|---|---|---|---|---|
| RI-4S | Mar. 2016 through Sept. 2018 (One exception is RI-15S, sample results from March 2012) | 21.9 | 507 | 9.8 |
| RI-6S | | 37.8 | 0 | 4.2 |
| RI-8S | | 0.5 | 0 | 0.25 |
| RI-11S | | 0.5 | 0 | 1.5 |
| RI-15S | | 0.5 | 0 | 2.7 |
| RI-17S | | 0.5 | 20 | 17.4 |
| RI-18S | | 66 | 118 | 8.4 |
| RI-19S | | 0.5 | 0 | 1.3 |
| RI-25S | | 16 | 591 | 11.6 |
| RI-28S | | 0.5 | 15 | 10 |
| RI-29S | | 0.5 | 63 | 30 |
| RI-30S | | 0.5 | 22 | 6.2 |
| RI-31S | | 0.5 | 55 | 0.8 |
| RI-32S | | 0.5 | 157 | 1.4 |
| RI-33S | | 9.5 | 206 | 1.4 |
| RI-35S | | 14.4 | 26 | 3.6 |
| RI-42S | | 0.5 | 0 | 2 |
| PW-2S | | 52.8 | 177.6 | 43.7 |

Water Quality Monitoring - Concentrations over last 3 years of monitoring (Mar. 2016 through Sept. 2018)

| Well | Sample Date | Benzene (ug/L) | Total Pyridines (ug/L) | Ammonia (mg/L) |
|---|---|---|---|---|
| RI-4S | Mar-16 | 0.5 | 0 | 3.2 |
| | Jun-16 | 0.5 | 507 | 1.9 |
| | Sep-16 | 0.5 | 0 | 2 |
| | Dec-16 | 0.5 | 0 | 4 |
| | Mar-17 | 0.5 | 14 | 6 |
| | Jun-17 | <5.0 | 81 | 5.8 |
| | Sep-17 | 14.2 | 158 | 7.9 |
| | Dec-17 | 20.4 | 400 | 7.1 |
| | Mar-18 | 21.9 | 117 | 6.5 |
| | Jun-18 | 15.2 | <10 | 8.5 |
| | Sep-18 | 21.2 | 11 | 9.8 |
| RI-6S | Mar-16 | 0.5 | 0 | 3.2 |
| | Sep-16 | 5.2 | 0 | 4 |
| | Mar-17 | 0.5 | 0 | 4.2 |
| | Sep-17 | <5.0 | <10 | 3.5 |
| | Mar-18 | 37.8 | <10 | 4.1 |
| | Sep-18 | 24 | <10 | 4.1 |
| RI-8S | Mar-16 | 0.5 | 0 | 0.25 |
| | Mar-17 | 0.5 | 0 | 0.25 |
| | Mar-18 | <5.0 | 0 | <0.50 |
| RI-11S | Mar-16 | 0.5 | 0 | 1.5 |
| | Mar-17 | 0.5 | 0 | 0.25 |
| | Mar-18 | <5.0 | 0 | <0.50 |

Notes: Non-detect is indicated by 0.5 ug/L for benzene, 0 for pyridines, 0.5 for ammonia.

# Table 4-2

Water Quality Monitoring - Concentrations over last 3 years of monitoring (Mar. 2016 through Sept. 2018)

| Well | Sample Date | Benzene (ug/L) | Total Pyridines (ug/L) | Ammonia (mg/L) |
|---|---|---|---|---|
| RI-17S | Mar-16 | 0.5 | 20 | 11.7 |
| | Sep-16 | 0.5 | 0 | 7.3 |
| | Mar-17 | 0.5 | 0 | 12.5 |
| | Sep-17 | <5.0 | 15.9 | 17.4 |
| | Mar-18 | <5.0 | <10 | 12.3 |
| | Sep-18 | <5.0 | <10 | 6.2 |
| RI-18S | Mar-16 | 8 | 96 | 7.7 |
| | Jun-16 | 66 | 118 | 8.4 |
| | Sep-16 | 9.9 | 69 | 1.8 |
| | Dec-16 | 12.6 | 97 | 4.2 |
| | Mar-17 | 0.5 | 66 | 3.1 |
| | Jun-17 | <5.0 | 58 | 1.1 |
| | Sep-17 | <5.0 | 102 | 2.7 |
| | Dec-17 | <5.0 | 111 | 2.5 |
| | Mar-18 | <5.0 | 40 | 1.6 |
| | Jun-18 | <5.0 | 10 | 2.2 |
| | Sep-18 | <5.0 | 41 | 2.7 |
| RI-19S | Mar-16 | 0.5 | 0 | 1.3 |
| | Mar-17 | 0.5 | 0 | 0.6 |
| | Mar-18 | <5.0 | 0 | 0.7 |
| RI-25S | Mar-16 | 16 | 591 | 11.6 |
| | Mar-17 | 9 | 364 | 3.9 |
| | Mar-18 | <5.0 | 178 | 4 |
| RI-28S | Mar-16 | 0.5 | 15 | 5.9 |
| | Mar-17 | 0.5 | 0 | 10 |
| | Mar-18 | <5.0 | 0 | 3.7 |
| RI-29S | Mar-16 | 0.5 | 63 | 30 |
| | Mar-17 | 0.5 | 0 | 4.8 |
| | Mar-18 | <5.0 | 23.7 | 5.4 |
| RI-30S | Mar-16 | 0.5 | 0 | 5.8 |
| | Mar-17 | 0.5 | 22 | 6.2 |
| | Mar-18 | <5.0 | 11 | 5.3 |
| RI-31S | Mar-16 | 0.5 | 55 | 0.8 |
| | Mar-17 | 0.5 | 27 | 0.25 |
| | Mar-18 | <5.0 | 0 | <0.50 |
| RI-32S | Mar-16 | 0.5 | 36 | 1.4 |
| | Mar-17 | 0.5 | 157 | 0.99 |
| | Mar-18 | <5.0 | 21 | 0.85 |
| RI-33S | Mar-16 | 9.5 | 203 | 1.4 |
| | Mar-17 | 9 | 172 | 1.1 |
| | Mar-18 | 7.5 | 206 | 1.2 |
| RI-35S | Mar-16 | 14.4 | 21 | 3.6 |
| | Sep-16 | 9.2 | 0 | 3.1 |
| | Mar-17 | 0.5 | 16 | 2.5 |
| | Sep-17 | <5 | 26 | 2.7 |
| | Mar-18 | 5.9 | 11 | 2.3 |
| | Sep-18 | <5 | 19 | 2.8 |

Notes: Non-detect is indicated by 0.5 ug/L for benzene, 0 for pyridines, 0.5 for ammonia.

# Table 4-2

Water Quality Monitoring - Concentrations over last 3 years of monitoring (Mar. 2016 through Sept. 2018)

| Well | Sample Date | Benzene (ug/L) | Total Pyridines (ug/L) | Ammonia (mg/L) |
|---|---|---|---|---|
| Vertellus PW-2S | Mar-16 | 13 | 15 | 33.6 |
| | Sep-16 | 9 | 11 | 30.1 |
| | Mar-17 | 0.5 | 16 | 43.7 |
| | Sep-17 | 29.9 | 177.6 | 43.7 |
| | Dec-17 | 25.7 | NA | NA |
| | Mar-18 | 14.8 | 175 | 40.4 |
| | Jun-18 | 26.6 | NA | NA |
| | Sep-18 | 52.8 | 125 | 39.1 |

Notes: Non-detect is indicated by 0.5 ug/L for benzene, 0 for pyridines, 0.5 for ammonia.

# Table 4-3

## Initial Concentration Profiles for 1-D Modeling - Deep Hydrostratigraphic Unit

Vertellus Integrated Products - OU5 NA Assessment

| Deep Run 1 | Start Distance (m) | End Distance (m) | Benzene Concentration (mg/L) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Max. Concentration (2016-2018) as listed in Table 4-1 | +25% of Max. Obs. 2016-2018 | -50% of Max. Obs. 2016-2018 | -75% of Max. Obs. 2016-2018 | -99% of Max. Obs. 2016-2018 |
| Interval1 | 0 | 12 | 1.500 | 1.875 | 0.750 | 0.375 | 0.015 |
| Interval2 | 12 | 52 | 0.600 | 0.750 | 0.300 | 0.150 | 0.006 |
| Interval3 | 52 | 91 | 0.150 | 0.188 | 0.075 | 0.038 | 0.002 |
| Interval4 | 91 | 183 | 0.040 | 0.050 | 0.020 | 0.010 | 0.000 |
| Interval5 | 183 | 259 | 0.020 | 0.025 | 0.010 | 0.005 | 0.000 |
| Interval6 | 259 | 366 | 0.015 | 0.019 | 0.008 | 0.004 | 0.000 |
| Interval7 | 366 | 486 | 0.005 | 0.006 | 0.003 | 0.001 | 0.000 |

| Deep Run 2 | Start Distance (m) | End Distance (m) | Benzene Concentration (mg/L) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Max. Concentration (2016-2018) as listed in Table 4-1 | +25% of Max. Obs. 2016-2018 | -50% of Max. Obs. 2016-2018 | -75% of Max. Obs. 2016-2018 | -90% of Max. Obs. 2016-2018 |
| Interval1 | 0 | 152 | 0.005 | 0.00625 | 0.0025 | 0.001 | 0.001 |
| Interval2 | 152 | 427 | 0.028 | 0.035 | 0.014 | 0.007 | 0.003 |
| Interval3 | 427 | 457 | 0.131 | 0.16375 | 0.0655 | 0.033 | 0.013 |
| Interval4 | 457 | 549 | 0.030 | 0.0375 | 0.015 | 0.008 | 0.003 |
| Interval5 | 549 | 671 | 0.015 | 0.01875 | 0.0075 | 0.004 | 0.002 |
| Interval6 | 671 | 762 | 0.007 | 0.00875 | 0.0035 | 0.002 | 0.001 |
| Interval7 | 762 | 878 | 0.005 | 0.00625 | 0.0025 | 0.001 | 0.001 |

| Deep Run 1 | Start Distance (m) | End Distance (m) | Pyridine Concentration (mg/L) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Max. Concentration (2016-2018) as listed in Table 4-1 | +25% of Max. Obs. 2016-2018 | -50% of Max. Obs. 2016-2018 | -75% of Max. Obs. 2016-2018 | -90% of Max. Obs. 2016-2018 |
| Interval1 | 0 | 12 | 0.90 | 1.125 | 0.450 | 0.225 | 0.090 |
| Interval2 | 12 | 52 | 0.40 | 0.500 | 0.200 | 0.100 | 0.040 |
| Interval3 | 52 | 91 | 0.10 | 0.125 | 0.050 | 0.025 | 0.010 |
| Interval4 | 91 | 183 | 0.07 | 0.088 | 0.035 | 0.018 | 0.007 |
| Interval5 | 183 | 259 | 0.05 | 0.063 | 0.025 | 0.013 | 0.005 |
| Interval6 | 259 | 366 | 0.02 | 0.025 | 0.010 | 0.005 | 0.002 |
| Interval7 | 366 | 486 | 0.01 | 0.013 | 0.005 | 0.003 | 0.001 |

| Deep Run 2 | Start Distance (m) | End Distance (m) | Pyridine Concentration (mg/L) | | |
|---|---|---|---|---|---|
| | | | Max. Concentration (2016-2018) as listed in Table 4-1 | +25% of Max. Obs. 2016-2018 | -50% of Max. Obs. 2016-2018 |
| Interval1 | 0 | 152 | 0.050 | 0.0625 | 0.025 |
| Interval2 | 152 | 427 | 0.070 | 0.0875 | 0.035 |
| Interval3 | 427 | 457 | 0.070 | 0.0875 | 0.035 |
| Interval4 | 457 | 549 | 0.045 | 0.05625 | 0.0225 |
| Interval5 | 549 | 671 | 0.030 | 0.0375 | 0.015 |
| Interval6 | 671 | 762 | 0.020 | 0.025 | 0.01 |
| Interval7 | 762 | 878 | 0.010 | 0.0125 | 0.005 |

| Deep Run 2 | Start Distance (m) | End Distance (m) | Ammonia Concentration (mg/L) | | |
|---|---|---|---|---|---|
| | | | Max. Concentration (2016-2018) as listed in Table 4-1 | +25% of Max. Obs. 2016-2018 | -25% of Max. Obs. 2016-2018 |
| Interval1 | 0 | 152 | 10 | 12.5 | 7.5 |
| Interval2 | 152 | 427 | 15 | 18.75 | 11.25 |
| Interval3 | 427 | 457 | 62 | 77.5 | 46.5 |
| Interval4 | 457 | 549 | 25 | 31.25 | 18.75 |
| Interval5 | 549 | 671 | 20 | 25 | 15 |
| Interval6 | 671 | 762 | 15 | 18.75 | 11.25 |
| Interval7 | 762 | 878 | 10 | 12.5 | 7.5 |

# Table 4-4

## Initial Concentration Profiles for 1-D Modeling - Shallow Hydrostratigraphic Unit

Vertellus Integrated Products - OU5 NA Assessment

| Shallow Run 1 | Start Distance (m) | End Distance (m) | Benzene Concentration (mg/L) | | | |
|---|---|---|---|---|---|---|
| | | | Max. Concentration (2016-2018) as listed in Table 4-2 | +25% of Max. Obs. 2016-2018 | -50% of Max. Obs. 2016-2018 | -75% of Max. Obs. 2016-2018 |
| Interval1 | 0 | 30 | 0.070 | 0.0875 | 0.035 | 0.018 |
| Interval2 | 30 | 61 | 0.040 | 0.05 | 0.02 | 0.010 |
| Interval3 | 61 | 107 | 0.025 | 0.03125 | 0.0125 | 0.006 |
| Interval4 | 107 | 168 | 0.015 | 0.01875 | 0.0075 | 0.004 |
| Interval5 | 168 | 229 | 0.010 | 0.0125 | 0.005 | 0.003 |
| Interval6 | 229 | 505 | 0.005 | 0.00625 | 0.0025 | 0.001 |

| Shallow Run 1 | Start Distance (m) | End Distance (m) | Pyridine Concentration (mg/L) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Max. Concentration (2016-2018) as listed in Table 4-2 | +25% of Max. Obs. 2016-2018 | -50% of Max. Obs. 2016-2018 | -75% of Max. Obs. 2016-2018 | -90% of Max. Obs. 2016-2018 |
| Interval1 | 0 | 30 | 0.500 | 0.625 | 0.25 | 0.125 | 0.050 |
| Interval2 | 30 | 61 | 0.300 | 0.375 | 0.15 | 0.075 | 0.030 |
| Interval3 | 61 | 107 | 0.200 | 0.25 | 0.1 | 0.050 | 0.020 |
| Interval4 | 107 | 168 | 0.100 | 0.125 | 0.05 | 0.025 | 0.010 |
| Interval5 | 168 | 229 | 0.050 | 0.0625 | 0.025 | 0.013 | 0.005 |
| Interval6 | 229 | 505 | 0.010 | 0.0125 | 0.005 | 0.003 | 0.001 |

| Shallow Run 1 | Start Distance (m) | End Distance (m) | Ammonia Concentration (mg/L) | | |
|---|---|---|---|---|---|
| | | | Max. Concentration (2016-2018) as listed in Table 4-2 | +10% of Max. Obs. 2016-2018 | -25% of Max. Obs. 2016-2018 |
| Interval1 | 0 | 30 | 45 | 49.5 | 33.75 |
| Interval2 | 30 | 61 | 35 | 38.5 | 26.25 |
| Interval3 | 61 | 107 | 24 | 26.4 | 18 |
| Interval4 | 107 | 168 | 18 | 19.8 | 13.5 |
| Interval5 | 168 | 229 | 10 | 11 | 7.5 |
| Interval6 | 229 | 505 | 2 | 2.2 | 1.5 |

Table 4-5
Results of Natural Attenuation Analysis in OU5
Vertellus Integrated Pyridines, LLC
Indianapolis, Indiana

| Migration / Transport Simulation | Constituent of Concern | Darcy Velocity | Segment Length of Maximum Concentration (2016-2018) | Change in Max. Initial Concentration | Maximum Initial Concentration[1] | Time to Reach RAO |
|---|---|---|---|---|---|---|
| | | (m/a) | (m) | (%) | (mg/L) | (Years) |
| Deep Run 1 | Benzene | 3.13 | 12 | -99% | 0.015 | 2.5 |
| | | | | -75% | 0.375 | 15.5 |
| | | | | -50% | 0.75 | 19 |
| | | | | Max[2] | 1.5 | 22 |
| | | | | +25% | 1.875 | 23 |
| Deep Run 1 | | 4.7 | 12 | -99% | 0.015 | 2 |
| | | | | -75% | 0.375 | 14.75 |
| | | | | -50% | 0.75 | 18 |
| | | | | Max[2] | 1.5 | 21 |
| | | | | +25% | 1.875 | 22 |
| Deep Run 2 | | 3.13 | 30 | -90% | 0.013 | 2.5 |
| | | | | -75% | 0.033 | 6 |
| | | | | -50% | 0.066 | 9 |
| | | | | Max[2] | 0.131 | 13 |
| | | | | +25% | 0.164 | 14 |
| Shallow Run 1 | | 3.13 | 30 | -75% | 0.018 | 5 |
| | | | | -50% | 0.035 | 7.5 |
| | | | | Max[2] | 0.070 | 10.5 |
| | | | | +25% | 0.088 | 11.5 |
| Deep Run 1 | Pyridine | 3.13 | 12 | -90% | 0.090 | 3 |
| | | | | -75% | 0.225 | 8.25 |
| | | | | -50% | 0.450 | 13 |
| | | | | Max[2] | 0.900 | 18 |
| | | | | +25% | 1.125 | 20 |
| Deep Run 2 | | 3.13 | 305 | -50% | 0.035 | 0.1 |
| | | | | Max[2] | 0.07 | 6 |
| | | | | +25% | 0.0875 | 8 |
| Shallow Run 1 | | 3.13 | 30 | -90% | 0.05 | 2 |
| | | | | -75% | 0.125 | 7.5 |
| | | | | -50% | 0.25 | 12.5 |
| | | | | Max[2] | 0.500 | 17.5 |
| | | | | +25% | 0.625 | 19.5 |
| Deep Run 2 | Ammonia | 3.13 | 30 | -50% | 31 | 0.1 |
| | | | | -25% | 47 | 2.5 |
| | | | | Max[2] | 62 | 9 |
| | | | | +25% | 78 | 21 |
| Shallow Run 1 | | 3.13 | 30 | -25% | 34 | 5 |
| | | | | Max[2] | 45 | 17 |
| | | | | +10% | 50 | 22 |

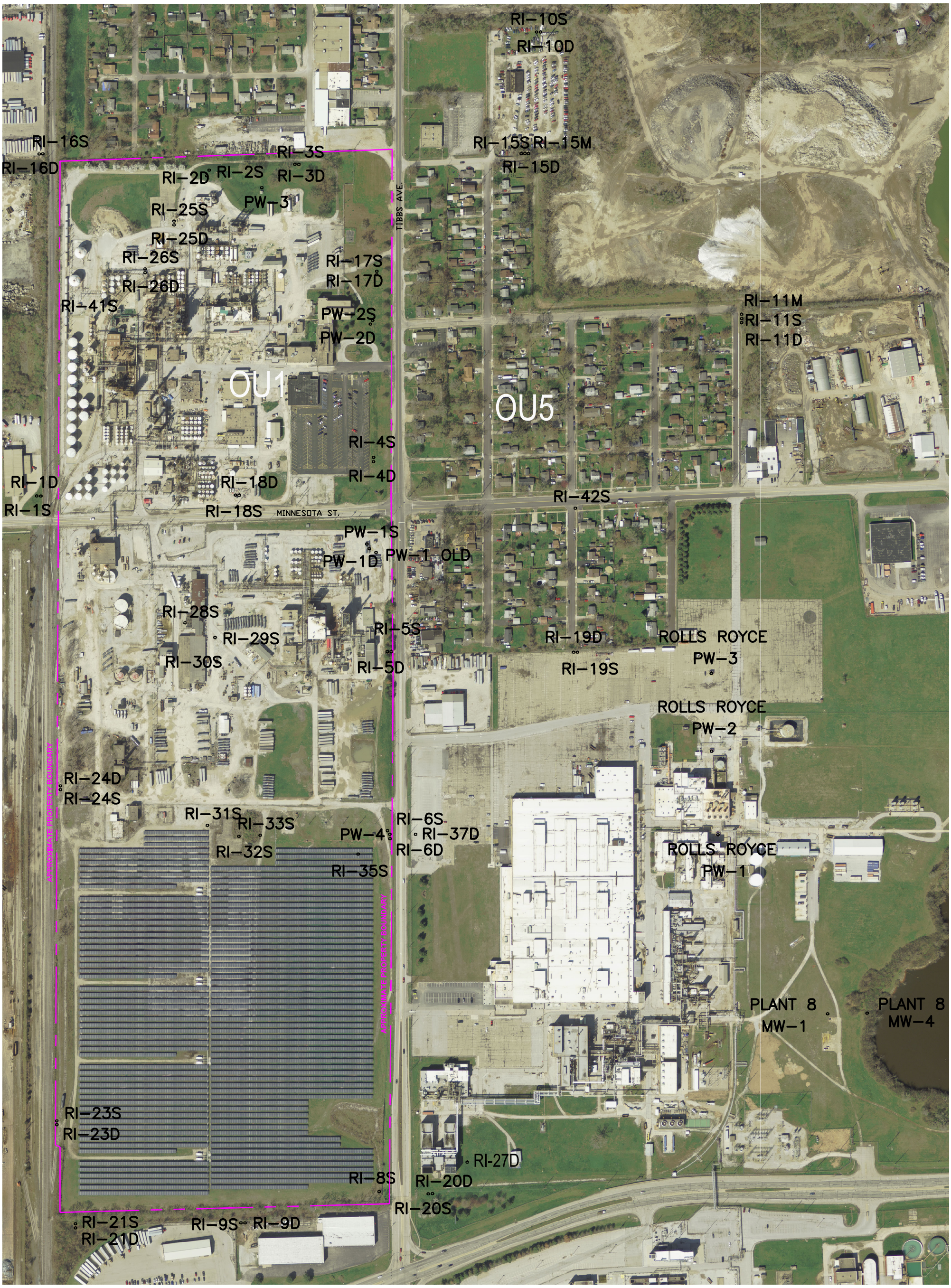
Notes:
1. Initial concentration values relate to the maximum observed concentrations (2016-2018) of the Initial Concentration Profile (See Figure 4-2 and 4-3 for the Deep and Shallow Aquifers, respectively).

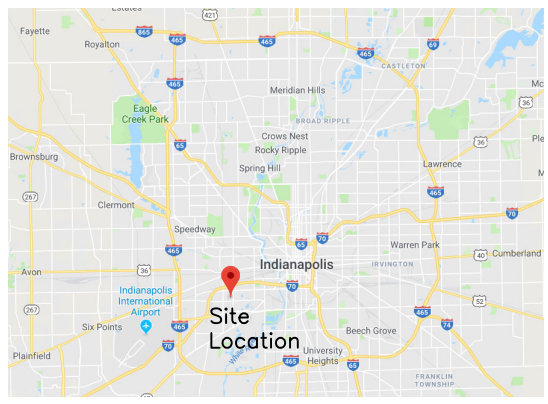
2. Maximum concentration from 2016-2018 from Table 4-1 (Deep Runs) and Table 4-2 (Shallow Run).

Abbreviations:
RAO = Remedial Action Objective
Benzene RAO = 0.005 mg/L
Pyridine RAO = 0.035 mg/L
Ammonia RAO = 30 mg/L
m = meters
m/a = meters per annum

# Figures


Figure 1-1 Site Map
Figure 2-1 Regional Hydrogeological Cross-Section
Figure 2-2 Hydrostratigraphic and Conceptual Model Cross-Section
Figure 2-3 Bedrock Elevation Map
Figure 3-1 Conceptual Site Model - Plan View
Figure 3-2 Bottom Elevation - Deep Unit
Figure 3-3 Bottom Elevation - Shallow Unit
Figure 3-4 Hydraulic Conductivity Distribution - Deep Hydrostatic Unit
Figure 3-5 Hydraulic Conductivity Distribution - Shallow Hydrostatic Unit
Figure 4-1 Calibrated 1-D Model Run: RI-33S to RI-6S (Simulated Concentration vs. Distance Plot)
Figure 4-2 Maximum Observed Concentrations (2016-2018) in OU5 for Natural Attenuation Modeling – Deep Hydrostratigraphic Unit
Figure 4-3 Maximum Observed Concentrations (2016-2018) in OU5 for Natural Attenuation Modeling – Shallow Hydrostratigraphic Unit
Figure 4-4A Natural Attenuation Modeling Results – Benzene
Figure 4-4B Natural Attenuation Modeling Results – Pyridines
Figure 4-4C Natural Attenuation Modeling Results – Ammonia




Source: Google, 2019

BEARING

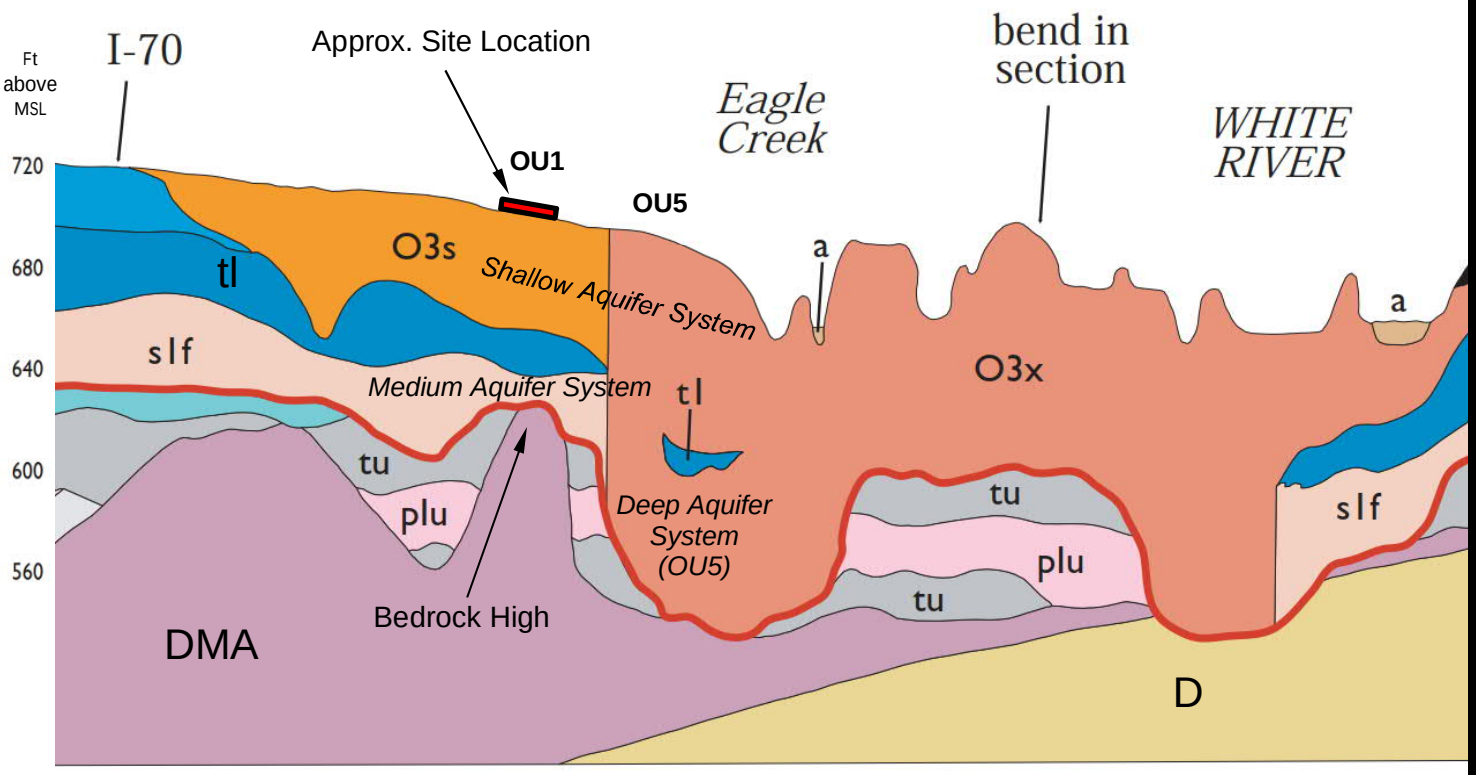
0 350 700

SCALE (FEET)

# Site Map

| | |
|---|---|
| DRAWING DATE: February 1, 2019 | ACAD FILE: INDY PLANT.DWG |
| CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC | AECOM |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | FIGURE: 1-1 |
| DESIGNED: JSM | APPROVED: GMB |
| PROJECT NO.: 60571463 | |

**WEST** **EAST**




**Source**: Hydrogeologic Cross-Section adopted from Brown and Laudick (ISG Open-file Study 00-14, 2000)

0 Approx. Scale (miles) 1

LEGEND:

| | |
|---|---|
| a | Alluvium in modern stream valleys. Texture ranges from silty clay to gravel, but is predominantly loamy in composition. |
| O3x | Thick composite bodies of sand and gravel in sluiceways and terraces. The unit typically consists of late Wisconsin outwash that has coalesced with much thicker exhumed fans, aprons, and channels of Wisconsin and (or) pre-Wisconsin age. |
| O3s | Outwash in linear sluiceways. The outwash generally cuts across other Wisconsin units; locally the sluiceways are deeply incised into the pre-Wisconsin surface. |
| tl | Lower till sequence. Till and till-like sediment deposited by the East White Sublobe of the Huron-Erie Lobe. In most places the unit is generally very stiff to hard, strongly overconsolidated loam, silt loam, or sandy loam having abundant pebbles and widely scattered lenses of sand and silt. |
| slf | Sand and gravel in extensive fans, aprons, and channel complexes at the base of the lower till sequence. Mostly deposited as ice-proximal outwash during the initial advance of the late Wisconsin ice sheet and subsequently overridden. |
| tu | Undifferentiated till and other fine-grained sediment. Includes small granular units of local extent. |
| plu | Relatively continuous bodies of sand and gravel bodies of predominantly pre-Illinoian age. In most places, they are associated with a prominent green, chert-rich paleosol as much as 20 feet thick and may be capped by thin, greenish-grey till. In some places, the unit includes abundant, well-rounded, pitted, red, iron-oxide-coated-dolomite pebbles. |
| DMA | New Albany Shale (Devonian and Mississippian Systems). Grey, brown, and black shale. Minor calcareous shale and argillaceous limestone near base of unit. |
| D | Muscatatuck Group (Devonian System). Chiefly crystalline limestone and lesser calcareous shale. Sandy dolomite (Geneva Member) at base (not mapped separately). |

**Regional Hydrogeological Cross-Section**
**(with Conceptual Depiction of Local Aquifer System)**
For Groundwater Modeling Evaluation in Support of FFS
Former Reilly Industries, Inc., 1500 S. Tibbs Ave., Indianapolis, Indiana

AECOM

| Project: 60571463 | Prepared on: Dec.27, 2018 | Prepared by: JM / Approved by: GB | **Figure 2-1** |
|---|---|---|---|

ANSIA 8.5" x 11"
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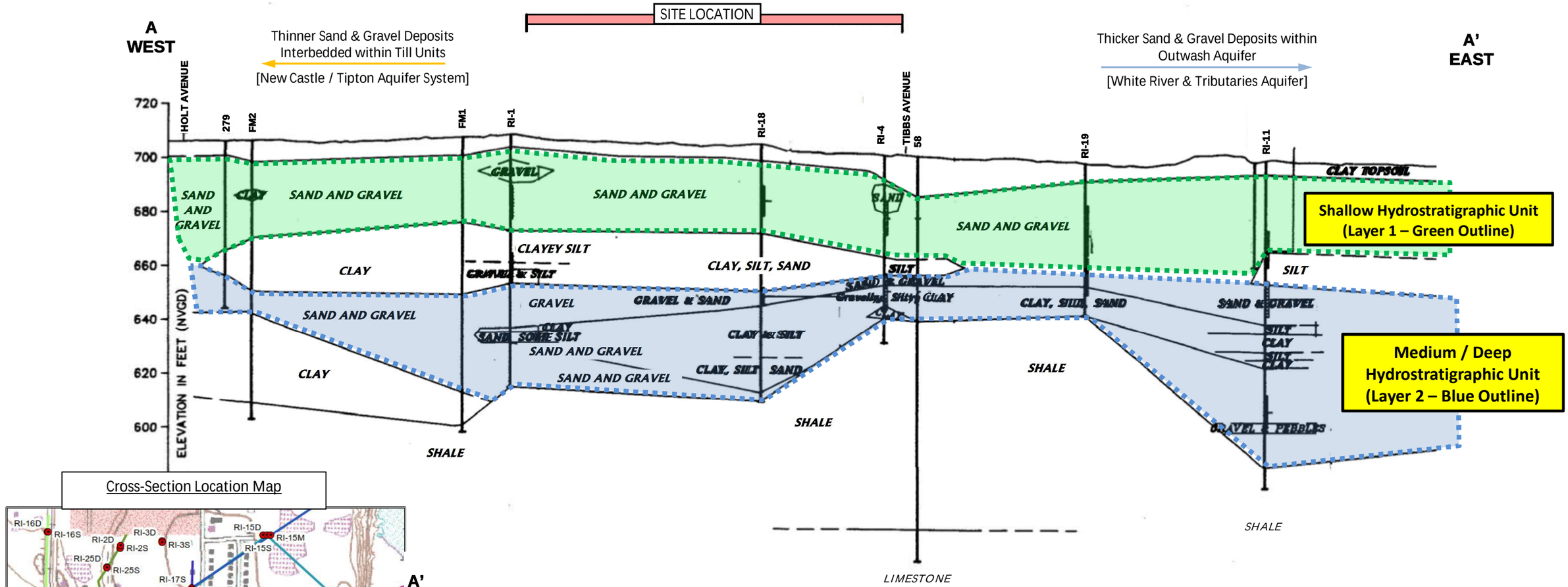
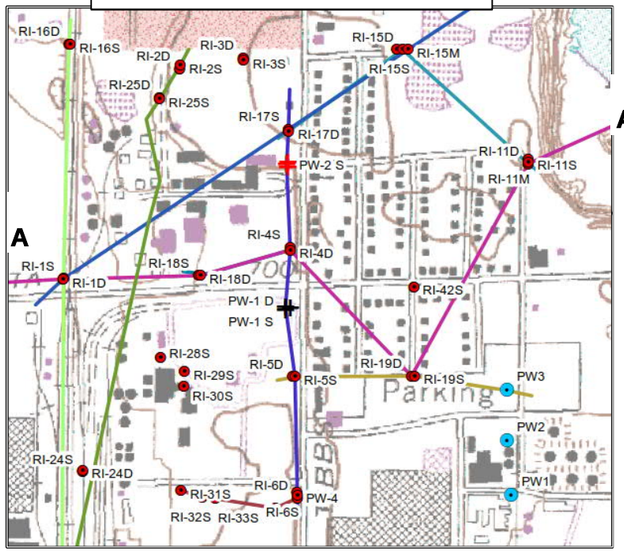



Cross-Section Location Map




Notes:

- The eastern half of the groundwater modeling domain represents the White River Outwash System (& tributary systems) which consists of thick glacial outwash sands and gravels that are generally capped by a layer of clay and silt deposits (Schmidt, 2011).
- Upgradient areas of the model primarily represent the New Castle /Tipton Aquifer System, which is observed to be up to about 305 feet in thickness and consists primarily of glacial till with intertill sand and gravel layers (Schmidt, 2011). This aquifer system has individual sand and gravel units that are commonly 5 to 15 feet thick that yield domestically 10 to 50 gpm, and 70 to 430 gpm for high-capacity wells.
- Model layers delineated from August-Mack groundwater models (A-M, 2011), and adopted into two unique analytic element groundwater models by AECOM.
- Cross-section adopted from ENSR, 1991 (Final CERCLA RI Report and the RCRA RFI Phase III Release Characterization Report)

0 500 1000
Approx. Scale
(feet)

**Hydrostratigraphic and Conceptual Model Cross-Section**
For Groundwater Modeling Evaluation in Support of FFS
Former Reilly Industries, Inc., 1500 S. Tibbs Ave., Indianapolis, Indiana

AECOM

| Project #60571463 | December 2018 | Drawn by: J. MacKinney / P. Nickles | Checked/Approved: G. Braun | Figure 2-2 |
|---|---|---|---|---|

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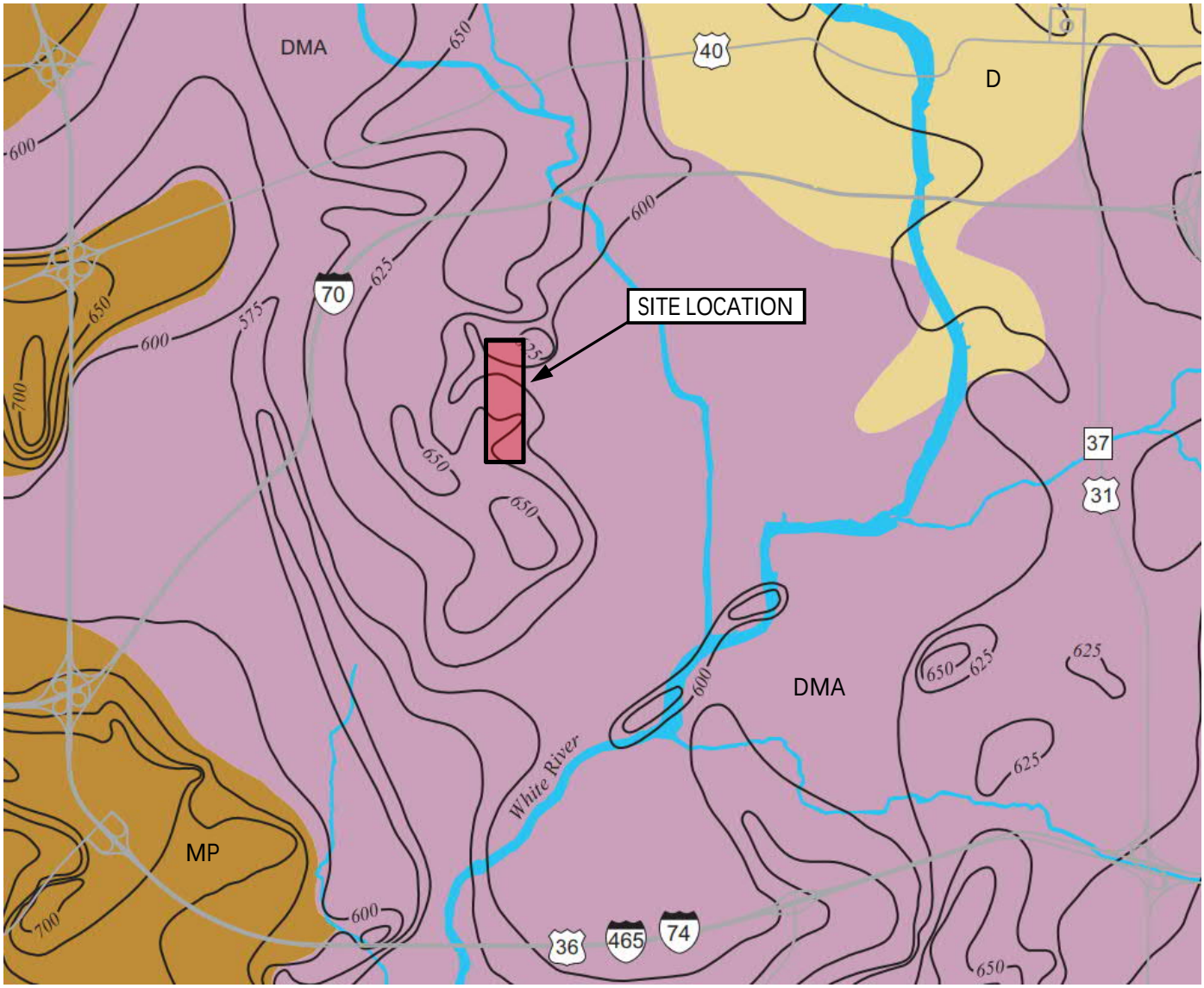


**Source**: Bedrock Elevation Map adopted from Brown and Laudick (ISG Open-file Study 00-14, 2000)

0 1 2

Approx. Scale (miles)

LEGEND:

MP — Borden Group undifferentiated (Mississippian System). Chiefly siltstone and shale with much lesser limestone and sandstone.

DMA — New Albany Shale (Devonian and Mississippian Systems). Grey, brown, and black shale. Minor calcareous shale and argillaceous limestone near base of unit.

D — Muscatatuck Group (Devonian System). Chiefly crystalline limestone and lesser calcareous shale. Sandy dolomite (Geneva Member) at base (not mapped separately).

Line of equal elevation on the bedrock surface. Hachured lines enclose depressions or sinkholes. Contour interval: 25 feet.

**Bedrock Elevation Map**

For Groundwater Modeling Evaluation in Support of FFS

Former Reilly Industries, Inc., 1500 S. Tibbs Ave., Indianapolis, Indiana

AECOM

| Project #/Date | Author/Reviewer | 60571463 / December 2018 | JM/GB | **Figure 2-3** |
|---|---|---|---|---|

ANSIA 8.5"

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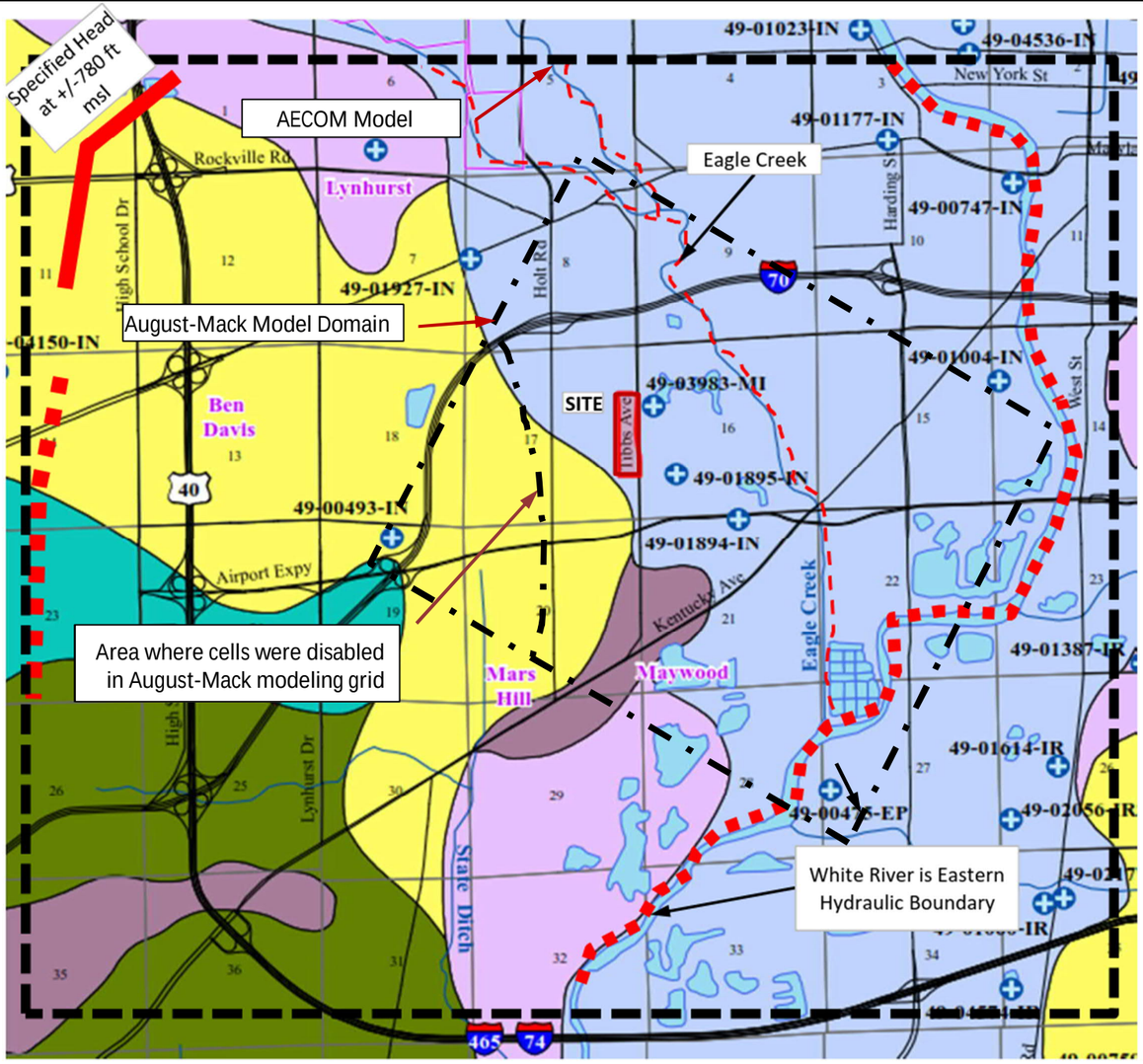
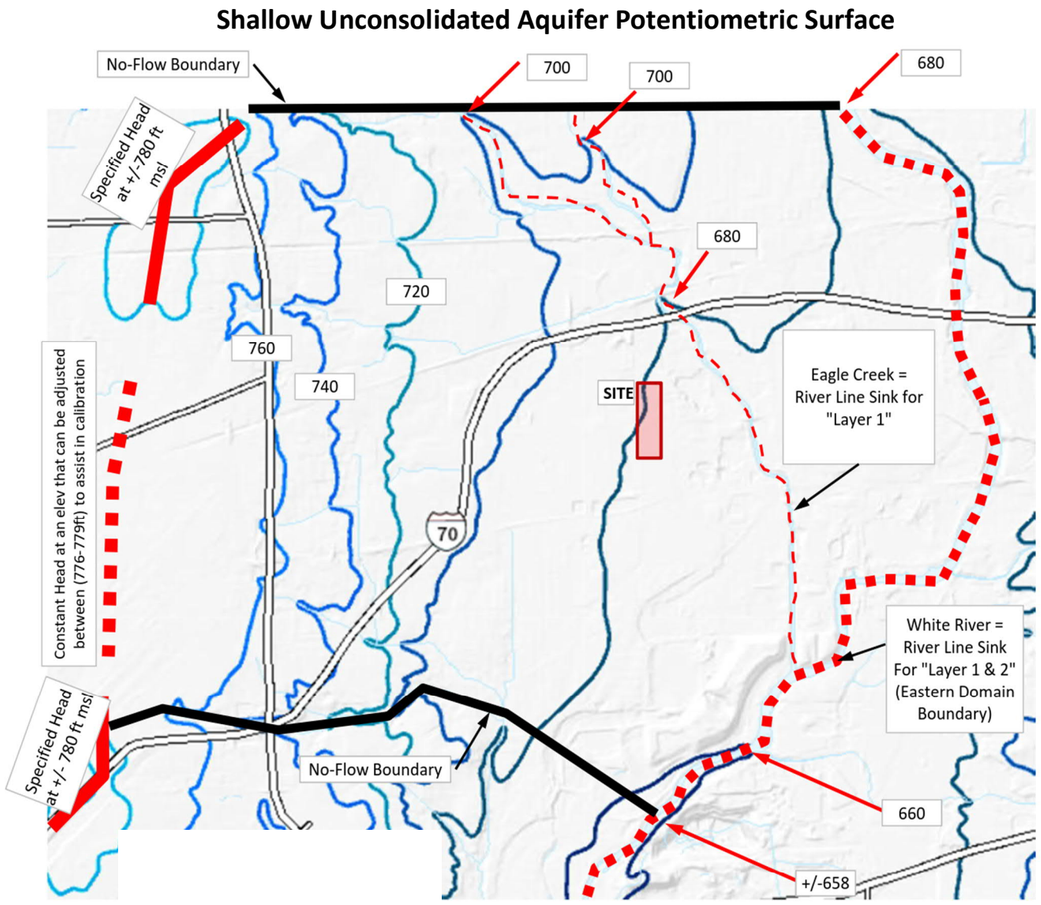



**Legend of Unconsolidated Aquifer Systems:**
Source: Schmidt (2011)

- White River and Tributaries Outwash Aquifer System
- New Castle / Tipton Till Aquifer System
- New Castle / Tipton Complex Aquifer System
- White River and Tributaries Outwash Aquifer Subsystem
- Till Veneer Aquifer System
- New Castle / Tipton Till Aquifer Subsystem

0 — 500 — 1000
Approx. Scale (feet)

Notes:

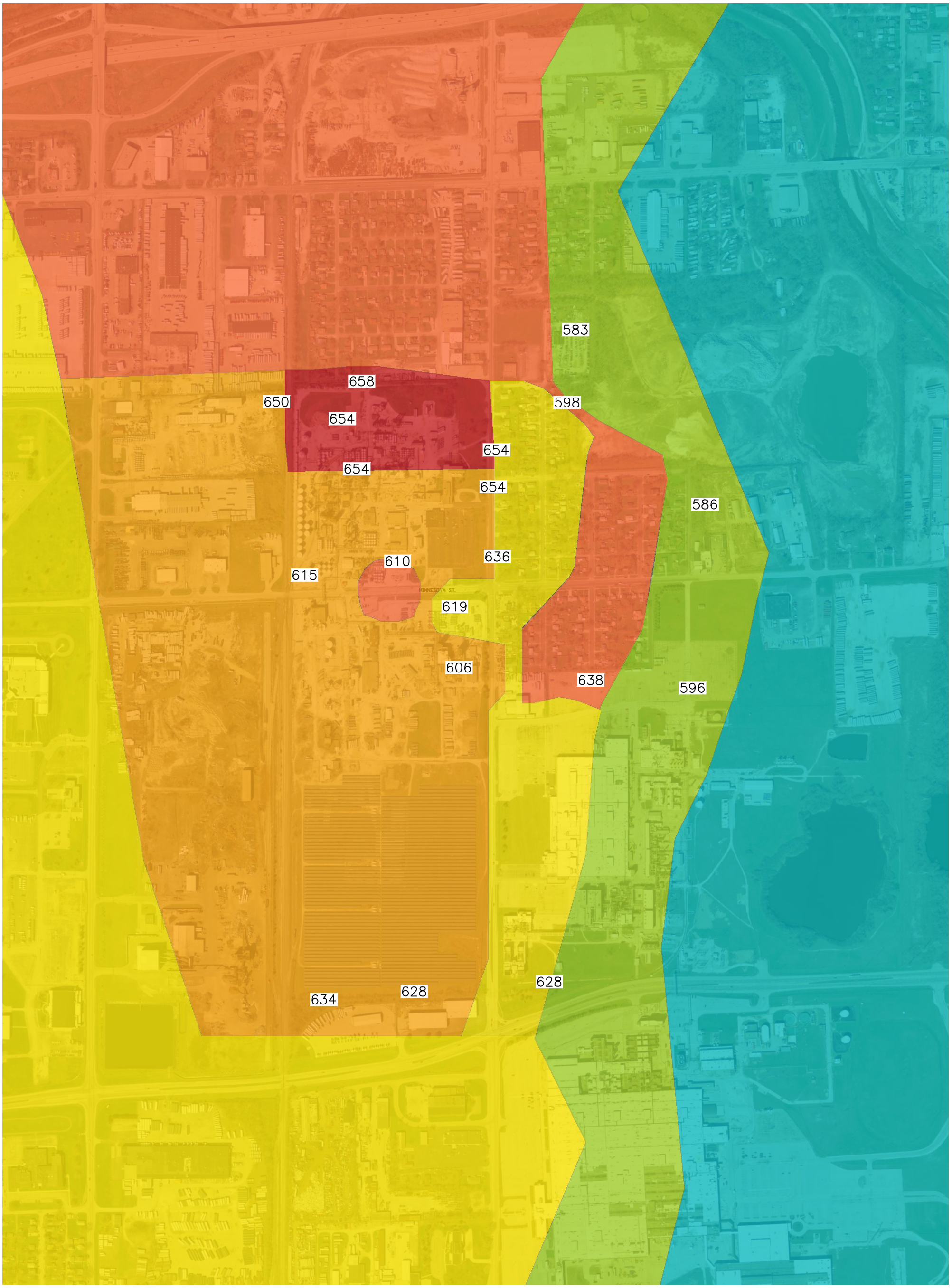
- The eastern half of the groundwater modeling domain represents the White River Outwash System (& tributary systems) which consists of thick glacial outwash sands and gravels that are generally capped by a layer of clay and silt deposits (Schmidt, 2011).
- Upgradient areas of the model primarily represent the New Castle /Tipton Aquifer System, which is observed to be up to about 305 feet in thickness and consists primarily of glacial till with intertill sand and gravel layers (Schmidt, 2011).
- Model layers delineated from August-Mack groundwater models (A-M, 2010), have been adopted into two unique analytic element groundwater models by AECOM.
- Hydraulic boundaries for the model are illustrated on the Shallow Unconsolidated Aquifer Potentiometric Map. A specified head source is located on a groundwater divide of the unconsolidated deposits located approximately four miles to the northwest. The downgradient hydraulic boundaries (line sink) consists of the White River.
- The head elevations of the White River and Eagle Creek river boundary have been established using USGS Topographic maps and interpolation between the points.
- Note that the Eagle Creek line sink will be only utilized when modeling the Shallow Aquifer.

**Conceptual Site Model – Map View**
For Groundwater Modeling Evaluation in Support of FFS
Former Reilly Industries, Inc., 1500 S. Tibbs Ave., Indianapolis, Indiana

AECOM

| Project #60571463 | August 2018 | Drawn by: J. MacKinney / P. Nickles | Checked/Approved: G. Braun | **Figure 3-1** |
|---|---|---|---|---|

File Name: P:\60571463_TEMP\Report\Figures\Docs\Bedrock Elevation Map01.docx [Local C:\Directory\Projects\Active\IN_Vertiks\Report\Figures\Docs\Bedrock Elevation Map01.docx]



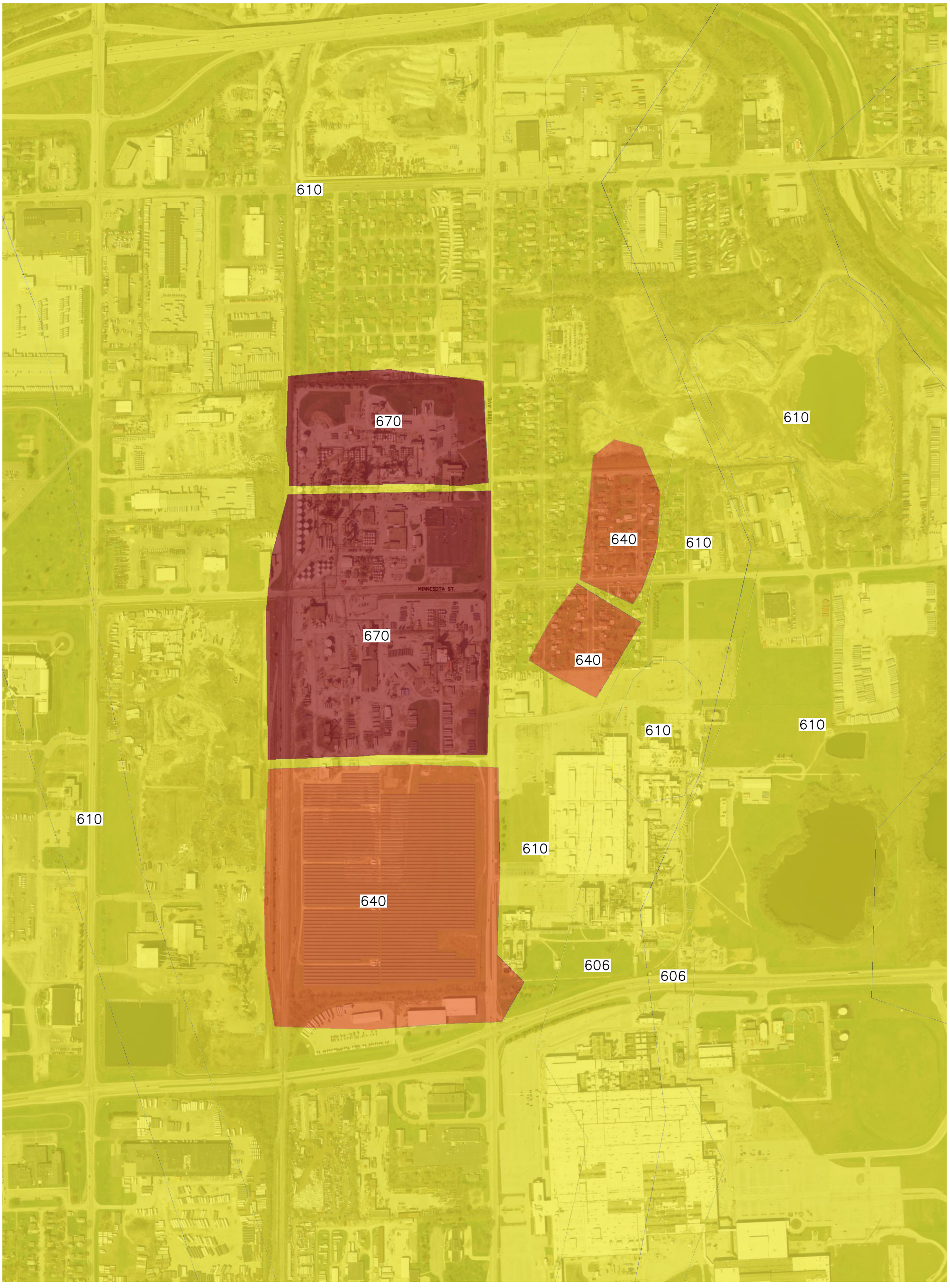
Notes:
GFLOW Model Approximate Aquifer Bottom Elevation

- 650–659 ft MSL
- 630–639 ft MSL
- 620–629 ft MSL
- 610–619 ft MSL
- 590–599 ft MSL
- 580–589 ft MSL

0 600 1200
SCALE (FEET)

# Bottom Elevation – Deep Hydrostatic Unit

| | |
|---|---|
| DRAWING DATE: JANUARY 15, 2019 | ACAD FILE: INDY PLANT_BotElev |
| CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC | AECOM |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | FIGURE: 3-2 |
| DESIGNED: JSM | APPROVED: GMB |
| PROJECT NO.: 60571463 | |



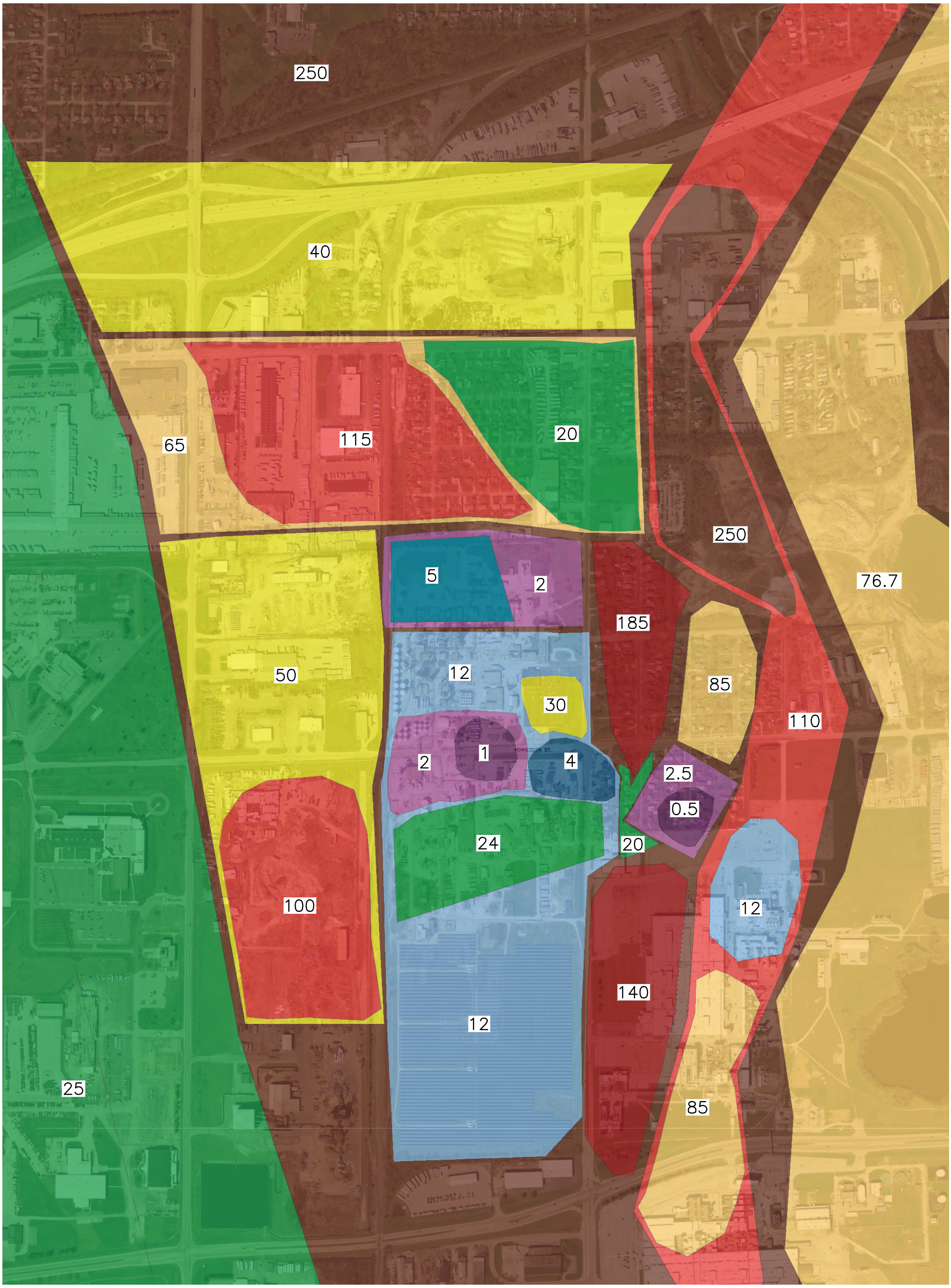

Notes:
GFLOW Model Approximate Aquifer Bottom Depth
- 670 ft MSL
- 640 ft MSL
- 600–610 ft MSL

BEARING

0 600 1200
SCALE (FEET)

# Bottom Elevation – Shallow Hydrostatic Unit

| | |
|---|---|
| DRAWING DATE: January 29, 2019 | ACAD FILE: INDY PLANT_BotElev |
| CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC | AECOM |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | FIGURE: 3-3 |
| DESIGNED: JSM | APPROVED: GMB |
| PROJECT NO.: 60571463 | |




Hydraulic Conductivity Distribution
(feet/day):

- 0–1
- 2–3
- 4–9
- 10–19
- 20–29
- 30–59
- 60–99
- 100–139
- 140–199
- 200–299

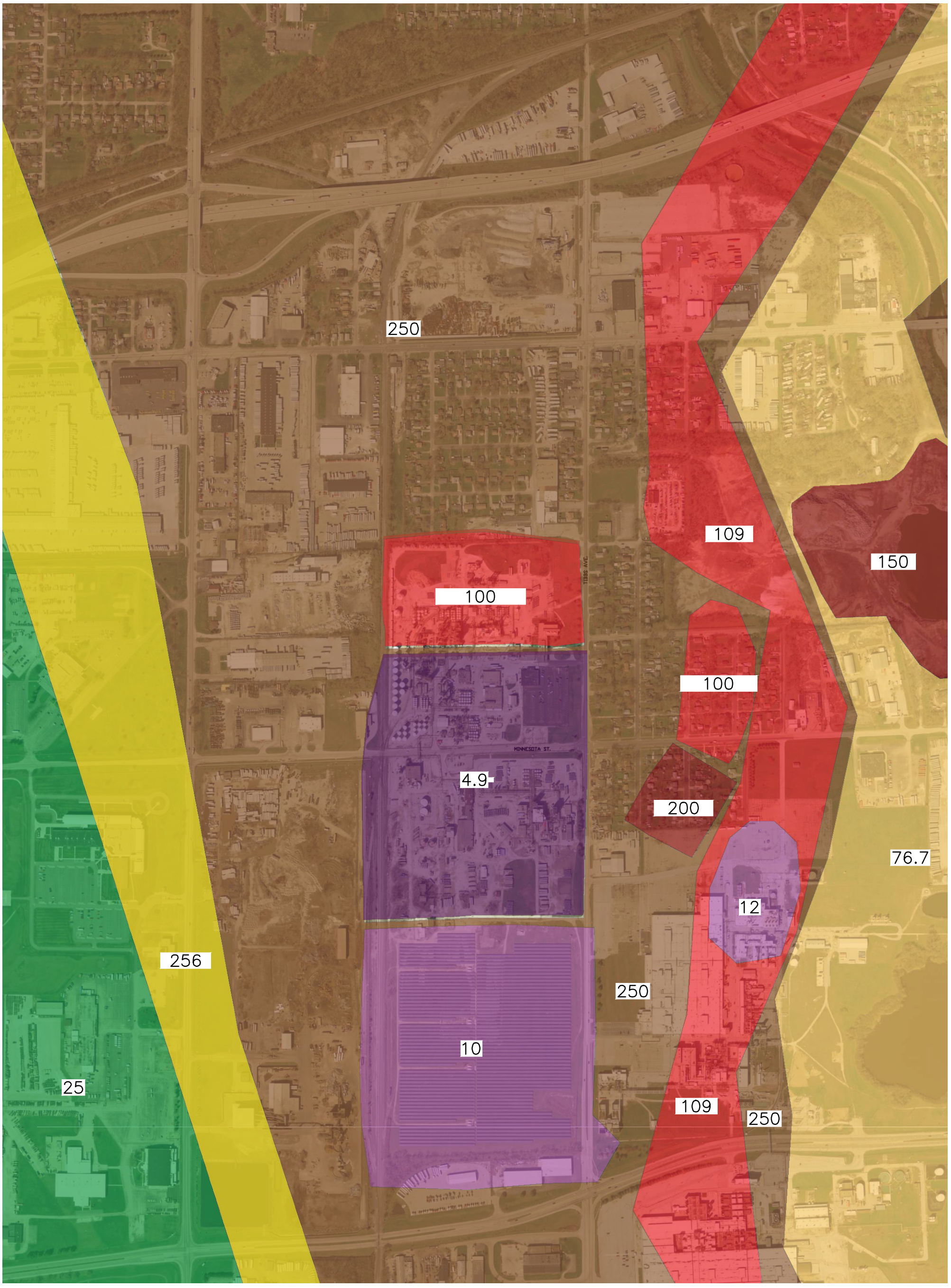
BEARING

0 600 1200

SCALE (FEET)

# Hydraulic Conductivity Distribution – Deep Hydrostatic Unit

| | |
|---|---|
| DRAWING DATE: JANUARY 15, 2019 | ACAD FILE: INDY PLANT_K-ZONE |
| CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC | AECOM |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | FIGURE: 3-4 |
| DESIGNED: JSM | APPROVED: GMB |
| PROJECT NO.: 60571463 | |




Hydraulic Conductivity Distribution (feet/day):

- 0–9
- 10–20
- 20–50
- 50–99
- 100–149
- 150–249
- 250–300

BEARING

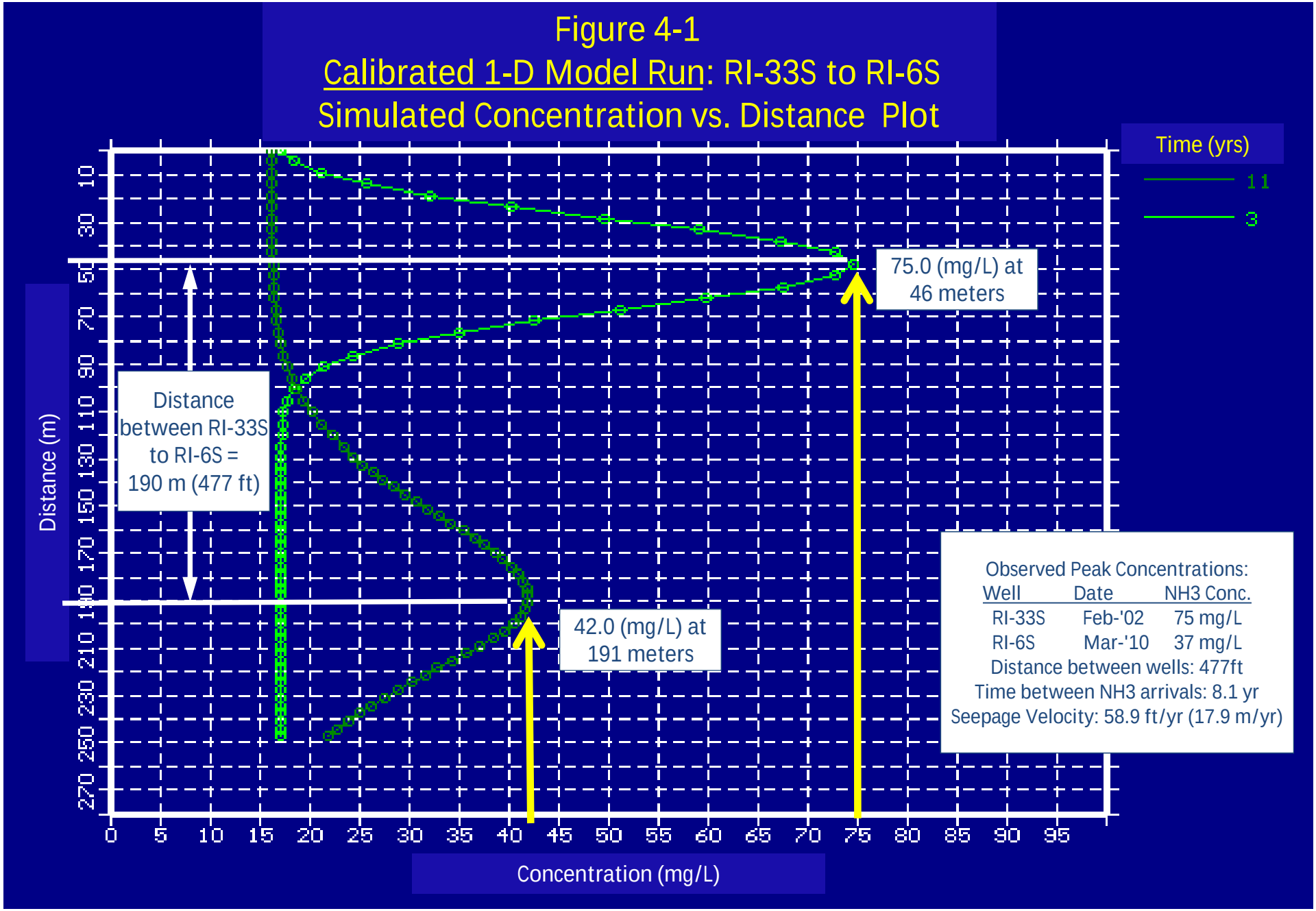
0 600 1200

SCALE (FEET)

# Hydraulic Conductivity Distribution – Shallow Hydrostatic Unit

| | |
|---|---|
| DRAWING DATE: January 29, 2019 | ACAD FILE: INDY PLANT_K–ZONE |
| CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC | AECOM |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | FIGURE: 3-5 |
| DESIGNED: JSM | APPROVED: GMB |
| PROJECT NO.: 60571463 | |

# Figure 4-1
## Calibrated 1-D Model Run: RI-33S to RI-6S
## Simulated Concentration vs. Distance Plot



686
684
682
680
678
676
674
672
670
668
666
664
662

RI–10D

RI–15M
RI–15D
RI-15M
B 0.028
P 0.071
A 13.4
RI-15D
B 0.0091
P 0.0211
A 7.3

RUN 2
0ft
500ft
B 0.005
P 0.050
A 10.0

RI–3D
PW–3
–2D
–25D
D

B 0.028
P 0.071
A 15.0

RI–17D

RI–11M
RI-11M
B 0.131
P 0.050
A 62

B 0.131
P 0.070
A 62.0
1400ft
1500ft

RI–11D
RI-11D
B 0.0005
P 0.000
A 8.5

PW–2D

OU1

OU5

B 0.030
P 0.045
A 25.0
1800ft

B 1.500
P 0.900
A 25.0
B 0.600
P 0.400
A 20.0
B 0.150
P 0.100
A 20.0

RUN 1
0ft
40ft
170ft
300ft
B 0.040
P 0.070
A 20.0

B 0.015
P 0.030
A 20.0

RI–18D

RI–4D
RI-4D
B 1.410
P 0.899
A 24

MINNESOTA ST.

600ft
B 0.020
P 0.050
A 15.0
850ft
B 0.015
P 0.020
A 12.5
2200ft
B 0.007
P 0.020
A 15.0

PW–1D

1200ft
2500ft

RI–5S
RI-5S
B 0.031
P 0.0686
A 9.9

RI–5D

RI–19D
RI-19D
B <0.005
P 0.0484
A 4.2

B 0.005
P 0.010
A 10.0

B 0.005
P 0.010
A 10.0

ROLLS ROYCE
PW–3
1593ft
2882ft

RR PW-3
B <0.005
P 0.0
A 3.5

ROLLS ROYCE
PW–2

PW–4
RI-37D
RI–6D

ROLLS ROYCE

## Legend

Existing Site Monitoring Well

Existing Site Extraction Well

Conservative Starting Concentrations in OU5:
RI–4D
Benzene (B)=1.410 mg/L
Total Pyridines (P)=0.899 mg/L
Ammonia (A)=24 mg/L

680.0 Simulated groundwater countours with no onsite pumping (ft MSL) – 2 foot contours

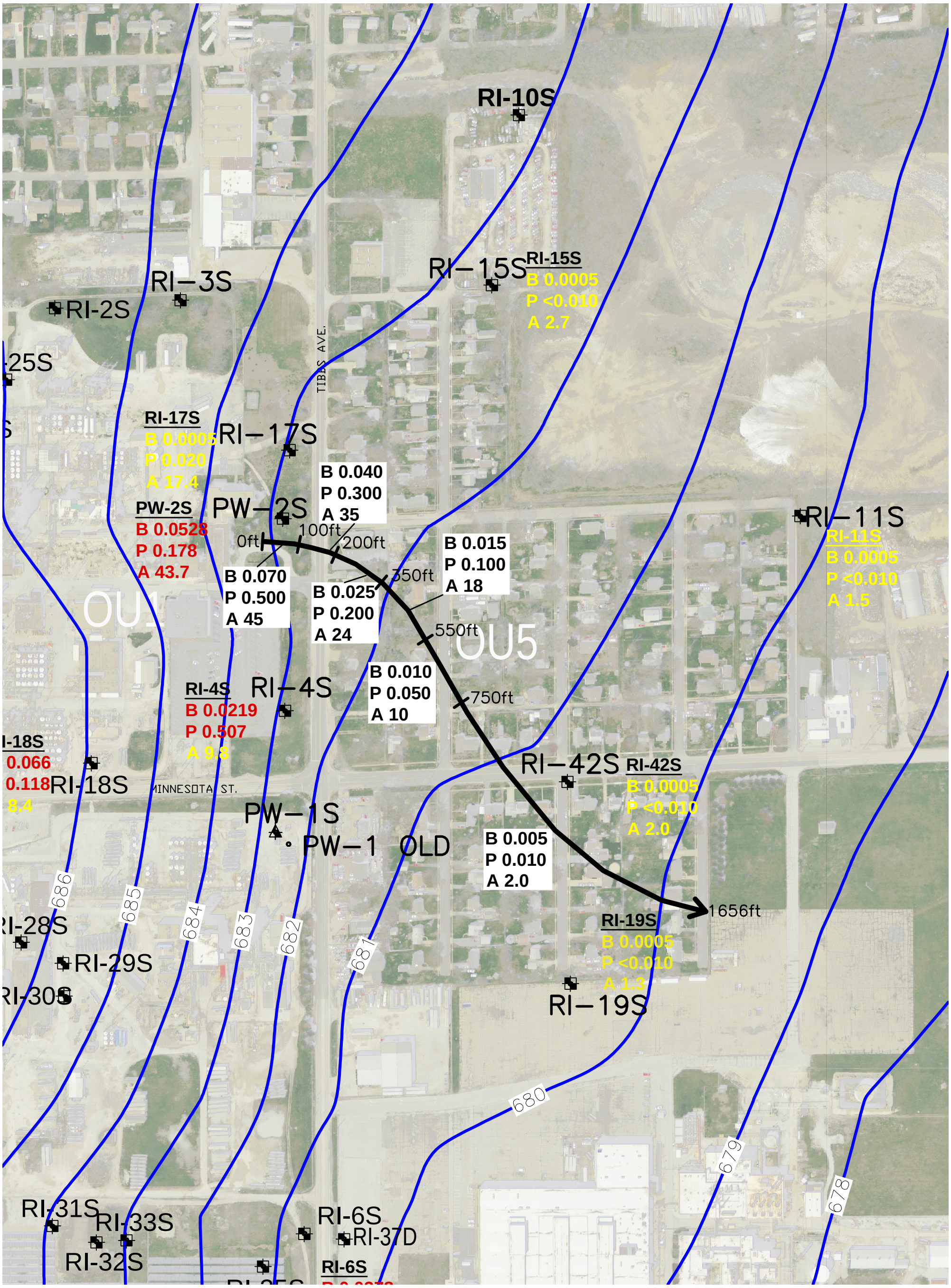
B 0.3
P 0.55
A 40
B 0.03
P 0.45
A 25
Simulated 1–D flow path (Scenario #1 & #3) with tick marks to indicate changes in starting concentrations

0 250 500
SCALE (FEET)

Notes:
1. Starting concentrations presented on this figure are based on highest observed concentrations (2016–2018)
2. All concentrations in mg/L
3. Remedial Action Objective (RAO)
   –Benzene (B) 0.005 mg/L
   –Pyridine (P) 0.035 mg/L
   –Ammonia (A) 30 mg/L

# Maximum Observed Concentrations (2016–2018) in OU5 for Natural Attenuation Modeling – Deep Hydrostatic Unit

| | |
|---|---|
| DRAWING DATE: FEBRUARY 8, 2019 | ACAD FILE: INDY PLANT.DWG |
| CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC | AECOM |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | FIGURE: 4–2 |
| DESIGNED: JSM | APPROVED: GMB |
| PROJECT NO.: 60571463 | |




Legend

- Existing Site Monitoring Well
- Existing Site Extraction Well
- Conservative Starting Concentrations in OU5:
  - RI-4S (Red indicates RAO exceedance)
  - Benzene (B)=0.0219 mg/L
  - Total Pyridines (P)=0.507 mg/L
  - Ammonia (A)=9.8 mg/L
- 680.0 — Simulated groundwater countours with no onsite pumping (ft MSL) – 1 foot contours
- B 0.3 P 0.55 A 40 / B 0.03 P 0.45 A 25 — Simulated 1-D flow path (Scenario #1 & #3) with tick marks to indicate changes in starting concentrations

BEARING

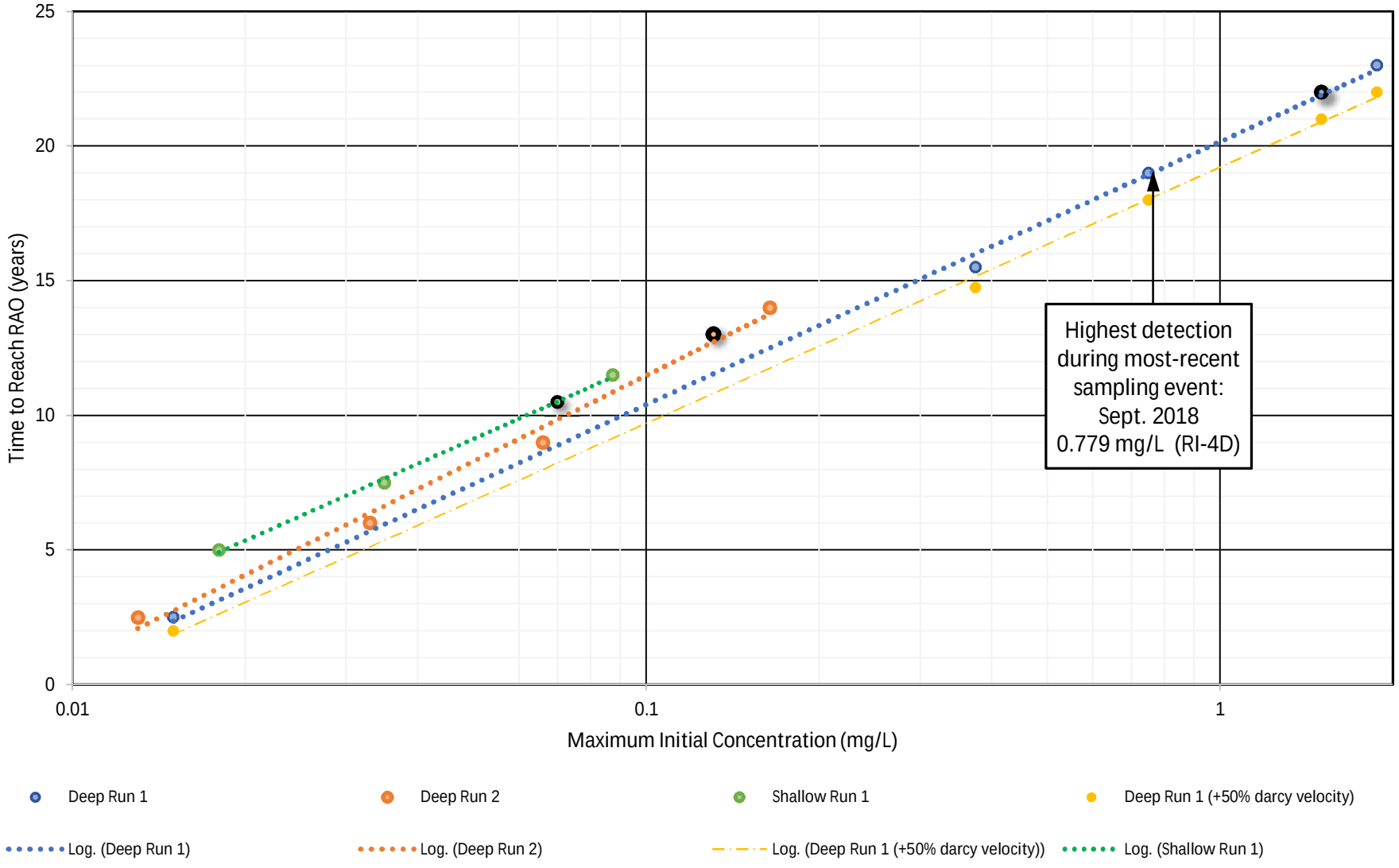
0 250 500
SCALE (FEET)

Notes:
1. Starting concentrations presented on this figure are based on highest observed concentrations (2016–2018)
2. All concentrations in mg/L
3. Remedial Action Objective (RAO)
   - –Benzene (B) 0.005 mg/L
   - –Pyridine (P) 0.035 mg/L
   - –Ammonia (A) 30 mg/L

# Maximum Observed Concentrations (2016–2018) in OU5 for Natural Attenuation Modeling – Shallow Hydrostatic Unit

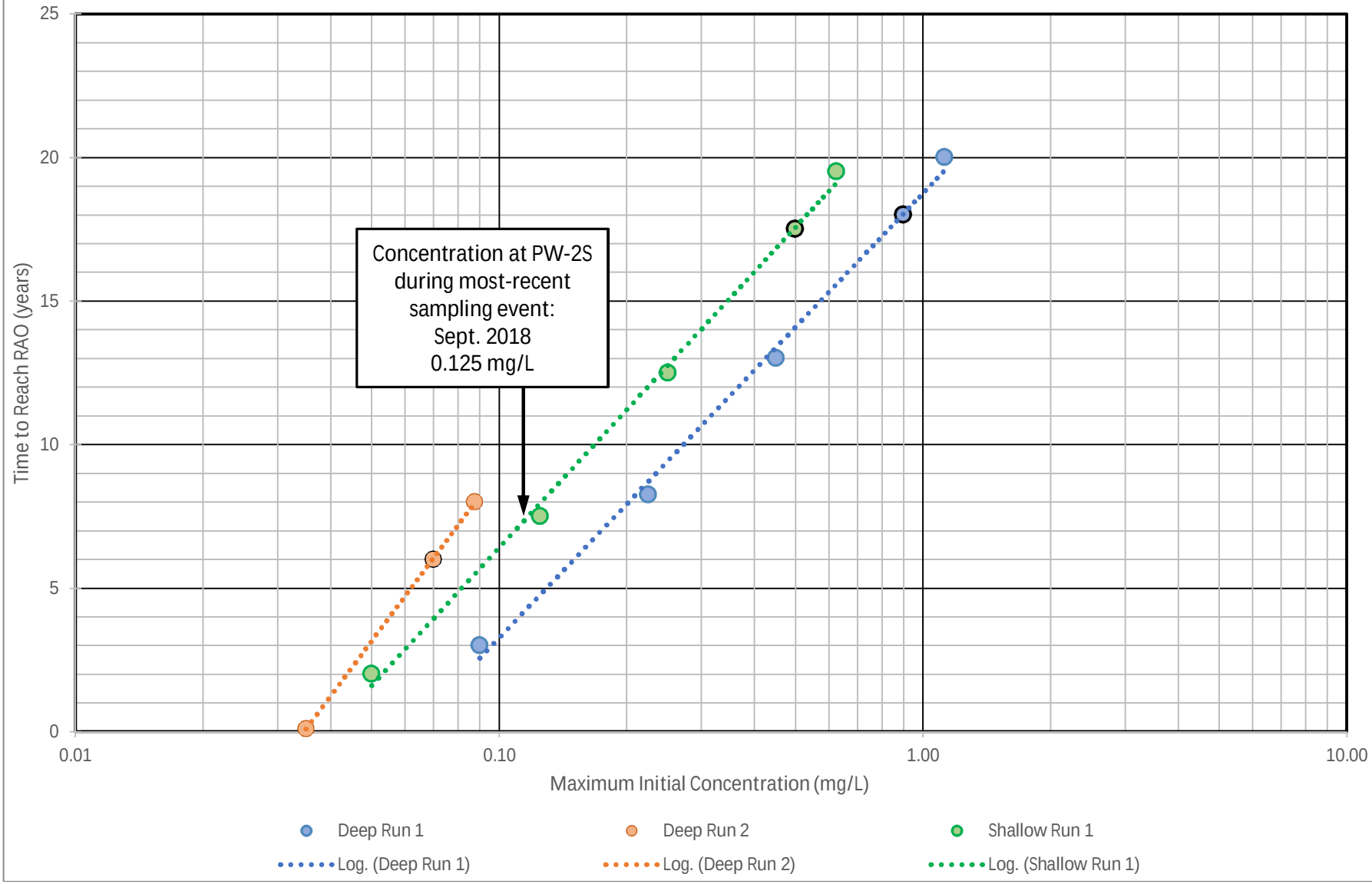
| | |
|---|---|
| DRAWING DATE: FEBRUARY 8, 2019 | ACAD FILE: INDY PLANT.DWG |
| CLIENT: VERTELLUS INTEGRATED PYRIDINES LLC | AECOM |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | FIGURE: 4-3 |
| DESIGNED: JSM / APPROVED: GMB / PROJECT NO.: 60571463 | |

# Figure 4-4A
## Natural Attenuation Curves for Benzene
Vertellus Integrated Pyridines, LLC
Indianapolis, Indiana

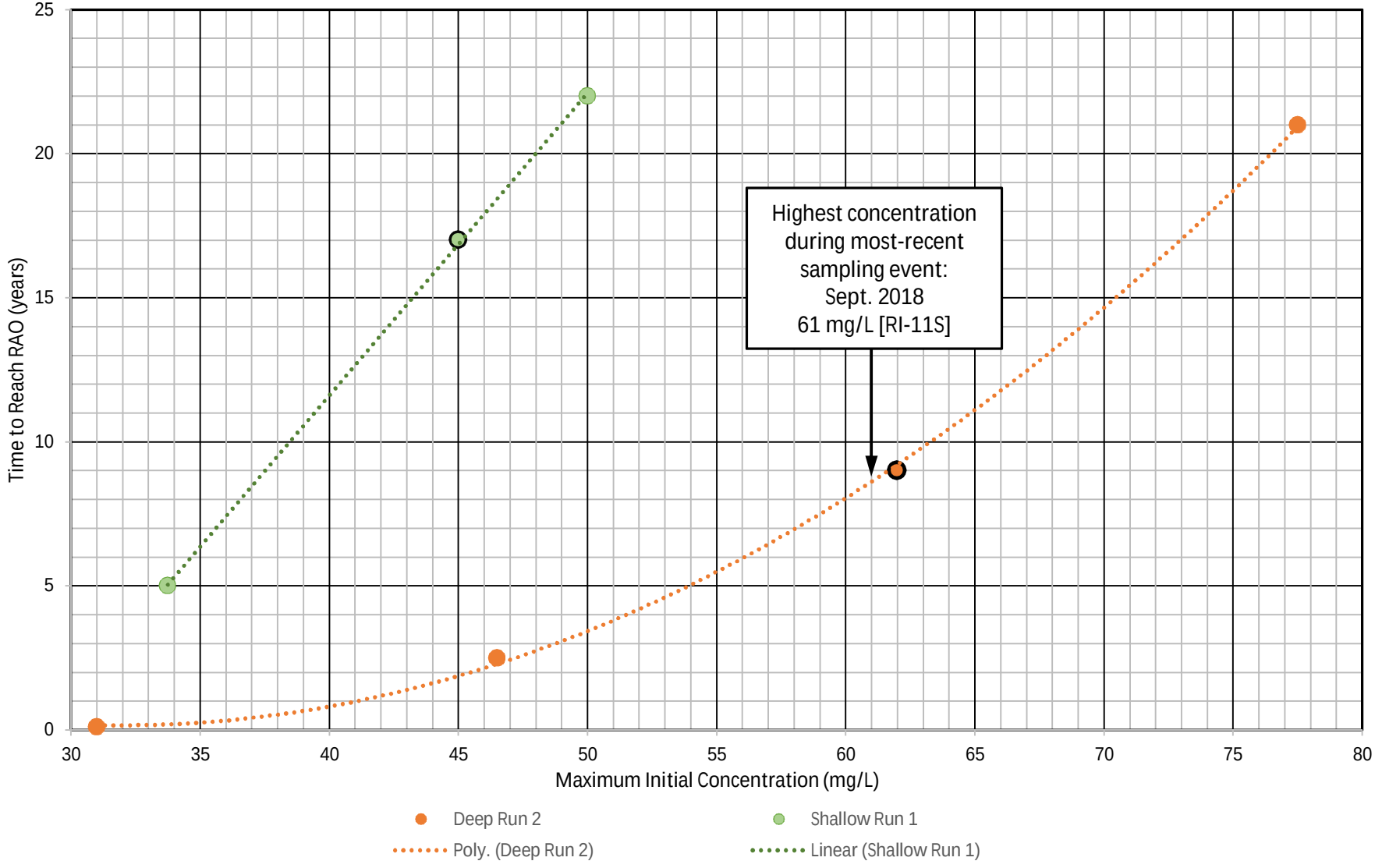



P:\60571463_TEMP\POLLUTE\Runs Initial Conc and Time to RAO_2019_03_01_V2.xlsxFig 4-4A Benzene

Figure 4-4B
Natural Attentuation Curves for Pyridines
Vertellus Integrated Pyridines, LLC
Indianapolis, Indiana



# Figure 4-4C
## Natural Attentuation Curves for Ammonia
Vertellus Integrated Pyridines, LLC
Indianapolis, Indiana




P:\60571463_TEMP\POLLUTE\Runs Initial Conc and Time to RAO_2019_03_01_V2.xlsxFig 4-4C Ammonia

# Appendices


Appendix A Background Information

A-1 Geologic Cross Sections

A-2 August-Mack Modeling Information

- September 2009 Groundwater Levels
- Qtr1-2018 Groundwater Levels

A-3 Groundwater Hydrographs

A-4 Time-Trend Graphs of RI-11 and RI-15 in OU5

Appendix B Groundwater Flow Modeling Results

B-1 Groundwater Flow Modeling of FFS Scenarios

B-2 Groundwater Flow Model Sensitivity Analysis – Deep Unit

B-3 Groundwater Flow Model Sensitivity Analysis – Shallow Unit

Appendix C Contaminant Transport Modeling Results

C-1 Transport Model Calibration Files

C-2 Transport Model Sensitivity Analyses

C-3 Set-Up Files for Transport Model

C-4 Contaminant Transport Modeling Results

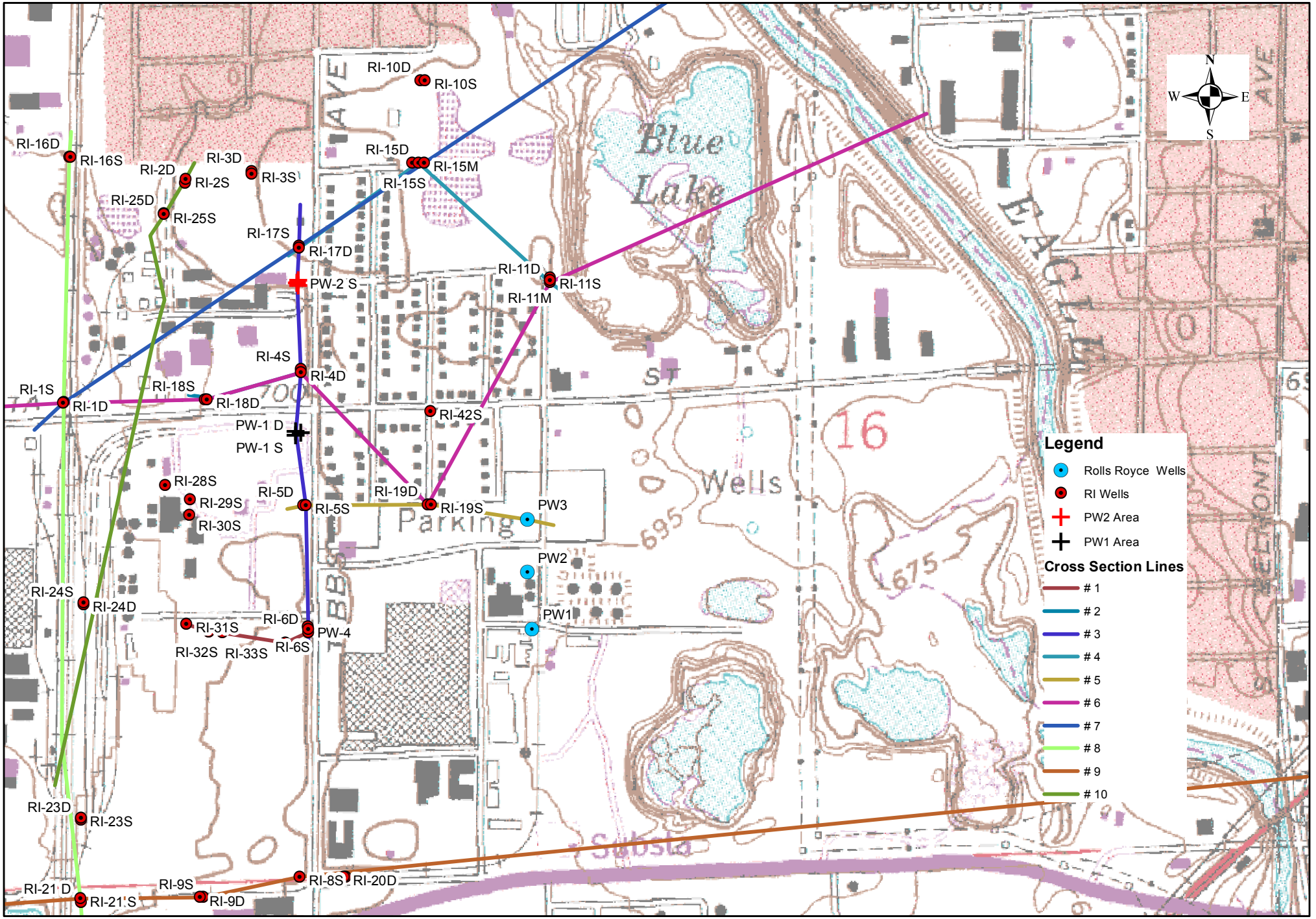
Appendix D Groundwater Flow Analysis in the area of RI-11 and RI-15

# Appendix A

# Background Information

# Appendix A-1

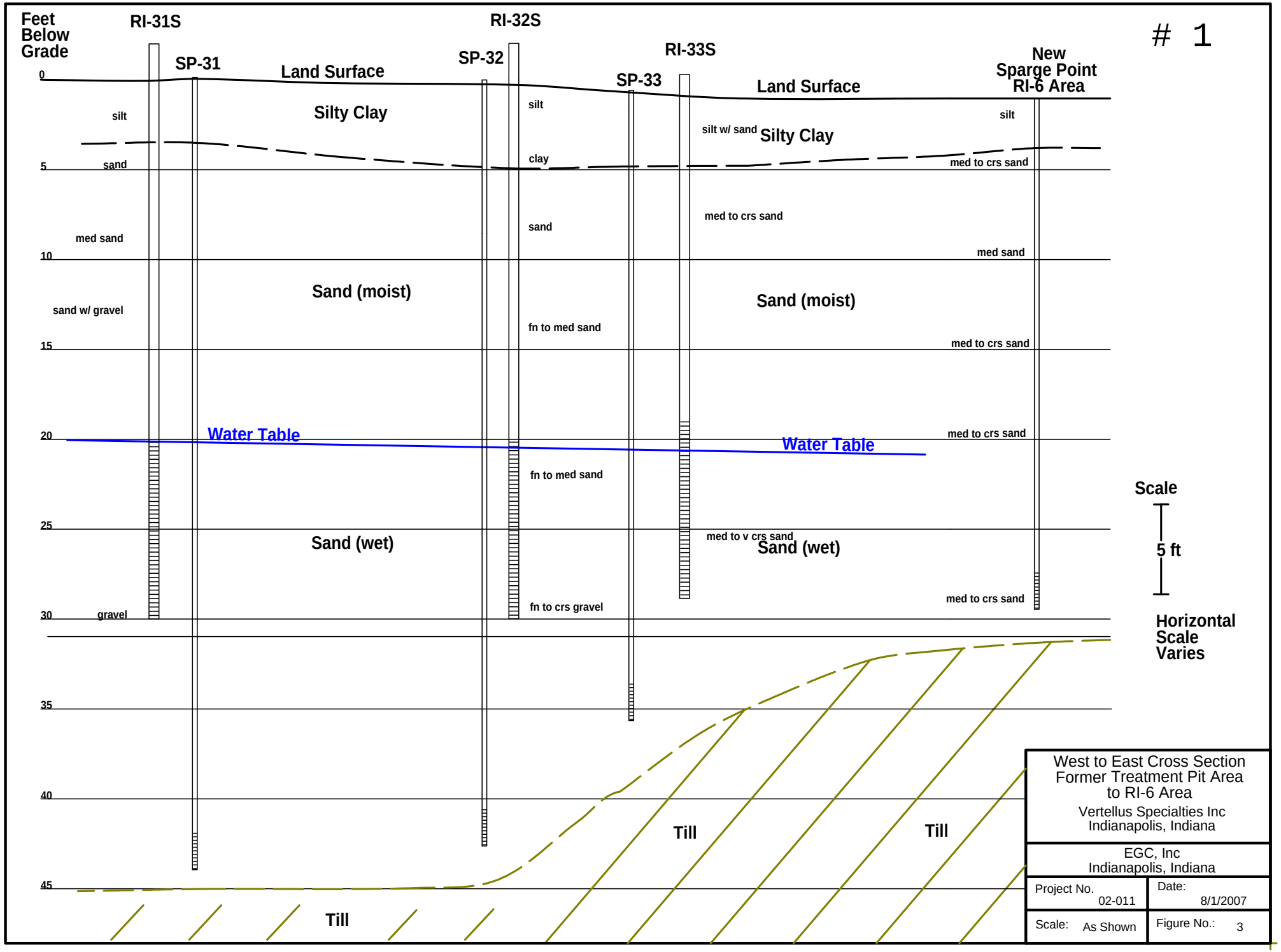
# Geologic Cross Sections



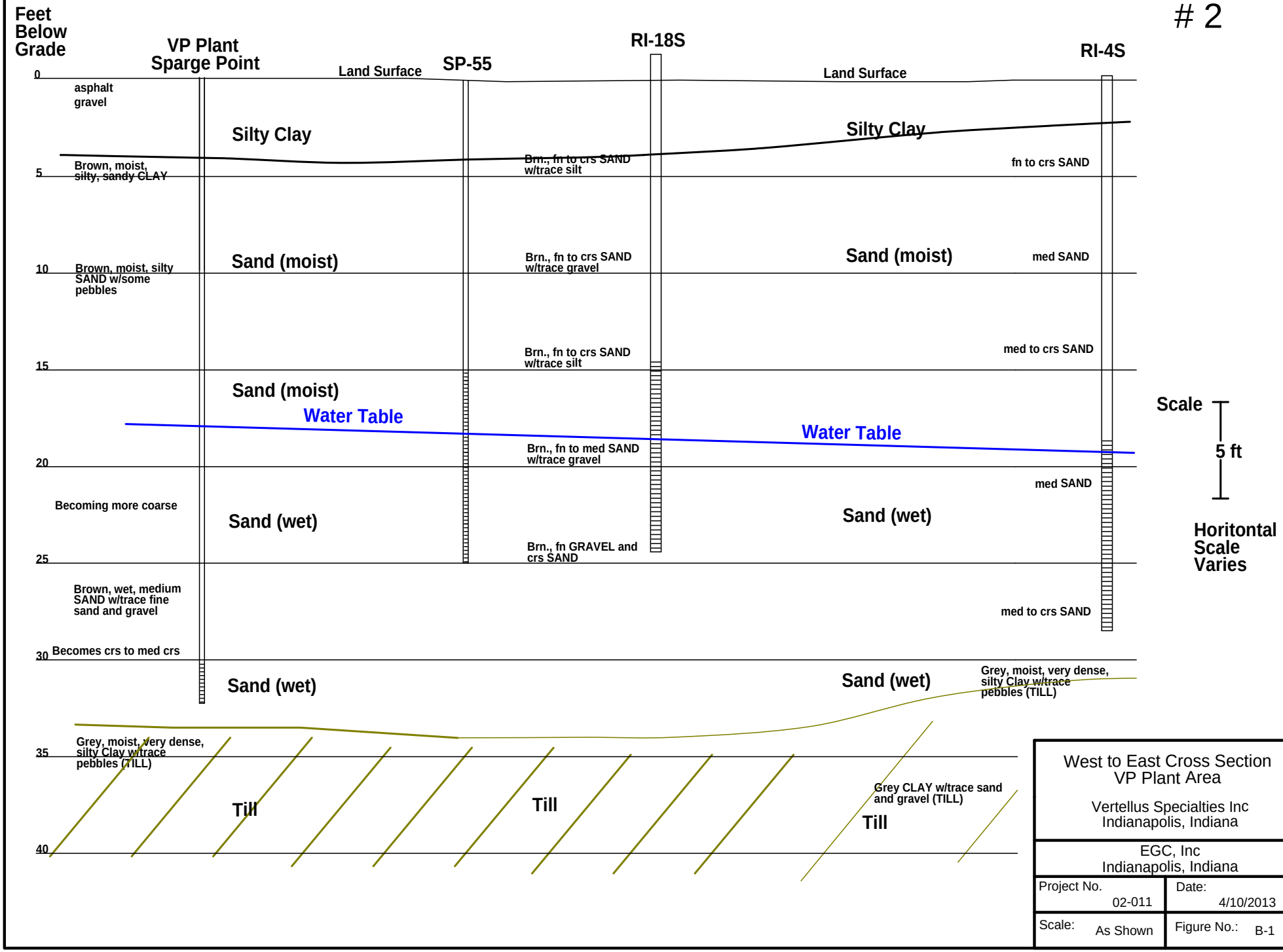

**Appendix A - Cross Section Location Map**

0 350 700 1,400 Feet

**Vertellus Specialties Inc**
**1500 S. Tibbs Ave.**
**Indianapolis, IN**


Feet Below Grade
RI-31S
SP-31
Land Surface
RI-32S
SP-32
RI-33S
SP-33
Land Surface
New Sparge Point RI-6 Area
# 1
0
5
10
15
20
25
30
35
40
45
silt
Silty Clay
sand
silt
clay
silt w/ sand
Silty Clay
med to crs sand
med sand
sand
med to crs sand
med sand
sand w/ gravel
Sand (moist)
fn to med sand
Sand (moist)
med to crs sand
Water Table
Water Table
med to crs sand
fn to med sand
med to v crs sand
Sand (wet)
Sand (wet)
gravel
fn to crs gravel
med to crs sand
Till
Till
Till
Scale
5 ft
Horizontal Scale Varies
West to East Cross Section
Former Treatment Pit Area
to RI-6 Area
Vertellus Specialties Inc
Indianapolis, Indiana
EGC, Inc
Indianapolis, Indiana
Project No. 02-011
Date: 8/1/2007
Scale: As Shown
Figure No.: 3

# 2



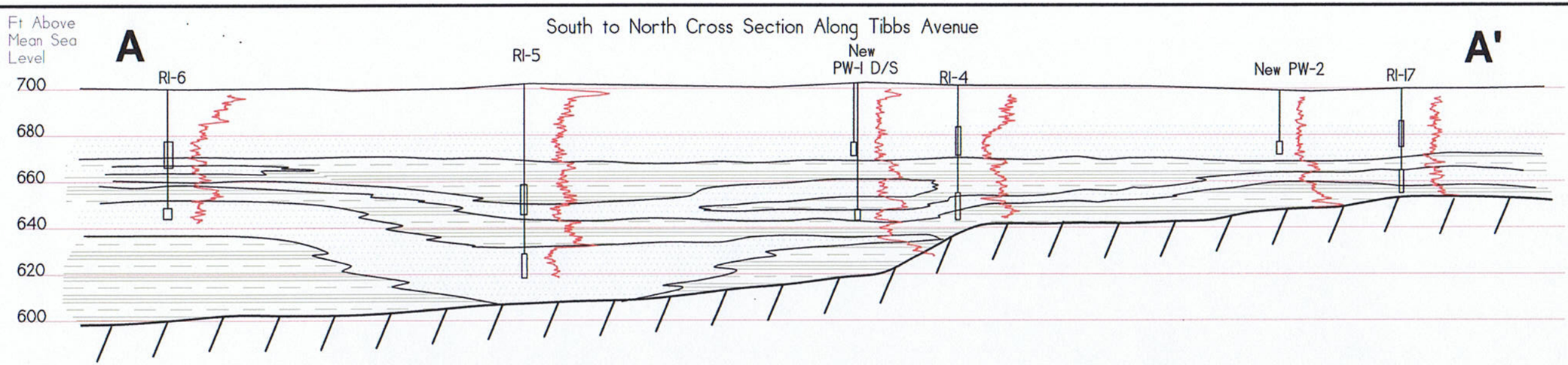

West to East Cross Section
VP Plant Area

Vertellus Specialties Inc
Indianapolis, Indiana

EGC, Inc
Indianapolis, Indiana

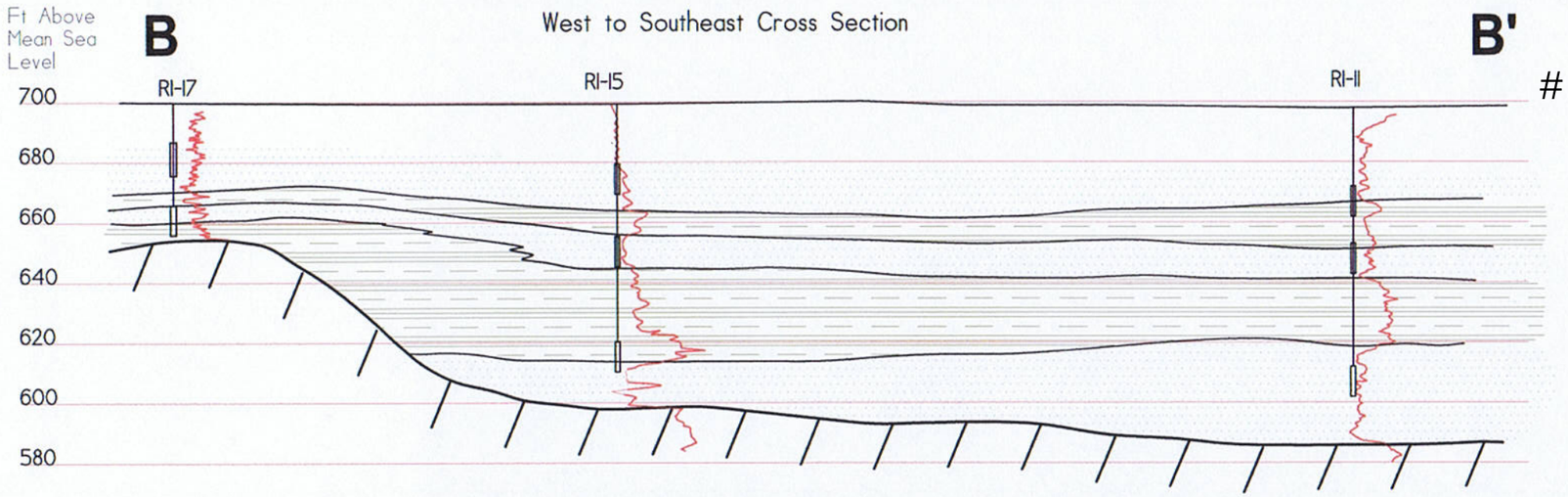
| Project No. | Date: |
|---|---|
| 02-011 | 4/10/2013 |
| Scale: As Shown | Figure No.: B-1 |

South to North Cross Section Along Tibbs Avenue



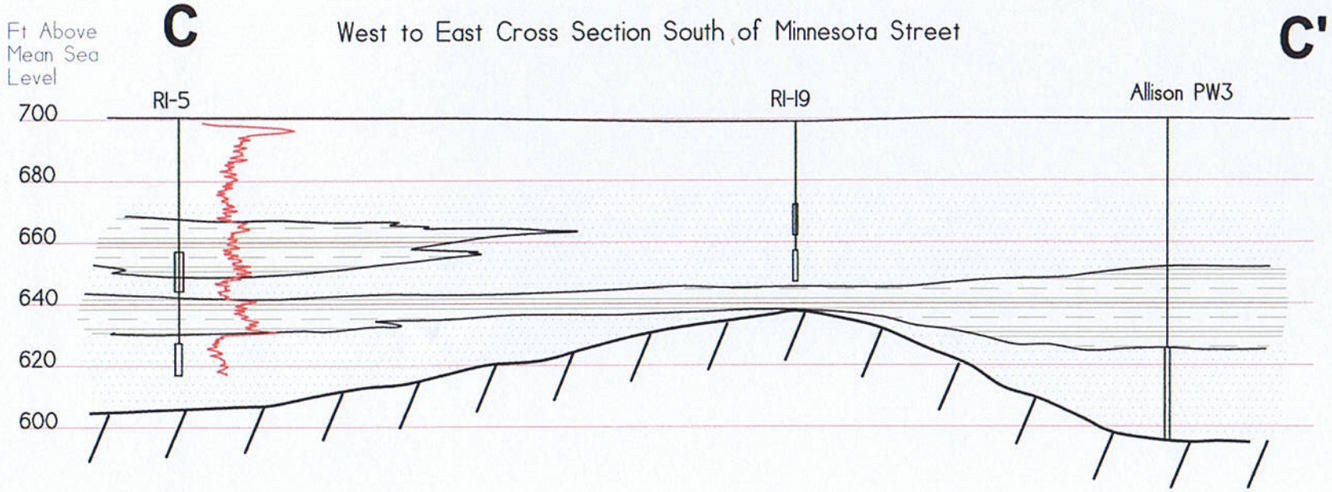

# 3

West to Southeast Cross Section




# 4

West to East Cross Section South of Minnesota Street




# 5

Scale

200 ft

50 ft

V.E. - 4X

## Legend

- unsaturated soils
- fine grained soils
- water saturated sandy soils
- bedrock
- well screened interval
- natural gamma logger response

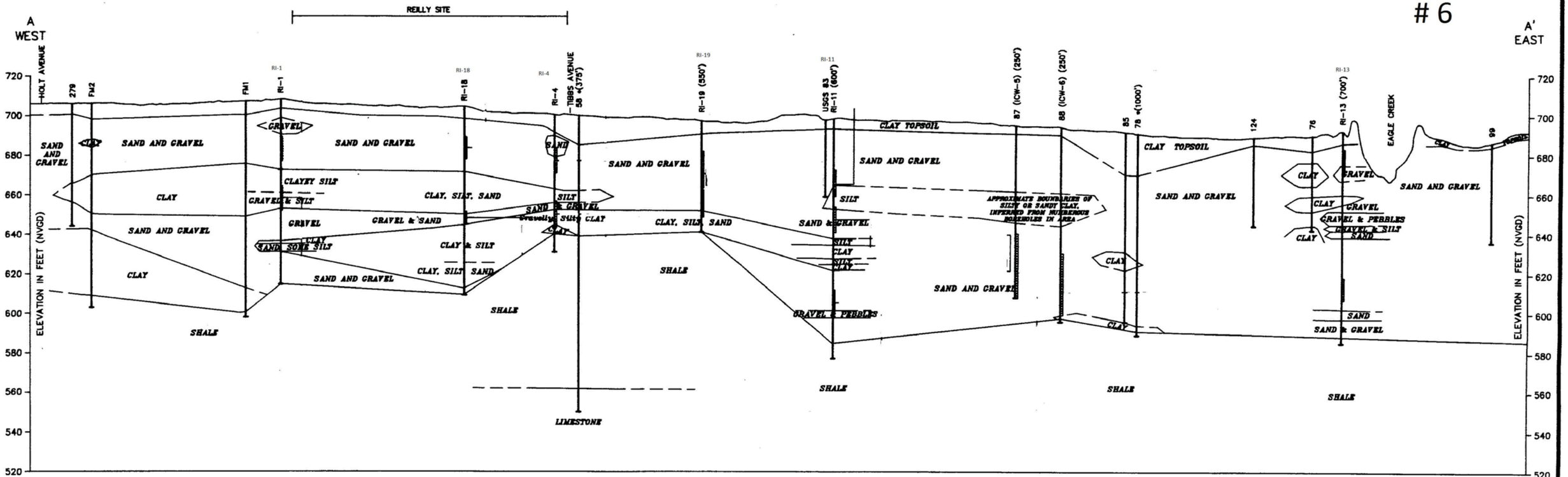
**Cross Sections Based on Soil Boring Logs and Gamma Logging**

**Reilly Industries Site and Vicinity**
**1500 South Tibbs Avenue**
**Indianapolis, Indiana**

**EGC, Inc.**
**Indianapolis, Indiana**

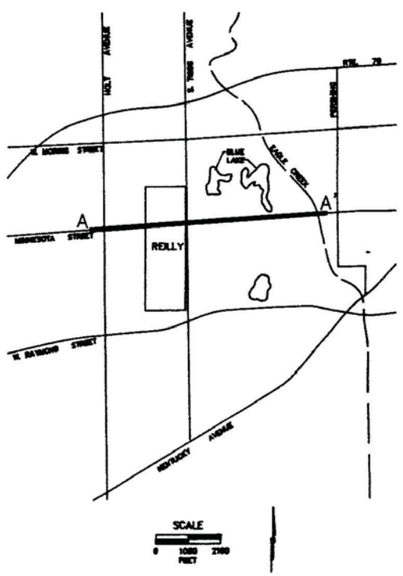
| Scale: | Figure No. |
|---|---|
| As Shown | 2 |

# #6




20'
0 200'
SCALE

LOCATION MAP




LEGEND

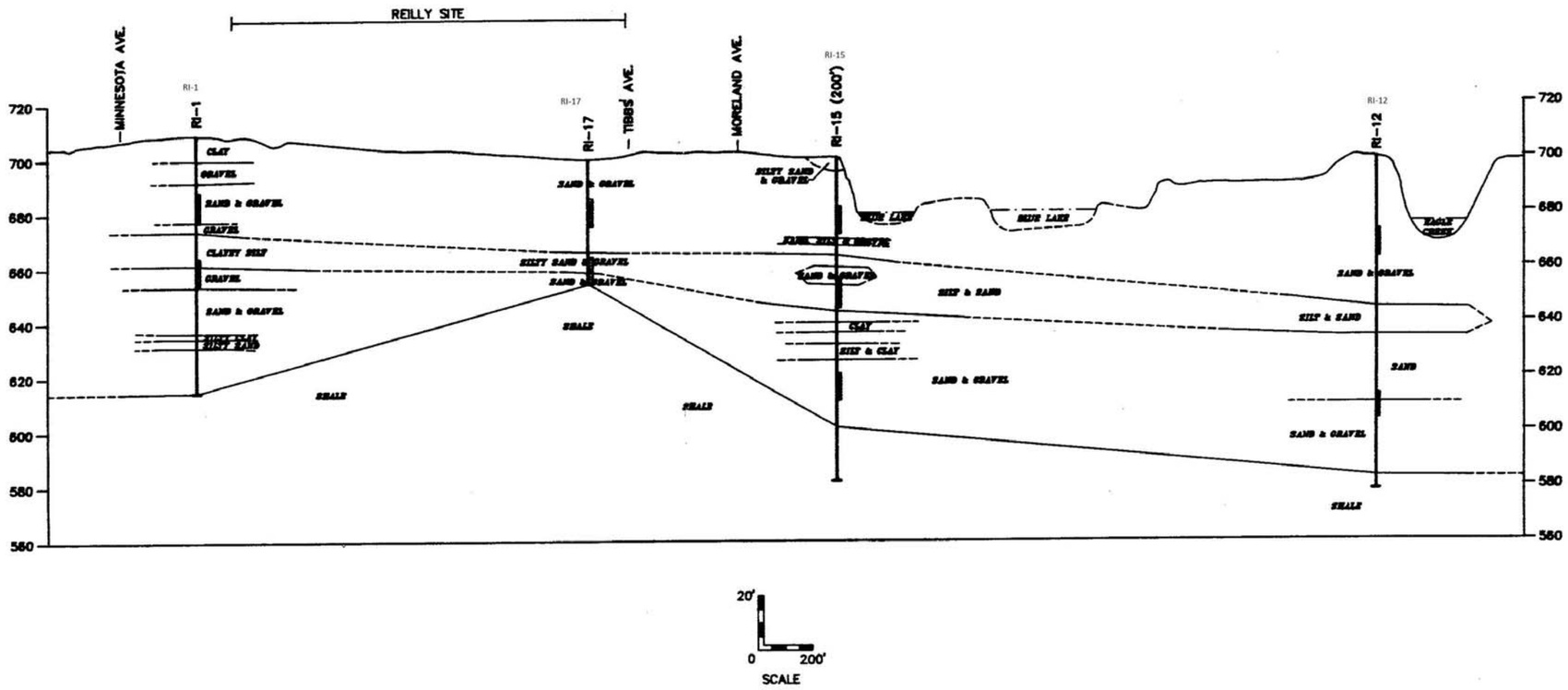
| | |
|---|---|
| | SCREENED INTERVAL AND BOTTOM OF TEST BORING/WELL, UPPER SCREEN INDICATES PIEZOMETER. |
| | STRATIGRAPHIC CONTACT (DASHED WHERE INFERRED) |
| *(139') | NUMBER IN PARENTHESES INDICATES THE DISTANCE THAT A BORING LOG WAS PROJECTED. ALL OTHER BORINGS ARE LOCATED WITHIN 100' OF THE CROSS-SECTION LINE. |
| 93 | WELL NUMBERS ARE THE RECORD NUMBERS USED IN THE WELL LOG DATABASE PRESENTED IN THE PHASE I TECHNICAL MEMORANDUM (ERT, SEPTEMBER, 1988). |

ENSR CONSULTING & ENGINEERING

**Figure 3-13**
Phase III Ground Water Sampling Results
Reilly Industries - Indianapolis, IN

| DRAWN BY: | DATE: | PROJECT NO. |
|---|---|---|
| J.E.B. | 10/90 | 5660-003-500 |

566023B




LOCATION MAP

LEGEND

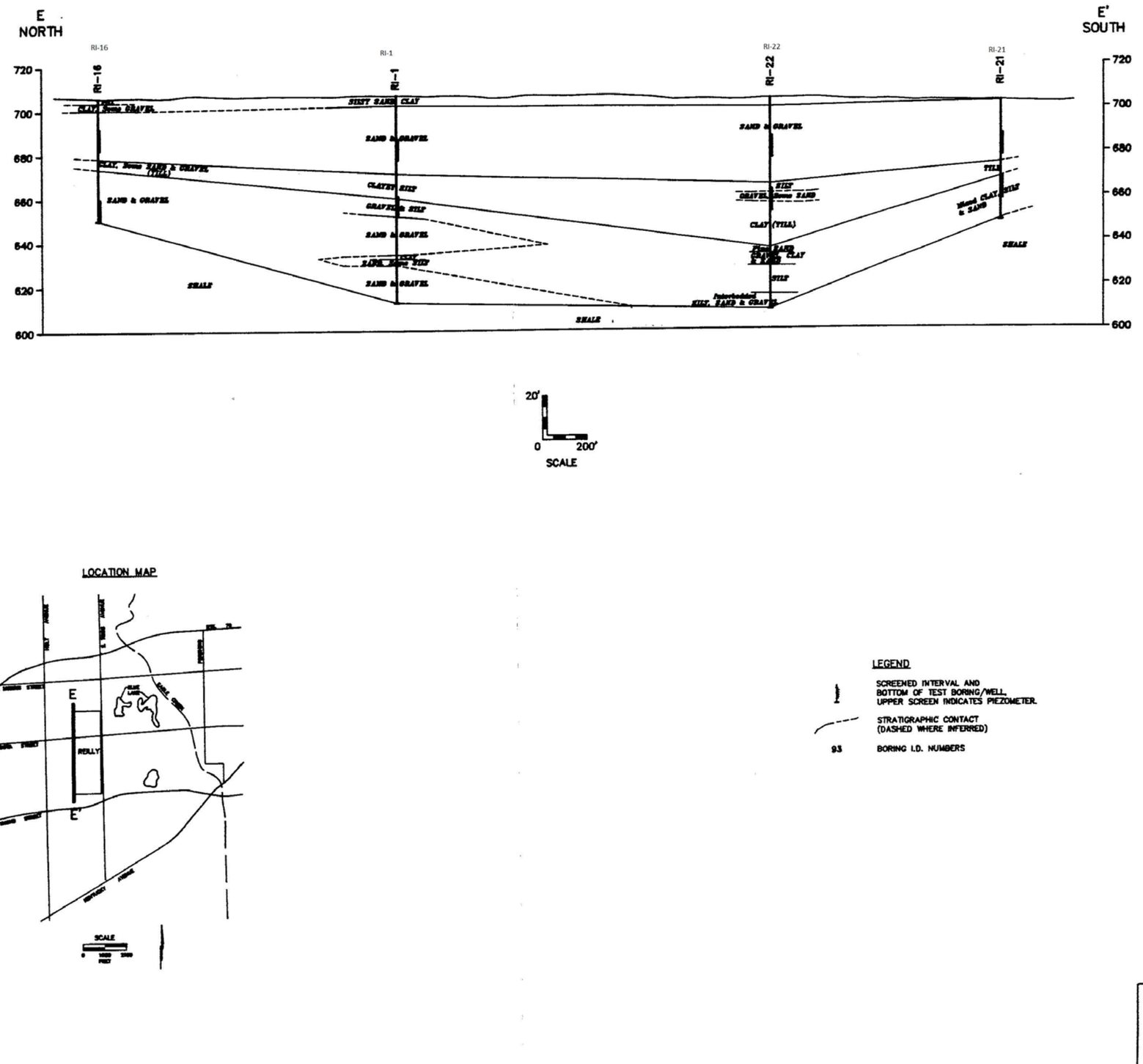
- SCREENED INTERVAL AND BOTTOM OF TEST BORING/WELL. UPPER SCREEN INDICATES PIEZOMETER.
- STRATIGRAPHIC CONTACT (DASHED WHERE INFERRED)
- «(130') NUMBER IN PARENTHESES INDICATES THE DISTANCE THAT A BORING LOG WAS PROJECTED. ALL OTHER BORINGS ARE LOCATED WITHIN 100' OF THE CROSS-SECTION LINE.
- 93 WELL NUMBERS ARE THE RECORD NUMBERS USED IN THE WELL LOG DATABASE PRESENTED IN THE PHASE I TECHNICAL MEMORANDUM (ERT, SEPTEMBER, 1988).

**Figure 3-4**
Cross Section D-D'
Reilly Industries - Indianapolis, IN

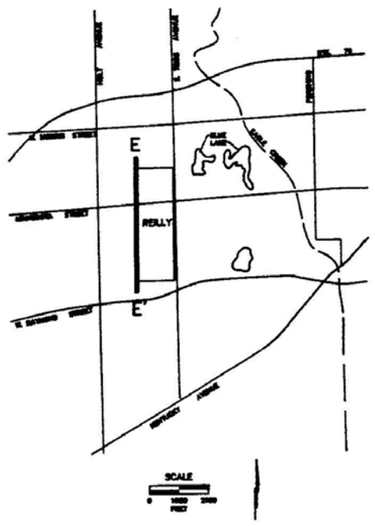
| | | | | | |
|---|---|---|---|---|---|
| 2 | 5/89 | REVISE STRATA/ADD WELLS | JEB | LP | |
| 1 | 7/88 | ADD WELLS | KLU | JR | |
| NO. | DATE | REVISIONS | BY | CHKD | APP'D |

ENSR CONSULTING & ENGINEERING

| | | |
|---|---|---|
| DRAWN: JR | DATE: 5/17/88 | DRAWING NUMBER: 4-5 |
| DESIGNED: KLU | STATUS: As Shown | |
| CHECKED: TC | APPROVED: | PROJECT NUMBER: 3880-003-012 REV. NO. 2 |




LOCATION MAP




LEGEND

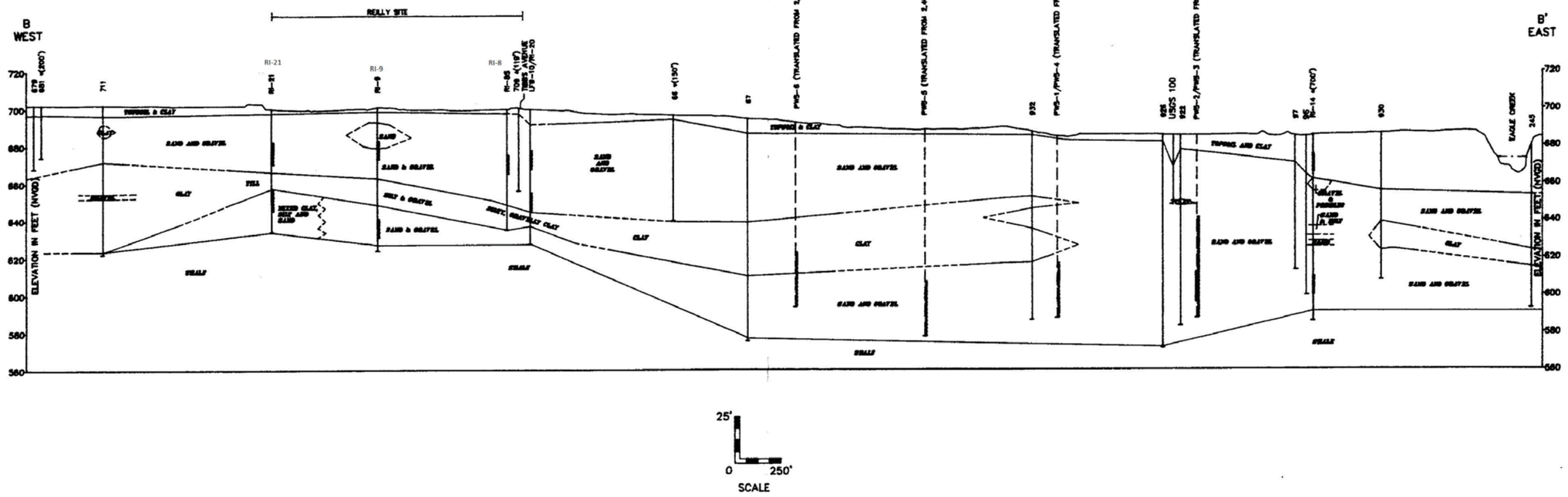
- SCREENED INTERVAL AND BOTTOM OF TEST BORING/WELL. UPPER SCREEN INDICATES PIEZOMETER.
- STRATIGRAPHIC CONTACT (DASHED WHERE INFERRED)
- 93 BORING I.D. NUMBERS

**Figure 3-5**
Cross Section E-E'
Reilly Industries - Indianapolis, IN

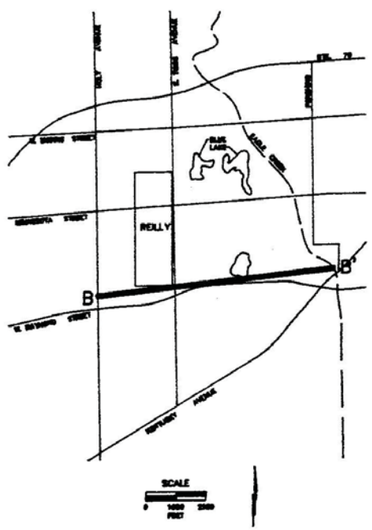
| | | | | | |
|---|---|---|---|---|---|
| 1 | 5/00 | NEW WELLS | JB | LP | |
| NO. | DATE | REVISIONS | BY | CHK'D | APP'VD |

ENSR CONSULTING & ENGINEERING

| | | |
|---|---|---|
| DESIGNED LP | DATE 5/15/00 | DRAWING NUMBER 5-5 |
| DRAWN JB | SCALE As Shown | |
| CHECKED TC | APPROVED | SHEET NUMBER 3880-003-012 REV. NO. 1 |




LOCATION MAP




LEGEND

| | |
|---|---|
| | SCREENED INTERVAL AND BOTTOM OF TEST BORING/WELL. UPPER SCREEN INDICATES PIEZOMETER. |
| | STRATIGRAPHIC CONTACT (DASHED WHERE INFERRED) |
| *(139') | NUMBER IN PARENTHESES INDICATES THE DISTANCE THAT A BORING LOG WAS PROJECTED. ALL OTHER BORINGS ARE LOCATED WITHIN 100' OF THE CROSS-SECTION LINE. |
| 93 | WELL NUMBERS ARE THE RECORD NUMBERS USED IN THE WELL LOG DATABASE PRESENTED IN THE PHASE I TECHNICAL MEMORANDUM (ERT, SEPTEMBER, 1988). |

NOTE: PUMPING WELL SCREENED INTERVALS HAVE BEEN SUPERIMPOSED ONTO EXISTING CROSS-SECTION AS THE SCREENED INTERVALS HAVE BEEN TRANSLATED FROM BETWEEN 430 TO 2,450 feet. STRATIGRAPHY HAS NOT BEEN MODIFIED TO REFLECT PUMPING WELL BORING LOGS.

**Figure 3-2**
Cross Section B-B'
Reilly Industries - Indianapolis, IN

| | | | | |
|---|---|---|---|---|
| 2 | 6/90 | REVISE STRATA/NEW WELLS | JCC | LP |
| 1 | 7/89 | NEW WELLS | VLH | JC |
| NO. | DATE | REVISION | BY | CHK'D |

BNR CONSULTING & ENGINEERING

| | | |
|---|---|---|
| DRAWN: JC | DATE: 9/28/88 | DRAWING NUMBER: 2-5 |
| CHECKED: KLU | SCALE: As Shown | |
| DESIGNED: TC | APPROVED: DSC E | PROJECT NUMBER: 8890-003-912 |

F (NORTH) — F' (SOUTH)

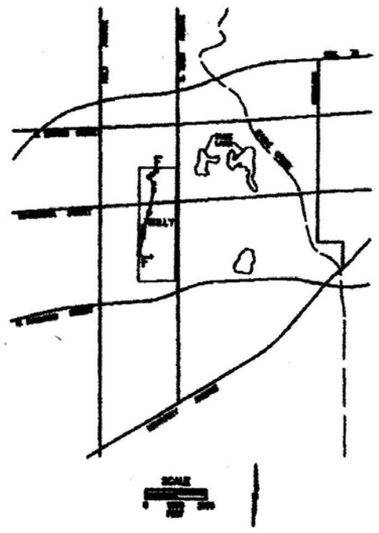
NORTH PROCESS AREA

RI-2 RI-25 RI-26 RI-40 RI-39 Q-11 Q-12 Q-15 Q-14 Q-13 RI-22

720 710 700 690 680 670 660 650 640 630 620 610 600 590

SILTY CLAY
CLAY & GRAVEL
SAND & GRAVEL
(OUTWASH)
(TILL)
SILTY GRAVEL
SILTY CLAY
SILT & GRAVEL
BLACK SHALE
BEDROCK SURFACE INTERPRETED FROM CONTOUR MAP
ODOR
SILT

LOCATION MAP



SCALE

10'
0
200'
SCALE

LEGEND

- SCREENED INTERVAL
- WATER LEVEL (ENCOUNTERED IN BORING)
- PHASE 1 RI/RFI SOIL SAMPLE
- PHASE 2 RI/RFI SOIL SAMPLE
- INTERVAL OF VISIBLE STAINING AND/OR ODOR
- STRATIGRAPHIC CONTACT (DASHED WHERE INFERRED)

FIGURE 1-2

CROSS SECTION F-F'
REILLY INDUSTRIES
INDIANAPOLIS, INDIANA

| | | |
|---|---|---|
| JR | 11/94 | 1 |
| G.E.S | As Shown | |
| TC | | 8906-004 |

80A04E

# Appendix A-2

# August-Mack Modeling Information

- **September 2009 Groundwater Levels**
- **Qtr1-2018 Groundwater Levels**

SEPT 2009 GROUNDWATER LEVELS USED FOR CALIBRATION OF 2010 AME MODEL 2018 AECOM MODELS

**TABLE 2**
**September 24, 2009 Monitoring Well Water Levels**
**Vertellus Specialties Inc.**
**1500 South Tibbs Avenue**
**Indianapolis, Indiana**
**August Mack Project Number JK0522.380**

| Monitoring Well ID | Well Casing Elevation (ft amsl) | Depth to Water (ft bg) 9/24/2009 3Q2009 | Groundwater Elevation (ft amsl) 9/24/2009 3Q2009 |
|---|---|---|---|
| RI-1S | 710.15 | 21.43 | 688.72 |
| RI-1D | 710.12 | 21.96 | 688.16 |
| RI-2S | 706.46 | 19.40 | 687.06 |
| RI-2D | 707.18 | 20.31 | 686.87 |
| RI-3S | 703.91 | 18.68 | 685.23 |
| RI-3D | 703.98 | 18.48 | 685.50 |
| RI-4S | 700.68 | 17.94 | 682.74 |
| RI-4D* | 700.69 | 28.06 | 672.63 |
| RI-5S | 703.24 | 28.17 | 675.07 |
| RI-5D | 703.82 | 28.00 | 675.82 |
| RI-6S | 703.09 | 25.84 | 677.25 |
| RI-6D | 702.59 | 27.08 | 675.51 |
| RI-7S | 703.38 | 26.27 | 677.11 |
| RI-7D | 702.84 | 25.18 | 677.66 |
| RI-8S | 702.24 | 23.92 | 678.32 |
| RI-9S | 700.23 | 20.74 | 679.49 |
| RI-9D | 700.44 | 22.73 | 677.71 |
| RI-10S* | 698.65 | NA | NA |
| RI-10D* | 698.73 | NA | NA |
| RI-11S | 701.96 | 25.87 | 676.09 |
| RI-11M | 701.85 | 26.27 | 675.58 |
| RI-11D | 701.99 | 25.22 | 676.77 |
| RI-15S | 699.17 | 17.37 | 681.80 |
| RI-15M | 699.28 | 23.91 | 675.37 |
| RI-15D | 699.60 | 18.81 | 680.79 |
| RI-16S* | 706.06 | NA | NA |

ft bg = feet below grade
ft amsl = feet above mean sea level
NA = Not Available
* = Not used for model calibration

**TABLE 2 (continued)**
**September 24, 2009 Monitoring Well Water Levels**
**Vertellus Specialties Inc.**
**1500 South Tibbs Avenue**
**Indianapolis, Indiana**
**August Mack Project Number JK0522.380**

| Monitoring Well ID | Well Casing Elevation (ft amsl) | Depth to Water (ft bg) 9/24/2009 3Q2009 | Groundwater Elevation (ft amsl) 9/24/2009 3Q2009 |
|---|---|---|---|
| RI-16D | 706.36 | NA | NA |
| RI-17S | 699.69 | 16.31 | 683.38 |
| RI-17D | 699.77 | 14.99 | 684.78 |
| RI-18S | 705.98 | 20.71 | 685.27 |
| RI-18D | 703.67 | 20.02 | 683.65 |
| RI-20S* | 699.18 | 22.20 | 676.98 |
| RI-20D* | 699.08 | 22.14 | 676.94 |
| RI-21S | 704.43 | 21.91 | 682.52 |
| RI-21D* | 704.75 | 23.60 | 681.15 |
| RI-22S* | 707.93 | 22.75 | 685.18 |
| RI-22D* | 708.48 | 24.34 | 684.14 |
| RI-23S | 706.97 | 23.58 | 683.39 |
| RI-23D | 706.97 | 27.83 | 679.14 |
| RI-24S | 705.70 | 20.72 | 684.98 |
| RI-24D | 708.79 | 23.18 | 685.61 |
| RI-25S | 709.43 | 22.10 | 687.33 |
| RI-25D | 709.32 | 22.41 | 686.91 |
| RI-28S | 704.78 | 19.15 | 685.63 |
| RI-29S | 706.03 | 20.88 | 685.15 |
| RI-30S | 705.59 | 20.42 | 685.17 |
| RI-19S | 697.00 | 20.48 | 676.52 |
| RI-19D | 696.72 | 20.48 | 676.24 |
| RI-31S | 707.48 | 23.38 | 684.10 |
| RI-32S | 706.32 | 22.47 | 683.85 |
| RI-33S | 703.69 | 20.31 | 683.38 |
| RI-34S | 701.97 | 21.92 | 680.05 |
| RI-35S | 702.02 | 23.44 | 678.58 |
| RI-36S | 702.16 | 24.42 | 677.74 |
| RI-42S | 695.94 | 18.06 | 677.88 |

ft bg = feet below grade
ft amsl = feet above mean sea level
NA = Not Available
* = Not used for model calibration

# Vertellus Integrated Pyridines LLC - 1Q2018 Groundwater Elevations

OU1 / OU5 SHALLOW AQUIFER WELLS

| Well ID | Op. Unit | Easting | Northing | TOC (ft asl) | DTW (ft) | Elev (ft asl) |
|---|---|---|---|---|---|---|
| PW-1 OLD | OU1 | 173525 | 1637340 | 704.81 | 22.25 | 682.56 |
| PW-1S | OU1 | 173490 | 1637371 | 705.67 | 24.84 | 680.83 |
| PW-2S | OU1 | 173512 | 1638230 | 700.81 | 22.75 | 678.06 |
| RI-1S | OU1 | 172238 | 1637556 | 710.15 | 21.09 | 689.06 |
| RI-2S | OU1 | 172884 | 1638807 | 706.46 | 19.07 | 687.39 |
| RI-3S | OU1 | 173229 | 1638829 | 703.91 | 18.2 | 685.71 |
| RI-4S | OU1 | 173515 | 1637705 | 700.68 | 17.18 | 683.5 |
| RI-6S | OU1 | 173569 | 1636267 | 703.09 | 23.48 | 679.61 |
| RI-8S | OU1 | 173537 | 1634886 | 702.24 | 23.44 | 678.8 |
| RI-9S | OU1 | 173006 | 1634765 | 700.23 | 19.81 | 680.42 |
| RI-10S | OU5 | 174157 | 1639338 | 698.65 | 16.78 | 681.87 |
| RI-11S | OU5 | 174929 | 1638237 | 701.96 | 23.88 | 678.08 |
| RI-15S | OU5 | 174082 | 1638871 | 699.17 | 23.21 | 675.96 |
| RI-16S | August Mack Calibrated to RI-16S | | | | | |
| RI-17S | OU1 | 173528 | 1638419 | 699.69 | 15.65 | 684.04 |
| RI-18S | OU1 | 172999 | 1637559 | 705.98 | 20.44 | 685.54 |
| RI-19S | OU5 | 174298 | 1636956 | 697 | 18.4 | 678.6 |
| RI-20S | OU5 | 173725 | 1634877 | 699.18 | 20.51 | 678.67 |
| RI-21S | OU1 | 172371 | 1634761 | 704.43 | 21.28 | 683.15 |
| RI-22S | August Mack Calibrated to RI-22S | | | | | |
| RI-23S | OU1 | 172300 | 1635157 | 706.97 | 22.19 | 684.78 |
| RI-24S | OU1 | 172313 | 1636429 | 705.7 | 20.45 | 685.25 |
| RI-25S | OU1 | 172749 | 1638611 | 709.43 | 21.75 | 687.68 |
| RI-28S | OU1 | 172792 | 1637070 | 704.78 | 18.76 | 686.02 |
| RI-29S | OU1 | 172906 | 1637013 | 706.03 | 20.93 | 685.1 |
| RI-30S | OU1 | 172913 | 1636921 | 705.59 | 20.15 | 685.44 |
| RI-31S | OU1 | 172877 | 1636292 | 707.48 | 22.87 | 684.61 |
| RI-32S | OU1 | 172998 | 1636249 | 706.32 | 22.08 | 684.24 |
| RI-33S | OU1 | 173080 | 1636254 | 703.69 | 19.71 | 683.98 |
| RI-35S | OU1 | 173456 | 1636182 | 702.02 | 21.57 | 680.45 |

OU1 DEEP / OU5 MEDIUM AQUIFER WELLS

| Well ID | Op. Unit | Easting | Northing | TOC (ft asl) | DTW (ft) | Elev (ft asl) |
|---|---|---|---|---|---|---|
| PW-1D | OU1 | 173499 | 1637354 | 705.37 | 40.55 | 664.82 |
| PW-2D | OU1 | 173503 | 1638216 | 701.35 | 17.63 | 683.72 |
| RI-1D | OU1 | 172222 | 1637556 | 710.12 | 20.99 | 689.13 |
| RI-2D | OU1 | 172875 | 1638785 | 707.18 | 20.04 | 687.14 |
| RI-3D | OU1 | 173213 | 1638830 | 703.98 | 18.1 | 685.88 |
| RI-4D | OU1 | 173515 | 1637688 | 700.69 | 24.61 | 676.08 |
| RI-5S | OU1 | 173583 | 1636959 | 703.24 | 24.76 | 678.48 |
| RI-9D | OU1 | 173022 | 1634765 | 700.44 | 21.18 | 679.26 |
| RI-10D | OU5 | 174141 | 1639338 | 698.73 | 21.56 | 677.17 |
| RI-11M | OU5 | 174929 | 1638254 | 701.85 | 24.12 | 677.73 |
| RI-15M | OU5 | 174110 | 1638871 | 699.28 | 21.85 | 677.43 |
| RI-17D | OU5 | 173527 | 1638406 | 699.77 | 13.5 | 686.27 |
| RI-19D | OU5 | 174283 | 1636956 | 696.72 | 18.41 | 678.31 |
| RI-20D | OU5 | 173741 | 1634878 | 699.08 | 20.43 | 678.65 |
| RI-21D | OU1 | 172371 | 1634745 | 704.75 | 21.62 | 683.13 |
| RI-22D | August Mack Calibrated to RI-22D | | | | | |
| RI-23D | OU1 | 172299 | 1635142 | 706.89 | 27.54 | 679.35 |
| RI-24D | OU1 | 172313 | 1636443 | 708.79 | 22.87 | 685.92 |
| RI-25D | OU1 | 172749 | 1638597 | 709.32 | 21.74 | 687.58 |
| RR P8 MW-1 | OU5 | 175258 | 1635567 | 695.38 | 15.2 | 680.18 |
| RR P8 MW-4 | OU5 | 175410 | 1635571 | 693.16 | 16.54 | 676.62 |

OU5 DEEP AQUIFER WELLS

| Well ID | Op. Unit | Easting | Northing | TOC (ft asl) | DTW (ft) | Elev (ft asl) |
|---|---|---|---|---|---|---|
| RI-5D | OU1 | 173568 | 1636959 | 703.82 | 25.07 | 678.75 |
| RI-11D | OU5 | 174928 | 1638222 | 701.99 | 25.62 | 676.37 |
| RI-15D | OU5 | 174096 | 1638871 | 699.6 | 23.21 | 676.39 |
| RR P8 PW-1 | OU5 | 174838 | 1636256 | 693.03 | 59 | 634.03 |
| RR P8 PW-2 | OU5 | 174813 | 1636576 | 691.98 | 28.5 | 663.48 |
| RR P8 PW-3 | OU5 | 174812 | 1636875 | 686.25 | 39 | 647.25 |

Notes:

1. Eastings and Northings in Indiana State Plane coordinates.
2. Well locations are estimated, not surveyed.
3. RR = Rolls-Royce (former GM Allison), P8 = Plant 8
4. OU1 and OU5 shallow aquifer wells are contoured together.
5. OU1 deep, OU5 medium, and OU5 deep aquifer wells are contoured together.
6. TOC = Top of Casing, DTW = Depth to Water, Elev = Groundwater Elevation

**TABLE 1**
**2009 Well Pumping Rates**
**Vertellus Specialties Inc.**
**1500 South Tibbs Avenue**
**Indianapolis, Indiana**
**August Mack Project Number JK0522.380**

| | Reilly Wells | | | | | Rolls Royce Wells | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Well ID** | **PW1 Deep** | **PW1 Shallow** | **PW2** | **PW3** | **PW-4** | **1B** | **2A** | **4A** | **1** | **2** | **3** |
| **Approximate Well Depth (ft)** | 58 | 31 | 25 | 52 | 65.5 | 102 ft | 104 ft | 106 ft | 110 ft | 114 ft | 110 ft |
| | **Reilly Wells Pumping Rates*** | | | | | **Rolls Royce Wells Pumping Rates**** | | | | | |
| **January-09** | 1.8614 | 0.2068 | 0.82146 | 0 | 0 | 16 | 16 | 0 | 5.2 | 4.6 | 5.6 |
| **February-09** | 1.7438 | 0.1341 | 0.78634 | 0 | 0 | 27 | 0 | 0 | 3.8 | 3.4 | 4.2 |
| **March-09** | 1.8224 | 0.1153 | 0.91363 | 0 | 0 | 0 | 15.6 | 15.6 | 4 | 3.6 | 4.3 |
| **April-09** | 1.5818 | 0.1063 | 0.84826 | 0 | 0 | 39 | 0 | 0 | 5.3 | 3.7 | 6 |
| **May-09** | 1.6035 | 0.1095 | 0.84689 | 0 | 0 | 0 | 32.7 | 0 | 4.8 | 2.1 | 4.9 |
| **June-09** | 1.7166 | 0.1315 | 0.81935 | 0 | 0 | 0 | 32.6 | 0 | 5.7 | 2.5 | 5.7 |
| **July-09** | 1.9199 | 0.1483 | 0.76964 | 0 | 0 | 0 | 43.2 | 0 | 7.1 | 3 | 7.2 |
| **August-09** | 1.9109 | 0.1491 | 0.87074 | 0 | 0 | 38 | 0 | 0 | 4.8 | 2.1 | 4.8 |
| **September-09** | 1.6978 | 0.13 | 0.81823 | 0 | 0 | 0 | 36.6 | 0 | 4.6 | 2 | 4.6 |
| **October-09** | 1.5102 | 0.1266 | 0.82274 | 0 | 0 | 0 | 50.1 | 0 | 6.2 | 2.8 | 0 |
| **November-09** | 1.3394 | 0.1173 | 0.75405 | 0 | 0 | 0 | 37.1 | 0 | 3.8 | 3.2 | 10.2 |
| **December-09** | 1.707 | 0.3521 | 0.658 | 0 | 0 | 0 | 30.3 | 0 | 3.1 | 2.9 | 3.4 |

Pumping rates in Million Gallons

* Information supplied by Vertellus

** Information supplied by IDNR - Division of Water - Water Use System

= Used for calibration purposes

# Comparison of Pumping Wells used in AME Model Historical (2009) vs. Recent (2014-2016) Pumping Rates
(RR Wells 1-3)

**TABLE 1**
**2009 Well Pumping Rates**
**Vertellus Specialties Inc.**
**1500 South Tibbs Avenue**
**Indianapolis, Indiana**
**August Mack Project Number JK0522.380**

| | Reilly Wells | | | | | Rolls Royce Wells | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Well ID | PW1 Deep | PW1 Shallow | PW2 | PW3 | PW-4 | 1B | 2A | 4A | 1 | 2 | 3 |
| Approximate Well Depth (ft) | 58 | 31 | 25 | 52 | 65.5 | 102 ft | 104 ft | 106 ft | 110 ft | 114 ft | 110 ft |
| | Reilly Wells Pumping Rates* | | | | | Rolls Royce Wells Pumping Rates** | | | | | |
| January-09 | 1.8614 | 0.2068 | 0.82146 | 0 | 0 | 16 | 16 | 0 | 5.2 | 4.6 | 5.6 |
| February-09 | 1.7438 | 0.1341 | 0.78634 | 0 | 0 | 27 | 0 | 0 | 3.8 | 3.4 | 4.2 |
| March-09 | 1.8224 | 0.1153 | 0.91363 | 0 | 0 | 0 | 15.6 | 15.6 | 4 | 3.6 | 4.3 |
| April-09 | 1.5818 | 0.1063 | 0.84826 | 0 | 0 | 39 | 0 | 0 | 5.3 | 3.7 | 6 |
| May-09 | 1.6035 | 0.1095 | 0.84689 | 0 | 0 | 0 | 32.7 | 0 | 4.8 | 2.1 | 4.9 |
| June-09 | 1.7166 | 0.1315 | 0.81935 | 0 | 0 | 0 | 32.6 | 0 | 5.7 | 2.5 | 5.7 |
| July-09 | 1.9199 | 0.1483 | 0.76964 | 0 | 0 | 0 | 43.2 | 0 | 7.1 | 3 | 7.2 |
| August-09 | 1.9109 | 0.1491 | 0.87074 | 0 | 0 | 38 | 0 | 0 | 4.8 | 2.1 | 4.8 |
| September-09 | 1.6978 | 0.13 | 0.81823 | 0 | 0 | 0 | 36.6 | 0 | 4.6 | 2 | 4.6 |
| October-09 | 1.5102 | 0.1266 | 0.82274 | 0 | 0 | 0 | 50.1 | 0 | 6.2 | 2.8 | 0 |
| November-09 | 1.3394 | 0.1173 | 0.75405 | 0 | 0 | 0 | 37.1 | 0 | 3.8 | 3.2 | 10.2 |
| December-09 | 1.707 | 0.3521 | 0.658 | 0 | 0 | 0 | 30.3 | 0 | 3.1 | 2.9 | 3.4 |

Pumping rates in Million Gallons
* Information supplied by Vertellus
** Information supplied by IDNR - Division of Water - Water Use
= Used for calibration purposes

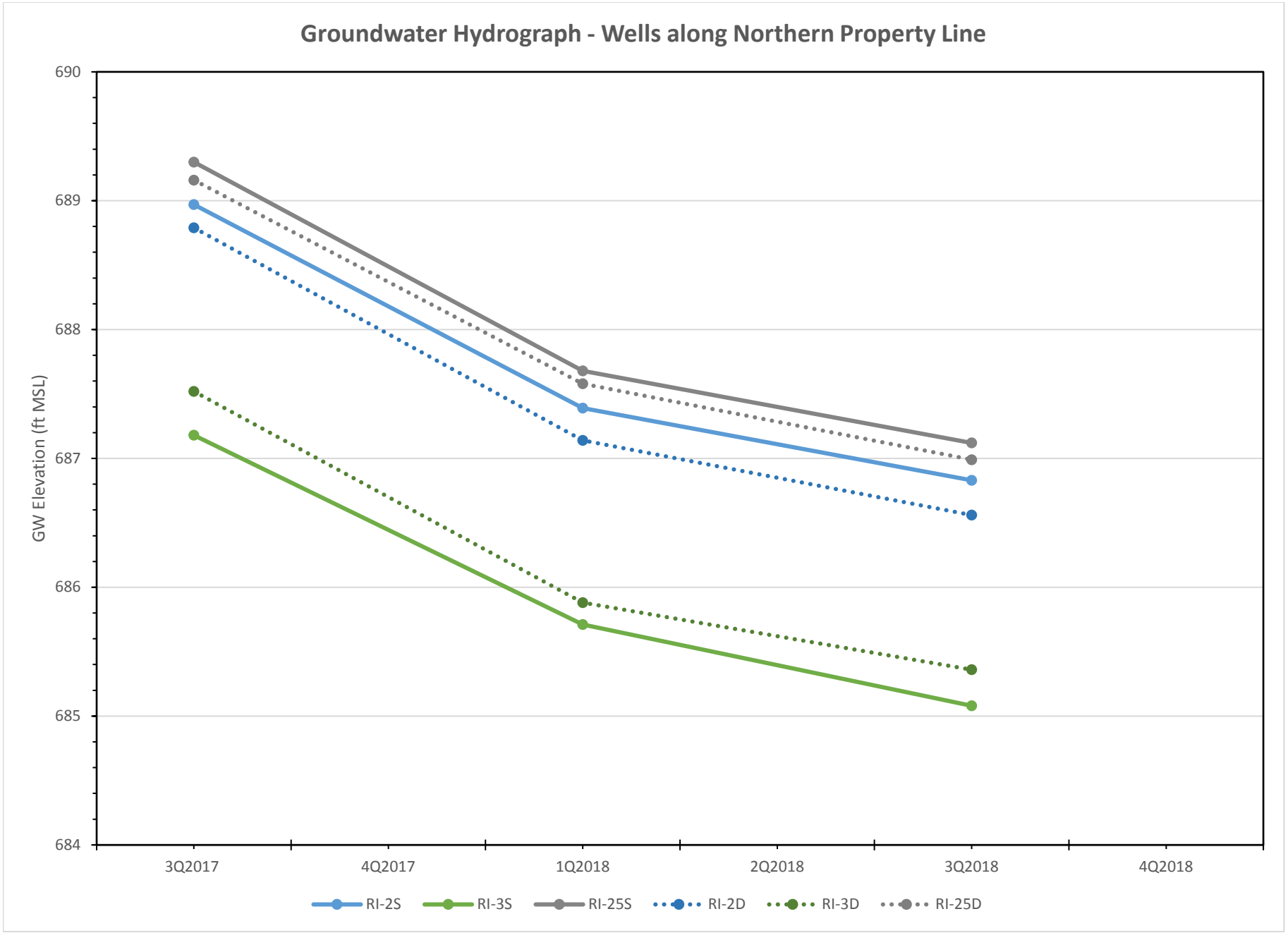
**Summary of Recent Groundwater Withdrawals from Rolls-Royce Plant**
Tibbs Avenue, Indianapolis, Indiana

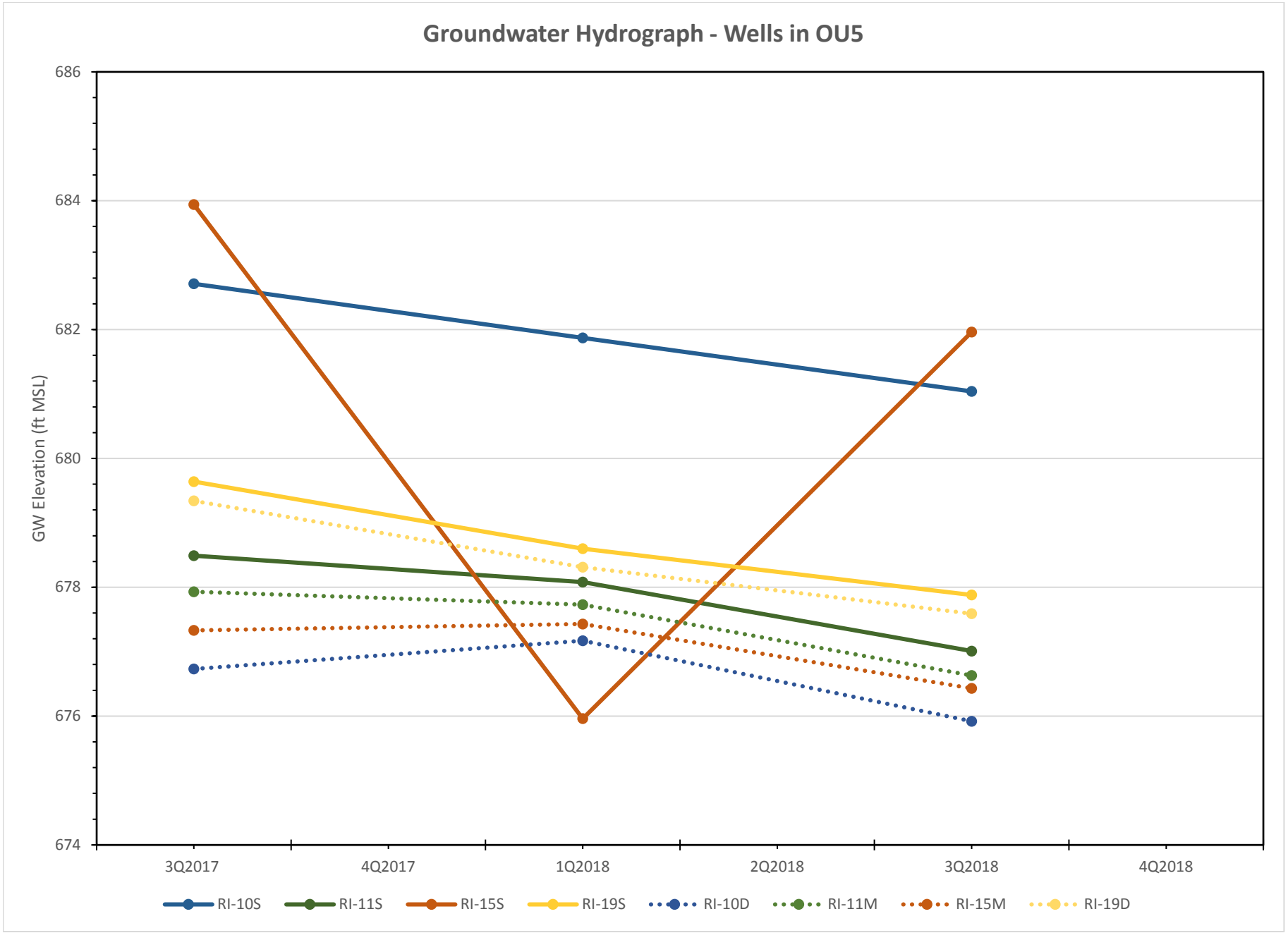
| Year | Rolls Royce Well ID | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec | Annual Withdrawal | Total Withdrawal (2014-2016) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Withdrawals listed in millions of gallons) | | | | | | | | | | | | | |
| **Sorted By Year** | | | | | | | | | | | | | | | |
| 2014 | PW-1 | 4.8 | 3.2 | 3.2 | 4.6 | 4.2 | 4.3 | 4.8 | 4.5 | 3.5 | 6.8 | 4.0 | 4.3 | 52.2 | 157 |
| | PW-2 | 4.5 | 3.1 | 2.9 | 4.3 | 3.7 | 3.9 | 4.6 | 4.1 | 3.3 | 6.3 | 3.8 | 4.1 | 48.6 | |
| | PW-3 | 5.3 | 3.5 | 3.5 | 5.0 | 4.2 | 4.7 | 5.2 | 4.9 | 3.7 | 7.4 | 4.4 | 4.7 | 56.5 | |
| 2015 | PW-1 | 3.0 | 2.4 | 2.3 | 3.8 | 3.2 | 3.7 | 0.4 | ---- | ---- | ---- | ---- | 2.5 | 21.3 | 130 |
| | PW-2 | 2.8 | 2.3 | 2.1 | 3.4 | 3.0 | 3.6 | 7.8 | 5.5 | 13.5 | 5.3 | 4.1 | 4.1 | 57.5 | |
| | PW-3 | 3.2 | 2.6 | 2.5 | 4.0 | 3.5 | 4.0 | 4.8 | 8.6 | 7.0 | 5.8 | 3.1 | 2.7 | 51.7 | |
| 2016 | PW-1 | 2.4 | 1.9 | 2.2 | 3.8 | 3.2 | 3.7 | 0.4 | ---- | ---- | ---- | ---- | 2.5 | 20.1 | 109 |
| | PW-2 | 2.3 | 1.7 | 1.9 | 3.4 | 3.0 | 3.6 | 7.8 | 5.5 | 13.5 | ---- | 3.1 | 4.0 | 49.9 | |
| | PW-3 | 2.6 | 2.1 | 2.3 | 4.0 | 3.5 | 4.0 | 4.8 | 3.1 | 7.0 | ---- | 3.1 | 2.7 | 39.1 | |

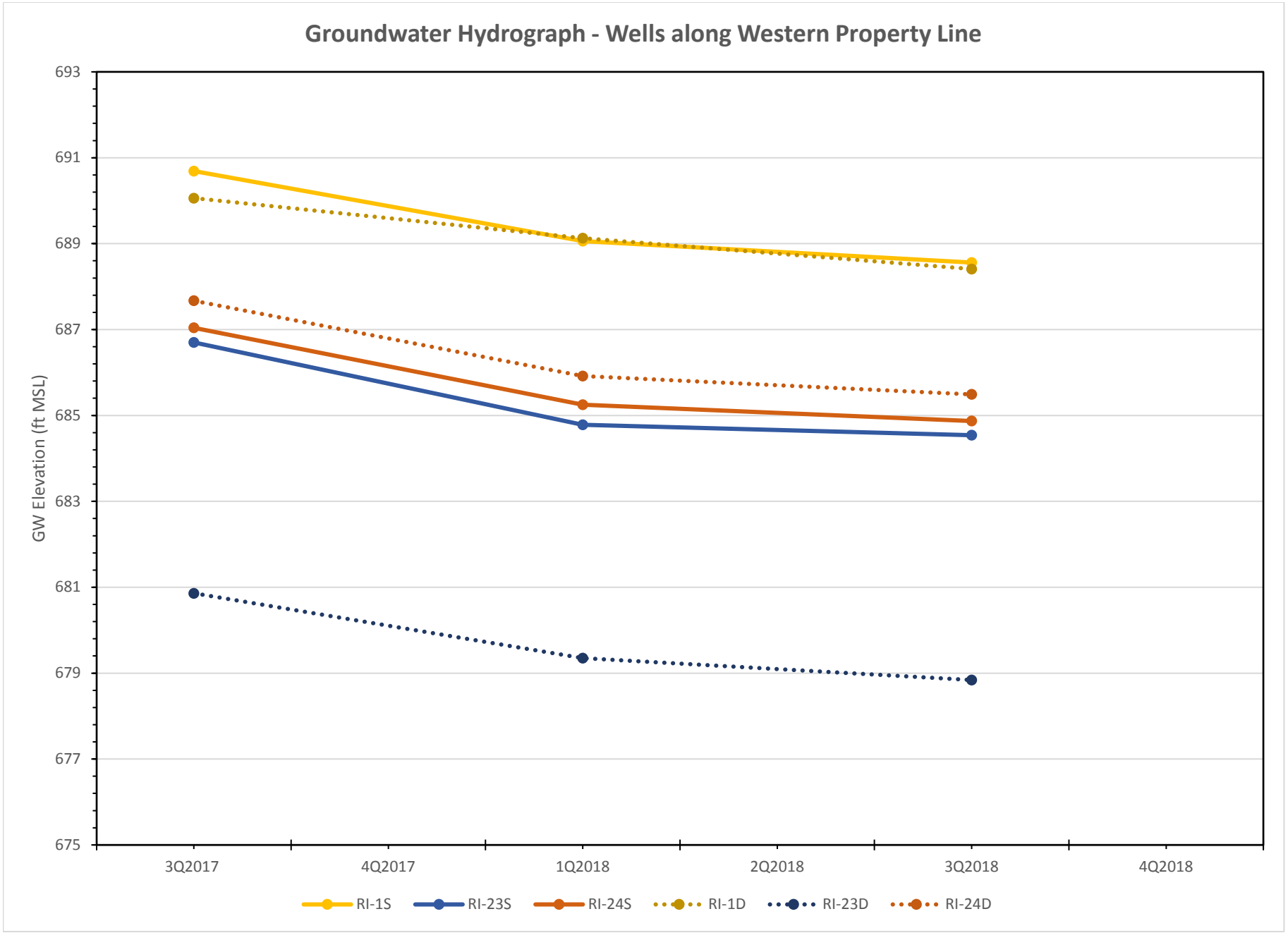
| **Sorted By Pumping Well** | | | | | | | | | | | | | | Average Annual Withdrawal (2014-2016) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Withdrawals listed in millions of gallons) | | | | | | | | | | | | | |
| PW-1 | 2014 | 4.8 | 3.2 | 3.2 | 4.6 | 4.2 | 4.3 | 4.8 | 4.5 | 3.5 | 6.8 | 4.0 | 4.3 | 52.2 | 31 |
| | 2015 | 3.0 | 2.4 | 2.3 | 3.8 | 3.2 | 3.7 | 0.4 | ---- | ---- | ---- | ---- | 2.5 | 21.3 | |
| | 2016 | 2.4 | 1.9 | 2.2 | 3.8 | 3.2 | 3.7 | 0.4 | ---- | ---- | ---- | ---- | 2.5 | 20.1 | |
| PW-2 | 2014 | 4.5 | 3.1 | 2.9 | 4.3 | 3.7 | 3.9 | 4.6 | 4.1 | 3.3 | 6.3 | 3.8 | 4.1 | 48.6 | 52 |
| | 2015 | 2.8 | 2.3 | 2.1 | 3.4 | 3.0 | 3.6 | 7.8 | 5.5 | 13.5 | 5.3 | 4.1 | 4.1 | 57.5 | |
| | 2016 | 2.3 | 1.7 | 1.9 | 3.4 | 3.0 | 3.6 | 7.8 | 5.5 | 13.5 | ---- | 3.1 | 4.0 | 49.9 | |
| PW-3 | 2014 | 5.3 | 3.5 | 3.5 | 5.0 | 4.2 | 4.7 | 5.2 | 4.9 | 3.7 | 7.4 | 4.4 | 4.7 | 56.5 | 49 |
| | 2015 | 3.2 | 2.6 | 2.5 | 4.0 | 3.5 | 4.0 | 4.8 | 8.6 | 7.0 | 5.8 | 3.1 | 2.7 | 51.7 | |
| | 2016 | 2.6 | 2.1 | 2.3 | 4.0 | 3.5 | 4.0 | 4.8 | 3.1 | 7.0 | ---- | 3.1 | 2.7 | 39.1 | |
| | | | | | | | | | | | | | | sum: | 132 |

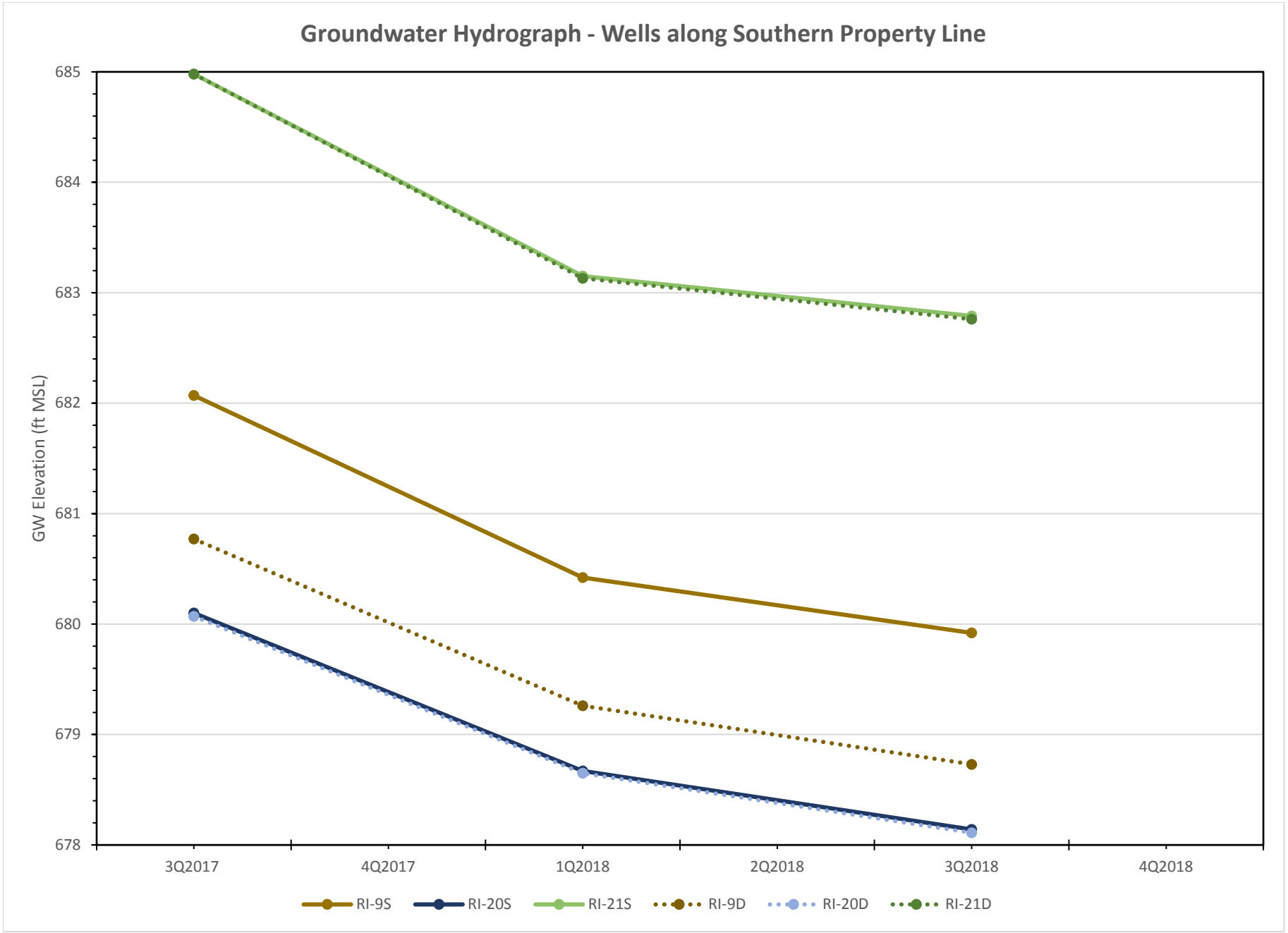
# Appendix A-3

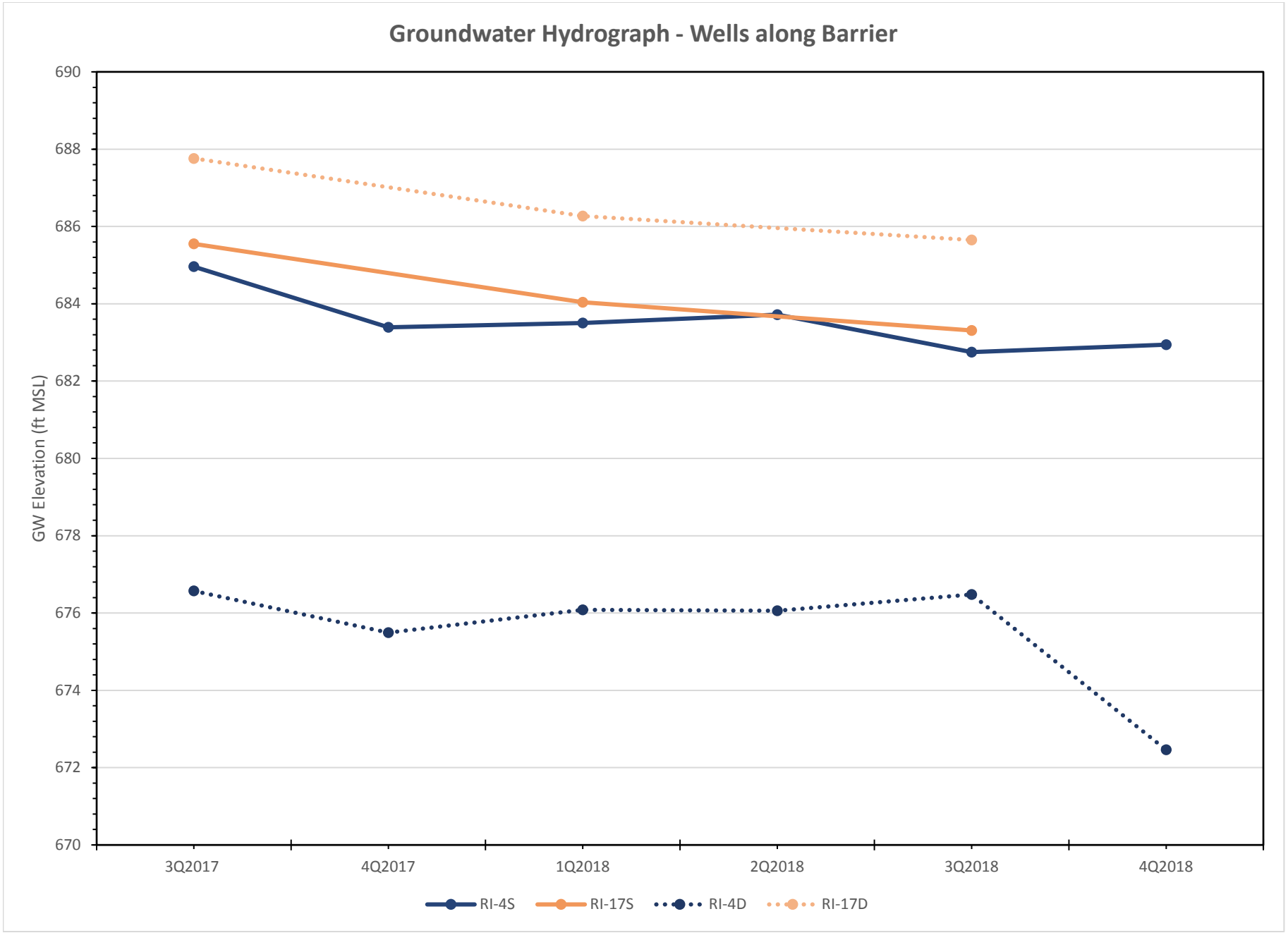
# Groundwater Hydrographs


Groundwater Hydrograph - Wells along Northern Property Line
690
689
688
687
686
685
684
GW Elevation (ft MSL)
3Q2017
4Q2017
1Q2018
2Q2018
3Q2018
4Q2018
RI-2S
RI-3S
RI-25S
RI-2D
RI-3D
RI-25D


Groundwater Hydrograph - Wells in OU5
GW Elevation (ft MSL)
686
684
682
680
678
676
674
3Q2017
4Q2017
1Q2018
2Q2018
3Q2018
4Q2018
RI-10S
RI-11S
RI-15S
RI-19S
RI-10D
RI-11M
RI-15M
RI-19D


Groundwater Hydrograph - Wells along Western Property Line
GW Elevation (ft MSL)
693
691
689
687
685
683
681
679
677
675
3Q2017
4Q2017
1Q2018
2Q2018
3Q2018
4Q2018
RI-1S
RI-23S
RI-24S
RI-1D
RI-23D
RI-24D


Groundwater Hydrograph - Wells along Southern Property Line
GW Elevation (ft MSL)
685
684
683
682
681
680
679
678
3Q2017
4Q2017
1Q2018
2Q2018
3Q2018
4Q2018
RI-9S
RI-20S
RI-21S
RI-9D
RI-20D
RI-21D

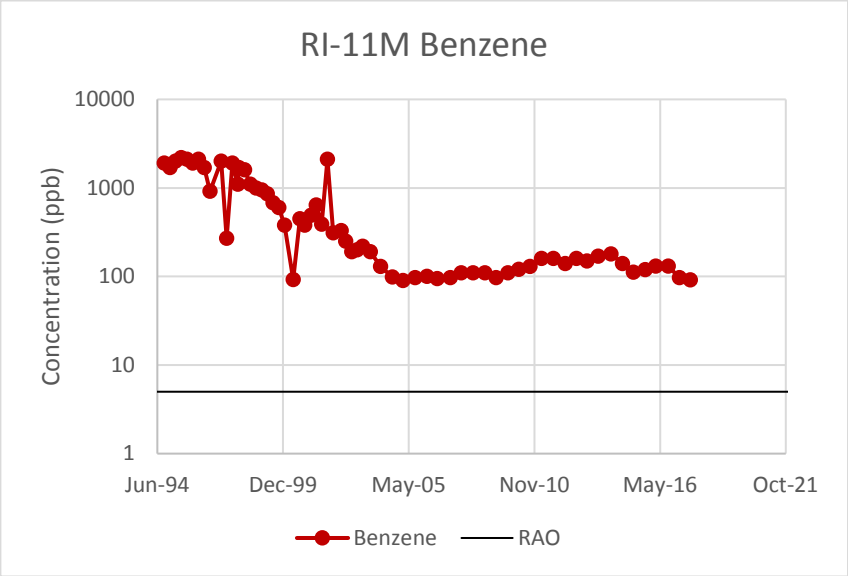

Groundwater Hydrograph - Wells along Barrier
GW Elevation (ft MSL)
690
688
686
684
682
680
678
676
674
672
670
3Q2017
4Q2017
1Q2018
2Q2018
3Q2018
4Q2018
RI-4S
RI-17S
RI-4D
RI-17D

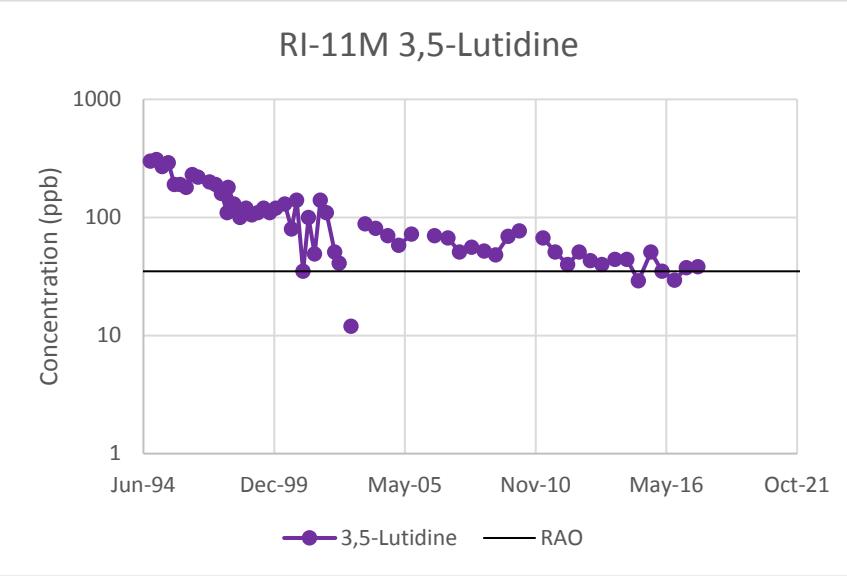
# Appendix A-4

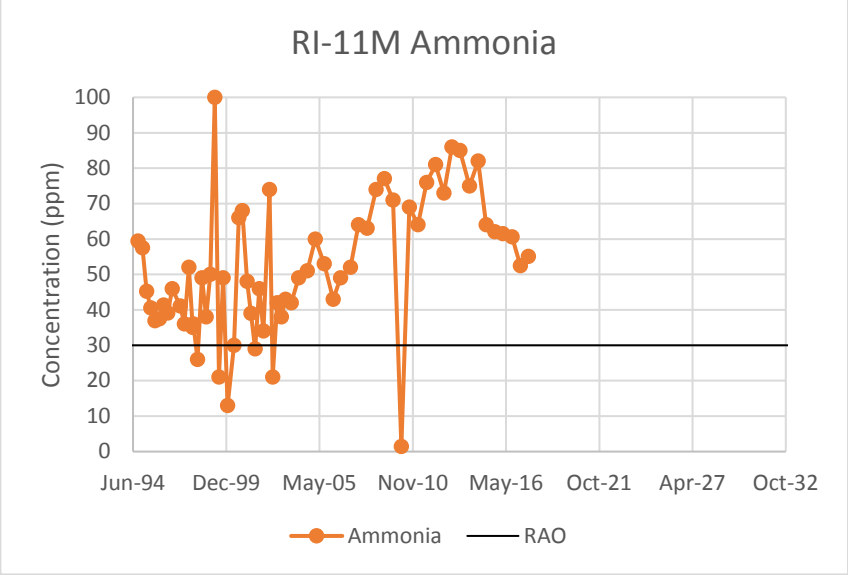
# Time-Trend Graphs of R1-11 and RI-15 in OU5

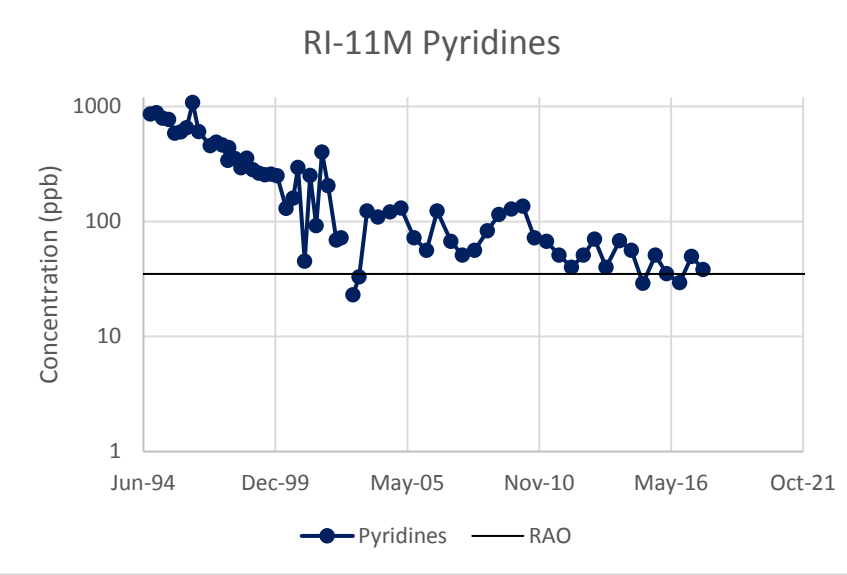
**GROUNDWATER PUMPING RESULTS**
**RI-11M GRAPHICAL ANALYSIS**

Note: Benzene steady for more than a decade and well above the RAO.



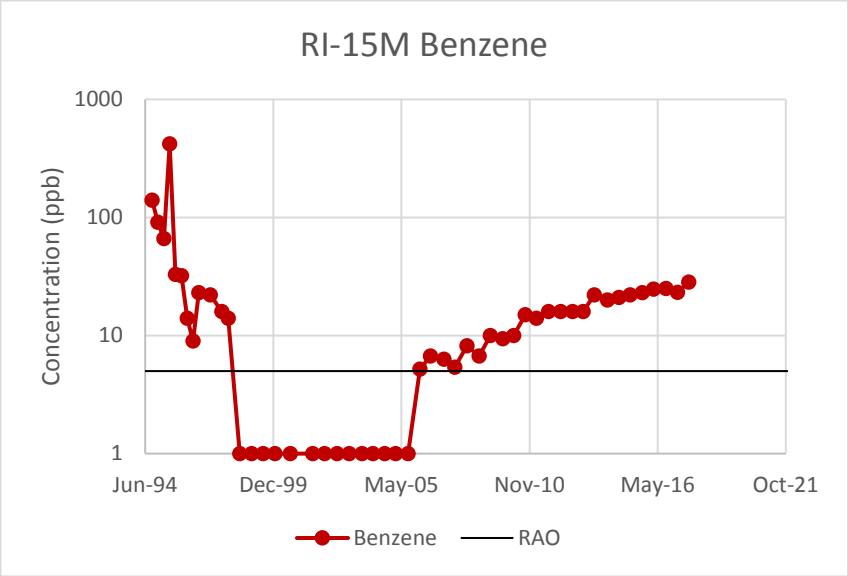



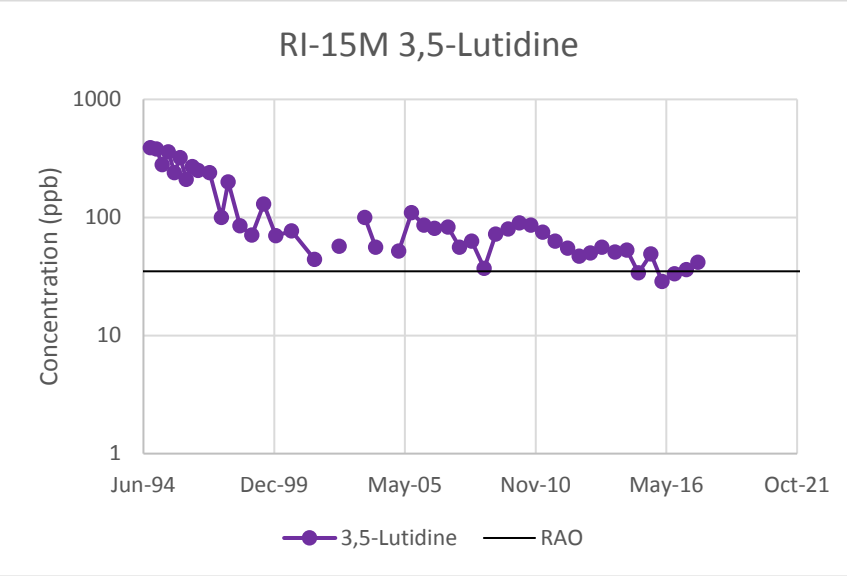



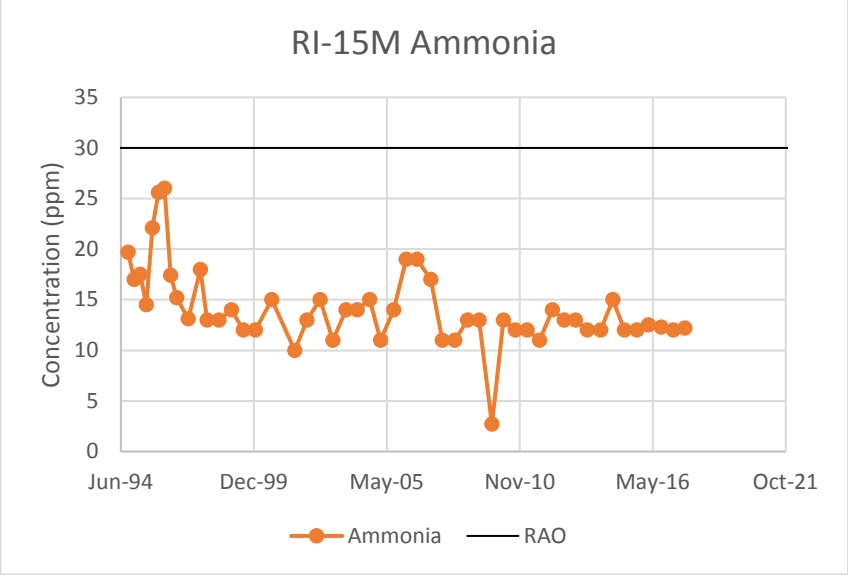



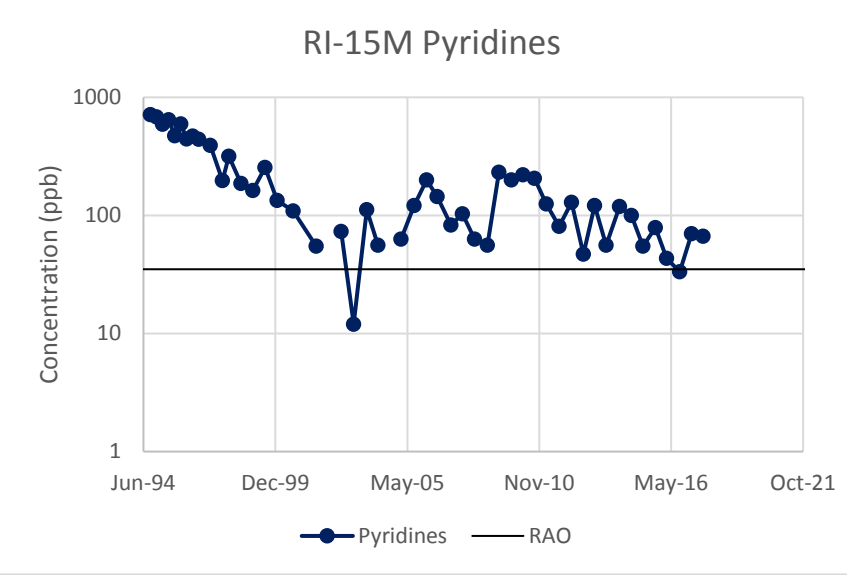
**GROUNDWATER PUMPING RESULTS**
**RI-15M GRAPHICAL ANALYSIS**

Note: Benzene has been increasing above the RAO for more than a decade.



# Appendix B

# Groundwater Flow Modeling Results

# Appendix B-1

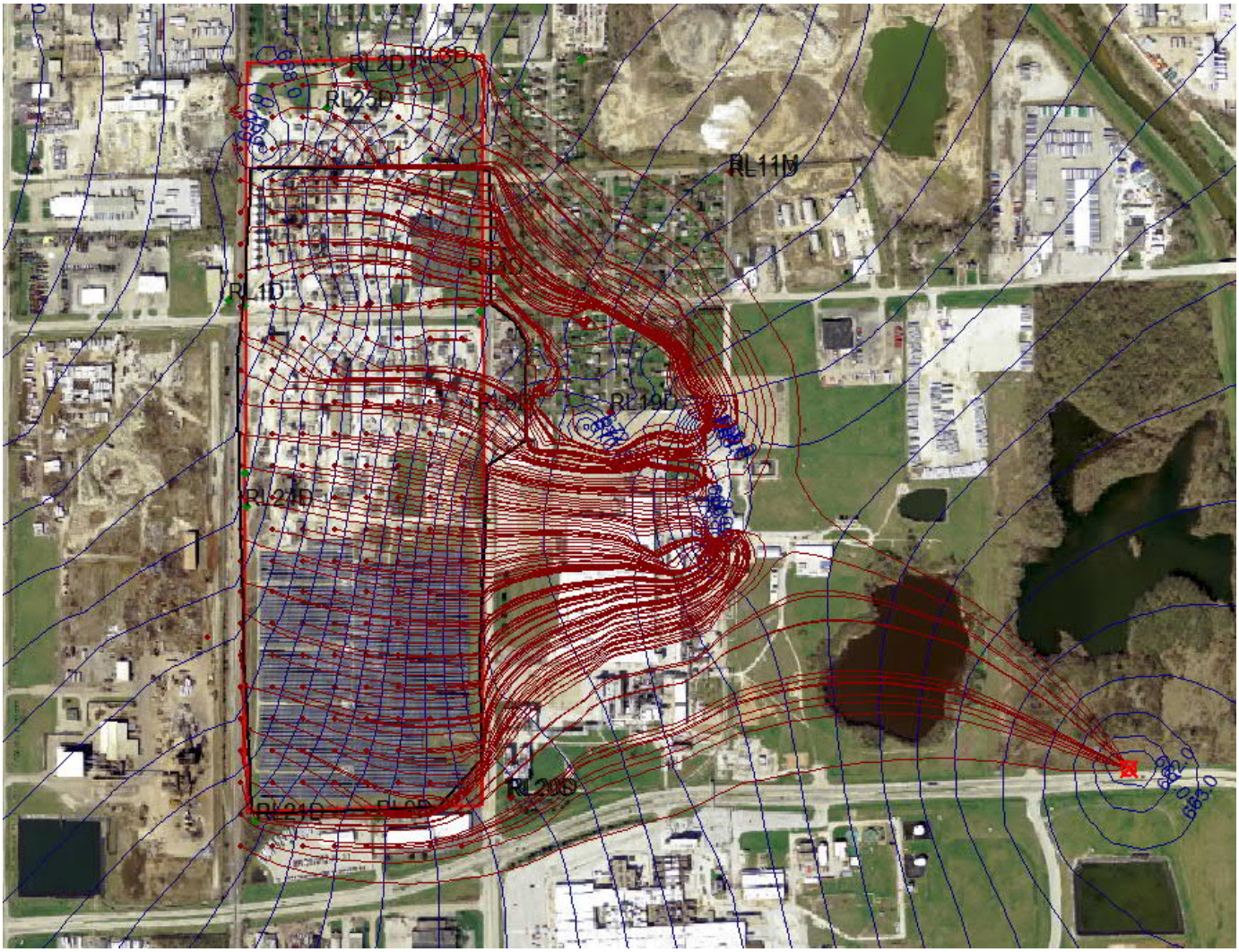
# Groundwater Flow Modeling of FFS Scenarios

# Deep Aquifer

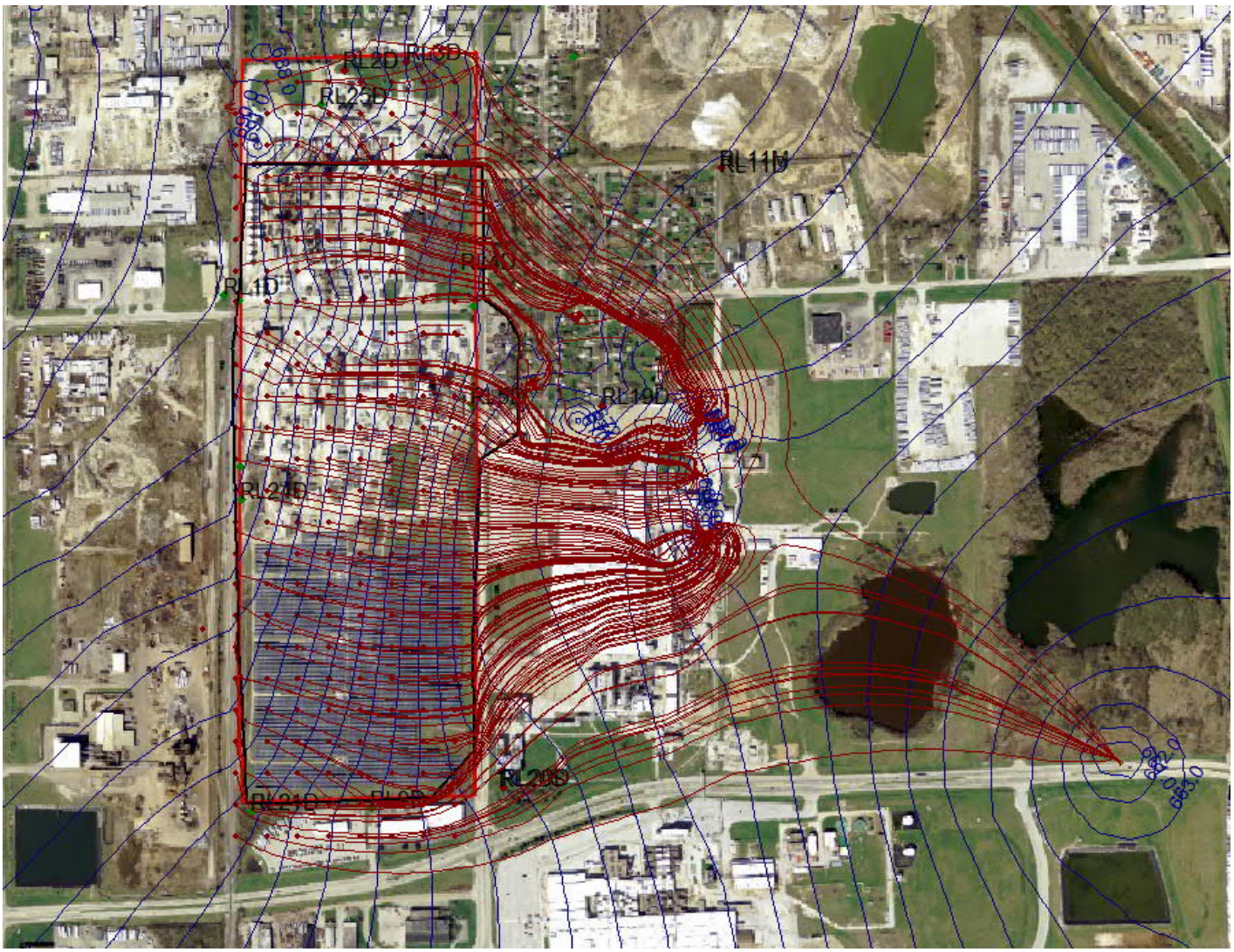
## Groundwater Flow Modeling Scenarios

| Label | Groundwater Flow Modeling Scenario |
|---|---|
| **Scenario 0** (Calibrated Model) | Calibrated to Sept. 2009 Pumping Rates |
| **Scenario #1 & #3** | |
| Sc1-3_A | **Scenario #1 &#3** Baseline; No On-Site Pumping, Consistent withdrawals at RR Plant 8 |
| Sc1-3_B | No On-Site Pumping, Increased Pumping at RR Plant 8 (Max. Month) |
| Sc1-3_C | No On-Site Pumping, Cease Pumping at RR Plant 8 (Low Seepage Velocity Case) |
| **Scenario #2** | |
| Sc2_A | Scenario #2 Baseline; Enhanced Site Pumping, Consistent withdrawals at RR Plant 8 |
| Sc2_B | Enhanced Site Pumping, Increased Pumping at RR Plant 8 (High Seepage Velocity Case) |
| Sc2_C | Enhanced Site Pumping, Cease Pumping at RR Plant 8 |

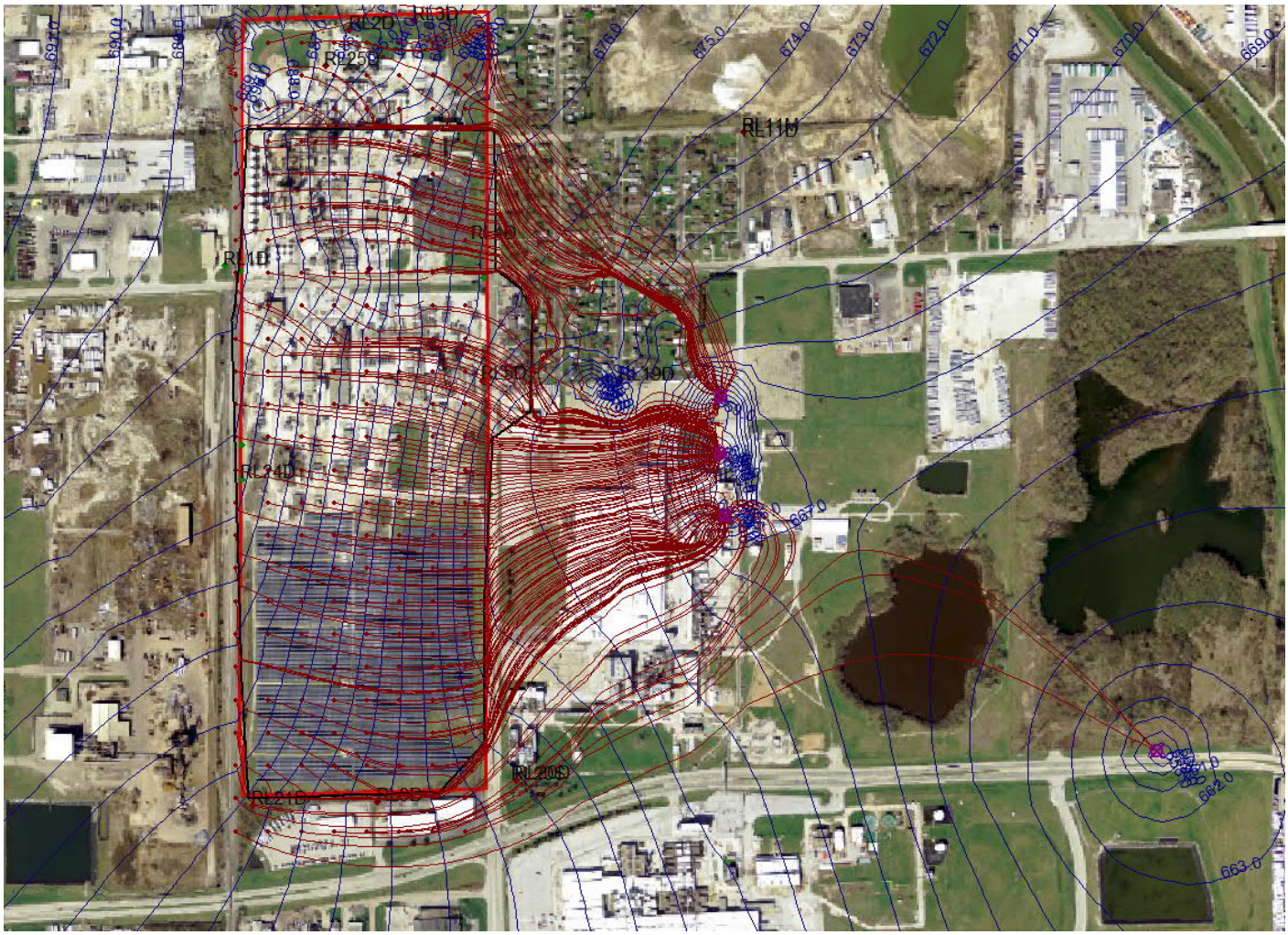
# Scenario #0 (Baseline Calibration Conditions)



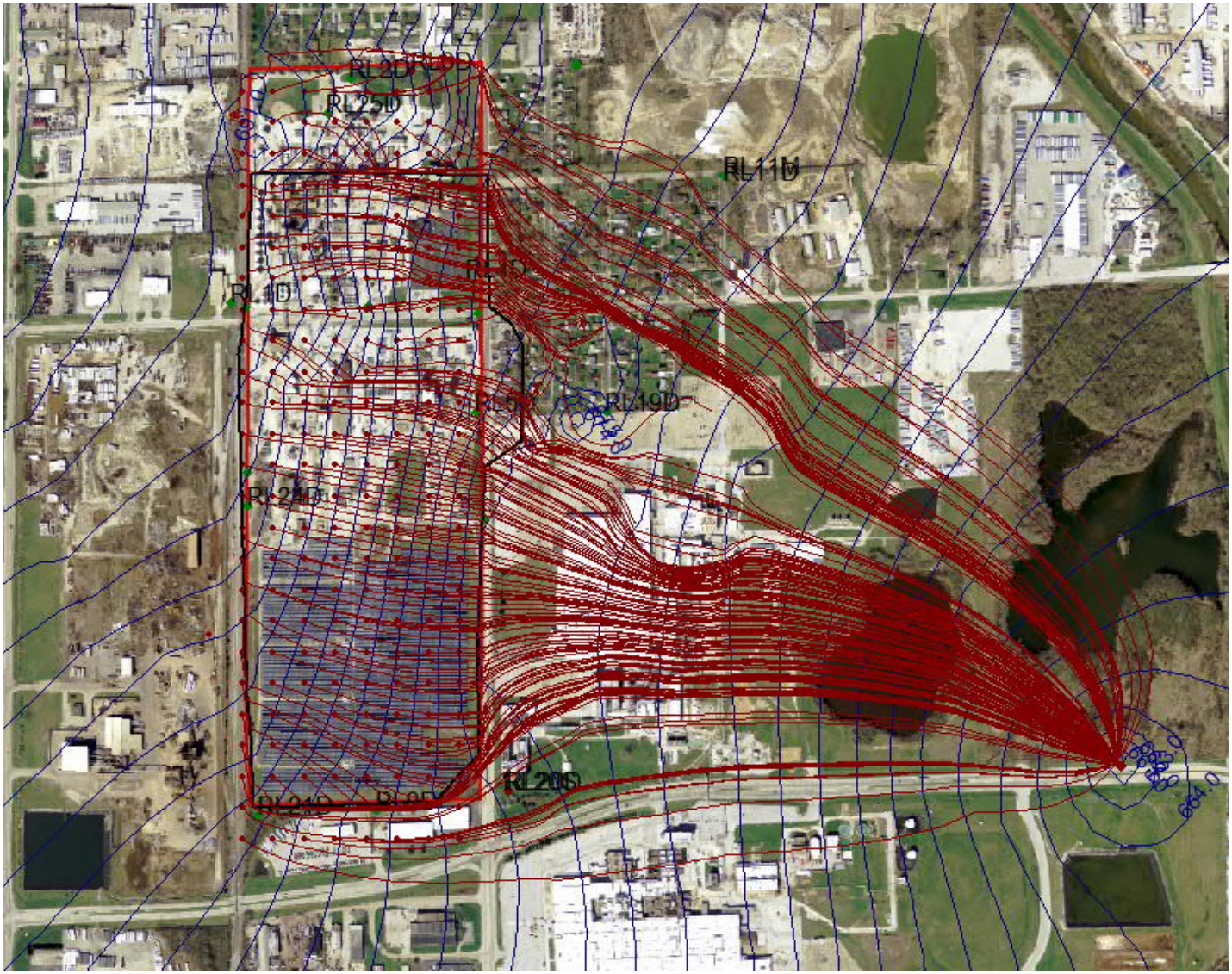
# SC1-3A: Scenario #1 & #3 Baseline; No On-Site Pumping, Consistent withdrawals at RR Plant 8



# SC1-3B: No On-Site Pumping, High Pumping at RR Plant 8 (High Monthly Pumping Rates – High Velocity Case)

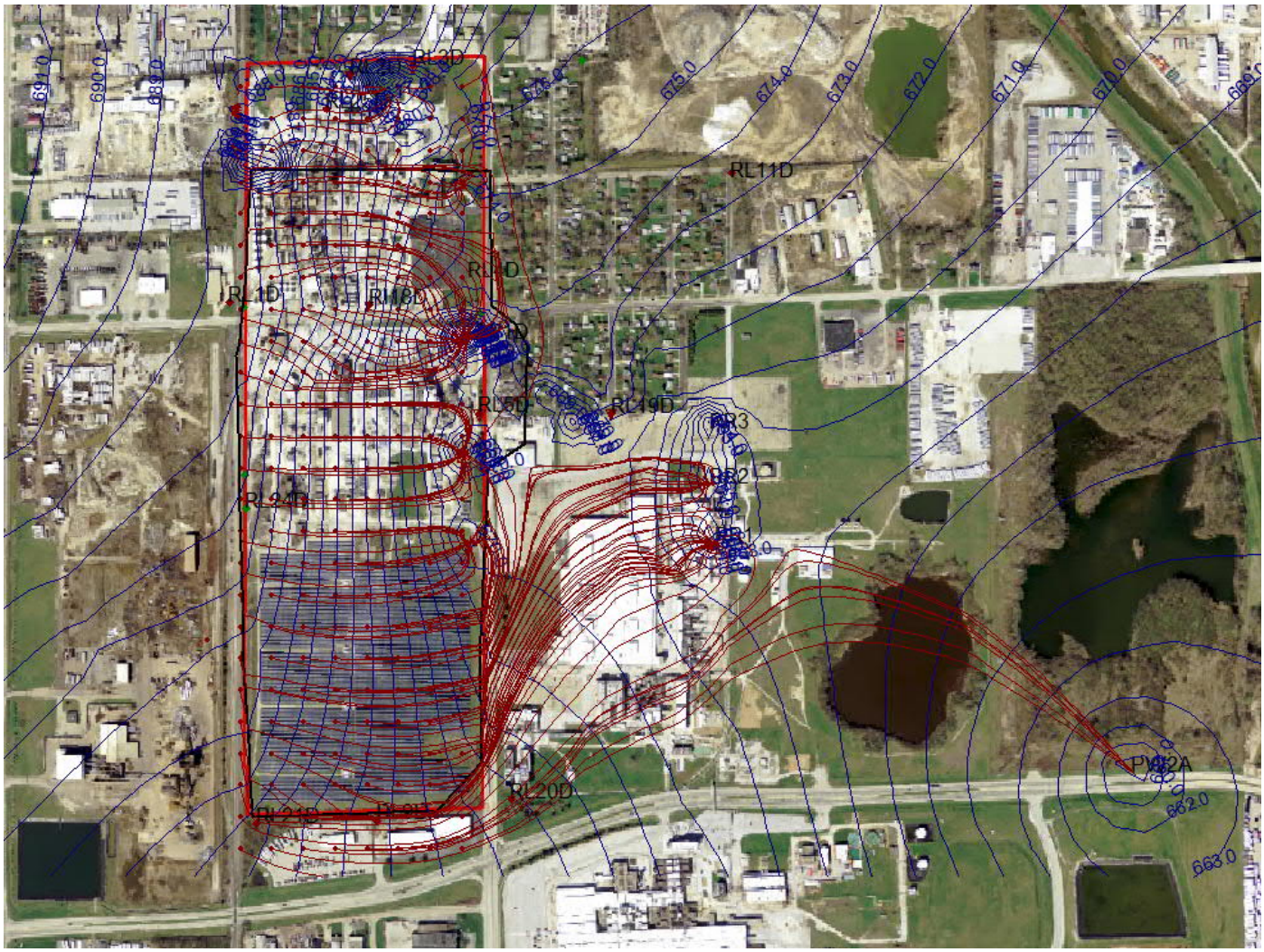


# SC1-3C: No On-Site Pumping, Cease Pumping at RR Plant 8 (Low Seepage Velocity Case)



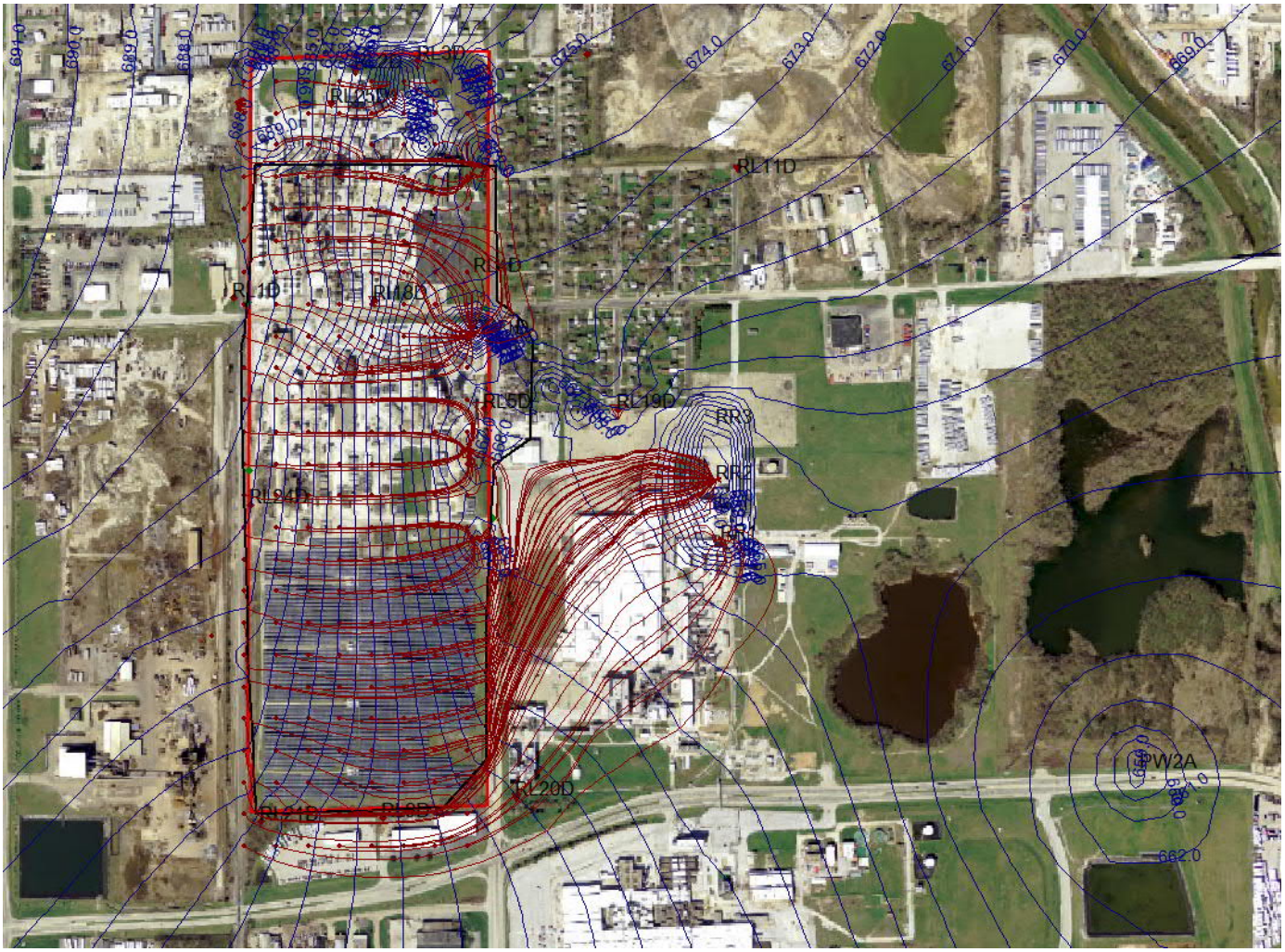
**Scenario #2**

# SC2_A: Scenario #2 Baseline; Enhanced Site Pumping, Consistent withdrawals at RR Plant 8



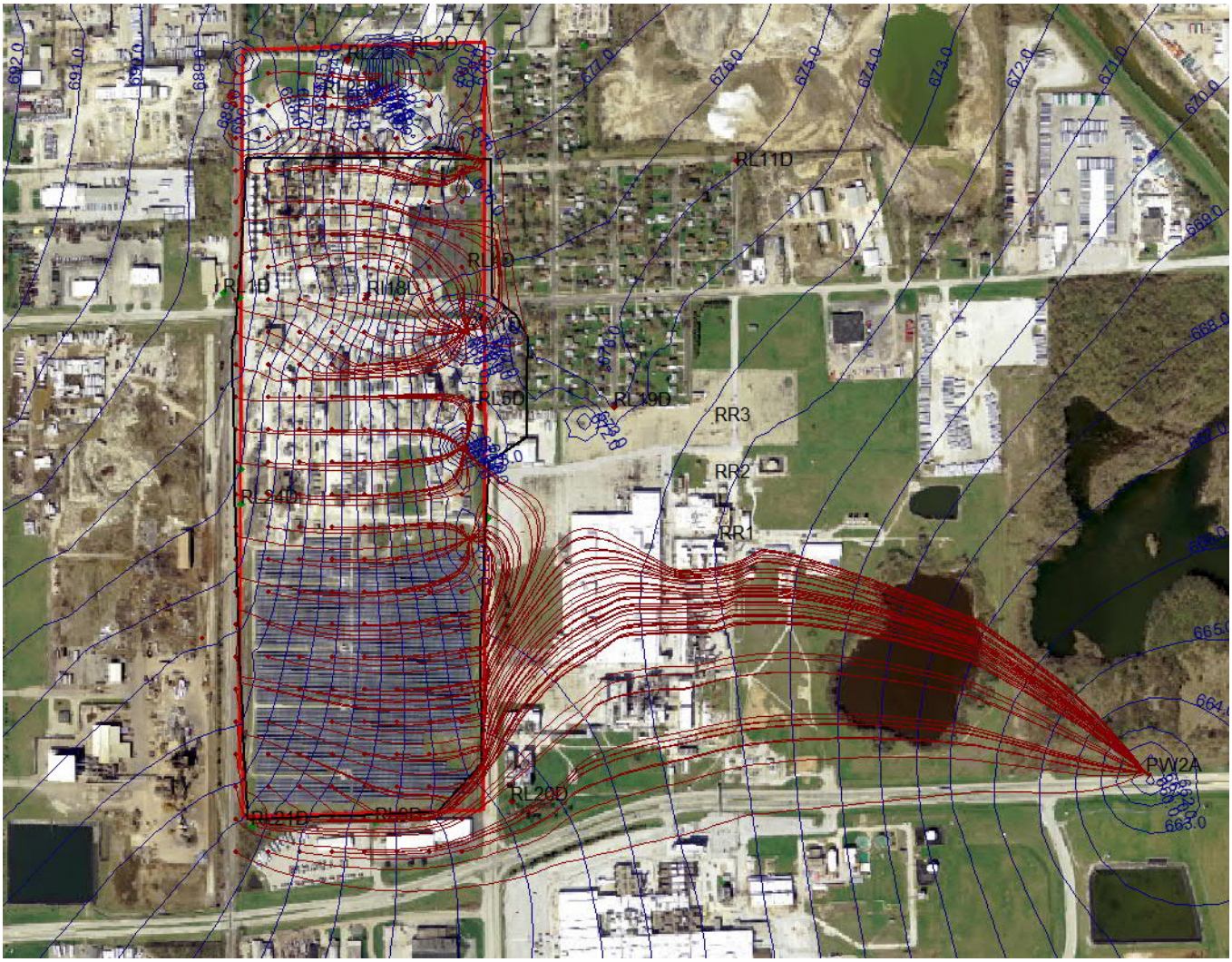
**Scenario #2**

# SC2_B: Enhanced Site Pumping, Increased Pumping at RR Plant 8 (High Seepage Velocity Case)



**Scenario #2**

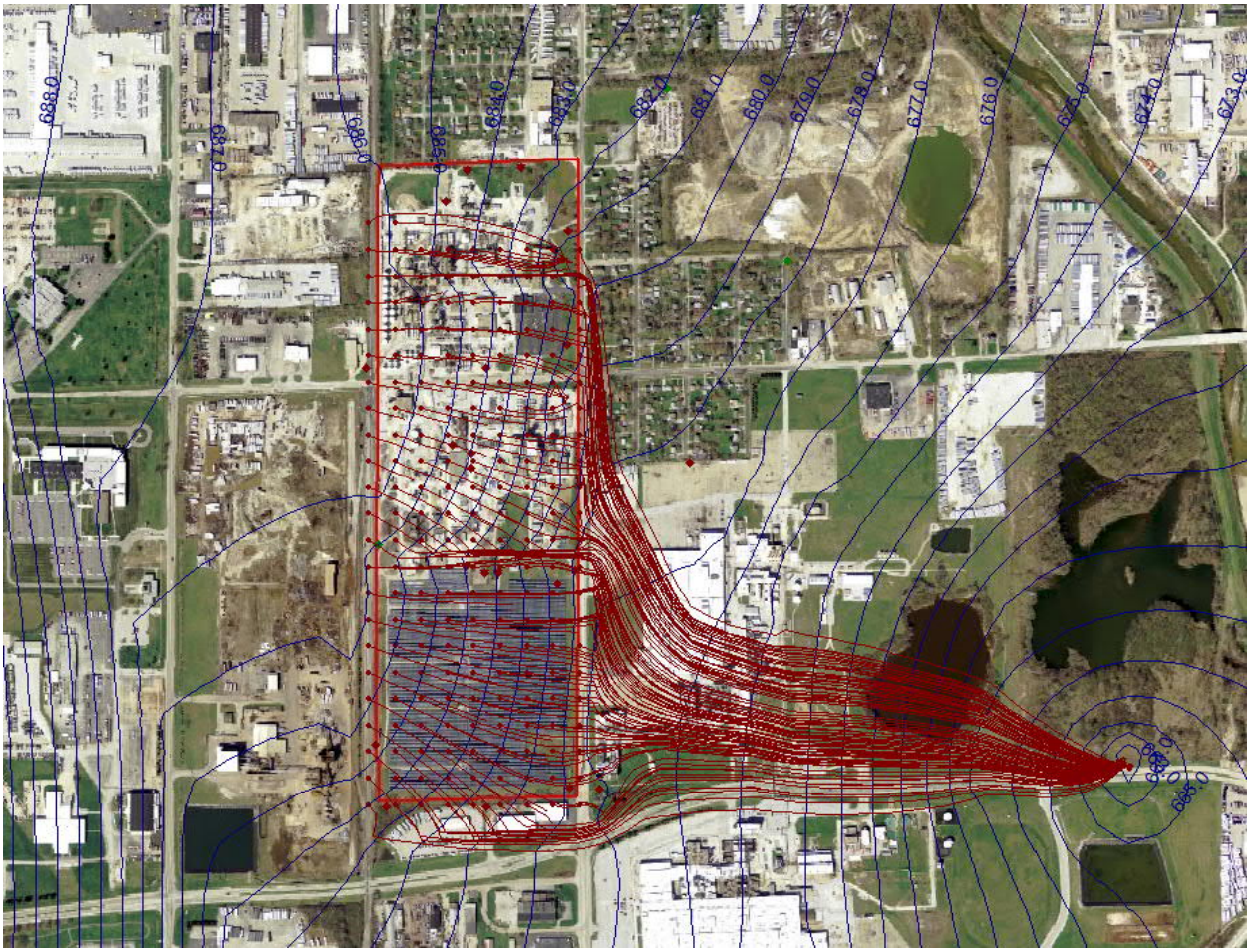
# SC2_C: Enhanced Site Pumping, Cease Pumping at RR Plant 8 (Low Seepage Velocity Case)



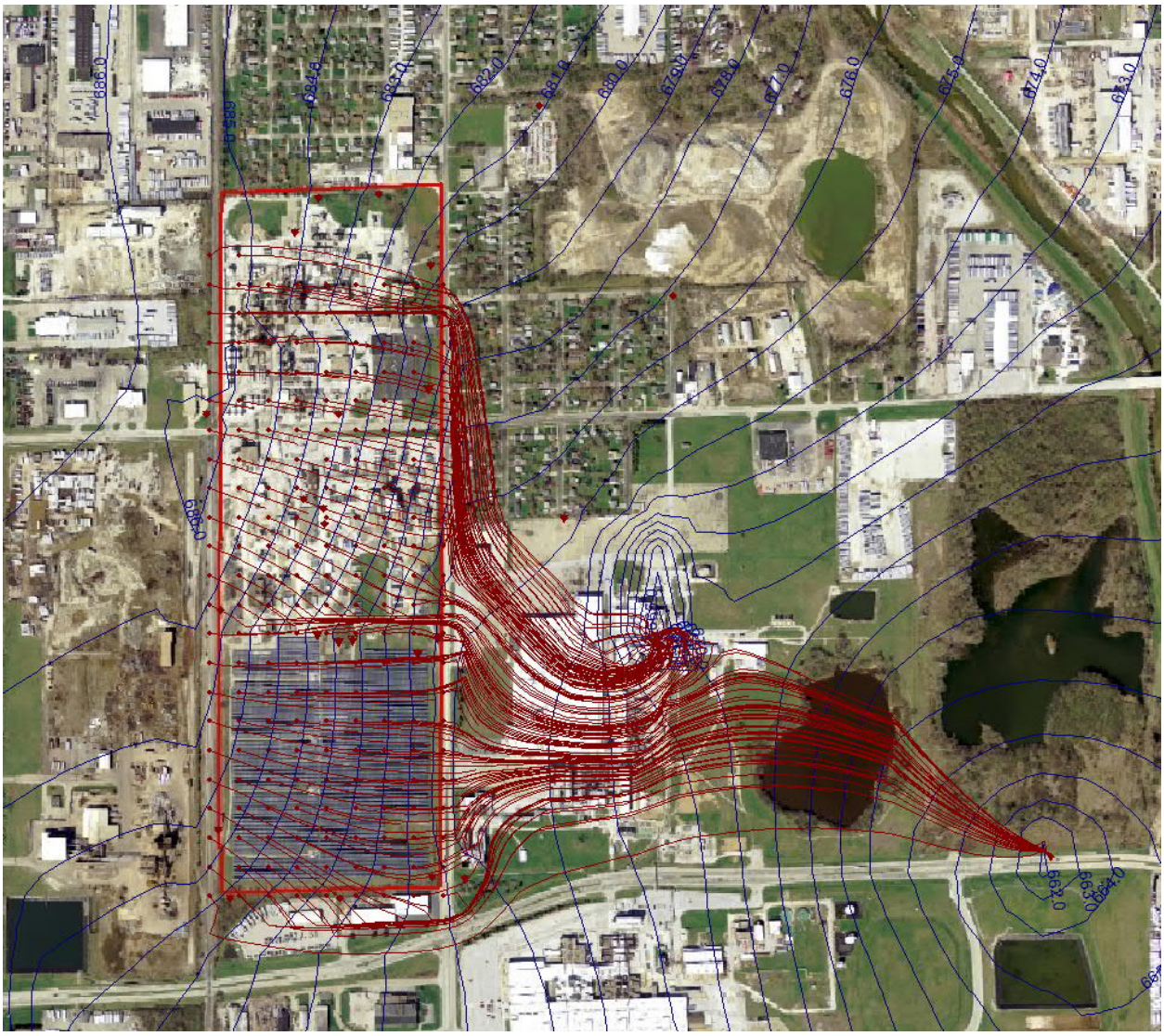
# Shallow Groundwater Modeling Scenarios

| Label | Groundwater Flow Modeling Scenario |
|---|---|
| Scenario 0 (Calibrated Model) | Calibrated to Sept. 2009 Pumping Rates |
| Sc1-3_A | **Scenario #1 & #3** Baseline; No On-Site Pumping, Consistent withdrawals at RR Plant 8 |
| Sc1-3_B | No On-Site Pumping Increased Pumping at RR Plant 8 (Max. Month) |
| Sc1-3_C | No On-Site Pumping, Cease Pumping at RR Plant 8 (Low Seepage Velocity Case) |
| Sc2_A | **Scenario #2** Baseline; Enhanced Site Pumping, Consistent withdrawals at RR Plant 8 |
| Sc2_B | Enhanced Site Pumping, Increased Pumping at RR Plant 8 (High Seepage Velocity Case) |
| Sc2_C | Enhanced Site Pumping, Cease Pumping at RR Plant 8 |

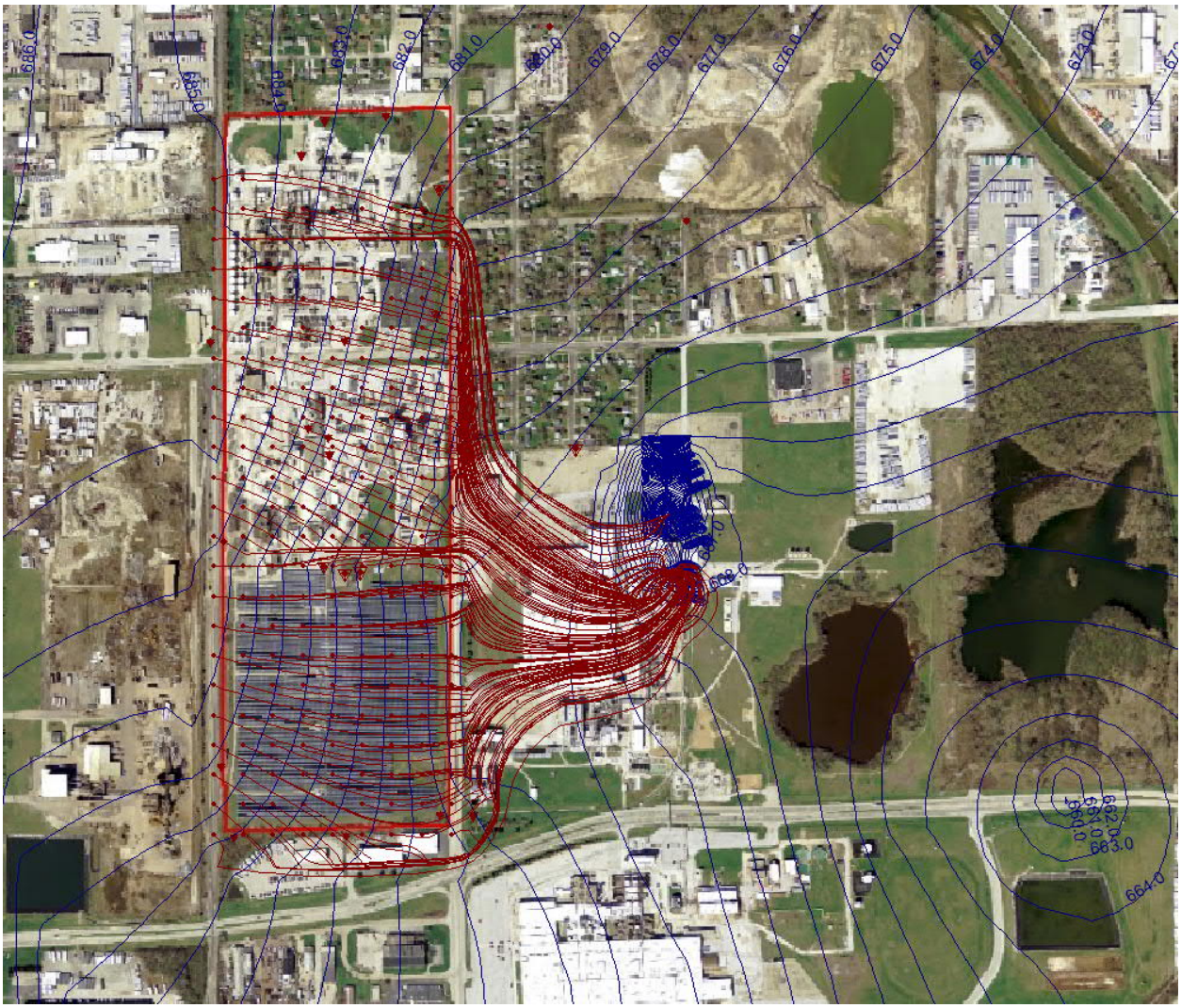
# Scenario #0 (Baseline Calibration Conditions)



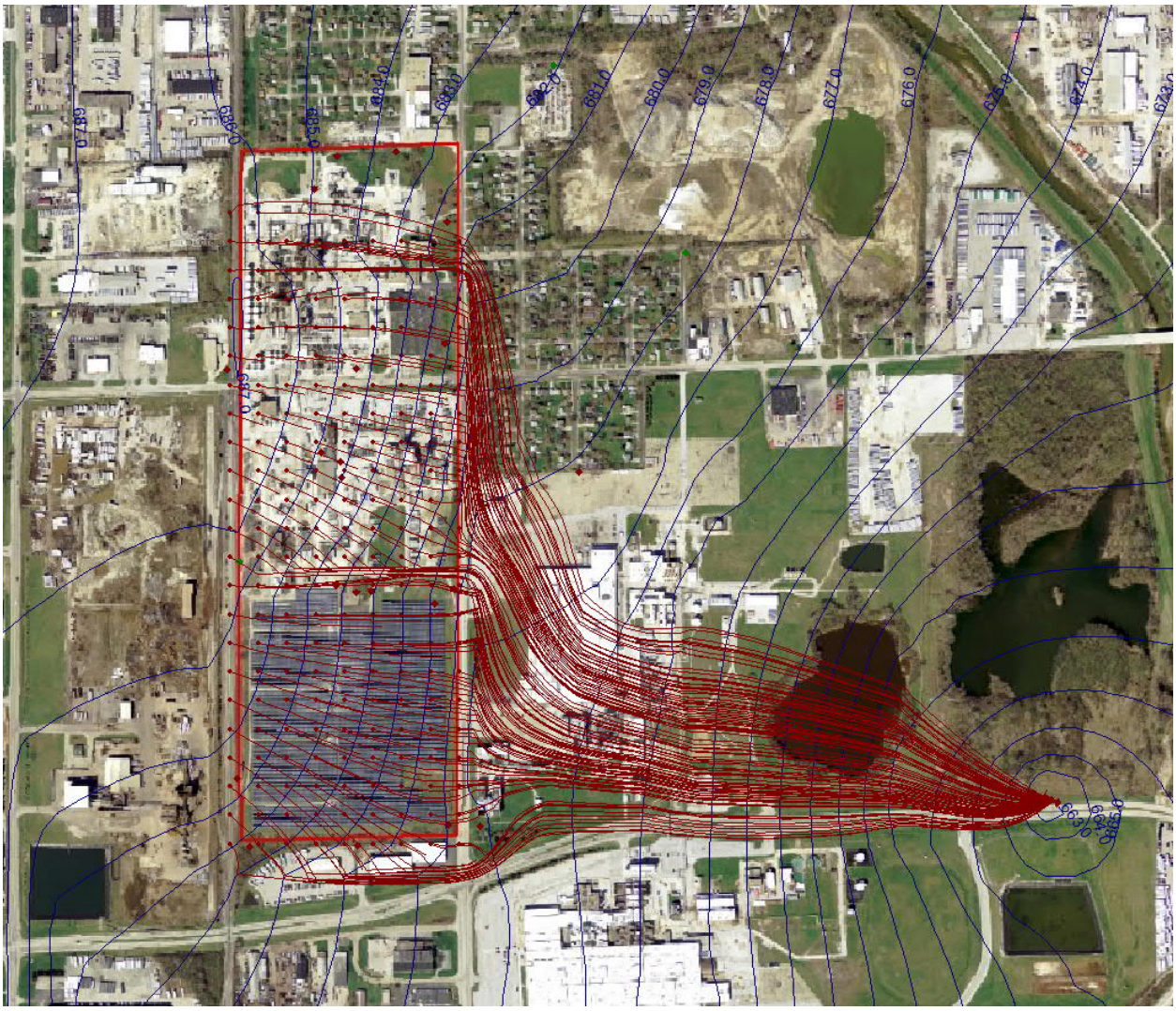
# SC1-3A: Scenario #1 & #3 Baseline; No On-Site Pumping, Consistent withdrawals at RR Plant 8



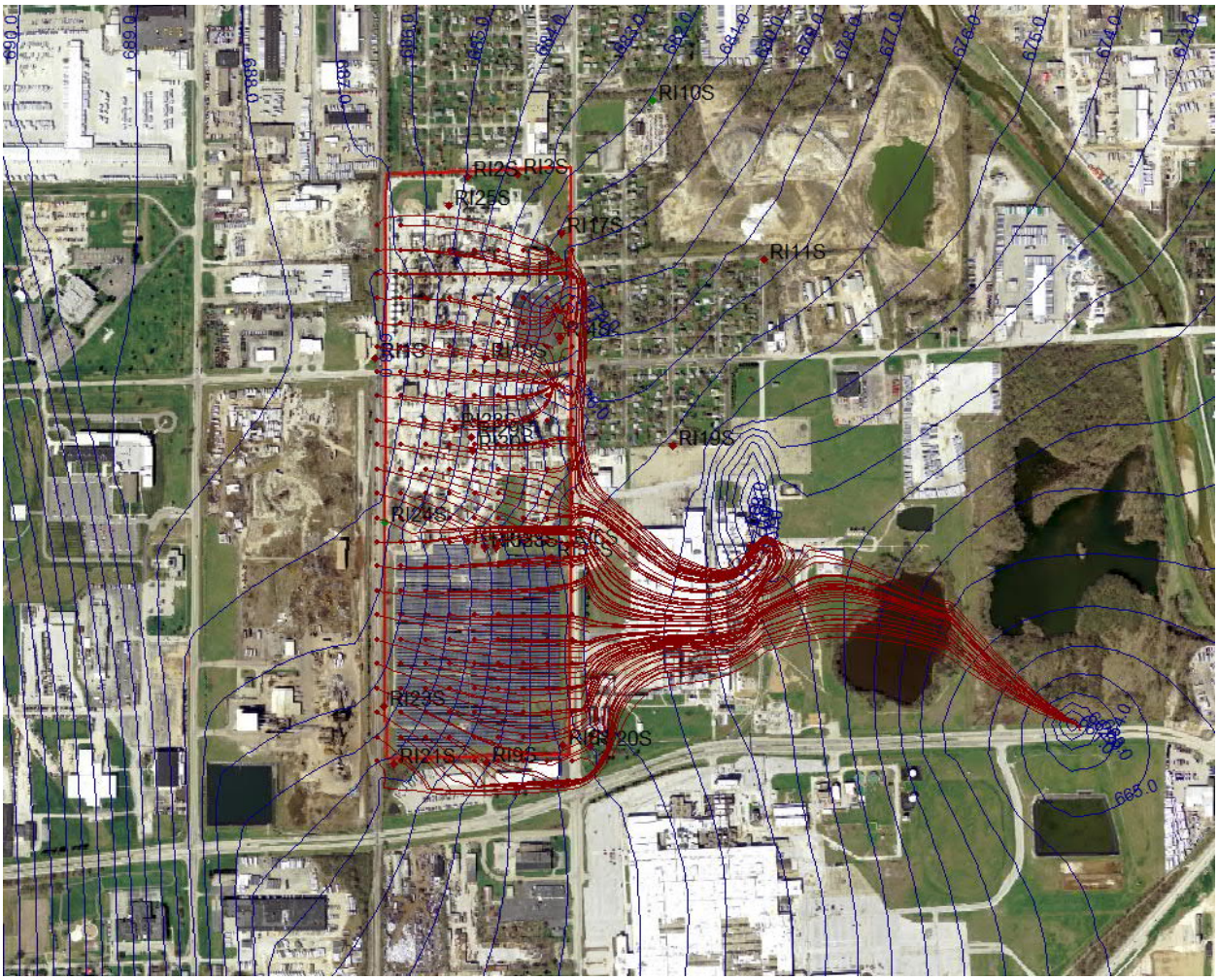
# SC1-3B: No On-Site Pumping, Increased Pumping at RR Plant 8 (Max. Month)



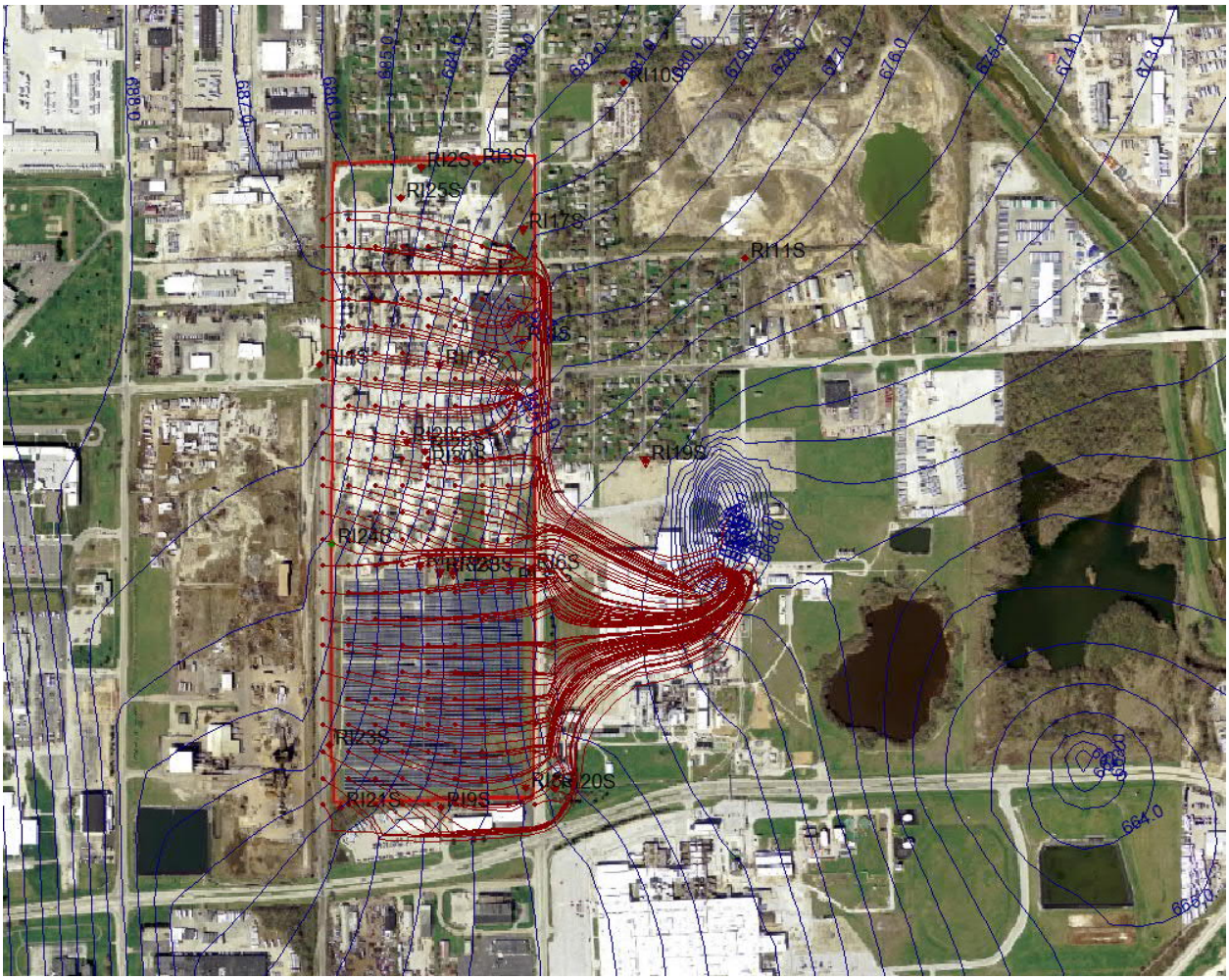
# SC1-3C: No On-Site Pumping, Cease Pumping at RR Plant 8 (Low Seepage Velocity Case)



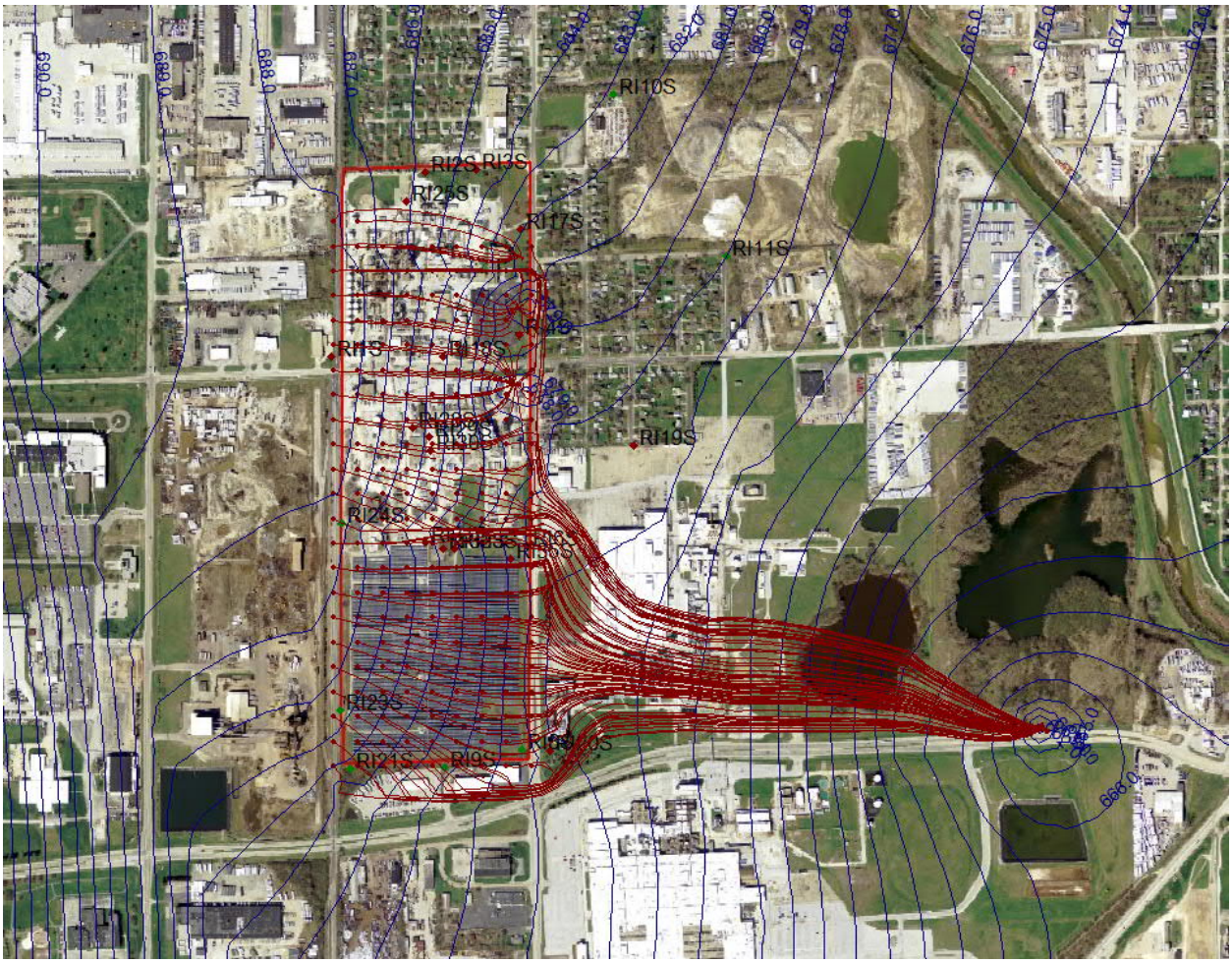
# SC2_A: Scenario #2 Baseline; Enhanced Site Pumping, Consistent withdrawals at RR Plant 8



# SC2_B: Enhanced Site Pumping, Increased Pumping at RR Plant 8 (High Seepage Velocity Case)

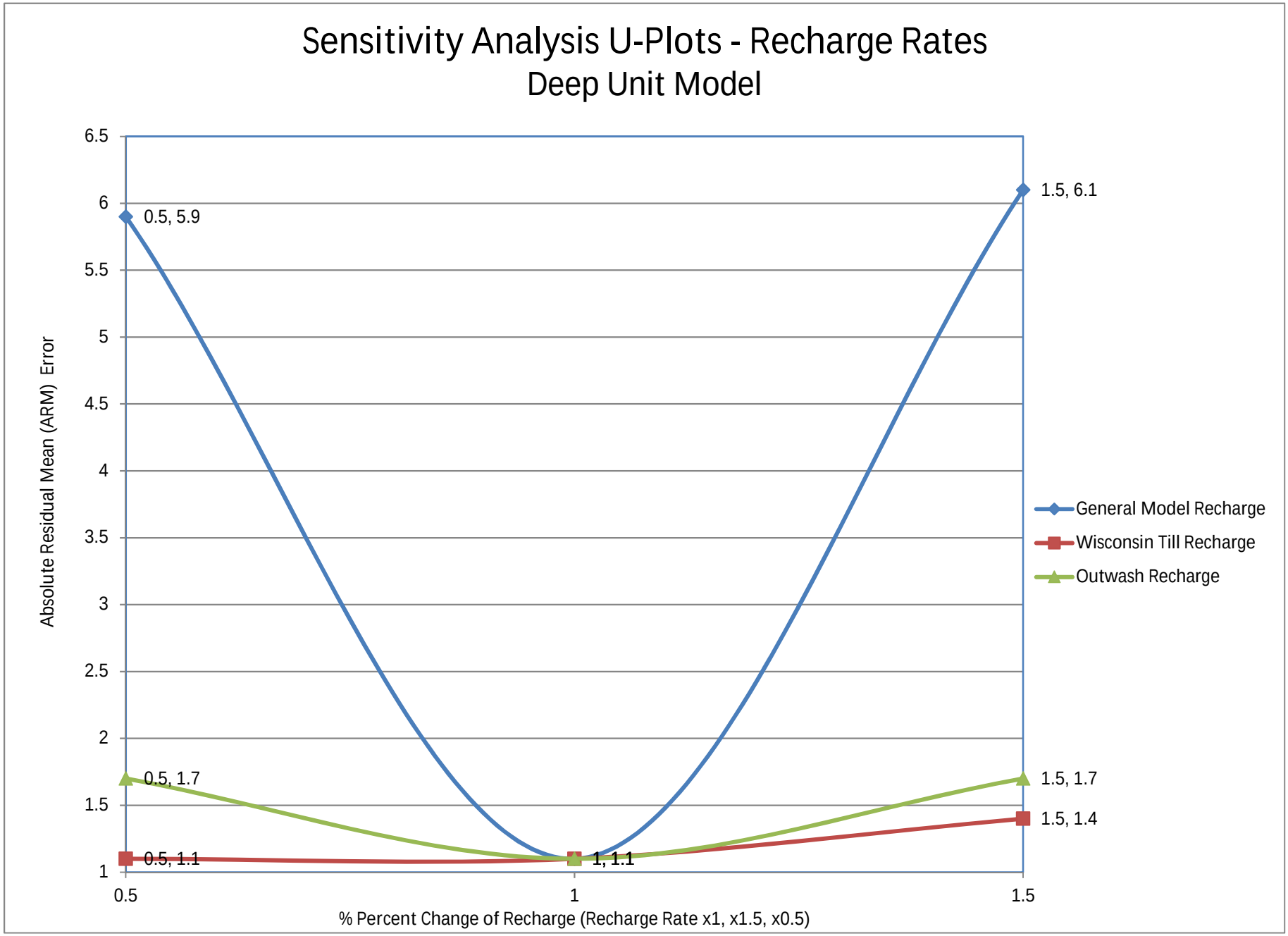


# SC2_C: Enhanced Site Pumping, Cease Pumping at RR Plant 8



# Appendix B-2

# Groundwater Flow Modeling Sensitivity Analysis - Deep Unit


Sensitivity Analysis U-Plots - Recharge Rates
Deep Unit Model
Absolute Residual Mean (ARM) Error
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
1
1.5
% Percent Change of Recharge (Recharge Rate x1, x1.5, x0.5)
0.5, 5.9
1.5, 6.1
0.5, 1.7
1.5, 1.7
0.5, 1.1
1, 1.1
1.5, 1.4
General Model Recharge
Wisconsin Till Recharge
Outwash Recharge

# Deep Recharge Sensitivity Results

| RECHARGE | % Change of Recharge for Sensitivity Analysis | Recharge (ft/day) | Recharge (In/Year) | Absolute Residual Mean (ARM) "Mean Absolute Difference" (ft) | Sensitivity Rating[1] |
|---|---|---|---|---|---|
| General Model | 0.50 | 0.0008 | 3.504 | 5.9 | Type II |
| | BASELINE | 0.0016 | 7.008 | 1.1 | |
| | 1.50 | 0.0024 | 10.512 | 6.1 | |
| | | | | | |
| Till Plains | 0.50 | 0.00034 | 1.4892 | 1.1 | Type I |
| | BASELINE | 0.00068 | 2.9784 | 1.1 | |
| | 1.50 | 0.00102 | 4.4676 | 1.4 | |
| | | | | | |
| White River & Tributary Outwash | 0.50 | 0.0008 | 3.504 | 1.7 | Type I |
| | BASELINE | 0.0016 | 7.008 | 1.1 | |
| | 1.50 | 0.0024 | 10.512 | 1.7 | |

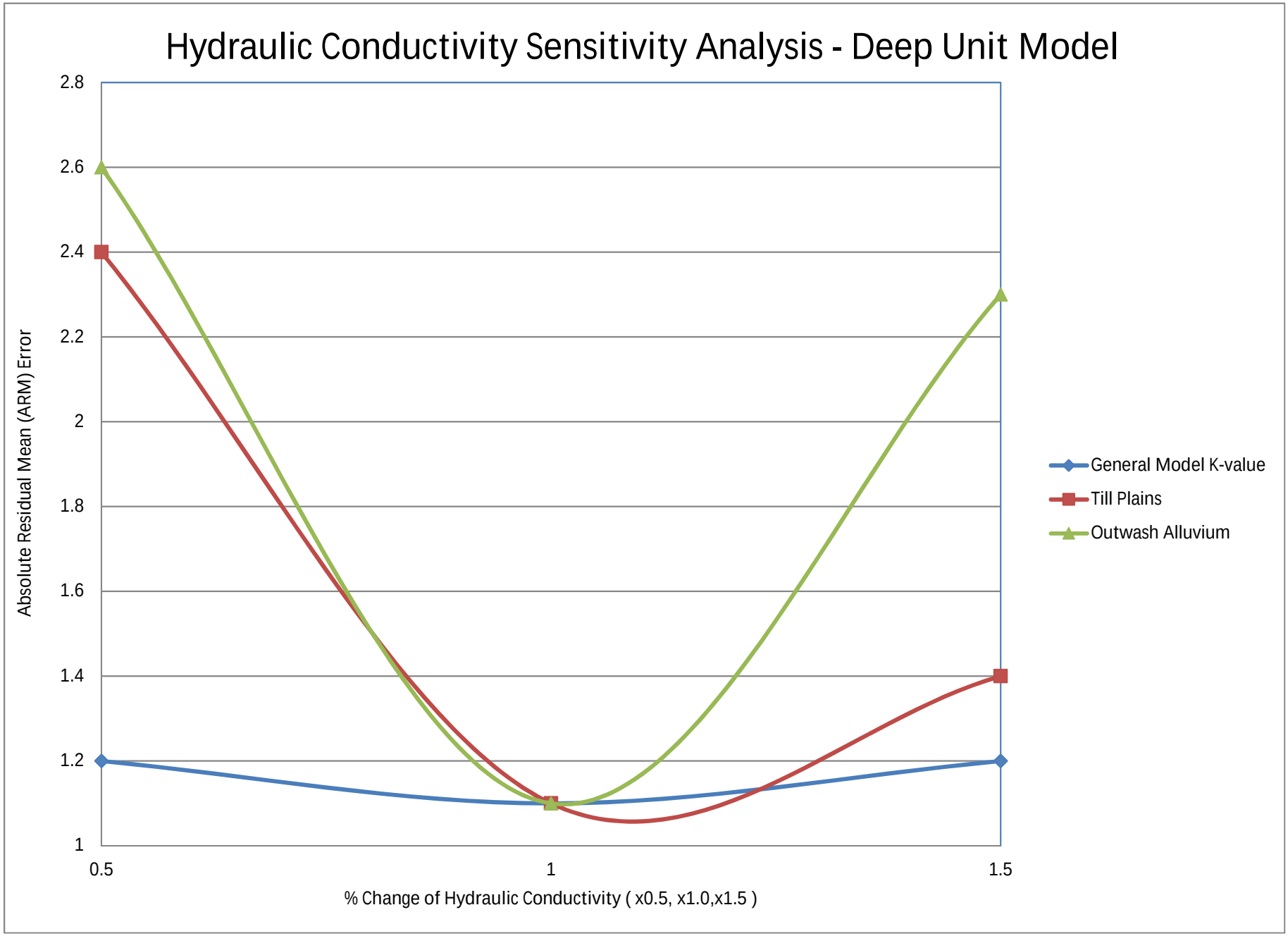
[1] ASTM D5611-94 (16) Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application. There are four types of sensitivity; Types through IV, depending on whether the changes to the calibration residual and model's conclusions are significant or insignificant.

Type I: When sensitivity is of no concern because regard- less of the value of the input, the conclusion will remain the same.

Type II: When variation of an input causes significant changes in the calibration residuals but insignificant changes in the model's conclusions

Type III: When variation of an input causes significant changes to both the calibration residuals and the model's conclusions

Type IV: If, for some value of the input that is being varied, the model's conclusions are changed but the change in calibration residuals is insignificant




C:\Directory\Projects\Active\IN_Vertellus\Report\Attachments\B. Flow Model\sensitivity runs_Deep.xlsxk chart

# Deep Hydraulic Conductivity Sensitivity Results (Till and Alluvium)

| Hydraulic Conductivity | % Change of Recharge for Sensistivty Analysis | Hydraulic Conductivity (ft/day) | Hydraulic Conductivity (cm/sec) | Absolute Residual Mean (ARM) "Mean Absolute Diffrence" (ft) | Sensitivity Rating[1] |
|---|---|---|---|---|---|
| General Model | 0.50 | 100 | 3.53E-02 | 1.2 | Type I |
| | BASELINE | 200 | 7.06E-02 | 1.1 | |
| | 1.50 | 300 | 1.06E-01 | 1.2 | |
| | | | | | |
| Wisconsin Till | 0.50 | 12.5 | 4.41E-03 | 2.4 | Type II |
| | BASELINE | 25 | 8.82E-03 | 1.1 | |
| | 1.50 | 37.5 | 1.32E-02 | 1.4 | |
| | | | | | |
| Outwash Alluvium | 0.50 | 125 | 4.41E-02 | 2.6 | Type II |
| | BASELINE | 250 | 8.82E-02 | 1.1 | |
| | 1.50 | 375.00 | 1.32E-01 | 2.3 | |

[1]ASTM D5611-94 (16) Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application.There are four types of sensitivity; Types I through IV, depending on whether the changes to the calibration residual and model's conclusions are significant or insignificant.

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Type II: When variation of an input causes significant changes in the calibration residuals but insignificant changes in the model's conclusions

Type III: When variation of an input causes significant changes to both the calibration residuals and the model's conclusions

Type IV: If, for some value of the input that is being varied, the model's conclusions are changed but the change in calibration residuals is insignificant

# Deep Aquifer Hydraulic Condutivity Sensitivity Results (OU1 OU5)
# (Changes to Hydraulic Conductivity Zonations were Separately)

| Hydraulic Conductivity Inhomogeneity | % Change of Recharge for Sensistivty Analysis | Hydraulic Conductivity (ft/day) | Hydraulic Conductivity (cm/sec) | Absolute Residual Mean (ARM) "Mean Absolute Diffrence" (ft) | Sensitivity Rating[1] |
|---|---|---|---|---|---|
| G14 | 0.50 | 125 | 4.41E-02 | 1.2 | Type I |
| | BASELINE | 250 | 8.82E-02 | 1.1 | |
| | 1.50 | 375 | 1.32E-01 | 1.1 | |
| | | | | | |
| G8 | 0.50 | 1 | 3.53E-04 | 1.1 | Type I |
| | BASELINE | 2 | 7.06E-04 | 1.1 | |
| | 1.50 | 3 | 1.06E-03 | 1.1 | |
| | | | | | |
| G9 | 0.50 | 2 | 7.06E-04 | 1.1 | Type I |
| | BASELINE | 4 | 1.41E-03 | 1.1 | |
| | 1.50 | 6 | 2.12E-03 | 1.1 | |
| | | | | | |
| G10 | 0.50 | 15 | 5.29E-03 | 1.1 | Type I |
| | BASELINE | 30 | 1.06E-02 | 1.1 | |
| | 1.50 | 45.00 | 1.59E-02 | 1.1 | |
| | | | | | |
| G3 | 0.50 | 32.5 | 1.15E-02 | 1.2 | Type I |
| | BASELINE | 65 | 2.29E-02 | 1.1 | |
| | 1.50 | 97.50 | 3.44E-02 | 1.1 | |
| | | | | | |
| G4 | 0.50 | 25 | 8.82E-03 | 1.2 | Type I |
| | BASELINE | 50 | 1.76E-02 | 1.1 | |
| | 1.50 | 75.00 | 2.65E-02 | 1.1 | |
| | | | | | |
| G12 | 0.50 | 57.5 | 2.03E-02 | 1.2 | Type I |
| | BASELINE | 115 | 4.06E-02 | 1.1 | |
| | 1.50 | 172.50 | 6.09E-02 | 1.1 | |
| | | | | | |
| G6 | 0.50 | 20 | 7.06E-03 | 1.1 | Type I |
| | BASELINE | 100 | 3.53E-02 | 1.1 | |
| | 1.50 | 60.00 | 2.12E-02 | 1.1 | |
| | | | | | |
| G2 | 0.50 | 20 | 7.06E-03 | 1.1 | Type I |
| | BASELINE | 40 | 1.41E-02 | 1.1 | |
| | 1.50 | 60.00 | 2.12E-02 | 1.1 | |

[1] ASTM D5611-94 (16) Standard Guidefor Conducting a Sensitivity Analysis for a Groundwater Flow Model Application. There are four types of sensitivity;TypesI through IV, depending on whether the changesto the calibration residual and model's conclusions are significant or insignificant.

Type I: When sensitivity is of noconcern because regard- less of the value of the input,the conclusion will remain the same.

Type II: When variation of an input causes significant changes in the calibration residuals but insignificant changes in the model's conclusions

Type III: When variation of an input causes significant changes to both the calibration residuals and the model's conclusions

Type IV: If, for some value of the input that is being varied, the model's conclusions are changed but the change in calibration residuals is insignificant

# Deep Aquifer Hydraulic Conductivity Sensitivity Results (OU1 OU5)

| Hydraulic Conductivity | % Change of Recharge for Sensitivity Analysis | Hydraulic Conductivity (ft/day) | Hydraulic Conductivity (cm/sec) | Absolute Residual Mean (ARM) "Mean Absolute Difference" (ft) after all zones changed in one sensitivity run (+) or (-) | Sensitivity Rating[1] |
|---|---|---|---|---|---|
| G14 | 0.50 | 125 | 4.41E-02 | 1.3 | Type I |
| | BASELINE | 250 | 8.82E-02 | 1.1 | |
| | 1.50 | 375 | 1.32E-01 | 1.2 | |
| | | | | | |
| G8 | 0.50 | 1 | 3.53E-04 | 1.3 | |
| | BASELINE | 2 | 7.06E-04 | 1.1 | |
| | 1.50 | 3 | 1.06E-03 | 1.2 | |
| | | | | | |
| G9 | 0.50 | 2 | 7.06E-04 | 1.3 | |
| | BASELINE | 4 | 1.41E-03 | 1.1 | |
| | 1.50 | 6 | 2.12E-03 | 1.2 | |
| | | | | | |
| G10 | 0.50 | 15 | 5.29E-03 | 1.3 | |
| | BASELINE | 30 | 1.06E-02 | 1.1 | |
| | 1.50 | 45.00 | 1.59E-02 | 1.2 | |
| | | | | | |
| G3 | 0.50 | 32.5 | 1.15E-02 | 1.3 | |
| | BASELINE | 65 | 2.29E-02 | 1.1 | |
| | 1.50 | 97.50 | 3.44E-02 | 1.2 | |
| | | | | | |
| G4 | 0.50 | 25 | 8.82E-03 | 1.3 | |
| | BASELINE | 50 | 1.76E-02 | 1.1 | |
| | 1.50 | 75.00 | 2.65E-02 | 1.2 | |
| | | | | | |
| G12 | 0.50 | 57.5 | 2.03E-02 | 1.3 | |
| | BASELINE | 115 | 4.06E-02 | 1.1 | |
| | 1.50 | 172.50 | 6.09E-02 | 1.2 | |
| | | | | | |
| G6 | 0.50 | 50 | 1.76E-02 | 1.3 | |
| | BASELINE | 100 | 3.53E-02 | 1.1 | |
| | 1.50 | 150.00 | 5.29E-02 | 1.2 | |
| | | | | | |
| G2 | 0.50 | 20 | 7.06E-03 | 1.3 | |
| | BASELINE | 40 | 1.41E-02 | 1.1 | |
| | 1.50 | 60.00 | 2.12E-02 | 1.2 | |

[1] ASTM D5611-94 (16) Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application. There are four types of sensitivity; Types I through IV, depending on whether the changes to the calibration residual and model's conclusions are significant or insignificant.

Type I: When sensitivity is of no concern because regard- less of the value of the input, the conclusion will remain the same.

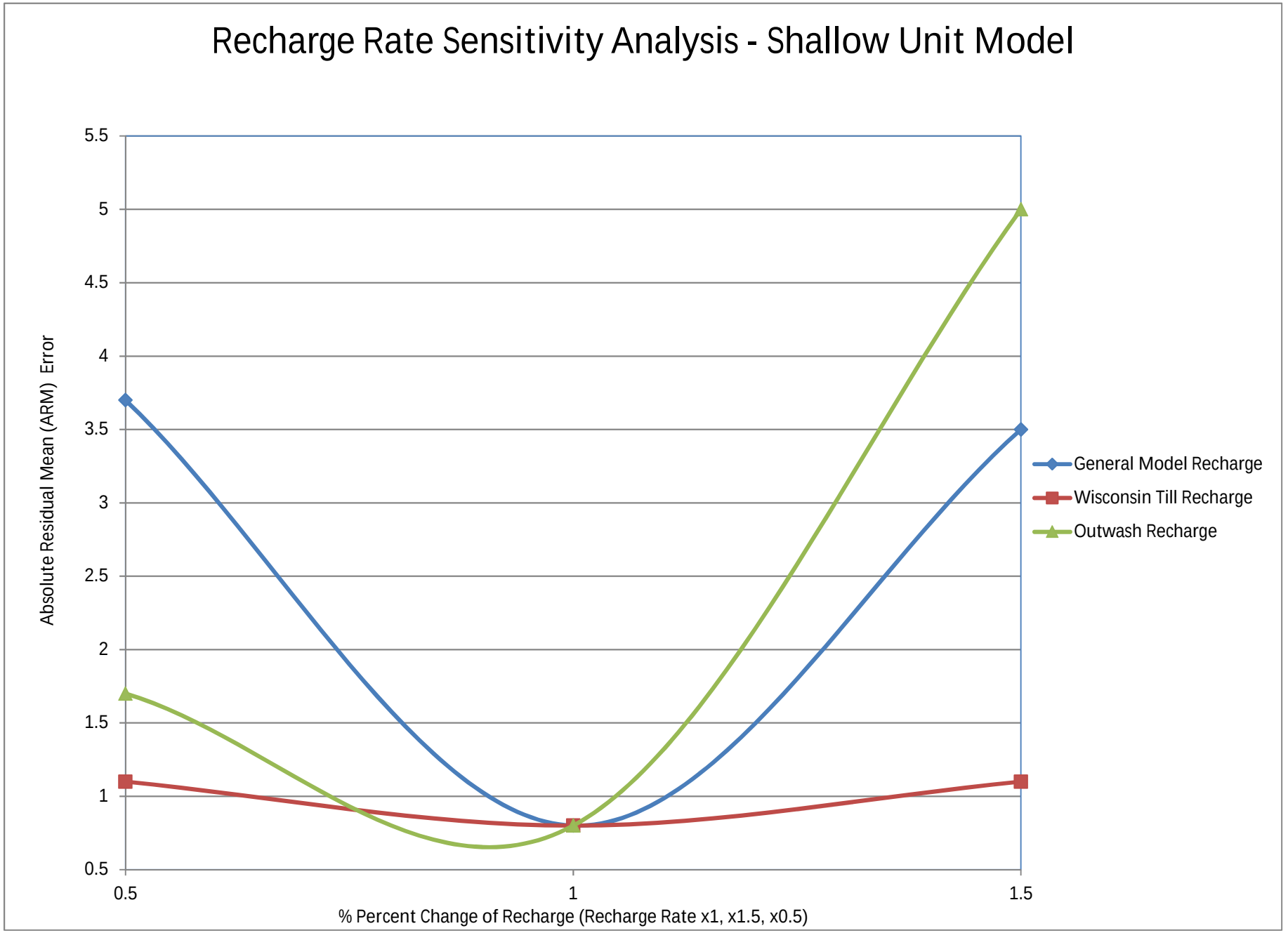
Type II: When variation of an input causes significant changes in the calibration residuals but insignificant changes in the model's conclusions

Type III: When variation of an input causes significant changes to both the calibration residuals and the model's conclusions

Type IV: If, for some value of the input that is being varied, the model's conclusions are changed but the change in calibration residuals is insignificant

# Appendix B-3

# Groundwater Flow Model Sensitivity Analysis – Shallow Unit


Recharge Rate Sensitivity Analysis - Shallow Unit Model
Absolute Residual Mean (ARM) Error
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0.5
1
1.5
% Percent Change of Recharge (Recharge Rate x1, x1.5, x0.5)
General Model Recharge
Wisconsin Till Recharge
Outwash Recharge

# Shallow Aquifer Recharge Sensitivity Results

| RECHARGE | % Change of Recharge for Sensistivty Analysis | Recharge (ft/day) | Recharge (In/Year) | Absolute Residual Mean (ARM) "Mean Absolute Diffrence" (ft) | Sensitivity Rating[1] |
|---|---|---|---|---|---|
| General Model | 0.50 | 0.0007 | 3.066 | 3.7 | Type II |
| | BASELINE | 0.0014 | 6.132 | 0.8 | |
| | 1.50 | 0.0021 | 9.198 | 3.5 | |
| | | | | | |
| Wisconsin Till | 0.50 | 0.00034 | 1.4892 | 1.1 | Type I |
| | BASELINE | 0.00068 | 2.9784 | 0.8 | |
| | 1.50 | 0.00102 | 4.4676 | 1.1 | |
| | | | | | |
| Outwash Recharge | 0.50 | 0.0007 | 3.066 | 1.7 | Type I |
| | BASELINE | 0.0014 | 6.132 | 0.8 | |
| | 1.50 | 0.0021 | 9.198 | 5 | |

[1] ASTM D5611-94 (16) Standard Guidefor Conducting a Sensitivity Analysis for a Groundwater Flow Model Application.There are four types of sensitivity; TypesI through IV, depending on whether the changes to the calibration residual and model's conclusions are significant or insignificant.

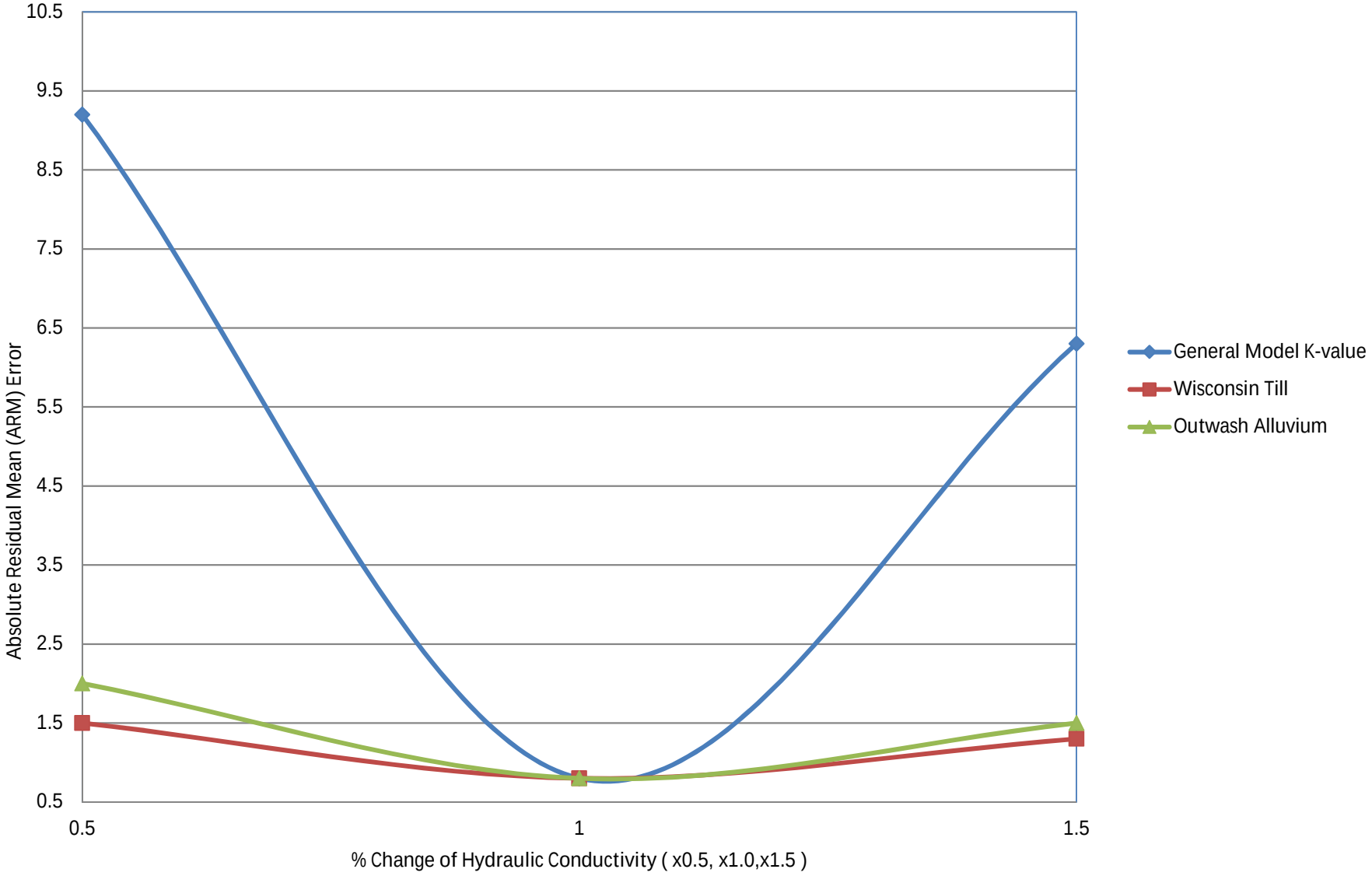
Type I: When sensitivity is of noconcern because regard- less of the value of the input,the conclusion will remain the same.

Type II: When variation of an input causes significant changes in the calibration residuals but insignificant changes in the model's conclusions

Type III: When variation of an input causes significant changes to both the calibration residuals and the model's conclusions

Type IV: If, for some value of the input that is being varied, the model's conclusions are changed but the change in calibration residuals is insignificant

# Shallow Aquifer Hydraulic Conductivity Sensitivity Analysis




C:\Directory\Projects\Active\IN_Vertellus\Report\Attachments\B. Flow Model\sensitivity runs_Shallow.xlsxk chart

## Shallow Aquifer Hydraulic Conductivity Sensitivity Results

| Hydraulic Conductivity | % Change of Recharge for Sensistivty Analysis | Hydraulic Conductivity (ft/day) | Hydraulic Conductivity (cm/sec) | Absolute Residual Mean (ARM) "Mean Absolute Diffrence" (ft) | Sensitivity Rating[1] |
|---|---|---|---|---|---|
| General Model | 0.50 | 128 | 4.52E-02 | 9.2 | Type III |
| | BASELINE | 256 | 9.03E-02 | 0.8 | |
| | 1.50 | 384 | 1.35E-01 | 6.3 | |
| | | | | | |
| Wisconsin Till | 0.50 | 12.5 | 4.41E-03 | 1.5 | Type I |
| | BASELINE | 25 | 8.82E-03 | 0.8 | |
| | 1.50 | 37.5 | 1.32E-02 | 1.3 | |
| | | | | | |
| Outwash Alluvium | 0.50 | 125 | 4.41E-02 | 2 | Type II |
| | BASELINE | 250 | 8.82E-02 | 0.8 | |
| | 1.50 | 375 | 1.32E-01 | 1.5 | |

[1]ASTM D5611-94 (16) Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application.There are four types of sensitivity; Types I through IV, depending on whether the changes to the calibration residual and model's conclusions are significant or insignificant.

Type I: When sensitivity is of noconcern because regard- less of the value of the input,the conclusion will remain the same.

Type II: When variation of an input causes significant changes in the calibration residuals but insignificant changes in the model's conclusions

Type III: When variation of an input causes significant changes to both the calibration residuals and the model's conclusions

Type IV: If, for some value of the input that is being varied, the model's conclusions are changed but the change in calibration residuals is insignificant

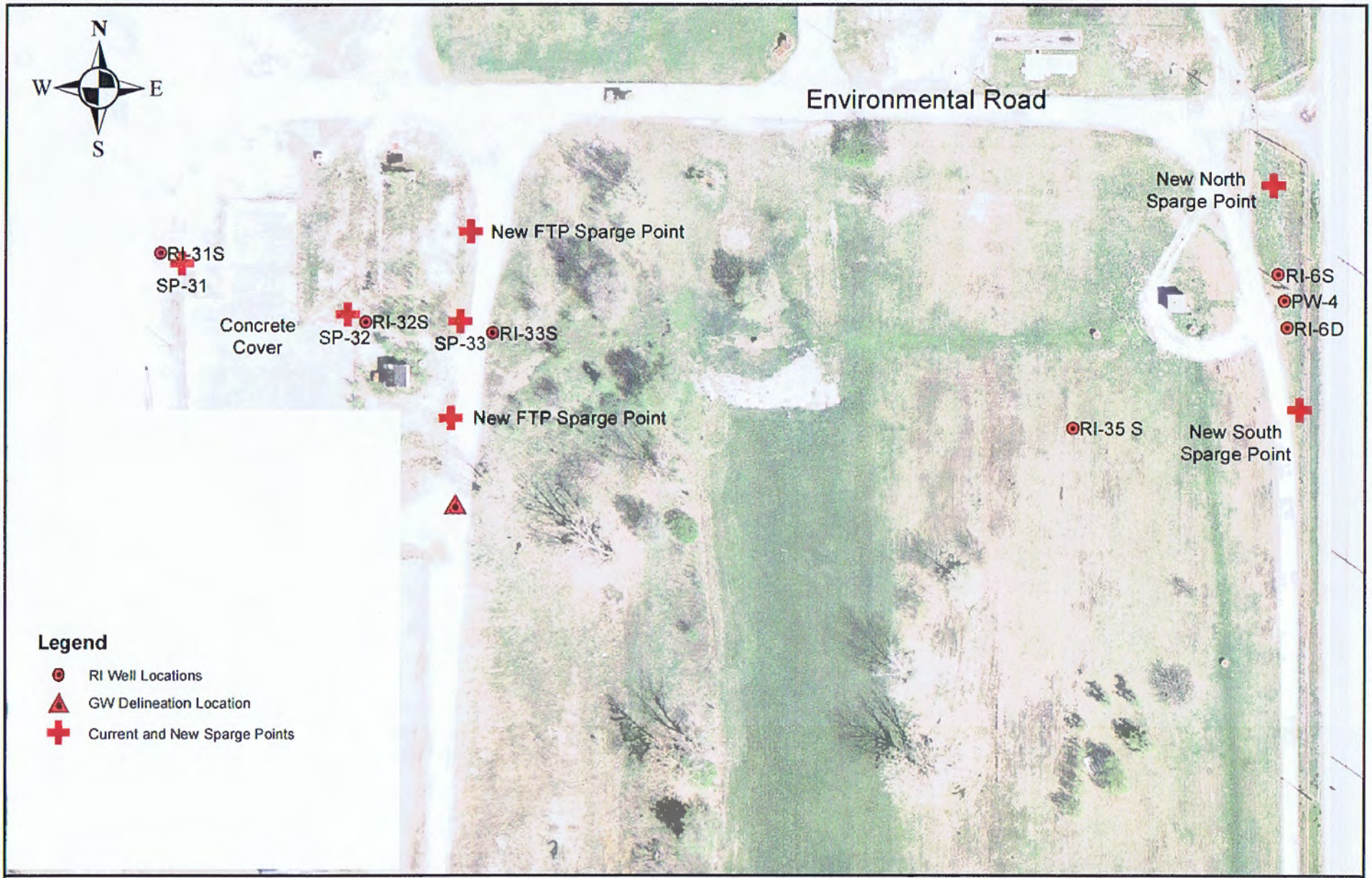
# Appendix C

# Contaminant Transport Modeling Results

# Appendix C-1

# Transport Model Calibration Files

# FTP Velocity and Retardation Assessment




**Former Treatment Pit and PW-4/RI-6 Area**
**Existing and Newly Installed**
**Wells and Sparge Points**

0 50 100 200 Feet

**Vertellus Specialties Inc**
**1500 S. Tibbs Ave.**
**Indianapolis, IN**

**Groundwater Velocity and Retardation Factor Assessment**
**Former Treatment Pit Area**

The groundwater velocity and chemical transport rates were assessed using chemical data from monitoring wells located down gradient of the Former Treatment Pit (FTP). on the Vertellus property.

The assessment first involved determining the rate of groundwater velocity using ammonia concentration versus time data in monitoring wells. Since ammonia is soluble in groundwater, the rate of transport of ammonia in groundwater is used as a proxy to determine the groundwater velocity.

Next, the rate of contaminant migration for benzene and 3,5 Lutidine were determined utilizing the same set of monitoring wells. Since organic compounds stick to aquifer materials, their migration rates are retarded. The migration rate determined for ammonia was then compared to the rates determined for benzene and 3,5 Lutidine to estimate retardation factors for benzene and pyridines. The data and results of this assessment are described below.

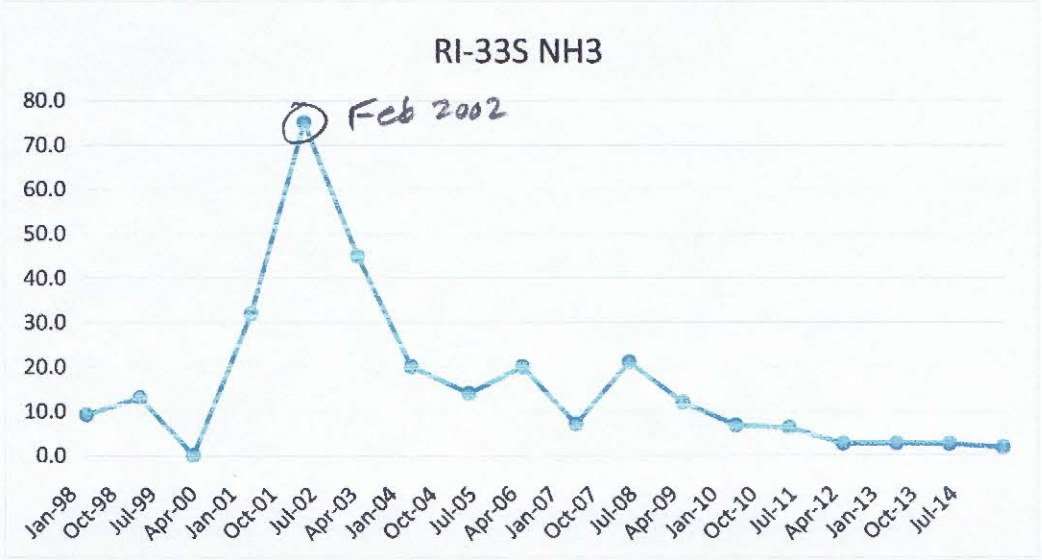
**FTP Area**
A map of the FTP area illustrating the locations of the monitoring wells is attached. In general, groundwater flows from west to east across the area. Ammonia, benzene, and 3,5 Lutidine data from monitoring wells RI-33S, RI-35S and RI-6S were plotted and the trends were examined to identify peaks from well to well to be utilized for velocity and transport calculations.

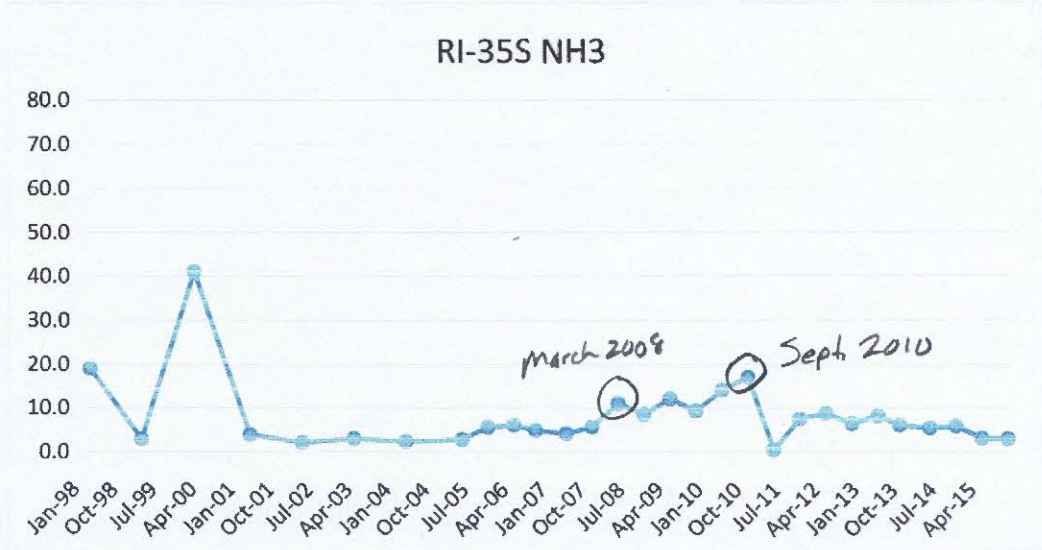
The attached pages provide graphs of the chemical data at each well versus time with a notation regarding the data point used in the assessment. In general, high peaks in the data between the wells were utilized. For example, to assess the velocity of ammonia in groundwater as it migrates from RI-33S to RI-35S, the highest peak at well RI-35S (Feb. 2002) was compared to the highest peak at the next ~~down~~ up gradient well RI-33S (Sept. 2010). Using the distance between the wells and the time difference between the peaks, a migration rate can be estimated. This approach was repeated for various well pairs and various data for ammonia, benzene and 3,5 Lutidine. Several tests were performed and the results were averaged. The computations for ammonia, benzene and 3,5 Lutidine are attached.

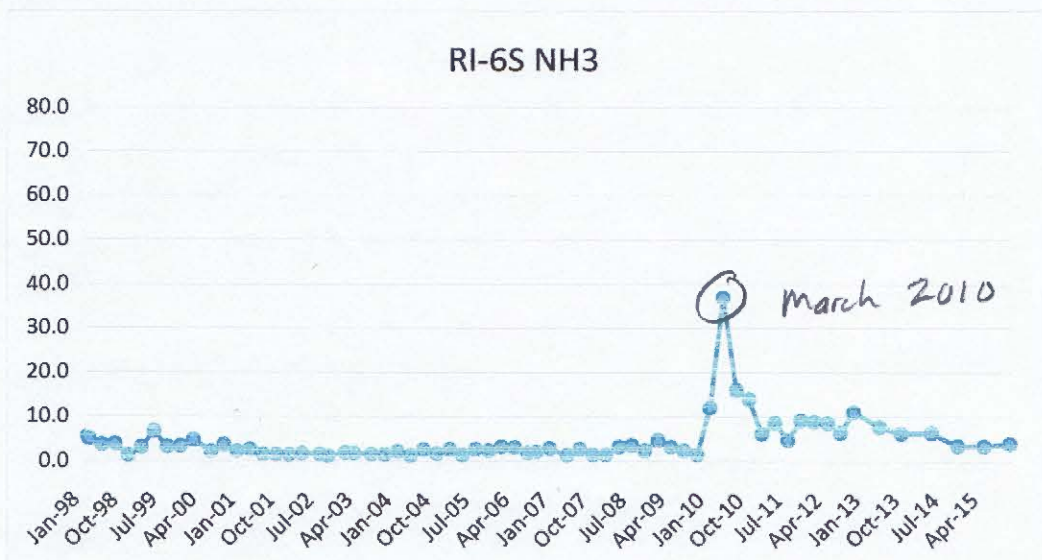
The average of the results for the FTP area are summarized in the table below.

| Velocity of Groundwater (based on ammonia) | Velocity of Benzene | Benzene Retardation Factor | Velocity of Pyridines | Pyridines Retardation Factor |
|---|---|---|---|---|
| 0.15 ft/day | 0.14 ft/day | 1.07 | 0.11 ft/day | 1.36 |

0
50
100
200 Feet
N
W
E
S
342.25 ft
RI-31S
RI-32S
RI-33S
RI-6S
PW-4
RI-6D
RI-35S


RI-33S NH3
Feb 2002
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jan-98
Oct-98
Jul-99
Apr-00
Jan-01
Oct-01
Jul-02
Apr-03
Jan-04
Oct-04
Jul-05
Apr-06
Jan-07
Oct-07
Jul-08
Apr-09
Jan-10
Oct-10
Jul-11
Apr-12
Jan-13
Oct-13
Jul-14


RI-35S NH3
March 2008
Sept 2010
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jan-98
Oct-98
Jul-99
Apr-00
Jan-01
Oct-01
Jul-02
Apr-03
Jan-04
Oct-04
Jul-05
Apr-06
Jan-07
Oct-07
Jul-08
Apr-09
Jan-10
Oct-10
Jul-11
Apr-12
Jan-13
Oct-13
Jul-14
Apr-15


RI-6S NH3
March 2010
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jan-98
Oct-98
Jul-99
Apr-00
Jan-01
Oct-01
Jul-02
Apr-03
Jan-04
Oct-04
Jul-05
Apr-06
Jan-07
Oct-07
Jul-08
Apr-09
Jan-10
Oct-10
Jul-11
Apr-12
Jan-13
Oct-13
Jul-14
Apr-15

## FTP Area
## Groundwater Velocity and Transport Analysis

Step 1 - Use ammonia data to estimate groundwater velocity

### Test 1 - Well Pairs RI-33S to RI-35S

| Well | Date | NH3 Concentration | Note |
|---|---|---|---|
| RI-33S | Feb-02 | 75 | Highest peak in the data |
| RI-35S | Sep-10 | 17 | Highest later peak in the data |

| | | |
|---|---|---|
| Distance between wells: | 357 | ft |
| Time between NH3 arrivals: | 8.6 | yrs |
| Velocity of groundwater: | 41.5 | ft/yr |
| | 0.1137 | ft/day |

### Test 2 - Well Pairs RI-33S to RI-35S

| Well | Date | NH3 Concentration | Note |
|---|---|---|---|
| RI-33S | Feb-02 | 75 | Highest peak in the data |
| RI-35S | Mar-08 | 11 | The rise in the trend in the data |

| | | |
|---|---|---|
| Distance between wells: | 357 | ft |
| Time between NH3 arrivals: | 6.1 | yrs |
| Velocity of groundwater: | 58.5 | ft/yr |
| | 0.160 | ft/day |

### Test 3 - Well Pairs RI-33S to RI-6S

| Well | Date | NH3 Concentration | Note |
|---|---|---|---|
| RI-33S | Feb-02 | 75 | Highest peak in the data |
| RI-6S | Mar-10 | 37 | Highest later peak in the data |

| | | |
|---|---|---|
| Distance between wells: | 477 | ft |
| Time between NH3 arrivals: | 8.1 | yrs |
| Velocity of groundwater: | 58.9 | ft/yr |
| | 0.161 | ft/day |

### Average of the results

| | | |
|---|---|---|
| Velocity of groundwater: | 53.0 | ft/yr |
| | 0.15 | ft/day |

# Appendix C-1

## Input Parameters for Calibrating 1-D Transport Model (Ammonia)

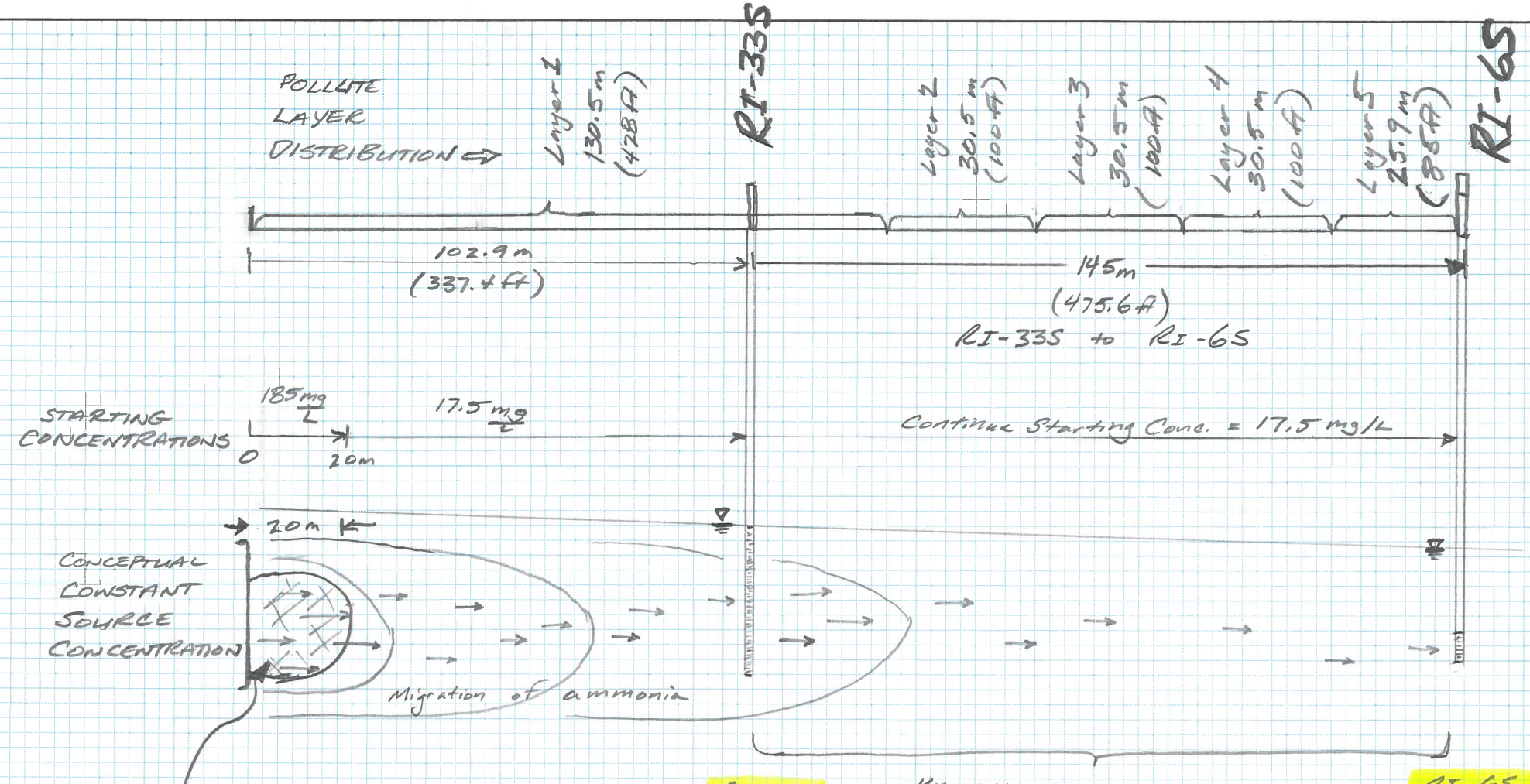
Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (17.5 mg/L)** | | | | | |
| Total Flow Length / Also "Layer Distance" | 813.3 | (ft) | 247.9 | (m) | |
| "Layer Distance: Layer 1" | 428.0 | (ft) | 130.5 | (m) | |
| "Layer Distance: Layers 2-4" | 100.0 | (ft) | 30.5 | (m) | |
| "Layer 5 Thickness" | 85.0 | (ft) | 25.9 | (m) | |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Surface Concentration ($C_o$) | 17.5 | (mg/L) | 17.5 | (mg/L) | Constant concentrations adjusted to match Site Data |
| **Layer 1-5 - Shallow Sand Unit (Assume same properties throughout upper sand unit)** | | | | | |
| | No. of Sub-Layers: | | 20 | | |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Calculated for alluvial sand & gravels (Sec. 4 in text) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in RI and previous modeling reports. |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 0.00 | (m/a) | qh (k*f); Mean velocity (55 ft/yr * Eff. Porosity). Adjusted slightly to match conc spikes. |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **General** | | | | | |
| **Layer 1 - Shallow Aquifer** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion |
| *Half-Life (ammonia) | ----- | ----- | 100.0 | (yrs) | Half-life for ammonia - consistent with FFS (DMP, 2017) |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 5.07 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 88.1 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.019 | ($m^2/a$) | Diffusion coefficient for ammonia surrogate group; Ref.: Quigley, et al. (1987) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.00 | ($cm^3/g$) | Conservatively assume that minimum distribution coefficient for ammonia is zero |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.00 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 88.2 | ($m^2/a$) | $D_{hiiT} = D_{hiM} + D_{hiD}$ (input to model [88.7 m2/a] adjusted slightly for better match) |
| **Layer 2-3-4 - Shallow Aquifer** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion |
| *Half-Life (ammonia) | ----- | ----- | 100.0 | (yrs) | Half-life for ammonia - consistent with FFS (DMP, 2017) |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 3.05 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 53.0 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.019 | ($m^2/a$) | Diffusion coefficient for ammonia surrogate group; Ref.: Quigley, et al. (1987) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.00 | ($cm^3/g$) | Conservatively assume that minimum distribution coefficient for ammonia is zero |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 53 | ($m^2/a$) | $D_{hiiT} = D_{hiM} + D_{hiD}$ |
| **Layer 5 - Shallow Aquifer** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion |
| *Half-Life (ammonia) | ----- | ----- | 100.0 | (yrs) | Half-life for ammonia - consistent with FFS (DMP, 2017) |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 2.59 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 45 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.019 | ($m^2/a$) | Diffusion coefficient for ammonia surrogate group; Ref.: Quigley, et al. (1987) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.00 | ($cm^3/g$) | Conservatively assume that minimum distribution coefficient for ammonia is zero |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 45 | ($m^2/a$) | $D_{hiiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.




Total flow length = 130.5 m + 30.5 m + 30.5 m + 30.5 m + 25.9 m = 247.9 m (813.3 ft)

| | | |
|---|---|---|
| L2 | 30.5 m | 100 ft |
| L3 | 30.5 m | 100 ft |
| L4 | 30.5 m | 100 ft |
| L5 | 25.9 m | 85 ft |
| | 117.4 m | 385 ft ← Dist. through Layers 2-5 |

145 m − 117.4 m = 27.6 m
475.6 ft − 385.0 ft = 90.6 ft ← Dist. from RI-335 to bottom of L1

130.5 m + 27.6 m = 102.9 m
428 ft − 90.6 ft = 337.4 ft ← Distance from source to RI-335

OBSERVED:

| RI-335 | RI-65 | |
|---|---|---|
| 75 mg/L | 37 mg/L | 75 mg/L − 37 mg/L = 38 mg/L |
| Highest Peak in data (Feb-07) | Highest Peak in data (Mar.-10) | ~50% drop in concentration over 145 m & 8.1 yrs |

Knowns: EVALUATION DISTANCE (145m)
TIME (8.1 yrs)

"CALIBRATED" RESULTS =

| | | |
|---|---|---|
| 75 mg/L | 42 mg/L | 75 mg/L − 42 mg/L = 33 mg/L |
| Year 3 | Year 11 | 44% drop in concentration over 145 m & 8.1 yrs |

POLLUTE INPUT VALUES:

- Half Life = 100 yrs (FFS DMP, 2017)
- Darcy Velocity ($V_a = n \cdot V$, where: n = effective porosity, V = seepage velocity)

  V = 0.15 ft/d (DMP, 2017) = 55 ft/yr × 18% = 9.9 ft/yr

  OR 3.02 m/yr

  Adjusted to 3.13 m/yr to match conc spikes
- Dry Density = 2.0 g/cm³ (refer to Sec 4 in text)
- Kd = Φ cm³/g (Distribution Coefficient)
- Effective Porosity = 18% Determined from matching to site data (~30% less than previously accepted porosity of 25%)

qhi)

fei)

| | |
|---|---|
| JOB TITLE | VERTELLUS INTEGRATED PYRIDINES |
| JOB NO. | 60571463 |
| CALCULATION NO. | APPDX C-1 |
| ORIGINATOR | GMB |
| DATE | 1-15-2019 |
| REVIEWER | JW/BM |
| DATE | 2-4-2019 |
| SCALE | — |
| SHEET NO. | 1 OF 2 |

Grid: 10x10 = 1"

Layer 1

Horizontal Dispersivity ($a_{h,i}$) = $0.83 * Log_{10}(scale)^{2.414} = 0.83 * Log_{10}(130.5)^{2.414} = 5.07m$ (based on Xu & Eckstein, 1995, since scale >100)

Horizontal Mechanical Dispersion ($D_{h,iM}$) = $a_L \times (q_{h,i} / fe_i) = 5.07m \times (3.13 m/a / 0.18) = 88.1 m^2/a$ ($a_L = a_{h,i}$)

Horizontal Hydrodynamic Dispersion ($D_{h,iT}$) = $D_{h,iM} + D_{h,iD} = 88.1 m^2/a + 0.019 m^2/a = 88.2 m^2/a$

Layers 2-3-4

Horizontal Dispersivity ($a_{h,i}$) = $0.1 \times scale = 0.1 \times 30.5m = 3.05m$ (based on Gelhar et. al. (1992) since scale <100)

Horizontal Mechanical Dispersion ($D_{h,iM}$) = $a_L \times (q_{h,i} / fe_i) = 3.05m \times (3.13 m/a / 0.18) = 53.04 m^2/a$ ($a_L = a_{h,i}$)

Horizontal Hydrodynamic Dispersion ($D_{h,iT}$) = $D_{h,iM} + D_{h,iD} = 53.04 m^2/a + 0.019 m^2/a = 53.06 m^2/a$

Layer 5

Horizontal Dispersivity ($a_{h,i}$) = $0.1 \times Scale = 0.1 \times 25.9m = 2.59m$ (based on Gelhar et. al. (1992) since Scale <100)

Horizontal Mechanical Dispersion ($D_{h,iM}$) = $a_L \times (q_{h,i} / fe_i) = 2.59m \times (3.13 m/a / 0.18) = 45.037 m^2/a$ ($a_L = a_{h,i}$)

Horizontal Hydrodynamic Dispersion ($D_{h,iT}$) = $D_{h,iM} + D_{h,iD} = 45.037 m^2/a + 0.019 m^2/a = 45.056 m^2/a$

For All Layers (1-5)

Vertical Darcy Velocity ($q_{v,i}$) = 0 m/a (conservatively assume no vertical hydrodynamic dispersion)

★ Diffusion Coefficient ($D_{h,D}$) = $0.019 m^2/a$ (Diffusion coefficient for ammonia surrogate group Quigley et. al. (1987))

Distribution Coefficient ($K_{d,i}$) = $0.00 cm^3/g$ (conservatively assume that minimum distribution coefficient for ammonia is zero)

Vertical Hydrodynamic Dispersion ($D_{v,iT}$) = $0.00 m^2/a$ (conservatively assume no loss of mass through vertical diffusion / dispersion)

AECOM

JOB TITLE VERTELLUS INTEGRATED PYRIDINES

JOB NO. 60571463 CALCULATION NO.

ORIGINATOR GMB DATE

REVIEWER DATE

SCALE — SHEET NO. 2 OF 2

Grid: 10x10 = 1"

```
**************************************************
*                                                *
*                                                *
*      P O L L U T E v 6   S I M U L A T I O N   *
*                                                *
*              RUN DATE -   12-12-**             *
*              TIME     -   24:31: 8             *
*                                                *
*              REVISION - 07/09/1997             *
*                                                *
*                   VERSION 6.3.3                *
*                                                *
* COPYRIGHT(c) R.K. ROWE & J.R. BOOKER  1983-1997 *
*                                                *
*  LICENSED USER: Unknown                        *
*                                                *
**************************************************
```

**********
RI33S to RI35S to RI6S

POLLUTE VERSION 6.3
**********

THE DARCY VELOCITY (Flux) THROUGH THE LAYERS Va = 0.3130E+01 m/a
(Positive for down or into the layer)

PROPERTIES OF THE MATRIX

| Layer No. | No. Of Sublayer | Coefficient Hydrodynamic Dispersion m2/a | Matrix Porosity | Distribution/ Partitioning Coefficient m3/kg | Dry Density kg/m3 | Layer Thickness m |
|---|---|---|---|---|---|---|
| 1 | 27 | 0.88700E+02 | 0.18000 | 0.0000E+00 | 2.0000 | 0.1305E+03 |
| 2 | 10 | 0.53000E+02 | 0.18000 | 0.0000E+00 | 2.0000 | 0.3050E+02 |
| 3 | 10 | 0.53000E+02 | 0.18000 | 0.0000E+00 | 2.0000 | 0.3050E+02 |
| 4 | 10 | 0.53000E+02 | 0.18000 | 0.2000E-01 | 2.0000 | 0.3050E+02 |
| 5 | 8 | 0.45000E+02 | 0.18000 | 0.0000E+00 | 2.0000 | 0.2590E+02 |

The TOP and BOTTOM BOUNDARY CONDITIONS
are defined by CODES Top = 2 Bottom = 4
See below for details

| CODE | TOP | BOTTOM |
|---|---|---|
| 1 = | Zero Flux | Zero Flux |
| 2 = | C = Const. | C = Const2. |
| 3 = | Finite Mass | Fixed Outflow Velocity |
| 4 = | | Infinite Bottom Layer |

Initial Source Concentration C0 = 0.1750E+02 mg/L

FIRST ORDER RADIOACTIVE OR BIOLOGICAL DECAY IS BEING CONSIDERED
IN THE FOLLOWING DEPTH RANGES:

| MINIMUM DEPTH m | MAXIMUM DEPTH m | HALF LIFE yr |
|---|---|---|
| 0.0000E+00 | 0.4850E+03 | 0.1000E+03 |

There is Radioactive or Biological Decay at the Source at the Top of the Deposi
with a Half Life of 0.1000E+03 yr

TOP 0.693099975585938D-002

THE INITIAL CONCENTRATION PROFILE IS OUTLINED BELOW:

| TIME yr | DEPTH m | CONCENTRATION mg/L | TOTAL MASS /UNIT AREA INTO SOIL m2/a | TOTAL MASS /UNIT AREA INTO BASE m2/a |
|---|---|---|---|---|
| 0.1000E+01 | 0.000E+00 | 0.18500E+03 | 0.16000E+03 | 0.16000E+03 |
| | 0.483E+01 | 0.18500E+03 | | |
| | 0.967E+01 | 0.18500E+03 | | |
| | 0.145E+02 | 0.18500E+03 | | |
| | 0.193E+02 | 0.18500E+03 | | |
| | 0.242E+02 | 0.17500E+02 | | |
| | 0.290E+02 | 0.17500E+02 | | |
| | 0.338E+02 | 0.17500E+02 | | |
| | 0.387E+02 | 0.17500E+02 | | |
| | 0.435E+02 | 0.17500E+02 | | |
| | 0.483E+02 | 0.17500E+02 | | |
| | 0.532E+02 | 0.17500E+02 | | |
| | 0.580E+02 | 0.17500E+02 | | |
| | 0.628E+02 | 0.17500E+02 | | |
| | 0.677E+02 | 0.17500E+02 | | |
| | 0.725E+02 | 0.17500E+02 | | |
| | 0.773E+02 | 0.17500E+02 | | |
| | 0.822E+02 | 0.17500E+02 | | |
| | 0.870E+02 | 0.17500E+02 | | |
| | 0.918E+02 | 0.17500E+02 | | |
| | 0.967E+02 | 0.17500E+02 | | |
| | 0.101E+03 | 0.17500E+02 | | |
| | 0.106E+03 | 0.17500E+02 | | |
| | 0.111E+03 | 0.17500E+02 | | |
| | 0.116E+03 | 0.17500E+02 | | |
| | 0.121E+03 | 0.17500E+02 | | |
| | 0.126E+03 | 0.17500E+02 | | |
| | 0.130E+03 | 0.17500E+02 | | |
| | 0.134E+03 | 0.17500E+02 | | |
| | 0.137E+03 | 0.17500E+02 | | |
| | 0.140E+03 | 0.17500E+02 | | |
| | 0.143E+03 | 0.17500E+02 | | |

| | |
|---|---|
| 0.146E+03 | 0.17500E+02 |
| 0.149E+03 | 0.17500E+02 |
| 0.152E+03 | 0.17500E+02 |
| 0.155E+03 | 0.17500E+02 |
| 0.158E+03 | 0.17500E+02 |
| 0.161E+03 | 0.17500E+02 |
| 0.164E+03 | 0.17500E+02 |
| 0.167E+03 | 0.17500E+02 |
| 0.170E+03 | 0.17500E+02 |
| 0.173E+03 | 0.17500E+02 |
| 0.176E+03 | 0.17500E+02 |
| 0.179E+03 | 0.17500E+02 |
| 0.182E+03 | 0.17500E+02 |
| 0.185E+03 | 0.17500E+02 |
| 0.188E+03 | 0.17500E+02 |
| 0.192E+03 | 0.17500E+02 |
| 0.195E+03 | 0.17500E+02 |
| 0.198E+03 | 0.17500E+02 |
| 0.201E+03 | 0.17500E+02 |
| 0.204E+03 | 0.17500E+02 |
| 0.207E+03 | 0.17500E+02 |
| 0.210E+03 | 0.17500E+02 |
| 0.213E+03 | 0.17500E+02 |
| 0.216E+03 | 0.17500E+02 |
| 0.219E+03 | 0.17500E+02 |
| 0.222E+03 | 0.17500E+02 |
| 0.225E+03 | 0.17500E+02 |
| 0.228E+03 | 0.17500E+02 |
| 0.232E+03 | 0.17500E+02 |
| 0.235E+03 | 0.17500E+02 |
| 0.238E+03 | 0.17500E+02 |
| 0.241E+03 | 0.17500E+02 |
| 0.245E+03 | 0.17500E+02 |
| 0.248E+03 | 0.17500E+02 |

The Parameters used to Invert the Laplace Transform are
TAU = 0.700E+01 N = 20 SIG = 0.000E+00 RNU = 0.200E+01

CALCULATED CONCENTRATIONS AT SELECTED DEPTHS AND TIMES

| TIME yr | DEPTH m | CONCENTRATION mg/L |
|---|---|---|
| 0.2000E+01 | 0.0000E+00 | 0.1738E+02 |
| | 0.4833E+01 | 0.2495E+02 |
| | 0.9667E+01 | 0.3825E+02 |
| | 0.1450E+02 | 0.5633E+02 |
| | 0.1933E+02 | 0.7575E+02 |
| | 0.2417E+02 | 0.9150E+02 |
| | 0.2900E+02 | 0.9908E+02 |
| | 0.3383E+02 | 0.9651E+02 |
| | 0.3867E+02 | 0.8521E+02 |
| | 0.4350E+02 | 0.6904E+02 |
| | 0.4833E+02 | 0.5240E+02 |
| | 0.5317E+02 | 0.3852E+02 |
| | 0.5800E+02 | 0.2874E+02 |
| | 0.6283E+02 | 0.2281E+02 |
| | 0.6767E+02 | 0.1968E+02 |

| | | |
|---|---|---|
| | 0.7250E+02 | 0.1825E+02 |
| | 0.7733E+02 | 0.1767E+02 |
| | 0.8217E+02 | 0.1746E+02 |
| | 0.8700E+02 | 0.1740E+02 |
| | 0.9183E+02 | 0.1738E+02 |
| | 0.9667E+02 | 0.1738E+02 |
| | 0.1015E+03 | 0.1738E+02 |
| | 0.1063E+03 | 0.1738E+02 |
| | 0.1112E+03 | 0.1738E+02 |
| | 0.1160E+03 | 0.1738E+02 |
| | 0.1208E+03 | 0.1738E+02 |
| | 0.1257E+03 | 0.1738E+02 |
| | 0.1305E+03 | 0.1738E+02 |
| | 0.1335E+03 | 0.1738E+02 |
| | 0.1366E+03 | 0.1738E+02 |
| | 0.1396E+03 | 0.1738E+02 |
| | 0.1427E+03 | 0.1738E+02 |
| | 0.1458E+03 | 0.1738E+02 |
| | 0.1488E+03 | 0.1738E+02 |
| | 0.1519E+03 | 0.1738E+02 |
| | 0.1549E+03 | 0.1738E+02 |
| | 0.1580E+03 | 0.1738E+02 |
| | 0.1610E+03 | 0.1738E+02 |
| | 0.1641E+03 | 0.1738E+02 |
| | 0.1671E+03 | 0.1738E+02 |
| | 0.1702E+03 | 0.1738E+02 |
| | 0.1732E+03 | 0.1738E+02 |
| | 0.1763E+03 | 0.1738E+02 |
| | 0.1793E+03 | 0.1738E+02 |
| | 0.1824E+03 | 0.1738E+02 |
| | 0.1854E+03 | 0.1738E+02 |
| | 0.1885E+03 | 0.1738E+02 |
| | 0.1915E+03 | 0.1738E+02 |
| | 0.1946E+03 | 0.1738E+02 |
| | 0.1976E+03 | 0.1738E+02 |
| | 0.2007E+03 | 0.1738E+02 |
| | 0.2037E+03 | 0.1738E+02 |
| | 0.2068E+03 | 0.1738E+02 |
| | 0.2098E+03 | 0.1738E+02 |
| | 0.2129E+03 | 0.1738E+02 |
| | 0.2159E+03 | 0.1738E+02 |
| | 0.2190E+03 | 0.1738E+02 |
| | 0.2220E+03 | 0.1738E+02 |
| | 0.2252E+03 | 0.1738E+02 |
| | 0.2285E+03 | 0.1738E+02 |
| | 0.2317E+03 | 0.1738E+02 |
| | 0.2350E+03 | 0.1738E+02 |
| | 0.2382E+03 | 0.1738E+02 |
| | 0.2414E+03 | 0.1738E+02 |
| | 0.2447E+03 | 0.1738E+02 |
| | 0.2479E+03 | 0.1738E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.3000E+01 | 0.0000E+00 | 0.1726E+02 |
| | 0.4833E+01 | 0.1865E+02 |
| | 0.9667E+01 | 0.2135E+02 |
| | 0.1450E+02 | 0.2579E+02 |
| | 0.1933E+02 | 0.3221E+02 |
| | 0.2417E+02 | 0.4043E+02 |
| | 0.2900E+02 | 0.4983E+02 |

| | |
|---|---|
| 0.3383E+02 | 0.5929E+02 |
| 0.3867E+02 | 0.6743E+02 |
| 0.4350E+02 | 0.7293E+02 |
| 0.4833E+02 | 0.7486E+02 |
| 0.5317E+02 | 0.7296E+02 |
| 0.5800E+02 | 0.6770E+02 |
| 0.6283E+02 | 0.6008E+02 |
| 0.6767E+02 | 0.5136E+02 |
| 0.7250E+02 | 0.4275E+02 |
| 0.7733E+02 | 0.3516E+02 |
| 0.8217E+02 | 0.2907E+02 |
| 0.8700E+02 | 0.2458E+02 |
| 0.9183E+02 | 0.2153E+02 |
| 0.9667E+02 | 0.1960E+02 |
| 0.1015E+03 | 0.1846E+02 |
| 0.1063E+03 | 0.1784E+02 |
| 0.1112E+03 | 0.1752E+02 |
| 0.1160E+03 | 0.1737E+02 |
| 0.1208E+03 | 0.1730E+02 |
| 0.1257E+03 | 0.1728E+02 |
| 0.1305E+03 | 0.1727E+02 |
| 0.1335E+03 | 0.1726E+02 |
| 0.1366E+03 | 0.1726E+02 |
| 0.1396E+03 | 0.1726E+02 |
| 0.1427E+03 | 0.1726E+02 |
| 0.1458E+03 | 0.1726E+02 |
| 0.1488E+03 | 0.1726E+02 |
| 0.1519E+03 | 0.1726E+02 |
| 0.1549E+03 | 0.1726E+02 |
| 0.1580E+03 | 0.1726E+02 |
| 0.1610E+03 | 0.1726E+02 |
| 0.1641E+03 | 0.1726E+02 |
| 0.1671E+03 | 0.1726E+02 |
| 0.1702E+03 | 0.1726E+02 |
| 0.1732E+03 | 0.1726E+02 |
| 0.1763E+03 | 0.1726E+02 |
| 0.1793E+03 | 0.1726E+02 |
| 0.1824E+03 | 0.1726E+02 |
| 0.1854E+03 | 0.1726E+02 |
| 0.1885E+03 | 0.1726E+02 |
| 0.1915E+03 | 0.1726E+02 |
| 0.1946E+03 | 0.1726E+02 |
| 0.1976E+03 | 0.1726E+02 |
| 0.2007E+03 | 0.1726E+02 |
| 0.2037E+03 | 0.1726E+02 |
| 0.2068E+03 | 0.1726E+02 |
| 0.2098E+03 | 0.1726E+02 |
| 0.2129E+03 | 0.1726E+02 |
| 0.2159E+03 | 0.1726E+02 |
| 0.2190E+03 | 0.1726E+02 |
| 0.2220E+03 | 0.1726E+02 |
| 0.2252E+03 | 0.1726E+02 |
| 0.2285E+03 | 0.1726E+02 |
| 0.2317E+03 | 0.1726E+02 |
| 0.2350E+03 | 0.1726E+02 |
| 0.2382E+03 | 0.1726E+02 |
| 0.2414E+03 | 0.1726E+02 |
| 0.2447E+03 | 0.1726E+02 |
| 0.2479E+03 | 0.1726E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |

| | | |
|---|---|---|
| 0.4000E+01 | 0.0000E+00 | 0.1714E+02 |
| | 0.4833E+01 | 0.1748E+02 |
| | 0.9667E+01 | 0.1818E+02 |
| | 0.1450E+02 | 0.1941E+02 |
| | 0.1933E+02 | 0.2137E+02 |
| | 0.2417E+02 | 0.2423E+02 |
| | 0.2900E+02 | 0.2811E+02 |
| | 0.3383E+02 | 0.3300E+02 |
| | 0.3867E+02 | 0.3871E+02 |
| | 0.4350E+02 | 0.4488E+02 |
| | 0.4833E+02 | 0.5101E+02 |
| | 0.5317E+02 | 0.5646E+02 |
| | 0.5800E+02 | 0.6065E+02 |
| | 0.6283E+02 | 0.6307E+02 |
| | 0.6767E+02 | 0.6345E+02 |
| | 0.7250E+02 | 0.6177E+02 |
| | 0.7733E+02 | 0.5828E+02 |
| | 0.8217E+02 | 0.5343E+02 |
| | 0.8700E+02 | 0.4779E+02 |
| | 0.9183E+02 | 0.4192E+02 |
| | 0.9667E+02 | 0.3634E+02 |
| | 0.1015E+03 | 0.3139E+02 |
| | 0.1063E+03 | 0.2727E+02 |
| | 0.1112E+03 | 0.2404E+02 |
| | 0.1160E+03 | 0.2165E+02 |
| | 0.1208E+03 | 0.1997E+02 |
| | 0.1257E+03 | 0.1886E+02 |
| | 0.1305E+03 | 0.1821E+02 |
| | 0.1335E+03 | 0.1784E+02 |
| | 0.1366E+03 | 0.1759E+02 |
| | 0.1396E+03 | 0.1742E+02 |
| | 0.1427E+03 | 0.1731E+02 |
| | 0.1458E+03 | 0.1724E+02 |
| | 0.1488E+03 | 0.1720E+02 |
| | 0.1519E+03 | 0.1717E+02 |
| | 0.1549E+03 | 0.1716E+02 |
| | 0.1580E+03 | 0.1715E+02 |
| | 0.1610E+03 | 0.1714E+02 |
| | 0.1641E+03 | 0.1714E+02 |
| | 0.1671E+03 | 0.1714E+02 |
| | 0.1702E+03 | 0.1714E+02 |
| | 0.1732E+03 | 0.1714E+02 |
| | 0.1763E+03 | 0.1714E+02 |
| | 0.1793E+03 | 0.1714E+02 |
| | 0.1824E+03 | 0.1714E+02 |
| | 0.1854E+03 | 0.1714E+02 |
| | 0.1885E+03 | 0.1714E+02 |
| | 0.1915E+03 | 0.1714E+02 |
| | 0.1946E+03 | 0.1714E+02 |
| | 0.1976E+03 | 0.1714E+02 |
| | 0.2007E+03 | 0.1714E+02 |
| | 0.2037E+03 | 0.1714E+02 |
| | 0.2068E+03 | 0.1714E+02 |
| | 0.2098E+03 | 0.1714E+02 |
| | 0.2129E+03 | 0.1714E+02 |
| | 0.2159E+03 | 0.1714E+02 |
| | 0.2190E+03 | 0.1714E+02 |
| | 0.2220E+03 | 0.1714E+02 |
| | 0.2252E+03 | 0.1714E+02 |
| | 0.2285E+03 | 0.1714E+02 |
| | 0.2317E+03 | 0.1714E+02 |
| | 0.2350E+03 | 0.1714E+02 |

| | | |
|---|---|---|
| | 0.2382E+03 | 0.1714E+02 |
| | 0.2414E+03 | 0.1714E+02 |
| | 0.2447E+03 | 0.1714E+02 |
| | 0.2479E+03 | 0.1714E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.5000E+01 | 0.0000E+00 | 0.1702E+02 |
| | 0.4833E+01 | 0.1712E+02 |
| | 0.9667E+01 | 0.1732E+02 |
| | 0.1450E+02 | 0.1770E+02 |
| | 0.1933E+02 | 0.1832E+02 |
| | 0.2417E+02 | 0.1929E+02 |
| | 0.2900E+02 | 0.2071E+02 |
| | 0.3383E+02 | 0.2269E+02 |
| | 0.3867E+02 | 0.2529E+02 |
| | 0.4350E+02 | 0.2853E+02 |
| | 0.4833E+02 | 0.3237E+02 |
| | 0.5317E+02 | 0.3667E+02 |
| | 0.5800E+02 | 0.4122E+02 |
| | 0.6283E+02 | 0.4572E+02 |
| | 0.6767E+02 | 0.4983E+02 |
| | 0.7250E+02 | 0.5321E+02 |
| | 0.7733E+02 | 0.5557E+02 |
| | 0.8217E+02 | 0.5668E+02 |
| | 0.8700E+02 | 0.5645E+02 |
| | 0.9183E+02 | 0.5492E+02 |
| | 0.9667E+02 | 0.5225E+02 |
| | 0.1015E+03 | 0.4869E+02 |
| | 0.1063E+03 | 0.4457E+02 |
| | 0.1112E+03 | 0.4022E+02 |
| | 0.1160E+03 | 0.3593E+02 |
| | 0.1208E+03 | 0.3198E+02 |
| | 0.1257E+03 | 0.2859E+02 |
| | 0.1305E+03 | 0.2610E+02 |
| | 0.1335E+03 | 0.2428E+02 |
| | 0.1366E+03 | 0.2272E+02 |
| | 0.1396E+03 | 0.2141E+02 |
| | 0.1427E+03 | 0.2034E+02 |
| | 0.1458E+03 | 0.1949E+02 |
| | 0.1488E+03 | 0.1882E+02 |
| | 0.1519E+03 | 0.1831E+02 |
| | 0.1549E+03 | 0.1792E+02 |
| | 0.1580E+03 | 0.1764E+02 |
| | 0.1610E+03 | 0.1744E+02 |
| | 0.1641E+03 | 0.1730E+02 |
| | 0.1671E+03 | 0.1720E+02 |
| | 0.1702E+03 | 0.1714E+02 |
| | 0.1732E+03 | 0.1709E+02 |
| | 0.1763E+03 | 0.1707E+02 |
| | 0.1793E+03 | 0.1705E+02 |
| | 0.1824E+03 | 0.1704E+02 |
| | 0.1854E+03 | 0.1703E+02 |
| | 0.1885E+03 | 0.1703E+02 |
| | 0.1915E+03 | 0.1702E+02 |
| | 0.1946E+03 | 0.1702E+02 |
| | 0.1976E+03 | 0.1702E+02 |
| | 0.2007E+03 | 0.1702E+02 |
| | 0.2037E+03 | 0.1702E+02 |
| | 0.2068E+03 | 0.1702E+02 |
| | 0.2098E+03 | 0.1702E+02 |

| | | |
|---|---|---|
| | 0.2129E+03 | 0.1702E+02 |
| | 0.2159E+03 | 0.1702E+02 |
| | 0.2190E+03 | 0.1702E+02 |
| | 0.2220E+03 | 0.1702E+02 |
| | 0.2252E+03 | 0.1702E+02 |
| | 0.2285E+03 | 0.1702E+02 |
| | 0.2317E+03 | 0.1702E+02 |
| | 0.2350E+03 | 0.1702E+02 |
| | 0.2382E+03 | 0.1702E+02 |
| | 0.2414E+03 | 0.1702E+02 |
| | 0.2447E+03 | 0.1702E+02 |
| | 0.2479E+03 | 0.1702E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.6000E+01 | 0.0000E+00 | 0.1690E+02 |
| | 0.4833E+01 | 0.1693E+02 |
| | 0.9667E+01 | 0.1700E+02 |
| | 0.1450E+02 | 0.1712E+02 |
| | 0.1933E+02 | 0.1732E+02 |
| | 0.2417E+02 | 0.1766E+02 |
| | 0.2900E+02 | 0.1817E+02 |
| | 0.3383E+02 | 0.1892E+02 |
| | 0.3867E+02 | 0.1998E+02 |
| | 0.4350E+02 | 0.2141E+02 |
| | 0.4833E+02 | 0.2325E+02 |
| | 0.5317E+02 | 0.2553E+02 |
| | 0.5800E+02 | 0.2826E+02 |
| | 0.6283E+02 | 0.3139E+02 |
| | 0.6767E+02 | 0.3481E+02 |
| | 0.7250E+02 | 0.3838E+02 |
| | 0.7733E+02 | 0.4193E+02 |
| | 0.8217E+02 | 0.4523E+02 |
| | 0.8700E+02 | 0.4808E+02 |
| | 0.9183E+02 | 0.5026E+02 |
| | 0.9667E+02 | 0.5162E+02 |
| | 0.1015E+03 | 0.5206E+02 |
| | 0.1063E+03 | 0.5156E+02 |
| | 0.1112E+03 | 0.5016E+02 |
| | 0.1160E+03 | 0.4799E+02 |
| | 0.1208E+03 | 0.4528E+02 |
| | 0.1257E+03 | 0.4234E+02 |
| | 0.1305E+03 | 0.3972E+02 |
| | 0.1335E+03 | 0.3739E+02 |
| | 0.1366E+03 | 0.3505E+02 |
| | 0.1396E+03 | 0.3276E+02 |
| | 0.1427E+03 | 0.3057E+02 |
| | 0.1458E+03 | 0.2851E+02 |
| | 0.1488E+03 | 0.2663E+02 |
| | 0.1519E+03 | 0.2493E+02 |
| | 0.1549E+03 | 0.2343E+02 |
| | 0.1580E+03 | 0.2214E+02 |
| | 0.1610E+03 | 0.2104E+02 |
| | 0.1641E+03 | 0.2012E+02 |
| | 0.1671E+03 | 0.1937E+02 |
| | 0.1702E+03 | 0.1876E+02 |
| | 0.1732E+03 | 0.1829E+02 |
| | 0.1763E+03 | 0.1791E+02 |
| | 0.1793E+03 | 0.1763E+02 |
| | 0.1824E+03 | 0.1742E+02 |
| | 0.1854E+03 | 0.1726E+02 |

| | | |
|---|---|---|
| | 0.1885E+03 | 0.1715E+02 |
| | 0.1915E+03 | 0.1707E+02 |
| | 0.1946E+03 | 0.1700E+02 |
| | 0.1976E+03 | 0.1697E+02 |
| | 0.2007E+03 | 0.1694E+02 |
| | 0.2037E+03 | 0.1693E+02 |
| | 0.2068E+03 | 0.1692E+02 |
| | 0.2098E+03 | 0.1691E+02 |
| | 0.2129E+03 | 0.1691E+02 |
| | 0.2159E+03 | 0.1691E+02 |
| | 0.2190E+03 | 0.1690E+02 |
| | 0.2220E+03 | 0.1690E+02 |
| | 0.2252E+03 | 0.1690E+02 |
| | 0.2285E+03 | 0.1690E+02 |
| | 0.2317E+03 | 0.1690E+02 |
| | 0.2350E+03 | 0.1690E+02 |
| | 0.2382E+03 | 0.1690E+02 |
| | 0.2414E+03 | 0.1690E+02 |
| | 0.2447E+03 | 0.1690E+02 |
| | 0.2479E+03 | 0.1690E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.7000E+01 | 0.0000E+00 | 0.1679E+02 |
| | 0.4833E+01 | 0.1680E+02 |
| | 0.9667E+01 | 0.1682E+02 |
| | 0.1450E+02 | 0.1686E+02 |
| | 0.1933E+02 | 0.1693E+02 |
| | 0.2417E+02 | 0.1705E+02 |
| | 0.2900E+02 | 0.1723E+02 |
| | 0.3383E+02 | 0.1751E+02 |
| | 0.3867E+02 | 0.1793E+02 |
| | 0.4350E+02 | 0.1851E+02 |
| | 0.4833E+02 | 0.1931E+02 |
| | 0.5317E+02 | 0.2037E+02 |
| | 0.5800E+02 | 0.2172E+02 |
| | 0.6283E+02 | 0.2339E+02 |
| | 0.6767E+02 | 0.2540E+02 |
| | 0.7250E+02 | 0.2773E+02 |
| | 0.7733E+02 | 0.3035E+02 |
| | 0.8217E+02 | 0.3317E+02 |
| | 0.8700E+02 | 0.3611E+02 |
| | 0.9183E+02 | 0.3903E+02 |
| | 0.9667E+02 | 0.4179E+02 |
| | 0.1015E+03 | 0.4425E+02 |
| | 0.1063E+03 | 0.4626E+02 |
| | 0.1112E+03 | 0.4770E+02 |
| | 0.1160E+03 | 0.4851E+02 |
| | 0.1208E+03 | 0.4868E+02 |
| | 0.1257E+03 | 0.4829E+02 |
| | 0.1305E+03 | 0.4756E+02 |
| | 0.1335E+03 | 0.4660E+02 |
| | 0.1366E+03 | 0.4536E+02 |
| | 0.1396E+03 | 0.4389E+02 |
| | 0.1427E+03 | 0.4221E+02 |
| | 0.1458E+03 | 0.4037E+02 |
| | 0.1488E+03 | 0.3842E+02 |
| | 0.1519E+03 | 0.3640E+02 |
| | 0.1549E+03 | 0.3437E+02 |
| | 0.1580E+03 | 0.3237E+02 |
| | 0.1610E+03 | 0.3043E+02 |

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|---|---|---|
| | 0.1641E+03 | 0.2859E+02 |
| | 0.1671E+03 | 0.2688E+02 |
| | 0.1702E+03 | 0.2531E+02 |
| | 0.1732E+03 | 0.2389E+02 |
| | 0.1763E+03 | 0.2264E+02 |
| | 0.1793E+03 | 0.2155E+02 |
| | 0.1824E+03 | 0.2061E+02 |
| | 0.1854E+03 | 0.1982E+02 |
| | 0.1885E+03 | 0.1915E+02 |
| | 0.1915E+03 | 0.1857E+02 |
| | 0.1946E+03 | 0.1808E+02 |
| | 0.1976E+03 | 0.1771E+02 |
| | 0.2007E+03 | 0.1743E+02 |
| | 0.2037E+03 | 0.1723E+02 |
| | 0.2068E+03 | 0.1709E+02 |
| | 0.2098E+03 | 0.1699E+02 |
| | 0.2129E+03 | 0.1692E+02 |
| | 0.2159E+03 | 0.1687E+02 |
| | 0.2190E+03 | 0.1684E+02 |
| | 0.2220E+03 | 0.1682E+02 |
| | 0.2252E+03 | 0.1681E+02 |
| | 0.2285E+03 | 0.1680E+02 |
| | 0.2317E+03 | 0.1680E+02 |
| | 0.2350E+03 | 0.1679E+02 |
| | 0.2382E+03 | 0.1679E+02 |
| | 0.2414E+03 | 0.1679E+02 |
| | 0.2447E+03 | 0.1679E+02 |
| | 0.2479E+03 | 0.1679E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.8000E+01 | 0.0000E+00 | 0.1667E+02 |
| | 0.4833E+01 | 0.1667E+02 |
| | 0.9667E+01 | 0.1668E+02 |
| | 0.1450E+02 | 0.1670E+02 |
| | 0.1933E+02 | 0.1672E+02 |
| | 0.2417E+02 | 0.1676E+02 |
| | 0.2900E+02 | 0.1683E+02 |
| | 0.3383E+02 | 0.1694E+02 |
| | 0.3867E+02 | 0.1710E+02 |
| | 0.4350E+02 | 0.1733E+02 |
| | 0.4833E+02 | 0.1766E+02 |
| | 0.5317E+02 | 0.1812E+02 |
| | 0.5800E+02 | 0.1873E+02 |
| | 0.6283E+02 | 0.1953E+02 |
| | 0.6767E+02 | 0.2055E+02 |
| | 0.7250E+02 | 0.2180E+02 |
| | 0.7733E+02 | 0.2332E+02 |
| | 0.8217E+02 | 0.2509E+02 |
| | 0.8700E+02 | 0.2711E+02 |
| | 0.9183E+02 | 0.2934E+02 |
| | 0.9667E+02 | 0.3173E+02 |
| | 0.1015E+03 | 0.3422E+02 |
| | 0.1063E+03 | 0.3670E+02 |
| | 0.1112E+03 | 0.3908E+02 |
| | 0.1160E+03 | 0.4127E+02 |
| | 0.1208E+03 | 0.4316E+02 |
| | 0.1257E+03 | 0.4466E+02 |
| | 0.1305E+03 | 0.4565E+02 |
| | 0.1335E+03 | 0.4624E+02 |
| | 0.1366E+03 | 0.4660E+02 |

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|---|---|---|
| | 0.1396E+03 | 0.4671E+02 |
| | 0.1427E+03 | 0.4656E+02 |
| | 0.1458E+03 | 0.4614E+02 |
| | 0.1488E+03 | 0.4547E+02 |
| | 0.1519E+03 | 0.4456E+02 |
| | 0.1549E+03 | 0.4343E+02 |
| | 0.1580E+03 | 0.4210E+02 |
| | 0.1610E+03 | 0.4060E+02 |
| | 0.1641E+03 | 0.3898E+02 |
| | 0.1671E+03 | 0.3726E+02 |
| | 0.1702E+03 | 0.3548E+02 |
| | 0.1732E+03 | 0.3369E+02 |
| | 0.1763E+03 | 0.3191E+02 |
| | 0.1793E+03 | 0.3017E+02 |
| | 0.1824E+03 | 0.2851E+02 |
| | 0.1854E+03 | 0.2693E+02 |
| | 0.1885E+03 | 0.2544E+02 |
| | 0.1915E+03 | 0.2398E+02 |
| | 0.1946E+03 | 0.2260E+02 |
| | 0.1976E+03 | 0.2141E+02 |
| | 0.2007E+03 | 0.2041E+02 |
| | 0.2037E+03 | 0.1957E+02 |
| | 0.2068E+03 | 0.1889E+02 |
| | 0.2098E+03 | 0.1835E+02 |
| | 0.2129E+03 | 0.1792E+02 |
| | 0.2159E+03 | 0.1759E+02 |
| | 0.2190E+03 | 0.1734E+02 |
| | 0.2220E+03 | 0.1717E+02 |
| | 0.2252E+03 | 0.1703E+02 |
| | 0.2285E+03 | 0.1692E+02 |
| | 0.2317E+03 | 0.1685E+02 |
| | 0.2350E+03 | 0.1679E+02 |
| | 0.2382E+03 | 0.1675E+02 |
| | 0.2414E+03 | 0.1673E+02 |
| | 0.2447E+03 | 0.1671E+02 |
| | 0.2479E+03 | 0.1670E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.9000E+01 | 0.0000E+00 | 0.1656E+02 |
| | 0.4833E+01 | 0.1656E+02 |
| | 0.9667E+01 | 0.1656E+02 |
| | 0.1450E+02 | 0.1656E+02 |
| | 0.1933E+02 | 0.1657E+02 |
| | 0.2417E+02 | 0.1659E+02 |
| | 0.2900E+02 | 0.1661E+02 |
| | 0.3383E+02 | 0.1665E+02 |
| | 0.3867E+02 | 0.1672E+02 |
| | 0.4350E+02 | 0.1681E+02 |
| | 0.4833E+02 | 0.1694E+02 |
| | 0.5317E+02 | 0.1713E+02 |
| | 0.5800E+02 | 0.1740E+02 |
| | 0.6283E+02 | 0.1776E+02 |
| | 0.6767E+02 | 0.1823E+02 |
| | 0.7250E+02 | 0.1885E+02 |
| | 0.7733E+02 | 0.1962E+02 |
| | 0.8217E+02 | 0.2058E+02 |
| | 0.8700E+02 | 0.2174E+02 |
| | 0.9183E+02 | 0.2311E+02 |
| | 0.9667E+02 | 0.2469E+02 |
| | 0.1015E+03 | 0.2646E+02 |

| | | |
|---|---|---|
| | 0.1063E+03 | 0.2840E+02 |
| | 0.1112E+03 | 0.3047E+02 |
| | 0.1160E+03 | 0.3261E+02 |
| | 0.1208E+03 | 0.3474E+02 |
| | 0.1257E+03 | 0.3673E+02 |
| | 0.1305E+03 | 0.3833E+02 |
| | 0.1335E+03 | 0.3962E+02 |
| | 0.1366E+03 | 0.4083E+02 |
| | 0.1396E+03 | 0.4193E+02 |
| | 0.1427E+03 | 0.4290E+02 |
| | 0.1458E+03 | 0.4371E+02 |
| | 0.1488E+03 | 0.4434E+02 |
| | 0.1519E+03 | 0.4477E+02 |
| | 0.1549E+03 | 0.4499E+02 |
| | 0.1580E+03 | 0.4499E+02 |
| | 0.1610E+03 | 0.4477E+02 |
| | 0.1641E+03 | 0.4433E+02 |
| | 0.1671E+03 | 0.4367E+02 |
| | 0.1702E+03 | 0.4281E+02 |
| | 0.1732E+03 | 0.4176E+02 |
| | 0.1763E+03 | 0.4055E+02 |
| | 0.1793E+03 | 0.3920E+02 |
| | 0.1824E+03 | 0.3773E+02 |
| | 0.1854E+03 | 0.3617E+02 |
| | 0.1885E+03 | 0.3451E+02 |
| | 0.1915E+03 | 0.3270E+02 |
| | 0.1946E+03 | 0.3079E+02 |
| | 0.1976E+03 | 0.2895E+02 |
| | 0.2007E+03 | 0.2722E+02 |
| | 0.2037E+03 | 0.2561E+02 |
| | 0.2068E+03 | 0.2415E+02 |
| | 0.2098E+03 | 0.2284E+02 |
| | 0.2129E+03 | 0.2170E+02 |
| | 0.2159E+03 | 0.2071E+02 |
| | 0.2190E+03 | 0.1990E+02 |
| | 0.2220E+03 | 0.1928E+02 |
| | 0.2252E+03 | 0.1872E+02 |
| | 0.2285E+03 | 0.1826E+02 |
| | 0.2317E+03 | 0.1788E+02 |
| | 0.2350E+03 | 0.1757E+02 |
| | 0.2382E+03 | 0.1732E+02 |
| | 0.2414E+03 | 0.1713E+02 |
| | 0.2447E+03 | 0.1698E+02 |
| | 0.2479E+03 | 0.1687E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.1000E+02 | 0.0000E+00 | 0.1644E+02 |
| | 0.4833E+01 | 0.1644E+02 |
| | 0.9667E+01 | 0.1644E+02 |
| | 0.1450E+02 | 0.1644E+02 |
| | 0.1933E+02 | 0.1645E+02 |
| | 0.2417E+02 | 0.1645E+02 |
| | 0.2900E+02 | 0.1646E+02 |
| | 0.3383E+02 | 0.1648E+02 |
| | 0.3867E+02 | 0.1650E+02 |
| | 0.4350E+02 | 0.1654E+02 |
| | 0.4833E+02 | 0.1659E+02 |
| | 0.5317E+02 | 0.1667E+02 |
| | 0.5800E+02 | 0.1678E+02 |
| | 0.6283E+02 | 0.1694E+02 |

| | | |
|---|---|---|
| | 0.6767E+02 | 0.1715E+02 |
| | 0.7250E+02 | 0.1743E+02 |
| | 0.7733E+02 | 0.1780E+02 |
| | 0.8217E+02 | 0.1828E+02 |
| | 0.8700E+02 | 0.1888E+02 |
| | 0.9183E+02 | 0.1963E+02 |
| | 0.9667E+02 | 0.2053E+02 |
| | 0.1015E+03 | 0.2159E+02 |
| | 0.1063E+03 | 0.2283E+02 |
| | 0.1112E+03 | 0.2424E+02 |
| | 0.1160E+03 | 0.2579E+02 |
| | 0.1208E+03 | 0.2744E+02 |
| | 0.1257E+03 | 0.2909E+02 |
| | 0.1305E+03 | 0.3051E+02 |
| | 0.1335E+03 | 0.3177E+02 |
| | 0.1366E+03 | 0.3305E+02 |
| | 0.1396E+03 | 0.3434E+02 |
| | 0.1427E+03 | 0.3561E+02 |
| | 0.1458E+03 | 0.3686E+02 |
| | 0.1488E+03 | 0.3807E+02 |
| | 0.1519E+03 | 0.3920E+02 |
| | 0.1549E+03 | 0.4024E+02 |
| | 0.1580E+03 | 0.4117E+02 |
| | 0.1610E+03 | 0.4197E+02 |
| | 0.1641E+03 | 0.4262E+02 |
| | 0.1671E+03 | 0.4310E+02 |
| | 0.1702E+03 | 0.4341E+02 |
| | 0.1732E+03 | 0.4353E+02 |
| | 0.1763E+03 | 0.4345E+02 |
| | 0.1793E+03 | 0.4318E+02 |
| | 0.1824E+03 | 0.4271E+02 |
| | 0.1854E+03 | 0.4204E+02 |
| | 0.1885E+03 | 0.4116E+02 |
| | 0.1915E+03 | 0.4001E+02 |
| | 0.1946E+03 | 0.3861E+02 |
| | 0.1976E+03 | 0.3706E+02 |
| | 0.2007E+03 | 0.3542E+02 |
| | 0.2037E+03 | 0.3371E+02 |
| | 0.2068E+03 | 0.3198E+02 |
| | 0.2098E+03 | 0.3027E+02 |
| | 0.2129E+03 | 0.2862E+02 |
| | 0.2159E+03 | 0.2706E+02 |
| | 0.2190E+03 | 0.2565E+02 |
| | 0.2220E+03 | 0.2449E+02 |
| | 0.2252E+03 | 0.2335E+02 |
| | 0.2285E+03 | 0.2231E+02 |
| | 0.2317E+03 | 0.2137E+02 |
| | 0.2350E+03 | 0.2054E+02 |
| | 0.2382E+03 | 0.1982E+02 |
| | 0.2414E+03 | 0.1919E+02 |
| | 0.2447E+03 | 0.1866E+02 |
| | 0.2479E+03 | 0.1821E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.1100E+02 | 0.0000E+00 | 0.1633E+02 |
| | 0.4833E+01 | 0.1633E+02 |
| | 0.9667E+01 | 0.1633E+02 |
| | 0.1450E+02 | 0.1633E+02 |
| | 0.1933E+02 | 0.1633E+02 |
| | 0.2417E+02 | 0.1633E+02 |

| | |
|---|---|
| 0.2900E+02 | 0.1634E+02 |
| 0.3383E+02 | 0.1634E+02 |
| 0.3867E+02 | 0.1635E+02 |
| 0.4350E+02 | 0.1637E+02 |
| 0.4833E+02 | 0.1639E+02 |
| 0.5317E+02 | 0.1642E+02 |
| 0.5800E+02 | 0.1646E+02 |
| 0.6283E+02 | 0.1653E+02 |
| 0.6767E+02 | 0.1662E+02 |
| 0.7250E+02 | 0.1675E+02 |
| 0.7733E+02 | 0.1692E+02 |
| 0.8217E+02 | 0.1714E+02 |
| 0.8700E+02 | 0.1744E+02 |
| 0.9183E+02 | 0.1781E+02 |
| 0.9667E+02 | 0.1828E+02 |
| 0.1015E+03 | 0.1886E+02 |
| 0.1063E+03 | 0.1956E+02 |
| 0.1112E+03 | 0.2039E+02 |
| 0.1160E+03 | 0.2135E+02 |
| 0.1208E+03 | 0.2242E+02 |
| 0.1257E+03 | 0.2353E+02 |
| 0.1305E+03 | 0.2452E+02 |
| 0.1335E+03 | 0.2544E+02 |
| 0.1366E+03 | 0.2642E+02 |
| 0.1396E+03 | 0.2745E+02 |
| 0.1427E+03 | 0.2854E+02 |
| 0.1458E+03 | 0.2967E+02 |
| 0.1488E+03 | 0.3082E+02 |
| 0.1519E+03 | 0.3200E+02 |
| 0.1549E+03 | 0.3319E+02 |
| 0.1580E+03 | 0.3437E+02 |
| 0.1610E+03 | 0.3553E+02 |
| 0.1641E+03 | 0.3666E+02 |
| 0.1671E+03 | 0.3772E+02 |
| 0.1702E+03 | 0.3871E+02 |
| 0.1732E+03 | 0.3960E+02 |
| 0.1763E+03 | 0.4039E+02 |
| 0.1793E+03 | 0.4105E+02 |
| 0.1824E+03 | 0.4156E+02 |
| 0.1854E+03 | 0.4192E+02 |
| 0.1885E+03 | 0.4210E+02 |
| 0.1915E+03 | 0.4207E+02 |
| 0.1946E+03 | 0.4181E+02 |
| 0.1976E+03 | 0.4131E+02 |
| 0.2007E+03 | 0.4059E+02 |
| 0.2037E+03 | 0.3965E+02 |
| 0.2068E+03 | 0.3853E+02 |
| 0.2098E+03 | 0.3726E+02 |
| 0.2129E+03 | 0.3587E+02 |
| 0.2159E+03 | 0.3442E+02 |
| 0.2190E+03 | 0.3299E+02 |
| 0.2220E+03 | 0.3171E+02 |
| 0.2252E+03 | 0.3033E+02 |
| 0.2285E+03 | 0.2896E+02 |
| 0.2317E+03 | 0.2763E+02 |
| 0.2350E+03 | 0.2635E+02 |
| 0.2382E+03 | 0.2514E+02 |
| 0.2414E+03 | 0.2400E+02 |
| 0.2447E+03 | 0.2295E+02 |
| 0.2479E+03 | 0.2199E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |

| | | |
|---|---|---|
| 0.1200E+02 | 0.0000E+00 | 0.1622E+02 |
| | 0.4833E+01 | 0.1622E+02 |
| | 0.9667E+01 | 0.1622E+02 |
| | 0.1450E+02 | 0.1622E+02 |
| | 0.1933E+02 | 0.1622E+02 |
| | 0.2417E+02 | 0.1622E+02 |
| | 0.2900E+02 | 0.1622E+02 |
| | 0.3383E+02 | 0.1622E+02 |
| | 0.3867E+02 | 0.1622E+02 |
| | 0.4350E+02 | 0.1623E+02 |
| | 0.4833E+02 | 0.1624E+02 |
| | 0.5317E+02 | 0.1625E+02 |
| | 0.5800E+02 | 0.1627E+02 |
| | 0.6283E+02 | 0.1630E+02 |
| | 0.6767E+02 | 0.1634E+02 |
| | 0.7250E+02 | 0.1639E+02 |
| | 0.7733E+02 | 0.1647E+02 |
| | 0.8217E+02 | 0.1657E+02 |
| | 0.8700E+02 | 0.1671E+02 |
| | 0.9183E+02 | 0.1689E+02 |
| | 0.9667E+02 | 0.1712E+02 |
| | 0.1015E+03 | 0.1741E+02 |
| | 0.1063E+03 | 0.1778E+02 |
| | 0.1112E+03 | 0.1823E+02 |
| | 0.1160E+03 | 0.1877E+02 |
| | 0.1208E+03 | 0.1938E+02 |
| | 0.1257E+03 | 0.2003E+02 |
| | 0.1305E+03 | 0.2064E+02 |
| | 0.1335E+03 | 0.2121E+02 |
| | 0.1366E+03 | 0.2185E+02 |
| | 0.1396E+03 | 0.2253E+02 |
| | 0.1427E+03 | 0.2328E+02 |
| | 0.1458E+03 | 0.2408E+02 |
| | 0.1488E+03 | 0.2494E+02 |
| | 0.1519E+03 | 0.2586E+02 |
| | 0.1549E+03 | 0.2682E+02 |
| | 0.1580E+03 | 0.2782E+02 |
| | 0.1610E+03 | 0.2887E+02 |
| | 0.1641E+03 | 0.2994E+02 |
| | 0.1671E+03 | 0.3103E+02 |
| | 0.1702E+03 | 0.3214E+02 |
| | 0.1732E+03 | 0.3324E+02 |
| | 0.1763E+03 | 0.3432E+02 |
| | 0.1793E+03 | 0.3537E+02 |
| | 0.1824E+03 | 0.3637E+02 |
| | 0.1854E+03 | 0.3731E+02 |
| | 0.1885E+03 | 0.3819E+02 |
| | 0.1915E+03 | 0.3901E+02 |
| | 0.1946E+03 | 0.3974E+02 |
| | 0.1976E+03 | 0.4027E+02 |
| | 0.2007E+03 | 0.4061E+02 |
| | 0.2037E+03 | 0.4074E+02 |
| | 0.2068E+03 | 0.4065E+02 |
| | 0.2098E+03 | 0.4036E+02 |
| | 0.2129E+03 | 0.3986E+02 |
| | 0.2159E+03 | 0.3919E+02 |
| | 0.2190E+03 | 0.3840E+02 |
| | 0.2220E+03 | 0.3761E+02 |
| | 0.2252E+03 | 0.3663E+02 |
| | 0.2285E+03 | 0.3556E+02 |
| | 0.2317E+03 | 0.3440E+02 |

| | | |
|---|---|---|
| | 0.2350E+03 | 0.3318E+02 |
| | 0.2382E+03 | 0.3192E+02 |
| | 0.2414E+03 | 0.3064E+02 |
| | 0.2447E+03 | 0.2936E+02 |
| | 0.2479E+03 | 0.2810E+02 |

| TIME | DEPTH | CONCENTRATION |
|---|---|---|
| yr | m | mg/L |
| 0.1300E+02 | 0.0000E+00 | 0.1610E+02 |
| | 0.4833E+01 | 0.1610E+02 |
| | 0.9667E+01 | 0.1610E+02 |
| | 0.1450E+02 | 0.1610E+02 |
| | 0.1933E+02 | 0.1610E+02 |
| | 0.2417E+02 | 0.1610E+02 |
| | 0.2900E+02 | 0.1610E+02 |
| | 0.3383E+02 | 0.1611E+02 |
| | 0.3867E+02 | 0.1611E+02 |
| | 0.4350E+02 | 0.1611E+02 |
| | 0.4833E+02 | 0.1611E+02 |
| | 0.5317E+02 | 0.1612E+02 |
| | 0.5800E+02 | 0.1613E+02 |
| | 0.6283E+02 | 0.1614E+02 |
| | 0.6767E+02 | 0.1615E+02 |
| | 0.7250E+02 | 0.1618E+02 |
| | 0.7733E+02 | 0.1621E+02 |
| | 0.8217E+02 | 0.1625E+02 |
| | 0.8700E+02 | 0.1632E+02 |
| | 0.9183E+02 | 0.1640E+02 |
| | 0.9667E+02 | 0.1651E+02 |
| | 0.1015E+03 | 0.1665E+02 |
| | 0.1063E+03 | 0.1684E+02 |
| | 0.1112E+03 | 0.1706E+02 |
| | 0.1160E+03 | 0.1734E+02 |
| | 0.1208E+03 | 0.1767E+02 |
| | 0.1257E+03 | 0.1802E+02 |
| | 0.1305E+03 | 0.1836E+02 |
| | 0.1335E+03 | 0.1869E+02 |
| | 0.1366E+03 | 0.1905E+02 |
| | 0.1396E+03 | 0.1946E+02 |
| | 0.1427E+03 | 0.1991E+02 |
| | 0.1458E+03 | 0.2041E+02 |
| | 0.1488E+03 | 0.2096E+02 |
| | 0.1519E+03 | 0.2155E+02 |
| | 0.1549E+03 | 0.2220E+02 |
| | 0.1580E+03 | 0.2290E+02 |
| | 0.1610E+03 | 0.2366E+02 |
| | 0.1641E+03 | 0.2446E+02 |
| | 0.1671E+03 | 0.2531E+02 |
| | 0.1702E+03 | 0.2621E+02 |
| | 0.1732E+03 | 0.2714E+02 |
| | 0.1763E+03 | 0.2812E+02 |
| | 0.1793E+03 | 0.2912E+02 |
| | 0.1824E+03 | 0.3014E+02 |
| | 0.1854E+03 | 0.3118E+02 |
| | 0.1885E+03 | 0.3224E+02 |
| | 0.1915E+03 | 0.3337E+02 |
| | 0.1946E+03 | 0.3454E+02 |
| | 0.1976E+03 | 0.3563E+02 |
| | 0.2007E+03 | 0.3662E+02 |
| | 0.2037E+03 | 0.3750E+02 |
| | 0.2068E+03 | 0.3824E+02 |

| | |
|---|---|
| 0.2098E+03 | 0.3883E+02 |
| 0.2129E+03 | 0.3925E+02 |
| 0.2159E+03 | 0.3950E+02 |
| 0.2190E+03 | 0.3960E+02 |
| 0.2220E+03 | 0.3956E+02 |
| 0.2252E+03 | 0.3936E+02 |
| 0.2285E+03 | 0.3902E+02 |
| 0.2317E+03 | 0.3854E+02 |
| 0.2350E+03 | 0.3792E+02 |
| 0.2382E+03 | 0.3717E+02 |
| 0.2414E+03 | 0.3631E+02 |
| 0.2447E+03 | 0.3535E+02 |
| 0.2479E+03 | 0.3431E+02 |

N O T I C E
---

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```
************************************************
*                                              *
*                                              *
*                                              *
*      P O L L U T E   S I M U L A T I O N     *
*                                              *
*             ANALYSIS      COMPLETED          *
*                                              *
*             TIME     -     24:31: 8          *
*             EXECUTION TIME     0: 0          *
*                                              *
*                                              *
************************************************
```

# Appendix C-2

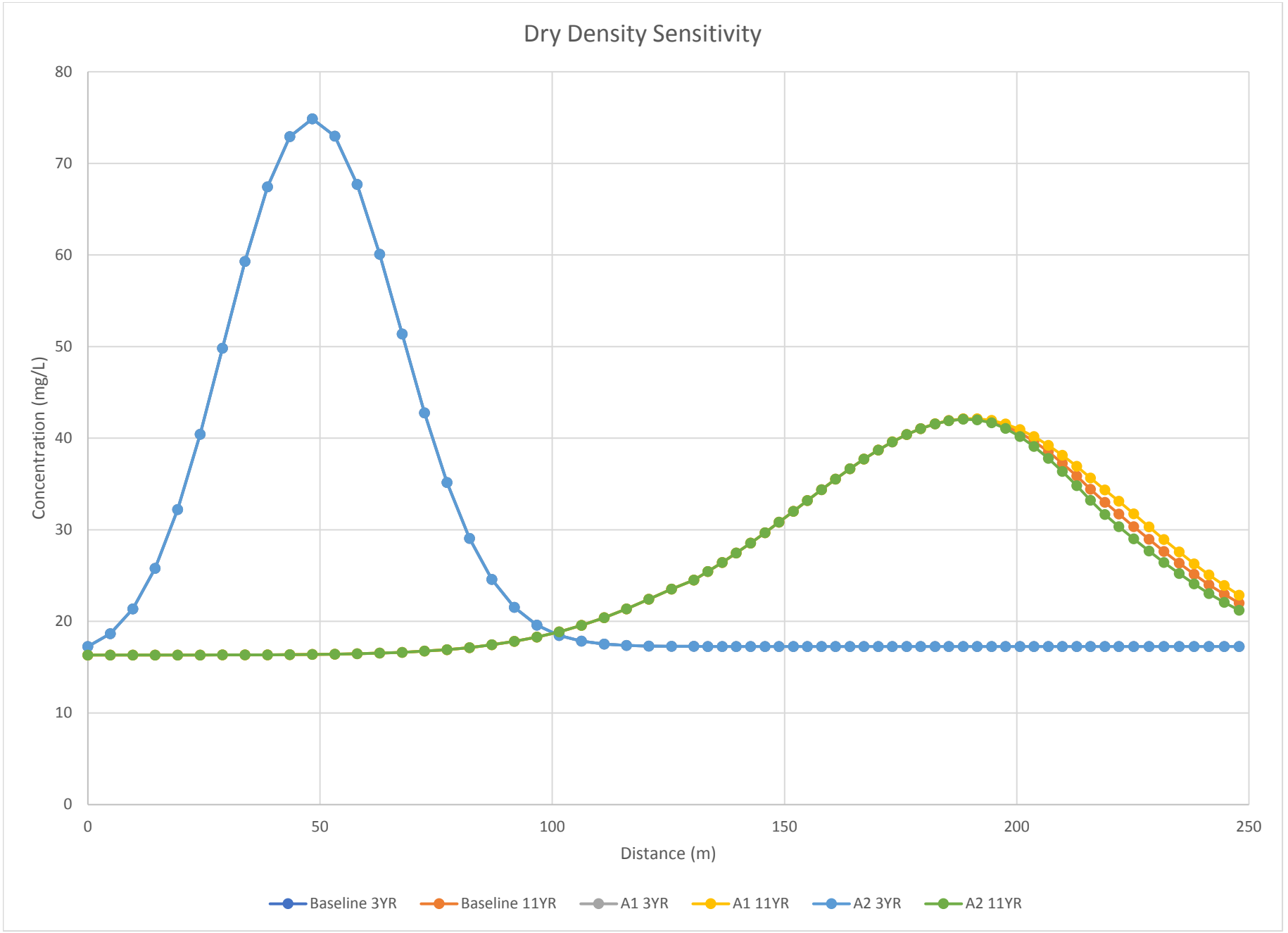
# Transport Model Sensitivity Analysis

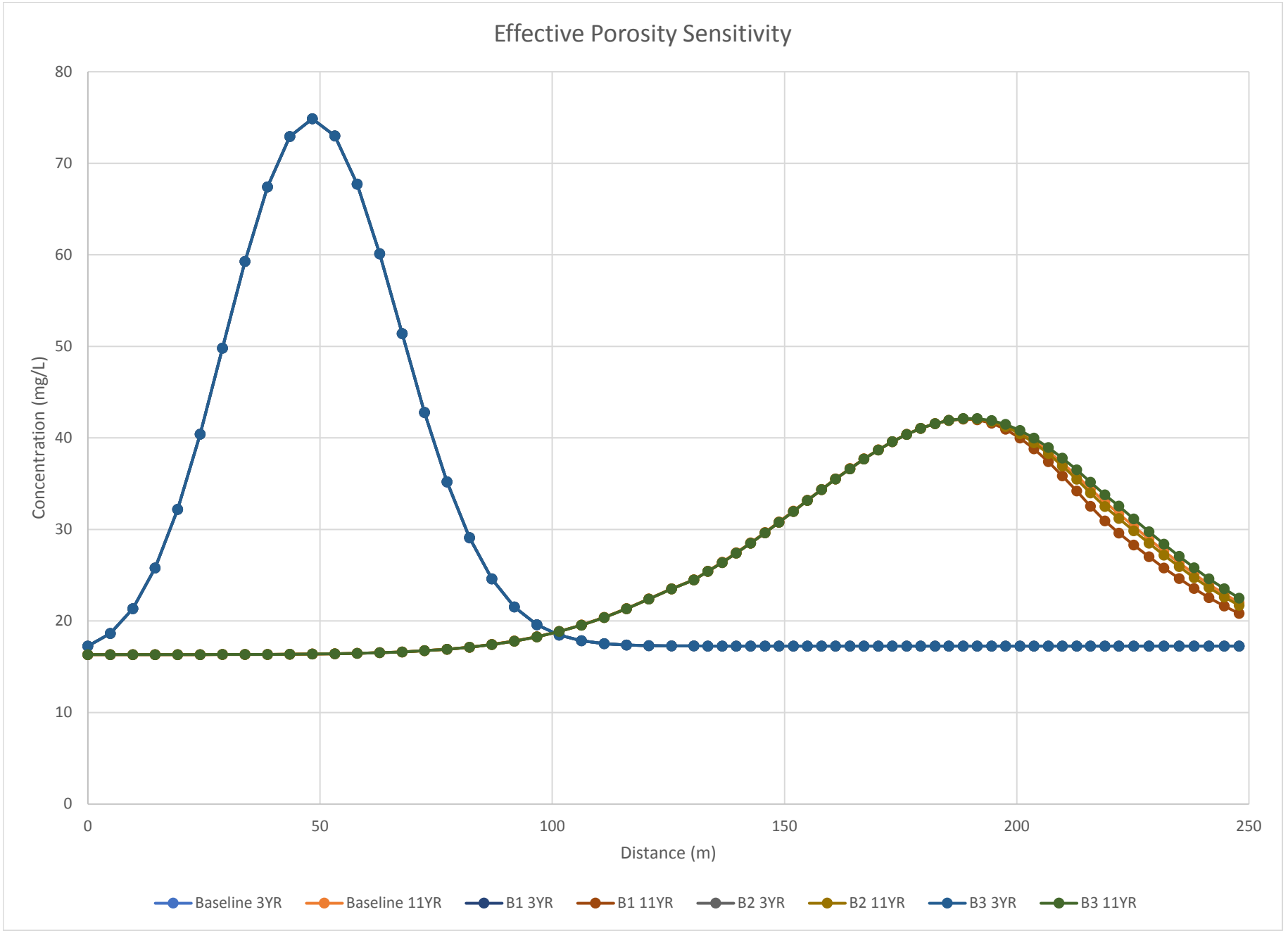
# Appendix C-2 - Table 1
## Sensitivity Analysis of 1-D Calibrated Model - Ammonia
Vertellus Integrated Pyridines LLC, Indianapolis, Indiana

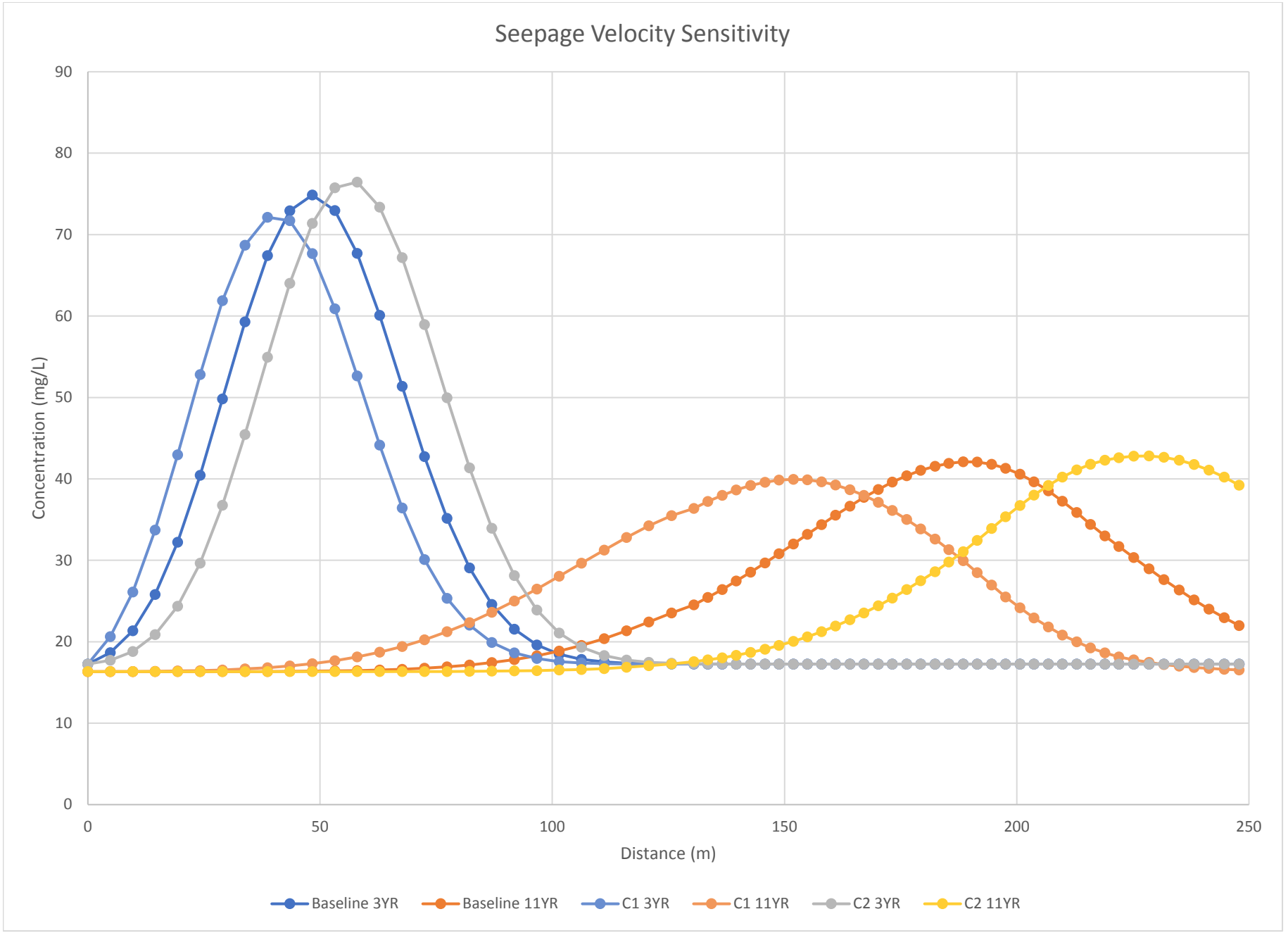
| Sensitivity Group | Sensitivity Range | Description of Changed Model Input Parameter | Value of Input Parameter | Baseline Value | Units | Run Number (File Name) | Time (years) | Distance between Spikes (Δ) (m) | Concentration: - First Spike - Second Spike (mg/L) | Concentration Difference (mg/L) | Percent change from baseline inputs (Δ dist.) | Percent change (conc) | Concentration: 140m from first spike (mg/L) | Percent change (conc.) 140m | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N/A | Baseline | Baseline | N/A | N/A | N/A | CAL34_24 | 3<br>11 | 140.17 | 74.86<br>42.1 | 32.76 | ---<br>---<br>--- | ---<br>---<br>--- | 42.1 | ---<br>---<br>--- | Calibrated Baseline Model Inputs |
| A | Low | Dry Density | 1 | 2 | g/cm$^3$ | C34_24A1 | 3<br>11 | 143.17 | 74.86<br>42.13 | 32.73 | 2%<br>---<br>--- | 0.00%<br>0.07%<br>-0.09% | 42.1 | ---<br>0%<br>--- | |
| | High | Dry Density | 3 | 2 | g/cm$^3$ | C34_24A2 | 3<br>11 | 143.17 | 74.86<br>42.07 | 32.79 | 2%<br>---<br>--- | 0.00%<br>-0.07%<br>0.09% | 42.1 | ---<br>0%<br>--- | |
| B | Low | Effective Porosity (10%) | 1.74 | 0.18 / 3.13 | m$^2$/a | C34_24B1 | 3<br>11 | 140.17 | 74.86<br>42.05 | 32.81 | 0%<br>---<br>--- | 0.00%<br>-0.12%<br>0.15% | 42.05 | ---<br>-0.12%<br>--- | Changes to effective porosity also varies Horizontal Darcy Velocity |
| | Low | Effective Porosity (15%) | 2.61 | 0.18 / 3.13 | m$^2$/a | C34_24B2 | 3<br>11 | 140.17 | 74.86<br>42.09 | 32.77 | 0%<br>---<br>--- | 0.00%<br>-0.02%<br>0.03% | 42.09 | ---<br>-0.02%<br>--- | Changes to effective porosity also varies Horizontal Darcy Velocity |
| | High | Effective Porosity (25%) | 4.35 | 0.18 / 3.13 | m$^2$/a | C34_24B3 | 3<br>11 | 140.17 | 74.86<br>42.11 | 32.75 | 0%<br>---<br>--- | 0.00%<br>0.02%<br>-0.03% | 42.11 | ---<br>0.02%<br>--- | Changes to effective porosity also varies Horizontal Darcy Velocity |
| C | Low | Seepage Velocity (13.05 m/a) 2.349 | 39.8 | 17.4 m/a / 53 | m$^2$/a | C34_24C1 | 3<br>11 | 113.23 | 72.13<br>39.94 | 32.19 | -19%<br>---<br>--- | -4%<br>-5%<br>-2% | 33.85 | ---<br>-20%<br>--- | Changes to seepage velocity also varies horizontal mechanical dispersion |
| | High | Seepage Velocity (21.75 m/a) 3.915 | 66.3 | 17.4 m/a / 53 | m$^2$/a | a | 3<br>11 | 170.5 | 76.45<br>42.81 | 33.64 | 22%<br>---<br>--- | 2%<br>2%<br>3% | 35.35 | ---<br>-16%<br>--- | Changes to seepage velocity also varies horizontal mechanical dispersion |
| D | High | Distribution Coefficient | 0.05 | 0.02 | cm$^3$/g | C34_24D1 | 3<br>11 | 96.67 | 88.87<br>46.61 | 42.26 | -31%<br>---<br>--- | 19%<br>11%<br>29% | 27.17 | ---<br>-35%<br>--- | |
| | High | Distribution Coefficient | 0.25 | 0.02 | cm$^3$/g | C34_24D2 | 3<br>11 | 38.67 | 123.8<br>63.32 | 60.48 | -72%<br>---<br>--- | 65%<br>50%<br>85% | 16 | ---<br>-61%<br>--- | |
| E | Low | Ammonia Half-life | 1000 | 100 | years | C34_24E1 | 3<br>11 | 140.17 | 75.8<br>44.81 | 30.99 | 0%<br>---<br>--- | 1%<br>6%<br>-5% | 44.81 | ---<br>6%<br>--- | |
| | High | Ammonia Half-life | 50 | 100 | years | C34_24E2 | 3<br>11 | 140.17 | 73.83<br>39.28 | 34.55 | 0%<br>---<br>--- | -1%<br>-7%<br>5% | 39.28 | ---<br>-7%<br>--- | |

Abbreviations:

| | |
|---|---|
| m | meter |
| cm | centimeter |
| a | annum (per year) |
| dist. | distance |
| mg/L | milligrams per liter (or parts per million) |


Dry Density Sensitivity
Concentration (mg/L)
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
Distance (m)
Baseline 3YR
Baseline 11YR
A1 3YR
A1 11YR
A2 3YR
A2 11YR


Effective Porosity Sensitivity
Concentration (mg/L)
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
Distance (m)
Baseline 3YR
Baseline 11YR
B1 3YR
B1 11YR
B2 3YR
B2 11YR
B3 3YR
B3 11YR


Seepage Velocity Sensitivity
Concentration (mg/L)
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
Distance (m)
Baseline 3YR
Baseline 11YR
C1 3YR
C1 11YR
C2 3YR
C2 11YR

# Appendix C-3

# Groundwater Set-up Files for Transport Modeling

# Input Parameters for 1-D Transport Model Deep Run #1
# Total Ammonia

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 1594.0 | (ft) | 486 | (m) | |
| Layer Thickness (Layers 1-15) | 106.3 | (ft) | 32.4 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (ammonia) | ----- | ----- | 100.0 | (yrs) | Half-life for ammonia |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 3.24 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 56.4 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.019 | ($m^2/a$) | Diffusion coefficient for ammonia surrogate group; Ref.: Quigley, et al. (1987) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.00 | ($cm^3/g$) | Assume that minimum distribution coefficient for ammonia is zero |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 56.4 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Input Parameters for 1-D Transport Model Deep Run #1
## Benzene

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 1594.0 | (ft) | 486 | (m) | |
| Layer Thickness (Layers 1-15) | 106.3 | (ft) | 32.4 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (Benzene) | ----- | ----- | 3.5 | (yrs) | Half-life for benzene |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 3.24 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 56.4 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.008 | ($m^2/a$) | Diffusion coefficient for benzene (TACO) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.036 | ($cm^3/g$) | Calculated distribution coefficient from retardation factor benzene |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 56.4 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Input Parameters for 1-D Transport Model Deep Run #1
# Pyridines

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 1594.0 | (ft) | 486 | (m) | |
| Layer Thickness (Layers 1-15) | 106.3 | (ft) | 32.4 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (pyridines) | ----- | ----- | 6.0 | (yrs) | Half-life for pyridines |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 3.24 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 56.4 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.036 | ($m^2/a$) | Diffusion coefficient for pyridines (conservative) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.036 | ($cm^3/g$) | Calculated distribution coefficient from retardation factor |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 56.4 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Input Parameters for 1-D Transport Model Deep Run #2
# Total Ammonia

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 2882.0 | (ft) | 878 | (m) | |
| Layer Thickness (Layers 1-15) | 192.1 | (ft) | 58.6 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (ammonia) | ----- | ----- | 100.0 | (yrs) | Half-life for ammonia |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 5.86 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 101.9 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.019 | ($m^2/a$) | Diffusion coefficient for ammonia surrogate group; Ref.: Quigley, et al. (1987) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.00 | ($cm^3/g$) | Assume that minimum distribution coefficient for ammonia is zero |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 101.9 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Input Parameters for 1-D Transport Model Deep Run #2
## Benzene

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 2882.0 | (ft) | 878 | (m) | |
| Layer Thickness (Layers 1-15) | 192.1 | (ft) | 58.6 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (Benzene) | ----- | ----- | 3.5 | (yrs) | Half-life for benzene |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 5.86 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 101.9 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.008 | ($m^2/a$) | Diffusion coefficient for benzene (TACO) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.036 | ($cm^3/g$) | Calculated distribution coefficient from retardation factor benzene |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 101.9 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Input Parameters for 1-D Transport Model Deep Run #2
# Pyridines

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 2882.0 | (ft) | 878 | (m) | |
| Layer Thickness (Layers 1-15) | 192.1 | (ft) | 58.6 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (pyridines) | ----- | ----- | 6.0 | (yrs) | Half-life for pyridines |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 5.86 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 101.9 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.036 | ($m^2/a$) | Diffusion coefficient for pyridines (conservative) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.036 | ($cm^3/g$) | Calculated distribution coefficient from retardation factor |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 101.9 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Input Parameters for 1-D Transport Model Shallow Run #3
# Total Ammonia

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 1656.0 | (ft) | 505 | (m) | |
| Layer Thickness (Layers 1-15) | 110.4 | (ft) | 33.6 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (ammonia) | ----- | ----- | 100.0 | (yrs) | Half-life for ammonia |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 3.36 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 58.6 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.019 | ($m^2/a$) | Diffusion coefficient for ammonia surrogate group; Ref.: Quigley, et al. (1987) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.00 | ($cm^3/g$) | Assume that minimum distribution coefficient for ammonia is zero |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 58.6 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Input Parameters for 1-D Transport Model Shallow Run #3
## Benzene

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 1656.0 | (ft) | 505 | (m) | |
| Layer Thickness (Layers 1-15) | 110.4 | (ft) | 33.6 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (Benzene) | ----- | ----- | 3.5 | (yrs) | Half-life for benzene |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 3.36 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 58.6 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.008 | ($m^2/a$) | Diffusion coefficient for benzene (TACO) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.036 | ($cm^3/g$) | Calculated distribution coefficient from retardation factor benzene |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 58.6 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Input Parameters for 1-D Transport Model Shallow Run #3
# Pyridines

Groundwater Modeling in Support of Focused Feasibility Study, Former Reilly Tar Site - Indianapolis, Indiana

| Input Values | Typical Units | | Consistent Units | | Reference/Equation |
|---|---|---|---|---|---|
| **General** | | | | | |
| **Top Boundary Assumption: Constant Concentration (Conservative)** | | | | | |
| Total Flow Length | 1656.0 | (ft) | 505 | (m) | |
| Layer Thickness (Layers 1-15) | 110.4 | (ft) | 33.6 | (m) | Match (Apprx) to calibrated model's layer thicknesses (distances) |
| Base Width | 3.3 | (ft) | 1.0 | (m) | Assume width is equal to 1.0 for 1-D model, since it has no bearing on results |
| *Constant Source Concentration ($C_o$) | 17.5 | (mg/L) | 18 | (mg/L) | Constant concentration adjusted to match calibrated run. |
| **Inputs Per Layer** | # of sub-layers: | | 10 | per layer | Match (approx.) sub-layer thickness (distance) as calibrated model |
| Dry Density ($r_i$) | 2.00 | ($g/cm^3$) | 2.00 | ($g/cm^3$) | Estimated for alluvial sand & gravels (input not sensitive) |
| Total Porosity ($f_i$) | 0.25 | ------ | 0.25 | ------ | Porosity used in FFS (November 2017) |
| Effective Porosity ($f_{ei}$) | 0.18 | ------ | 0.18 | ------ | Effective Porosity Adjusted to match observed concentrations (calibrated input value) |
| **Bottom Boundary Assumption: Infinite Thickness** | | | | | |
| Calculated Values | Typical Units | | Consistent Units | | Reference/Equation |
| **Calculated Inputs - Per Layer in OU5** | | | | | |
| +Vertical Darcy Velocity ($q_{vi}$) | ----- | ----- | 0.0 | (m/a) | Conservatively assume no vertical hydrodynamic dispersion (no downward flow) |
| +Horizontal Darcy Velocity ($q_{hi}$) | ----- | ----- | 3.13 | (m/a) | Darcy velocity = (k*i); Mean seepage (darcy) velocity calculated from site data & calibrated to. |
| *Half-Life (pyridines) | ----- | ----- | 6.0 | (yrs) | Half-life for pyridines |
| Horizontal Dispersivity ($a_{hi}$) | ----- | ----- | 3.36 | (m) | If scale is >100, Xu & Eckstein, 1995 (0.83*scale^2.414), If <100m, then Gelhar et al (1992) |
| +Horizontal Mechanical Dispersion ($D_{hiM}$) | ----- | ----- | 58.6 | ($m^2/a$) | $Dh_{iM} = a_L \times (q_{hi} / f_{ei})$ |
| *Diffusion Coefficient ($D_{iD}$) | ----- | ----- | 0.036 | ($m^2/a$) | Diffusion coefficient for pyridines (conservative) |
| *Distribution Coefficient ($K_{di}$) | ----- | ----- | 0.036 | ($cm^3/g$) | Calculated distribution coefficient from retardation factor |
| +*Vertical Hydrodynamic Dispersion ($D_{viT}$) | ----- | ----- | 0.000 | ($m^2/a$) | Conservatively assume no loss of mass through vertical diffusion/dispersion. |
| *Horizontal Hydrodynamic Dispersion ($D_{hiT}$) | ----- | ----- | 58.6 | ($m^2/a$) | $D_{hiT} = D_{hiM} + D_{hiD}$ |

Notes:

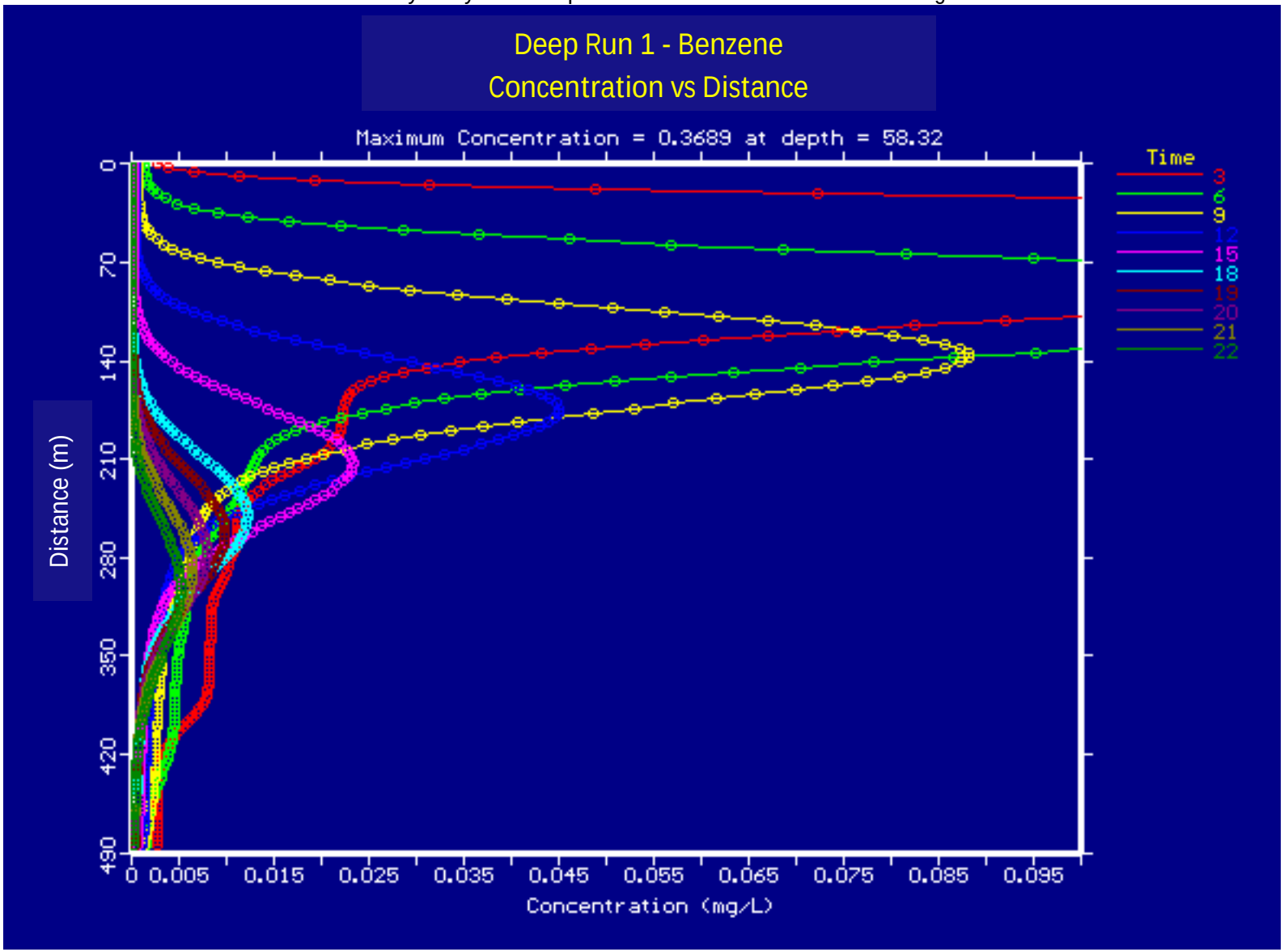
* Input for Surrogate Group.

\+ Input dependent on transient head levels.

# Appendix C-4

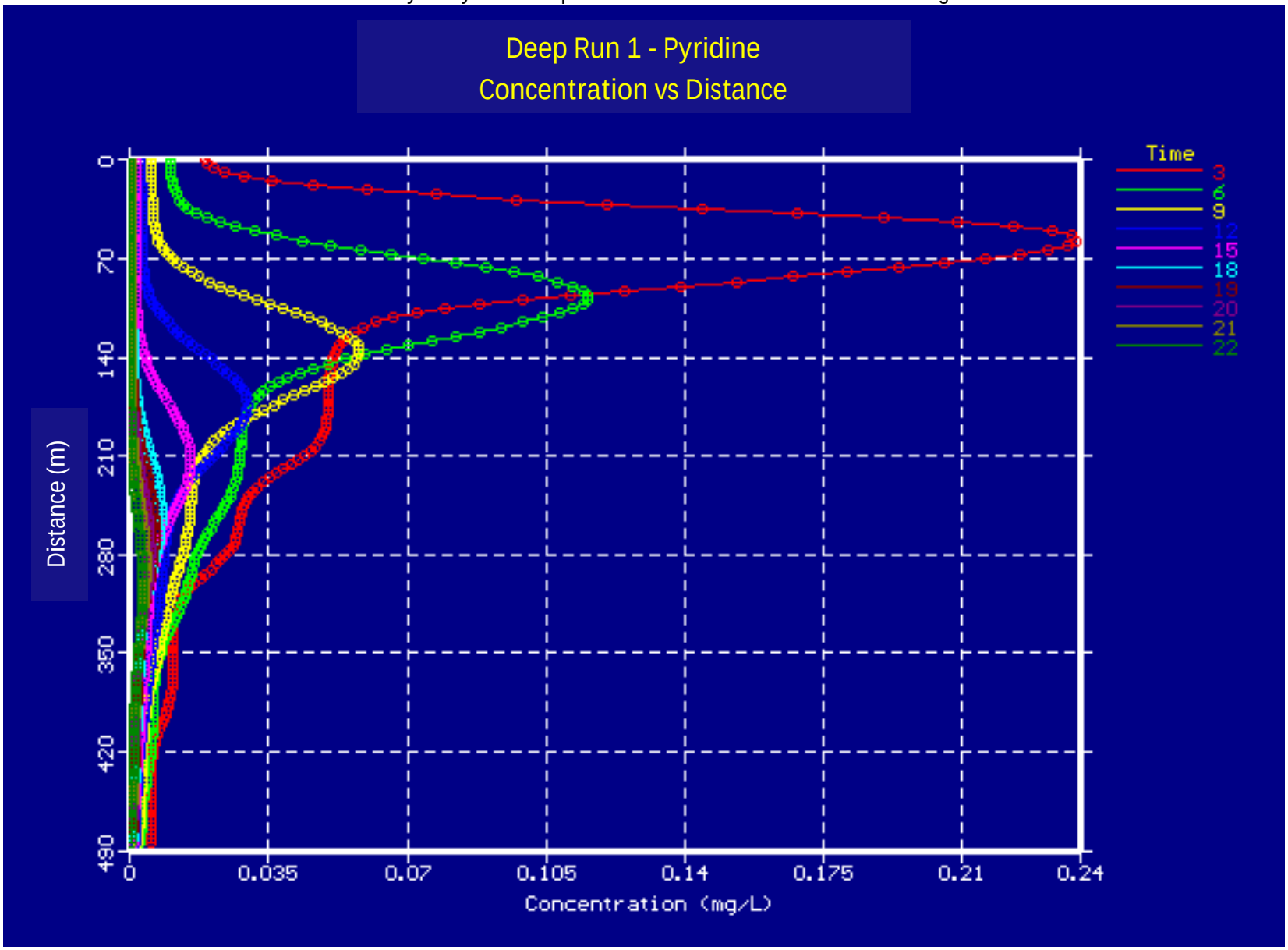
# Contaminant Transport Modeling Results

Deep Run 1 Benzene (DP_R1BZ)
15 layers at 32.4m each
Horz. Hydrodynamic Dispersion = 56.4 m2/a.  Kd = 0.036 cm3/g



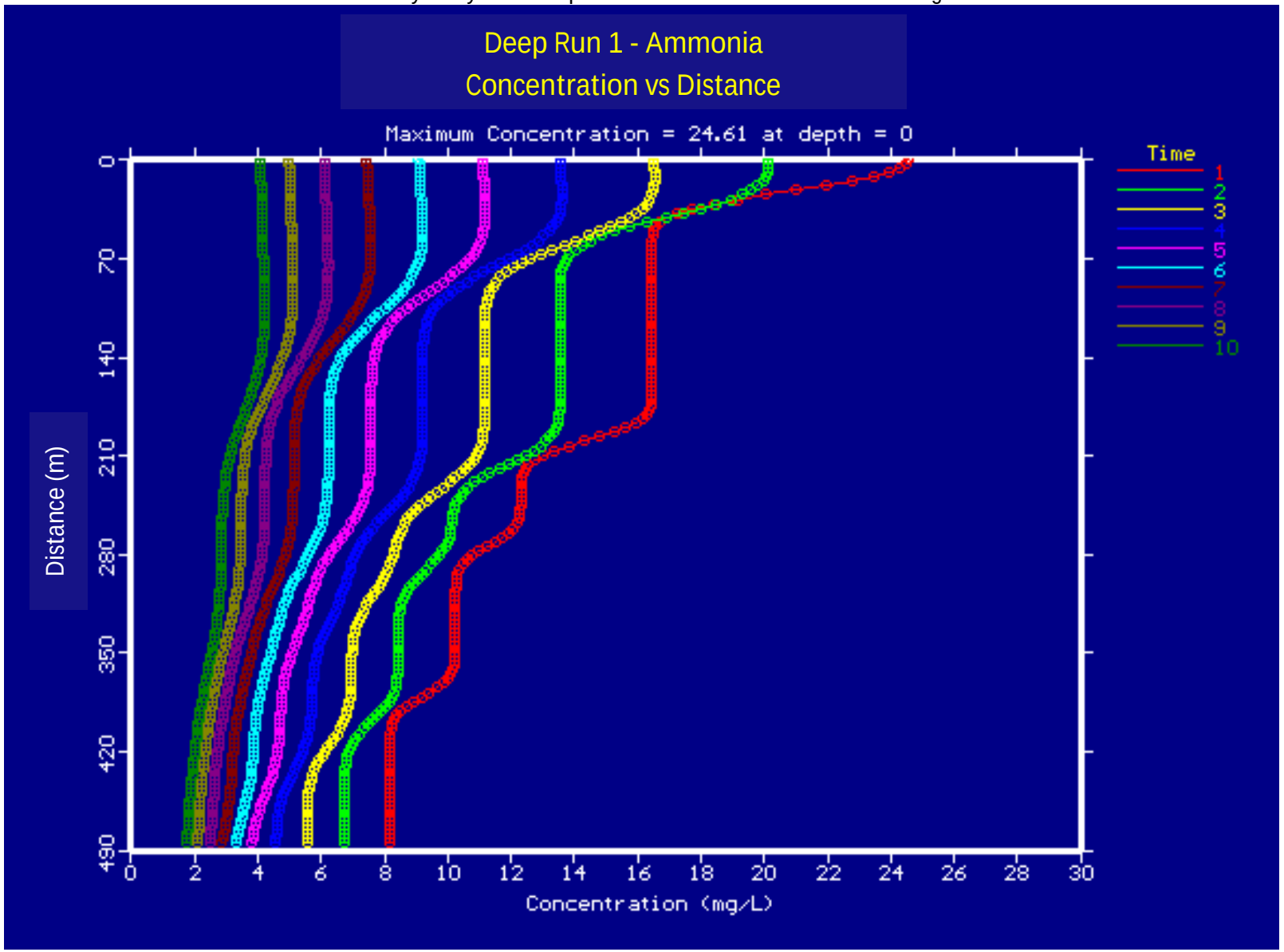

Concentrations go below 0.005 mg/L in about 22 years

Deep Run 1 Pyridine (DP_R1PY)
15 layers at 32.4m each
Horz. Hydrodynamic Dispersion = 56.4 m2/a.  Kd = at 0.036 cm3/g



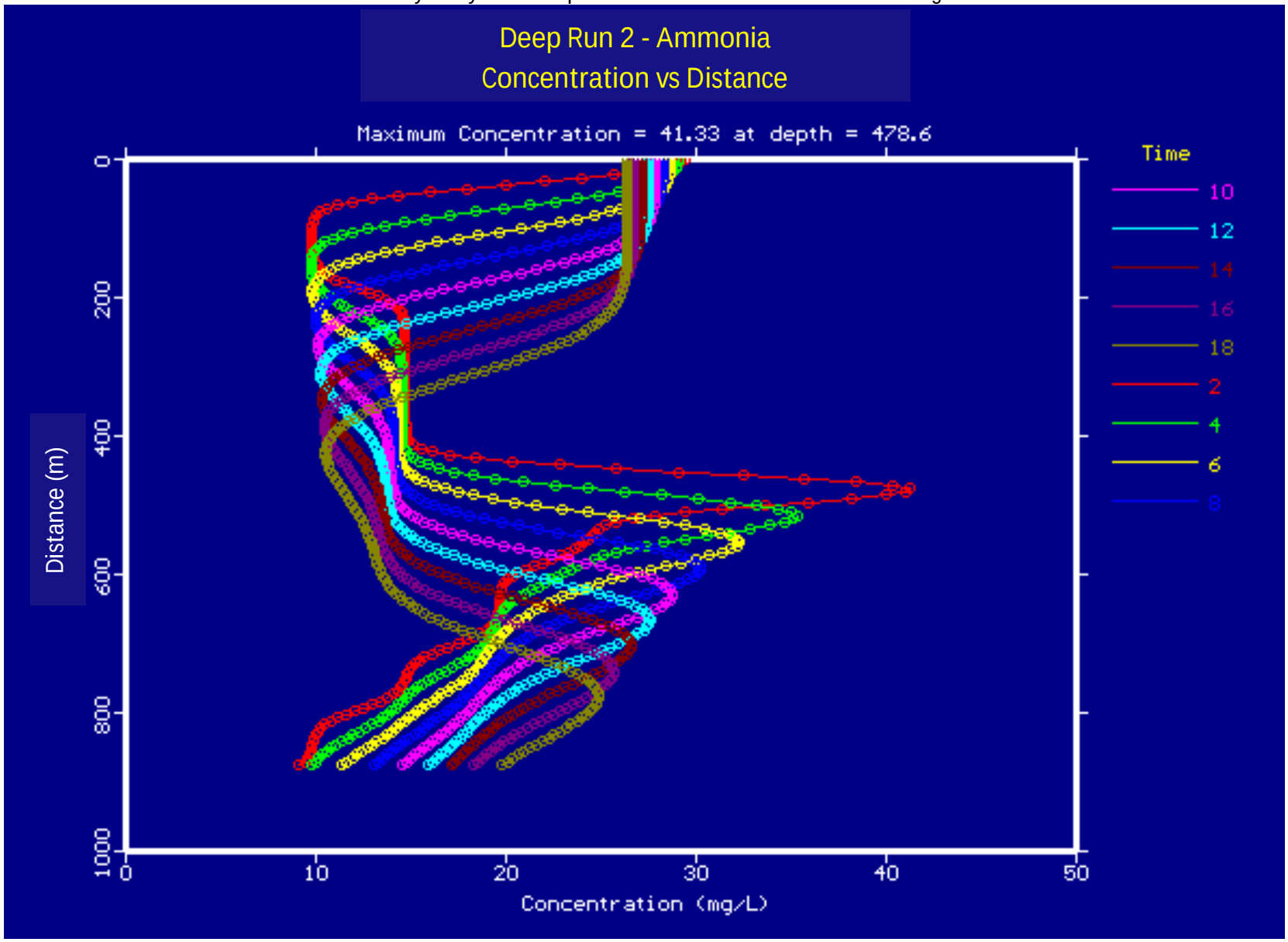

Concentrations go below 0.035 mg/L around 12 years

Deep Run 1 Ammonia (DP_R1NH3)
15 layers at 32.4m each
Horz. Hydrodynamic Dispersion = 56.4 m2/a.  Kd = at 0.0 cm3/g



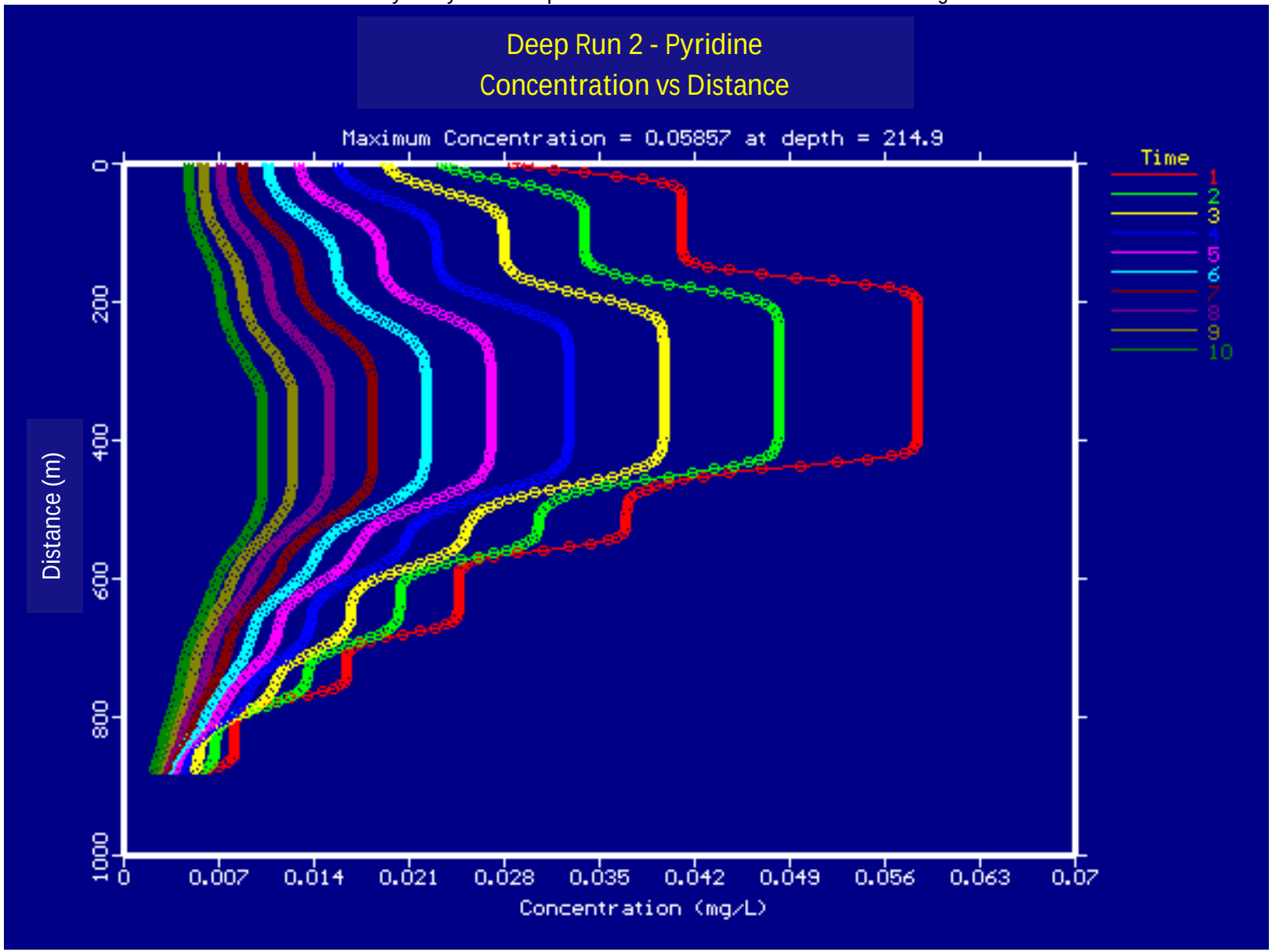

Ammonia is below 30mg/L from the start at Run 1

Deep Run 2 Ammonia (DP_R2NH3)
15 layers at 58.6m each
Horz. Hydrodynamic Dispersion = 101.9 m2/a.  Kd = at 0.0 cm3/g



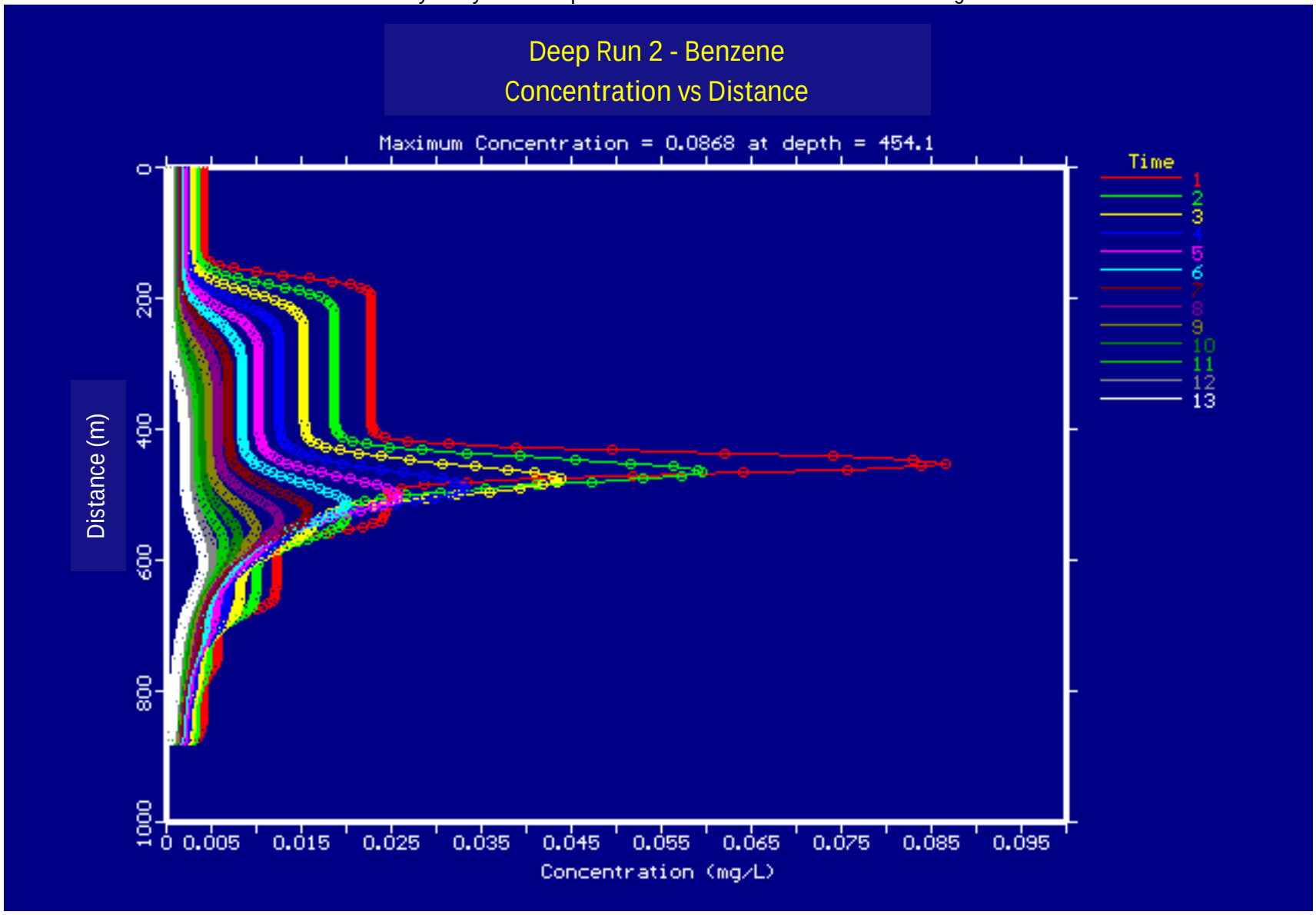

Ammonia takes ~9 years to go below 30mg/L

Deep Run 2 Pyridine (DP_R2PY)
15 layers at 58.6m each
Horz. Hydrodynamic Dispersion = 101.9 m2/a.  Kd = at 0.036 cm3/g



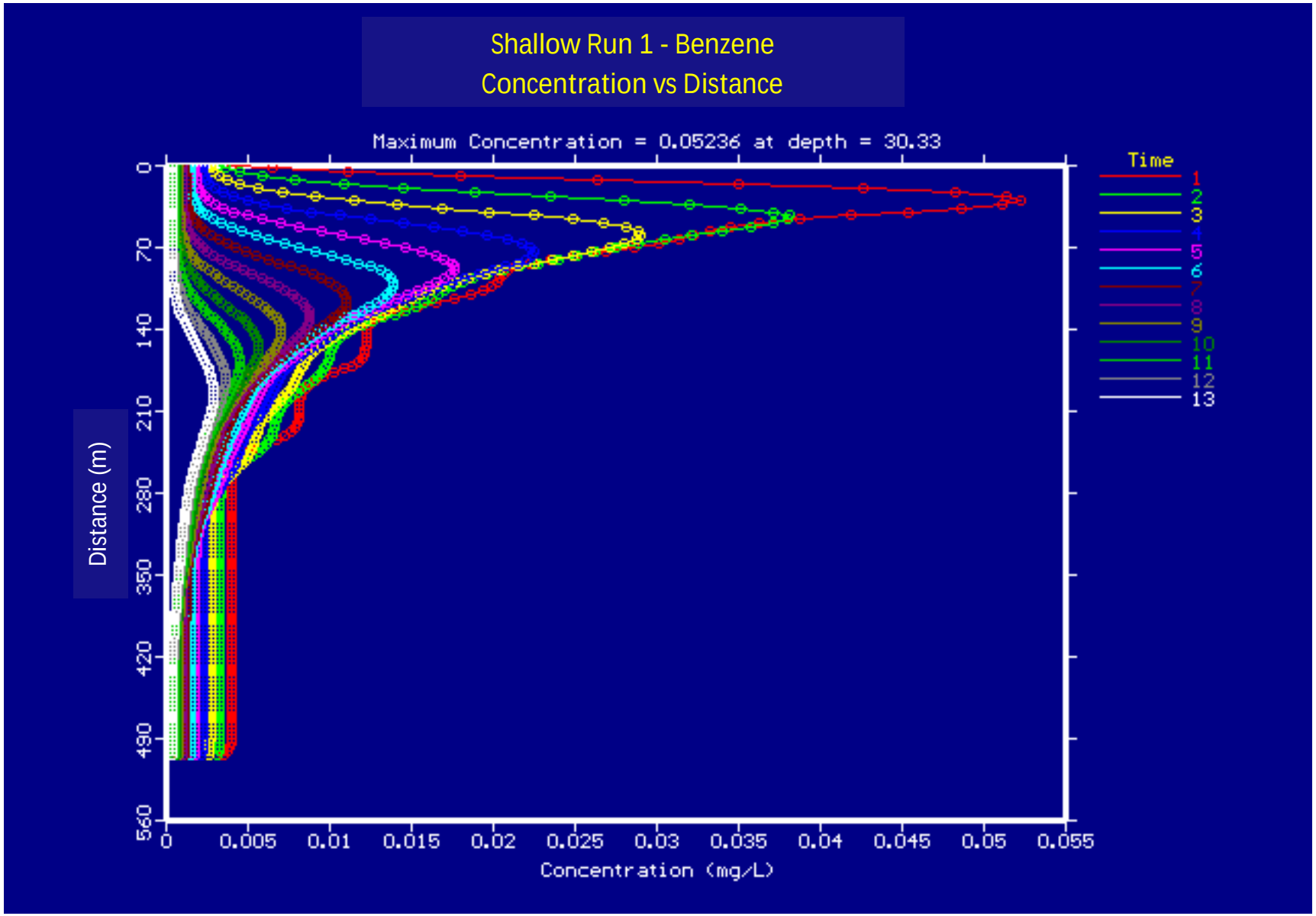

Ammonia takes 4 years to go below 0.035 mg/L

Deep Run 2 Benzene (DP_R2BZ)
15 layers at 58.6m each
Horz. Hydrodynamic Dispersion = 101.9 m2/a.  Kd = at 0.036 cm3/g



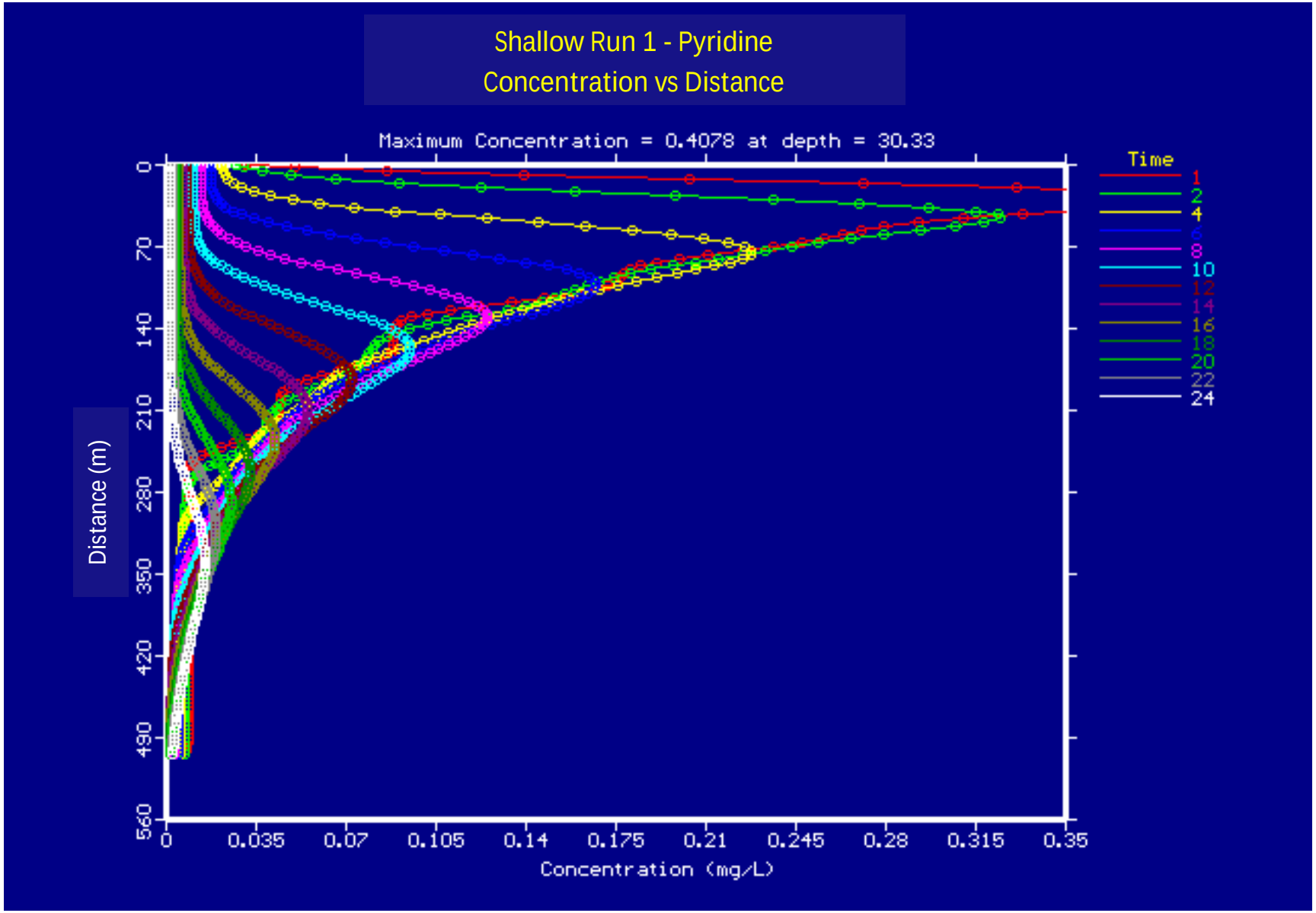

Benzene takes 12 or 13 years to go below 0.005 mg/L

Shallow Run 1 Benzene (SH_R1BZ)
15 layers at 33.7m each
dispersion at 58.6. Kd 0.036



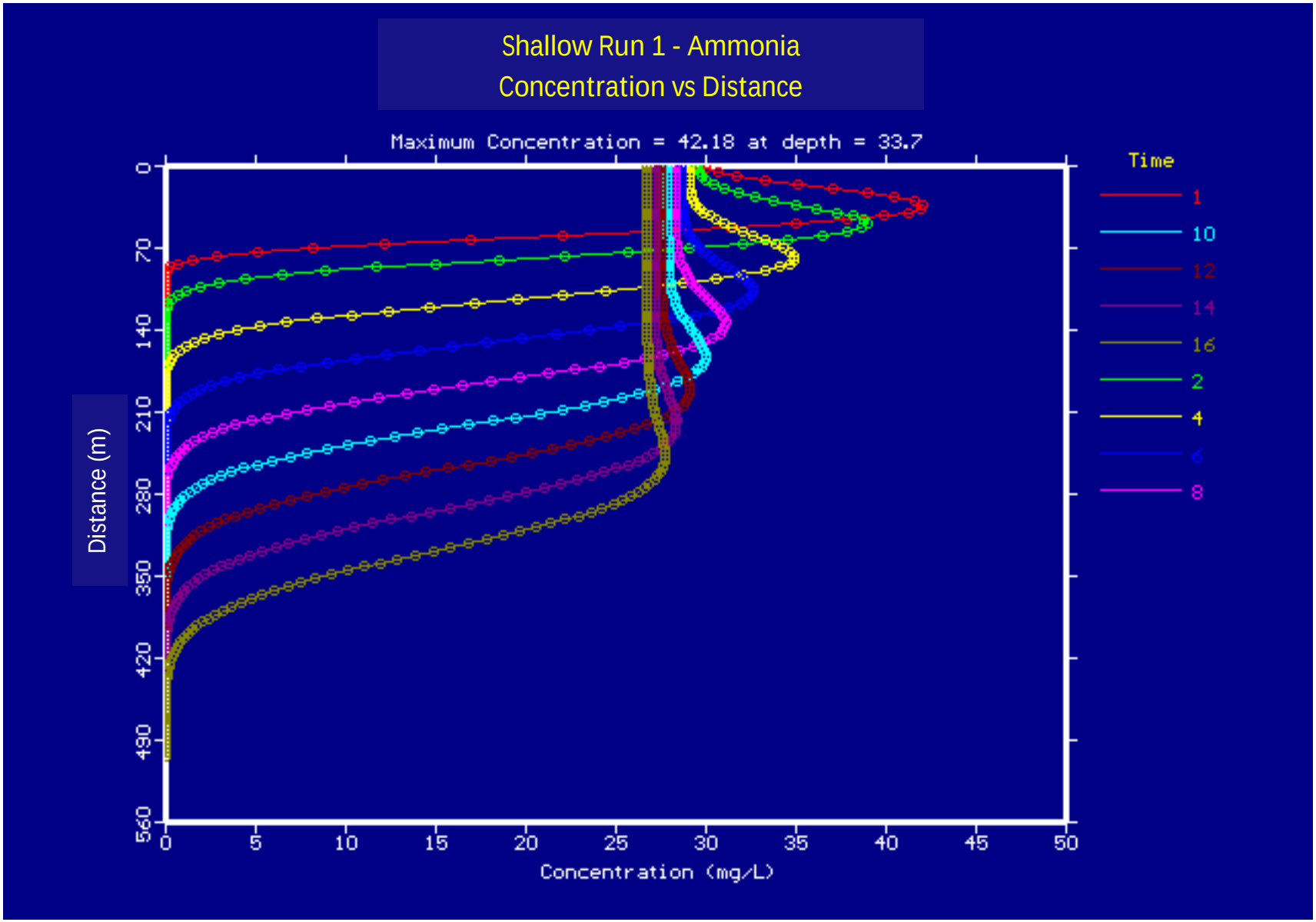

Concentrations go below 0.005 mg/L at about 11 years

Shallow Run 1 Pyridine (SH_R1PY)
15 layers at 33.7m each
dispersion at 58.6. Kd 0.036




Concentrations go below 0.035 mg/L at about 18 years

Shallow Run 1 Ammonia (VIPA3_01)
15 layers at 33.7m each
dispersion at 58.6. Kd 0.0



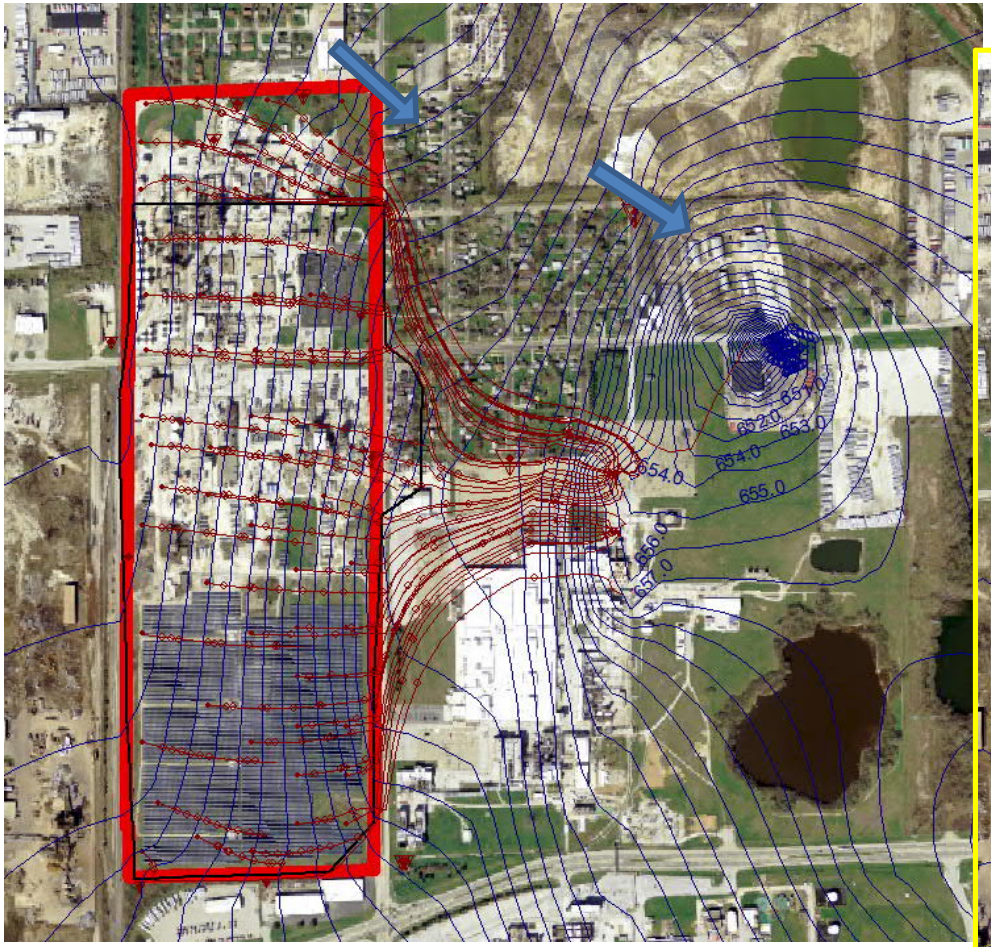

Concentrations go below 30 mg/L at about 10 years

# Appendix D

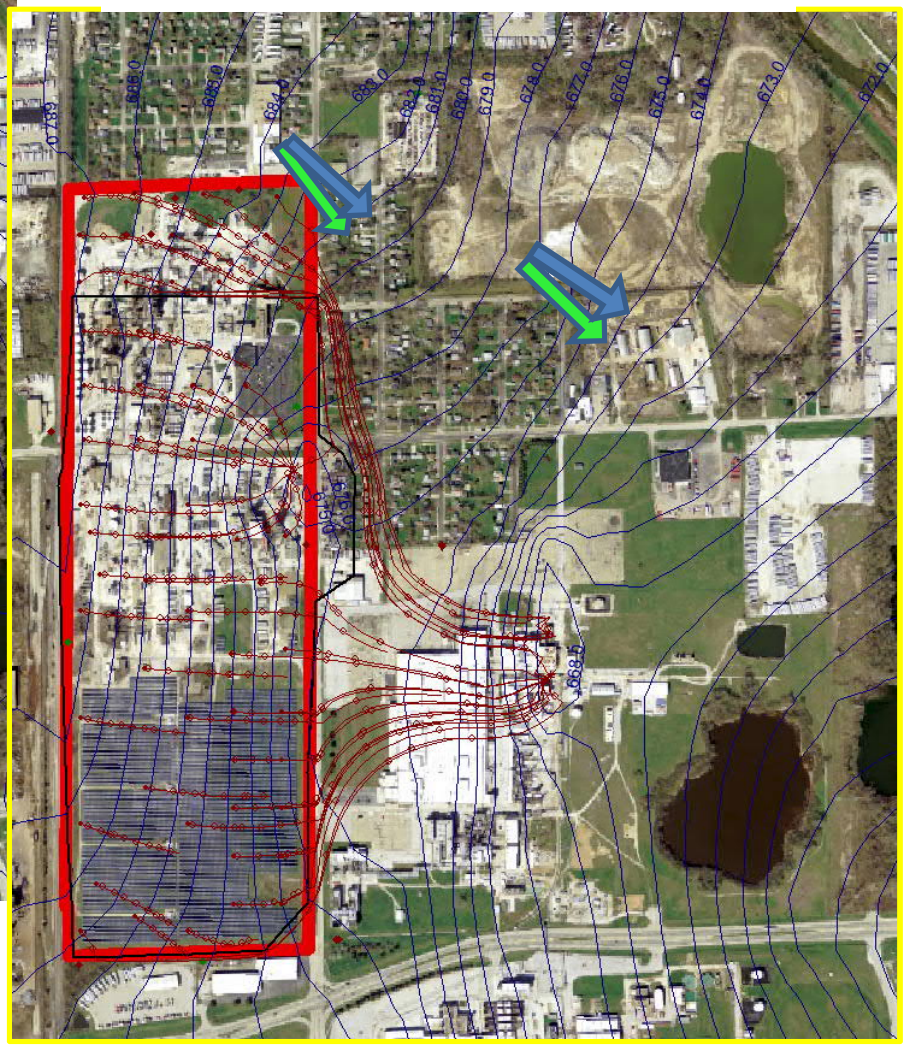
# Groundwater Flow Analysis in the area of RI-11 and RI-15

# DEEP FLOW MODEL
# Compare Blue Lake GW Flow Vectors

RR Wells Pumping; Historical Olin Brass Well Pumping (Blue Arrows)

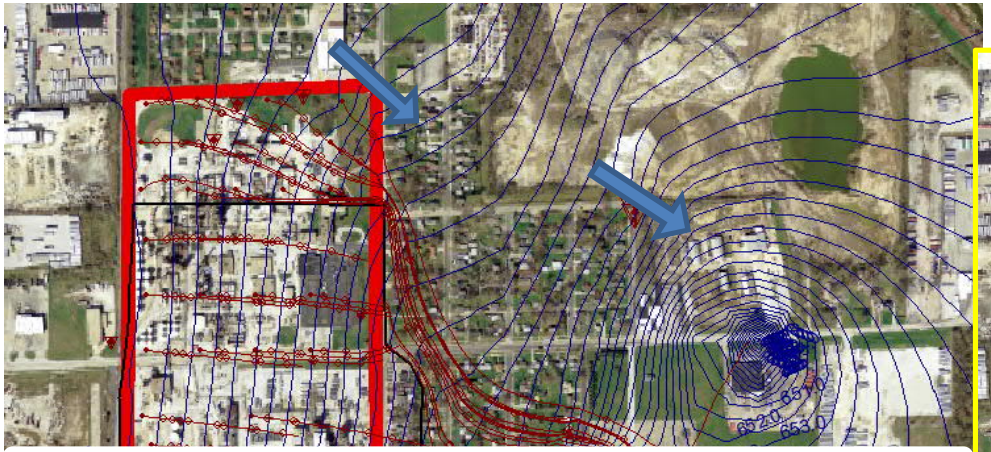



Current Conditions (Green Arrows)

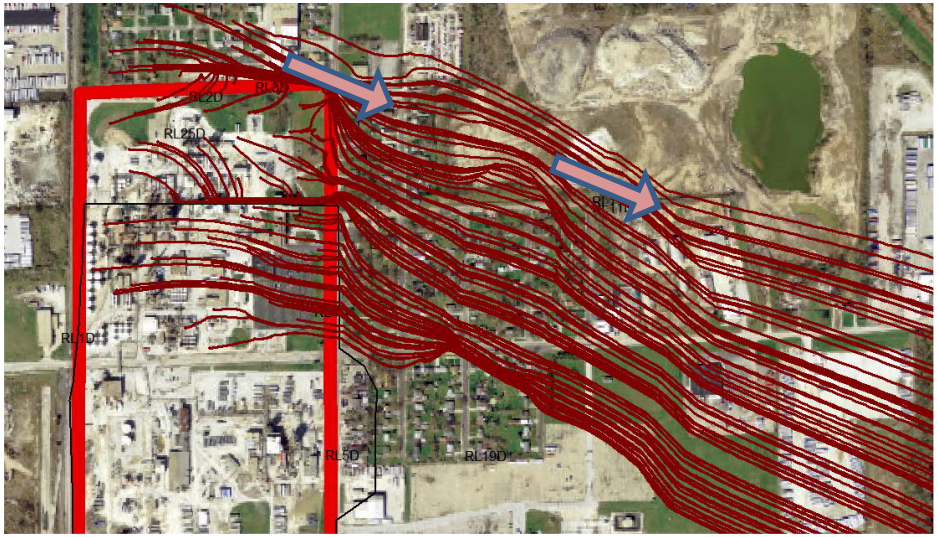


# DEEP FLOW MODEL
# Compare Blue Lake GW Flow Vectors

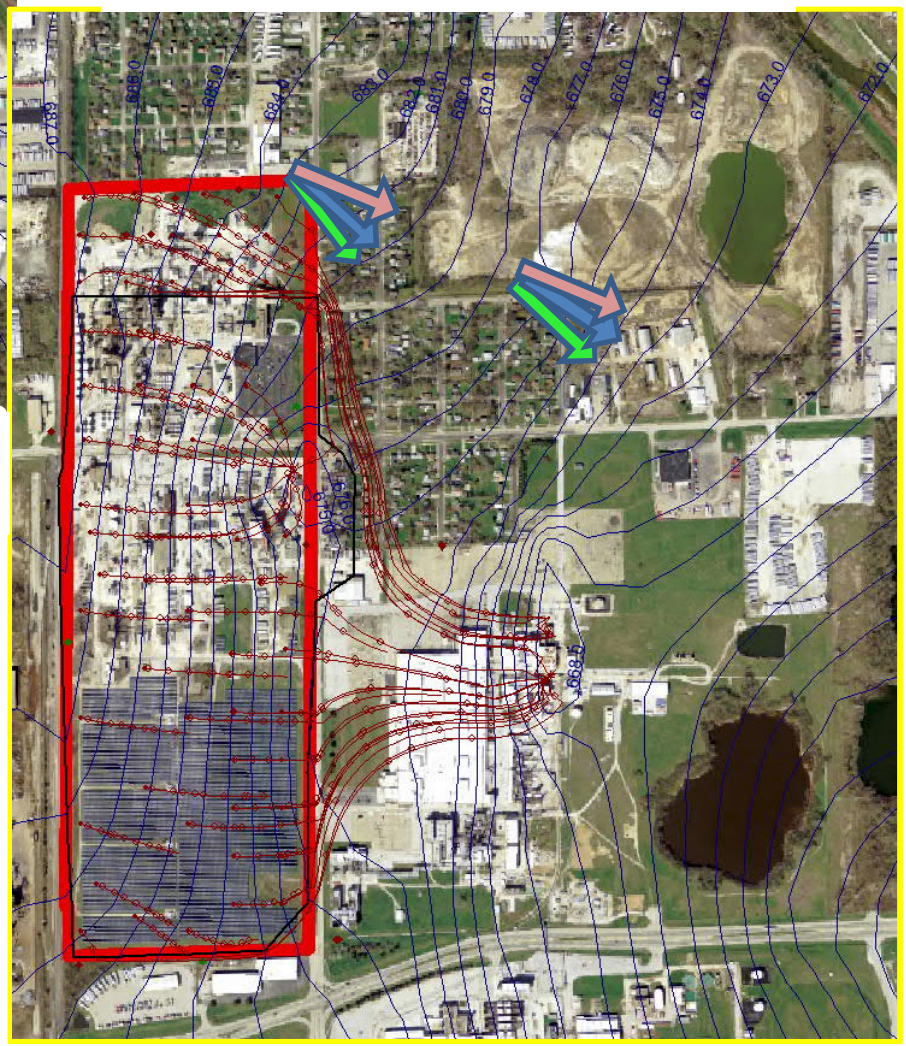
RR Wells Pumping; Historical Olin Brass Well Pumping (Blue Arrows)




Pre-Aquifer Development (No Pumping) Conditions (Pink Arrows)

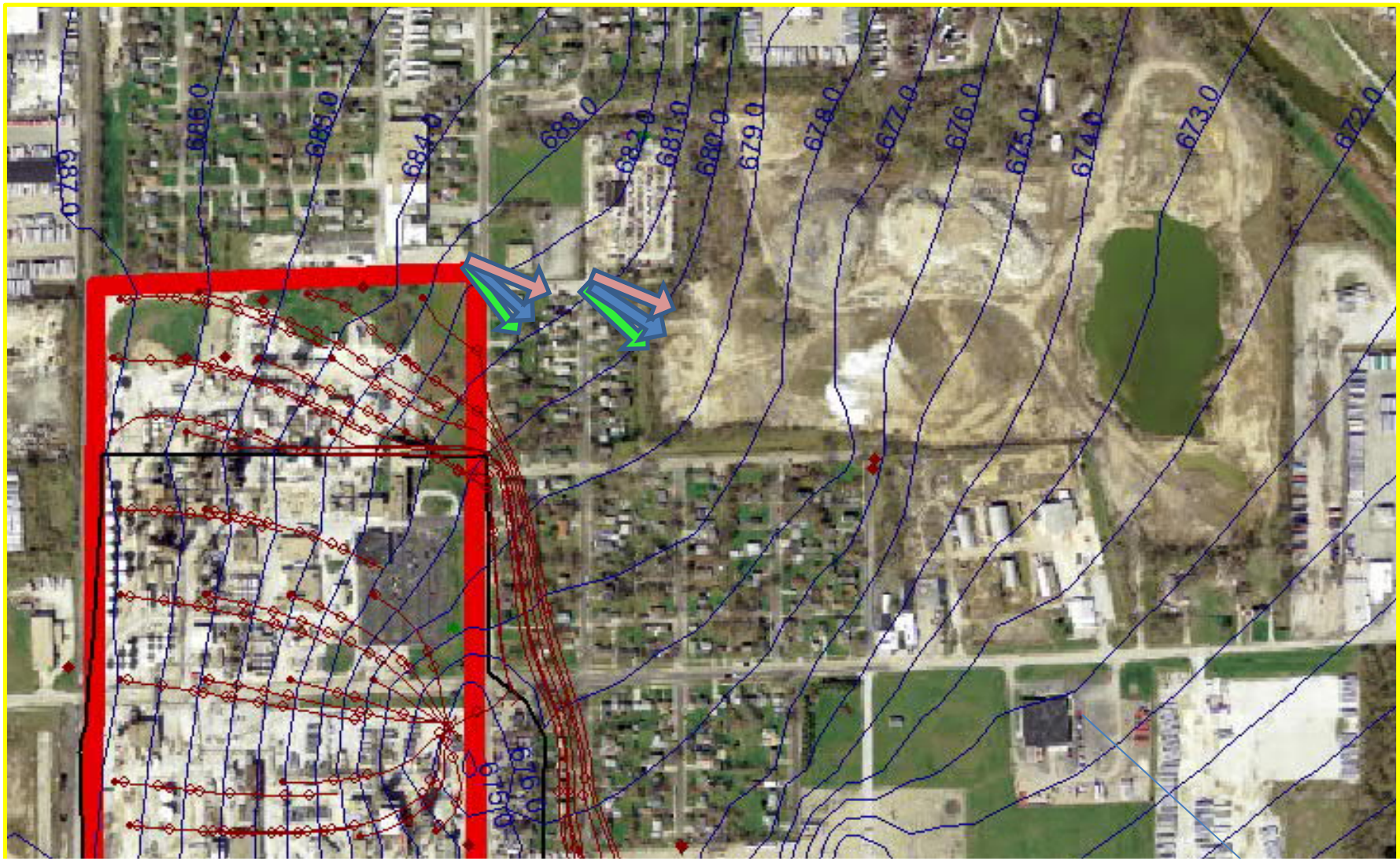



Current Conditions (Green Arrows)



# DEEP FLOW MODEL
# Compare Blue Lake GW Flow Vectors

RR Wells Pumping; Historical Olin Brass Well Pumping (Blue Arrows)
Pre-Aquifer Development (No Pumping) Conditions (Pink Arrows)
Current Conditions (Green Arrows)



**Vertellus Integrated Pyridines LLC, Indianapolis, IN**

**Response to USEPA Comments received May 9, 2019**
**for Groundwater Modeling Report dated March 5, 2019**
September 11, 2019

Response prepared by: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| | |
|---|---|
| **General Comments** | |
| Comment 1 | As indicated at the meeting, the use of this screening model for the FFS will require a more robust monitoring network to properly evaluate the sparging performance. This will be included in the updated FFS report. |
| Response 1 | The robust monitoring network will include numerous groundwater monitoring wells and vapor monitoring points, which will be located downgradient of the sparge barrier in OU1. These wells will be used to evaluate performance of the Sparge Barrier. There are 17 pairs of monitoring wells planned (shallow and deep) with 9 pairs between approximately 60 and 150 feet downgradient of the sparge barrier. These wells supplement the 4 existing pairs of monitoring wells. In addition, there are 12 vapor monitoring points planned in OU1 with 10 of them being downgradient of the sparge barrier. |
| Comment 2 | Previous projections for cleanup in the OU5 FFS were not achieved with the perimeter GW system. This may have been due the lack of consideration for matrix diffusion. Additional lines of analysis, such as point-attenuation calculations using observed time-series concentrations at specific well locations near the OU1 boundary would be appropriate to avoid a repeat of the underestimation for off-site cleanup. |
| Response 2 | Point attenuation evaluations have been performed for monitoring wells in OU5 as an additional means of estimating the cleanup time via monitored natural attenuation. This has been performed for RI-11S, RI-11M, RI-11D, RI-15S, RI-15M, RI-15D, RI-19S, RI-19D, RI-42S (destroyed), and RR PW-3. Results are consistent with the groundwater modeling. Furthermore, the previous projections for cleanup in OU5 are most likely caused by erroneous retardation factors and half-lives that were not adjusted for concentration (as described further in Response to Comment #9). |
| **Specific Comments** | |
| Comment 1 | Section 2.2. Are there vertical hydraulic conductivity data available in areas where the model evaluated the shallow and intermediate aquifers as separate? If so, do the values justify modeling the aquifer interface as a no flow boundary? |
| Response 1 | Shallow and intermediate/deep aquifers are separated generally by a lower permeability silty clay. Groundwater elevations between the shallow and intermediate/deep aquifer have not been the same which indicates that a downward vertical gradient exists. It also supports the presence of a lower permeability layer between the shallow and intermediate/deep aquifers. Over the past 8 years: RI-4S has averaged of 8.5 feet higher than RI-4D; RI-11S has averaged 0.37 feet higher than |

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| | RI-11M; RI-15S has averaged 5.6 feet higher than RI-15M; and RI-19S has averaged 0.30 feet higher than RI-19D.<br><br>The purpose of the groundwater flow modeling evaluation was to assess groundwater flow directions at the downgradient edge of OU1 from changes to remedial alternatives. Since the preferred alternative (sparge barrier) will be effective across both hydrostratigraphic units, flows between units are not required for achieving the modeling goal. |
| Comment 2 | Section 3.2. Are there data to evaluate hydraulic responses in the deep aquifer from shallow aquifer pumping or vice versa? |
| Response 2 | Groundwater pumping data and resultant groundwater contours are presented in the first and third quarterly reports. A comparison of the shallow and intermediate/deep groundwater contours may be made using this data. Since the shallow and deep pumping wells operate continuously, there is no field data reflecting pumping one aquifer and measuring the resultant impact to the other aquifer. Initial pumping wells installed in the 1990s were screened across both the shallow and intermediate/deep aquifer. |
| Comment 3 | Section 3.2.2. The statement regarding the conductivity values around the pump wells being limited because the wells could be pumped dry if they were too high does not make sense. Please correct with updated figures showing estimated field data to justify this statement. |
| Response 3 | This statement was meant to be that the wells could be pumped dry if the hydraulic conductivity was too low. Zones of high conductivity surrounded by areas of hydraulic conductivity will experience significant drawdown resulting in simulated pumping wells going dry. The statement was revised in the text to indicate that hydraulic conductivity around pumping wells were also adjusted to match observed head values. |
| Comment 4 | Section 3.3. Comparison of modeled and estimated flux was not presented to justify the statement that input data were varied within established ranges until the computed heads approximated what was measured. |
| Response 4 | The flux to the White River was used as a calibration target but was not described in the March 2019 Groundwater Modeling Report Draft. Comparison to estimated White River unit length discharge (Meyer et al.,1975), has been added to the Modeling Report in Section 3-3 and summarized on new Table 3-6. There was very low error (~2%) between the estimated discharge (42.0 $ft^3$/d per ft of channel length) and the modeled discharge (42.9 $ft^3$/d/ft). |
| Comment 5 | Section 3.5.1. Include underflow estimates to compare with modeled pump rates to help to evaluate hydraulic capture. This will help to document the pumping rates of 186 and 22 gpm presented here. |
| Response 5 | The groundwater model and remedial alternative are based upon pumping from the complete aquifer thickness. As such, there is no underflow component that was modeled. Pumping from the shallow and deep aquifer at the downgradient limit of OU1 addresses the entire water column. There will be no underflow component between the shallow and deep aquifers. The underflow component beneath the deep aquifer will be limited due to the underlying lower permeability layer that overlies bedrock. |

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| Comment 6 | Section 4.1. The lack of modeling information considering back diffusion may underestimate accurate remediation timeframes-please address this oversight. Please justify the use of mean values for geologic and hydrologic parameters. Harmonic averaging may be more appropriate than using the mean as this would result in lower estimates for conductivity. |
| Response 6 | The issue of matrix diffusion is a natural attenuation process which involves the temporary storage of chemicals of concern (COCs) within low permeability zones. The solutes are not held in an adsorption process, but rather distributed through a diffusion process. Back diffusion relates to COCs migrating back to the transmissive units after source concentrations are reduced and concentrations within the low permeable materials are higher than concentrations within the transmissive unit. Sequestration within low permeable materials occurs over the periods of decades (NRC, 2005). While high concentrations of COCs may have been sequestered originally, back diffusion into transmissive units will occur at much lower concentrations and continue to reduce in concentrations as mass is removed. The occurrences of back diffusion will be recognizable by long tails on concentration versus time plots.<br><br>The solute transport model that was agreed upon for use in the Natural Attenuation (NA) evaluation does not include a back-diffusion component, so there were no omissions in the groundwater modeling evaluation. The primary reason for not including back diffusion processes in the NA evaluation is that advective flow will continue through the low permeable zone separating the upper and lower hydrostratigraphic units for the foreseeable future.<br><br>The greatest potential source for additional mass discharge of COCs from back diffusion is from the low permeable materials that separate the upper and lower hydrostratigraphic units within OU1 and OU5. However, due to the on-going pumping from the Rolls-Royce/Allison Production Wells within OU5, an advective flow (albeit small in rate) will continue through this unit resulting in continued hydrodynamic dispersion, biodegradation, and concentration reductions throughout the natural attenuation simulation periods. Furthermore, some of the reintroduction of the COC mass within the upper aquifer is believed to be offset by conservative inputs used in the NA modeling assessment.<br><br>Variation of hydraulic conductivity values to harmonic averaging is not warranted since the hydraulic conductivity values used in the flow modeling were purposely matched very closely to the approved August-Mack (2010) groundwater model – and approved by USEPA during meetings to discuss the development of the model.<br><br>The groundwater model was calibrated to 42.9 $ft^3/d$ per foot of channel length or 2.1% of this flux target (Table 3-6). Comparison of the calibrated model to flux estimates to the White River has provided a positive independent check to calibrated hydraulic conductivity values used in the flow modeling evaluation. Furthermore, sensitivity analyses have been completed on a wide range of hydraulic conductivity values observed on-site. The results of the sensitivity analysis do not indicate anomalous results that would suggest changes to hydraulic conductivity are necessary. Finally, the recommendation to lower hydraulic conductivities, would actually be less conservative since it would result in longer flow times through the sparge barrier. Mean conductivities were not used in the natural attenuation assessment. Rather, the darcy velocity was based on observed groundwater velocity that was determined between spikes in concentrations at RI-33S and RI-6S. |

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| Comment 7 | Section 4.2. Without more definitive site-specific data, use of an effective porosity value of 18% is not conservative and may be a result of not modeling matrix diffusion effects during the calibration process-please address. |
| Response 7 | The groundwater modeling evaluation has incorporated existing site-specific data as calibration targets. An effective porosity of 18% matched to the site-specific data. Since an effective porosity of 18% matched observed data, it was determined to be representative. In fact, matching to site observed average linear velocity (as described in the Response to Detailed Comment #9), indicates that an effective porosity greater than 18% (ie., 18.6%) would provide a better match to observed concentration peaks. Therefore, the effective porosity is appropriate and slightly conservative.<br><br>Also as discussed previously, the transport model approved for the natural attenuation model does not include a back diffusion, or matrix diffusion, component due to on-going advective flow through all hydrostratigraphic units caused by Rolls-Royce groundwater withdrawals. |
| Comment 8 | Section 4.4. What is the basis for the degradation half-lives for benzene, pyridine and ammonia here? Are site specific values for organic carbon available to justify the K-d values being used in the model? Please provide. |
| Response 8 | Half-lives of benzene, pyridine, and ammonia were 3.5, 6, and 100 years, respectively. Benzene and pyridine half-lives were determined based upon inputs to a Bioscreen Model as presented in the November 2017 Focused Feasibility Study (FFS). The half-life was input to the Bioscreen model along with the seepage velocity and retardation factor to generate groundwater concentration trends that matched actual data trends. The seepage velocity was determined by using concentration peaks measured over time between an upgradient and downgradient wells. The retardation factor was calculated by comparing the benzene and pyridine velocity to the ammonia velocity.<br><br>Site-specific values were used to calculate the retardation factors of 4.3 for benzene and 3.3 for pyridines in the 1996 FFS. In addition, benzene and pyridine half-lives were determined to range from 1 to 2 years and 0.5 to 1.5 years, respectively in the 1996 FFS. In addition, a degradation rate analysis performed by August Mack Environmental in 2011 determined the benzene half-life to be 2.13 years and pyridine half-life to be 2.26 years. These are close to the 1996 FFS values that estimated cleanup times that were not realized.<br><br>The distribution coefficient ($K_d$) for benzene and pyridines were evaluated using site retardation factors, as well as typical values observed for an alluvial aquifer as described in Section 4.4. Retardation factors were calculated in the draft FFS (Peterson, 2017) for benzene (1.07) and pyridines (1.4) based on observed spikes in the groundwater quality data. The retardation factors ($R_f$) were used to the estimate for $K_d$'s using the following equation:<br>$$R_f = 1 + \frac{\rho_b}{n_e} K_d$$<br>where<br>$\rho_b$ = Bulk density<br>$n_e$ = Effective porosity<br><br>A $K_d$ of 0.036 cm$^3$/g was estimated for pyridines assuming a bulk density of 2.0 g/cm$^3$ and an effective porosity of 18%. The $K_d$ for benzene was further evaluated due to the greater availability of retardation references. This information was used to estimate $K_d$ using<br>$$K_d = K_{oc} \times f_{oc}$$ |

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| | where<br>$K_{oc}$ = organic carbon partition coefficient<br>$f_{oc}$ = fraction of organic carbon in soil (as %)<br><br>A $K_{oc}$ of of 61.7 L/kg was obtained from USEPA documentation (USEPA, 2008). While no organic content was found within historical site reports, a conservative fraction organic content ($f_{oc}$) of 0.06% was developed as a lower interval of available references of alluvial aquifers. As reported in ITRC (2015), alluvial aquifers generally averaged $f_{oc}$'s that were nearly an order of magnitude greater than 0.06%.<br><br>ITRC (Interstate Technology & Regulatory Council). 2015. Integrated DNAPL Site Characterization and Tools Selection (ISC-1). Washington, D.C.: Interstate Technology & Regulatory Council, DNAPL Site Characterization Team. www.itrcweb.org/DNAPL-ISC_ tools-selection.<br><br>USEPA, 2008. U.S. Environmental Protection Agency - Office of Pollution Prevention & Toxics and Syracuse Research Corporation (SRC) Estimation Programs Interface (EPI) SuiteTM (including KOCWIN) and all component programs; Copyright 2000-2008. |
| Comment 9 | Section 4.5. Effects of matrix diffusion were not utilized in previous modeling, resulting in underestimation of cleanup timeframes. How do the current estimates compare with contaminant trends at individual wells near the OU1 boundary? Please address this lack of information. |
| Response 9 | It is not believed that matrix diffusion resulted in an underestimation of cleanup timeframes. Rather, erroneous retardation factors are believed to have contributed to the inaccurate cleanup time calculations. Furthermore, half-lives of benzene and pyridines were not adjusted for concentration (shorter half-lives at higher concentrations, longer half-lives at lower concentrations), which is also believed to have resulted in shorter cleanup time calculations.<br><br>Contaminant trends in OU5 were reviewed as part of a natural attenuation evaluation. RI-11M represents the only well with decreasing concentration trends that are currently above the remedial action objectives (RAOs) for benzene and ammonia. Based upon this evaluation, the benzene and ammonia RAOs will be achieved in 9 and 10 years, respectively. This is consistent with the groundwater modeling results.<br><br>Contaminant trends at the downgradient limit of OU1 were also evaluated. RI-5S represents the only well with a decreasing benzene concentration trend that is currently above the RAO. It is estimated that the benzene RAO will be achieved at RI-5S in 2-3 years. PW-2S represents the only well with a decreasing pyridine concentration trend that is currently above the RAO. It is estimated that the pyridine RAO will be achieved at PW-2S in 1-2 years. |
| Comment 10 | Section 6.1. Well efficiency and available drawdown information from each extraction well should be factored into the modeled pumping rates. The current model assumes 100% efficiency, which is unrealistic for wells near each other. |
| Response 10 | Well efficiency or a ground-truthing was factored into the enhanced pumping scenario. The model assumed that the pumping rates were achievable at the formerly used extraction wells. For example, when PW-1D was installed in 2003 the pumping rate was in excess of 140 gpm. Furthermore, the model assumed that the pumping wells would be replaced if they could not achieve the modeled pumping rate. |

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| Comment 11 | Section 6.2. See comment 9. |
| Response 11 | See Response 9. |
| **Detailed Comments** | |
| Comment 1 | Section 3.5, page 3-8, par 1. This section should refer to Appendix B-1. |
| Response 1 | OK. A reference was added. |
| Comment 2 | Section 3.5.1. Please label the easternmost wells where particle flow is moving-this will help to understand the text. |
| Response 2 | A description was added to the text to assist in understanding particle tracking plots. |
| Comment 3 | Section 3.5.2. What is the purpose of the flow velocity analysis and how does it guide modeling decisions? |
| Response 3 | It demonstrates that the modeled groundwater velocities are consistent with the measured groundwater velocities. Therefore, as pumping is decreased or increased from the current rates, resultant groundwater velocities can be calculated. These groundwater velocities are then used to demonstrate that sufficient residence time will allow the sparge barrier degrade benzene and pyridines to RAOs. |
| Comment 4 | Section 3.5.3. Please locate the Olin wells on the figures and how does their operation fit into the conceptual site model? |
| Response 4 | Indiana Department of Natural Resource well logs indicate that the Olin wells were abandoned in March 2007. The exact location of these wells is not known but have been based on August-Mack modeling documentation (August-Mack, 2010) that estimates their location to be about 1200 feet east of Tibbs Avenue near E. Minnesota Street. The simulated drawdown from the former Olin wells can be seen in the figures provided in Appendix D. The operation of these wells helps to simulate a historical groundwater flow pathway in an effort to determine why impacts at RI-15M are being observed. |
| Comment 5 | Section 4.2. The 2nd figure in Appendix C-1 lists an incorrect distance between RI-33S and RI-6S-correct value is 477 feet. What does the output boundary concentration set as an infinite bottom layer mean? Please define. |
| Response 5 | The reference to 377 feet in Section 4.2 was a typo. Calculations were based upon 477 feet.<br><br>The infinite thickness bottom boundary condition represents the case where the deposit (whether the shallow or deep sand units) is assumed to extend beyond the length of the prescribed model distance in each of the POLLUTE modeling runs. This boundary condition option was specifically developed to model lateral migration within a deposit (Rowe and Booker, 1990). |
| Comment 6 | Section 4.3. the fact that change in ammonia results from varying bulk density indicates either an error in input or results interpretation. Replace “darcy velocity” with “specific discharge” throughout this TM. The presented values are not velocities. |
| Response 6 | Bulk density is not an input parameter for POLLUTE modeling, but rather dry density. |

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| | Mathematically, small changes to dry density would vary predicted concentrations based on the fact that POLLUTE is a one-dimensional (1-D) semi-analytical program which uses numerical inversion of the Laplace transform to solve the following 1-D dispersion advection equation for porous media:<br><br>$$n\frac{\partial c}{\partial t} = nD\frac{\partial^2 c}{\partial^2 z} + nv\frac{\partial c}{\partial z} - n v_x \frac{\partial c}{\partial x} - \rho K_d \frac{\partial c}{\partial t} - n\lambda c$$<br><br>where:<br>c = concentration at point (x,z) where c = c(x,z,t) [ML-3]<br>Dx = coefficient of hydrodynamic dispersion in x direction [L2T-1]<br>$\bar{v}$ x = groundwater (seepage) velocity in x direction [LT-2]<br>n = porosity of the soil [L3/L-3]<br>ρ = dry density of the soil [ML-3]<br>Kd = distribution/partitioning coefficient [L3M-1]<br>λ = decay constant of the contaminant species [T-1]<br><br>The sensitivity analyses indicated that changes to dry density that there were very small changes – on the order of a fraction of a percent - in the predicted concentrations. This indicates that the predicted results are not sensitive to variations in dry density inputs.<br><br>Darcy velocity ($V_a$) is synonymous with specific discharge (Bear and Verruijt, 1987, Rowe et al., 2004, etc.):<br><br>$V_a = n_e * v$<br><br>Where,<br>$n_e$ = effective porosity, and<br>v = groundwater velocity.<br><br>It is used to calculate the mass of solute transported by advection per unit area per unit of time. Since the term “darcy velocity” is used in the POLLUTE software, the nomenclature will remain consistent with the transport model used for the natural attenuation analysis.<br><br>Bear, J., and A. Verruijt. 1987. Modeling Groundwater Flow and Pollution: With Computer Programs for Sample Cases. Dordrecht: Reidel.<br><br>Rowe, K., Quigley R., Brachman, R., and Booker, J., 2004. Barrier Systems for Waste Disposal, 2nd Edition, Spon Press New York, NY. |
| Comment 7 | Section 4.4. Is AECOM aware of the 1996 Al-Suwaiyan report? This describes an error in the dataset and dispersivity equation and is provided for reference. |
| Response 7 | The referenced “report” by Al-Suwaiyan, M.S.(1996) is a *Discussion* in the May 1996 issue of Ground Water (pg. 578) that indicates a decimal point error in a data point reported by Gelhar et al. (1992). The authors (Xu and Eckstein, 1995) indicate that “*since this data point is characterized by the lowest reliability, the error has very little influence on the regression equation weighting scheme*.” Therefore, the conclusions stated in Xu and Eckstein (1995) and the methods used in the groundwater modeling work remain unchanged.<br><br>Gelhar, L.W., Welty, C. and Rehfeldt, K. R. (1992) “A Critical Review of Data on Field-Scale Dispersion in Aquifers,” Water Resources Research, Vol. 28, No. 7, 1992, pp. 1955-1974. |

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| | Xu, M. and Eckstein, Y. (1995) "Use of Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Field Scale" Ground Water November-December 1995 issue, v. 33, no. 6, pp. 905-908. |
| Comment 8 | Section 4.5. This section confuses the darcy velocity (not a velocity) with the average linear groundwater velocity. |
| Response 8 | The discussion in Section 4.5 is correct. There is not a confusion between darcy velocity and average linear velocity. Rather, there is a lack of an example in this section. An example has been added to assist the reader to understand the calculation. The following explanation (provided in italics) was added after the 1st sentence of the last paragraph in Section 4.5:<br><br>The darcy velocity used in POLLUTE simulations (3.13 m/yr) was based on the observed groundwater velocity between wells RI-33S and RI-6S within OU1 *(0.15 ft/d or 0.046 m/d) and the calibrated effective porosity value of 18%. The darcy velocity used in the natural attenuation modeling was adjusted slightly (e.g. from 3.02 m/yr to 3.13 m/yr) to better match the concentration spikes observed in RI-6S. Note that the calibrated darcy velocity (3.13 m/yr) was higher than what the observed average linear velocity would have indicated (i.e., 3.02 m/yr). Considering average linear velocity is a field-measured parameter, it would be anticipated that effective porosity be adjusted higher to match the observed data. A higher effective porosity of 18.6% would be required to match the observed data. However, effective porosity was not increased and therefore is considered conservative for transport simulations.* |
| Comment 9 | Section 6.1. See comment 3. Conclusions on Biosparge should be limited to flow velocity and residence time rather than effectiveness, which is based on system design. This report should not conclude whether the sparge line coverage is sufficient or effective-this will be addressed in the revised FFS. |
| Response 9 | OK |
| Comment 10 | Section 6.1. Analysis of GW flow. Please delete the 2nd paragraph and any references to off-site sources. This is speculative and not supported by site information. |
| Response 10 | Disagree, benzene concentrations are rising in the absence of rising pyridine or ammonia concentrations. This is not consistent with current site information nor past groundwater sampling results in OU5. Therefore, there may be an off-site source. |
| **Final Comment** | |
| Comment 1 | Please let me know if you have any questions regarding these comments. Please also provide a schedule for proceeding with incorporation of these modeling results into a revised FFS along with a schedule for submittal. |
| Response 1 | <u>Estimated 2019 Schedule:</u><br><br>• Submit OU5 Natural Attenuation Evaluation by June 7.<br>• Submit OU1 Vapor Intrusion Evaluation by June 7.<br>• Respond to USEPA comments by July 5.<br>• Submit revised FFS by September 30. |

**Attachment E**

**Sparging Feasibility Testing Description**

**Sparging Feasibility Testing Description**

Sparge feasibility testing was performed at multiple areas in OU1 as illustrated on **Figure 6** of Attachment A to the RAWP.

Summary of testing areas

The following items are present in the basis of design.

1. Former Treatment Pit (FTP) Area
2. Vinyl Pyridine (VP) Plant Area
3. Well PW-4 and RI-6 S/D Area
4. Well RI-5 Area
5. PW-1 Old
6. PW-2 Old

(1) Former Treatment Pit Area

Air sparging was first tested in the shallow aquifer at the Former Treatment Pit (FTP) area in 2008. Long-term sparging was initiated in 2010. The shallow aquifer in the FTP area is similar to the shallow aquifer in OU1 and OU5. A pilot test layout (map), cross section, well logs, and pilot test data are attached.

Three sparge points (SP-31, SP-32 and SP-33) were installed near the base of the shallow aquifer in the FTP area for the initial short-term 2008 pilot testing. Results indicated that the shallow aquifer would accept sparged air and that dissolved oxygen (DO) levels increased rapidly.

For the longer term sparging that commenced in November 2010, a 5-horsepower reciprocating compressor was installed as a more permanent source of compressed air. Air was injected in the center of the FTP area (at SP-32) at a rate of approximately 10 to 13 standard cubic feet per minute (scfm) and the compressor was operated on a timer system (30 minutes on followed by 30 minutes off) in order to pulse the injection of air. Routine monitoring of the area showed significant dissolved oxygen (DO) increase at the nearby monitoring well RI-32S.

Sparging efforts in the FTP area in 2008 and 2010 successfully elevated the local dissolved oxygen levels to create an aerobic environment which, in turn, rapidly reduced levels of benzene and each pyridine derivative.

In the first quarter of 2011, benzene had decreased to non-detect while total pyridines had increased from 1,613 ug/L to 8,410 ug/L in nearby well RI-32S. Ten of the 14 pyridine derivatives were routinely detected at this well. Ammonia decreased from 1.9 mg/L to 1.1 mg/L. Results at the next downgradient well RI-33S increased for benzene and decreased for total pyridines. Sparge operations continued in the center of the FTP area through 2011 and until May 2012, when the air line was extended and attached to a sparge point to the east (SP-33).

The groundwater monitoring results at well RI-32S for the first quarter of 2012 (after 5 quarters of sparging) again showed favorable results with benzene and ammonia being non-detect. All of the pyridine derivatives had also declined to non-detect with the exception of 2-methyl-3-ethyl pyridine, which declined from 990 ug/L to 19 ug/L, below the RAO. These results indicate that sparging can be used to address pyridine and pyridine derivative impacts at the site.

Sparging continued on the east side of the FTP area until October 2012, when the compressor was moved to the PW-4 pump house for sparging activities in this area. In order to resume sparging in the FTP area, a new compressor was installed and began operating during March 2013. This compressor operated until June 2013, when the power was removed from the area for the solar farm construction activities.

The sparging system was later expanded in the FTP area and further east of the FTP at the RI-6/PW-4 area. During the week of September 11, 2013, 2 sparge points were installed within the shallow aquifer along the east side of the FTP at locations approximately 50 feet north and south of the current eastern sparge point, SP-33. The purpose of these 2 additional points was to provide a sparge curtain on the eastern (down gradient) side of the FTP and improve groundwater remedial

capabilities. A new source of power for the compressor was established nearby and sparging resumed from May 21, 2014 until September 2014.

In addition to the installation of the 2 sparge points, the extent of groundwater impacts to the south of the area were defined by the collection and analysis of a groundwater sample. A boring was advanced approximately 100 feet south of SP-33. The boring was continuously sampled with no evidence of impacts being observed. A temporary well was then installed, purged and sampled. VOCs, SVOCs, and ammonia were not detected in the groundwater.

The sparge monitoring data indicated that 14 to 17 scfm of air can be sparged into the shallow aquifer at wellhead pressures of 9 to 12 psi operating in a pulsed mode. Significant DO increases were measured from SP-33 at a distance of 20 feet away and slight DO increases were measured at a distance of 50 feet away. Benzene concentrations in groundwater decreased by 97% to below the RAOs within 4 months and total pyridines decreased by 99% and also below the RAOs within 16 months.

(2) Vinyl Pyridine (VP) Plant Area

Groundwater monitoring results at well RI-18S in March 2012 indicated a substantial spike in benzene and pyridines concentrations. An investigation into the adjacent VP Plant operations identified a few sewer components that had the potential to be the source of a release to groundwater approximately 100 feet west of RI-18S. By September 2012, all of the identified sewer components were tested, repaired if necessary, and had successful follow-up sewer testing to confirm the repairs.

Sparge pilot testing in the area east of the VP Plant was presented to the USEPA during a September 2012 meeting. A follow-up summary letter of planned sparging activities was then provided to the USEPA and the field work was initiated on November 29, 2012. A pilot test layout (map), cross section, well logs, and pilot test data are attached.

One sparge point and 3 sparge monitoring points were installed in the shallow aquifer on the east side of the VP Plant using a Geoprobe. Soil types were typical in this area consisting of an unconfined shallow aquifer from approximately 19 to 33 feet below grade. A fine grained unit was encountered below this level.

The sparge point was installed 1 foot above the fine grain unit. In order to monitor the progression of the sparging activities and determine the radius of influence for the sparge point, three 1-inch PVC monitoring points were installed 20 feet, 40 feet, and 55 feet away from the sparge point. RI-18S was located approximately 90 feet east of the sparge well.

A short-term sparge pilot test was performed on December 5, 2012 using a tow behind air compressor. Air was injected into the sparge well over a 10 hour period using the compressor. The flow rate, pressure, and temperature of the injected air were monitored. The testing started at a flow rate of 10 scfm and was gradually increased to approximately 20 scfm over the test period. The result of this short-term test was that the shallow aquifer would readily accept air and that DO rapidly increased at the monitoring point 20 feet away from 0.3 mg/L to 7 mg/L.

A short-term pilot test was also performed at well RI-18D on December 6, 2012 using the tow behind compressor. Sparge air flow rates ranged from 15 to 25 scfm. This pilot test showed that the deep aquifer would easily accept the injected air and that air migrated to the upper, shallow aquifer. Once the flow rate was increased above 15 scfm, bubbling of air and increased DO was observed in the nearby well RI-18S. During the pilot test, DO increased from 1.2 mg/L to 6.1 mg/L at well RI-18S within 3.5 hours.

On December 13, 2012, the adjacent instrument air source was connected to the new shallow sparge well in order to initiate a long-term pilot test. Air was sparged at up to 25 scfm and varied at wellhead pressures of 9 to 14 psi. DO in the nearby monitoring points was observed to increase and peaked during early to mid- February 2013 when readings of 9.8 mg/L (20 feet away), 10.0 mg/L (40 feet away), and 9.3 mg/L (55 feet away) were recorded. These results indicate a substantial radius of influence in the shallow aquifer of at least 55 feet.

Continued monitoring of groundwater quality at RI-18S indicated significant declines in benzene and pyridine concentrations. By June 2013, benzene had declined from 7,400 ug/L to 17 ug/L and total pyridines had declined from 1,700 ug/L to 23 ug/L.

Shallow sparging ceased in May 2013 when instrument air was routed to RI-18D. Long-term deep aquifer sparging continued at RI-18D until October 2013. Long-term pilot testing at RI-18D was successful. The monitoring data for the deep aquifer sparge testing indicated that the plant instrument air can be utilized to easily inject up to 20 scfm of air into the deep shallow aquifer at wellhead pressures ranging from 18 to 32 psi. Increased DO was routinely observed in well RI-18S (11 feet away, 7 to 10 mg/L) and at the next farthest observation point (51 feet away, 3 to 9 mg/L). These results further demonstrated that the fine grained, lower permeability unit separating the shallow and deep aquifers does not confine the flow of air to the deep aquifer, and that deep aquifer sparging can address the shallow aquifer.

In October 2013, a solenoid and timer system was installed allowing instrument air to be pulsed between the shallow sparge point and the deep sparge point (well RI-18D). The shallow sparge point received about 8 to 10 scfm of air for 12 hours/day. The pulsed operation minimized channeling of sparge air, lead to elevated DO in the shallow aquifer, and RI-18S benzene and pyridines were reduced to below detection limits.

(3) Well PW-4 and RI-6S/D Area

Following USEPA approval to sparge PW-4 in 2012, a 5-HP air compressor was installed in the PW-4 pump house and plumbed to PW-4 for sparging. A pilot test layout (map), well logs, and pilot test data are attached. An inflatable packer was utilized to seal and position a Schumasoil microscreen at 33 feet bgs inside the well. Air was sparged into the well at a rate of about 15 scfm and the air was observed to be short circuiting back into the casing above the packer instead of out into the aquifer. The sparge point was then set at a lower depth of 55 feet bgs and sparging continued at a rate of about 15 scfm with the same result. These results indicated this plumbing configuration would not be successful for sparging PW-4; sparge wells need to be in direct contact with the soil, not within another larger well.

During February 2013, the compressed air line was extended from PW-4 and connected to the adjacent well RI-6D. Air was sparged into RI-6D at a rate of approximately 13 scfm from February 2013 through October 2013. The air compressor operated on a timer system being on 30 minutes out of every hour. The results were that air could be readily injected into the deep aquifer and that DO increased from 0.3 up to 11 mg/L in well PW-4 located 19 feet away. No increases in DO were measured at well RI-6S located 34 feet away.

During September 2013, two additional sparge points were installed with a Geoprobe within the shallow aquifer north and south of PW-4/RI-6S/D. The south point was installed 50 feet south of RI-6D and the north point was installed 50 feet north of RI-6S. Soil sampling indicated consistent soil conditions as in other areas of the site. The shallow aquifer was present from about 22 to 32 feet bgs. The sparge points were installed near the bottom of the shallow aquifer approximately 1 foot above the lower permeability layer.

Both of the new sparge points were plumbed to the existing compressed air system. Air was sparged to the new south sparge point from October 2 until November 8, 2013 at a flow rate of 12 to 13 scfm. No increases in DO were observed at well PW-4 and RI-6S due to the distance between the sparge point and these wells (>50 feet). From November 8, 2013 to September 2014, air was injected into the new north sparge point at rates ranging from 15 to 16 scfm. No increases in DO were observed at RI-6S (50 feet away).

(4) Well RI-5 Area

A sparge point (SP) was installed to a depth of 57 feet bgs in the deep aquifer 45 feet west of RI-5S in November 2012 using a hollow stem auger drill rig. A pilot test layout (map), well logs, and pilot test data are attached. Short term pilot testing was performed on December 4, 2012 using a tow behind compressor to sparge flow rates ranging from 10 to 20 scfm. While the water level was observed to increase at RI-5S, no changes in DO were observed. On December 6, 2012, a 30 minute pilot test was performed by injecting air within well RI-5S using a tow behind compressor. Flow was initiated in RI-5S at about 25 scfm and an immediate increase in pressure at the new sparge point was observed.

A new 5-HP air compressor was installed within the MRM building, adjacent to SP. Sparge operations were initiated into SP on February 22, 2013 and ceased during September 2014. During sparging, air was injected at rates ranging from 15 to 17 scfm and the groundwater level rose by one foot in the first hour and then returned to nearly the pre-sparge level when measured the next day. Although no substantial increase in DO was observed in RI-5S, the groundwater quality improved

significantly over time. Benzene trends decreased by an order of magnitude from 370 ppb to 19 ppb between March 2013 and March 2015. Similar improved results were observed for pyridines where pyridines rapidly declined from approximately 323 ppb to 54 ppb over that time period.

(5) PW-1 Old

Well PW-1 Old was converted by Peerless-Midwest, Inc. into a multi-level piezometer following the installation of PW-1S and PW-1D during the early 2000's. A pilot test layout (map), well logs, and pilot test data are attached. One of the existing water level measurement drop tubes is isolated in the deep aquifer similar to PW-1D (approx. 55 feet bgs), and this tube was used for sparging.

A 5-HP air compressor was installed within the PW-1 pump house with sparging operations being initiated on January 16, 2013. From January 2013 to September 2014, air was sparged into PW-1 Old at a rate ranging from approximately 15 to 16 scfm. The results indicated that this well will readily accept the air. Monitoring of the PW-1S and PW-1D effluent (47 and 37 feet away from PW-1 Old, respectively) was performed. An increase in DO was measured in the PW-1S effluent as high as 3.7 mg/L. The DO did not increase in the PW-1D effluent and remained approximately 0.7 mg/L.

In 2013 individual samples at PW-1S and PW-1D were collected by the Plant for the analyses of benzene. PW-1S results were non-detect for benzene and ammonia has trended down from 26 mg/L to 10 mg/L. Corresponding PW-1D results indicated benzene levels varied and were above the RAO.

(6) PW-2 Old

Well PW-2 Old is a 10 inch diameter well screened from 19 to 39 feet below grade. The well was replaced with PW-2S during 2003 after PW-2 Old began to pump sand. **Appendix K** contains a pilot test layout (map), well logs, and pilot test data. Similar to well PW-4, during December 2012, an inflatable packer was utilized to seal and position a Schumasoil microscreen approximately 28 feet bgs (at the base of the shallow aquifer) within PW-2 Old for sparging.

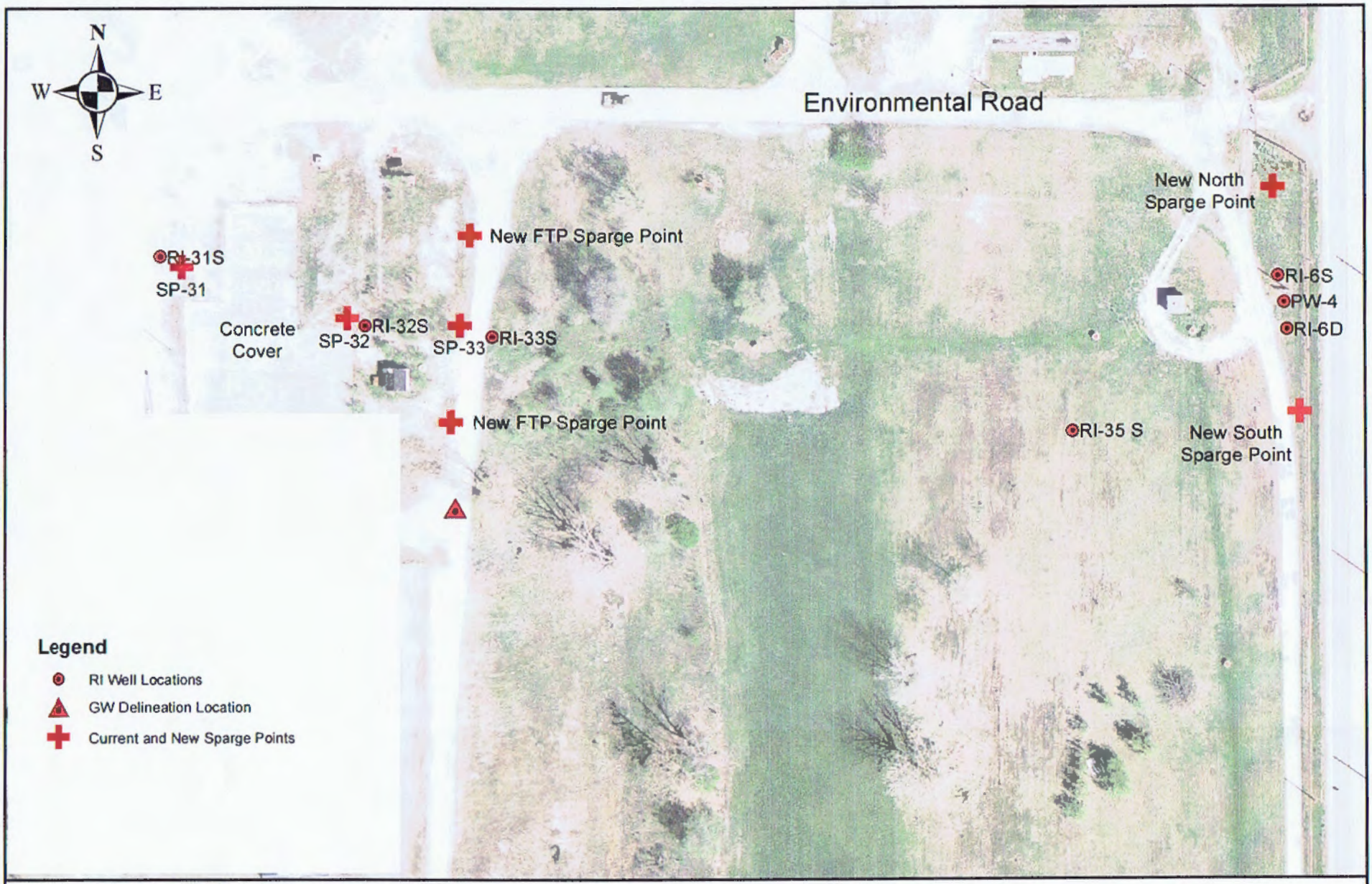
A 5-HP air compressor was installed within the PW-2 pump house with sparging operations being initiated on January 18, 2013 at a rate of 15 to 17 scfm and ceased during September 2014. PW-2 Old is approximately 16 feet away from PW-2S. The DO in PW-2S effluent from monitoring was scattered but often above 1 mg/L. PW-2 Old was determined to not be in effective communication with the aquifer and it is believed most air short circuited near the well similar to testing results at PW-4 where it was determined that sparge wells need to be in direct contact with the soil, not within another larger well.

(7) Supporting Documentation

Attachment 1 – Former Treatment Pit (FTP) Area Test Data
Attachment 2 – Vinyl Pyridine (VP) Plant Area Test Data
Attachment 3 – Well PW-4 and RI-6S/D Area Test Data
Attachment 4 – Well RI-5 Area Test Data
Attachment 5 – PW-1 Old Test Data
Attachment 6 – PW-2 Old Test Data

**Attachment 1**

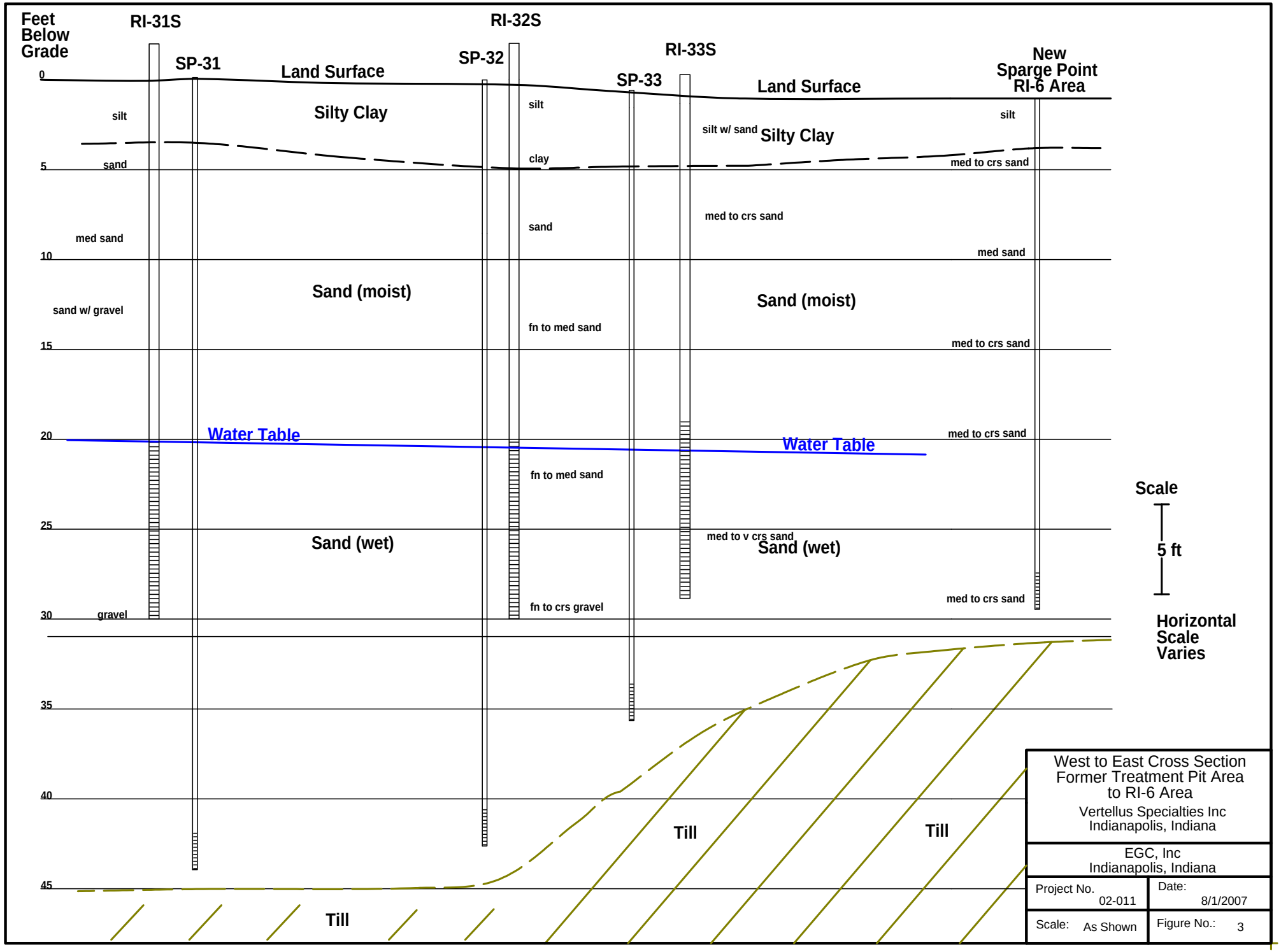
**Former Treatment Pit (FTP) Area Test Data**

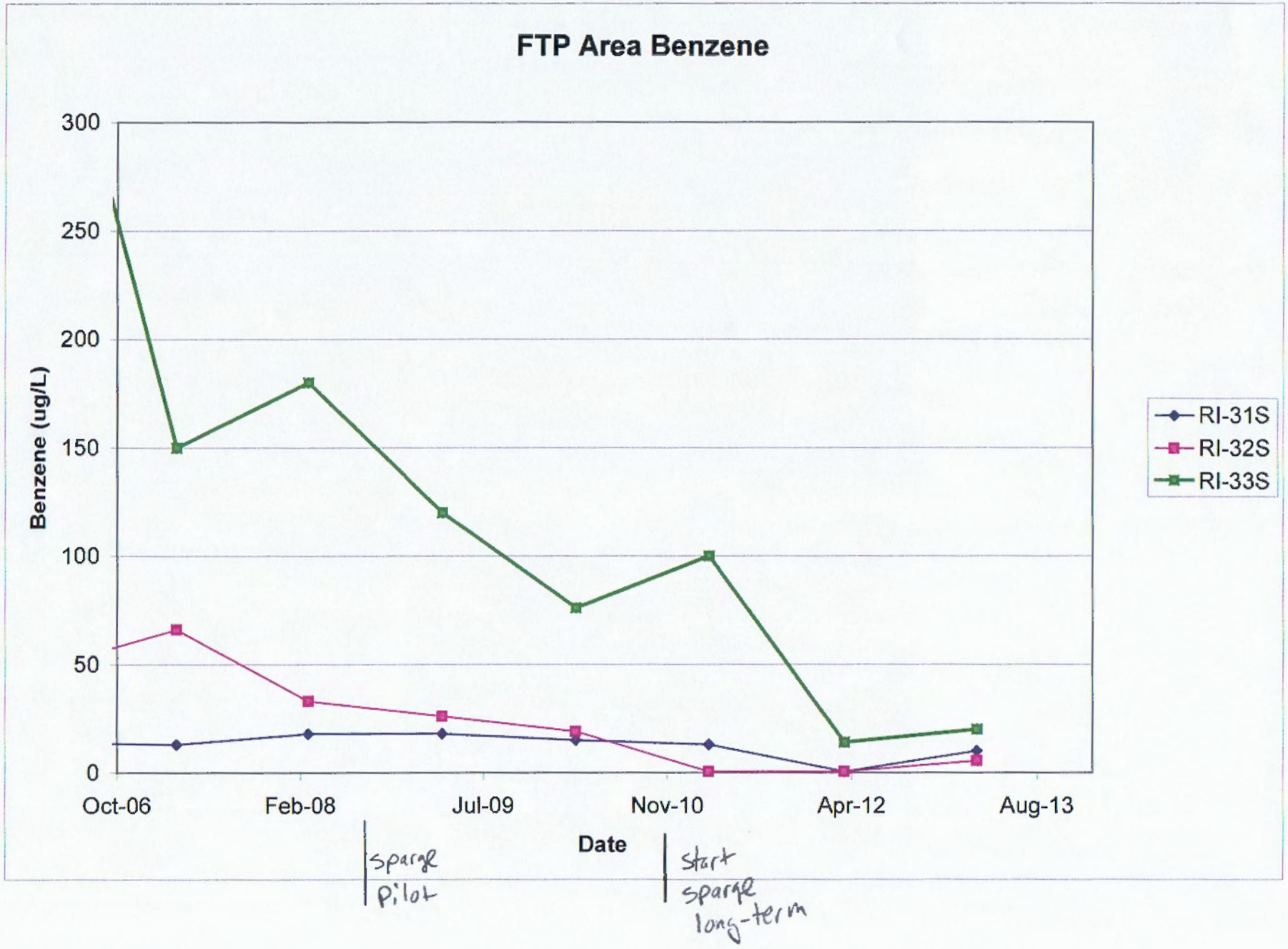


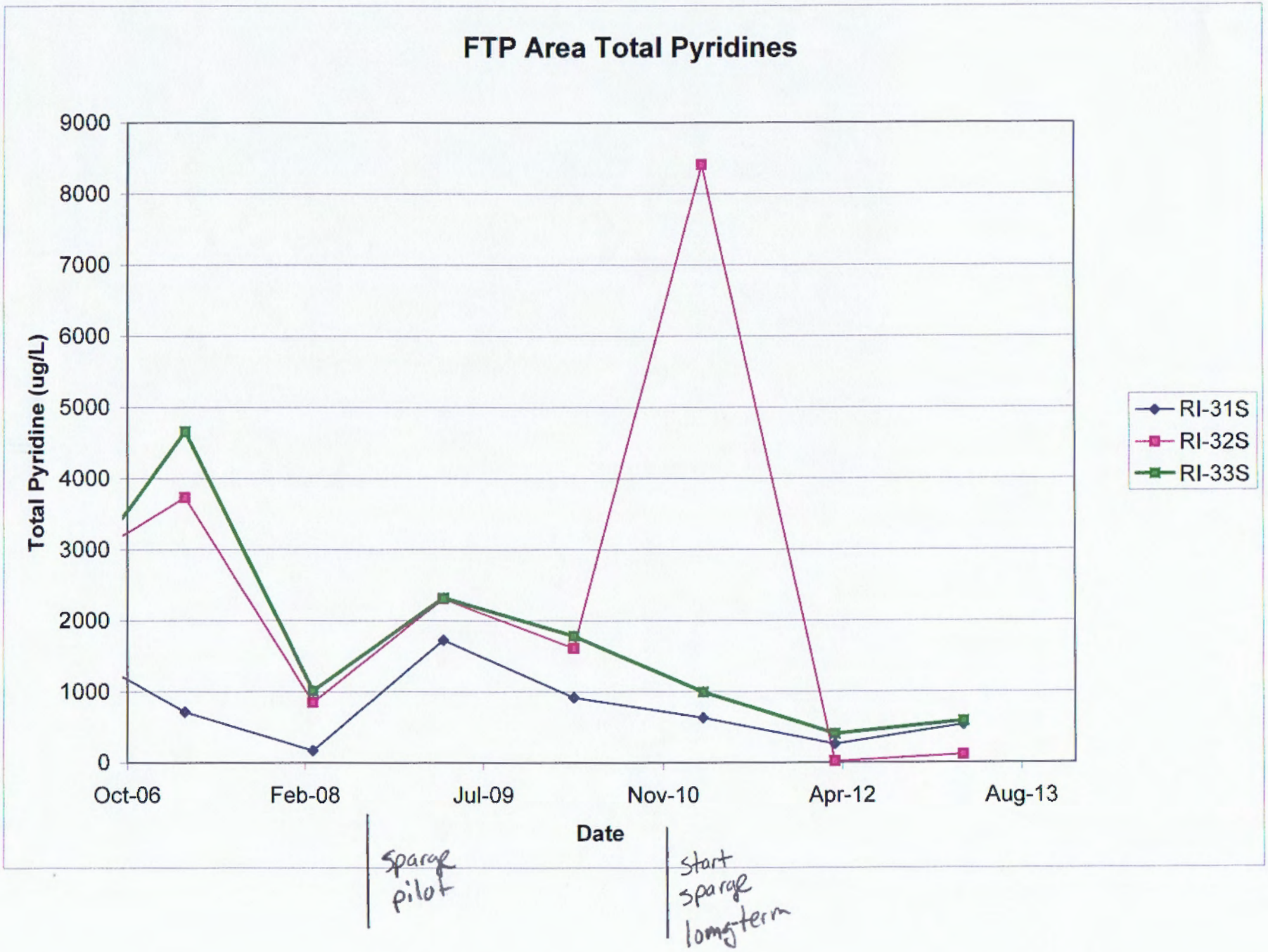

**Former Treatment Pit - Existing, Newly Installed Sparge Points and Groundwater Delineation Point**

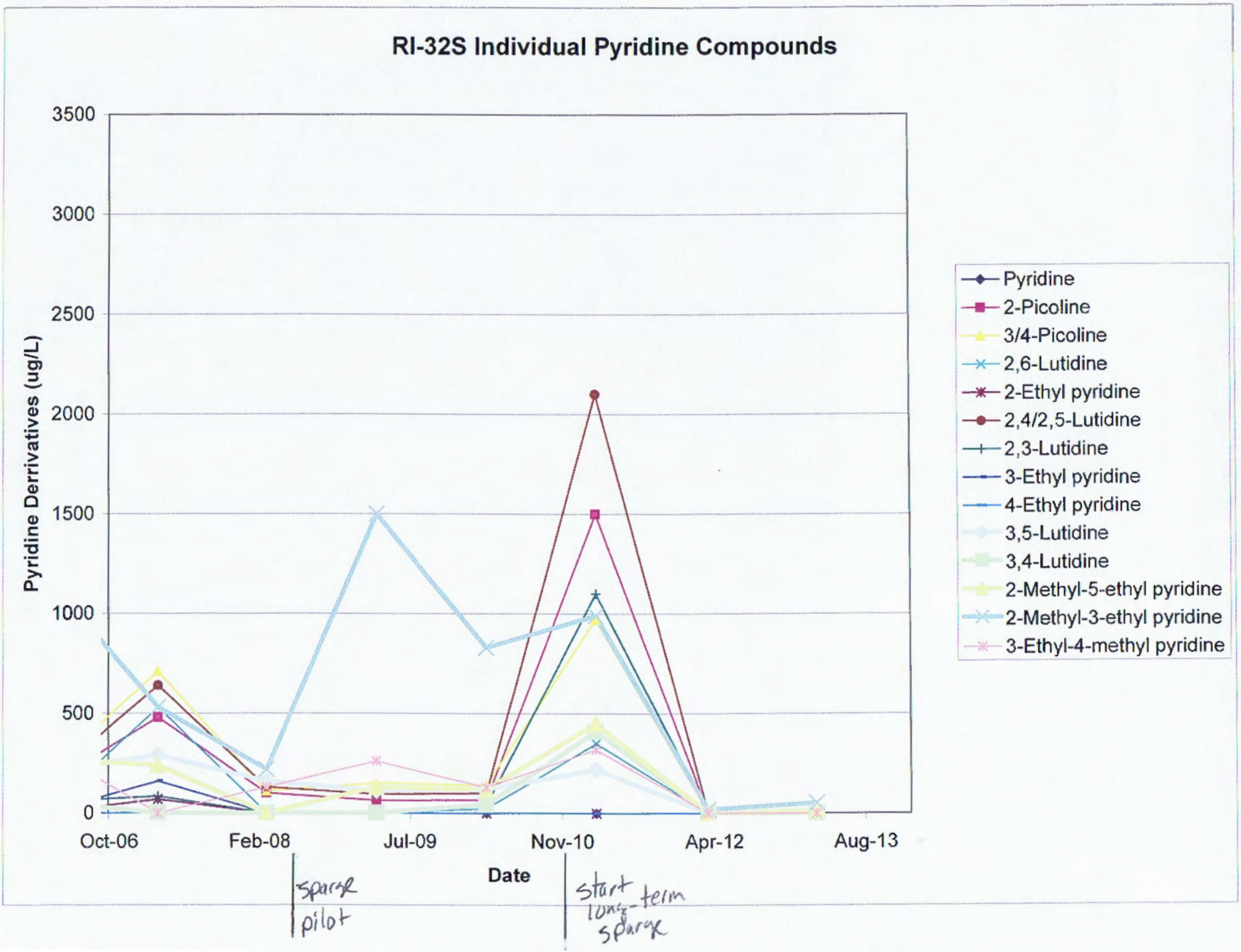
0 50 100 200 Feet

**Vertellus Specialties Inc**
**1500 S. Tibbs Ave.**
**Indianapolis, IN**


Feet Below Grade
RI-31S
SP-31
Land Surface
RI-32S
SP-32
RI-33S
SP-33
Land Surface
New Sparge Point RI-6 Area
0
5
10
15
20
25
30
35
40
45
silt
sand
Silty Clay
silt
clay
silt w/ sand
Silty Clay
silt
med to crs sand
med sand
sand
med to crs sand
med sand
sand w/ gravel
Sand (moist)
fn to med sand
Sand (moist)
med to crs sand
Water Table
Water Table
med to crs sand
fn to med sand
med to v crs sand
Sand (wet)
Sand (wet)
gravel
fn to crs gravel
med to crs sand
Till
Till
Till
Scale
5 ft
Horizontal Scale Varies
West to East Cross Section
Former Treatment Pit Area
to RI-6 Area
Vertellus Specialties Inc
Indianapolis, Indiana
EGC, Inc
Indianapolis, Indiana
Project No. 02-011
Date: 8/1/2007
Scale: As Shown
Figure No.: 3


FTP Area Benzene
300
250
200
150
100
50
0
Benzene (ug/L)
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Aug-13
Date
RI-31S
RI-32S
RI-33S
sparge pilot
start sparge long-term


FTP Area Total Pyridines
Total Pyridine (ug/L)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Aug-13
Date
RI-31S
RI-32S
RI-33S
sparge pilot
start sparge longterm


RI-32S Individual Pyridine Compounds
Pyridine Derrivatives (ug/L)
3500
3000
2500
2000
1500
1000
500
0
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Aug-13
Date
sparge pilot
start long-term sparge
Pyridine
2-Picoline
3/4-Picoline
2,6-Lutidine
2-Ethyl pyridine
2,4/2,5-Lutidine
2,3-Lutidine
3-Ethyl pyridine
4-Ethyl pyridine
3,5-Lutidine
3,4-Lutidine
2-Methyl-5-ethyl pyridine
2-Methyl-3-ethyl pyridine
3-Ethyl-4-methyl pyridine

# Vertellus Specialties Inc.
## Groundwater Monitoring Data 1994 to 4Q2013

| Well Name | Sample Date | Benzene ug/l | Total Pyridines ug/l | Ammonia mg/l | Toluene | Ethyl benzene | Xylene-total | Pyridine | 2-Picoline | 3/4-Picoline | 2,6-Lutidine | 2-Ethyl pyridine | 2,4/2,5-Lutidine | 2,3-Lutidine | 3-Ethyl pyridine | 4-Ethyl pyridine | 3,5-Lutidine | 3,4-Lutidine | 2-Methyl-5-ethyl pyridine | 2-Methyl-3-ethyl pyridine | 3-Ethyl-4-methyl pyridine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RI-31S** | | | | | | | | | | | | | | | | | | | | | |
| | Jan-98 | 37.0 | 1119 | 2.2 | ND | 110 | 103 | 0 | 270 | 17 | 22 | 16 | 91 | 13 | 0 | 0 | 210 | 0 | 270 | 210 | 0 |
| | Jan-99 | 17.0 | 690 | 1.1 | ND | 190 | 110 | 0 | 240 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 130 | 0 | 130 | 190 | 0 |
| | Jan-00 | 24.0 | 505 | 1.5 | 7.1 | 150 | 95 | 0 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 95 | 0 | 130 | 200 | 0 |
| | Feb-01 | 0.5 | 158 | 1.4 | ND | 130 | 73 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 98 | 0 |
| | Feb-02 | 28.0 | 117 | 1.8 | ND | 200 | 74.8 | 0 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 31 | 41 | 0 |
| | Feb-03 | 28.0 | 127 | 1.8 | ND | 180 | 104.7 | 0 | 55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72 | 0 |
| | Feb-04 | 19.0 | 420 | 2.8 | ND | 160 | 95 | 0 | 130 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 79 | 0 | 51 | 160 | 0 |
| | Mar-05 | 13.0 | 957 | 2.0 | ND | 130 | 75 | 0 | 57 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 40 | 0 | 29 | 760 | 53 |
| | Mar-06 | 14.0 | 1763 | 1.3 | ND | 140 | 91.4 | 0 | 110 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 1500 | 89 |
| | Mar-07 | 13.0 | 713 | 0.5 | ND | 97 | 52 | 0 | 25 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 30 | 0 | 20 | 580 | 45 |
| | Mar-08 | 18.0 | 172 | 1.9 | ND | 99 | 59 | 0 | 28 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 32 | 0 | 27 | 0 | 68 |
| | Mar-09 | 16.0 | 1726 | 1.5 | ND | 87 | 62 | 0 | 35 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 40 | 0 | 34 | 1600 | 0 |
| | Mar-10 | 15.0 | 920 | 1.2 | ND | 94 | 57 | 0 | 39 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 44 | 0 | 0 | 790 | 27 |
| | Mar-11 | 13.0 | 631 | 1.4 | ND | 97 | 58 | 0 | 32 | 0 | 12 | 12 | 22 | 0 | 0 | 0 | 52 | 0 | 0 | 470 | 31 |
| | Mar-12 | 0.5 | 260 | 0.5 | ND | 8.2 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 13 | 230 | 0 |
| | Mar-13 | 10.0 | 536 | 0.5 | ND | 10 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 510 | 0 |
| **RI-32S** | | | | | | | | | | | | | | | | | | | | | |
| | Jan-98 | 120.0 | 3340 | 8.6 | 480 | 250 | 690 | 0 | 820 | 1700 | 0 | 0 | 150 | 0 | 0 | 0 | 140 | 0 | 190 | 100 | 240 |
| | Jan-99 | 180.0 | 6870 | 16.0 | 230 | 230 | 490 | 0 | 3100 | 3100 | 0 | 200 | 0 | 0 | 140 | 0 | 190 | 0 | 140 | 0 | 0 |
| | Jan-00 | 110.0 | 3980 | 0.1 | 390 | 260 | 670 | 0 | 810 | 1400 | 140 | 110 | 360 | 0 | 0 | 0 | 400 | 0 | 320 | 160 | 280 |
| | Feb-01 | 59.0 | 451 | 10.0 | 210 | 210 | 540 | 0 | 180 | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 71 | 0 | 0 | 0 | 0 |
| | Feb-02 | 75.0 | 4522 | 7.1 | 230 | 250 | 610 | 0 | 540 | 2800 | 97 | 120 | 170 | 0 | 200 | 0 | 270 | 0 | 270 | 55 | 0 |
| | Feb-03 | 65.0 | 2614 | 7.0 | 250 | 250 | 600 | 0 | 170 | 1200 | 0 | 0 | 200 | 85 | 75 | 0 | 71 | 0 | 160 | 53 | 0 |
| | Feb-04 | 83.0 | 350 | 10.0 | 240 | 210 | 540 | 0 | 0 | 110 | 0 | 0 | 0 | 0 | 0 | 0 | 110 | 0 | 130 | 0 | 0 |
| | Mar-05 | 58.0 | 748 | 8.7 | 180 | 220 | 510 | 0 | 82 | 69 | 12 | 10 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 540 | 0 |
| | Mar-06 | 48.0 | 2598 | 7.3 | 250 | 300 | 790 | 0 | 130 | 190 | 0 | 0 | 150 | 56 | 0 | 0 | 210 | 62 | 270 | 1200 | 330 |
| | Mar-07 | 66.0 | 3733 | 4.0 | 130 | 150 | 310 | 0 | 480 | 710 | 530 | 69 | 840 | 84 | 160 | 0 | 290 | 0 | 240 | 530 | 0 |
| | Mar-08 | 33.0 | 850 | 4.6 | 150 | 220 | 520 | 0 | 100 | 110 | 0 | 0 | 130 | 0 | 0 | 0 | 160 | 0 | 0 | 220 | 130 |
| | Mar-09 | 26.0 | 2307 | 2.8 | 150 | 200 | 650 | 0 | 63 | 150 | 0 | 0 | 94 | 0 | 0 | 0 | 110 | 0 | 130 | 1500 | 260 |
| | Mar-10 | 19.0 | 1613 | 1.9 | 120 | 230 | 600 | 0 | 65 | 140 | 23 | 0 | 100 | 41 | 0 | 0 | 120 | 44 | 120 | 830 | 130 |
| | Mar-11 | 0.5 | 8410 | 1.1 | 16 | 32 | 140 | 0 | 1500 | 970 | 350 | 0 | 2100 | 1100 | 0 | 0 | 220 | 410 | 450 | 990 | 320 |
| | Mar-12 | 0.5 | 19 | 0.5 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 |
| | Mar-13 | 5.5 | 113 | 1.5 | 5 | 16 | 37 | 0 | 0 | 0 | 0 | 0 | 17 | 11 | 0 | 0 | 18 | 0 | 15 | 52 | 0 |
| **RI-33S** | | | | | | | | | | | | | | | | | | | | | |
| | Jan-98 | 200.0 | 3260 | 9.2 | 750 | 110 | 180 | 0 | 550 | 660 | 100 | 330 | 180 | 0 | 0 | 0 | 1200 | 0 | 260 | 0 | 0 |
| | Jan-99 | 490.0 | 2860 | 13.0 | 450 | 140 | 270 | 0 | 400 | 800 | 200 | 340 | 150 | 0 | 0 | 0 | 580 | 0 | 280 | 130 | 0 |
| | Jan-00 | 94.0 | 1827 | 0.0 | 180 | 170 | 294 | 0 | 95 | 270 | 140 | 310 | 130 | 44 | 15 | 0 | 330 | 0 | 410 | 83 | 0 |
| | Feb-01 | 240.0 | 484 | 32.0 | 72 | 170 | 320 | 0 | 55 | 100 | 0 | 120 | 0 | 0 | 0 | 0 | 110 | 0 | 79 | 0 | 0 |
| | Feb-02 | 530.0 | 3441 | 75.0 | 2800 | 110 | 207 | 0 | 250 | 820 | 120 | 620 | 180 | 55 | 78 | 0 | 790 | 0 | 360 | 110 | 78 |
| | Feb-03 | 310.0 | 1780 | 45.0 | 710 | 110 | 249 | 0 | 170 | 350 | 0 | 530 | 120 | 57 | 0 | 0 | 180 | 0 | 310 | 63 | 0 |
| | Feb-04 | 430.0 | 1010 | 20.0 | 1200 | 110 | 269 | 0 | 100 | 120 | 0 | 430 | 0 | 0 | 0 | 0 | 240 | 0 | 120 | 0 | 0 |
| | Mar-05 | 320.0 | 876 | 14.0 | 980 | 120 | 320 | 0 | 40 | 69 | 11 | 480 | 26 | 0 | 0 | 0 | 100 | 0 | 0 | 170 | 0 |
| | Mar-06 | 390.0 | 2100 | 20.0 | 200 | 110 | 270 | 0 | 190 | 220 | 58 | 550 | 99 | 0 | 0 | 0 | 330 | 0 | 160 | 410 | 83 |
| | Mar-07 | 150.0 | 4861 | 7.1 | 650 | 110 | 380 | 0 | 76 | 110 | 37 | 460 | 76 | 20 | 0 | 0 | 280 | 0 | 0 | 3600 | 0 |
| | Mar-08 | 180.0 | 1014 | 21.0 | 110 | 100 | 260 | 0 | 110 | 110 | 24 | 390 | 43 | 13 | 0 | 17 | 170 | 0 | 86 | 51 | 0 |
| | Mar-09 | 120.0 | 2323 | 12.0 | 96 | 110 | 350 | 0 | 72 | 110 | 28 | 950 | 49 | 18 | 0 | 0 | 210 | 0 | 80 | 740 | 68 |
| | Mar-10 | 76.0 | 1783 | 6.7 | 98 | 43 | 250 | 0 | 73 | 110 | 29 | 860 | 45 | 17 | 0 | 27 | 140 | 10 | 64 | 380 | 28 |
| | Mar-11 | 100.0 | 994 | 6.2 | 27 | 80 | 230 | 0 | 43 | 83 | 25 | 410 | 48 | 14 | 0 | 0 | 150 | 0 | 0 | 190 | 31 |
| | Mar-12 | 14.0 | 405 | 2.6 | 44 | 100 | 250 | 0 | 38 | 23 | 23 | 110 | 43 | 30 | 0 | 0 | 83 | 0 | 55 | 0 | 0 |
| | Mar-13 | 20.0 | 587 | 2.7 | 8.9 | 33 | 55 | 0 | 13 | 17 | 24 | 160 | 30 | 20 | 0 | 0 | 75 | 0 | 28 | 220 | 0 |

Notes: Non-detect is indicated by 0.5 ug/L for benzene, 0 for pyridines, 0.5 for ammonia and ND for other compounds

## FTP Area Sparge Data - Inject in SP-33

| Date | Time | Compressor psi | Spool psi | Temp | Anameter SCFM | Wellhead PSI | RI-33 WL | RI-33 DO | RI-33S Temp | RI-32 WL | RI-32 DO | RI-32S Temp | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/4/2013 | initial cond | 0 | 0 | 0 | 0 | 0 | 20.65 | 0.14 | 15.9 | 22.32 | 0.69 | 16.8 | |
| 3/5/2013 | start up | 52 | 54 | 75 | | 11.5 | | | | | | | |
| | | | | | | | | | | | | | |
| 3/8/2013 | 1432 | 46 | 50 | 68 | | 11 | | 0.48 | 16.5 | | 0.7 | 16.9 | |
| 3/8/2013 | 1435 | 55 | 60 | 66 | | 11 | | | | | | | |
| 3/8/2013 | | | | | | | | | | | | | |
| 3/11/2013 | 1243 | 62 | 62 | 58 | 17 | 11 | | 0.45 | 16.2 | | 0.66 | 17 | add flow meter, turn down |
| 3/11/2013 | 1247 | 49 | | | 17 | | | | | | | | |
| 3/11/2013 | 1250 | 50 | 50 | 60 | 15 | | | | | | | | |
| 3/11/2013 | 1253 | 56 | 57 | 60 | 15 | | | | | | | | |
| 3/20/2013 | 1545 | 75 | 64 | 46 | 16.5 | 11 | | | | | | | |
| 3/28/2013 | 1030 | 48 | 48 | 50 | 16 | 11 | | 0.67 | 17.1 | | 0.63 | 16.7 | |
| 3/28/2013 | 1047 | 48 | 48 | 53 | 16 | 11 | | | | | | | |
| 4/5/2013 | | | | | | | | | | | | | off on arrival, added oil |
| 4/12/2013 | 1350 | 70 | 69 | 60 | 15 | 9 | 21.11 | 0.75 | 17.4 | | 0.7 | 17.3 | |
| 4/22/2013 | 1035 | 70 | 70 | 70 | 14.5 | 10 | 19.56 | 0.65 | 17.3 | 21.04 | 0.72 | 16.4 | |
| 5/2/2013 | 935 | 65 | 62 | 78 | 15 | 10.5 | | | | | | | |
| 5/10/2013 | 1225 | 42 | 40 | 70 | 15 | 11.5 | 19.01 | 1.05 | 17.1 | 21.54 | 0.95 | 16.4 | |
| 5/21/2013 | 1151 | 79 | 78 | 97 | 14.5 | 9.5 | 19.07 | 5.4 | 17 | 21.56 | 1.1 | 16.2 | can hear high bubble flow at RI-33S |
| 5/29/2013 | 14:35 | 45 | 43 | 83 | 14 | 10 | | | | | | | |
| 6/4/2013 | 10:15 | shut down for pole removal | | | 0 | 0 | 19.19 | 3.95 | 16.9 | 21.53 | 0.82 | 16 | |
| 8/30/2013 | Moved compresosor from FTP to South sump. Need electrical. | | | | | | | | | | | | |
| 9/15/2013 | Electrical hook up from the sump to the compressor established. Need clearance from Hanwha to extend air line to FTP area. | | | | | | | | | | | | |

## FTP Sparging

### Injecting at SP31

| Date | time | orifice plate pressure (in H2O) | pressure (psi) | temp (deg F) | calculated flowrate (scfm) | AS wellhead pressure (psi) |
|---|---|---|---|---|---|---|
| 8/28/2008 | 9:55 | 0 | 116 | 82 | 0.00 | 5 |
| 8/28/2008 | 9:55 | 0 | 116 | 81 | 0.00 | 9.5 |
| 8/28/2008 | 9:55 | 0 | 116 | 80 | 0.00 | 10 |
| 8/28/2008 | 10:00 | 0 | 115 | 80 | 0.00 | 12.5 |
| 8/28/2008 | 10:00 | 0.1 | 117 | 80 | 1.91 | 15.5 |
| 8/28/2008 | 10:00 | 0.5 | 115 | 81 | 4.24 | 19.2 |
| 8/28/2008 | 10:00 | 0.55 | 111 | 82 | 4.36 | 17.2 |
| 8/28/2008 | 10:06 | 0.75 | 111 | 83 | 5.09 | 17 |
| 8/28/2008 | 10:15 | 0.8 | 111 | 84 | 5.25 | 16 |
| 8/28/2008 | 10:18 | 0.85 | 111 | 85 | 5.41 | 15.9 |
| 8/28/2008 | 10:28 | 0.8 | 111 | 86 | 5.24 | 14.9 |
| 8/28/2008 | 10:33 | 0.75 | 111 | 87 | 5.07 | 14.4 |
| 8/28/2008 | 10:39 | 0.75 | 111 | 87 | 5.07 | 14.4 |
| 8/28/2008 | 10:58 | 0.8 | 111 | 92 | 5.21 | 13.6 |
| 8/28/2008 | 11:22 | 0.85 | 111 | 94 | 5.36 | 13.4 |
| 8/28/2008 | 11:44 | 0.75 | 111 | 94 | 5.04 | 12.5 |
| 8/28/2008 | 12:09 | 0.75 | 111 | 93 | 5.04 | 12.4 |
| 8/28/2008 | 12:13 | 1 | 111 | 93 | 5.82 | 13.2 |
| 8/28/2008 | 12:13 | 2 | | | | 16.5 |
| 8/28/2008 | 12:13 | 3 | 108 | 95 | 9.93 | 18.5 |
| 8/28/2008 | 12:15 | 3.5 | 107 | 96 | 10.67 | 19.2 |
| 8/28/2008 | 12:16 | 4 | 107 | 97 | 11.39 | 19.6 |
| 8/28/2008 | 12:16 | 4.8 | 107 | 100 | 12.44 | 20 |
| 8/28/2008 | 12:24 | 5.3 | 108 | 114 | 12.98 | 19.4 |
| 8/28/2008 | 12:32 | 5.3 | 108 | 116 | 12.95 | 19 |
| 8/28/2008 | 12:50 | 5.3 | 108 | 117 | 12.94 | 18.1 |
| 8/28/2008 | 13:35 | 5.3 | 108 | 116 | 12.95 | 18 |
| 8/28/2008 | 14:03 | 5.4 | 108 | 116 | 13.07 | 18 |
| 8/28/2008 | 14:23 | 10.5 | 105 | 117 | 17.95 | 22 |
| 8/28/2008 | 14:28 | 12.5 | 105 | 117 | 19.58 | 23.1 |
| 8/28/2008 | 14:30 | 16 | 104 | 119 | 22.00 | 25.1 |
| 8/28/2008 | 14:31 | 20.5 | 103 | 122 | 24.71 | 26.9 |
| 8/28/2008 | 14:35 | 22.5 | 102 | 125 | 25.69 | 27.5 |
| 8/28/2008 | 14:40 | 23 | 102 | 127 | 25.92 | 27.5 |
| 8/28/2008 | 14:45 | 23 | 103 | 129 | 26.01 | 27.2 |
| 8/28/2008 | 15:03 | 24.5 | 103 | 130 | 26.82 | 27.1 |
| 8/28/2008 | 15:23 | 23.5 | 102 | 130 | 26.14 | 26.6 |
| 8/28/2008 | 15:45 | 24 | 102 | 130 | 26.41 | 26.6 |
| 8/28/2008 | 16:05 | 24 | 102 | 130 | 26.41 | 26.6 |
| 8/28/2008 | 16:27 | 24.5 | 102 | 130 | 26.68 | 26.8 |
| 8/28/2008 | 16:30 | 21 | 104 | 128 | 25.00 | 25 |
| 8/28/2008 | 16:34 | 19 | 104 | 127 | 23.80 | 23.9 |
| 8/28/2008 | 16:38 | 17 | 105 | 126 | 22.65 | 22.5 |
| 8/28/2008 | 16:43 | 15 | 105 | 125 | 21.30 | 21.3 |
| 8/28/2008 | 16:47 | 13 | 106 | 123 | 19.96 | 19.9 |
| 8/28/2008 | 16:50 | 11 | 107 | 122 | 18.47 | 18.6 |
| 8/28/2008 | 16:54 | 9 | 107 | 120 | 16.74 | 17.1 |
| 8/28/2008 | 16:57 | 7 | 108 | 117 | 14.87 | 15.6 |
| 8/28/2008 | 17:03 | 5 | 109 | 114 | 12.66 | 14.4 |
| 8/28/2008 | 17:05 | 3 | 110 | 113 | 9.86 | 12.5 |
| 8/28/2008 | 17:08 | 1 | 112 | 110 | 5.76 | 10 |
| 8/28/2008 | 17:08 | 0.5 | 113 | 108 | 4.10 | 9 |

Note: Sparge operation and measurements performed by K. Might

**FTP Sparging**

**Injecting at Sparge Point SP32  10 feet west of Well RI-32S**

| Date | Time | Orifice plate pressure (in H2O) | Spool pressure (psig) | Spool temp (deg F) | Calculated Flow Rate (SCFM) | Wellhead pressure (psig) |
|---|---|---|---|---|---|---|
| 8/27/2008 | 8:30 | 1 | 110 | 68 | 5.93 | 7.4 |
| 8/27/2008 | 8:31 | 0.9 | 110 | 68 | 5.63 | 7 |
| 8/27/2008 | 8:35 | 0.9 | 111 | 69 | 5.65 | 7.2 |
| 8/27/2008 | 8:38 | 0.7 | 111 | 69 | 4.98 | 7 |
| 8/27/2008 | 8:41 | 0.7 | 110 | 70 | 4.95 | 7 |
| 8/27/2008 | 8:51 | 0.7 | 110 | 72 | 4.95 | 7 |
| 8/27/2008 | 9:01 | 0.7 | 111 | 72 | 4.97 | 7 |
| 8/27/2008 | 9:02 | 0.75 | 112 | 73 | 5.16 | 7 |
| 8/27/2008 | 9:03 | 0.75 | 112 | 73 | 5.16 | 7 |
| 8/27/2008 | 9:13 | 0.75 | 112 | 75 | 5.15 | 7 |
| 8/27/2008 | 9:51 | 0.58 | 112 | 82 | 4.50 | 6.6 |
| 8/27/2008 | 9:52 | 0.7 | 112 | 82 | 4.94 | 6.6 |
| 8/27/2008 | 10:04 | 0.8 | 112 | 82 | 5.29 | 6.6 |
| 8/27/2008 | 10:25 | 0.8 | 112 | 87 | 5.26 | 6.5 |
| 8/27/2008 | 10:38 | 2.9 | 112 | 94 | 9.95 | 6.6 |
| 8/27/2008 | 10:40 | 2.9 | 112 | 94 | 9.95 | 6.6 |
| 8/27/2008 | 10:43 | 2.9 | 112 | 97 | 9.92 | 6.6 |
| 8/27/2008 | 11:00 | 2.4 | 112 | 106 | 8.96 | 6 |
| 8/27/2008 | 11:19 | 2.3 | 110 | 108 | 8.67 | 5.6 |
| 8/27/2008 | 11:20 | 3 | 110 | 108 | 9.91 | 6 |
| 8/27/2008 | 11:35 | 2.9 | 108 | 110 | 9.63 | 6 |
| 8/27/2008 | 11:40 | 3.1 | 108 | 110 | 9.96 | 6 |
| 8/27/2008 | 12:16 | 2.7 | 109 | 113 | 9.31 | 5.5 |
| 8/27/2008 | 12:35 | 3.2 | 108 | 116 | 10.07 | 5.5 |
| 8/27/2008 | 12:41 | 5.3 | 107 | 117 | 12.88 | 5.9 |
| 8/27/2008 | 12:46 | 5.3 | 108 | 118 | 12.93 | 5.6 |
| 8/27/2008 | 12:49 | 5.3 | 108 | 119.5 | 12.91 | 5.6 |
| 8/27/2008 | 13:26 | 5.3 | 108 | 116 | 12.95 | 6 |
| 8/27/2008 | 14:25 | 4.4 | 108 | 122 | 11.74 | 5.5 |
| 8/27/2008 | 14:33 | 5.3 | 108 | 120 | 12.91 | 5.5 |
| 8/27/2008 | 15:04 | 5.3 | 108 | 115 | 12.96 | 6 |
| 8/27/2008 | 15:20 | 5 | 108 | 120 | 12.54 | 6 |
| 8/27/2008 | 15:24 | 4.5 | 108 | 120 | 11.89 | 5.8 |
| 8/27/2008 | 15:27 | 4 | 108 | 120 | 11.22 | 5.7 |
| 8/27/2008 | 15:29 | 3.5 | 109 | 121 | 10.53 | 5.6 |
| 8/27/2008 | 15:31 | 3 | 109 | 120 | 9.76 | 5.5 |
| 8/27/2008 | 15:33 | 2.5 | 110 | 120 | 8.95 | 5.5 |
| 8/27/2008 | 15:35 | 2 | 110 | 120 | 8.01 | 5.5 |
| 8/27/2008 | 15:37 | 1.5 | 111 | 118 | 6.98 | 5.4 |
| 8/27/2008 | 15:39 | 1 | 112 | 117 | 5.73 | 5.1 |
| 8/27/2008 | 15:41 | 0.5 | 112 | 115 | 4.06 | 5 |

Note:  Sparge operation and measurements performed by K. Might

**FTP Sparging**

**Injecting at SP33**

| Date | time | orifice plate pressure (in H2O) | pressure (psi) | temp (deg F) | calculated flowrate (scfm) | pressure (psi) |
|---|---|---|---|---|---|---|
| 8/29/2008 | 8:48 | 1 | 111 | 80 | 5.89 | 7.8 |
| 8/29/2008 | 8:50 | 1 | 112 | 80 | 5.92 | 8 |
| 8/29/2008 | 8:55 | 1 | 112 | 80 | 5.92 | 7.7 |
| 8/29/2008 | 9:00 | 0.9 | 112 | 80 | 5.62 | 7.6 |
| 8/29/2008 | 9:05 | 0.9 | 112 | 81 | 5.61 | 7.6 |
| 8/29/2008 | 9:10 | 0.8 | 112 | 81 | 5.29 | 7.5 |
| 8/29/2008 | 9:15 | 0.8 | 112 | 82 | 5.29 | 7.5 |
| 8/29/2008 | 9:22 | 0.7 | 112 | 80.5 | 4.95 | 7.6 |
| 8/29/2008 | 10:04 | 0.7 | 112 | 80 | 4.95 | 7.6 |
| 8/29/2008 | 10:27 | 0.75 | 112 | 82 | 5.12 | 7.5 |
| 8/29/2008 | 10:42:00 | 0.5 | 113 | 87 | 4.18 | 7.2 |
| 8/29/2008 | 10:45 | 5 | 109 | 88 | 12.96 | 8.1 |
| 8/29/2008 | 10:47 | 5.1 | 107 | 88 | 12.97 | 7.7 |
| 8/29/2008 | 10:50 | 5 | 108 | 89 | 12.89 | 7.5 |
| 8/29/2008 | 10:55 | 5.2 | 108 | 93 | 13.09 | 7.5 |
| 8/29/2008 | 11:00 | 5 | 108 | 95 | 12.82 | 7.4 |
| 8/29/2008 | 11:10 | 5.5 | 108 | 98 | 13.41 | 7.4 |
| 8/29/2008 | 11:48 | 5.1 | 108 | 104 | 12.84 | 7 |
| 8/29/2008 | 12:16 | 5.4 | 108 | 108 | 13.17 | 7 |
| 8/29/2008 | 12:30 | 5.1 | 108 | 109 | 12.78 | 6.8 |
| 8/29/2008 | 12:44 | 5.5 | 108 | 109 | 13.28 | 6.9 |
| 8/29/2008 | 12:45 | 25 | 100 | 110 | 27.15 | 8.1 |
| 8/29/2008 | 12:47 | 23 | 103 | 112 | 26.39 | 8 |
| 8/29/2008 | 12:50 | 23.5 | 102 | 114 | 26.50 | 8 |
| 8/29/2008 | 12:55 | 23.5 | 102 | 119 | 26.38 | 7.8 |
| 8/29/2008 | 13:00 | 22.5 | 103 | 124 | 25.83 | 7.5 |
| 8/29/2008 | 13:05 | 24.2 | 101 | 122 | 26.57 | 7.7 |
| 8/29/2008 | 13:10 | 24.5 | 101 | 124 | 26.69 | 7.6 |
| 8/29/2008 | 13:47 | 23 | 102 | 125 | 25.97 | 6.4 |
| 8/29/2008 | 14:03 | 25 | 101 | 124 | 26.96 | 7.5 |
| 8/29/2008 | 14:14 | 24.5 | 102 | 125 | 26.80 | 7.5 |
| 8/29/2008 | 14:40 | 22.5 | 102 | 128 | 25.62 | 7.1 |
| 8/29/2008 | 14:46 | 24 | 102 | 126 | 26.50 | 7.5 |
| 8/29/2008 | 14:49 | 22 | 102 | 125 | 25.40 | 7.4 |
| 8/29/2008 | 14:51 | 19.5 | 104 | 125 | 24.15 | 7.3 |
| 8/29/2008 | 14:55 | 15.5 | 104 | 126 | 21.53 | 7.1 |
| 8/29/2008 | 14:58 | 13 | 105 | 127 | 19.80 | 7 |
| 8/29/2008 | 15:01 | 10 | 107 | 125 | 17.56 | 6.9 |
| 8/29/2008 | 15:03 | 7.8 | 107 | 125 | 15.52 | 6.8 |
| 8/29/2008 | 15:06 | 6.8 | 108 | 124 | 14.57 | 6.6 |
| 8/29/2008 | 15:09 | 4.9 | 109 | 109 | 12.59 | 6.5 |
| 8/29/2008 | 15:13 | 2.4 | 110 | 110 | 8.85 | 6.5 |
| 8/29/2008 | 15:17 | 1 | 111 | 111 | 5.73 | 6.3 |
| 8/29/2008 | 15:19 | 0.3 | 112 | 112 | 3.15 | 6.1 |
| 8/29/2008 | 15:20 | 0 | 0 | 0 | 0.00 | 5.4 |

Note: Sparge operation and measurements performed by K. Might

**R1-31S**

| Sparge Point being tested | Time | Target Flow Rate (scfm) | DTW (ft btoc) | DO (mg/L) | Instrument | DO (mg/L) | Redox (mV) | Instrument | purge flow rate liters per min | purge back pressure (in H2O) | O2 (%) | CO2 (%) | CH4 (%) | PID (ppm) | TCVs (ppm) | Air Pressure (in H20) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **August 26, 2008** | | | | | | | | | | | | | | | | |
| none | 13:48 | baseline | 22.62 | 1.64 | YSI 55 | | | | | | 6.2 | 5 | 0 | nm | 0 | nm |
| **August 27, 2008** | | | | | | | | | | | | | | | | |
| SP-32 | 9:45 | 5 | 22.62 | 0.26 | YSI 55 | | | | 15 | 2.5 | 4.1 | 5 | 0 | nm | 0 | 0 |
| SP-32 | 11:15 | 10 | 22.65 | 0.38 | YSI 55 | | | | 15.5 | 6.5 | 12.7 | 5 | 0 | nm | 210 | 0 |
| SP-32 | 12:13 | 10 | 22.64 | 0.35 | YSI 55 | | | | 15 | 3 | 4.4 | 5 | 0 | nm | 140 | 0 |
| SP-32 | 14:22 | 13 | 22.64 | 0.36 | YSI 55 | | | | 14 | 3.5 | 9.8 | 5 | 0 | nm | 0 | 0 |
| SP-32 | 14:48 | 13 | nm | | | 0.42 | 51.3 | YSI 600 | | | nm | nm | nm | nm | nm | nm |
| **August 28, 2008** | | | | | | | | | | | | | | | | |
| none | 9:00 | baseline | 22.69 | 0.23 | YSI 55 | | | | 16 | 3 | 4.3 | 5 | 0 | nm | 280 | nm |
| | 9:28 | baseline | | | | 0.68 | 80.8 | YSI 600 | | | | | | | | |
| SP-31 | 10:52 | 5 | 22.61 | 0.24 | YSI 55 | | | | 15 | 3 | 5 | 5 | 0.5 | nm | 170 | nm |
| SP-31 | 11:16 | 5 | | | | 0.46 | 13.7 | YSI 600 | | | | | | | | |
| SP-31 | 12:47 | 13 | 22.56 | 0.25 | YSI 55 | | | | 15.5 | 3.5 | 5.1 | 5 | 1 | nm | 2950 | 0.1 |
| SP-31 | 13:06 | 13 | | | | 0.88 | 4 | YSI 600 | | | | | | | | |
| SP-31 | 14:55 | 26 | 22.53 | 3.65 | YSI 55 | | | | 15 | 3.5 | 12.8 | 5 | 1 | nm | 5700 | 0.28 |
| SP-31 | 15:25 | 26 | | | | 8.07 | 72 | YSI 600 | | | | | | | | |
| SP-31 | 16:09 | 26 | 22.62 | 6.39 | YSI 55 | | | | 15 | 3 | 14.2 | 5 | 1 | nm | 7200 | 0.26 |
| SP-31 | 16:25 | 26 | | | | 9.18 | 78.2 | YSI 600 | | | | | | | | |
| **August 29, 2008** | | | | | | | | | | | | | | | | |
| none | 8:19 | baseline | 22.73 | 1.98 | YSI 55 | | | | 16 | 3.5 | 14 | 5 | 0 | nm | 1900 | nm |
| | 8:40 | baseline | | | | 2.21 | 44.9 | YSI 600 | | | | | | | | |
| SP-33 | 9:52 | 5 | 22.73 | 1.68 | YSI 55 | | | | 15 | 3.5 | 13.4 | 5 | 0 | nm | 1800 | -0.02 |
| SP-33 | 11:38 | 13 | 22.72 | 1.59 | YSI 55 | | | | 15.5 | 3.5 | 13.6 | 5 | 0 | nm | 1510 | 0 |
| SP-33 | 13:39 | 26 | 22.71 | 1.55 | YSI 55 | | | | 1.5 | 3.5 | 13.3 | 5 | 0 | nm | 1300 | 0 |

Note: Sparge operation and measurements performed by K. Might

**R1-32S**

| Sparge Point being tested | Time | Target Flow Rate (scfm) | DTW (ft btoc) | DO (mg/L) | Instrument | DO (mg/L) | Redox (mV) | Instrument | purge flow rate liters per min | purge back pressure (in H2O) | O2 (%) | CO2 (%) | CH4 (%) | PID (ppm) | TCVs (ppm) | Air Pressure (in H20) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **August 26, 2008** | | | | | | | | | | | | | | | | |
| none | 15:10 | baseline | 21.95 | 0.25 | YSI 55 | | | | | | 20.9 | 0.06 | 0 | nm | 0 | nm |
| **August 27, 2008** | | | | | | | | | | | | | | | | |
| SP-32 | 9:10 | 5 | 21.68 | 0.79 | YSI 55 | | | | 18 | >25 | 20.9 | 0 | 0 | nm | 0 | 0 |
| SP-32 | 10:18 | 5 | 21.74 | 2.01 | YSI 55 | | | | 7 | >25 | 20.9 | 0.08 | 0 | nm | 95 | 0 |
| SP-32 | 10:41 | 10 | nm | nm | -- | | | | 6.5 | >25 | nm | nm | nm | nm | nm | 1.35 |
| SP-32 | 11:34 | 10 | 21.67 | 2.94 | YSI 55 | | | | 14.5 | >25 | 20.9 | 0.34 | 0 | nm | 390 | 1.75 |
| SP-32 | 13:41 | 13 | 21.81 | 3.75 | YSI 55 | | | | 15 | >25 | 20.9 | 0.04 | 0 | nm | 30 | 0 |
| SP-32 | 14:04 | 13 | nm | | | 2.03 | -62.3 | YSI 600 | | | nm | nm | nm | nm | nm | nm |
| SP-32 | 15:13 | 13 | 21.75 | | | 3.55 | -47.5 | YSI 600 | | | 20.9 | 0.02 | 0 | nm | 5 | 0.01 |
| **August 28, 2008** | | | | | | | | | | | | | | | | |
| none | 9:19 | baseline | 21.87 | 1.05 | YSI 55 | | | | 15 | >25 | 20.9 | 0.18 | 0 | nm | 300 | nm |
| none | 9:48 | baseline | | | | 0.3 | -80.6 | YSI 600 | | | | | | | | |
| SP-31 | 11:11 | 5 | 21.94 | 0.77 | YSI 55 | | | | 14.5 | >25 | 20.9 | 0.04 | 0 | nm | 75 | 0.24 |
| SP-31 | 11:38 | 5 | | | | 0.58 | -54.2 | YSI 600 | | | | | | | | |
| SP-31 | 13:11 | 13 | 21.98 | 0.68 | YSI 55 | | | | 8 | >25 | 20.9 | 0.1 | 0 | nm | 110 | 0.45 |
| SP-31 | 13:31 | 13 | | | | 0.76 | -56.8 | YSI 600 | | | | | | | | |
| SP-31 | 15:14 | 26 | 21.84 | 0.38 | YSI 55 | | | | 8 | >25 | 20.9 | 0.06 | 0 | nm | 40 | 0.04 |
| SP-31 | 15:42 | 26 | | | | 0.27 | -75.1 | YSI 600 | | | | | | | | |
| **August 29, 2008** | | | | | | | | | | | | | | | | |
| none | 8:07 | baseline | 21.81 | 0.2 | YSI 55 | | | | | | | | | | | |
| none | 8:26 | | | | | 0.32 | -84.5 | YSI 600 | 14 | >25 | 20.9 | 0 | 0 | | 0 | nm |
| SP-33 | 9:35 | 5 | 21.92 | 0.19 | YSI 55 | | | | 7 | >25 | 20.9 | 0.02 | 0 | nm | 30 | 0.02 |
| SP-33 | 11:22 | 13 | 21.89 | 0.22 | YSI 55 | | | | 7 | >25 | 20.9 | 0.02 | 0 | nm | 15 | 0.02 |
| SP-33 | 13:23 | 26 | 21.91 | 0.23 | YSI 55 | | | | 10 | >25 | 20.9 | 0 | 0 | nm | 15 | 0.01 |

Note: Sparge operation and measurements performed by K. Might

**R1-33S**

| Sparge Point being tested | Time | Target Flow Rate (scfm) | DTW (ft btoc) | DO (mg/L) | Instrument | DO (mg/L) | Redox (mV) | Instrument | purge flow rate liters per min | purge back pressure (in H2O) | O2 (%) | CO2 (%) | CH4 (%) | PID (ppm) | TCVs (ppm) | Air Pressure (in H20) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **August 26, 2008** | | | | | | | | | | | | | | | | |
| none | 14:36 | baseline | 19.65 | 0.27 | YSI 55 | | | | | | 20.9 | 0.2 | 0 | nm | 540 | nm |
| **August 27, 2008** | | | | | | | | | | | | | | | | |
| SP-32 | 9:32 | 5 | 19.63 | 0.22 | YSI 55 | | | | 17 | >25 | 20.9 | 0 | 0 | nm | 140 | 0 |
| SP-32 | 10:59 | 10 | 19.62 | 0.24 | YSI 55 | | | | 15 | >25 | 20.9 | 0.02 | 0 | nm | 500 | 0 |
| SP-32 | 12:01 | 10 | 19.63 | 0.24 | YSI 55 | | | | 14 | >25 | 20.9 | 0.04 | 0 | nm | 1150 | 0 |
| SP-32 | 14:04 | 13 | 19.64 | 0.22 | YSI 55 | | | | 13.5 | >25 | 20.9 | 0 | 0 | nm | 150 | 0 |
| SP-32 | 14:24 | 13 | nm | | | 0.26 | -127 | YSI 600 | | | nm | nm | nm | nm | nm | nm |
| **August 28, 2008** | | | | | | | | | | | | | | | | |
| none | 9:40 | baseline | 19.69 | 0.18 | YSI 55 | | | | 10.5 | >25 | 20.9 | 0.12 | 0.5 | nm | 3000 | nm |
| none | 10:15 | baseline | | | | 0.2 | -141.8 | YSI 600 | | | | | | | | |
| SP-31 | 11:34 | 5 | 19.69 | 0.19 | YSI 55 | | | | 9 | >25 | 20.9 | 0.02 | 0 | nm | 430 | nm |
| SP-31 | 12:06 | 5 | | | | 0.12 | -138.8 | YSI 600 | | | | | | | | |
| SP-31 | 13:24 | 13 | 19.68 | 0.22 | YSI 55 | | | | 10 | >25 | 20.9 | 0 | 0 | nm | 40 | 0 |
| SP-31 | 14:07 | 13 | | | | 0.11 | -139.9 | YSI 600 | | | | | | | | |
| SP-31 | 15:38 | 26 | 19.67 | 0.23 | YSI 55 | | | | 10 | >25 | 20.9 | 0 | 0 | nm | 60 | -0.02 |
| SP-31 | 16:00 | 26 | | | | 0.16 | -132.7 | YSI 600 | | | | | | | | |
| **August 29, 2008** | | | | | | | | | | | | | | | | |
| none | 7:43 | baseline | 19.74 | 0.29 | YSI 55 | | | | | | 20.9 | 0.02 | 0 | 270 | nm | |
| none | 7:48 | baseline | | | | 0.35 | -131.6 | YSI 600 | | | | | | | | |
| SP-33 | 8:50 | 5 | | | | 0.33 | -120.9 | YSI 600 | | | | | | | | |
| SP-33 | 8:52 | 5 | | | | 0.26 | -123.7 | YSI 600 | | | | | | | | |
| SP-33 | 9:57 | 5 | | | | 0.44 | -101.8 | YSI 600 | appart | | | | | | | |
| SP-33 | 10:00 | 5 | | | | 0.43 | -101.8 | YSI 600 | | | | | | | | |
| SP-33 | 10:03 | 5 | | | | 0.31 | -109.2 | YSI 600 | | | | | | | | |
| SP-33 | 10:08 | 5 | | | | 0.26 | -116.7 | YSI 600 | | | | | | | | |
| SP-33 | 10:25 | 5 | | | | 0.17 | -126.6 | YSI 600 | | | | | | | | |
| SP-33 | 10:31 | 5 | | | | 0.18 | -128.8 | YSI 600 | | | | | | | | |
| SP-33 | 12:00 | 13 | | | | 0.35 | -88.7 | YSI 600 | | | | | | | | |
| SP-33 | 12:05 | 13 | | | | 0.36 | -90 | YSI 600 | | | | | | | | |
| SP-33 | 12:10 | 13 | | | | 0.37 | -87.9 | YSI 600 | | | | | | | | |
| SP-33 | 12:15 | 13 | | | | 0.27 | -86.5 | YSI 600 | | | | | | | | |
| SP-33 | 12:20 | 13 | | | | 0.22 | -90.1 | YSI 600 | | | | | | | | |
| SP-33 | 12:25 | 13 | | | | 0.29 | -84.6 | YSI 600 | | | | | | | | |
| SP-33 | 12:30 | 13 | | | | 0.33 | -85 | YSI 600 | | | | | | | | |
| SP-33 | 12:35 | 13 | | | | 0.33 | -86.3 | YSI 600 | | | | | | | | |
| SP-33 | 12:40 | 13 | | | | 0.29 | -86.8 | YSI 600 | | | | | | | | |
| SP-33 | 12:45 | 26 | | | | 0.15 | -104.3 | YSI 600 | | | | | | | | |
| SP-33 | 12:50 | 26 | | | | 0.11 | -109.8 | YSI 600 | | | | | | | | |
| SP-33 | 12:55 | 26 | | | | 0.11 | -121.2 | YSI 600 | | | | | | | | |
| SP-33 | 13:00 | 26 | | | | 0.11 | -123.9 | YSI 600 | | | | | | | | |
| SP-33 | 13:05 | 26 | | | | 0.12 | -125.2 | YSI 600 | | | | | | | | |
| SP-33 | 13:10 | 26 | | | | 0.13 | -120 | YSI 600 | | | | | | | | |
| SP-33 | 13:15 | 26 | | | | 0.16 | -116 | YSI 600 | | | | | | | | |
| SP-33 | 13:20 | 26 | | | | 0.67 | -99.2 | YSI 600 | | | | | | | | |
| SP-33 | 13:25 | 26 | | | | 1.24 | -77.8 | YSI 600 | | | | | | | | |
| SP-33 | 13:30 | 26 | | | | 1.49 | -71.9 | YSI 600 | | | | | | | | |
| SP-33 | 13:35 | 26 | | | | 1.68 | -68.7 | YSI 600 | | | | | | | | |
| SP-33 | 13:40 | 26 | | | | 1.99 | -66.1 | YSI 600 | | | | | | | | |
| SP-33 | 13:45 | 26 | | | | 2.14 | -62.8 | YSI 600 | | | | | | | | |
| SP-33 | 13:50 | 26 | | | | 2.21 | -62.1 | YSI 600 | | | | | | | | |
| SP-33 | 13:55 | 26 | | | | 2.26 | -62.1 | YSI 600 | | | | | | | | |
| SP-33 | 14:00 | 26 | | | | 1.95 | -64.8 | YSI 600 | | | | | | | | |
| SP-33 | 14:05 | 26 | | | | 1.65 | -64.8 | YSI 600 | | | | | | | | |
| SP-33 | 14:10 | 26 | | | | 1.77 | -64.4 | YSI 600 | | | | | | | | |
| SP-33 | 14:15 | 26 | | | | 1.98 | -64.8 | YSI 600 | | | | | | | | |
| SP-33 | 14:39 | 26 | | | | 2.17 | -60.7 | YSI 600 | | | | | | | | |
| SP-33 | 14:44 | 26 | | | | 1.55 | -64.7 | YSI 600 | | | | | | | | |
| SP-33 | 14:50 | begin step down | | | | 0.41 | -78.7 | YSI 600 | | | | | | | | |
| SP-33 | 14:54 | | | | | 0.96 | -70.2 | YSI 600 | | | | | | | | |
| SP-33 | 14:57 | | | | | 1.72 | -65.7 | YSI 600 | | | | | | | | |
| SP-33 | 15:00 | | | | | 2.42 | -57.2 | YSI 600 | | | | | | | | |
| SP-33 | 15:02 | | | | | 2.36 | -58.5 | YSI 600 | | | | | | | | |
| SP-33 | 15:05 | | | | | 2 | -63.8 | YSI 600 | | | | | | | | |
| SP-33 | 15:08 | | | | | 1.76 | -67 | YSI 600 | | | | | | | | |
| SP-33 | 15:12 | | | | | 1.55 | -68.9 | YSI 600 | | | | | | | | |
| SP-33 | 15:16 | | | | | 1.36 | -68 | YSI 600 | | | | | | | | |
| SP-33 | 15:21 | | | | | 1.1 | -68.7 | YSI 600 | | | | | | | | |
| SP-33 | 15:35 | | | | | 0.68 | -67.8 | YSI 600 | | | | | | | | |
| SP-33 | 15:47 | | | | | 0.17 | -63.4 | YSI 600 | | | | | | | | |
| SP-33 | 16:03 | | | | | 0.13 | -72.8 | YSI 600 | | | | | | | | |
| SP-33 | 16:13 | | | | | 0.13 | -80.4 | YSI 600 | | | | | | | | |

Note: Sparge operation and measurements performed by K. Might

## FTP Sparging

| Date | Sparge Point Being Tested | time | SP31 Pressure (in H2O) |
|---|---|---|---|
| 8/27/2008 | SP32 | 9:36 | 0 |
| 8/27/2008 | SP32 | 11:05 | 0.03 |
| 8/27/2008 | SP32 | 12:05 | 0.12 |
| 8/27/2008 | SP32 | 14:12 | 0.16 |
| | | | |
| 8/29/2008 | SP33 | 9:45 | 0.01 |
| 8/29/2008 | SP33 | 11:32 | 0.05 |
| 8/29/2008 | SP33 | 13:33 | 0.14 |

| Date | Sparge Point Being Tested | time | SP32 Pressure (in H2O) |
|---|---|---|---|
| 8/28/2008 | SP31 | 11:04 | 0.26 |
| 8/28/2008 | SP31 | 12:55 | 0.51 |
| 8/28/2008 | SP31 | 15:08 | -0.98 |
| 8/28/2008 | SP31 | 16:07 | -0.5 |
| | | | |
| 8/29/2008 | SP33 | 9:26 | 0.02 |
| 8/29/2008 | SP33 | 11:15 | 0.21 |
| 8/29/2008 | SP33 | 13:16 | 0.39 |

| Date | Sparge Point Being Tested | time | SP33 Pressure (in H2O) |
|---|---|---|---|
| 8/27/2008 | SP32 | 9:16 | 0.22 |
| 8/27/2008 | SP32 | 10:50 | 0.32 |
| 8/27/2008 | SP32 | 11:52 | 0.32 |
| 8/27/2008 | SP32 | 13:56 | 0.155 |
| | | | |
| 8/28/2008 | SP31 | 9:37 | 0.08 |
| 8/28/2008 | SP31 | 11:28 | 0.18 |
| 8/28/2008 | SP31 | 13:20 | 0.24 |
| 8/28/2008 | SP31 | 15:30 | 0.26 |
| 8/28/2008 | SP31 | 16:20 | 0.1 |

Note: Sparge operation and measurements performed by K. Might

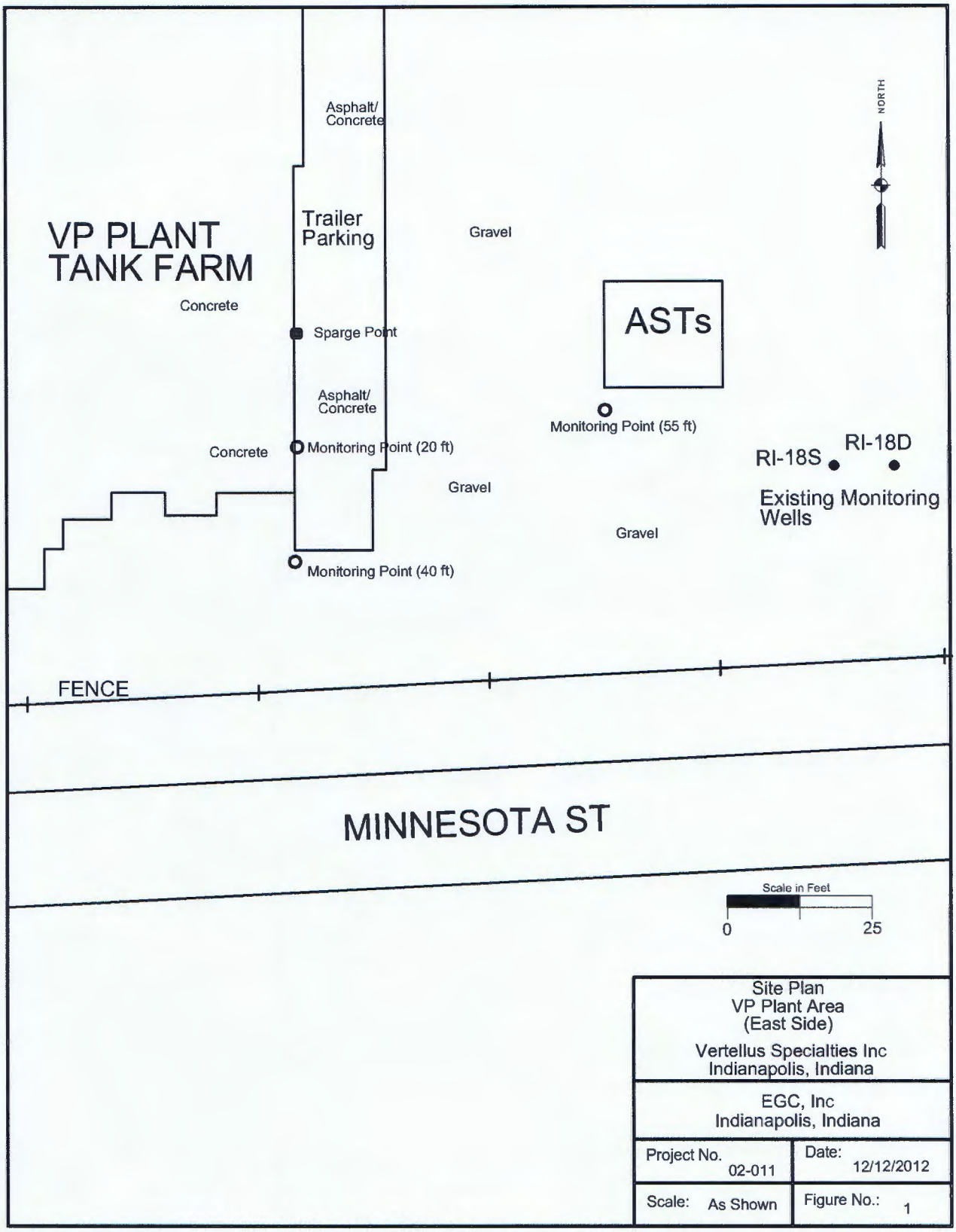
# FTP Area Sparge - Inject near RI-33S

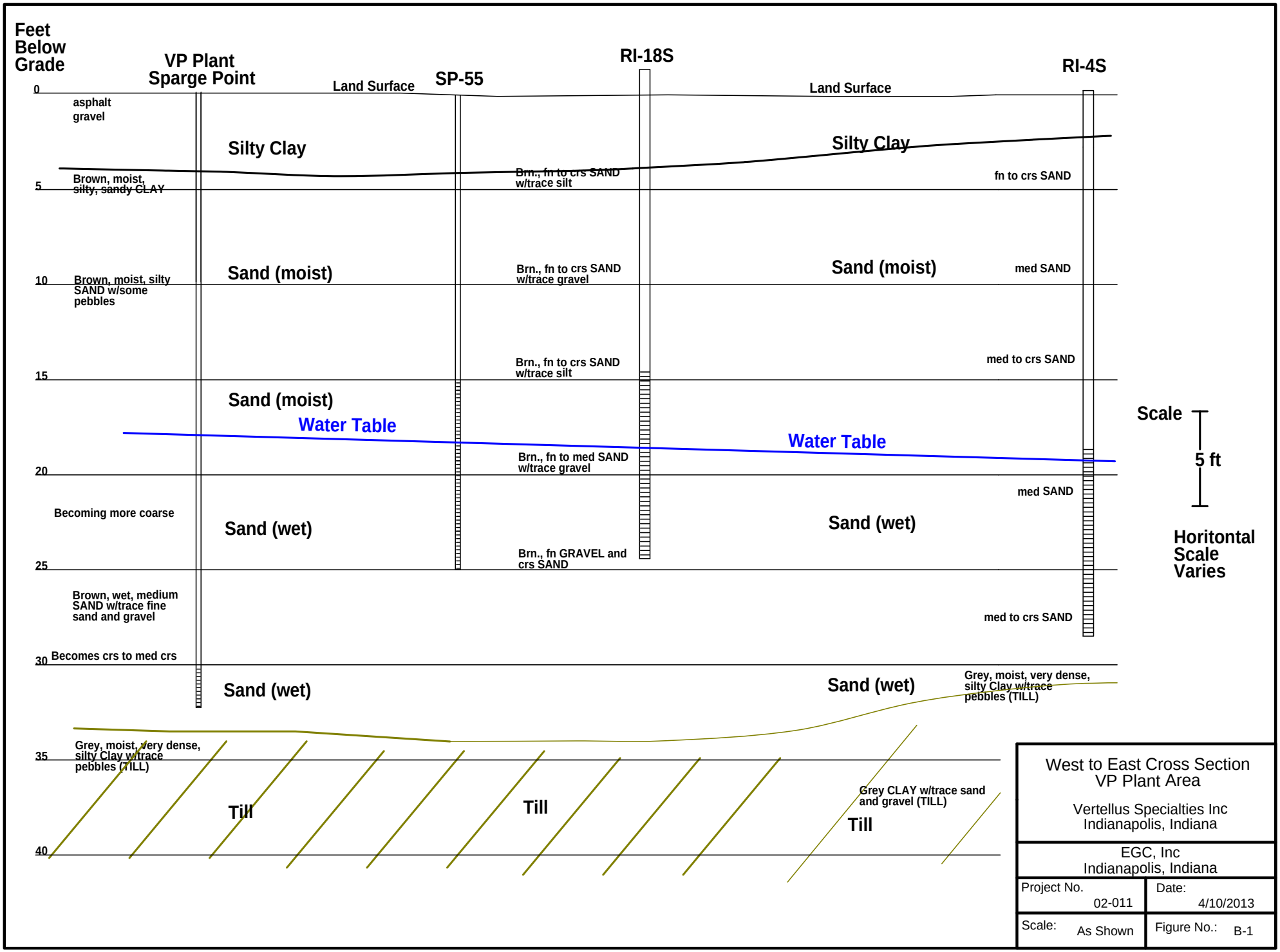
| Date | Time | Compressor psi | Spool psi | Temp | SCFM | Wellhead PSI | RI-33 WL | RI-33 DO | RI-33S Temp | RI-32 WL | RI-32 DO | RI-32S Temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/4/2013 | initial condi | 0 | 0 | 0 | 0 | 0 | 20.65 | 0.14 | 15.9 | | | |
| 3/5/2013 | start up | 52 | 54 | 75 | | 11.5 | | | | | | |
| 3/8/2013 | 1432 | 46 | 50 | 68 | | 11 | | | | | | |
| 3/8/2013 | 1435 | 55 | 60 | 66 | | 11 | | | | | | |
| 3/11/2013 | 1243 | 62 | 62 | 58 | 17 | 11 | | 0.45 | 16.2 | | | |
| 3/11/2013 | 1247 | 49 | | | 17 | | | | | | | |
| 3/11/2013 | 1250 | 50 | 50 | 60 | 15 | | | | | | | |
| 3/11/2013 | 1253 | 56 | 57 | 60 | 15 | | | | | | | |
| 3/20/2013 | 1545 | 75 | 64 | 46 | 16.5 | 11 | | | | | | |
| 3/28/2013 | 1030 | 48 | 48 | 50 | 16 | 11 | | 0.67 | 17.1 | | | |
| 3/28/2013 | 1047 | 48 | 48 | 53 | 16 | 11 | | | | | | |
| 4/12/2013 | 1350 | 70 | 69 | 60 | 15 | 9 | 21.11 | 0.75 | 17.4 | | 0.59 | 17.3 |
| 4/22/2013 | 1035 | 70 | 70 | 70 | 14.5 | 10 | 19.56 | 0.65 | 17.3 | | | |
| 5/2/2013 | 935 | 65 | 62 | 78 | 15 | 10.5 | | | | | | |
| 5/10/2013 | 1225 | 42 | 40 | 70 | 15 | 11.5 | 19.01 | 0.83 | 17.1 | 21.54 | 0.53 | 16.4 |
| 5/21/2013 | 1151 | 79 | 78 | 97 | 14.5 | 9.5 | 19.07 | 5.4 (Bubbles) | 17 | 21.56 | 0.52 | 16.2 |
| 5/29/2013 | 14:35 | 45 | 43 | 83 | 14 | 10 | | | | | | |
| 6/4/2013 | 10:15 | shut down at 8AM for pole removal | | | 0 | 0 | 19.19 | 0.68 | 16.9 | | | |

Note: Sparge operation and measurements performed by K. Might

**Attachment 2**

**Vinyl Pyridine (VP) Plant Area Test Data**


VP PLANT
TANK FARM
Concrete
Asphalt/
Concrete
Trailer
Parking
Gravel
Sparge Point
Asphalt/
Concrete
Concrete
Monitoring Point (20 ft)
Monitoring Point (40 ft)
Gravel
ASTs
Monitoring Point (55 ft)
Gravel
RI-18S
RI-18D
Existing Monitoring
Wells
NORTH
FENCE
MINNESOTA ST
Scale in Feet
0
25
Site Plan
VP Plant Area
(East Side)
Vertellus Specialties Inc
Indianapolis, Indiana
EGC, Inc
Indianapolis, Indiana
Project No. 02-011
Date: 12/12/2012
Scale: As Shown
Figure No.: 1




West to East Cross Section
VP Plant Area

Vertellus Specialties Inc
Indianapolis, Indiana

EGC, Inc
Indianapolis, Indiana

| Project No. | Date: |
|---|---|
| 02-011 | 4/10/2013 |
| Scale: As Shown | Figure No.: B-1 |

ENSR

# BORING LOG

Sheet 1 of 3

Project No. 5660-003-012 Date - Start 6/22/90 Finish 6/23/90 Boring BI-18

Project Name REILLY INDUSTRIES SITE Drilling Co ATEC ASSOC.

Location INDIANAPOLIS , INDIANA Drilling Method 3 3/8 AUGER

Total Depth 94.6' Inspector L. S. EICKHOFF Reviewer L. SCHALCH EICKHOFF

Remarks

| Depth Feet | Sample Type & No. | Blows per 6 in. | Depth Range | Rec. | HNU Read. | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 5 | S-1 | 2-1-6 | 3.5-5' | 8" | 0 | M Br. VF-C sand, some VF-F gravel, tr. silt. no odor. Dry Fill. | 0 |
| 10 | S-2 | 12-13-21 | 8.5-10' | 7" | 0 | Tan-Br. VF-M gravel and VF-VC sand, tr. C gravel (rounded). Fill | .4 |
| 15 | S-3 | 8-11-11 | 13.5-15' | 10" | 0 | M. Br. VF-C sand, some VF-F gravel, tr. silt. Fill. No odor. | .8 |
| 20 | S-4 | 12-13-21 | 18.5-20' | 8" | 0. | Moist, M-Light Br. -Tan F-M sand, little F-M gravel, little-tr. C. gravel. No odor | 65 |
| 25 | S-5 | 11-12-13 | 23.5-25' | 8" | 0 | WET SPOON , Dk. grey-Br. VF-F gravel and M-VC sand, tr. M-C gravel, little-tr. silt. Strong odor. | 60 |
| 30 | S-6 | 10-11-9 | 28.5-30' | 14" | 0 | Dk. grey-Br. VF-M gravel and VF-VC sand, some-little silt. Strong odor. | 40 |
| 35 | S-7 | 16-23-32 | 33.5-35' | 18" | 0 | 34 Dense Br.-grey clay, tr. VC sand-VF gravel. No odor | 0 |
| | S-8 | 38-95-50/1" | 38.5-39.5' | 13" | 0 | Tan-grey VF sand, tr. silt. | 0 |

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## BORING LOG (continued)

Project REILLY INDUSTRIES Boring RI-18 Sheet 2 of 3

| Depth Feet | Sample Type & No. | Blows per 6 in. | Depth Range | Rec. | HNU reading | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 45 | S-9 | 16-22-30 | 43.5-45' | 18" | | dense gray-BR. clay, little VC sand-F gravel, little VF sand, little silt (till) | 1.5 |
| 50 | S-10 | 14-21-38 | 48.5-50' | 18" | | | |
| 55 | S-11 | 13-15-28 | 53.5-55' | 14" | | DR. brown silt, some-little clay-less than till above-reworked-lacustrine? | 0 Screen |
| 60 | S-12 | 16-28-76 | 58.5-60' | | | tan-gray VC sand-VF gravel, some F-C sand, little-tr. silt<br>tan-gray silt, some-little clay | 0 |
| 65 | S-13 | 7-21-30 | 63.5-65' | 14" | | tan M-brown silt, some little clay, tr. VF sand tr. organic matter | |
| 70 | S-14 | 10-13-28 | 68.5-70' | 18" | | DR. brown silt and clay-moist, silty clay as above | |
| 75 | S-15 | 10-14-19 | 73.5-75' | 18" | | DR. brown-gray clay | |
| 80 | S-16 | 6-8-18 | 78.5-80' | 18" | | clay and some silt, little VF sand | |
| 85 | S-17 | 13-15-27 | 83.5-85' | 18" | | DR. brown-gray silt and some clay, some-little VF sand | |
| | S-18 | 21-24-80 | 88.5-90' | | | M-Dr. brown clay, some silt-color banding<br>M Br VF-C sand and VF-M gravel, tr. M gravel, little silt/clay | |

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## BORING LOG (continued)

Project REILLY INDUSTRIES Boring RI-18 Sheet 3 of 3

| Depth Feet | Sample Type & No. | Sample Blows per 6 in. | Sample Depth Range | Sample Rec. | HNU reading | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| | | | | | | M-Dr. Br. VF-M gravel and F-C sand, some clay, some -little silt | |
| 95 | S--19 | 60-103-100/1 | 93.5-95' | 13" | | SHALE AT END OF SPOON<br>BEDROCK REFUSAL=94.6' | |
| 100 | | | | | | | |
| 105 | | | | | | | |
| 110 | | | | | | | |
| 115 | | | | | | | |
| 120 | | | | | | | |
| 125 | | | | | | | |
| 130 | | | | | | | |
| 135 | | | | | | | |

ENSR

# BORING LOG

Sheet 1 of 2

Project No. 5660-003-012 Date - Start 6/22/90 Finish 6/23/90 Boring RI-18D

Project Name REILLY INDUSTRIES SITE Drilling Co ATEC ASSOC.

Location INDIANAPOLIS , INDIANA Drilling Method 3 3/8 AUGER

Total Depth 94.6' Inspector L. S. EICKHOFF Reviewer L. SCHALCH EICKHOFF

Remarks

| Depth Feet | Sample Type & No. | Sample Blows per 6 In. | Sample Depth Range | Sample Rec. | HNU Read. | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| 5 | S-1 | 2-1-6 | 3.5-5' | 8" | 0 | M Br. VF-C sand, some VF-F gravel, tr. silt. no odor. Dry Fill. | 0 |
| 10 | S-2 | 12-13-21 | 8.5-10' | 7" | 0 | Tan-Br. VF-M gravel and VF-VC sand, tr. C gravel (rounded). Fill | .4 |
| 15 | S-3 | 8-11-11 | 13.5-15' | 10" | 0 | M. Br. VF-C sand, some VF-F gravel, tr. silt. Fill. No odor. | .8 |
| 20 | S-4 | 12-13-21 | 18.5-20' | 8" | 0 | Moist, M-Light Br. -Tan F-M sand, little F-M gravel, little-tr. C. gravel. No odor | 65 |
| 25 | S-5 | 11-12-13 | 23.5-25' | 8" | 0 | WET SPOON , Dk. grey-Br. VF-F gravel and M-VC sand, tr. M-C gravel, little-tr. silt. Strong odor. | 60 |
| 30 | S-6 | 10-11-9 | 28.5-30' | 14" | 0 | Dk. grey-Br. VF-M gravel and VF-VC sand, some-little silt. Strong odor. | 40 |
| 35 | S-7 | 16-23-32 | 33.5-35' | 18" | 0 | Dense Br.-grey clay, tr. VC sand-VF gravel. No odor | 0 |
| | S-8 | 38-95-50/1" | 38.5-39.5' | 13" | 0 | Tan-grey VF sand, tr. silt. | 0 |

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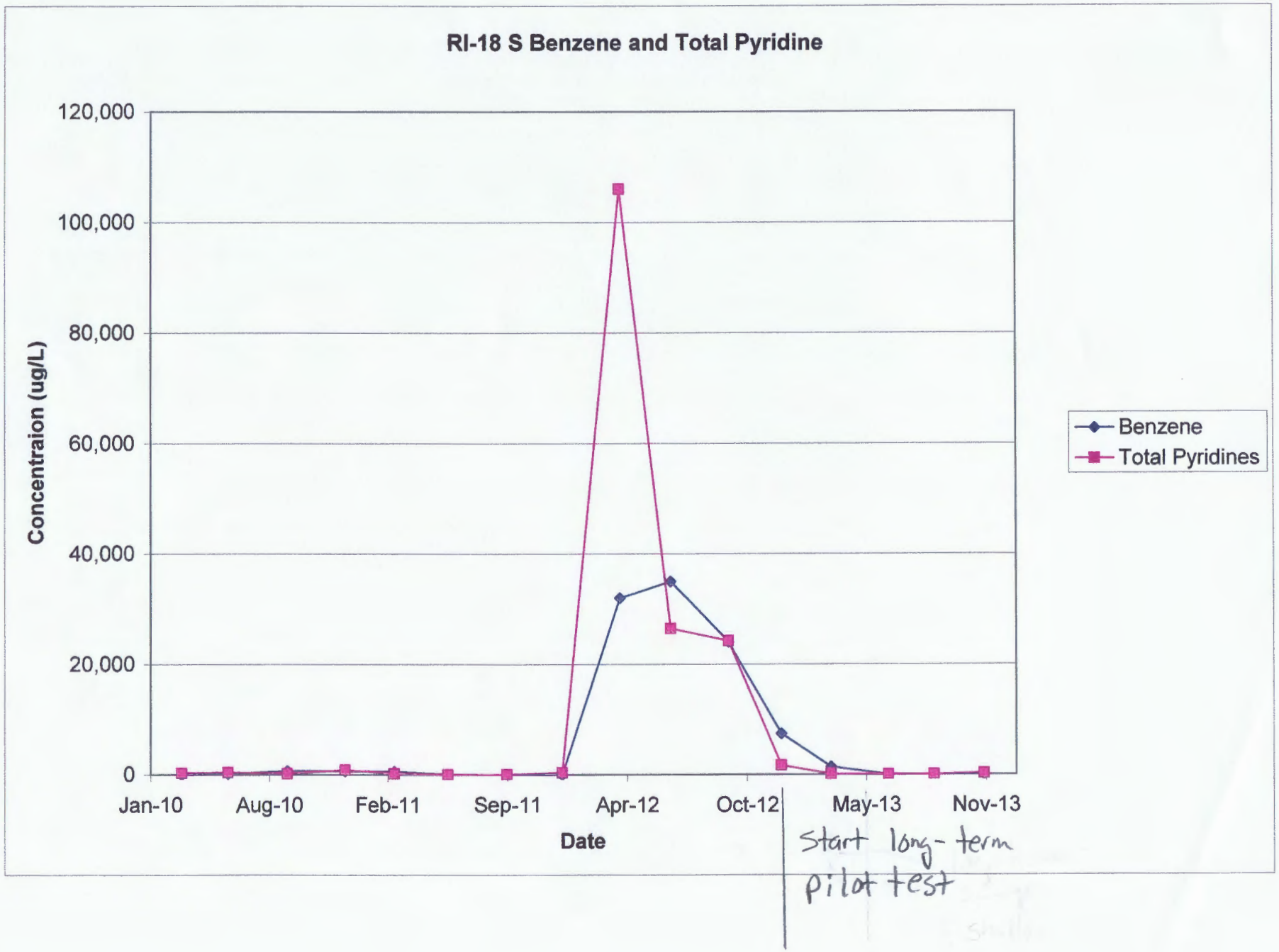
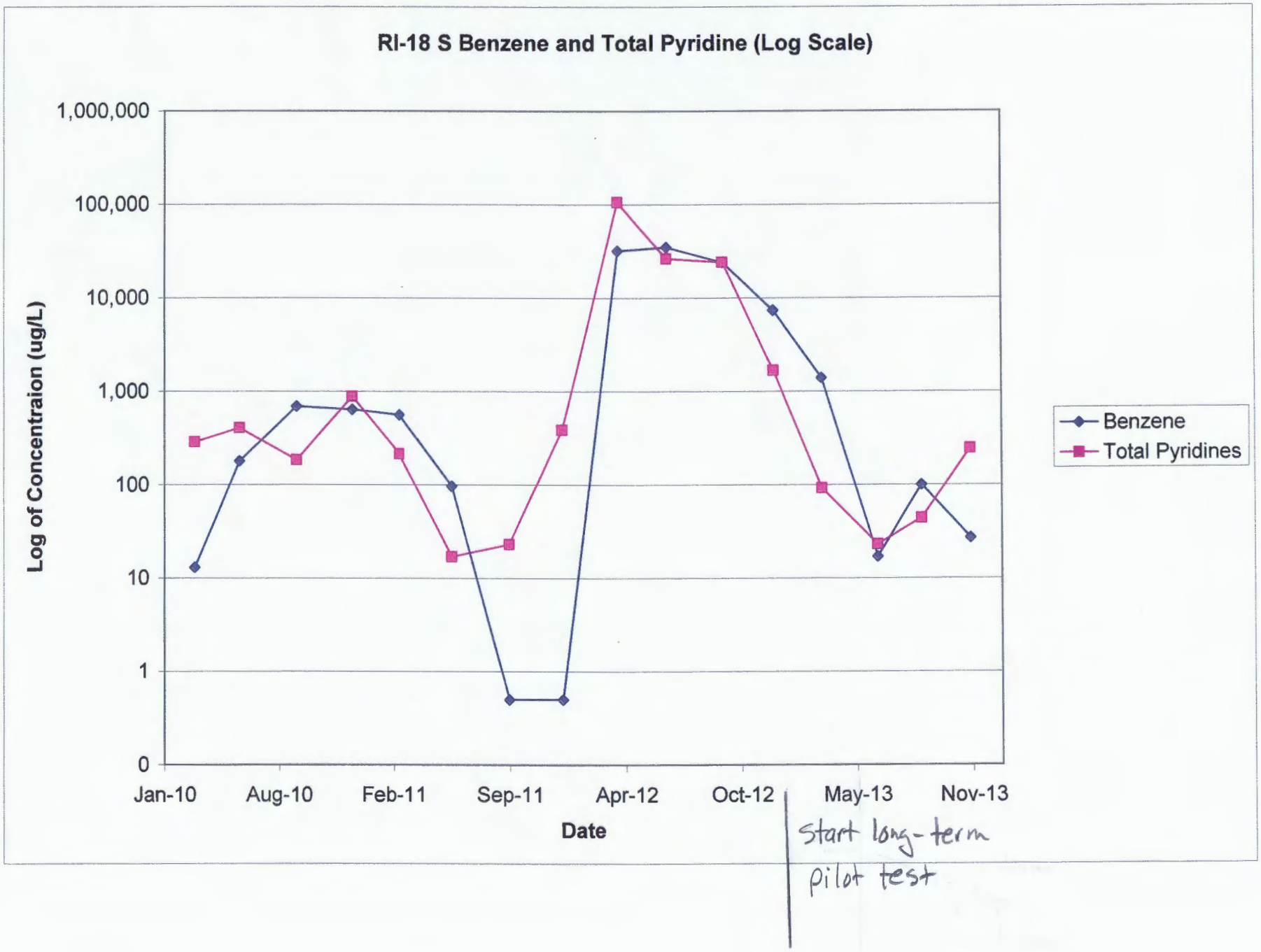
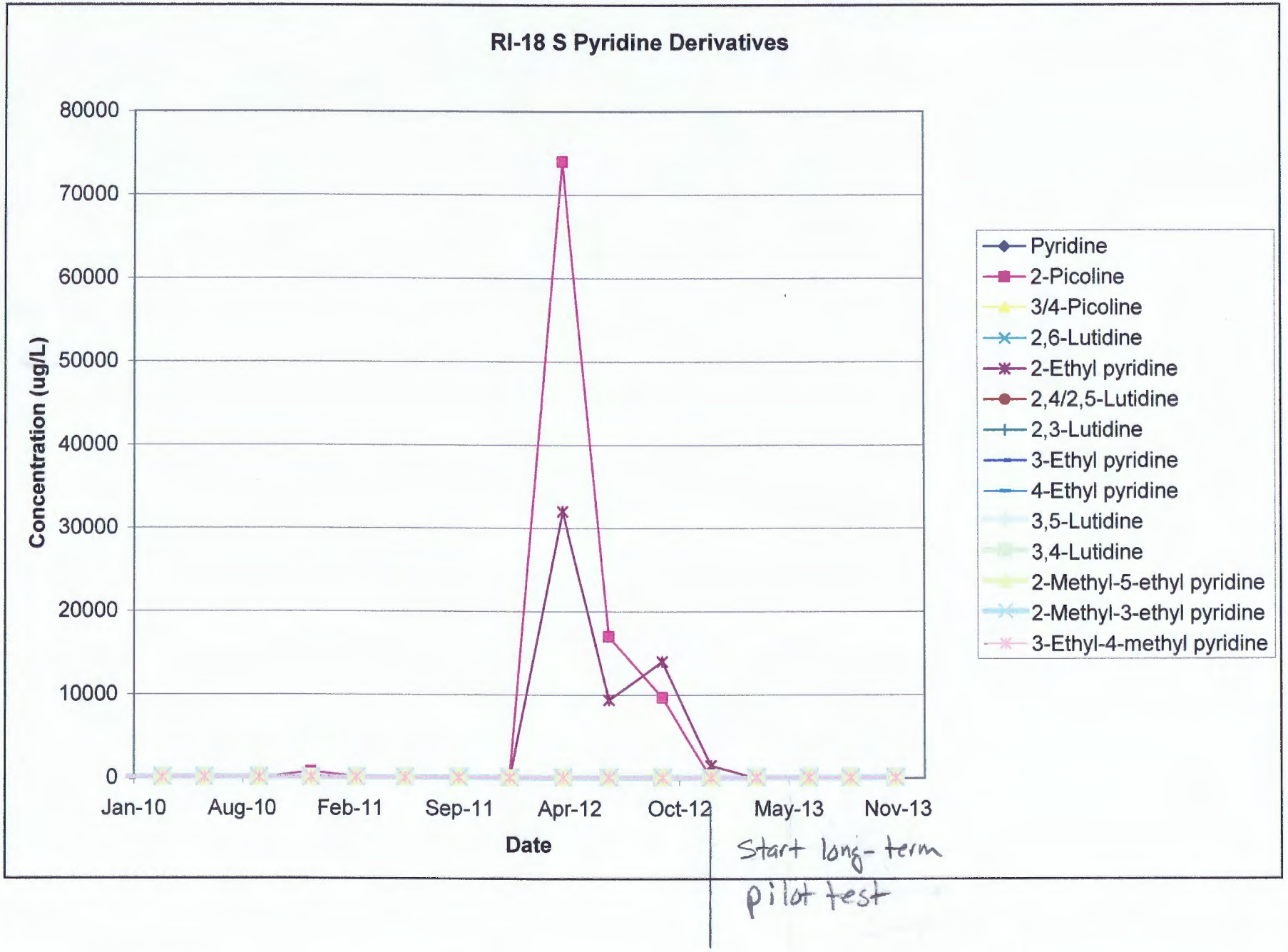
## BORING LOG (continued)

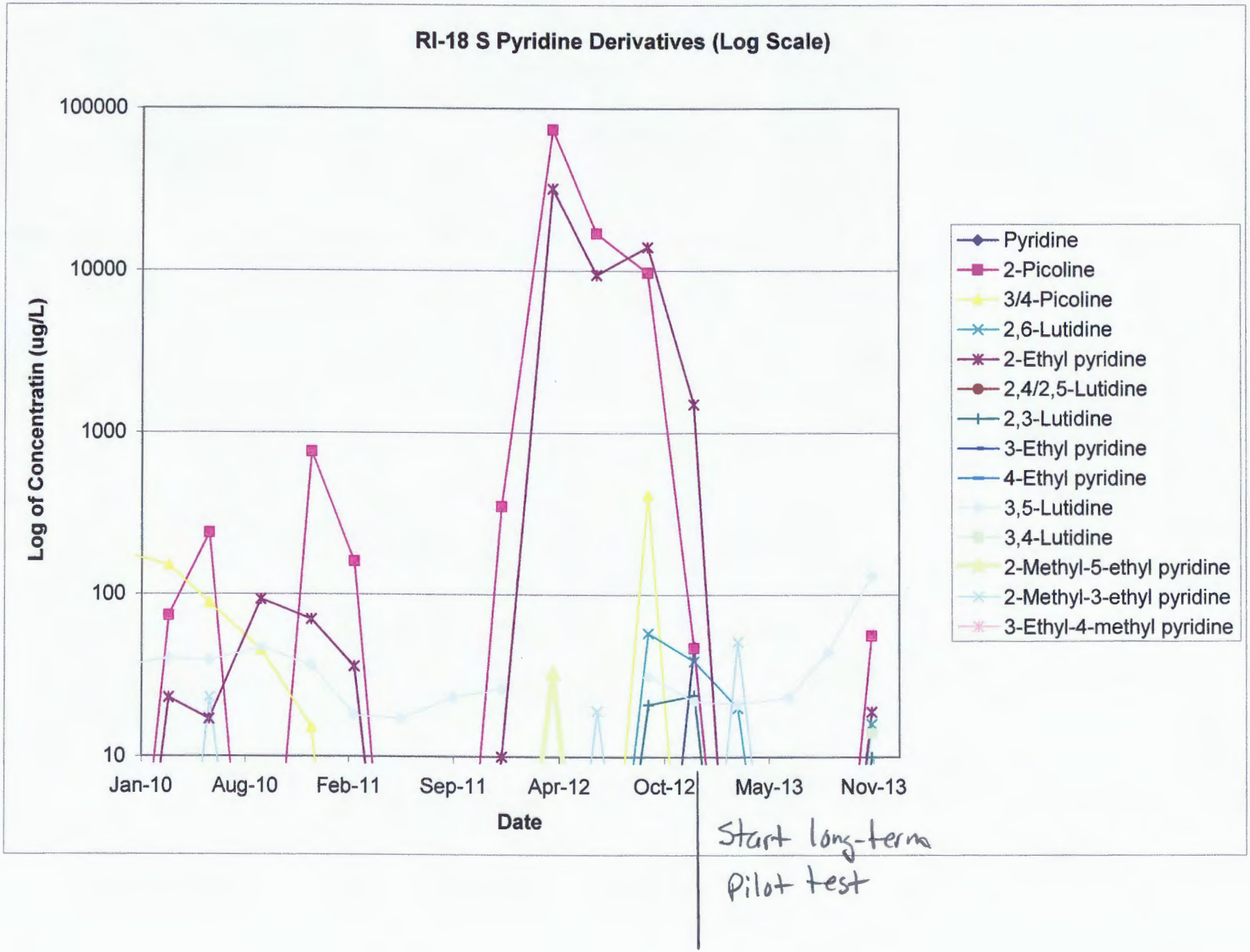
Project REILLY INDUSTRIES Boring RI-18D Sheet 2 of 2

| Depth Feet | Sample Type & No. | Sample Blows per 6 in. | Sample Depth Range | Sample Rec. | HNU reading | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| 45 | | | | | | | 1.5 |
| 50 | | | | | | DR. brown silt, some-little clay-less than till above-reworked-lacustrine? | |
| 55 | S-1 | 19-31-67-46 | 54-56' | 14" | | VF-C Gravel and/some VF-VC sand, some silt/clay, trace lenses weathered shale and till | 0 |
| | S-2 | 43-60-85 | 56-57.5' | 18" | | Tan-gray VF-C gravel and F-C sand, some silt, little trace clay. | |
| | S-3 | 106-100/4" | | 0" | | Cobble | |
| 60 | | | | | | BORING TERMINATED AT 58.8' | 0 |
| 65 | | | | | | | |
| 70 | | | | | | | |
| 75 | | | | | | | |
| 80 | | | | | | | |
| 85 | | | | | | | |


RI-18 S Benzene and Total Pyridine
120,000
100,000
80,000
60,000
40,000
20,000
0
Concentraion (ug/L)
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
Benzene
Total Pyridines
Start long-term
pilot test


RI-18 S Benzene and Total Pyridine (Log Scale)
Log of Concentraion (ug/L)
1,000,000
100,000
10,000
1,000
100
10
1
0
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
Benzene
Total Pyridines
Start long-term
pilot test


RI-18 S Pyridine Derivatives
80000
70000
60000
50000
40000
30000
20000
10000
0
Concentration (ug/L)
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
Pyridine
2-Picoline
3/4-Picoline
2,6-Lutidine
2-Ethyl pyridine
2,4/2,5-Lutidine
2,3-Lutidine
3-Ethyl pyridine
4-Ethyl pyridine
3,5-Lutidine
3,4-Lutidine
2-Methyl-5-ethyl pyridine
2-Methyl-3-ethyl pyridine
3-Ethyl-4-methyl pyridine
Start long-term pilot test

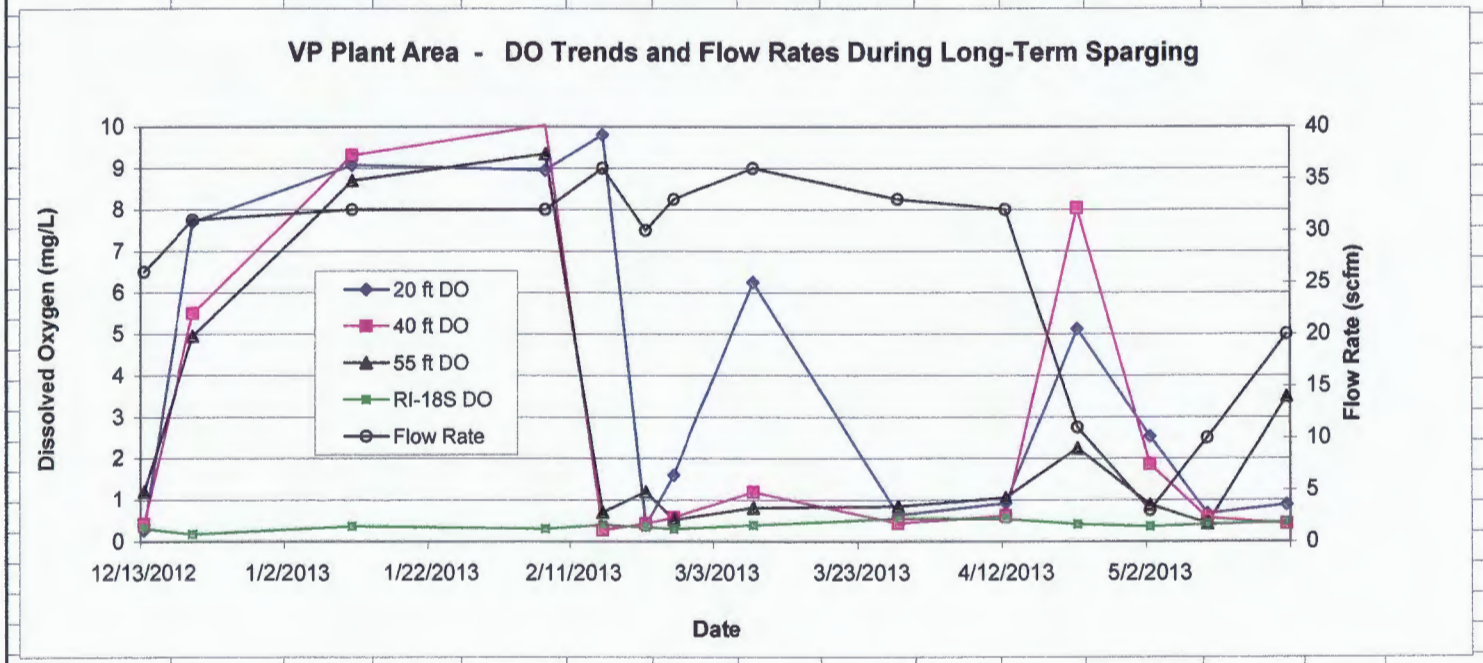

RI-18 S Pyridine Derivatives (Log Scale)
Log of Concentratin (ug/L)
100000
10000
1000
100
10
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
Pyridine
2-Picoline
3/4-Picoline
2,6-Lutidine
2-Ethyl pyridine
2,4/2,5-Lutidine
2,3-Lutidine
3-Ethyl pyridine
4-Ethyl pyridine
3,5-Lutidine
3,4-Lutidine
2-Methyl-5-ethyl pyridine
2-Methyl-3-ethyl pyridine
3-Ethyl-4-methyl pyridine
Start long-term
Pilot test

**Well RI-18S**

| Sample Date | Benzene ug/l | Total Pyridines ug/l | Ammonia mg/l | Toluene | Ethyl benzene | Xylene-total | Pyridine | 2-Picoline | 3/4-Picoline | 2,6-Lutidine | 2-Ethyl pyridine | 2,4/2,5-Lutidine | 2,3-Lutidine | 3-Ethyl pyridine | 4-Ethyl pyridine | 3,5-Lutidine | 3,4-Lutidine | 2-Methyl-5-ethyl pyridine | 2-Methyl-3-ethyl pyridine | 3-Ethyl-4-methyl pyridine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar-10 | 13.0 | 287 | 6.6 | ND | ND | ND | 0 | 74 | 150 | 0 | 23 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 0 | 0 |
| Jun-10 | 180.0 | 407 | 7.4 | ND | ND | ND | 0 | 240 | 88 | 0 | 17 | 0 | 0 | 0 | 0 | 39 | 0 | 0 | 23 | 0 |
| Sep-10 | 690.0 | 185 | 6.8 | ND | ND | ND | 0 | 0 | 45 | 0 | 93 | 0 | 0 | 0 | 0 | 47 | 0 | 0 | 0 | 0 |
| Dec-10 | 640.0 | 881 | 8.3 | ND | ND | ND | 0 | 760 | 15 | 0 | 70 | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 0 | 0 |
| Mar-11 | 560.0 | 214 | 7.2 | ND | ND | ND | 0 | 160 | 0 | 0 | 36 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 |
| Jun-11 | 97.0 | 17 | 6.6 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 |
| Sep-11 | 0.5 | 23 | 6.6 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 0 |
| Dec-11 | 0.5 | 386 | 6.7 | ND | ND | ND | 0 | 350 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 |
| Mar-12 | 32000.0 | 106033 | 7.8 | 7 | ND | ND | 0 | 74000 | 0 | 0 | 32000 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 0 | 0 |
| Jun-12 | 35000.0 | 26419 | 14.0 | 33 | 6 | ND | 0 | 17000 | 0 | 0 | 9400 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 |
| Sep-12 | 24000.0 | 24220 | 13.0 | 140 | ND | ND | 0 | 9700 | 410 | 58 | 14000 | 0 | 21 | 0 | 0 | 31 | 0 | 0 | 0 | 0 |
| Dec-12 | 7400.0 | 1680 | 9.6 | 5.5 | 9.5 | ND | 48 | 47 | 0 | 39 | 1500 | 0 | 24 | 0 | 0 | 22 | 0 | 0 | 0 | 0 |
| Mar-13 | 1400.0 | 92 | 10.0 | ND | 7 | ND | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 21 | 0 | 0 | 51 | 0 |
| Jun-13 | 17.0 | 23 | 6.2 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 0 |
| Aug-13 | 100.0 | 44 | 1.6 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | 0 | 0 | 0 | 0 |
| Nov-13 | 27.0 | 245 | 3.7 | ND | 9.1 | ND | 0 | 56 | 0 | 16 | 19 | 0 | 10 | 0 | 0 | 130 | 14 | 0 | 0 | 0 |

# VP Plant Long-Term Sparge Data using Shallow Sparge Point and Instrument Air

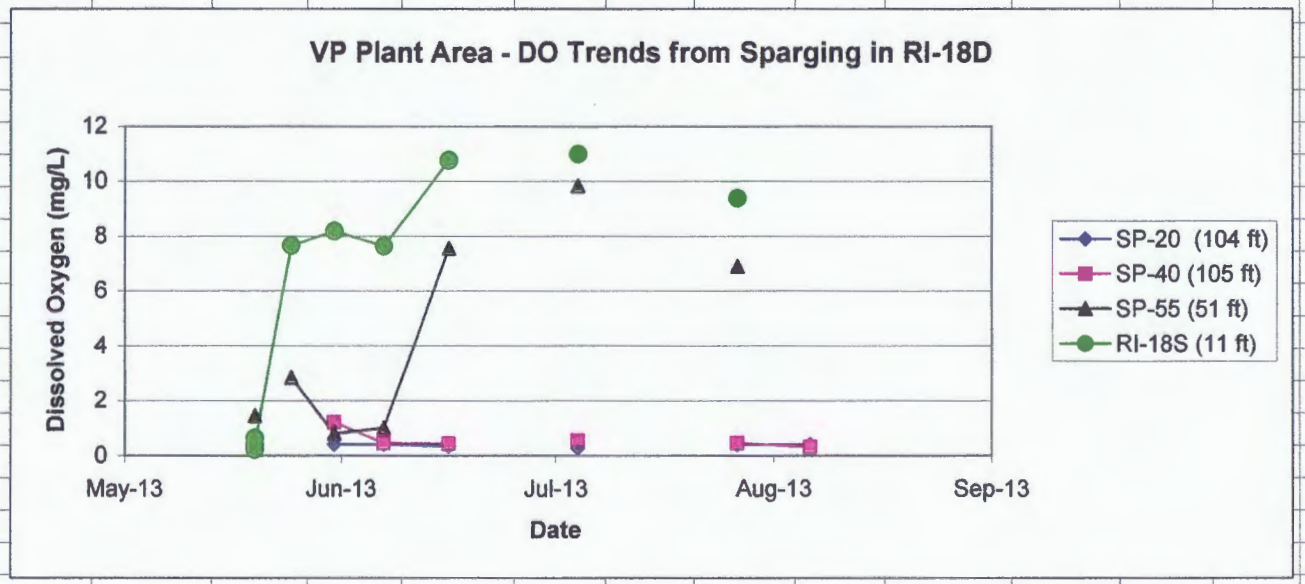
| | | 20 ft Spaced Point | | | 40 ft Spaced Point | | | 55 ft Spaced Point | | | RI-18S (90 ft) | | | Well head | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | DO | Temp C | WL | DO | Temp C | WL | DO | Temp C | WL | DO | Temp C | WL | Flow rate | PSI Wellhead |
| 12/5/2013 | 840 | 0.27 | 17.2 | 21.34 | 0.42 | 17.2 | 21.43 | 1.2 | 18 | 19.35 | 0.31 | 20.5 | 21.61 | 0 | 0 |
| 12/13/2012 | START UP | | | | | | | | | | | | | 26 | 9 |
| 12/20/2012 | 1420 | 7.7 | | WL from grad | 5.5 | | | 4.95 | | | 0.18 | | | 31 | 9 |
| 1/11/2013 | 1030 | 9.07 | 18.8 | 20.68 | 9.31 | 16.5 | 22.16 | 8.7 | 19.2 | 19.92 | 0.37 | 19.9 | 22.18 | 32 | 13 |
| 1/21/2013 | | | | | | | | | | | | | | | 14 |
| 2/7/2013 | | 8.95 | 18.2 | 19.68 | 10.04 | 14.7 | 21.18 | 9.34 | 16.5 | 18.97 | 0.31 | 19.2 | 21.19 | 32 | 12 |
| 2/15/2013 | 1135 | 9.81 | 16.4 | 19.82 | 0.28 | 18.9 | 21.32 | 0.7 | 18.6 | 19.11 | 0.4 | 18.9 | 21.32 | 36 | 13 |
| 2/21/2013 | 1345 | 0.39 | 19.3 | 19.9 | 0.43 | 18.5 | 21.41 | 1.2 | 18.3 | 19.18 | 0.35 | 18.6 | 21.4 | 30 | 13 |
| 2/25/2013 | 1225 | 1.6 | 19 | | 0.58 | 18.5 | | 0.52 | 18.3 | | 0.3 | | | | |
| 3/8/2013 | 1437 | 6.25 | 18.9 | 19.68 | 1.19 | 18 | 21.18 | 0.81 | 17.7 | 18.95 | 0.39 | 18.2 | 21.15 | 36 | 13 |
| 3/11/2013 | 1314 | | | | | | | | | | | | | 0 | 10 |
| 3/11/2013 | 1315 | | | | | | | | | | | | | 22 | 12 |
| 3/20/2013 | 1555 | | | | | | | | | | | | | 20 | 12 |
| 3/28/2013 | 1305 | 0.63 | 18.4 | 19.71 | 0.44 | 17.9 | 21.19 | 0.84 | 17.2 | 19 | 0.55 | 17.8 | 21.18 | 33 | 12 |
| 4/5/2013 | 1300 | | | | | | | | | | | | | 32 | 12 |
| 4/12/2013 | 1200 | 0.92 | 17.9 | 19.76 | 0.62 | 17.3 | 21.27 | 1.05 | 16.6 | 19.04 | 0.54 | 17.3 | 21.24 | 32 | 12 |
| 4/22/2013 | 1140 | 5.12 | 17.8 | 19.47 | 8.04 | 16.7 | 19.96 | 2.25 | 16.5 | 17.73 | 0.42 | 17.1 | 19.91 | 11 | 12 |
| 5/2/2013 | | 2.53 | 17 | | 1.86 | 17.2 | | 0.88 | 16.3 | | 0.36 | 18 | | 3 | 13 |
| 5/10/2013 | | 0.67 | 17.8 | | 0.57 | 16.9 | | 0.43 | 16.7 | | 0.41 | 17.5 | | 10 | 12 |
| 5/21/2013 | 1255 | 0.89 | 18.2 | 17.81 | 0.43 | 17.1 | 19.33 | 3.5 | 16.8 | | 0.47 | 16.9 | 19.3 | 20 | 9 |
| 5/24/2013 | CHANGE FROM SPARGING AT SHALLOW SPARGE POINT TO WELL RI-18 DEEP | | | | | | | | | | | | | | |



# VP Plant Long-Term Sparge Data using RI-18D and Instrument Air

| | | | SP-20 | | | SP-40 | | | SP-55 | | | RI-18S | | | Well head RI-18D | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | DO | Temp C | WL | DO | Temp C | WL | DO | Temp C | WL | DO | Temp C | WL | Flow rate | PSI Wellhead |
| 5/24/2013 | 13:40 | PRIOR TO START | | | | | | 1.45 | 16.4 | 17.21 | 0.63 | 17.6 | 19.43 | | |
| 5/24/2013 | 13:50 | START AIR FLOW AT RI-18D | | | | | | | | | | | | 18 | 32 |
| 5/24/2013 | 14:05 | | | | | | | | | | 0.22 | 16.8 | 19.29 | 19 | 32 |
| 5/24/2013 | 14:35 | | | | | | | | | | 0.23 | 16.8 | 19.32 | 19.5 | 30 |
| 5/24/2013 | 14:55 | | | | | | | | | | 0.23 | 16.7 | 19.33 | 19.5 | 30 |
| 5/24/2013 | 15:02 | | | | | | | | | | | | | | |
| 5/24/2013 | 15:05 | | | | | | | | | 17.17 | 0.41 | 16.7 | 19.3 | 19.5 | 30 |
| 5/29/2013 | 15:00 | | | | | | | 2.85 | 16.9 | 17.19 | 7.66 | 17.1 | 19.41 | 23 | 24 |
| 6/4/2013 | 14:55 | 0.41 | 17.7 | 17.63 | 1.21 | 16.9 | 19.16 | 0.79 | 16.7 | 16.92 | 8.18 | 16.7 | 19.11 | 17 | 20 |
| 6/11/2013 | 10:15 | 0.41 | 18.2 | 17.79 | 0.45 | 17.1 | 19.33 | 1 | 16.9 | 17.11 | 7.63 | 16.8 | 19.33 | 18 | 29 |
| 6/20/2013 | 14:01 | 0.34 | 20.1 | | 0.43 | 17.3 | | 7.55 | 17 | | 10.76 | 17 | | 18 | 18 |
| 6/28/2013 | 14:36 | | | | | | | | | | | | | 18 | 28 |
| 7/8/2013 | 14:35 | 0.28 | 25.9 | 18.15 | 0.55 | 18.5 | 19.67 | 9.83 | 19.9 | 16.02 | 10.99 | 16.9 | 19.7 | 17 | 18 |
| 7/22/2013 | | | | | | | | | | | | | | 18 | 19 |
| 7/30/2013 | 13:05 | 0.4 | 37.5 | 18.46 | 0.45 | 23.2 | 20.02 | 6.9 | 25.8 | 17.79 | 9.39 | 19.9 | 20.04 | 18 | 19 |
| 8/9/2013 | 11:23 | 0.41 | 37 | 18.67 | 0.31 | 28.2 | 20.23 | | | | | | | 18 | 19 |

Distances: 18D to 18S = 11 ft; 18D to SP-20 = 104 ft
18D to SP55 Point = 51 ft; 18D to SP-40 = 105 ft



**VP Plant Sparge Pilot Testing Data**
**RI-18D Sparging**

| | | RI-18D | RI-18D | | RI-18S | | | | 20 ft Spaced Point | | | | 40 ft Spaced Point | | | | 55 ft Spaced Point | | | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Sparge Well Press. (psi) | Air Flow (scfm) | | DO | WL | Press. | Temp (C) | DO | WL | Press. | Temp (C) | DO | WL | Press. | Temp (C) | DO | WL | Press. | Temp (C) | |
| 12/6/2012 | 8:45 | | 0 | | 0.3 | 21.58 | 0.00 | 19.4 | 5.1 | 21.30 | 0.00 | 17.7 | 0.4 | 21.38 | 0.00 | 17.7 | 1.8 | 19.30 | 0.00 | 17.1 | Baseline for RI-18D & recovery for RI-18S pilot testing |
| 12/6/2012 | 10:10 | 55 | 1 | | | | 0.00 | | | | | | | | | | | | | | Start air flow, pressure at 55 psi to initiate flow |
| 12/6/2012 | 10:15 | 38 | 27 | | | | 0.00 | | | | | | | | | | | | | | |
| 12/6/2012 | 10:17 | 32 | 21 | | | | 0.00 | | | | | | | | | | | | | | |
| 12/6/2012 | 10:19 | 27 | 15 | | | | 0.00 | | | | | | | | | | | | | | |
| 12/6/2012 | 10:31 | 26 | 15 | | | | 0.00 | | | | | | | | | | | | | | |
| 12/6/2012 | 10:40 | 26 | 15 | | | | 0.00 | | | | | | | | | | | | | | |
| 12/6/2012 | 11:08 | 26 | 16 | | 1.6 | 21.49 | 0.00 | 20.1 | | 21.29 | | | | 21.37 | | | 1.9 | 19.27 | 0.00 | 19.3 | no bubbles in 18S |
| 12/6/2012 | 11:10 | 28 | 20 | | | | 0.00 | | | | | | | | | | | | | | go to 20 scfm, see bubbles at increased flow |
| 12/6/2012 | 11:28 | 28 | 13 | | 6.1 | 21.49 | 0.04 | 20.1 | | | | | | | | | | | | | |
| 12/6/2012 | 11:41 | 29 | | | | | 0.00 | | | 21.26 | | | | 21.33 | | | 1.6 | 19.23 | 0.00 | 18.3 | |
| 12/6/2012 | 11:52 | 30 | 21 | | | | 0.06 | | | | | | | | | | | | | | |
| 12/6/2012 | 12:05 | 30 | 23 | | | | 0.08 | | | | | | | | | | | | | | |
| 12/6/2012 | 2:10 | 31 | 25 | | | | 0.08 | | | | | | | | | | | | | | |
| 12/6/2012 | 12:13 | 31 | 25 | | 4.1 | 21.33 | 0.09 | 20.4 | | | | | | | | | | | | | |

Note: Sparge operation and measurements performed by K. Might

**VP Plant Sparge Pilot Testing Data**
**SP Shallow Sparging**

| | | Shallow Sparge Point | | 20 ft Spaced Point | | | | 40 ft Spaced Point | | | | 55 ft Spaced Point | | | | RI-18S (90 ft) | | | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Sparge Press. (psi) | Air Flow (scfm) | DO | WL | Press. | Temp (C) | DO | WL | Press. | Temp (C) | DO | WL | Press. | Temp (C) | DO | WL | Press. | Temp (C) | |
| 12/5/2012 | 8:40 | 0.0 | 0.0 | 0.27 | 21.34 | 0.00 | 17.2 | 0.3 | 21.39 | 0.00 | 17.2 | 1.2 | 19.28 | 0.00 | 18.0 | 0.3 | 21.61 | 0.0 | 20.5 | Baseline prior to start-up |
| 12/5/2012 | 9:45 | | | | | | | | | | | | | | | | | | | 9:45 AM Start air flow, goal is 10 scfm |
| 12/5/2012 | 9:55 | 8.0 | 17.9 | | | | | | | | | | | | | | | | | |
| 12/5/2012 | 10:03 | 7.0 | 12.6 | | | 0.04 | | | | 0.00 | | | | | | | | | | |
| 12/5/2012 | 10:13 | 7.0 | 10.7 | | | 0.22 | | | | 0.00 | | | | | | | | | | |
| 12/5/2012 | 10:25 | 7.0 | 10.2 | | | 0.00 | | | | 0.01 | | | | | | | | | | |
| 12/5/2012 | 10:35 | 6.8 | 10.0 | | | 0.00 | | | | 0.01 | | | | | | | | | | |
| 12/5/2012 | 11:02 | 6.6 | 11.8 | 2.40 | 21.30 | 0.00 | 20.2 | 0.6 | 21.35 | 0.00 | 18.9 | 1.3 | 19.28 | 0.00 | 15.6 | | | | | |
| 12/5/2012 | 11:26 | 6.5 | 11.4 | | | 0.08 | | | | 0.06 | | | | | | | | | | |
| 12/5/2012 | 12:07 | 6.5 | 10.0 | 2.55 | 21.28 | 0.12 | 19.2 | | | 0.05 | | | | | | | | | | |
| 12/5/2012 | 12:20 | | | | | | | | | | | | | | | | | | | Increase flow |
| 12/5/2012 | 12:21 | 6.5 | 13.9 | | | 0.11 | | | | | | | | | | | | | | |
| 12/5/2012 | 12:24 | 6.5 | 15.4 | | | 0.11 | | | | 0.06 | | 1.2 | 19.26 | 0.02 | 17.7 | 0.3 | 21.55 | 0.0 | 20.3 | |
| 12/5/2012 | 12:47 | 6.5 | 14.9 | | | 0.11 | | | | | | | | | | | | | | |
| 12/5/2012 | 13:10 | 6.5 | 14.6 | | | 0.10 | | | | 0.04 | | | | | | | | | | |
| 12/5/2012 | 13:20 | 6.5 | 14.0 | 4.05 | 21.28 | | 19.7 | 0.4 | 21.35 | 0.04 | 18.2 | | | | | | | | | |
| 12/5/2012 | 13:30 | | | | | | | | | | | | | | | | | | | Increase flow |
| 12/5/2012 | 13:32 | 6.9 | 17.1 | | | | | | | | | | | | | | | | | |
| 12/5/2012 | 13:41 | 6.9 | 17.1 | | | | | | | | | | | | | | | | | |
| 12/5/2012 | 14:04 | 6.9 | 15.7 | | | 0.10 | | | | 0.04 | | | | | | | | | | |
| 12/5/2012 | 14:30 | 7.0 | 15.7 | 5.60 | 21.26 | 0.11 | 17.8 | 0.4 | 21.34 | 0.05 | 19.1 | | | | | | | | | |
| 12/5/2012 | 14:40 | | | | | | | | | | | 1.3 | 19.23 | 0.06 | 17.3 | | | | | Increase flow |
| 12/5/2012 | 14:45 | 7.3 | 18.7 | | | | | | | | | | | | | 0.3 | 21.54 | 0.0 | 20.4 | |
| 12/5/2012 | 15:05 | 7.5 | 25.0 | | | 0.12 | | | | | | | | | | | | | | |
| 12/5/2012 | 15:27 | 7.7 | 21.3 | | | 0.13 | | | | 0.06 | | | | | | | | | | |
| 12/5/2012 | 15:45 | 7.1 | 24.1 | 6.45 | 21.21 | 0.12 | 18.1 | 0.4 | 21.32 | 0.06 | 18.4 | 1.4 | 19.23 | 0.04 | 18.2 | | | | | Will switch over to instrument air and continue pilot test |
| 12/5/2012 | 16:12 | 7.4 | 11.0 | | | | | | | | | | | | | | | | | Running on instrument air |
| 12/5/2012 | 16:26 | 7.1 | 8.4 | | | | | | | | | | | | | | | | | |
| 12/5/2012 | 16:45 | 7.0 | 6.2 | | | | | | | | | | | | | | | | | Demister clogged, replaced with new filter |
| 12/5/2012 | 16:54 | 9.1 | 23.0 | | | | | | | | | | | | | | | | | |
| 12/5/2012 | 17:05 | 8.0 | 24.9 | | | | | | | | | | | | | | | | | |
| 12/5/2012 | 17:40 | 8.0 | 25.2 | | | | | | | | | | | | | | | | | |
| 12/5/2012 | 17:52 | 8.0 | 25.5 | 6.80 | 21.23 | 0.19 | 18.1 | 0.5 | 21.31 | 0.06 | 18.3 | 1.4 | 19.21 | 0.04 | | 0.3 | 21.55 | 0.0 | 20.3 | End air injection |
| 12/6/2012 | 8:45 | next day | | 5.08 | 21.30 | 0.00 | 17.7 | 0.4 | 21.38 | 0.00 | 17.7 | 1.8 | 19.30 | 0.00 | 17.1 | 0.3 | 21.58 | 0.0 | 19.4 | Next day, recovery |

Note: Sparge operation and measurements performed by K. Might

| VP Plant Long-Term Sparge Data | | | | | | RI-18 DEEP INJECTION | | | | | | Distances | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | 18D to 18S = 11.3 ft | | | | | | | | | | |
| | | | | | | | | | | | | | 18S to 55 Point = 39.4 ft | | | | | | | | | | |
| | | 20 ft Spaced Point | | | | | 40 ft Spaced Point | | | | 55 ft Spaced Point | | | | original sparge point | | | | RI-18S (90 ft) | | | | Well head RI-18D | |
| Date | Time | DO | Temp C | WL | in/h20 | DO | Temp C | WL | in/h20 | DO | Temp C | WL | in/h20 | DO | Temp C | WL | DO | Temp C | WL | in/h20 | Flow rate | PSI Inst Air | PSI Wellhead |
| 5/24/2013 | 13:40 | PRIOR TO START | | | | | | | | 1.45 | 16.4 | 17.21 | | | | | 0.63 | 17.6 | 19.43 | | | 81 | |
| 5/24/2013 | 13:50 | START AIR FLOW AT RI-18D | | | | | | | | | | | | | | | | | | | 18 | 72 | 32 |
| 5/24/2013 | 14:05 | | | | | | | | | | | | | | | | 0.22 | 16.8 | 19.29 | | 19 | 69 | 32 |
| 5/24/2013 | 14:35 | | | | | | | | | | | | | | | | 0.23 | 16.8 | 19.32 | | 19.5 | 68 | 30 |
| 5/24/2013 | 14:55 | | | | | | | | | | | | | | | | 0.23 | 16.7 | 19.33 | | 19.5 | 68 | 30 |
| 5/24/2013 | 15:02 | | | | | | | | | | | | | | | | bubbles at 18S | | | | | | |
| 5/24/2013 | 15:05 | | | | | | | | | | | 17.17 | | | | | 0.41 | 16.7 | 19.3 | | 19.5 | 68 | 30 |
| 5/29/2013 | 15:00 | | | | | | | | | 2.85 | 16.9 | 17.19 | | | | | 7.66 | 17.1 | 19.41 | bubbles | 23 | 61 | 24 |
| 6/4/2013 | 14:55 | 0.41 | 17.7 | 17.63 | | 1.21 | 16.9 | 19.16 | | 0.79 | 16.7 | 16.92 | | | | | 8.18 | 16.7 | 19.11 | bubbles | 17 | 73 | 20 |
| 6/11/2013 | 10:15 | 0.41 | 18.2 | 17.79 | | 0.45 | 17.1 | 19.33 | | 1 | 16.9 | 17.11 | | | | | 7.63 | 16.8 | 19.33 | bubbles | 18 | 72 | 29 |
| 6/20/2013 | 14:01 | 0.34 | 20.1 | | | 0.43 | 17.3 | | | 7.55 | 17 | strong bubbles | | | | | 10.76 | 17 | | bubbles | 18 | 74 | 18 |
| 6/28/2013 | 14:36 | | | | | | | | | | | | | | | | | | | | 18 | 66 | 28 |
| 7/8/2013 | 14:35 | 0.28 | 25.9 | 18.15 | | 0.55 | 18.5 | 19.67 | | 9.83 | 19.9 | 16.02 | bubbles | | | | 10.99 | 16.9 | 19.7 | bubbles | 17 | 74 | 18 |
| 7/22/2013 | | | | | | | | | | | | | | | | | | | | | 18 | 74 | 19 |
| 7/30/2013 | 13:05 | 0.4 | 37.5 | 18.46 | | 0.45 | 23.2 | 20.02 | | 6.9 | 25.8 | 17.79 | bubbles | | | | 9.39 | 19.9 | 20.04 | bubbles | 18 | 72 | 19 |
| 8/9/2013 | 11:23 | 0.41 | 37 | 18.67 | | 0.31 | 28.2 | 20.23 | | | | | | | | | | | | | 18 | 73 | 19 |
| 8/19/2013 | 13:10 | error | >45 | 18.91 | | error | >45 | 20.46 | | 3.55 | 31.7 | 17.71 | | error | >45 | 19.45 | 3.92 | 29 | 20.47 | bubbles | 9 | 73 | 23 |
| 8/19/2013 | 13:20 | | | | | | | | | | | | | | | | | | | | 14 | 69 | |
| | | | | | | | | | | | | | | | | | | | | | | | |
| Notes: | 5/29/2013 | Turn down to 18 cfm | | | | | | | | | | | | | | | | | | | | | |
| | 8/9/2013 | 2 position solenoid valve installed and hooked up, 12 hrs on 12 hrs off | | | | | | | | | | | | | | | | | | | | | |
| | 8/19/2013 | temp instrument air = 21.4 C | | | | | | | | | | | | | | | | | | | | | |
| | 8/19/2013 | spot 24 - steam pot blow down west of spot 24, 24 gpm at 170F to hole in ground | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | |
| Note: Sparge operation and measurements performed by K. Might | | | | | | | | | | | | | | | | | | | | | | | |

# VP Plant Long-Term Sparge Data

**SPARGING SP POINT**

| | | 20 ft Spaced Point | | | | 40 ft Spaced Point | | | | 55 ft Spaced Point | | | | RI-18S (90 ft) | | | | | Well head | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **DO** | **Temp C** | **WL** | **in/h20** | **DO** | **Temp C** | **WL** | **in/h20** | **DO** | **Temp C** | **WL** | **in/h20** | **DO** | **Temp C** | **WL** | **in/h20** | **Flow rate** | **PSI Inst Air** | **PSI Wellhead** |
| 12/5/2013 | 840 | 0.27 | 17.2 | 21.34 | 0.00 | 0.42 | 17.2 | 21.43 | 0 | 1.2 | 18 | 19.35 | 0 | 0.31 | 20.5 | 21.61 | 0 | 0 | 0 | 0 |
| 12/13/2012 | | START UP | | | | | | | | | | | | | | | | 26 | 70 | 9 |
| 12/20/2012 | 1420 | 7.7 | | WL from grade | | 5.5 | | | | 4.95 | | | | 0.18 | | | | 31 | 67 | 9 |
| 1/11/2013 | 1030 | 9.07 | 18.8 | 20.68 | 0.16 | 9.31 | 16.5 | 22.16 | 0.09 | 8.7 | 19.2 | 19.92 | 0.05 | 0.37 | 19.9 | 22.18 | 0.01 | 32 | 73 | 13 |
| 1/21/2013 | | | | | | | | | | | | | | | | | | | 72 | 14 |
| 2/7/2013 | | 8.95 | 18.2 | 19.68 | | 10.04 | 14.7 | 21.18 | | 9.34 | 16.5 | 18.97 | | 0.31 | 19.2 | 21.19 | | 32 | 81 | 12 |
| 2/15/2013 | 1135 | 9.81 | 16.4 | 19.82 | 0.13 | 0.28 | 18.9 | 21.32 | 0.06 | 0.7 | 18.6 | 19.11 | 0.02 | 0.4 | 18.9 | 21.32 | 0.01 | 36 | 73 | 13 |
| 2/21/2013 | 1345 | 0.39 | 19.3 | 19.9 | | 0.43 | 18.5 | 21.41 | | 1.2 | 18.3 | 19.18 | | 0.35 | 18.6 | 21.4 | | 30 | 77 | 13 |
| 2/25/2013 | 1225 | 1.6 | 19 | | 0.14 | 0.58 | 18.5 | | 0.09 | 0.52 | 18.3 | | 0.04 | 0.3 | | | 0 | | | |
| 3/8/2013 | 1437 | 6.25 | 18.9 | 19.68 | 0.1 | 1.19 | 18 | 21.18 | 0.07 | 0.81 | 17.7 | 18.95 | 0.04 | 0.39 | 18.2 | 21.15 | 0.01 | 36 | 79 | 13 |
| 3/11/2013 | 1314 | | | | | | | | | | | | | | | | | 0 | 85 | 10 |
| 3/11/2013 | 1315 | | | | | | | | | | | | | | | | | 22 | 81 | 12 |
| 3/20/2013 | 1555 | | | | | | | | | | | | | | | | | 20 | 73 | 12 |
| 3/28/2013 | 1305 | 0.63 | 18.4 | 19.71 | 0.12 | 0.44 | 17.9 | 21.19 | 0.07 | 0.84 | 17.2 | 19 | 0.06 | 0.55 | 17.8 | 21.18 | 0.01 | 33 | 76 | 12 |
| 4/5/2013 | 1300 | | | | | | | | | | | | | | | | | 32 | 78 | 12 |
| 4/12/2013 | 1200 | 0.92 | 17.9 | 19.76 | | 0.62 | 17.3 | 21.27 | | 1.05 | 16.6 | 19.04 | | 0.54 | 17.3 | 21.24 | | 32 | 71 | 12 |
| 4/22/2013 | 1140 | 5.12 | 17.8 | 19.47 | | 8.04 | 16.7 | 19.96 | | 2.25 | 16.5 | 17.73 | | 0.42 | 17.1 | 19.91 | | 11 | 83 | 12 |
| 5/2/2013 | | 2.53 | 17 | | | 1.86 | 17.2 | | | 0.88 | 16.3 | | | 0.36 | 18 | | | 3 | 88 | 13 |
| 5/10/2013 | | 0.67 | 17.8 | | | 0.57 | 16.9 | | | 0.43 | 16.7 | | | 0.41 | 17.5 | | | 10 | 76 | 12 |
| 5/21/2013 | 1255 | 0.89 | 18.2 | 17.81 | | 0.43 | 17.1 | 19.33 | | 3.5 | 16.8 | | | 0.47 | 16.9 | 19.3 | | 20 | 79 | 9 |
| 5/24/2013 | CHANGE FROM SPARGING AT SHALLOW SPARGE POINT TO WELL RI-18 DEEP | | | | | | | | | | | | | | | | | | | |

Notes

Feb 8 or 9th plant had instrument air pressure decline, unknown if VP sparge point was turned off

March 8 turned off instrument air for the weekend, turn back on on 3/11 (Monday)

| | | |
|---|---|---|
| 4/12/2013 | Adjust to 10 cfm | |
| 5/2/2013 | air flow was low, turn up to 10 cfm | |
| 5/10/2013 | air was off, turn on to 20 cfm, reg does not work well at low Q | |

**Long-term DO Change Versus Distance**

| **Date** | **Days** | **20 ft DO** | **40 ft DO** | **55 ft DO** | **RI-18S DO** |
|---|---|---|---|---|---|
| 12/13/2012 | 0 | 0.27 | 0.42 | 1.2 | 0.31 |
| 12/20/2012 | 7 | 7.7 | 5.5 | 4.95 | 0.18 |
| 1/11/2013 | 29 | 9.07 | 9.31 | 8.7 | 0.37 |
| 2/7/2013 | 56 | 8.95 | 10.04 | 9.34 | 0.31 |
| 2/15/2013 | 64 | 9.81 | 0.28 | 0.7 | 0.4 |
| 2/21/2013 | 70 | 0.39 | 0.43 | 1.2 | 0.35 |
| 2/25/2013 | 74 | 1.6 | 0.58 | 0.52 | 0.3 |
| 3/8/2013 | 85 | 6.25 | 1.19 | 0.81 | 0.39 |
| 3/28/2013 | 105 | 0.63 | 0.44 | 0.84 | 0.55 |
| 4/12/2013 | 120 | 0.92 | 0.62 | 1.05 | 0.54 |
| 4/22/2013 | 130 | 5.12 | 8.04 | 2.25 | 0.42 |

Note: Sparge operation and measurements performed by K. Might

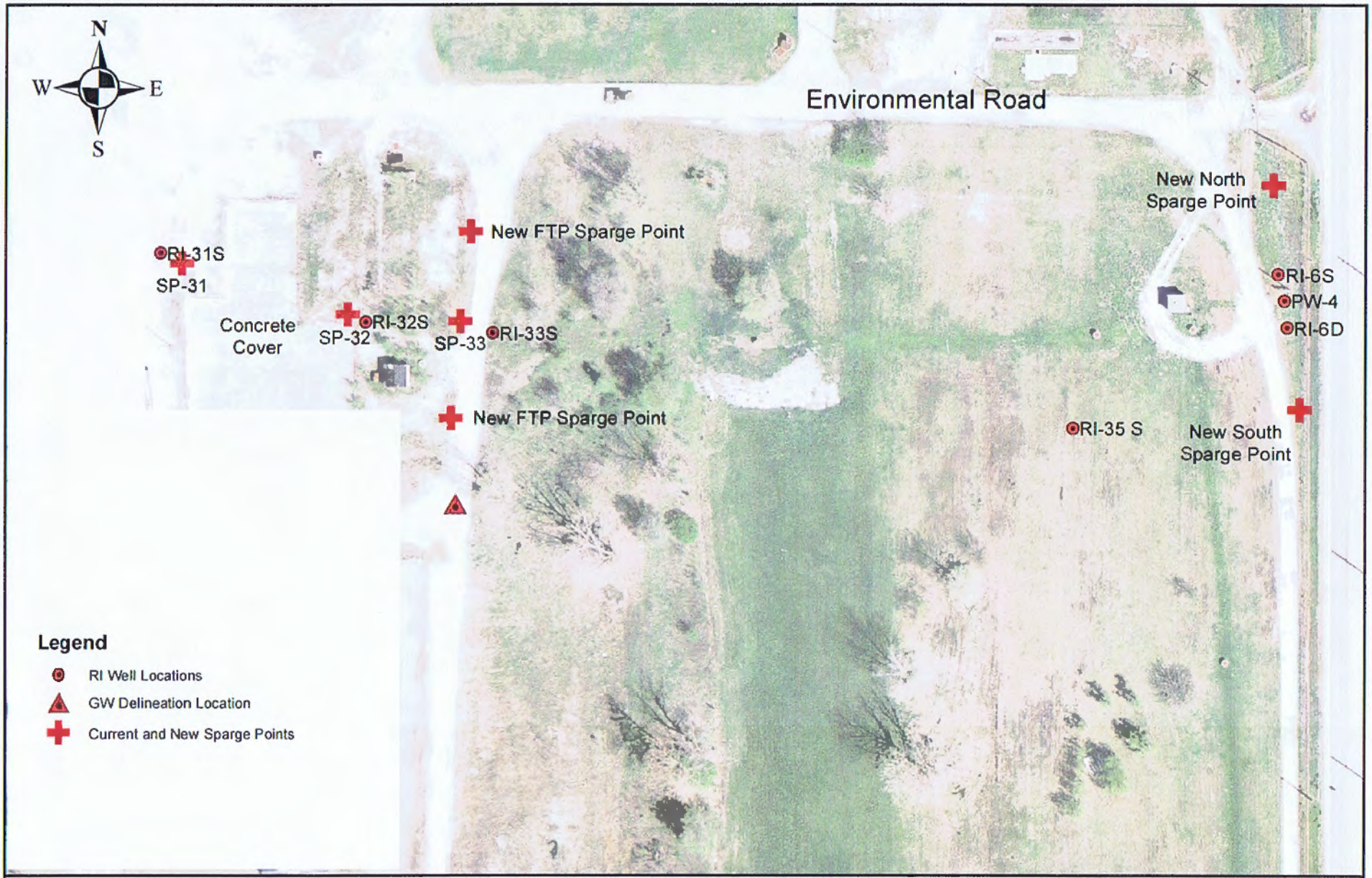
**VP Plant Sparge Pilot Testing Data**
**SP Shallow Sparging**

| Date | Time | upsed Time (h | hrs | fract hr | Sparge Press. (psi) | 20 ft Pressure Readings | 40 ft Pressure Readings | 55 ft Pressure Readings | RI-18S Pressure Readings (90ft) |
|---|---|---|---|---|---|---|---|---|---|
| 12/5/2012 | 8:40 | 0.0 | 8.0 | 0.67 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 |
| 12/5/2012 | 9:45 | 1.8 | 9.0 | 0.75 | | | | | |
| 12/5/2012 | 9:55 | 1.9 | 9.0 | 0.92 | 8.0 | | | | |
| 12/5/2012 | 10:03 | 2.1 | 10.0 | 0.05 | 7.0 | 0.04 | 0.00 | | |
| 12/5/2012 | 10:13 | 2.2 | 10.0 | 0.22 | 7.0 | 0.22 | 0.00 | | |
| 12/5/2012 | 10:25 | 2.4 | 10.0 | 0.42 | 7.0 | 0.00 | 0.01 | | |
| 12/5/2012 | 10:35 | 2.6 | 10.0 | 0.58 | 6.8 | 0.00 | 0.01 | | |
| 12/5/2012 | 11:02 | 3.0 | 11.0 | 0.03 | 6.6 | 0.00 | 0.00 | 0.00 | |
| 12/5/2012 | 11:26 | 3.4 | 11.0 | 0.43 | 6.5 | 0.08 | 0.06 | | |
| 12/5/2012 | 12:07 | 4.1 | 12.0 | 0.12 | 6.5 | 0.12 | 0.05 | | |
| 12/5/2012 | 12:20 | 4.3 | 12.0 | 0.33 | | | | | |
| 12/5/2012 | 12:21 | 4.4 | 12.0 | 0.35 | 6.5 | 0.11 | | | |
| 12/5/2012 | 12:24 | 4.4 | 12.0 | 0.40 | 6.5 | 0.11 | 0.06 | 0.02 | 0.0 |
| 12/5/2012 | 12:47 | 4.8 | 12.0 | 0.78 | 6.5 | 0.11 | | | |
| 12/5/2012 | 13:10 | 5.2 | 13.0 | 0.17 | 6.5 | 0.10 | 0.04 | | |
| 12/5/2012 | 13:20 | 5.3 | 13.0 | 0.33 | 6.5 | | 0.04 | | |
| 12/5/2012 | 13:30 | 5.5 | 13.0 | 0.50 | | | | | |
| 12/5/2012 | 13:32 | 5.5 | 13.0 | 0.53 | 6.9 | | | | |
| 12/5/2012 | 13:41 | 5.7 | 13.0 | 0.68 | 6.9 | | | | |
| 12/5/2012 | 14:04 | 6.1 | 14.0 | 0.07 | 6.9 | 0.10 | 0.04 | | |
| 12/5/2012 | 14:30 | 6.5 | 14.0 | 0.50 | 7.0 | 0.11 | 0.05 | | |
| 12/5/2012 | 14:40 | 6.7 | 14.0 | 0.67 | | | | 0.06 | |
| 12/5/2012 | 14:45 | 6.8 | 14.0 | 0.75 | 7.3 | | | | 0.0 |
| 12/5/2012 | 15:05 | 7.1 | 15.0 | 0.08 | 7.5 | 0.12 | | | |
| 12/5/2012 | 15:27 | 7.5 | 15.0 | 0.45 | 7.7 | 0.13 | 0.06 | | |
| 12/5/2012 | 15:45 | 7.8 | 15.0 | 0.75 | 7.1 | 0.12 | 0.06 | 0.04 | |
| 12/5/2012 | 16:12 | 8.2 | 16.0 | 0.20 | 7.4 | | | | |
| 12/5/2012 | 16:26 | 8.4 | 16.0 | 0.43 | 7.1 | | | | |
| 12/5/2012 | 16:45 | 8.8 | 16.0 | 0.75 | 7.0 | | | | |
| 12/5/2012 | 16:54 | 8.9 | 16.0 | 0.90 | 9.1 | | | | |
| 12/5/2012 | 17:05 | 9.1 | 17.0 | 0.08 | 8.0 | | | | |
| 12/5/2012 | 17:40 | 9.7 | 17.0 | 0.67 | 8.0 | | | | |
| 12/5/2012 | 17:52 | 9.9 | 17.0 | 0.87 | 8.0 | 0.19 | 0.06 | 0.04 | 0.0 |
| 12/6/2012 | 7:45 | 23.8 | 31.0 | 0.75 | next day | 0.00 | 0.00 | 0.00 | 0.0 |

Note: Sparge operation and measurements performed by K. Might

**Attachment 3**

**Well PW-4 and RI-6S/D Area Test Data**




**Former Treatment Pit and PW-4/RI-6 Area**
**Existing and Newly Installed**
**Wells and Sparge Points**

0 50 100 200 Feet

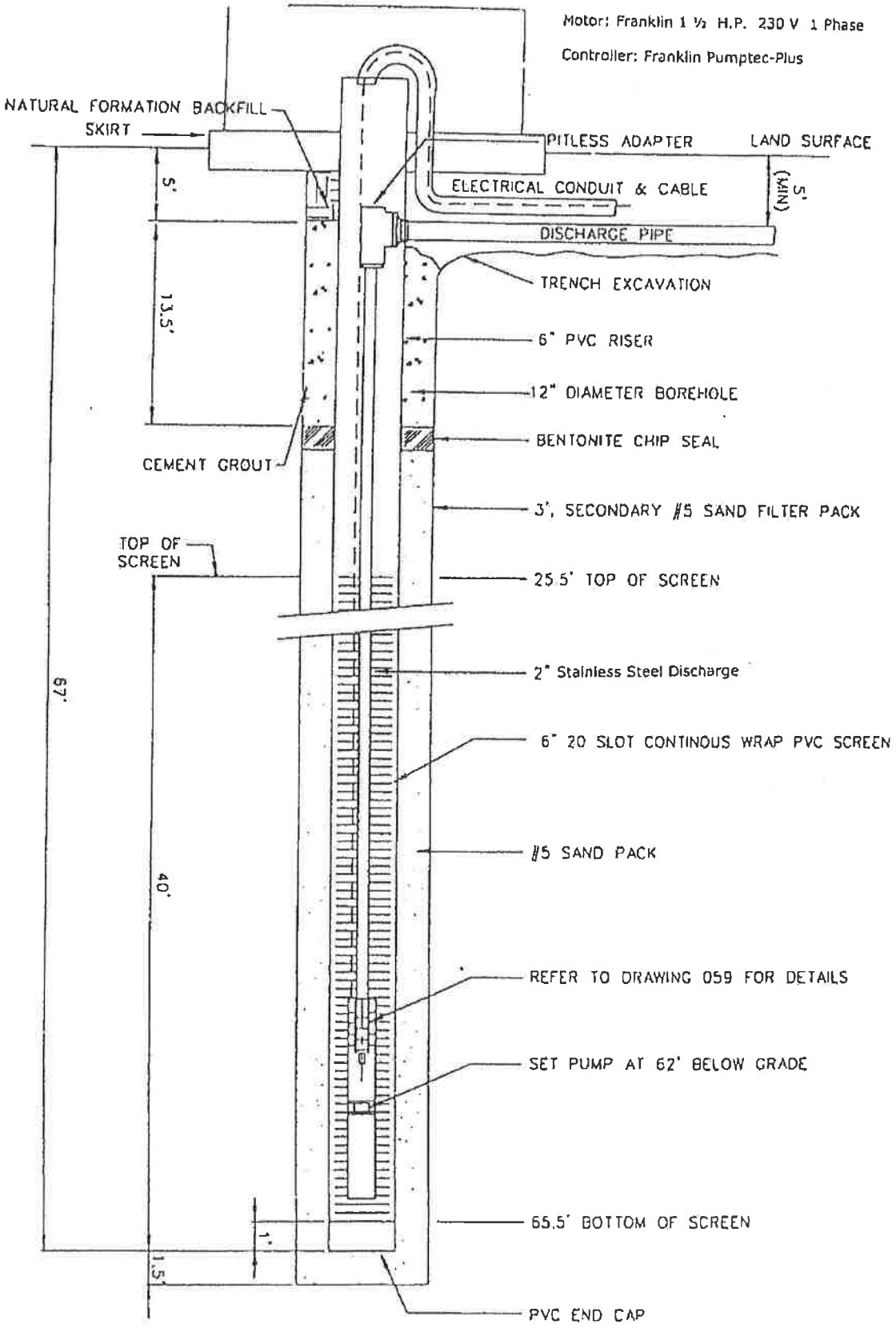
**Vertellus Specialties Inc**
**1500 S. Tibbs Ave.**
**Indianapolis, IN**

PW 4

Pump: GRUNDFOS 25 S 15-9

Motor: Franklin 1 ½ H.P. 230 V 1 Phase

Controller: Franklin Pumptec-Plus



**PEERLESS-MIDWEST, INC.**
65860 RUSSELL INDUSTRIAL PARKWAY / MISHAWAKA, INDIANA

# SUBMERSIBLE PUMP INSTALLATION REPORT

Sales Order No. 16935 Date 10/25/01

Jmp Mfg. Grundfos Model ~~Serial~~ No. 2243009204 Well No. PW-4

Owner Reilly Industries City Indianapolis State IN

Location of Well 30' west of Tibbs Avenue & 1/8 mile south of Minnesota Avenue

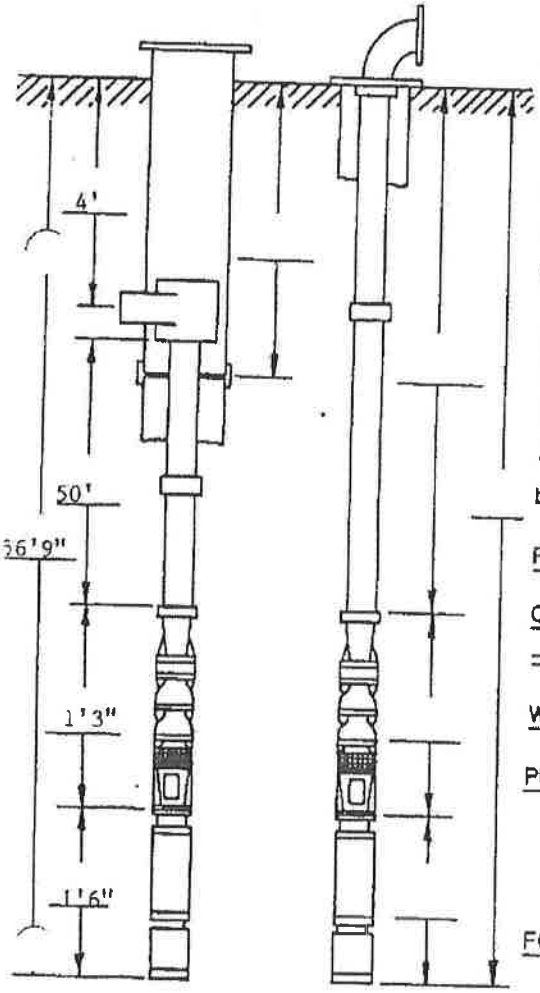
MOTOR: Make Franklin Dia. 4" Frame ____ Serial No. ____

Hp 1½ Volts 230 Phase 1 Cycles 60 RPM 3450

Full Load Amps 10 Service Factor .5 S.F. Amps 8

STARTER: Make Square D Size ____ Type ____

CONTROL: Make Coyote Type - Range - To - lbs.




PUMP DISCHARGE: Mfg. MASS Model ____

Flanged Elbow ____ Pitless Adapter X

Pitless Tank ____ Tank Capacity ____ gal.

Discharge Pipe Size 2 " Column Conn. Size 1½ "

Adapter Connected to Well Casing 4' " below ground with ____

COLUMN: Pipe Size 1½ " Black s.s. Galv. ____

Column Check Valve Type ____ " located X " above bowl

Air Line Length none '

Air Intake Valve Type ____ located ____ " below ground.

PUMP BOWL: Type Grundfos 25S15-9 Dia. 4" Stages 9

CABLE: Size 12-3 Length 55'

WELL: No. PW-4 Type ____ Dia. 6 " Depth 72 '

PUMPING TEST: GPM 25 Pumping Level 30 '

Static Level 26 ' Specific Capacity ____ GPF

PSI 60 Volts 230 Amps: 1 ____ 2 ____ 3 ____

FOUNDATION: 1 ' above / below ground level

REMARKS: ____

J. Blatz
Installer

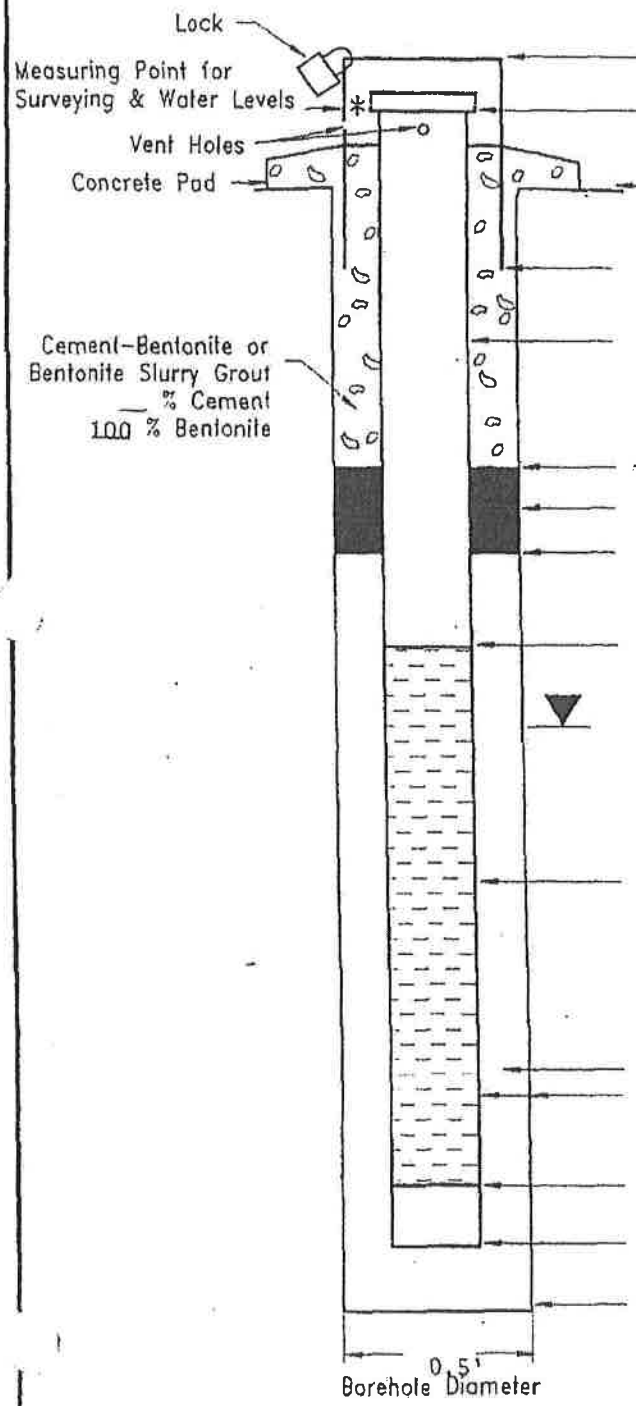
Project No: 5660-003-008 Client: Reilly Site: Indianapolis

**WELL No: RI-6S**

Well Location: East Side of Reilly Properry Date Installed: 5 / 18

Contractor: LAYNE-NORTHWEST Method: Dual Tube, Reverse Air Inspector: B.G.

# MONITORING WELL CONSTRUCTION DETAIL




| | | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|---|
| Top of Steel Guard Pipe | | 2.5' | 703.26 |
| Top of Riser Pipe | | 2.3' | 703.09 |
| Ground Surface (G.S.) | | 0.00 | 700.8 |
| Bottom of Steel Guard Pipe | | 2.5' | 698.3 |
| Riser Pipe: | | | |
| Length | 26.5' | | |
| Inside Diameter (ID) | 2" | | |
| Type of Material | PVC | | |
| Top of Bentonite Seal | | 20.0 | 680.8 |
| Bentonite Seal Thickness | 2.0 | | |
| Top of Sand | | 22.0 | 678.8 |
| Top of Screen | | 24.4' | 676.4 |
| Stabilized Water Level | | 26.8' | 674.0 |
| Screen: | | | |
| Length | 9.8' | | |
| Inside Diameter (ID) | 2" | | |
| Slot Size | 0.010 | | |
| Type of Material | PVC | | |
| Type/Size of Sand | 45/55 | | |
| Sand Pack Thickness | 2" | | |
| Bottom of Screen | | 34.2' | 666.6 |
| Bottom of Tail Pipe: | | 34.4' | 666.3 |
| Length | 0.3' | | |
| Bottom of Borehole | | 37.0' | 663.8 |

* Describe Measuring Point:
V-NOTCH IN PVC RISER

Approved:

Signature

8-31-89
Date

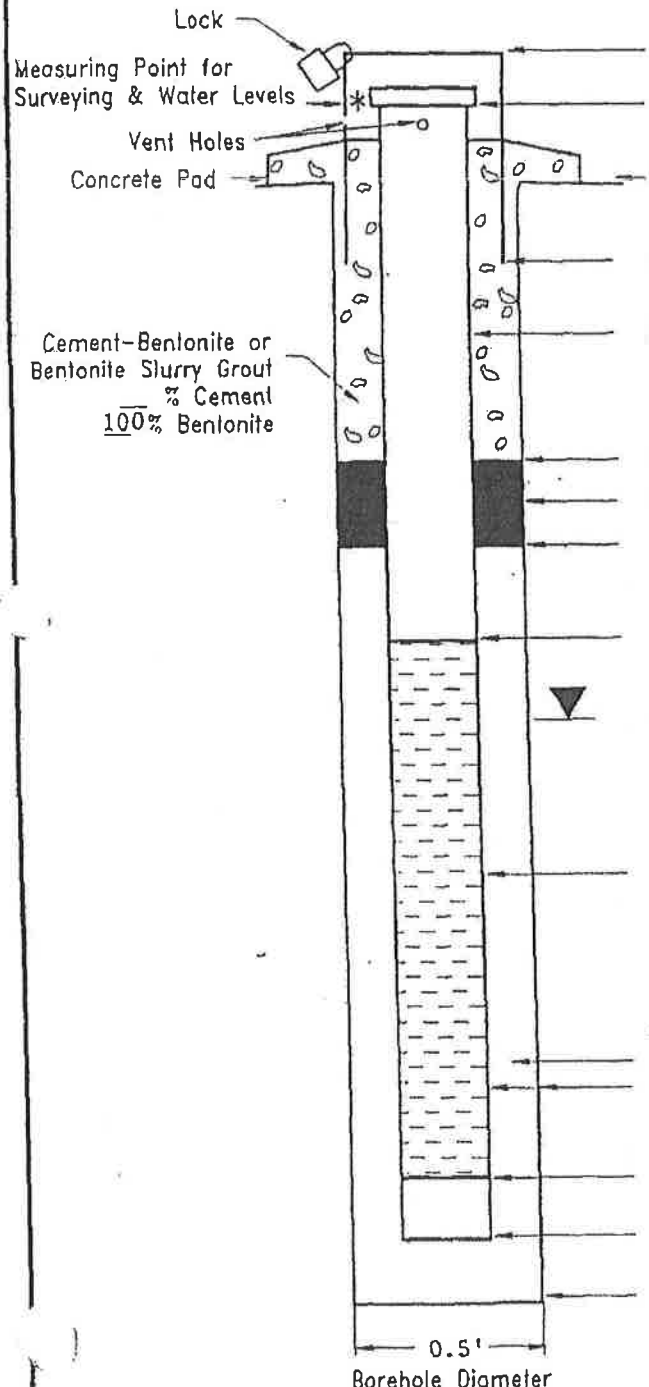
ENSR

Project No: 5660-003-008 Client: Reilly Site: Indianapolis WELL No: RI-6D

Well Location: East Side of Reilly Property Date Installed: 6/29/8

Contractor: LAYNE-NORTHWEST Method: Dual Tube, Reverse Air Inspector: L.P.

# MONITORING WELL CONSTRUCTION DETAIL




| | | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|---|
| Top of Steel Guard Pipe | | 2.2' | 702.72 |
| Top of Riser Pipe | | 2.1' | 702.59 |
| Ground Surface (G.S.) | | 0.00 | 700.5 |
| Bottom of Steel Guard Pipe | | 2.8' | 697.7 |
| Riser Pipe: Length | 5.4' | | |
| Inside Diameter (ID) | 2" | | |
| Type of Material | PVC | | |
| Top of Bentonite Seal | | 49.2' | 651.3 |
| Bentonite Seal Thickness | 1.1' | | |
| Top of Sand | | 50.3' | 650.2 |
| Top of Screen | | 52.7' | 647.8 |
| Stabilized Water Level | | 28.1' | 672.4 |
| Screen: Length | 4.4' | | |
| Inside Diameter (ID) | 2" | | |
| Slot Size | 0.010 | | |
| Type of Material | PVC | | |
| Type/Size of Sand | 45/55 | | |
| Sand Pack Thickness | 2" | | |
| Bottom of Screen | | 57.1' | 643.4 |
| Bottom of Tail Pipe: Length | 0.5' | 57.6' | 642.9 |
| Bottom of Borehole | | 57.6' | 642.9 |

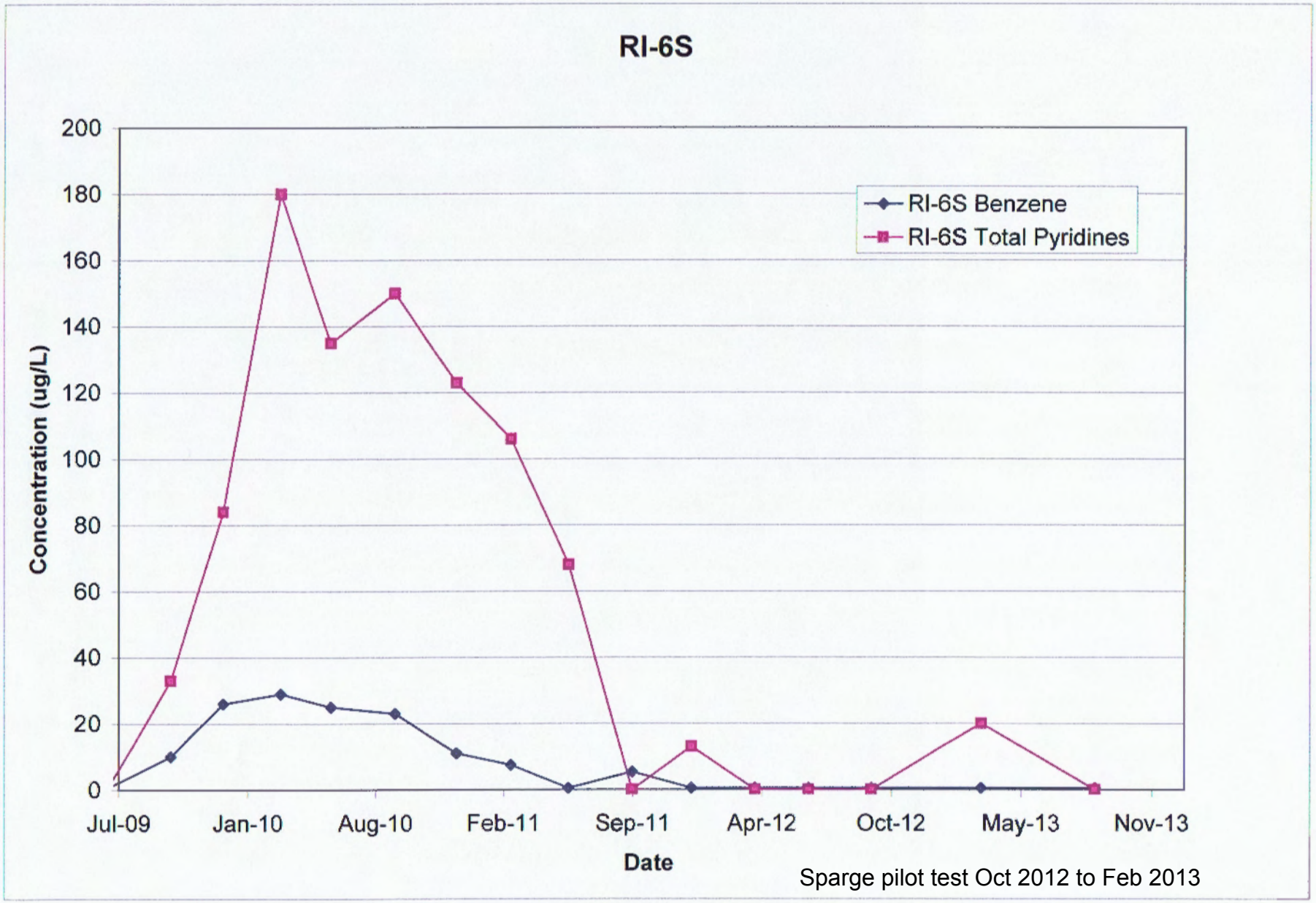
Approved:

* Describe Measuring Point:
V-NOTCH IN PVC RISER

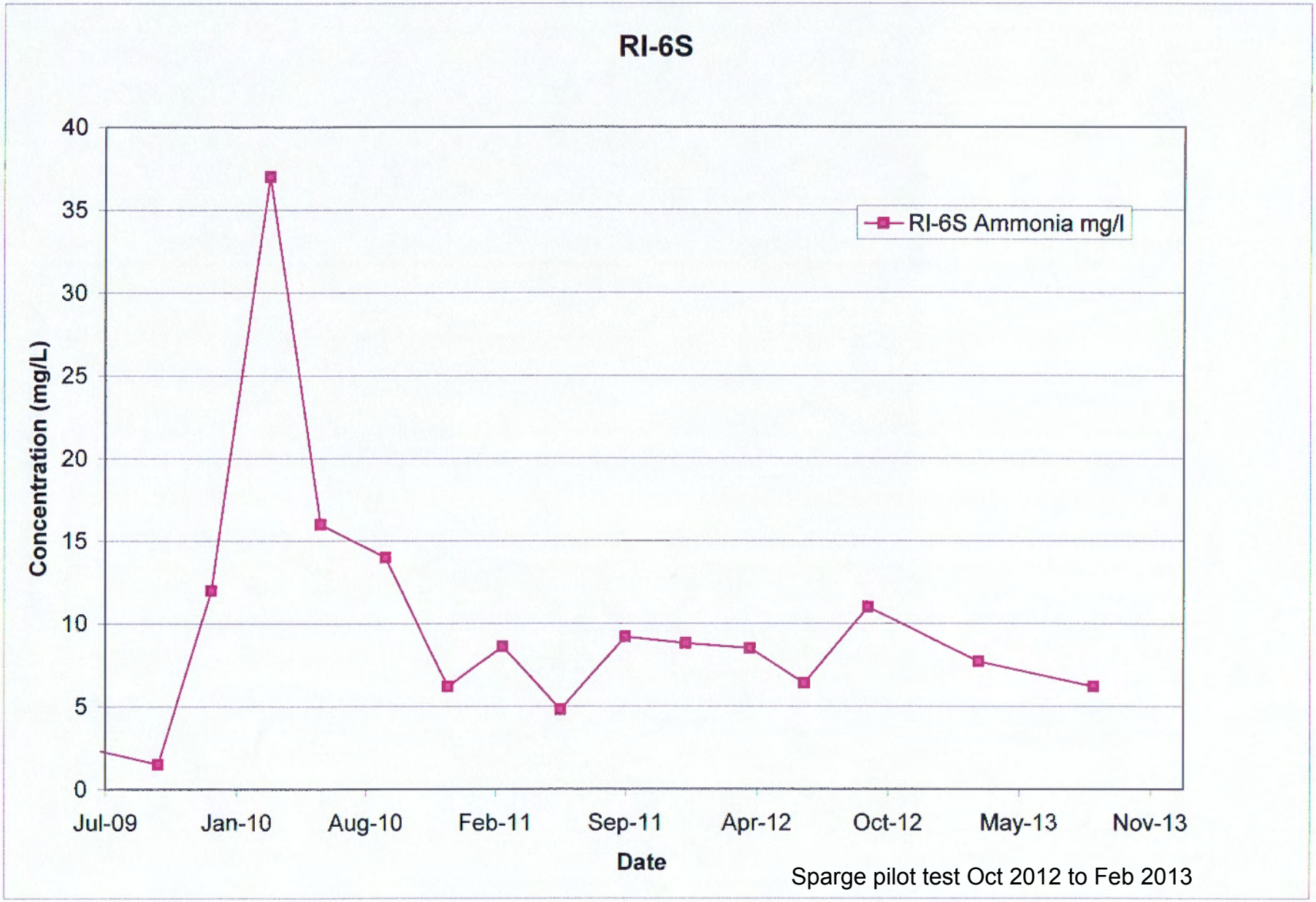
Signature

8/21/89
Date

ENSR®




Sparge pilot test Oct 2012 to Feb 2013




Sparge pilot test Oct 2012 to Feb 2013

# Vertellus Specialties Inc.
## Groundwater Monitoring Data 1994 to 4Q2013

| Well Name | Sample Date | Benzene ug/l | Total Pyridines ug/l | Ammonia mg/l | Toluene | Ethyl benzene | Xylene-total | Pyridine | 2-Picoline | 3/4-Picoline | 2,6-Lutidine | 2-Ethyl pyridine | 2,4/2,5-Lutidine | 2,3-Lutidine | 3-Ethyl pyridine | 4-Ethyl pyridine | 3,5-Lutidine | 3,4-Lutidine | 2-Methyl-5-ethyl pyridine | 2-Methyl-3-ethyl pyridine | 3-Ethyl-4-methyl pyridine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RI-6S** | Mar-09 | 0.5 | 0 | 3.3 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Jun-09 | 0.5 | 0 | 2.4 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sep-09 | 10.0 | 33 | 1.5 | ND | ND | ND | 0 | 16 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Dec-09 | 26.0 | 84 | 12.0 | ND | ND | ND | 0 | 22 | 52 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Mar-10 | 29.0 | 180 | 37.0 | ND | ND | ND | 0 | 38 | 110 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Jun-10 | 25.0 | 135 | 16.0 | ND | ND | ND | 0 | 24 | 51 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 29 |
| | Sep-10 | 23.0 | 150 | 14.0 | ND | ND | ND | 0 | 0 | 19 | 100 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 |
| | Dec-10 | 11.0 | 123 | 6.2 | ND | ND | ND | 0 | 0 | 13 | 69 | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 15 | 0 |
| | Mar-11 | 7.5 | 106 | 8.6 | ND | ND | ND | 0 | 0 | 0 | 69 | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 11 | 0 |
| | Jun-11 | 0.5 | 68 | 4.8 | ND | ND | ND | 0 | 0 | 0 | 47 | 0 | 0 | 0 | 0 | 0 | 21 | 0 | 0 | 0 | 0 |
| | Sep-11 | 5.4 | 0 | 9.2 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Dec-11 | 0.5 | 13 | 8.8 | ND | ND | ND | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Mar-12 | 0.5 | 0 | 8.5 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Jun-12 | 0.5 | 0 | 6.4 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sep-12 | 0.5 | 0 | 11.0 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Mar-13 | 0.5 | 20 | 7.7 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 |
| | Aug-13 | 0.5 | 0 | 6.2 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Sparge pilot test Oct 2012 to Feb 2013

Notes: Non-detect is indicated by 0.5 ug/L for benzene, 0 for pyridines, 0.5 for ammonia and ND for other compounds

# PW-4 Sparging

| Date | Time | Compressor psi | Spool psi | Temp | Diff P | Line out psi | SCFM |
|---|---|---|---|---|---|---|---|
| 10/23/2012 | 145 | turn on | set point at 33 ft | | | | |
| 10/23/2012 | 150 | 50 | 36 | 110 | 23 | 29 | 15.3 |
| 10/23/2012 | 155 | 46 | 28 | 122 | 22.5 | 23 | |
| 10/23/2012 | 159 | 45 | 28 | 124 | 24 | 22 | |
| 10/23/2012 | 205 | 45 | 28 | 128 | 25.5 | 20.5 | |
| 10/23/2012 | 210 | 45 | 28 | 130 | 25 | 20 | 14 |
| 10/23/2012 | 216 | off | | | | | |
| 10/25/2012 | 1200 | on | set point down to 55 ft | | | | |
| 10/25/2012 | 1220 | 51 | 36 | 113 | 20.5 | 31 | |
| 10/25/2012 | 1225 | 50 | 33 | 120 | 21.5 | 30.5 | 14.3 |
| 10/25/2012 | 1230 | 50 | 32 | 128 | 22.5 | 29.5 | |
| 10/25/2012 | 1235 | 50 | 32 | 130 | 22.5 | 29.5 | |
| 10/25/2012 | 1350 | 90 | 76 | 142 | 15 | 34 | 17.9 |
| 10/25/2012 | 1357 | 50 | 32 | 146 | 22 | 29 | 14 |
| 10/25/2012 | 1407 | 50 | 30 | 140 | 22.5 | 28.5 | 13.7 |
| 10/25/2012 | 1420 | 48 | 30 | 138 | 23 | 28 | |
| 10/25/2012 | 1421 | off | | | | | |
| 10/25/2012 | 1438 | 58 | 40 | 122 | 21.5 | 33 | |
| 10/25/2012 | 1500 | 45 | 27 | 135 | >25 | 28.5 | |
| 11/14/2012 | 1028 | 56 | 40 | 104 | 23 | 33 | 16.5 |
| 11/14/2012 | 1043 | 50 | 32 | 122 | 25 | 32 | |
| 11/14/2012 | 1046 | 50 | 31 | 122 | 25 | 30.5 | 14.9 |
| 12/18/2012 | 1615 | 50 | 32 | 123 | 17 | 33 | 12.5 |
| 12/18/2012 | 1620 | 50 | 32 | 123 | 16.8 | 33 | |
| 12/20/2012 | 1005 | 52 | 36 | 130 | 21 | 36 | 14.6 |
| 12/20/2012 | 1110 | 51 | 35 | 134 | 21.2 | 35.5 | |
| 1/11/2013 | 1223 | 80 | 66 | 133 | 12 | 69 | 15 |
| 1/11/2013 | 1228 | 78 | 62 | 146 | 13.5 | 68 | 15.2 |
| 1/11/2013 | 1231 | 76 | 64 | 153 | 13.5 | 68 | |
| 1/11/2013 | 1525 | 75 | 64 | 142 | 13.5 | 59 | |
| 1/17/2013 | 1215 | 94 | 82 | 121 | 10 | 78 | 15.4 |
| 1/18/2013 | 1525 | 75 | 64 | 142 | 13.5 | 59 | |
| 1/21/2013 | 1412 | 75 | 60 | 136 | 14.8 | 59 | |
| 1/23/2013 | 1412 | 75 | 60 | 136 | 14.8 | 59 | 15.8 |
| 1/28/2013 | 1115 | 83 | 68 | 114 | 7.5 | 68 | |

| Distances | ft |
|---|---|
| 6D to PW-4 | 18.5 |
| 6S to PW-4 | 15 |
| 6D to 6S | 33.5 |

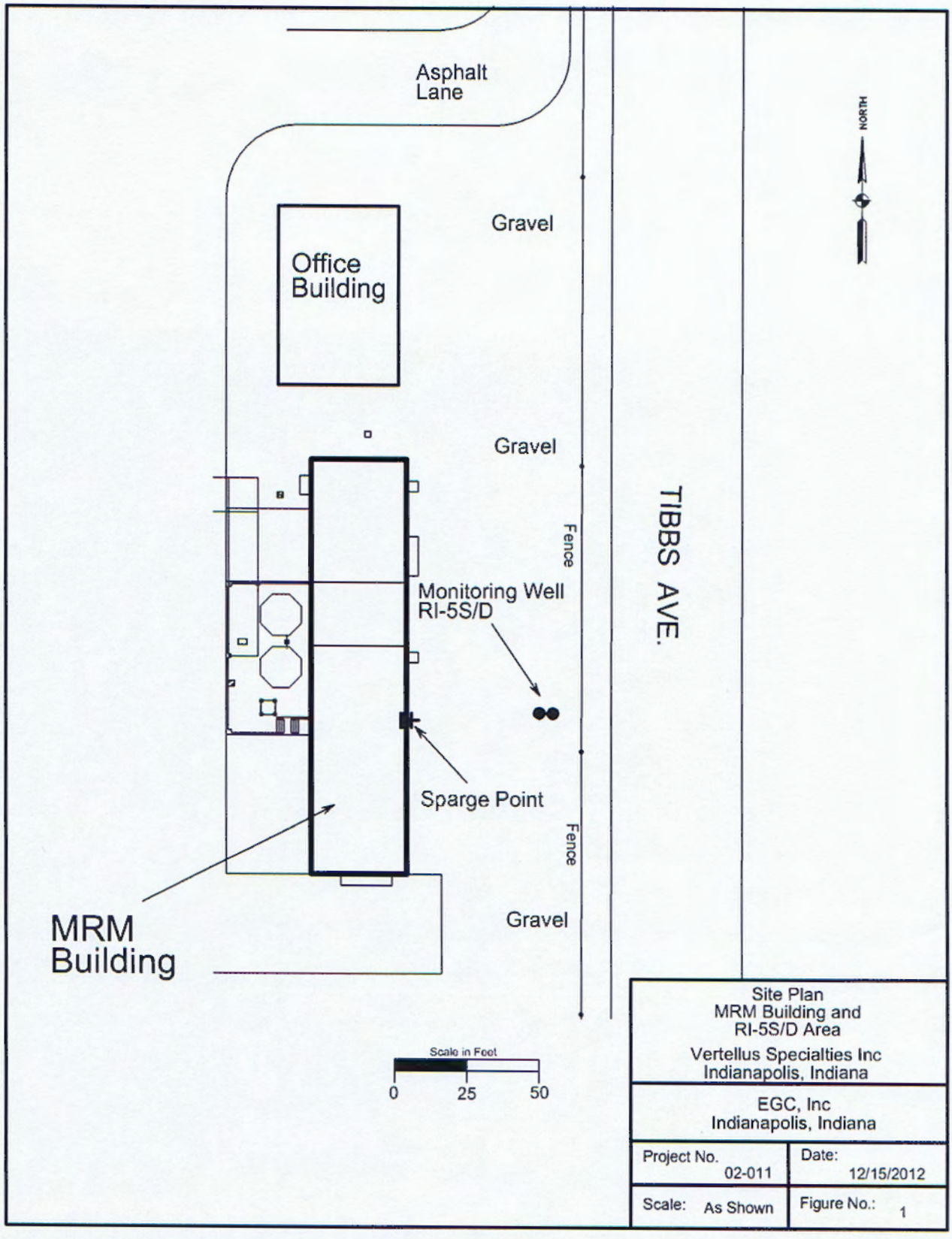
Note: Sparge operation and measurements performed by K. Might

## RI-6D Sparging

| | | | | | | | | | | | | | | | RI6S Press | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Distances | ft | | RI6S WL | RI6S DO | RI6S T | in h20 | PW4 Press | PW4 DO | PW4 T |
| 12/20/2012 | | | | | | | | Sparging | 6D to PW-4 | 18.5 | | 26.38 | 0.31 | 16.2 | | | | |
| 1/11/2013 | Time | Compressor psi | Spool psi | Temp | Diff P | Line out psi | SCFM | Wellhead | 6S to PW-4 | 15 | | 26.43 | 0.35 | 15.5 | | | | |
| 2/5/2013 | change from PW-4 to RI-6D on 2/5/2013 | | | | | | | | 6D to 6S | 33.5 | | | | | | | | |
| 2/5/2013 | 1604 | 55 | 36 | 115 | 14.8 | 10 | 13 | 15 | | | | 25.2 | 0.3 | 15.1 | 0 | na | | |
| 2/5/2013 | 1608 | 55 | 36 | 117 | 14.4 | 10 | | 15 | | | | | | | | | | |
| 2/7/2013 | 1251 | 49 | 28 | 122 | 17.1 | 19 | 11.7 | 13 | install side air disch at PW-4 to RI-6D | | | 25.26 | 0.37 | 15.5 | 0.04 | 4.8 | 0.35 | 15.9 |
| 2/7/2013 | 1257 | 49 | 30 | 131 | 17 | 19 | | 13 | | | | | | | | | | |
| 2/7/2013 | 1303 | 50 | 29 | 136 | 17 | 19 | | 13 | | | | | | | | | | |
| 2/7/2013 | 1308 | 50 | 29 | 138 | 17 | | 11.7 | 13 | | | | | | | | | | |
| 2/21/2013 | 1230 | 48 | 32 | 128 | 18.5 | 19 | | 14 | | | | | 0.41 | 15.3 | 0.05 | 4.7 | 2.75 | 15.8 |
| 2/25/2013 | 1215 | 50 | 33 | 96 | 16.5 | 19 | | 13 | | | | | | | | | | |
| 3/4/2013 | 1305 | | | | | | | | | | | 25.05 | 0.28 | 13.5 | | | | |
| 3/20/2013 | 1535 | 60 | 44 | 140 | 13.5 | | 12.9 | 14 | | | | | | | | | | |
| 3/28/2013 | | | | | | | | | belt is broken. Turned off power | | | | | | | | | |
| 5/7/2013 | | 55 | 35 | 90 | 17 | 19 | | 13 | replace motor mount and belt | | | 26.11 | 0.38 | 16.5 | | | | |
| 5/10/2013 | 1253 | 49 | 33 | 134 | | 18 | | 13.5 | | | | 23.02 | 0.45 | 14.1 | | 4 | | |
| 5/21/2013 | 1336 | 49 | 30 | 151 | >25 | 18 | | 13 | turned off, ordered in line flow meter | | | 23.08 | 0.65 | 13.6 | | | | |
| 6/4/2013 | 1235 | 60 | 62 | 78 | | | 15.5 | 14 | back on after fix spool, orif plate broke | | | | | | | 2 | | |
| 6/11/2013 | | 59 | 48 | 76 | | | 15.5 | 13.5 | | | | | | | | | | |
| 6/20/2013 | 1341 | 71 | 60 | 78 | | | 16 | 13 | motor thermal switch popped out, reset | | | | 0.33 | 13.66 | | | 11.48 | 14.3 |
| 6/28/2013 | 1334 | 50 | 46 | 120 | | 19 | 16 | 13 | | | | | | | | 3 | | |
| 7/8/2013 | | 50 | 61 | 106 | | 19 | 15.5 | 13 | | | | 23.93 | 0.65 | 19.8 | | | | |
| 7/19/2013 | 1153 | 53 | 43 | 117 | | 19 | 16 | 13.5 | | | | 24.25 | | 16.7 | | | | |
| 7/30/2013 | 1142 | 58 | 48 | 108 | | 20 | 16 | 13.5 | | | | 24.51 | 0.45 | 13.9 | | | | |
| 8/9/2013 | 1000 | 70 | 60 | 131 | | 19 | 15 | 14 | | | | | | | | | | |
| 8/19/2013 | 1240 | 70 | 60 | 128 | | 19 | 15 | 13 | | | | 25.13 | 0.51 | 14.3 | | | | |
| | | | | | | | | | | | | | | | | | | |
| Note: Sparge operation and measurements performed by K. Might | | | | | | | | | | | | | | | | | | |

**Attachment 4**

**Well RI-5 Area Test Data**


Asphalt
Lane
NORTH
Gravel
Office
Building
Gravel
TIBBS AVE.
Fence
Monitoring Well
RI-5S/D
Sparge Point
Fence
MRM
Building
Gravel
Scale in Feet
0
25
50
Site Plan
MRM Building and
RI-5S/D Area
Vertellus Specialties Inc
Indianapolis, Indiana
EGC, Inc
Indianapolis, Indiana
Project No.
02-011
Date:
12/15/2012
Scale: As Shown
Figure No.: 1

ENSR

# BORING LOG

Sheet 1 of 3

Project No. 5660-003-008 Date - Start 5-3-89 Finish 5-4-89 Boring RI-05

Project Name REILLY INDUSTRIES Drilling Co. LAYNE-NORTHWEST

Location INDIANAPOLIS Drilling Method DUAL TUBE

Total Depth 105' Inspector Reviewer J.R.

Remarks

| Depth Feet | Sample Type & No. | Sample Blows per 6 in | Sample Depth Range | Sample Rec. | Graphic Log | Lithologic Description | Equipment Installed |
|---|---|---|---|---|---|---|---|
| | | | | | | some Gravel at 2 feet<br>Silty Clay rich organic TOPSOIL | |
| 5 | S-1 | | 6' | | | Fine GRAVEL<br>Med. to Cs. Brown SAND & GRAVEL | |
| 10 | | | | | | Cs. SAND, some Gravel | |
| 15 | | | | | | GRAVEL, some Sand<br>SAND, some Gravel | |
| 20 | | | | | | Gray SAND & GRAVEL | |
| 25 | S-2 | | 24.5' | | | | |
| | S-3 | | 29.5' | | | Gray SAND, some Gravel | |
| 30 | S-4 | | 30' | | | | |
| | S-5 | | 31' | | | Black Cs. SAND & GRAVEL | |
| | S-6 | | 33' | | | | |
| 35 | | | | | | SILT & Fine SAND<br>(head space sample SB05-Z1 = 0.00 ppm Benzene) | |
| | | | | | | GRAVEL & SAND | |
| | | | | | | SILT & GRAVEL | |

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## BORING LOG (continued)

Project REILLY INDUSTRIES Boring RI-05 Sheet 2 of 3

| Depth Feet | Sample Type & No. | Sample Blows per 6 in. | Sample Depth Range | Sample Rec. | Graphic Log | Lithologic Description | Equipment Installed |
|---|---|---|---|---|---|---|---|
| | S-7 | | 41' | | | SILT & GRAVEL | |
| | S-8 | | 41.5' | | | GRAVEL, some Silt | |
| 45 | | | | | | Gray SILT, some Gravel | |
| | S-9 | | 47' | | | | |
| | S-10 | | 48' | | | SAND & SILT (head space sample SB05-Z2 = 0.114 ppm Benzene) | |
| 50 | | | | | | Pyridine odor at 53 feet | |
| | S-11 | | 52' | | | GRAVEL & SAND | |
| 55 | | | | | | GRAVEL, some Cobbles | |
| | S-12 | | 56' | | | CLAY, some Silt | |
| | | | | | | Pyridine odor at 59 feet | |
| 60 | S-13 | | 60' | | | GRAVEL & SILT | |
| | | | | | | CLAY & SILT (head space sample SB05-Z3 = 0.00 ppm Benzene) | |
| | | | | | | GRAVEL, some Silt | |
| 65 | S-14 | | 65' | | | Gray CLAY, some Silt | |
| | S-15 | | 69.5' | | | | |
| 70 | | | | | | Black GRAVEL & SILT | |
| | S-16 | | 73' | | | (head space sample SB05-Z4 = 0.00 ppm Benzene | |
| 75 | S-17 | | 76' | | | GRAVEL, some Silt & Sand | |
| | | | | | | SILT & SAND | |
| 80 | | | | | | SAND, some Gravel | |
| | | | | | | Gray Med. to Cs. SAND & GRAVEL | |

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# BORING LOG (continued)

Project REILLY INDUSTRIES Boring RI-05 Sheet 3 of 3

| Depth Feet | Sample Type & No. | Sample Blows per 6 in. | Sample Depth Range | Sample Rec. | Graphic Log | Lithologic Description | Equipment Installed |
|---|---|---|---|---|---|---|---|
| 90 | S-18 | | 91.5' | | | (head space sample SB05-Z5 = 0.00 ppm Benzene) Gray Med. to Cs. SAND & GRAVEL | |
| 95 | S-19 | | 96.5' | | | | |
| | S-20 | | 99' | | | Black SHALE | |
| 100 | S-21 | | 100' | | | (head space sample SB05-Z6 = 0.00 ppm Benzene) | |
| 105 | | | | | | BOTTOM OF BORING AT 105 FEET | |

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

BORING IDENTIFICATION: **RI-5D** Replacement



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 1 | | | | | No samples collected until |
| | 2 | | | | | 3.0 feet below grade |
| | 3 | | | | | |
| Medium brown (10YR 3/4) dry CLAY with trace of sand. Changes to yellowish brown (10YR 5/4) coarse SAND with some gravel at 4.5 to 5.0 feet | 4 | 1 | 6-6-6-6 | 60% | 60 | |
| | 5 | | | | | |
| | 6 | | | | | |
| | 7 | | | | | |
| | 8 | | | | | |
| Yellowish reddish brown (10 YR 5/8) dry coarse SAND with little gravel and trace of silt. Changes to a yellowish brown (10yr 5/4) coarse SAND with some gravel at 9.5 feet | 9 | 2 | 9-13-14-15 | 70% | 80 | |
| | 10 | | | | | |
| | 11 | | | | | |
| | 12 | | | | | |
| | 13 | | | | | |
| Light yellowish brown (10 YR 6/4) dry coarse SAND and GRAVEL with a trace of silt | 14 | 3 | 12-17-21-12 | 90% | 40 | |
| | 15 | | | | | |
| | 16 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

TCV=TOTAL COMBUSTIBLE VAPORS No=SAMPLE
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

**BORING IDENTIFICATION: RI-5D**



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 17 | | | | | |
| | 18 | | | | | |
| Brown (10 YR 5/3) slightly moist SAND with little gravel | 19 | 4 | 14-14-15-12 | 90% | 80 | |
| | 20 | | | | | |
| | 21 | | | | | |
| | 22 | | | | | |
| | 23 | | | | | |
| Dark gray (10 YR 4/1) wet coarse SAND and GRAVEL | 24 | 5 | 6-8-9-10 | 70% | 620 | Some water on rods, saturated at 23.5 feet |
| | 25 | | | | | |
| | 26 | | | | | |
| | 27 | | | | | |
| | 28 | | | | | |
| Dark gray (10YR 4/1) moist coarse SAND and GRAVEL with 2" layer of grayish brown (10YR 5/2) fine sandy CLAY | 29 | 6 | 12-15-25-30 | 90% | 580 | Black stains, Reilly odor |
| | 30 | | | | | |
| | 31 | | | | | |
| | 32 | | | | | |
| | 33 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS-SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

BORING IDENTIFICATION: **RI-5D**



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| Grayish brown (10YR 5/2) moist fine SAND with a trace of silt changing to dark gray (10 YR 4/1) SILT and little gravel | 34 | 7 | 35-50->50 | 90% | 220 | Slight odor |
| | 35 | | | | | |
| | 36 | | | | | |
| | 37 | | | | | |
| Dark gray (10 YR 4/1) moist SILT with little gravel trace of sand becoming SAND and GRAVEL with a trace of clay | 38 | 8 | 17-24-25-23 | 95% | 120 | No odor |
| | 39 | | | | | |
| | 40 | | | | | |
| | 41 | | | | | |
| | 42 | | | | | |
| | 43 | | | | | |
| Gray (10 YR 5/1) fine sandy SILT with little gravel | 44 | 9 | 43-42-50 (5") | 90% | 180 | No odor |
| | 45 | | | | | |
| | 46 | | | | | |
| | 47 | | | | | |
| | 48 | | | | | |
| No recovery, sample not available | 49 | 10 | 50 (1") | 0% | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
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*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

**BORING IDENTIFICATION: RI-5D**



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 50 | 10 | | | | |
| | 51 | | | | | |
| | 52 | | | | | |
| | 53 | | | | | |
| Dark gray (10 YR 4/1) sandy CLAY trace of gravel changing at 54 feet to fine sandy GRAVEL | 54 | 11 | 21-17-9-8 | 60% | 180 | No odor |
| | 55 | | | | | |
| | 56 | | | | | |
| | 57 | | | | | |
| | 58 | | | | | |
| No recovery | 59 | 12 | 50/2" | 0 | | |
| | 60 | | | | | |
| | 61 | | | | | |
| | 62 | | | | | |
| | 63 | | | | | |
| Gray (10 YR 5/1) sandy GRAVEL with little clay | 64 | 13 | 42-50 | 50 | 220 | No odor, slight black stain |
| | 65 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL
TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

BORING IDENTIFICATION: **RI-5D**



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 66 | | | | | |
| | 67 | | | | | |
| | 68 | | | | | |
| Very dark gray (10 YR 3/1) SAND and GRAVEL with a trace of clay | 69 | 14 | 16-8-14-28 | 60% | 140 | Slight odor and 2" of staining at 69 to 70 feet |
| | 70 | | | | | |
| | 71 | | | | | |
| | 72 | | | | | |
| | 73 | | | | | |
| Dark Gray (10 YR 4/1) fine SAND with a trace of clay | 74 | 15 | 30-33-50 (6") | 80 | 200 | slight odor |
| | 75 | | | | | |
| | 76 | | | | | |
| | 77 | | | | | |
| | 78 | | | | | |
| Gray (10YR 5/1) SAND with trace of gravel | 79 | 16 | 10-16-36-40 | 80 | 200 | Slight odor |
| | 80 | | | | | |
| | 81 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
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*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

BORING IDENTIFICATION: RI-5D

PAGE 6 of 6

CLIENT: Reilly Industries, Inc.
PROJECT NAME: Monitoring well installation
SITE LOCATION: Indianapolis, Indiana
BORING LOCATION: 11' west and 1.25' north of RI-5S

PROJECT NUMBER: 97132.40
DATE DRILLED: 7/8/97
ELEVATION:
DRILLING METHOD: HSA

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 82 | | | | | |
| Boring terminated at 83 feet | 83 | | | | | |
| | 84 | | | | | |
| | 85 | | | | | |
| | 86 | | | | | |
| | 87 | | | | | |
| | 88 | | | | | |
| | 89 | | | | | |
| | 90 | | | | | |
| | 91 | | | | | |
| | 92 | | | | | |
| | 93 | | | | | |
| | 94 | | | | | |
| | 95 | | | | | |
| | 96 | | | | | |
| | 97 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

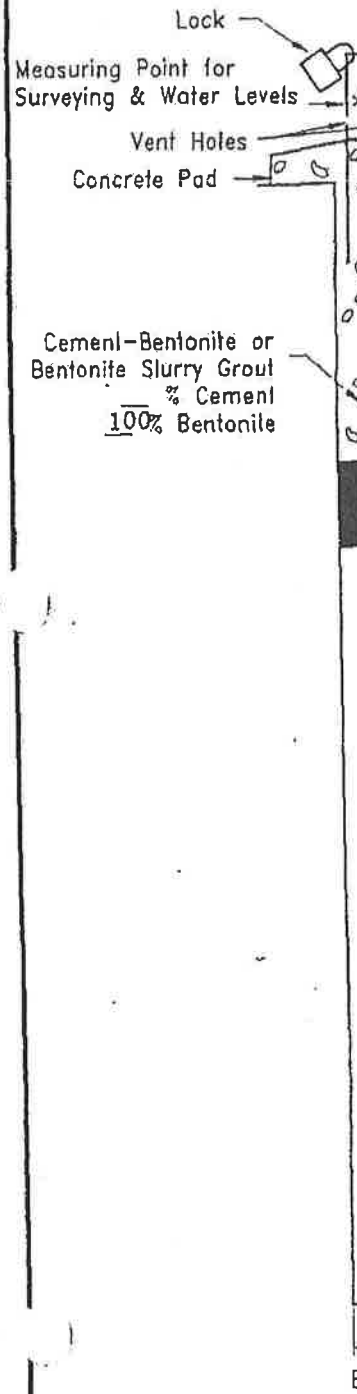
TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

Project No: 5660-003-008 Client: Reilly Site: Indianapolis WELL No: RI-5

Well Location: East Side of Reilly Property, Just South of Minnesota Date Installed: 6/21/

Contractor: LAYNE- NORTHWEST Method: Dual Tube, Reverse Air Inspector: L.P.

# MONITORING WELL CONSTRUCTION DETAIL




| | | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|---|
| Top of Steel Guard Pipe | | 2.7' | 703.37 |
| Top of Riser Pipe | | 2.50' | 703.24 |
| Ground Surface (G.S.) | | 0.00 | 700.7 |
| Bottom of Steel Guard Pipe | | 2.3' | 698.4 |
| Riser Pipe: | | | |
| Length | 48.0' | | |
| Inside Diameter (ID) | 2" | | |
| Type of Material | PVC | | |
| Top of Bentonite Seal | | -42.2' | 658.5 |
| Bentonite Seal Thickness | 1.2' | | |
| Top of Sand | | 43.4' | 657.3 |
| Top of Screen | | 45.9' | 654.8 |
| Stabilized Water Level | | 26.5' | 674.2 |
| Screen: | | | |
| Length | 9.8' | | |
| Inside Diameter (ID) | 2" | | |
| Slot Size | 0.010 | | |
| Type of Material | PVC | | |
| Type/Size of Sand | 45/55 | | |
| Sand Pack Thickness | 2" | | |
| Bottom of Screen | | 55.5' | 645.2 |
| Bottom of Tail Pipe: | | 55.8' | 644.9 |
| Length | 0.3' | | |
| Bottom of Borehole | | 55.8' | 644.9 |

Approved:

* Describe Measuring Point:
V-NOTCH IN PVC RISER

Signature

8-21-89
Date

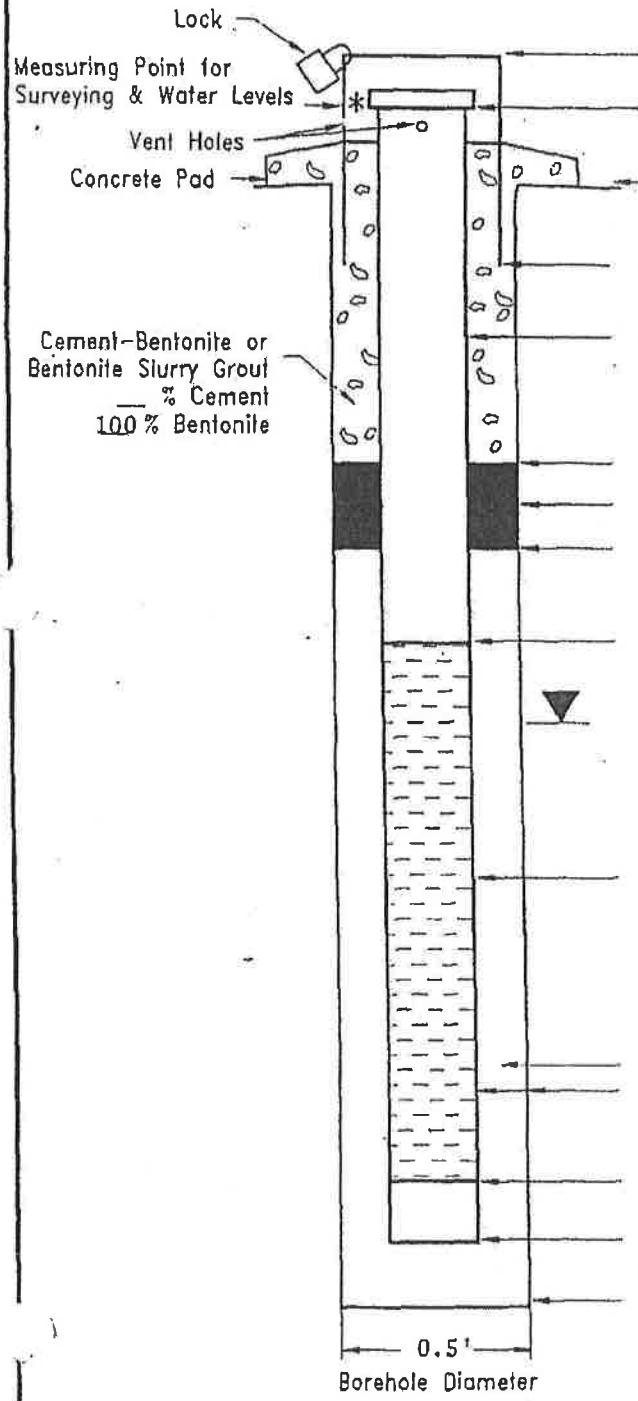
ENSR

Project No: 5660-003-008 Client: Reilly Site: Indianapolis WELL No: RI-5I

Well Location: East Side of Reilly Property, Just South of Minnesota Date Installed: 6/21/

Contractor: LAYNE-NORTHWEST Method: Dual Tube, Reverse Air Inspector: L.P.

# MONITORING WELL CONSTRUCTION DETAIL




| | | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|---|
| Top of Steel Guard Pipe | | 2.6' | 703.20 |
| Top of Riser Pipe | | 2.50' | 703.07 |
| Ground Surface (G.S.) | | 0.00 | 700.6 |
| Bottom of Steel Guard Pipe | | 2.4' | 698.2 |
| Riser Pipe: | | | |
| Length | 74.4' | | |
| Inside Diameter (ID) | 2" | | |
| Type of Material | PVC | | |
| Top of fine sand Seal | | 67.7' | 632.9 |
| Seal Thickness | 2.08' | | |
| Top of Sand | | 69.7' | 630.9 |
| Top of Screen | | 72.2' | 628.4 |
| Stabilized Water Level | | 33.1' | 667.5 |
| Screen: | | | |
| Length | 9.8' | | |
| Inside Diameter (ID) | 2" | | |
| Slot Size | 0.010 | | |
| Type of Material | PVC | | |
| Type/Size of Sand | 45/55 | | |
| Sand Pack Thickness | 2" | | |
| Bottom of Screen | | 81.9' | 618.7 |
| Bottom of Tail Pipe: | | 82.2' | 618.4 |
| Length | 0.3' | | |
| Bottom of Borehole | | 82.2' | 618.4 |

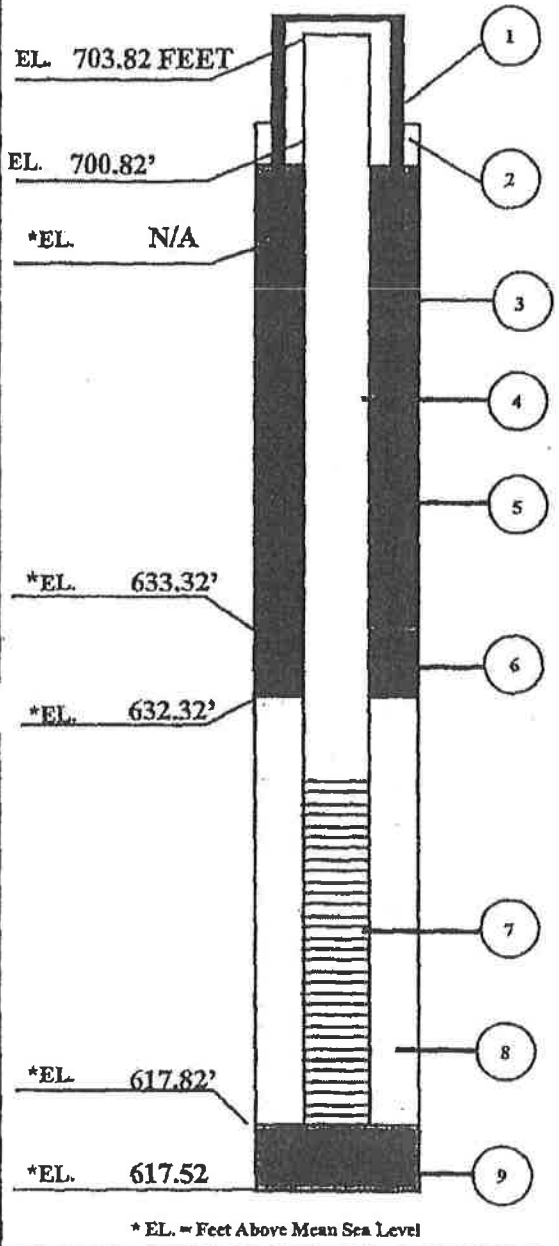
Approved:

* Describe Measuring Point:
V-NOTCH IN PVC RISER

Signature Date 8-21-89

ENSR®

# MONITOR WELL DIAGRAM




* EL. = Feet Above Mean Sea Level

1. PROTECTIVE CASING I.D. N/A
2. SURFACE SEAL TYPE CONCRETE
3. BOREHOLE DIAMETER 8.25 inches
4. RISER PIPE:
   a. Type PVC
   b. I.D. 2 inches
   c. Length 76 feet
   d. Joint Type THREADED
5. BACKFILL:
   a. Type CEMENTACIOUS GROUT
   b. Installation TREMMIE PIPE
6. TYPE OF SEAL BENTONITE
7. SCREEN:
   a. Type PVC
   b. I.D. 2 inches
   c. Slot size 0.010 inches
   d. Length 10 feet
8. SCREEN FILTER TYPE #5 QUARTZ SAND
9. BACKFILL TYPE BENTONITE GROUT

AUGUST MACK ENVIRONMENTAL, INC.

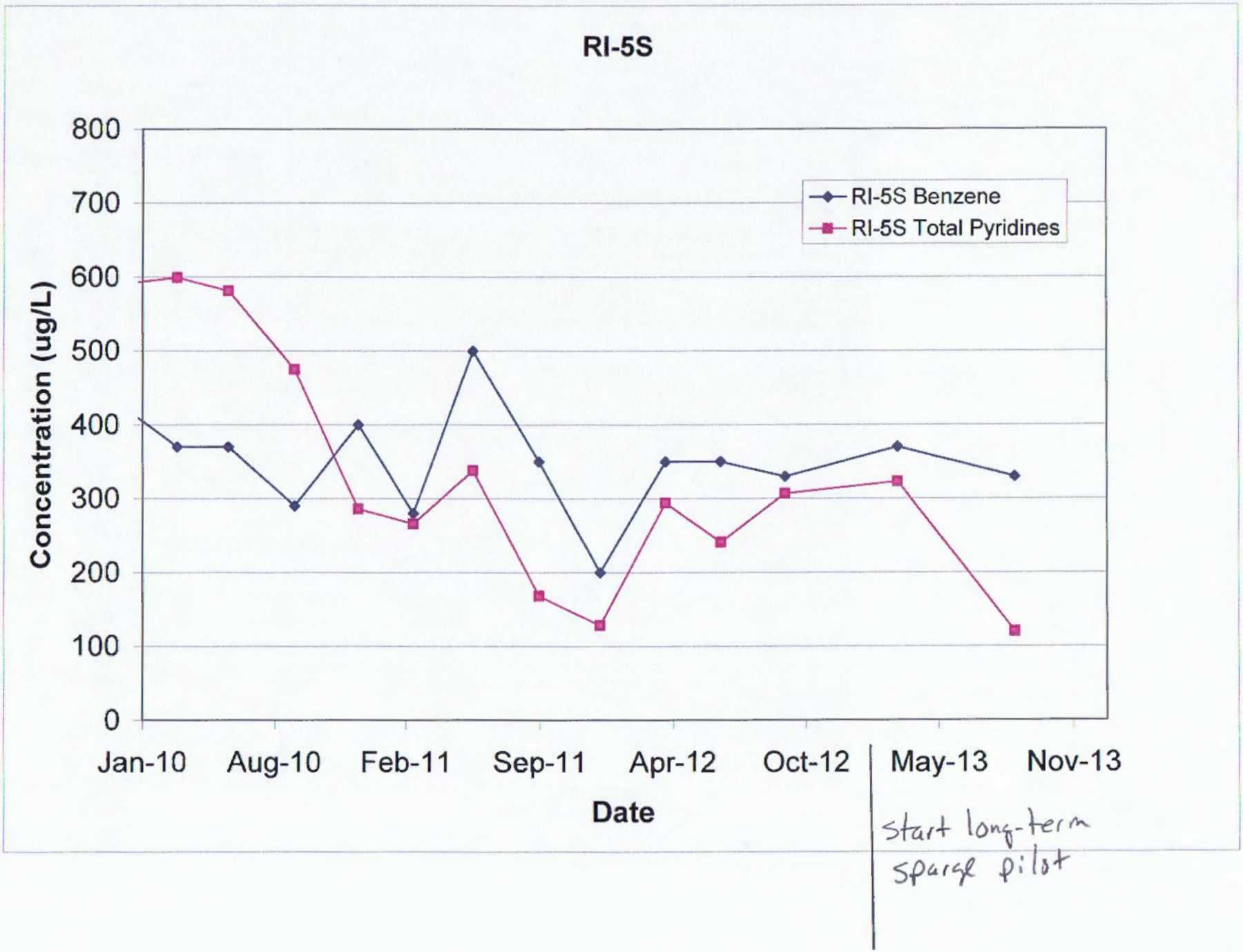
MONITORING WELL DIAGRAM

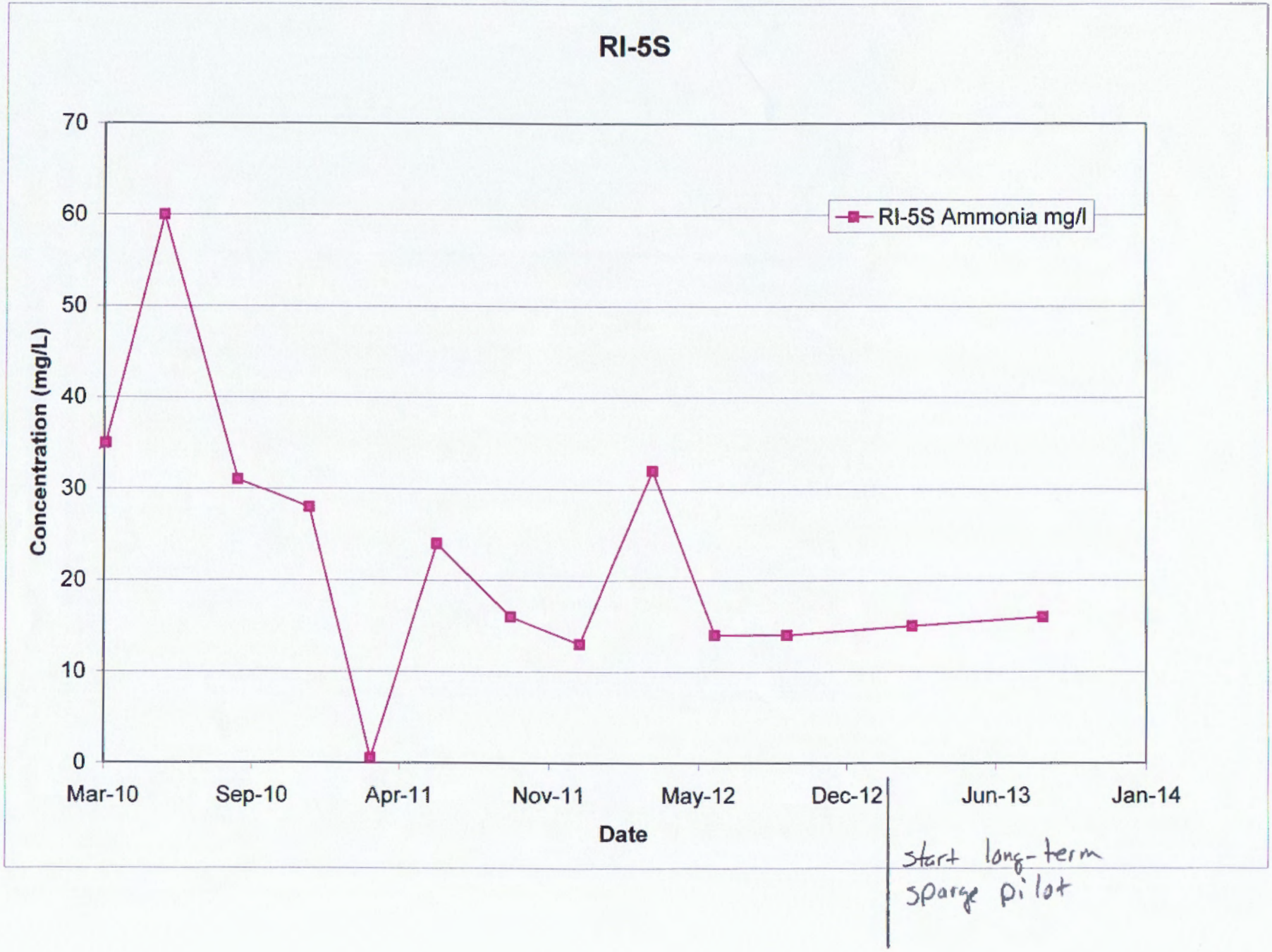
REILLY INDUSTRIES
1500 SOUTH TIBBS AVE.
INDIANAPOLIS, INDIANA

PROJECT NO. 97132.40

DATE: 7-8-97

WELL NO. RI-5D


RI-5S
800
700
600
500
400
300
200
100
0
Concentration (ug/L)
RI-5S Benzene
RI-5S Total Pyridines
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
start long-term
sparge pilot


RI-5S
70
60
50
40
30
20
10
0
Concentration (mg/L)
RI-5S Ammonia mg/l
Mar-10
Sep-10
Apr-11
Nov-11
May-12
Dec-12
Jun-13
Jan-14
Date
start long-term
sparge pilot

| Well Name | Sample Date | Benzene ug/l | Total Pyridines ug/l | Ammonia mg/l | Toluene | Ethyl benzene | Xylene-total | Pyridine | 2-Picoline | 3/4-Picoline | 2,6-Lutidine | 2-Ethyl pyridine | 2,4/2,5-Lutidine | 2,3-Lutidine | 3-Ethyl pyridine | 4-Ethyl pyridine | 3,5-Lutidine | 3,4-Lutidine | 2-Methyl-5 ethyl pyridine | 2-Methyl-3 ethyl pyridine | 3-Ethyl-4-methyl pyridine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RI-5S** | Mar-09 | 360 | 1575 | 33 | ND | ND | ND | 0 | 0 | 90 | 21 | 0 | 39 | 30 | 0 | 0 | 270 | 0 | 25 | 1100 | 0 |
| | Jun-09 | 350 | 783 | 25 | ND | ND | ND | 0 | 0 | 61 | 14 | 0 | 32 | 21 | 0 | 0 | 170 | 0 | 25 | 460 | 0 |
| | Sep-09 | 250 | 707 | 20 | ND | ND | ND | 0 | 0 | 52 | 14 | 0 | 32 | 20 | 0 | 0 | 160 | 0 | 19 | 410 | 0 |
| | Dec-09 | 430 | 590 | 28 | ND | ND | ND | 0 | 0 | 38 | 15 | 0 | 31 | 16 | 0 | 0 | 150 | 0 | 20 | 320 | 0 |
| | Mar-10 | 370 | 599 | 35 | ND | ND | ND | 0 | 0 | 15 | 15 | 0 | 33 | 16 | 0 | 0 | 170 | 0 | 0 | 350 | 0 |
| | Jun-10 | 370 | 581 | 60 | ND | ND | ND | 0 | 0 | 0 | 13 | 0 | 29 | 11 | 0 | 0 | 180 | 0 | 18 | 330 | 0 |
| | Sep-10 | 290 | 475 | 31 | ND | ND | ND | 0 | 0 | 0 | 11 | 0 | 27 | 10 | 0 | 0 | 160 | 0 | 17 | 250 | 0 |
| | Dec-10 | 400 | 286 | 28 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 140 | 0 | 14 | 110 | 0 |
| | Mar-11 | 280 | 266 | 1 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 21 | 0 | 0 | 0 | 120 | 0 | 15 | 110 | 0 |
| | Jun-11 | 500 | 338 | 24 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 0 | 0 | 160 | 0 | 20 | 130 | 0 |
| | Sep-11 | 350 | 168 | 16 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 110 | 0 | 11 | 33 | 0 |
| | Dec-11 | 200 | 128 | 13 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 88 | 0 | 0 | 29 | 0 |
| | Mar-12 | 350 | 294 | 32 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 89 | 0 | 14 | 180 | 0 |
| | Jun-12 | 350 | 241 | 14 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 91 | 0 | 0 | 150 | 0 |
| | Sep-12 | 330 | 307 | 14 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 94 | 0 | 13 | 190 | 0 |
| | Mar-13 | 370 | 323 | 15 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 93 | 0 | 0 | 230 | 0 |
| | Aug-13 | 330 | 120 | 16 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 110 | 0 | 10 | 0 | 0 |

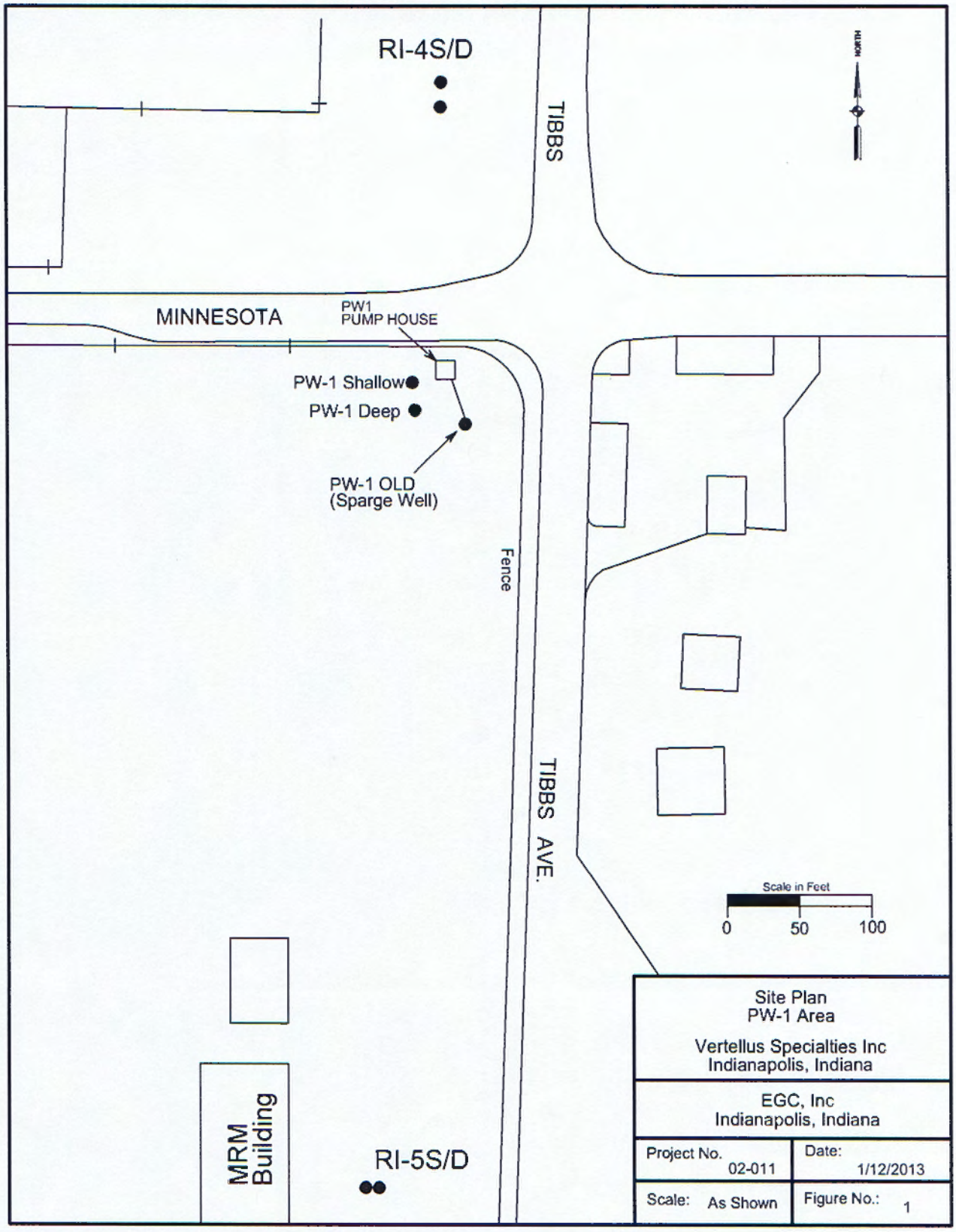
# RI-5 Area Sparge

| Date | Time | Compressor psi | Spool psi | Temp | SCFM | Wellhead PSI | RI-5S WL | RI-5S DO | RI-5S Temp |
|---|---|---|---|---|---|---|---|---|---|
| 2/22/2013 | 1500 | | | | | | 25.83 | 0.39 | 16.4 |
| 2/22/2013 | 1530 | start up | | | | | | | |
| 2/22/2013 | 1615 | 70 | 67 | 88 | 16 | 20 | 24.90 | | |
| 2/22/2013 | 1618 | 60 | 56 | 88 | 16 | 20 | | | |
| 2/22/2013 | 1625 | 550 | 51 | 90 | 15.5 | 20 | 24.71 | | |
| 2/25/2013 | 1145 | 62 | 58 | 80 | 14.2 | 19 | | | |
| 2/25/2013 | 1156 | 50 | 44 | 80 | 17 | 19 | 25.89 | 0.48 | 16.8 |
| 2/25/2013 | 1202 | 49 | 43 | 84 | 16.5 | 19 | | | |
| 3/8/2013 | 1349 | 49 | 38 | 73 | 17.5 | 21 | | | |
| 3/8/2013 | 1352 | 50 | 39 | 73 | 17.5 | 20 | | | |
| 3/11/2013 | 1258 | 52 | 42 | 80 | 17 | 20 | | | |
| 3/11/2013 | 1303 | 52 | 43 | 80 | 17 | 20 | | | |
| 3/20/2013 | 1525 | 60 | 58 | 92 | 16.5 | 20 | | | |
| 3/28/2013 | 1221 | 64 | 58 | 85 | 16.5 | 19 | 26.83 | 0.46 | 16.7 |
| 3/28/2013 | 1230 | 66 | 52 | 95 | 16.5 | 18.5 | | | |
| 4/5/2013 | 1620 | 110 | | | 6 | open up flow | | | |
| 4/5/2013 | 1630 | 50 | 41 | 103 | 16 | 19 | | | |
| 4/12/2013 | 1408 | 65 | 55 | 98 | 15 | 21 | 27.28 | 0.47 | 16.5 |
| 4/22/2013 | 1010 | | | | | | | | |
| 5/2/2013 | 1035 | 70 | 64 | 93 | 15 | 21 | 26.53 | 0.52 | 16.7 |
| 5/10/2013 | 1317 | 78 | 75 | 93 | 13.5 | 21.5 | 25.53 | 0.49 | 16.3 |
| 5/21/2013 | 1225 | 50 | 47 | 108 | 15 | 21 | 25.02 | 0.52 | 16.4 |
| 5/29/2013 | 14:45 | 56 | 49 | 103 | 16 | 22 | | | |
| 6/4/2013 | 12:53 | 60 | 53 | 110 | 16 | 20 | 24.68 | 0.73 | 16.3 |
| 6/11/2013 | 9:30 | 55 | 48 | 110 | 16 | 20 | 24.93 | 0.71 | 16.3 |
| 6/20/2013 | 12:58 | 55 | 58 | 98 | 16 | 20 | | 0.47 | 16.3 |
| 6/28/2013 | 13:44 | 75 | 70 | 129 | 14 | 18 | | | |
| 6/28/2013 | 13:51 | 56 | 59 | 129 | 16 | 18.5 | | | |
| 7/8/2013 | 12:18 | 52 | 45 | 112 | 16.5 | 21 | 25.63 | 0.59 | 16.3 |
| 7/19/2013 | 12:10 | 50 | 42 | 102 | 16.5 | 22 | | | 16.4 |
| 7/30/2013 | | 52 | 44 | 95 | 16.5 | 21 | 26.31 | 1.07 | 16.4 |
| 8/9/2013 | 10:38 | | | | | | | | |
| 8/19/2013 | 12:25 | 51 | 46 | 92 | 16.5 | 22 | 27.38 | 0.52 | 16.5 |

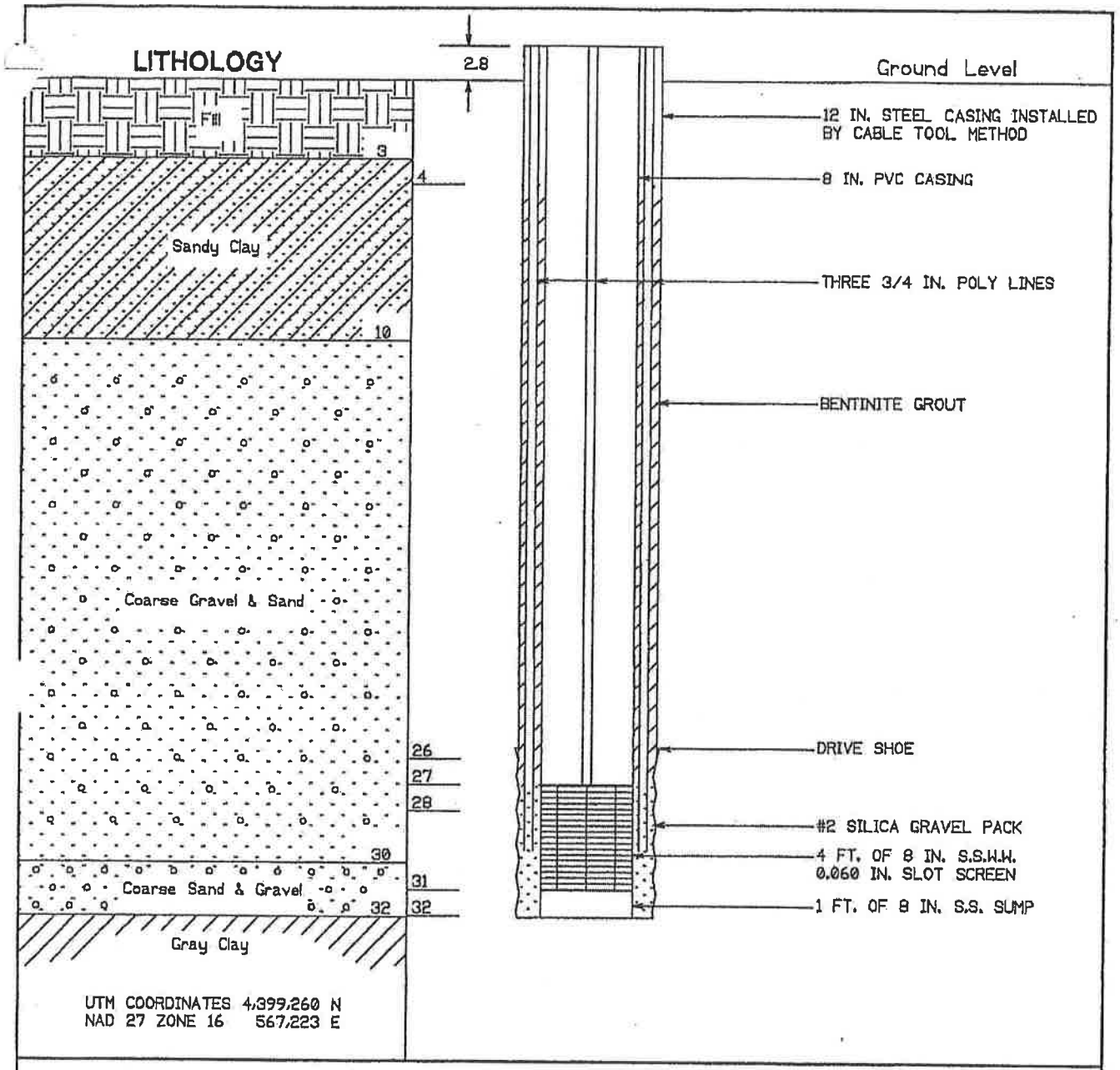
Note: Sparge operation and measurements performed by K. Might

**Attachment 5**

**PW-1 Old Test Data**


RI-4S/D
TIBBS
NORTH
MINNESOTA
PW1
PUMP HOUSE
PW-1 Shallow
PW-1 Deep
PW-1 OLD
(Sparge Well)
Fence
TIBBS AVE.
Scale in Feet
0
50
100
MRM
Building
RI-5S/D
Site Plan
PW-1 Area
Vertellus Specialties Inc
Indianapolis, Indiana
EGC, Inc
Indianapolis, Indiana
Project No.
02-011
Date:
1/12/2013
Scale: As Shown
Figure No.: 1

New PW-1 Shallow




City Indianapolis State Indiana

Well Location Corner of Maywood & Tibbs Ave.

County Marion Twp. Wayne T 15N R 3E ___ ¼ ___ ¼ NE ¼ 17

Test Rate 27 GPM

Static Water Level 27.5 Ft.

Pumping Level 31.1 Ft.

Specific Capacity 7.5 GPM/Ft. D.D.

Driller John Blatz

Date Drilled 2-27-03 Job No. 17956

Well No. PW-1B

Reilly Industries

Indianapolis, Indiana

PEERLESS-MIDWEST, INC.

55860 Russel Industrial Pkwy., Mishawaka, IN 46545

Water Supply Contractors

New PW-1 shallow

PEERLESS-MIDWEST, INC.
Mishawaka, IN (574) 254-9050
Ionia, MI (616) 527-0050
Indianapolis, IN (317) 896-2987
Muncie, IN (765) 759-8120

# SUBMERSIBLE PUMP INSTALLATION REPORT

Sales Order No. 17956 Date 4/1/03

Pump Mfg. Grundfos Serial No. _____ Well No. 1B

Owner Reilly Industries City Indianapolis State IN

Location of Well 10' SW of Pump Building, Corner Maywood & Tibbs Ave

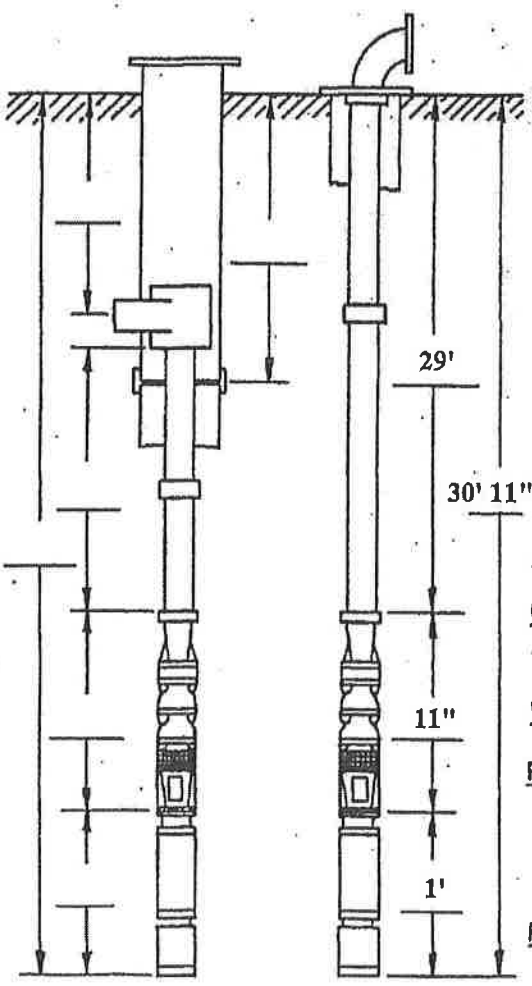
MOTOR: Make Franklin Dia. 4" Frame 02F18 Serial No. 23452394W

Hp 1 Volts 460 Phase 3 Cycles 60 RPM 3450

Full Load Amps 2 Service Factor 1.15 S.F. Amps 4

STARTER: Make Allen Bradley Size 1 Type _____

CONTROL: Make _____ Type _____ Range _____ To _____ lbs.




PUMP DISCHARGE: Mfg. 2" s.s. Tee Model _____

Flanged Elbow _____ Pitless Adapter _____

Pitless Tank _____ Tank Capacity _____ gal.

Discharge Pipe Size 2" Column Conn. Size 2"

Adapter Connected to Well Casing 2' abv" below ground with lid seal

COLUMN: Pipe Size 2"s.s." Black _____ Galv. _____

Column Check Valve Type Flap located 1" above bowl

Air Line Length _____'

Air Intake Valve Type _____ located _____

30' 11" below ground.

PUMP BOWL: Type 25S10 Dia. 4" Stages 7

CABLE: Size #12 Flat Length 11"

WELL: No. 1B Type G.W. Dia. 8" Depth 34'

PUMPING TEST: GPM 25.0 Pumping Level 31'

Static Level 27.0' Specific Capacity _____ GPF

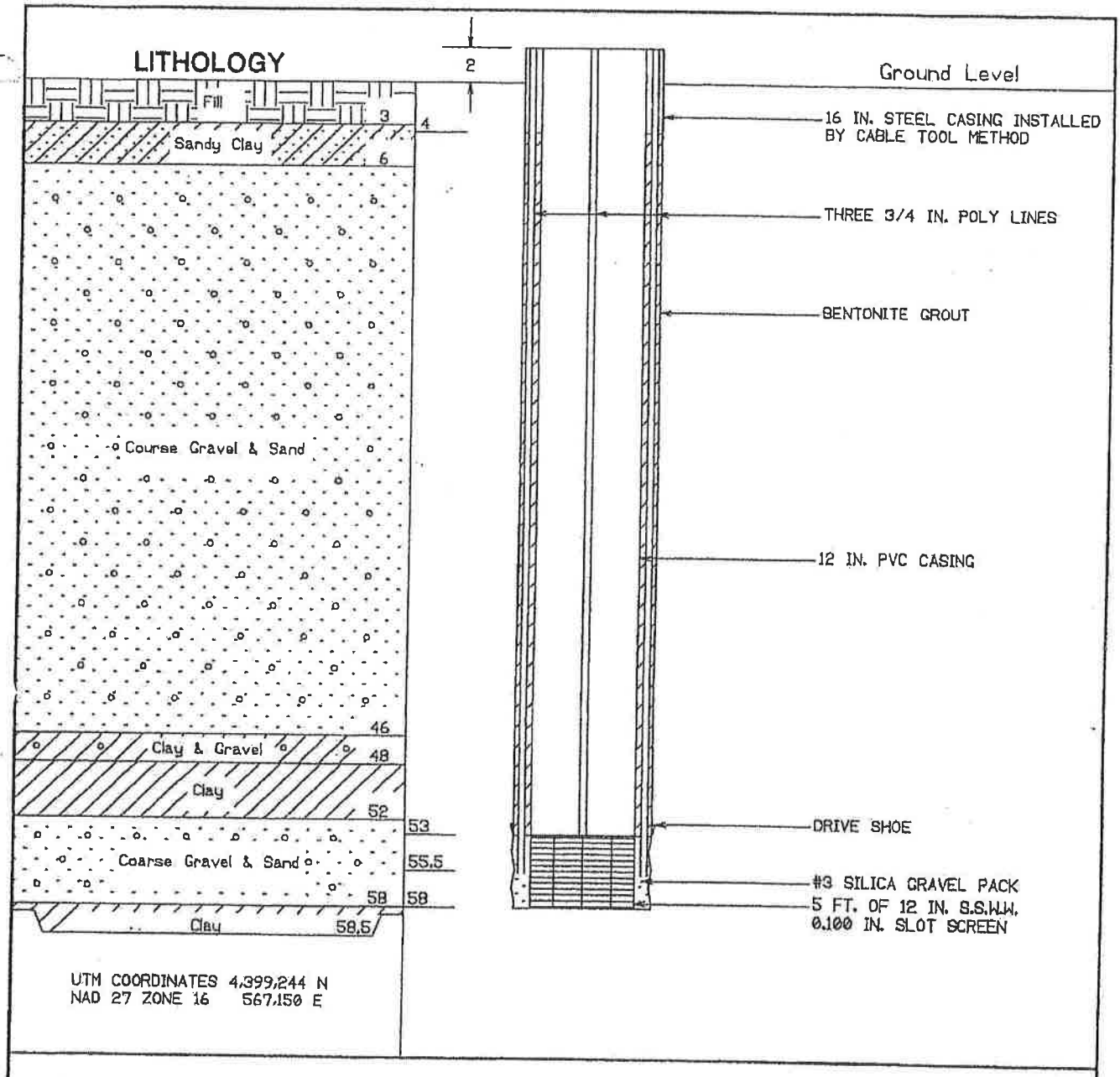
PSI _____ Volts _____ Amps: 1 _____ 2 _____ 3 _____

FOUNDATION: _____' above ground level

REMARKS: _____

J. Blatz Installer

New PW-1 Deep




City Indianapolis State Indiana

Well Location 70' W of Tibbs & 84' S of Maywood

County Marion Twp. Wayne T 15N R 3E ¼ ¼ NE ¼ 17

Test Rate 270 GPM

Static Water Level 28 Ft.

Pumping Level 52 Ft.

Specific Capacity 11.3 GPM/Ft. D.D.

Driller John Blatz

Date Drilled 11-12-02 Job No. 17717

Well No. PW-1A

Reilly Industries

Indianapolis, Indiana

PEERLESS-MIDWEST, INC.

55860 Russell Industrial Pkwy., Mishawaka, IN 46545

Water Supply Contractors

ENSR

# BORING LOG

Sheet 1 of 2

Project No. 5660-003-008 Date - Start 5-4-89 Finish 5-5-89 Boring RI-04

Project Name REILLY INDUSTRIES Drilling Co. LAYNE-NORTHWEST

Location INDIANAPOLIS Drilling Method DUAL TUBE

Total Depth 69' Inspector M.M. / B.G. Reviewer J.R.

Remarks

| Depth Feet | Sample Type & No. | Sample Blows per 6 In. | Sample Depth Range | Sample Rec. | Graphic Log | Lithologic Description | Equipment Installed |
|---|---|---|---|---|---|---|---|
| | S-1 | | 3' | | | Lt. Brown GRAVEL, some Cs. Sand | |
| 5 | | | | | | | |
| | | | | | | Brown Med. SAND, some Gravel | |
| 10 | | | | | | | |
| | | | | | | Brown Med. to Cs. SAND & GRAVEL | |
| 15 | | | | | | | |
| | | | | | | Brown Med. to Cs. SAND | |
| 20 | | | | | | | |
| 25 | | | | | | | |
| | S-2 | | 26' | | | (head space sample SB04-Z1 = 0.231 ppm Benzene) Slight pyridine odor at 26 feet | |
| | | | | | | Brown Med. to Cs. SAND & GRAVEL | |
| 30 | S-3 | | 30' | | | | |
| | S-4 | | 31' | | | | |
| | S-5 | | 31.5' | | | | |
| 35 | | | | | | Gray SILT, some Gravel | |
| | | | | | | Gray GRAVEL & SILT | |

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# BORING LOG (continued)

Project REILLY INDUSTRIES Boring RI-04 Sheet 2 of 2

| Depth Feet | Sample Type & No. | Sample Blows per 6 In. | Sample Depth Range | Sample Rec. | Graphic Log | Lithologic Description | Equipment Installed |
|---|---|---|---|---|---|---|---|
| | | | | | | Slight pyridine odor at 41 feet | |
| 45 | S-6 | | 46' | | | (head space sample SB04-Z2 = 0.00 ppm Benzene)<br>Cs. Sand at 46 feet<br>Gray GRAVEL & SILT | |
| 50 | | | | | | | |
| 55 | S-7 | | 55' | | | Gray CLAY | |
| 60 | S-8 | | 60.5' | | | (head space sample SB04-Z3 = 0.00 ppm Benzene) | |
| | S-9 | | 64' | | | Black SHALE | |
| 65 | | | | | | | |
| | S-10 | | 69' | | | Trace pyridine odor at 68 feet | |
| 70 | | | | | | BOTTOM OF BORING AT 69 FEET | |

Project No: 5660-003-008 Client: Reilly Site: Indianapolis

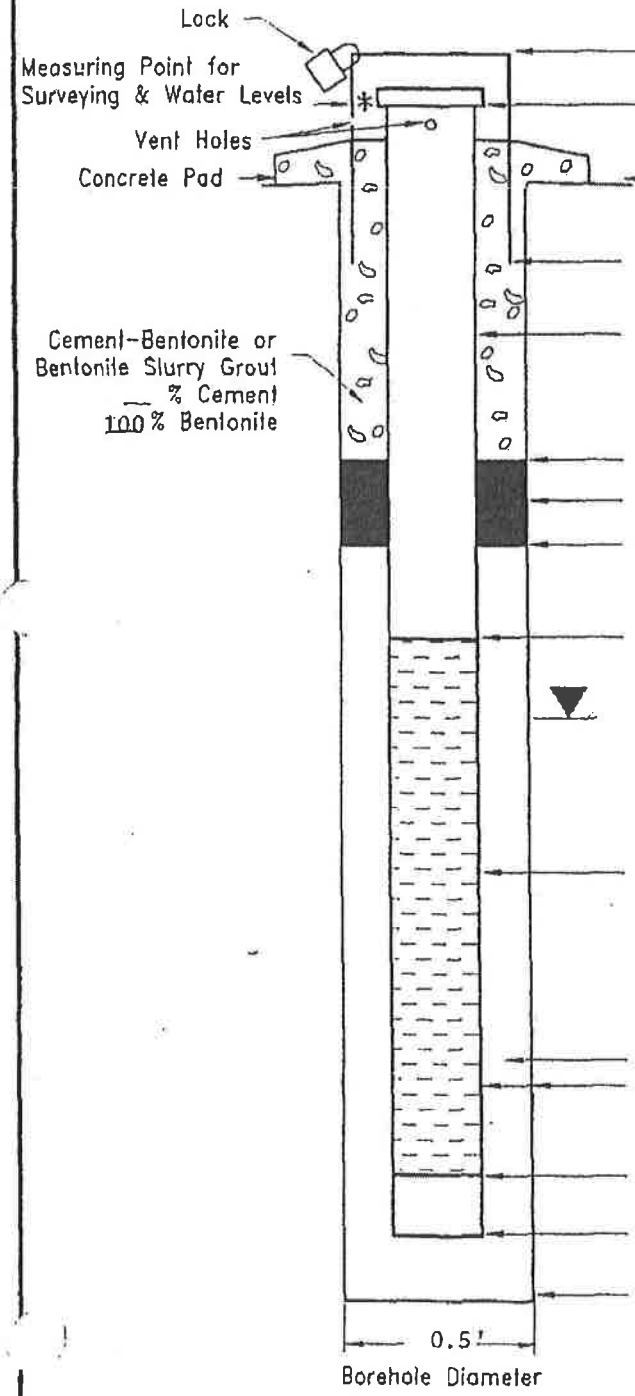
WELL No: RI-4S

Well Location: East Side of Reilly Property, Just North of Minnesota

Date Installed: 6/20/89

Contractor: LAYNE-NORTHWEST Method: Dual Tube, Reverse Air Inspector: L.P.

# MONITORING WELL CONSTRUCTION DETAIL




| | | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|---|
| Top of Steel Guard Pipe | | Flush | 700.92 |
| Top of Riser Pipe | | | 700.68 |
| Ground Surface (G.S.) | | 0.00 | 700.92 |
| Bottom of Steel Guard Pipe | | 0.5' | 700.4 |
| Riser Pipe: | | | |
| Length | 17.5' | | |
| Inside Diameter (ID) | 2" | | |
| Type of Material | PVC | | |
| Top of Bentonite Seal | | 14.9' | 686.0 |
| Bentonite Seal Thickness | 1.0' | | |
| Top of Sand | | 15.9' | 685.0 |
| Top of Screen | | 17.9' | 683.0 |
| Stabilized Water Level | | 20.9' | 680.0 |
| Screen: | | | |
| Length | 9.8 | | |
| Inside Diameter (ID) | 2" | | |
| Slot Size | 0.010 | | |
| Type of Material | PVC | | |
| Type/Size of Sand | 45/55 | | |
| Sand Pack Thickness | 2" | | |
| Bottom of Screen | | 27.7' | 673.2 |
| Bottom of Tail Pipe: | | 28.0' | 672.9 |
| Length | 0.3' | | |
| Bottom of Borehole | | 28.0' | 672.9 |

Approved:

* Describe Measuring Point:
V-NOTCH IN PVC RISER

Signature Date

ENSR

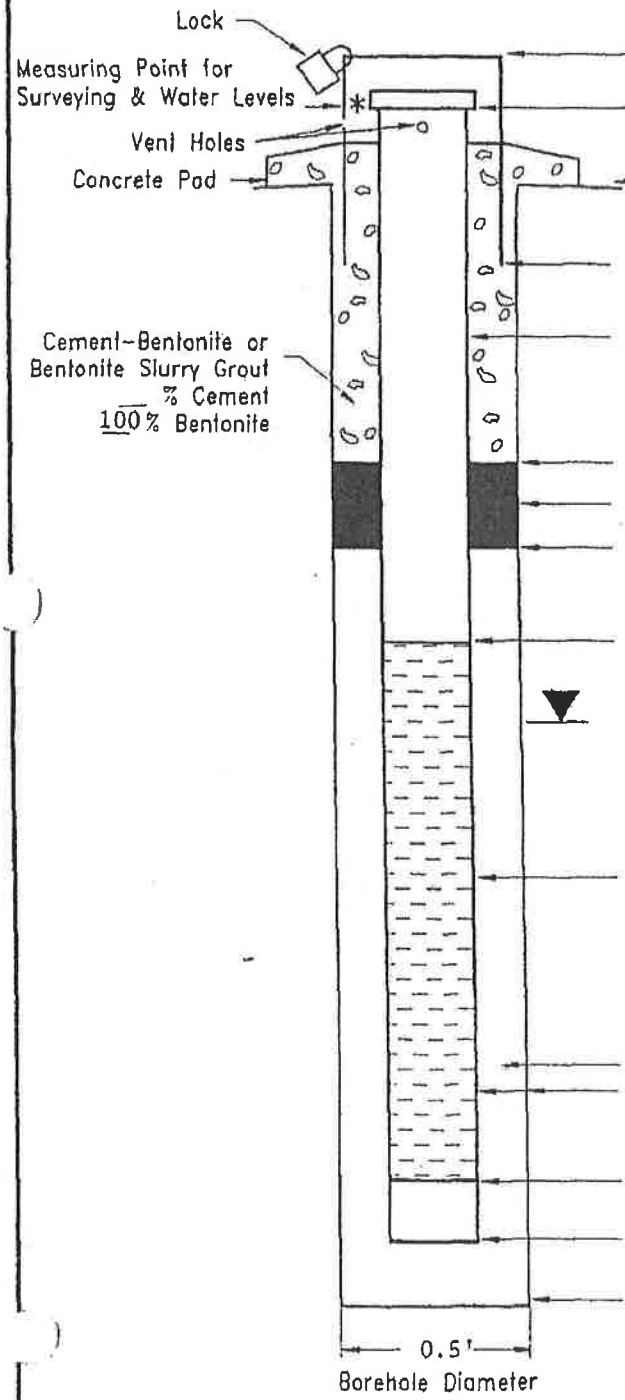
Project No: 5660-003-008 Client: Reilly Site: Indianapolis

WELL No: RI-41

Well Location: East Side of Reilly Property, Just North of Minnesota Date Installed: 6/20/

Contractor: LAYNE-NORTHWEST Method: Dual Tube, Reverse Air Inspector: L.P.

# MONITORING WELL CONSTRUCTION DETAIL




| | | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|---|
| Top of Steel Guard Pipe | | Flush | 700.90 |
| Top of Riser Pipe | | | 700.69 |
| Ground Surface (G.S.) | | 0.00 | 700.90 |
| Bottom of Steel Guard Pipe | | 0.5' | 700.4 |
| Riser Pipe: | | | |
| Length | 44.8' | | |
| Inside Diameter (ID) | 2" | | |
| Type of Material | PVC | | |
| Top of fine sand Seal | | 41.8' | 659.1 |
| Seal Thickness | 1.0' | | |
| Top of Sand | | 42.8' | 658.1 |
| Top of Screen | | 45.2' | 655.7 |
| Stabilized Water Level | | 22.8 | 678.1 |
| Screen: | | | |
| Length | 9.8' | | |
| Inside Diameter (ID) | 2" | | |
| Slot Size | 0.010 | | |
| Type of Material | PVC | | |
| Type/Size of Sand | 45/55 | | |
| Sand Pack Thickness | 2" | | |
| Bottom of Screen | | 54.9' | 646.0 |
| Bottom of Tail Pipe: | | 55.2' | 645.7 |
| Length | 0.3' | | |
| Bottom of Borehole | | 56.2' | 645.7 |

Approved:

* Describe Measuring Point:
V-NOTCH IN PVC RISER

Signature

8-27-07
Date

ENSR

ENSR

# BORING LOG

Sheet 1 of 3

Project No. 5660-003-008 Date - Start 5-3-89 Finish 5-4-89 Boring RI-05

Project Name REILLY INDUSTRIES Drilling Co. LAYNE-NORTHWEST

Location INDIANAPOLIS Drilling Method DUAL TUBE

Total Depth 105' Inspector Reviewer J.R.

Remarks

| Depth Feet | Sample Type & No. | Sample Blows per 6 in | Sample Depth Range | Sample Rec. | Graphic Log | Lithologic Description | Equipment Installed |
|---|---|---|---|---|---|---|---|
| | | | | | | some Gravel at 2 feet<br>Silty Clay rich organic TOPSOIL | |
| 5 | S-1 | | 6' | | | Fine GRAVEL<br>Med. to Cs. Brown SAND & GRAVEL | |
| 10 | | | | | | Cs. SAND, some Gravel | |
| 15 | | | | | | GRAVEL, some Sand<br>SAND, some Gravel | |
| 20 | | | | | | Gray SAND & GRAVEL | |
| 25 | S-2 | | 24.5' | | | | |
| | S-3 | | 29.5' | | | Gray SAND, some Gravel | |
| 30 | S-4 | | 30' | | | | |
| | S-5 | | 31' | | | Black Cs. SAND & GRAVEL | |
| | S-6 | | 33' | | | | |
| 35 | | | | | | SILT & Fine SAND<br>(head space sample SB05-Z1 = 0.00 ppm Benzene) | |
| | | | | | | GRAVEL & SAND | |
| | | | | | | SILT & GRAVEL | |

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## BORING LOG (continued)

Project REILLY INDUSTRIES Boring RI-05 Sheet 2 of 3

| Depth Feet | Sample Type & No. | Sample Blows per 6 in. | Sample Depth Range | Sample Rec. | Graphic Log | Lithologic Description | Equipment Installed |
|---|---|---|---|---|---|---|---|
| | S-7 | | 41' | | | SILT & GRAVEL | |
| | S-8 | | 41.5' | | | GRAVEL, some Silt | |
| 45 | | | | | | Gray SILT, some Gravel | |
| | S-9 | | 47' | | | | |
| | S-10 | | 48' | | | SAND & SILT (head space sample SB05-Z2 = 0.114 ppm Benzene) | |
| 50 | | | | | | Pyridine odor at 53 feet | |
| | S-11 | | 52' | | | GRAVEL & SAND | |
| 55 | | | | | | GRAVEL, some Cobbles | |
| | S-12 | | 56' | | | CLAY, some Silt | |
| | | | | | | Pyridine odor at 59 feet | |
| 60 | S-13 | | 60' | | | GRAVEL & SILT | |
| | | | | | | CLAY & SILT (head space sample SB05-Z3 = 0.00 ppm Benzene) | |
| | | | | | | GRAVEL, some Silt | |
| 65 | S-14 | | 65' | | | Gray CLAY, some Silt | |
| | S-15 | | 69.5' | | | | |
| 70 | | | | | | Black GRAVEL & SILT | |
| | S-16 | | 73' | | | (head space sample SB05-Z4 = 0.00 ppm Benzene | |
| 75 | S-17 | | 76' | | | GRAVEL, some Silt & Sand | |
| | | | | | | SILT & SAND | |
| 80 | | | | | | SAND, some Gravel | |
| | | | | | | Gray Med. to Cs. SAND & GRAVEL | |

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# BORING LOG (continued)

Project REILLY INDUSTRIES Boring RI-05 Sheet 3 of 3

| Depth Feet | Sample Type & No. | Sample Blows per 6 in. | Sample Depth Range | Sample Rec. | Graphic Log | Lithologic Description | Equipment Installed |
|---|---|---|---|---|---|---|---|
| 90 | S-18 | | 91.5' | | | (head space sample SB05-Z5 = 0.00 ppm Benzene) Gray Med. to Cs. SAND & GRAVEL | |
| 95 | S-19 | | 96.5' | | | | |
| | S-20 | | 99' | | | Black SHALE | |
| 100 | S-21 | | 100' | | | (head space sample SB05-Z6 = 0.00 ppm Benzene) | |
| 105 | | | | | | BOTTOM OF BORING AT 105 FEET | |

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

BORING IDENTIFICATION: **RI-5D** Replacement



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 1 | | | | | No samples collected until |
| | 2 | | | | | 3.0 feet below grade |
| | 3 | | | | | |
| Medium brown (10YR 3/4) dry CLAY with trace of sand. Changes to yellowish brown (10YR 5/4) coarse SAND with some gravel at 4.5 to 5.0 feet | 4 | 1 | 6-6-6-6 | 60% | 60 | |
| | 5 | | | | | |
| | 6 | | | | | |
| | 7 | | | | | |
| | 8 | | | | | |
| Yellowish reddish brown (10 YR 5/8) dry coarse SAND with little gravel and trace of silt. Changes to a yellowish brown (10yr 5/4) coarse SAND with some gravel at 9.5 feet | 9 | 2 | 9-13-14-15 | 70% | 80 | |
| | 10 | | | | | |
| | 11 | | | | | |
| | 12 | | | | | |
| | 13 | | | | | |
| Light yellowish brown (10 YR 6/4) dry coarse SAND and GRAVEL with a trace of silt | 14 | 3 | 12-17-21-12 | 90% | 40 | |
| | 15 | | | | | |
| | 16 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

TCV=TOTAL COMBUSTIBLE VAPORS No=SAMPLE
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

**BORING IDENTIFICATION: RI-5D**



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 17 | | | | | |
| | 18 | | | | | |
| Brown (10 YR 5/3) slightly moist SAND with little gravel | 19 | 4 | 14-14-15-12 | 90% | 80 | |
| | 20 | | | | | |
| | 21 | | | | | |
| | 22 | | | | | |
| | 23 | | | | | |
| Dark gray (10 YR 4/1) wet coarse SAND and GRAVEL | 24 | 5 | 6-8-9-10 | 70% | 620 | Some water on rods, saturated at 23.5 feet |
| | 25 | | | | | |
| | 26 | | | | | |
| | 27 | | | | | |
| | 28 | | | | | |
| Dark gray (10YR 4/1) moist coarse SAND and GRAVEL with 2" layer of grayish brown (10YR 5/2) fine sandy CLAY | 29 | 6 | 12-15-25-30 | 90% | 580 | Black stains, Reilly odor |
| | 30 | | | | | |
| | 31 | | | | | |
| | 32 | | | | | |
| | 33 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS-SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

BORING IDENTIFICATION: **RI-5D**



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| Grayish brown (10YR 5/2) moist fine SAND with a trace of silt changing to dark gray (10 YR 4/1) SILT and little gravel | 34 | 7 | 35-50->50 | 90% | 220 | Slight odor |
| | 35 | | | | | |
| | 36 | | | | | |
| | 37 | | | | | |
| Dark gray (10 YR 4/1) moist SILT with little gravel trace of sand becoming SAND and GRAVEL with a trace of clay | 38 | 8 | 17-24-25-23 | 95% | 120 | No odor |
| | 39 | | | | | |
| | 40 | | | | | |
| | 41 | | | | | |
| | 42 | | | | | |
| | 43 | | | | | |
| Gray (10 YR 5/1) fine sandy SILT with little gravel | 44 | 9 | 43-42-50 (5") | 90% | 180 | No odor |
| | 45 | | | | | |
| | 46 | | | | | |
| | 47 | | | | | |
| | 48 | | | | | |
| No recovery, sample not available | 49 | 10 | 50 (1") | 0% | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

**BORING IDENTIFICATION: RI-5D**



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 50 | 10 | | | | |
| | 51 | | | | | |
| | 52 | | | | | |
| | 53 | | | | | |
| Dark gray (10 YR 4/1) sandy CLAY trace of gravel changing at 54 feet to fine sandy GRAVEL | 54 | 11 | 21-17-9-8 | 60% | 180 | No odor |
| | 55 | | | | | |
| | 56 | | | | | |
| | 57 | | | | | |
| | 58 | | | | | |
| No recovery | 59 | 12 | 50/2" | 0 | | |
| | 60 | | | | | |
| | 61 | | | | | |
| | 62 | | | | | |
| | 63 | | | | | |
| Gray (10 YR 5/1) sandy GRAVEL with little clay | 64 | 13 | 42-50 | 50 | 220 | No odor, slight black stain |
| | 65 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL
TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

BORING IDENTIFICATION: **RI-5D**



| | | | |
|---|---|---|---|
| CLIENT: | Reilly Industries, Inc. | PROJECT NUMBER: | 97132.40 |
| PROJECT NAME: | Monitoring well installation | DATE DRILLED: | 7/8/97 |
| SITE LOCATION: | Indianapolis, Indiana | ELEVATION: | |
| BORING LOCATION: | 11' west and 1.25' north of RI-5S | DRILLING METHOD: | HSA |

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 66 | | | | | |
| | 67 | | | | | |
| | 68 | | | | | |
| Very dark gray (10 YR 3/1) SAND and GRAVEL with a trace of clay | 69 | 14 | 16-8-14-28 | 60% | 140 | Slight odor and 2" of staining at 69 to 70 feet |
| | 70 | | | | | |
| | 71 | | | | | |
| | 72 | | | | | |
| | 73 | | | | | |
| Dark Gray (10 YR 4/1) fine SAND with a trace of clay | 74 | 15 | 30-33-50 (6") | 80 | 200 | slight odor |
| | 75 | | | | | |
| | 76 | | | | | |
| | 77 | | | | | |
| | 78 | | | | | |
| Gray (10YR 5/1) SAND with trace of gravel | 79 | 16 | 10-16-36-40 | 80 | 200 | Slight odor |
| | 80 | | | | | |
| | 81 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

AUGUST MACK ENVIRONMENTAL INC

**RECORD OF SUBSURFACE INVESTIGATION**

BORING IDENTIFICATION: RI-5D

PAGE 6 of 6

CLIENT: Reilly Industries, Inc.
PROJECT NAME: Monitoring well installation
SITE LOCATION: Indianapolis, Indiana
BORING LOCATION: 11' west and 1.25' north of RI-5S

PROJECT NUMBER: 97132.40
DATE DRILLED: 7/8/97
ELEVATION:
DRILLING METHOD: HSA

| GEOLOGIC DESCRIPTION | FT | No | BLW | REC | TCV (ppm) | COMMENTS |
|---|---|---|---|---|---|---|
| | 82 | | | | | |
| Boring terminated at 83 feet | 83 | | | | | |
| | 84 | | | | | |
| | 85 | | | | | |
| | 86 | | | | | |
| | 87 | | | | | |
| | 88 | | | | | |
| | 89 | | | | | |
| | 90 | | | | | |
| | 91 | | | | | |
| | 92 | | | | | |
| | 93 | | | | | |
| | 94 | | | | | |
| | 95 | | | | | |
| | 96 | | | | | |
| | 97 | | | | | |

FT=STRATUM DEPTH IN FEET BELOW GRADE
No=SAMPLE NUMBER
BLW=BLOWS PER 6 INCHES
REC=PERCENT OF TOTAL SAMPLE RECOVERED
*SAMPLE SUBMITTED FOR ANALYSIS
AMSL=ABOVE MEAN SEA LEVEL

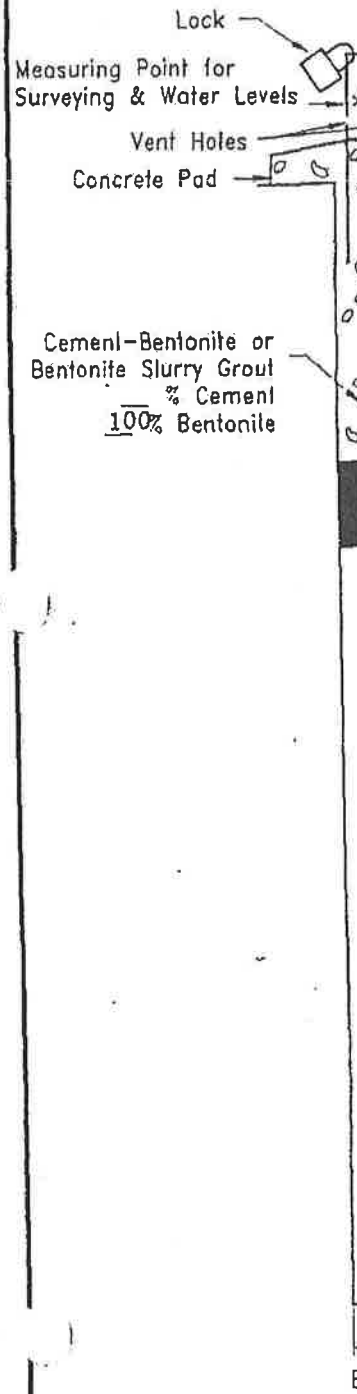
TCV=TOTAL COMBUSTIBLE VAPORS
ppm=PARTS PER MILLION
HSA=HOLLOW STEM AUGER
ND=NOT DETECTED AT 0.2 ppm
SS=SPLIT-SPOON SAMPLER

Project No: 5660-003-008 Client: Reilly Site: Indianapolis WELL No: RI-5

Well Location: East Side of Reilly Property, Just South of Minnesota Date Installed: 6/21/

Contractor: LAYNE- NORTHWEST Method: Dual Tube, Reverse Air Inspector: L.P.

# MONITORING WELL CONSTRUCTION DETAIL




| | | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|---|
| Top of Steel Guard Pipe | | 2.7' | 703.37 |
| Top of Riser Pipe | | 2.50' | 703.24 |
| Ground Surface (G.S.) | | 0.00 | 700.7 |
| Bottom of Steel Guard Pipe | | 2.3' | 698.4 |
| Riser Pipe: | | | |
| Length | 48.0' | | |
| Inside Diameter (ID) | 2" | | |
| Type of Material | PVC | | |
| Top of Bentonite Seal | | -42.2' | 658.5 |
| Bentonite Seal Thickness | 1.2' | | |
| Top of Sand | | 43.4' | 657.3 |
| Top of Screen | | 45.9' | 654.8 |
| Stabilized Water Level | | 26.5' | 674.2 |
| Screen: | | | |
| Length | 9.8' | | |
| Inside Diameter (ID) | 2" | | |
| Slot Size | 0.010 | | |
| Type of Material | PVC | | |
| Type/Size of Sand | 45/55 | | |
| Sand Pack Thickness | 2" | | |
| Bottom of Screen | | 55.5' | 645.2 |
| Bottom of Tail Pipe: | | 55.8' | 644.9 |
| Length | 0.3' | | |
| Bottom of Borehole | | 55.8' | 644.9 |

Approved:

* Describe Measuring Point:
V-NOTCH IN PVC RISER

Signature

8-21-89
Date

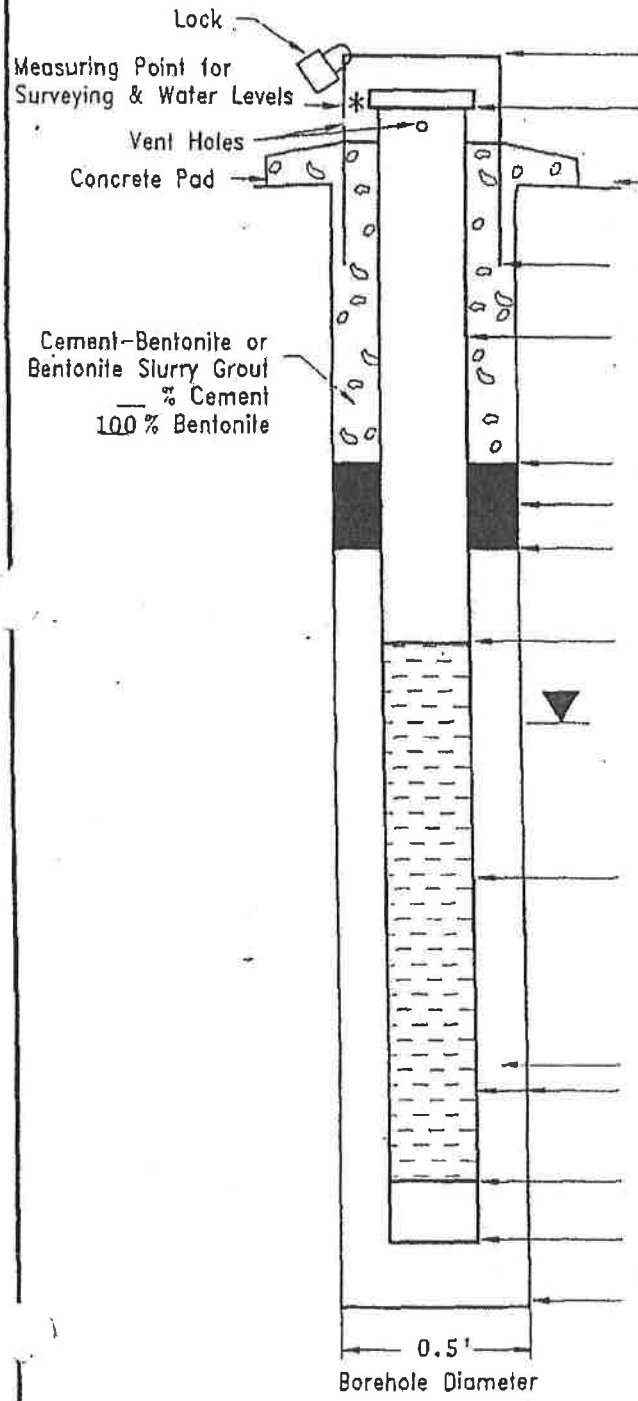
ENSR

Project No: 5660-003-008 Client: Reilly Site: Indianapolis WELL No: RI-5I

Well Location: East Side of Reilly Property, Just South of Minnesota Date Installed: 6/21/

Contractor: LAYNE-NORTHWEST Method: Dual Tube, Reverse Air Inspector: L.P.

# MONITORING WELL CONSTRUCTION DETAIL




| | | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|---|
| Top of Steel Guard Pipe | | 2.6' | 703.20 |
| Top of Riser Pipe | | 2.50' | 703.07 |
| Ground Surface (G.S.) | | 0.00 | 700.6 |
| Bottom of Steel Guard Pipe | | 2.4' | 698.2 |
| Riser Pipe: | | | |
| Length | 74.4' | | |
| Inside Diameter (ID) | 2" | | |
| Type of Material | PVC | | |
| Top of fine sand Seal | | 67.7' | 632.9 |
| Seal Thickness | 2.08' | | |
| Top of Sand | | 69.7' | 630.9 |
| Top of Screen | | 72.2' | 628.4 |
| Stabilized Water Level | | 33.1' | 667.5 |
| Screen: | | | |
| Length | 9.8' | | |
| Inside Diameter (ID) | 2" | | |
| Slot Size | 0.010 | | |
| Type of Material | PVC | | |
| Type/Size of Sand | 45/55 | | |
| Sand Pack Thickness | 2" | | |
| Bottom of Screen | | 81.9' | 618.7 |
| Bottom of Tail Pipe: | | 82.2' | 618.4 |
| Length | 0.3' | | |
| Bottom of Borehole | | 82.2' | 618.4 |

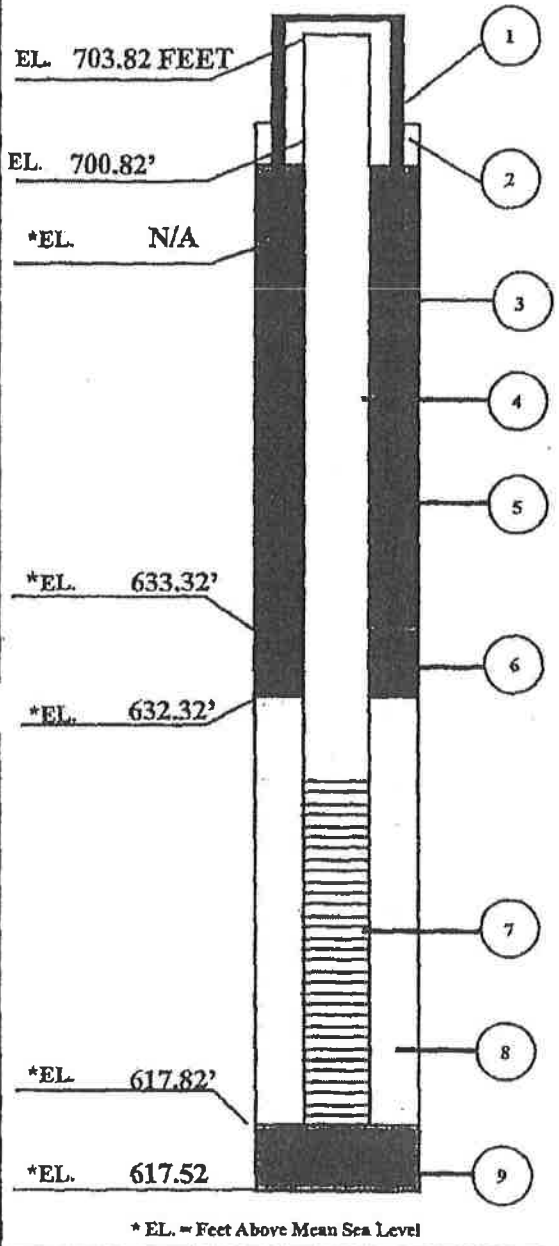
Approved:

* Describe Measuring Point:
V-NOTCH IN PVC RISER

Signature Date 8-21-89

ENSR®

# MONITOR WELL DIAGRAM




* EL. = Feet Above Mean Sea Level

1. PROTECTIVE CASING I.D. N/A
2. SURFACE SEAL TYPE CONCRETE
3. BOREHOLE DIAMETER 8.25 inches
4. RISER PIPE:
   a. Type PVC
   b. I.D. 2 inches
   c. Length 76 feet
   d. Joint Type THREADED
5. BACKFILL:
   a. Type CEMENTACIOUS GROUT
   b. Installation TREMMIE PIPE
6. TYPE OF SEAL BENTONITE
7. SCREEN:
   a. Type PVC
   b. I.D. 2 inches
   c. Slot size 0.010 inches
   d. Length 10 feet
8. SCREEN FILTER TYPE #5 QUARTZ SAND
9. BACKFILL TYPE BENTONITE GROUT

AUGUST MACK ENVIRONMENTAL, INC.

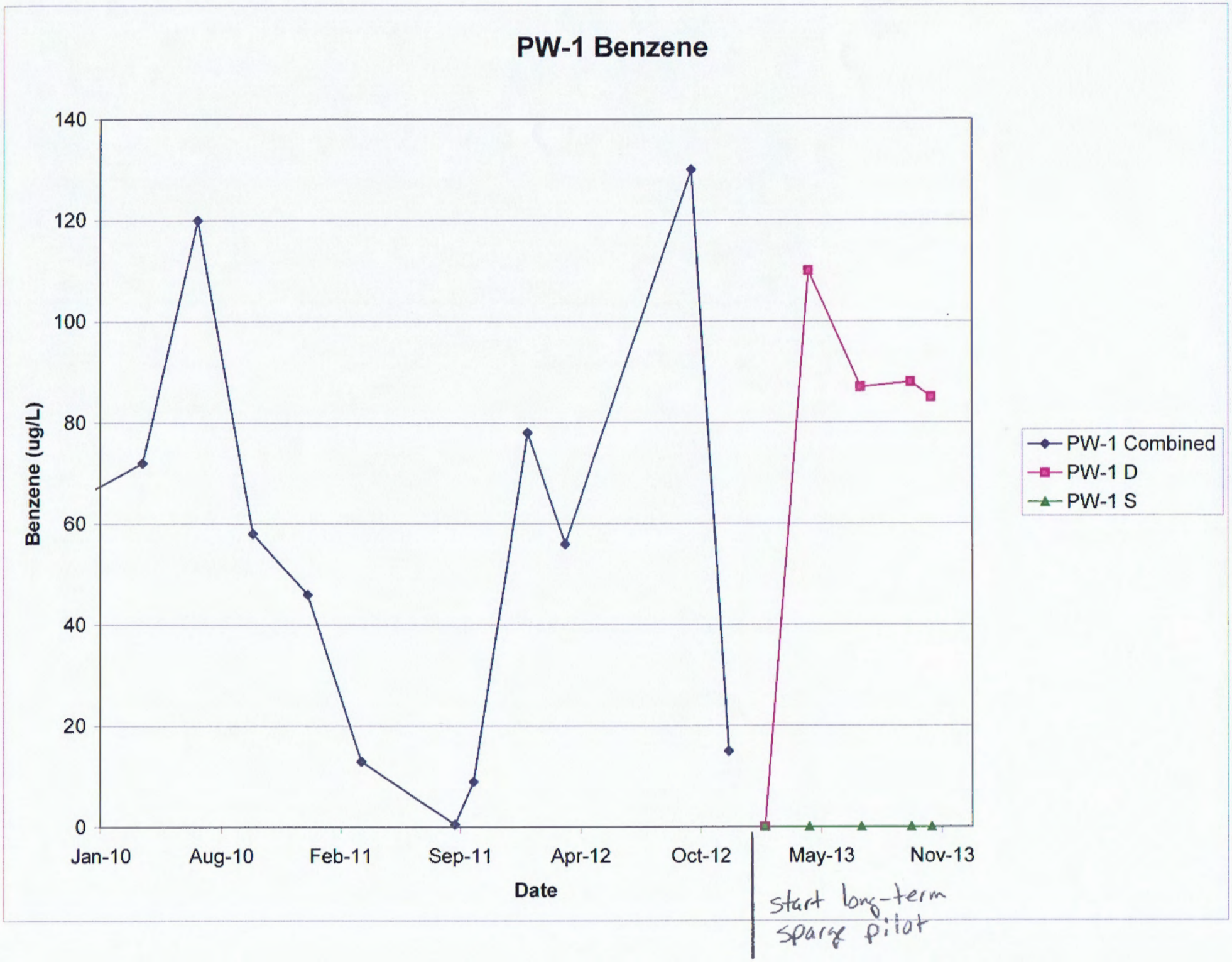
MONITORING WELL DIAGRAM

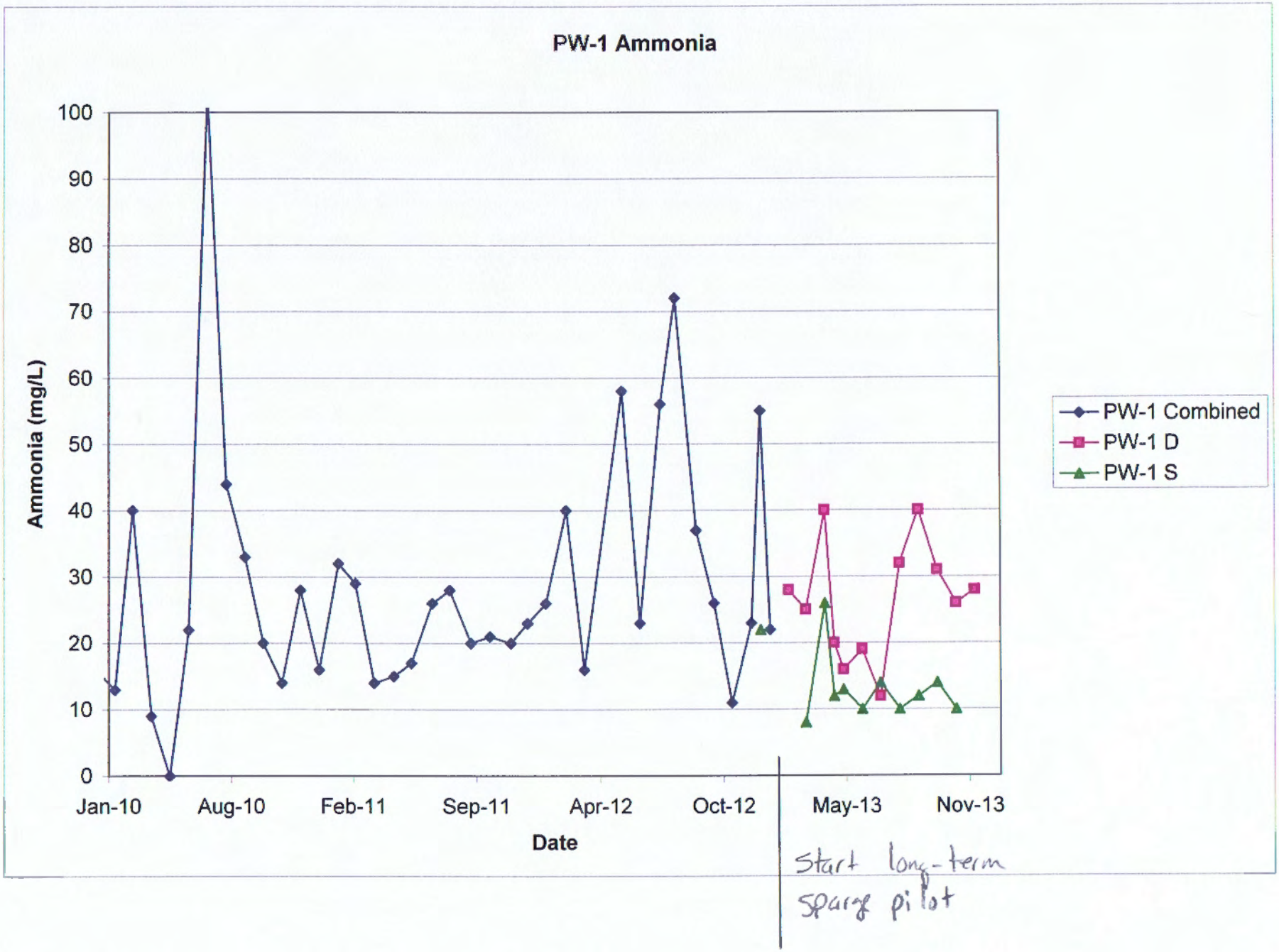
REILLY INDUSTRIES
1500 SOUTH TIBBS AVE.
INDIANAPOLIS, INDIANA

PROJECT NO. 97132.40

DATE: 7-8-97

WELL NO. RI-5D


PW-1 Benzene
Benzene (ug/L)
140
120
100
80
60
40
20
0
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
PW-1 Combined
PW-1 D
PW-1 S
start long-term
sparge pilot


PW-1 Ammonia
Ammonia (mg/L)
100
90
80
70
60
50
40
30
20
10
0
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
PW-1 Combined
PW-1 D
PW-1 S
Start long-term sparg pilot

# Recent Plant Testing Data at PW-1

## Benzene

| Date | PW-1 Combined | PW-1 D | PW-1 S |
|---|---|---|---|
| Apr-09 | 78 | | |
| May-09 | 53 | | |
| Jun-09 | 85 | | |
| Aug-09 | 15 | | |
| Sep-09 | 65 | | |
| Oct-09 | 75 | | |
| Nov-09 | 76 | | |
| Dec-09 | 65 | | |
| Jan-10 | 66 | | |
| Apr-10 | 72 | | |
| Jul-10 | 120 | | |
| Oct-10 | 58 | | |
| Jan-11 | 46 | | |
| Apr-11 | 13 | | |
| Sep-11 | 1 | | |
| Oct-11 | 9 | | |
| Jan-12 | 78 | | |
| Mar-12 | 56 | | |
| Oct-12 | 130 | | |
| Dec-12 | 15 | | |
| Feb-13 | | 0 | 0 |
| Apr-13 | | 110 | 0 |
| Jul-13 | | 87 | 0 |
| Oct-13 | | 88 | 0 |
| Nov-13 | | 85 | 0 |

Commenced sparging Jan. 2013

## Ammonia

| Date | PW-1 Combined |
|---|---|
| Jan-10 | 16 |
| Feb-10 | 13 |
| Mar-10 | 40 |
| Apr-10 | 9 |
| May-10 | 0 |
| Jun-10 | 22 |
| Jul-10 | 103 |
| Aug-10 | 44 |
| Sep-10 | 33 |
| Oct-10 | 20 |
| Nov-10 | 14 |
| Dec-10 | 28 |
| Jan-11 | 16 |
| Feb-11 | 32 |
| Mar-11 | 29 |
| Apr-11 | 14 |
| May-11 | 15 |
| Jun-11 | 17 |
| Jul-11 | 26 |
| Aug-11 | 28 |
| Sep-11 | 20 |
| Oct-11 | 21 |
| Nov-11 | 20 |
| Dec-11 | 23 |

| Date | PW-1 Combined (continued) | PW-1 D | PW-1 S |
|---|---|---|---|
| Jan-12 | 26 | | |
| Feb-12 | 40 | | |
| Mar-12 | 16 | | |
| May-12 | 58 | | |
| Jun-12 | 23 | | |
| Jul-12 | 56 | | |
| Aug-12 | 72 | | |
| Sep-12 | 37 | | |
| Oct-12 | 26 | | |
| Nov-12 | 11 | | |
| Dec-12 | 23 | | |
| Dec-12 | 55 | | 22 |
| Jan-13 | 22 | | |
| Feb-13 | | 28 | |
| Mar-13 | | 25 | 8 |
| Apr-13 | | 40 | 26 |
| Apr-13 | | 20 | 12 |
| May-13 | | 16 | 13 |
| Jun-13 | | 19 | 10 |
| Jul-13 | | 12 | 14 |
| Aug-13 | | 32 | 10 |
| Sep-13 | | 40 | 12 |
| Oct-13 | | 31 | 14 |
| Nov-13 | | 26 | 10 |
| Dec-13 | | 28 | |

Commenced sparging Jan. 2013

## OLD SP Sparging south of PW-1

Data collected during pilot test at the new monitoring well called "OLD SP". Includes baseline data.

Note: Sparge operation and measurements performed by K. Might

| Well | Date/Time | DTW (ft btoc) | DO (mg/L) | ORP (mV) | Wellhead Pressure (inches H2O) | Helium (ppm) |
|---|---|---|---|---|---|---|
| PW-1S | 9/8/2008 14:30 | 23.37 | | | | |
| PW-1S | 9/9/2008 16:27 | 23.38 | | | | |
| PW-1S | 9/10/2008 8:46 | | | | | |
| PW-1S | 9/10/2008 9:26 | 23.39 | | | | |
| PW-1S | 9/10/2008 14:04 | | | | | 650 |
| PW-1S | 9/10/2008 17:49 | | | | | 400 |
| PW-1S | 9/11/2008 9:40 | | | | 0 | 38,000 |
| PW-1S | 9/12/2008 9:35 | | | | 0 | 29,000 |
| PW-1S | 9/13/2008 10:50 | | | | 0 | |
| PW-1S | 9/13/2008 11:17 | | | | 0 | 3,775 |
| PW-1S | 9/14/2008 15:10 | | | | 0 | |
| PW-1S | 9/15/2008 16:45 | | | | 0 | 950 |
| PW-1S | 9/16/2008 9:20 | | | | 0 | 3150 |
| PW-1S | 9/16/2008 10:43 | | | | | 2625 |
| PW-1S | 9/16/2008 11:41 | | | | | 2075 |
| PW-1S | 9/16/2008 12:16 | | | | | 2000 |
| PW-1S | 9/16/2008 13:21 | | | | 0 | 2125 |
| PW-1S | 9/16/2008 14:03 | | | | | 2450 |
| PW-1S | 9/16/2008 15:05 | | | | | 3425 |
| PW-1S | 9/16/2008 16:24 | | | | 0 | 5175 |
| PW-1S | 9/17/2008 10:17 | | | | 0 | 12000 |
| PW-1S | 9/17/2008 12:32 | | | | | 10075 |
| PW-1S | 9/17/2008 13:16 | | | | | 9050 |
| PW-1S | 9/17/2008 13:57 | | | | | 8375 |
| PW-1S | 9/17/2008 15:01 | | | | | 8450 |
| PW-1S | 9/18/2008 10:18 | | | | | 8950 |
| PW-1S | 9/19/2008 10:19 | | | | 0 | 1225 |
| | | | | | | |
| | | | | | | |
| PW-1D | 9/8/2008 14:15 | 32.71 | | | | |
| PW-1D | 9/10/2008 9:26 | 26.69 | 0.73 | -37.5 | | |
| PW-1D | 9/10/2008 14:16 | | 0.45 | -17.7 | | |
| PW-1D | 9/10/2008 14:41 | | | | | 0 |
| PW-1D | 9/10/2008 15:49 | | 0.34 | -19.4 | | |
| PW-1D | 9/10/2008 17:38 | | | | | 0 |
| PW-1D | 9/11/2008 9:40 | 25.33 | 0.01 | | | |
| PW-1D | 9/11/2008 16:13 | | 0.01 | -124.2 | | |
| PW-1D | 9/12/2008 10:44 | | 0.01 | -193.3 | | |
| PW-1D | 9/13/2008 10:50 | 24.58 | | | | |
| PW-1D | 9/13/2008 11:17 | | | | | 0 |
| PW-1D | 9/14/2008 15:10 | 24.21 | 0.01 | -212.8 | | |
| PW-1D | 9/15/2008 16:45 | 25.12 | | | | 0 |
| PW-1D | 9/16/2008 9:20 | | 0.01 | | | 0 |
| PW-1D | 9/16/2008 10:43 | | | | | 0 |
| PW-1D | 9/16/2008 11:41 | | | | | 0 |
| PW-1D | 9/16/2008 12:26 | | | | | 12260 |
| PW-1D | 9/16/2008 13:22 | | | | | 1322 |
| PW-1D | 9/16/2008 14:02 | 23.72 | | | | |
| PW-1D | 9/16/2008 14:05 | | | | | 0 |
| PW-1D | 9/16/2008 14:36 | 23.69 | | | | |
| PW-1D | 9/16/2008 15:05 | 23.7 | | | | |
| PW-1D | 9/16/2008 15:08 | | | | | 0 |
| PW-1D | 9/16/2008 15:42 | 23.81 | | | | |
| PW-1D | 9/16/2008 16:28 | 23.82 | 0.01 | -219 | | 0 |
| PW-1D | 9/17/2008 10:10 | 24.35 | 0.01 | -248.2 | | 0 |
| PW-1D | 9/17/2008 11:36 | | | | | 0 |
| PW-1D | 9/17/2008 13:08 | 24.38 | | | | |
| PW-1D | 9/17/2008 13:56 | | | | | 0 |
| PW-1D | 9/17/2008 14:11 | 23.86 | | | | |
| PW-1D | 9/17/2008 14:48 | 24.36 | | | | |
| PW-1D | 9/17/2008 15:58 | 24.38 | | | | |
| PW-1D | 9/17/2008 16:16 | 25.19 | | | | |
| PW-1D | 9/17/2008 16:30 | 24.92 | | | | |
| PW-1D | 9/18/2008 8:25 | 25.03 | 0.01 | -286.9 | | |
| PW-1D | 9/18/2008 10:13 | | | | | 0 |
| PW-1D | 9/19/2008 10:06 | 24.33 | 0.01 | -366 | | 0 |
| PW-1D | 9/19/2008 11:10 | 24.13 | 0.13 | | | |
| | | | | | | |
| | | | | | | |
| PW-1D North PZ | 9/13/2008 10:50 | | | | 0.16 | |
| PW-1D North PZ | 9/14/2008 15:10 | | | | | |
| PW-1D North PZ | 9/15/2008 16:45 | | | | 0 | 0 |
| PW-1D North PZ | 9/16/2008 9:20 | | | | 1.1 | 30000 |
| PW-1D North PZ | 9/16/2008 9:48 | | | | 4.7 | |
| PW-1D North PZ | 9/16/2008 10:43 | | | | | 24000 |
| PW-1D North PZ | 9/16/2008 11:41 | | | | | 16850 |
| PW-1D North PZ | 9/16/2008 12:23 | | | | -0.04 | 13425 |
| PW-1D North PZ | 9/16/2008 13:26 | | | | 0.85 | 12250 |
| PW-1D North PZ | 9/16/2008 14:09 | | | | 0 | 8275 |
| PW-1D North PZ | 9/16/2008 15:11 | | | | 0.06 | 7450 |
| PW-1D North PZ | 9/16/2008 16:35 | | | | 0.06 | 7975 |
| PW-1D North PZ | 9/17/2008 10:15 | | | | -0.09 | 12775 |
| PW-1D North PZ | 9/17/2008 12:26 | | | | 0.02 | 13375 |
| PW-1D North PZ | 9/17/2008 13:19 | | | | 0 | 9400 |
| PW-1D North PZ | 9/17/2008 13:35 | | | | - | |
| PW-1D North PZ | 9/17/2008 14:00 | | | | - | 6325 |
| PW-1D North PZ | 9/17/2008 14:58 | | | | 0.3 | 3850 |
| PW-1D North PZ | 9/18/2008 8:25 | | | | 0.06 | |
| PW-1D North PZ | 9/18/2008 10:13 | | | | 0.03 | 12100 |
| PW-1D North PZ | 9/19/2008 10:06 | | | | 0 | 7650 |

## OLD SP Sparging south of PW-1

Data collected during pilot test at the new monitoring well called "OLD SP". Includes baseline data.

Note: Sparge operation and measurements performed by K. Might

| Well | Date/Time | DTW (ft btoc) | DO (mg/L) | ORP (mV) | Wellhead Pressure (inches H2O) | Helium (ppm) |
|---|---|---|---|---|---|---|
| PW-1D South PZ | 9/13/2008 10:50 | | | | 0 | |
| PW-1D South PZ | 9/14/2008 15:10 | | | | 0 | |
| PW-1D South PZ | 9/15/2008 16:45 | | | | 0 | 0 |
| PW-1D South PZ | 9/16/2008 9:20 | | | | 0 | 0 |
| PW-1D South PZ | 9/16/2008 10:43 | | | | 0 | 0 |
| PW-1D South PZ | 9/16/2008 11:41 | | | | | 0 |
| PW-1D South PZ | 9/16/2008 12:21 | | | | 0.1 | 0 |
| PW-1D South PZ | 9/16/2008 13:25 | | | | 0 | 0 |
| PW-1D South PZ | 9/16/2008 14:07 | | | | 0 | 0 |
| PW-1D South PZ | 9/16/2008 15:09 | | | | | 0 |
| PW-1D South PZ | 9/16/2008 16:33 | | | | 0 | 0 |
| PW-1D South PZ | 9/17/2008 10:13 | | | | 0 | 0 |
| PW-1D South PZ | 9/17/2008 12:27 | | | | 0 | 0 |
| PW-1D South PZ | 9/17/2008 13:08 | | | | 0.38 | |
| PW-1D South PZ | 9/17/2008 13:15 | | | | 0.22 | 0 |
| PW-1D South PZ | 9/17/2008 13:22 | | | | 0.5 | |
| PW-1D South PZ | 9/17/2008 14:01 | | | | 0.5 | 0 |
| PW-1D South PZ | 9/17/2008 14:57 | | | | | 0 |
| PW-1D South PZ | 9/18/2008 8:25 | | | | 5 | |
| PW-1D South PZ | 9/18/2008 10:13 | | | | 0.4 | 0 |
| PW-1D South PZ | 9/19/2008 10:06 | | | | -0.04 | 0 |
| | | | | | | |
| PW-1D Dip Tube | 9/13/2008 10:50 | | | | 0.66 | |
| PW-1D Dip Tube | 9/14/2008 15:10 | | | | 5.5 | |
| PW-1D Dip Tube | 9/15/2008 16:45 | | | | 0 | 0 |
| PW-1D Dip Tube | 9/16/2008 9:20 | | | | 1.85 | 21000 |
| PW-1D Dip Tube | 9/16/2008 0:00 | | | | | 18350 |
| PW-1D Dip Tube | 9/16/2008 11:41 | | | | | 16500 |
| PW-1D Dip Tube | 9/16/2008 12:19 | | | | 0.83 | 11000 |
| PW-1D Dip Tube | 9/16/2008 13:23 | | | | 0.075 | 12250 |
| PW-1D Dip Tube | 9/16/2008 14:07 | | | | 0.13 | 13850 |
| PW-1D Dip Tube | 9/16/2008 15:10 | | | | 0.5 | 11500 |
| PW-1D Dip Tube | 9/16/2008 16:34 | | | | 0.25 | 10850 |
| PW-1D Dip Tube | 9/17/2008 10:14 | | | | 0.05 | 14450 |
| PW-1D Dip Tube | 9/17/2008 12:28 | | | | 0.7 | 14900 |
| PW-1D Dip Tube | 9/17/2008 13:17 | | | | 0.75 | 12125 |
| PW-1D Dip Tube | 9/17/2008 13:59 | | | | 4.3 | 16775 |
| PW-1D Dip Tube | 9/17/2008 14:57 | | | | -3.8 | 13725 |
| PW-1D Dip Tube | 9/18/2008 10:13 | | | | 4.3 | 3975 |
| PW-1D Dip Tube | 9/19/2008 10:06 | | | | 0 | 7500 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| RI-4S | 9/8/2008 11:53 | | 0.19 | | | |
| RI-4S | 9/9/2008 8:57 | 17.68 | 0.18 | | | |
| RI-4S | 9/9/2008 17:01 | 17.68 | 0.38 | | | |
| RI-4S | 9/10/2008 12:01 | 17.70 | 0.16 | | | 0 |
| RI-4S | 9/10/2008 18:35 | | | | | 0 |
| RI-4S | 9/11/2008 8:37 | 17.73 | 0.32 | | | 0 |
| RI-4S | 9/11/2008 14:45 | | | | | 0 |
| RI-4S | 9/11/2008 17:03 | 17.72 | 0.16 | | | 0 |
| RI-4S | 9/12/2008 11:21 | 17.74 | 0.18 | | | 0 |
| RI-4S | 9/13/2008 11:48 | 17.65 | 0.15 | | | 0 |
| RI-4S | 9/16/2008 8:40 | 17.77 | | | | 0 |
| RI-4S | 9/16/2008 16:05 | 17.77 | | | 0 | 0 |
| RI-4S | 9/17/2008 9:49 | 17.81 | 0.14 | | 0 | 0 |
| RI-4S | 9/18/2008 13:08 | 17.83 | 0.14 | | 0 | 0 |
| RI-4S | 9/19/2008 9:45 | 17.86 | 0.15 | | -0.06 | 0 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| RI-4D | 9/8/2008 10:37 | 29.51 | | -203.4 | | |
| RI-4D | 9/9/2008 8:57 | 24.04 | 0.98 | -205.7 | | |
| RI-4D | 9/9/2008 17:01 | 23.42 | 0.21 | -145 | | |
| RI-4D | 9/10/2008 12:01 | 22.03 | | | | 3,900 |
| RI-4D | 9/10/2008 13:35 | | 0.17 | -154 | | 0 |
| RI-4D | 9/10/2008 18:31 | | 0.11 | -134.1 | | 2,450 |
| RI-4D | 9/11/2008 8:37 | 20.69 | | | | 3,775 |
| RI-4D | 9/11/2008 14:45 | | 0.08 | -184.6 | | 150 |
| RI-4D | 9/11/2008 17:03 | 20.31 | 0.07 | -129.9 | | 225 |
| RI-4D | 9/12/2008 11:21 | 20.28 | | | | 3,600 |
| RI-4D | 9/16/2008 8:40 | 20.08 | | | | 2,150 |
| RI-4D | 9/16/2008 16:05 | 19.07 | 0.10 | -169.9 | | 75 |
| RI-4D | 9/17/2008 9:49 | 19.73 | | | | 1,025 |
| RI-4D | 9/18/2008 13:08 | 19.45 | 0.16 | | | 1,000 |
| RI-4D | 9/17/2008 17:47 | | 0.13 | -174.2 | | 0 |
| RI-4D | 9/19/2008 9:45 | 19.72 | 0.15 | | -0.08 | 875 |

## OLD SP Sparging south of PW-1

Data collected during pilot test at the new monitoring well called "OLD SP". Includes baseline data.

Note: Sparge operation and measurements performed by K. Might

| Well | Date/Time | DTW (ft btoc) | DO (mg/L) | ORP (mV) | Wellhead Pressure (inches H2O) | Helium (ppm) |
|---|---|---|---|---|---|---|
| RI-5S | 9/8/2008 12:06 | 28.84 | 0.16 | | | |
| RI-5S | 9/9/2008 16:31 | 24.88 | 0.19 | | | |
| RI-5S | 9/10/2008 10:49 | 24.16 | 0.18 | | | 0 |
| RI-5S | 9/10/2008 11:52 | | | | | 100 |
| RI-5S | 9/11/2008 9:11 | 23.26 | 0.16 | | 0 | 0 |
| RI-5S | 9/11/2008 16:24 | 22.97 | 0.17 | | 0 | 425 |
| RI-5S | 9/12/2008 12:10 | 23.00 | 0.15 | | 0 | 625 |
| RI-5S | 9/16/2008 9:10 | 22.75 | | | | 775 |
| RI-5S | 9/16/2008 15:48 | 22.19 | | | -0.06 | 275 |
| RI-5S | 9/17/2008 11:00 | 22.50 | 0.13 | | -0.04 | 175 |
| RI-5S | 9/18/2008 12:52 | 22.66 | 0.16 | 15.7 | 0.02 | 250 |
| RI-5S | 9/19/2008 11:50 | 22.45 | 0.14 | | -0.08 | 550 |
| RI-5D | 9/8/2008 12:06 | 27.85 | 0.20 | | | |
| RI-5D | 9/9/2008 16:31 | 27.68 | 0.29 | | | |
| RI-5D | 9/10/2008 10:49 | 27.64 | 0.19 | | | 0 |
| RI-5D | 9/10/2008 11:52 | | | | | 0 |
| RI-5D | 9/11/2008 9:11 | 27.49 | 0.13 | | 0.8 | 0 |
| RI-5D | 9/11/2008 16:24 | 27.38 | 0.20 | | 2.5 | 0 |
| RI-5D | 9/12/2008 12:10 | 27.72 | 0.15 | | -0.68 | 0 |
| RI-5D | 9/16/2008 9:10 | 27.60 | | | | 0 |
| RI-5D | 9/16/2008 15:48 | 27.51 | | | 0.63 | 0 |
| RI-5D | 9/17/2008 11:00 | 27.47 | 0.17 | | 0 | 0 |
| RI-5D | 9/18/2008 12:52 | 27.64 | 0.16 | | 0.8 | 0 |
| RI-5D | 9/19/2008 11:50 | 27.63 | 0.16 | | 0.04 | 0 |
| PW-1OLD | 9/8/2008 14:33 | 22.82 | | | | |
| PW-1OLD | 9/9/2008 16:24 | 22.77 | | | | |
| PW-1OLD | 9/10/2008 9:26 | 22.77 | 0.73 | | | |
| PW-1OLD | 9/10/2008 14:10 | | | | | 25,000 |
| PW-1OLD | 9/10/2008 14:42 | | | | | 17,250 |
| PW-1OLD | 9/10/2008 17:40 | | | | | 34,000 |
| PW-1OLD | 9/11/2008 9:40 | | | | | 7,350 |
| PW-1OLD | 9/11/2008 13:55 | | | | | 58,000 |
| PW-1OLD | 9/11/2008 14:15 | | 11.27 | | | |
| PW-1OLD | 9/12/2008 9:27 | | | | | 7,350 |
| PW-1OLD | 9/12/2008 9:35 | 21.92 | 11.45 | | | 3,175 |
| PW-1OLD | 9/17/2008 15:40 | 21.75 | 12.44 | | | |
| PW-1OLD | 9/18/2008 8:23 | 23.03 | | | | |
| PW-1OLD | 9/18/2008 10:10 | | | | | 0 |
| PW-1OLD | 9/18/2008 10:30 | | 8.59 | | | |
| PW-1OLD | 9/19/2008 10:04 | | | | 62.4 | |
| PW-1OLD East PZ | 9/8/2008 14:33 | 32.39 | | | | |
| PW-1OLD East PZ | 9/9/2008 16:24 | 27.57 | | | | |
| PW-1OLD East PZ | 9/10/2008 9:26 | 26.38 | | | | |
| PW-1OLD East PZ | 9/10/2008 14:10 | | | | | 1,325 |
| PW-1OLD East PZ | 9/10/2008 17:40 | | | | | 5,750 |
| PW-1OLD East PZ | 9/11/2008 9:40 | | | | 0.48 | 3,250 |
| PW-1OLD East PZ | 9/12/2008 9:35 | 24.57 | | | 0.68 | 200 |
| PW-1OLD East PZ | 9/12/2008 14:40 | | | | 66 | |
| PW-1OLD East PZ | 9/13/2008 10:40 | | | | 66 | |
| PW-1OLD East PZ | 9/16/2008 9:20 | | | | 32 | |
| PW-1OLD East PZ | 9/16/2008 10:43 | | | | | 3,025 |
| PW-1OLD East PZ | 9/16/2008 11:41 | | | | 60 | 1,850 |
| PW-1OLD East PZ | 9/16/2008 12:29 | | | | 61.2 | 1,925 |
| PW-1OLD East PZ | 9/16/2008 13:30 | | | | 61.2 | 7,625 |
| PW-1OLD East PZ | 9/16/2008 14:21 | | | | 61.2 | 16,575 |
| PW-1OLD East PZ | 9/16/2008 15:32 | | | | 61.2 | 19,250 |
| PW-1OLD East PZ | 9/16/2008 16:52 | | | | 61.2 | 23000 |
| PW-1OLD East PZ | 9/17/2008 15:48 | 23.83 | 0.18 | | | |
| PW-1OLD East PZ | 9/17/2008 10:23 | | | | 61.2 | 12950 |
| PW-1OLD East PZ | 9/17/2008 11:33 | | | | 63.6 | 6600 |
| PW-1OLD East PZ | 9/17/2008 12:00 | | | | 57.6 | 4925 |
| PW-1OLD East PZ | 9/17/2008 12:04 | | | | | 3850 |
| PW-1OLD East PZ | 9/17/2008 12:23 | | | | 50.4 | 5950 |
| PW-1OLD East PZ | 9/17/2008 12:47 | | | | 57.6 | 8350 |
| PW-1OLD East PZ | 9/17/2008 13:11 | | | | 49.2 | 10150 |
| PW-1OLD East PZ | 9/17/2008 13:32 | | | | 54 | 11325 |
| PW-1OLD East PZ | 9/17/2008 13:53 | | | | 51.6 | 12525 |
| PW-1OLD East PZ | 9/17/2008 14:54 | | | | 66 | 14050 |
| PW-1OLD East PZ | 9/18/2008 10:30 | | 0.23 | | | |
| PW-1OLD East PZ | 9/18/2008 10:10 | | | | | 0 |

## OLD SP Sparging south of PW-1

Data collected during pilot test at the new monitoring well called "OLD SP". Includes baseline data.

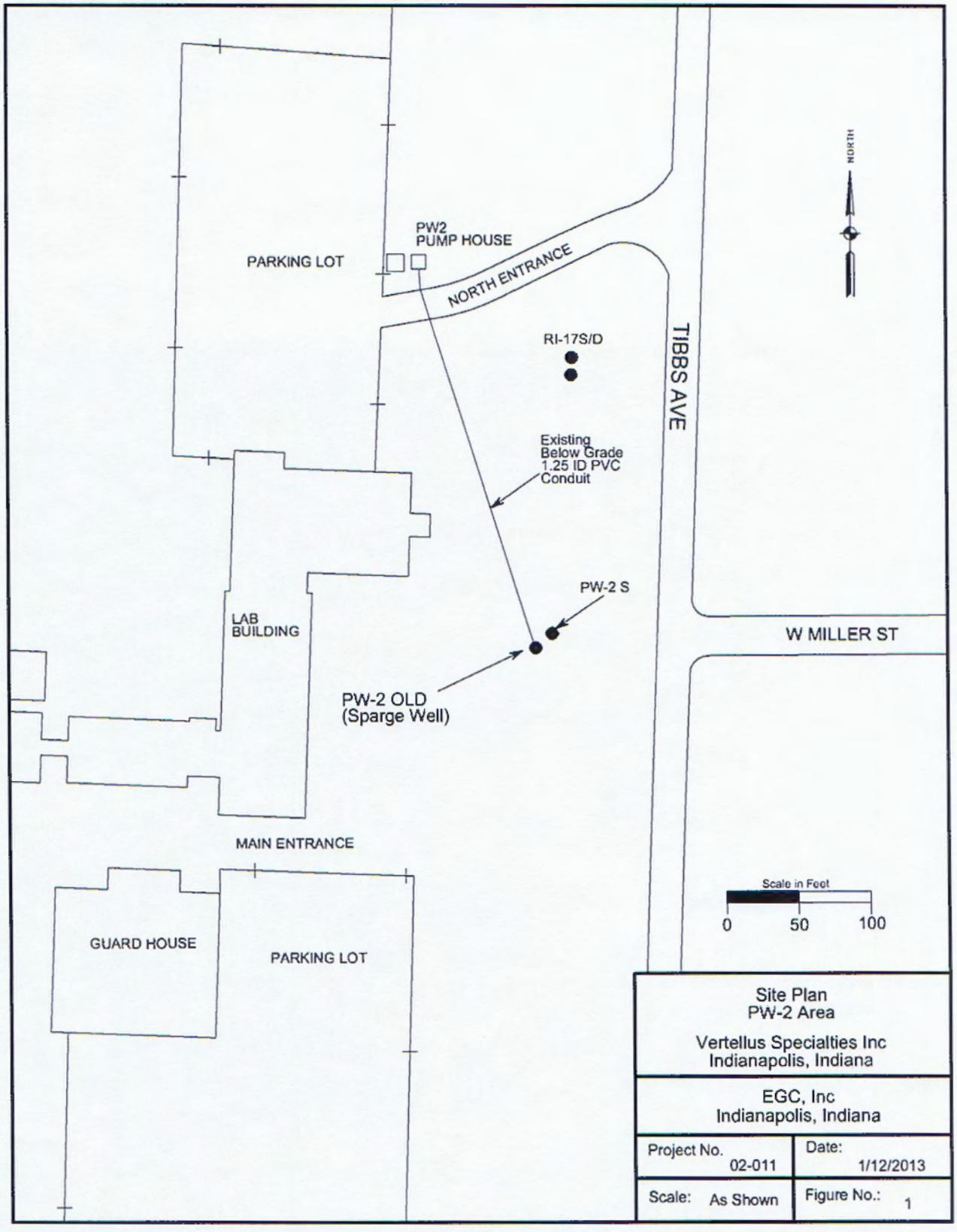
Note: Sparge operation and measurements performed by K. Might

| Well | Date/Time | DTW (ft btoc) | DO (mg/L) | ORP (mV) | Wellhead Pressure (inches H2O) | Helium (ppm) |
|---|---|---|---|---|---|---|
| PW-1OLD West PZ | 9/8/2008 14:33 | 32.07 | | | | |
| PW-1OLD West PZ | 9/9/2008 16:24 | 27.38 | | | | |
| PW-1OLD West PZ | 9/10/2008 9:26 | 26.26 | | | | |
| PW-1OLD West PZ | 9/10/2008 14:10 | | | | | 7,750 |
| PW-1OLD West PZ | 9/10/2008 17:40 | | | | | 2,600 |
| PW-1OLD West PZ | 9/11/2008 9:40 | | | | 0.48 | 1,975 |
| PW-1OLD West PZ | 9/12/2008 9:35 | 24.48 | | | 1 | 2,650 |
| PW-1OLD West PZ | 9/12/2008 14:40 | | | | 24 | |
| PW-1OLD West PZ | 9/13/2008 10:40 | | | | 13.2 | |
| PW-1OLD West PZ | 9/16/2008 9:20 | | | | 14 | |
| PW-1OLD West PZ | 9/16/2008 9:48 | | | | 54 | |
| PW-1OLD West PZ | 9/16/2008 10:43 | | | | | 225 |
| PW-1OLD West PZ | 9/16/2008 11:41 | | | | | 0 |
| PW-1OLD West PZ | 9/16/2008 12:31 | | | | 14 | 175 |
| PW-1OLD West PZ | 9/16/2008 13:32 | | | | 48 | 2,000 |
| PW-1OLD West PZ | 9/16/2008 14:22 | | | | 46.8 | 4,225 |
| PW-1OLD West PZ | 9/16/2008 15:33 | | | | 54 | 2,750 |
| PW-1OLD West PZ | 9/16/2008 16:51 | | | | 48 | 2,450 |
| PW-1OLD West PZ | 9/17/2008 15:42 | | 0.24 | | | |
| PW-1OLD West PZ | 9/17/2008 15:54 | 23.87 | | | | |
| PW-1OLD West PZ | 9/17/2008 10:24 | | | | 14.4 | 1,800 |
| PW-1OLD West PZ | 9/17/2008 11:34 | | | | 21.6 | 575 |
| PW-1OLD West PZ | 9/17/2008 12:02 | | | | | 2,850 |
| PW-1OLD West PZ | 9/17/2008 12:25 | | | | <6 | 1,150 |
| PW-1OLD West PZ | 9/17/2008 12:48 | | | | 12 | 800 |
| PW-1OLD West PZ | 9/17/2008 13:12 | | | | 6 | 8,375 |
| PW-1OLD West PZ | 9/17/2008 13:32 | | | | | 8,550 |
| PW-1OLD West PZ | 9/17/2008 13:54 | | | | 12 | 5,475 |
| PW-1OLD West PZ | 9/17/2008 14:55 | | | | 18 | 8,975 |
| PW-1OLD West PZ | 9/18/2008 10:30 | | 0.23 | | | |
| PW-1OLD West PZ | 9/18/2008 10:10 | | | | | 0 |
| | | | | | | |
| PW-1OLD Dip Tube | 9/8/2008 14:33 | 32.55 | | | | |
| PW-1OLD Dip Tube | 9/10/2008 9:26 | 26.09 | | | | |
| PW-1OLD Dip Tube | 9/10/2008 14:10 | | | | | 400 |
| PW-1OLD Dip Tube | 9/10/2008 17:40 | | | | | 625 |
| PW-1OLD Dip Tube | 9/11/2008 9:40 | | | | 0 | 200 |
| PW-1OLD Dip Tube | 9/12/2008 9:35 | | | | 0 | 0 |
| PW-1OLD Dip Tube | 9/13/2008 10:40 | | | | 0 | |
| PW-1OLD Dip Tube | 9/14/2008 15:10 | | | | 0 | |
| PW-1OLD Dip Tube | 9/16/2008 9:20 | | | | 0 | |
| PW-1OLD Dip Tube | 9/16/2008 10:43 | | | | | 0 |
| PW-1OLD Dip Tube | 9/16/2008 11:41 | | | | | 0 |
| PW-1OLD Dip Tube | 9/16/2008 12:33 | | | | | 0 |
| PW-1OLD Dip Tube | 9/16/2008 13:29 | | | | | 0 |
| PW-1OLD Dip Tube | 9/16/2008 15:30 | | | | | 0 |
| PW-1OLD Dip Tube | 9/16/2008 16:50 | | | | 0 | 0 |
| PW-1OLD Dip Tube | 9/17/2008 10:22 | | | | | 0 |
| PW-1OLD Dip Tube | 9/17/2008 11:35 | | | | | 0 |
| PW-1OLD Dip Tube | 9/17/2008 12:25 | | | | | 0 |
| PW-1OLD Dip Tube | 9/17/2008 12:50 | | | | | 0 |
| PW-1OLD Dip Tube | 9/17/2008 13:13 | | | | | 0 |
| PW-1OLD Dip Tube | 9/17/2008 13:55 | | | | | 0 |
| PW-1OLD Dip Tube | 9/17/2008 14:51 | | | | | 0 |
| PW-1OLD Dip Tube | 9/18/2008 10:10 | | | | | 0 |
| | | | | | | |
| RI-18S | 9/8/2008 11:31 | 20.39 | 0.39 | | | |
| RI-18S | 9/9/2008 16:46 | 20.42 | 0.17 | | | |
| RI-18S | 9/10/2008 13:41 | 20.45 | 0.14 | | | 0 |
| RI-18S | 9/11/2008 9:01 | 20.47 | 0.12 | | | 0 |
| RI-18S | 9/11/2008 16:40 | 20.45 | 0.12 | | 0 | 0 |
| RI-18S | 9/12/2008 11:04 | 20.49 | 0.26 | | 0 | 0 |
| RI-18S | 9/13/2008 11:43 | 20.38 | 0.13 | | 0 | 0 |
| RI-18S | 9/16/2008 9:00 | 20.55 | | | | 0 |
| RI-18S | 9/16/2008 15:57 | 19.13 | | | -0.1 | 0 |
| RI-18S | 9/17/2008 11:19 | 20.56 | 0.13 | | -0.02 | 0 |
| RI-18S | 9/19/2008 12:10 | 20.62 | 0.12 | | 0 | 0 |
| | | | | | | |
| RI-18D | 9/8/2008 11:31 | 19.93 | 0.21 | | | |
| RI-18D | 9/9/2008 16:46 | 19.39 | 0.21 | | | |
| RI-18D | 9/10/2008 13:41 | 19.28 | 0.16 | | | 0 |
| RI-18D | 9/11/2008 9:01 | 19.22 | 0.15 | | | 0 |
| RI-18D | 9/11/2008 16:40 | 19.14 | 0.14 | | 0 | 0 |
| RI-18D | 9/12/2008 11:04 | 19.18 | 0.15 | | 0 | 0 |
| RI-18D | 9/13/2008 11:43 | 19.12 | 0.17 | | 0 | 0 |
| RI-18D | 9/16/2008 9:00 | 19.24 | | | | 0 |
| RI-18D | 9/16/2008 15:57 | 20.54 | | | -0.09 | 0 |
| RI-18D | 9/17/2008 11:19 | 19.19 | 0.15 | | -0.7 | 0 |
| RI-18D | 9/19/2008 12:10 | 20.1 | 0.14 | | -0.04 | 0 |

| PW-1 OLD | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Wellhead | | | | | | PW1D Nh3 | | | | | | PW1S Nh3 | | | | 41 feet from this well to PW-1 Old (sparge point) | | | | |
| Date | Time | Comp psi | Spool psi | Temp | Diff P | SCFM | PSI | PW1D Q | PW1D P | PW1D WL | PW1D DO | PW1D T | ppm | PW1S Q | PW1S P | PW1S WL | PW1S DO | PW1S T | ppm | PW-1 Old WL | PW1 Old DO | PW1 Old T | 40 ft WL | 40 ft DO | 40 ft T | | | |
| 12/18/2012 | 1130 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 92 | 49.06 | 0.40 | 16.4 | 55 | 8 | 49 | 29.28 | 0.71 | 17.3 | 22 | 24.19 | | | 32.23 | 0.20 | 16 | | | |
| 1/16/2013 | 1045 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 93 | 47.96 | 1.70 | 16.2 | 22 | 5 | 56 | 26.73 | 0.62 | 17.1 | | 23.39 | 0.18 | 17.5 | 31.02 | 0.18 | 17.8 | | | |
| **1/16/2013** | start up of sparge at 1207 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1215 | 44 | 47 | 82 | 3.7 | 17.2 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1220 | 50 | 55 | 98 | 3.1 | 16.8 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1225 | 59 | 62 | 108 | 2.7 | 16.5 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1230 | 68 | 72 | 113 | 1 | | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1233 | increase flow | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1236 | 45 | 50 | 123 | 3.8 | 17.4 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1245 | 44 | 47 | 122 | 3.5 | | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1250 | 54 | 58 | 123 | 2.8 | | | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1254 | 62 | 66 | 124 | 2.3 | 15.5 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1300 | 46 | 47 | 130 | 4.1 | | | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1305 | 48 | 52 | 130 | 3.2 | | | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1233 | increase flow | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1236 | 45 | 50 | 123 | 3.8 | 17.4 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1245 | 44 | 47 | 122 | 3.5 | | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1250 | 54 | 58 | 123 | 2.8 | | | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1254 | 62 | 66 | 124 | 2.3 | 15.5 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1300 | 46 | 47 | 130 | 4.1 | | | | | | | | | | | | | | | | | | | | | | | |
| 1/16/2013 | 1305 | 48 | 52 | 130 | 3.2 | | | | | | | | | | | | | | | | | | | | | | | |
| 1/17/2013 | very little flow on visit, open up | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1/17/2013 | 1120 | 52 | 55 | 124 | 2.2 | 13.9 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/17/2013 | 1125 | 50 | 54 | 130 | 2.2 | | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/18/2013 | 1518 | 65 | 69 | 108 | 2.2 | 15.7 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/21/2013 | 1406 | 40 | 73 | 118 | 2.9 | 18.4 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/21/2013 | 1408 | 69 | 72 | 119 | 2.4 | 16.7 | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/28/2013 | 1058 | 82 | 85 | 117 | 0 | | 14 | | | | | | | | | | | | | | | | | | | | | |
| 1/28/2013 | 1105 | 50 | 50 | 133 | 1.7 | | 14 | | | | | | | | | | | | | | | | | | | | | |
| 2/7/2013 | 1317 | 49 | 46 | 127 | 2.8 | | | 41 | 90 | | 0.79 | 18.1 | 28 | 4 | 60 | | 1.41 | 18.6 | | | | | | | | | | |
| 2/21/2013 | 1300 | 43 | 40 | 102 | 3.5 | | 14 | 40 | 92 | 46.81 | 0.54 | 16.9 | | 4 | 58 | 25.4 | 3.68 | 16.4 | | | | | 31.05 | 1.03 | 17.4 | | | |
| 3/5/2013 | 1552 | 35 | 32 | 138 | 3.2 | | 14 | | | | | | 25 | | | | | | 8 | | | | | | | | | |
| 3/8/2013 | 1245 | 34 | 36 | 108 | 4.2 | | 14 | 39 | 93 | | 0.94 | 17.4 | | 0 | need to investigate PW-1S pumping | | | | | | | | | | | | | |
| 3/8/2013 | 1307 | 52 | 58 | 110 | 1.7 | | | | | | | | | | | | | | | | | | | | | | | |
| 3/20/2013 | 1510 | 60 | 60 | 108 | 0 | | 13.5 | | | | | | | | | | | | | | | | | | | | | |
| 3/28/2013 | 1115 | 54 | 50 | 102 | 0.8 | | 14 | 38 | 92 | 42.66 | 0.62 | 17.2 | | 5 | 56 | 24.64 | 0.75 | | | 22.76 | | | 31.13 | 3.04 | 17.3 | | | |
| 4/5/2013 | 1638 | off on arrival, added oil and moved on | | | | | | 37 | 90 | | | | 40 | 3.4 | 56 | 24.45 | | | 26 | | | | | | | | | |
| 4/12/2013 | 1420 | 48 | 44 | 128 | 1.5 | | 13.5 | 37 | 93 | | 0.63 | 18.1 | | 3 | 60 | | 0.97 | 18.3 | | | | | | | | | | |
| 4/22/2013 | 945 | 100 | open up flow, add oil, then went to off cycle | | | | | | | | | | 20 | | | | | | 12 | | | | | | | | | |
| 5/2/2013 | | 75 | 72 | 150 | | 14 | 14.5 | 36 | 94 | | 0.72 | 18 | 16 | 4.5 | 56 | | 1 | 17.5 | 13 | | | | | | | | | |
| 5/10/2013 | 1324 | 70 | 67 | 148 | | 13 | 14 | 38 | 93 | | 0.61 | 18.7 | | 5 | 55 | | 1.75 | 17.7 | | | | | 29.17 | 4.95 | 16.9 | | | |
| 5/21/2013 | 1145 | 45 | 41 | 137 | 0.3 | 15.5 | 13.5 | 38 | 94 | 40.03 | 0.80 | 18.8 | | 2 | 60 | 22.45 | 1.25 | 19.4 | | | | | 29.21 | 2.1 | 16.8 | | | |
| 6/3/2013 | lab data line | | | | | | | | | | | | 19 | | | | | | 10 | | | | | | | | | |
| 6/4/2013 | 13:22 | 55 | 51 | 141 | flow meter | 14 | 13.5 | 37 | 94 | 40.15 | 0.61 | 18.9 | | 3 | 32 | 23.19 | 1.97 | 18.3 | | | | | 29.09 | 2.83 | 16.6 | | | |
| 6/20/2013 | 12:54 | 60 | 47 | 109 | | 17 | 12.5 | 37 | 94 | | 0.81 | 19.6 | | 2 | 14 | | 0.75 | 18.9 | | | | | | 4.98 | 16.3 | | | |
| 6/20/2013 | 14:01 | 70 | 56 | 135 | | 16 | | | | | | | | | | | | | | | | | | | | | | |
| 6/28/2013 | 14:20 | 43 | 40 | 118 | | 14.5 | 12.5 | | | | | | | | | | | | | | | | | | | | | |
| 6/28/2013 | 14:33 | 58 | 58 | 133 | | 14 | 13 | | | | | | | | | | | | | | | | | | | | | |
| 7/8/2013 | 12:15 | 48 | 44 | 122 | | 17 | 14 | | | | | | | 0.3 | | 22.36 | well TD = 29.85 from TOC | | | | | | | | | | | |
| 7/19/2013 | | 55 | 52 | 137 | | 15.5 | 13 | | | | | | | 0 | | 22.41 | | | | | | | | | | | | |
| 7/22/2013 | | 48 | 44 | 118 | | 17 | 12.5 | | | | | | | | | | | | | | | | | | | | | |
| 7/30/2013 | 11:05 | 52 | 50 | 115 | | 15.5 | 13 | 38 | 93 | | 0.69 | 19 | | | | | | | | | | | 30.22 | 2.44 | 15.9 | | | |
| 7/30/2013 | work on PW-1 s. Add drop tube, 1 gal acid, recirculate just in the well and not outside the well | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7/30/2013 | 1105 | 56 | 55 | 131 | | 15.5 | 13.5 | | | | | | | | | | | | | | | | | | | | | |
| 7/30/2013 | 13:40 | | | | | | | | | | | | | 15 GPM MEASURED AT WELL HEAD, ph = 3, DEADHEAD PRESSURE = 52 PSI | | | | | | | | | | | |
| 7/30/2013 | 14:40 | | | | | | | | | | | | | 7 | 32 | 24.91 | | | | | | | | | | | | |
| 7/30/2013 | 14:37 | | | | | | | 39 | 94 | 41.27 | | | | 7 | 28 | NO ACCESS DUE TO RECIRCULATING WATER DROP TUBE | | | | | | | | | | | | |
| 9/9/2013 | 10:00 | 42 | 41 | 103 | | 16 | 13 | 38 | 93 | 43.19 | | | | 2 | 35 | 24.73 | reset Q to 5 gpm | | | | | | | | | | | |
| 9/9/2013 | 14:00 | | | | | | | | | | | | | 7 | 32 | 25.48 | | | | | | | | | | | | |
| 8/19/2013 | 11:30 | 56 | 54 | 142 | | 16 | 13 | 38 | 92 | | | | | 0.3 | 19 | 23.27 | iron fouling in pump, try recirculating hard | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Note: Sparge operation and measurements performed by K. Might | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

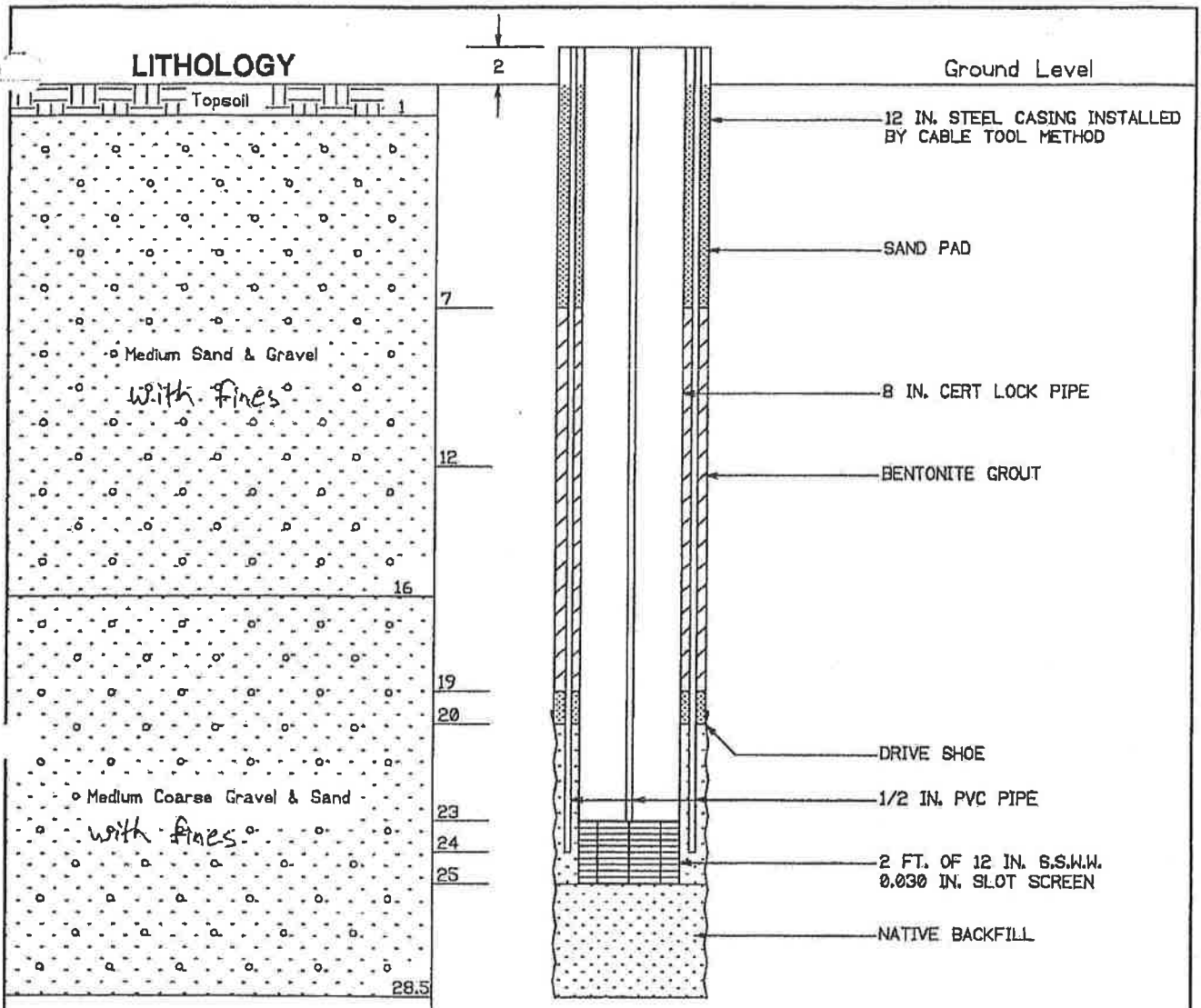
**Attachment 6**

**PW-2 Old Test Data**


PARKING LOT
PW2
PUMP HOUSE
NORTH ENTRANCE
RI-17S/D
TIBBS AVE
NORTH
Existing
Below Grade
1.25 ID PVC
Conduit
PW-2 S
LAB
BUILDING
W MILLER ST
PW-2 OLD
(Sparge Well)
MAIN ENTRANCE
GUARD HOUSE
PARKING LOT
Scale in Feet
0
50
100
Site Plan
PW-2 Area
Vertellus Specialties Inc
Indianapolis, Indiana
EGC, Inc
Indianapolis, Indiana
Project No.
02-011
Date:
1/12/2013
Scale: As Shown
Figure No.: 1

New PW-2

## LITHOLOGY




UTM COORDINATES 4,399,518 N
NAD 27 ZONE 16 567,143 E

City Indianapolis State Indiana

Well Location 100' W of Tibbs Av. & 85' N of Main Gate

County Marion Twp. Wayne T 15N R 3E ¼ ¼ NE ¼ 17

Test Rate _____ GPM

Static Water Level _____ Ft.

Pumping Level _____ Ft.

Specific Capacity _____ GPM/Ft. D.D.

Driller John Blatz

Date Drilled 9-22-02 Job No. 17652

Well No. PW-2S

Reilly Industries

Indianapolis, Indiana


**PEERLESS-MIDWEST, INC.**
55860 Russell Industrial Pkwy., Mishawaka, IN 46545
Water Supply Contractors

New PW-2

PEERLESS-MIDWEST, INC.
Mishawaka, IN (574) 254-9050
Ionia, MI (616) 527-0050
Indianapolis, IN (317) 896-2987
Muncie, IN (765) 759-8120

# SUBMERSIBLE PUMP INSTALLATION REPORT

Sales Order No. 17652 Date 9/25/02

Pump Mfg. Grundfos Serial No. 60S30-5 Well No. PW-2A

Owner Reilly Industries, Inc. City Indianapolis State In

Location of Well Front Yard, 100' west of Tibbs Ave 85' north of Main Gate

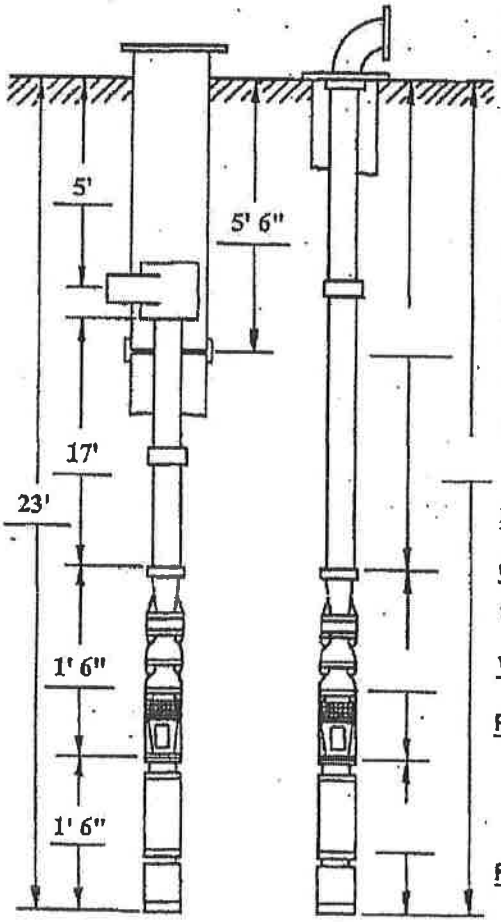
MOTOR: Make Franklin Dia. 4" Frame 3515 Serial No. 2343262604

Hp 3 Volts 460 Phase 3 Cycles 60 RPM

Full Load Amps 4.8 Service Factor 1.15 S.F. Amps 5.5

STARTER: Make Allen-Bradley Size One Type

CONTROL: Make Type Range To lbs.




PUMP DISCHARGE: Mfg. Merrill Model 8"

Flanged Elbow Pitless Adapter X

Pitless Tank Tank Capacity gal.

Discharge Pipe Size 2" Column Conn. Size 3x2"

Adapter Connected to Well Casing 5' 6" below ground with Coupling

COLUMN: Pipe Size s.s. 2" Block Galv.

Column Check Valve Type Flap located in" above bowl

Air Line Length '

Air Intake Valve Type located in pump house below ground.

PUMP BOWL: Type 60S30-5 Dia. 4" Stages

CABLE: Size 12 Length 40'

WELL: No. PW-2 Type Gravel wall Dia. 8" Depth 25'

PUMPING TEST: GPM 37.0 Pumping Level 18.9'

Static Level ' Specific Capacity GPF

PSI 47 Volts 460 Amps: 1 4.2 2 4.2 3 4.5

FOUNDATION: 2' above ground level

REMARKS:

J. Blatz Installer

ENSR

# BORING LOG

Sheet 1 of 2

Project No. 5660-003-012 Date - Start 6/28/90 Finish 6/28/90 Boring RI-17

Project Name REILLY INDUSTRIES SITE Drilling Co. ATEC ASSOC.

Location INDIANAPOLIS, INDIANA Drilling Method 3 3/8 AUGER

Total Depth 44.6' Inspector L. S. EICKHOFF Reviewer L. SCHALCH EICKHOFF

Remarks

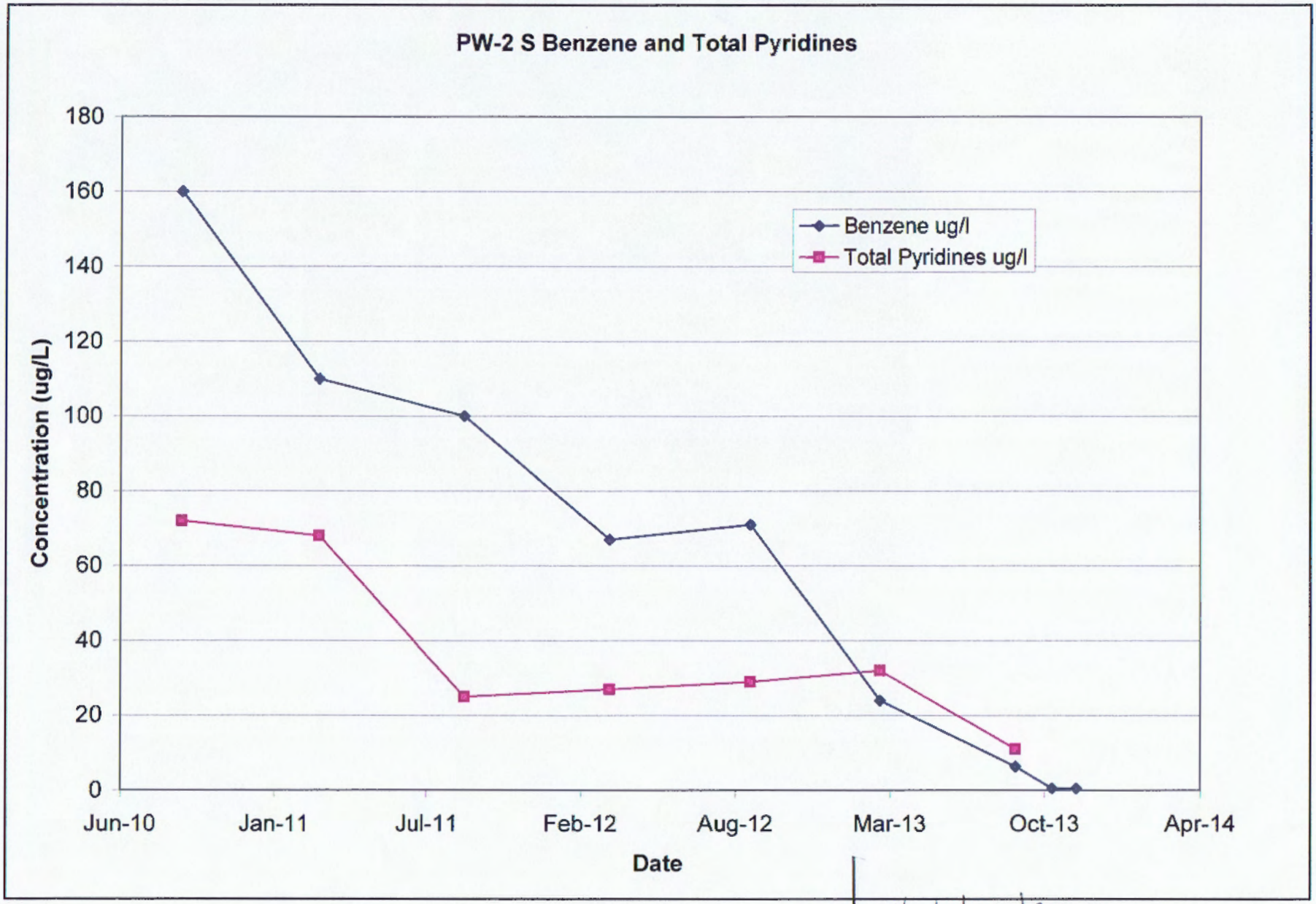
| Depth Feet | Sample Type & No. | Blows per 6 in. | Depth Range | Rec. | HNU Read. | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| 5 | S-1 | 11-12-15 | 3.5-5' | 6" | 0 | Tan VF-M gravel and F-VC sand, tr. silt and C gravel. Fill. | 1.5 |
| 10 | S-2 | 8-8-9 | 8.5-10' | 8" | 0 | Tan-Br. VF-VC sand, some VF-F gravel, tr. M gravel | 0 |
| 15 | S-3 | 10-12-12 | 13.5-15 | 14" | 0 | Tan- L. Br. VF-VC sand and VF-M gravel, tr. silt, dry - moist. Slight odor.(?) | 1 |
| 20 | S-4 | 9-11-13 | 18.5-20' | 15" | 0 | WET SPOON Tan-L. Br. VF-VC sand and VF-M gravel little-tr. silt. slight odor. | 25 |
| 25 | S-5 | 7-7-8 | 23.5-25' | 16" | 1 | Black discoloration - not oily. definite odor at 24.5' | 40 |
| | | | | | | Still discolored - VF-M sand and F-C gravel, little silt. | 70 |
| 30 | S-6 | 23-36-50 | 28.5-30' | 18" | 4 | Tan-grey VF-C gravel, and/some F-VC sand, little silt. Strong odor | |
| 35 | S-7 | 10-13-18 | 33.5-35' | 18" | 0 | Grading tan-grey F-C gravel and VF-M sand, some silt, little clay to F-C sand to tan-grey VF sand, some silt, tr. VF gravel. Slight odor. | 2 |
| | S-8 | 28-36-30 | 38.5-40' | 18" | 0 | Tan-grey-Br. VF-VC sand and VF-C gravel, some-little silt no to slight odor. | 0 |

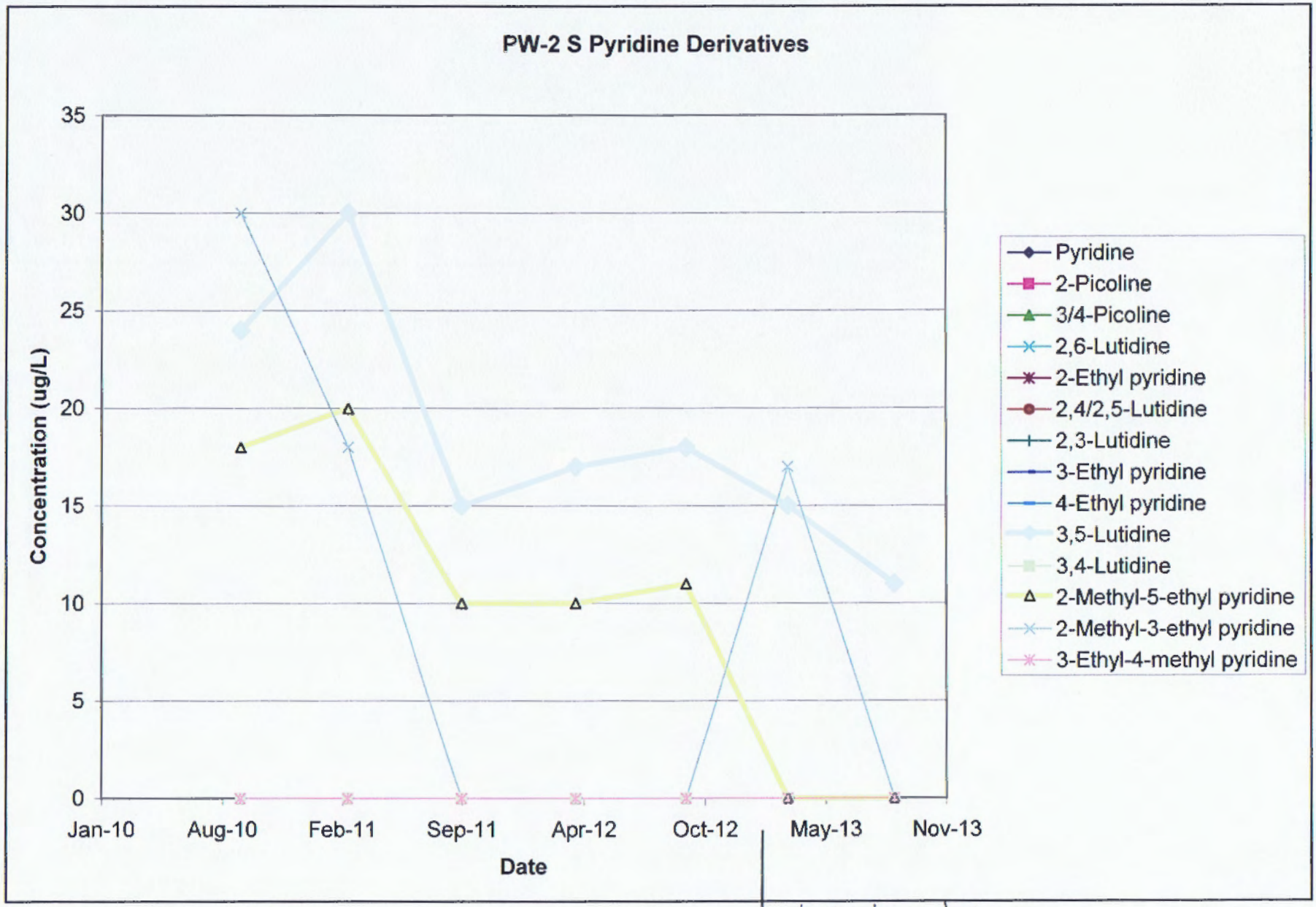
ENSR

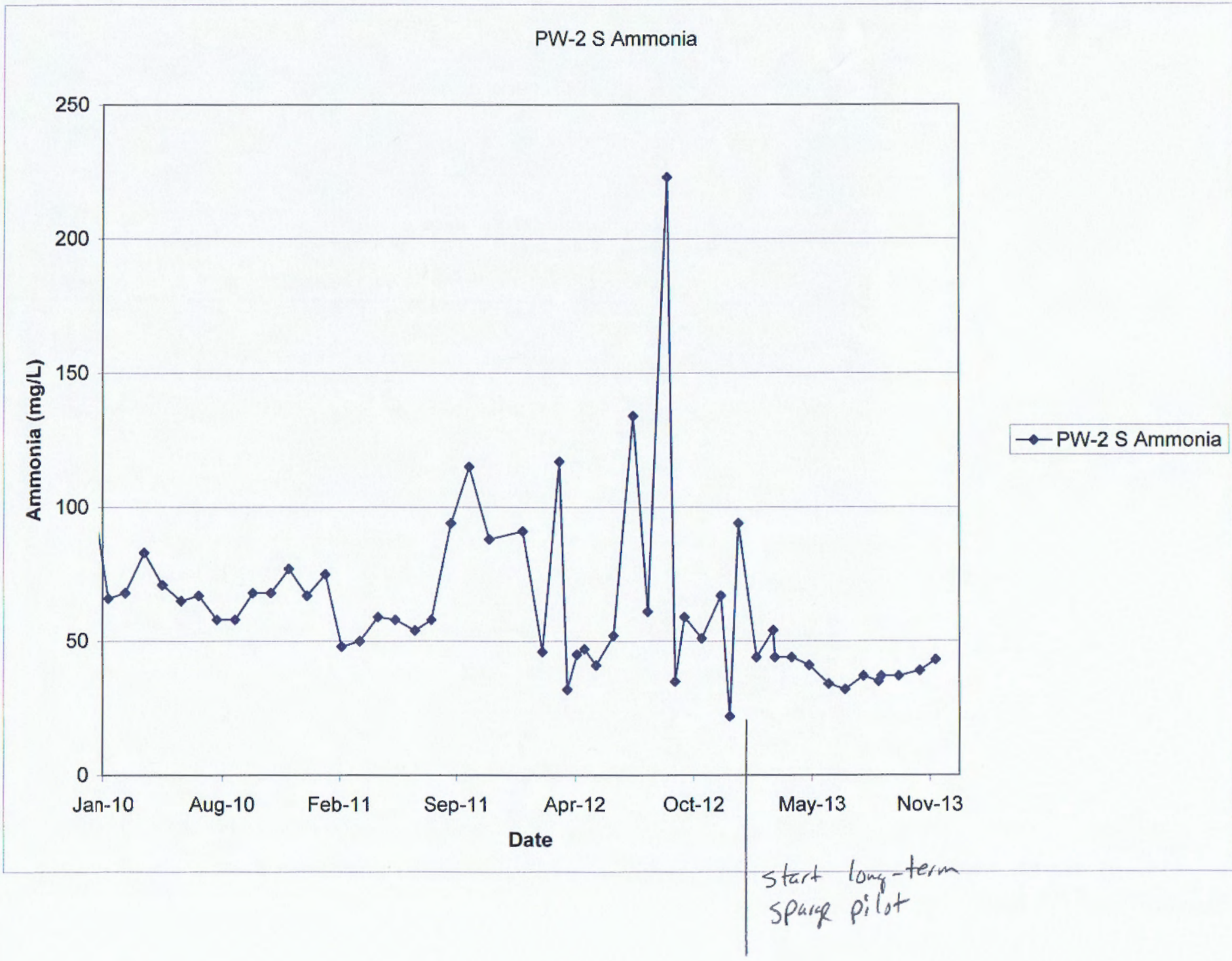
## BORING LOG (continued)

Project REILLY INDUSTRIES Boring RI-17 Sheet 2 of 2

| Depth Feet | Sample Type & No. | Sample Blows per 6 In. | Sample Depth Range | Sample Rec. | HNU reading | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| 45 | S-9 | 35-50-100/.1 | 43.5-44.6 | 16" | 0 | Tan-Br. VF-VC sand and VF-F gravel, little-tr. silt, tr. M gravel. very slight odor. | 0 |
| | | | | | | Bedrock encountered at 44.6' - recovered dk. Br.-black shale, ground to silt texture. | |
| 50 | | | | | | | |
| 55 | | | | | | | |
| 60 | | | | | | | |
| 65 | | | | | | | |
| 70 | | | | | | | |
| 75 | | | | | | | |
| 80 | | | | | | | |


PW-2 S Benzene and Total Pyridines
Concentration (ug/L)
180
160
140
120
100
80
60
40
20
0
Benzene ug/l
Total Pyridines ug/l
Jun-10
Jan-11
Jul-11
Feb-12
Aug-12
Mar-13
Oct-13
Apr-14
Date
Start long-term
Sparge pilot


PW-2 S Pyridine Derivatives
Concentration (ug/L)
35
30
25
20
15
10
5
0
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
Pyridine
2-Picoline
3/4-Picoline
2,6-Lutidine
2-Ethyl pyridine
2,4/2,5-Lutidine
2,3-Lutidine
3-Ethyl pyridine
4-Ethyl pyridine
3,5-Lutidine
3,4-Lutidine
2-Methyl-5-ethyl pyridine
2-Methyl-3-ethyl pyridine
3-Ethyl-4-methyl pyridine
Start long-term
sparge pilot


PW-2 S Ammonia
250
200
150
100
50
0
Ammonia (mg/L)
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
Nov-13
Date
PW-2 S Ammonia
start long-term
sparge pilot

## Recent Plant Testing Data at PW-2

### Benzene

| Date | PW-2 |
|---|---|
| Jun-09 | 240.0 |
| Aug-09 | 2.5 |
| Sep-09 | 260.0 |
| Oct-09 | 150.0 |
| Nov-09 | 200.0 |
| Dec-09 | 200.0 |
| Jan-10 | 5.0 |
| Apr-10 | 200.0 |
| Jun-10 | 210.0 |
| Sep-10 | 160.0 |
| Oct-10 | 170.0 |
| Jan-11 | 130.0 |
| Feb-11 | 110.0 |
| Mar-11 | 110.0 |
| Sep-11 | 100.0 |
| Mar-12 | 67.0 |
| Sep-12 | 71.0 |
| Oct-12 | 73.0 |
| Dec-12 | 50.0 |
| Feb-13 | 0.5 |
| Mar-13 | 24 |
| Apr-13 | 0.5 |
| Jul-13 | 0.5 |
| Aug-13 | 6.3 |
| Oct-13 | 0.5 |
| Nov-13 | 0.5 |

Commenced sparging Jan. 2013

### Ammonia

| Date | PW-2 |
|---|---|
| Jan-09 | 93.0 |
| Feb-09 | 102.0 |
| Mar-09 | 130.0 |
| Apr-09 | 161.0 |
| May-09 | 80.0 |
| Jun-09 | 82.0 |
| Aug-09 | 61.0 |
| Sep-09 | 108.0 |
| Oct-09 | 80.0 |
| Nov-09 | 80.0 |
| Dec-09 | 70.0 |
| Jan-10 | 108 |
| Feb-10 | 66 |
| Mar-10 | 68 |
| Apr-10 | 83 |
| May-10 | 71 |
| Jun-10 | 65 |
| Jul-10 | 67 |
| Aug-10 | 58 |
| Sep-10 | 58 |
| Oct-10 | 68 |
| Nov-10 | 68 |
| Dec-10 | 77 |
| Jan-11 | 67 |
| Feb-11 | 75 |
| Mar-11 | 48 |
| Jan-11 | 67 |
| Feb-11 | 75 |
| Mar-11 | 48 |
| Apr-11 | 50 |
| May-11 | 59 |
| Jun-11 | 58 |
| Jul-11 | 54 |
| Aug-11 | 58 |

| Date | PW-2 (Continued) |
|---|---|
| Sep-11 | 94 |
| Oct-11 | 115 |
| Nov-11 | 88 |
| Jan-12 | 91 |
| Feb-12 | 46 |
| Mar-12 | 117 |
| Mar-12 | 32 |
| Apr-12 | 45 |
| May-12 | 41 |
| Jun-12 | 52 |
| Jul-12 | 134 |
| Aug-12 | 61 |
| Sep-12 | 223 |
| Sep-12 | 35 |
| Oct-12 | 59 |
| Nov-12 | 51 |
| Dec-12 | 67 |
| Dec-12 | 29 |
| Jan-13 | 94 |
| Feb-13 | 44 |
| Mar-13 | 54 |
| Mar-13 | 44 |
| Apr-13 | 44 |
| May-13 | 41 |
| Jun-13 | 34 |
| Jul-13 | 32 |
| Aug-13 | 37 |
| Aug-13 | 35 |
| Sep-13 | 37 |
| Oct-13 | 37 |
| Nov-13 | 39 |
| Dec-13 | 43 |

Commenced sparging Jan. 2013

| Well Name | Sample Date | Benzene ug/l | Total Pyridines ug/l | Ammonia mg/l | Toluene | Ethyl benzene | Xylene-total | Pyridine | 2-Picoline | 3/4-Picoline | 2,6-Lutidine | 2-Ethyl pyridine | 2,4/2,5-Lutidine | 2,3-Lutidine | 3-Ethyl pyridine | 4-Ethyl pyridine | 3,5-Lutidine | 3,4-Lutidine | 2-Methyl-5-ethyl pyridine | 2-Methyl-3-ethyl pyridine | 3-Ethyl-4-methyl pyridine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vertellus PW-2 | | | | | | | | | | | | | | | | | | | | | |
| | Sep-10 | 160.0 | 72 | 58.0 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 0 | 18 | 30 | 0 |
| | Mar-11 | 110.0 | 68 | 48.0 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 20 | 18 | 0 |
| | Sep-11 | 100.0 | 25 | 52.0 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 10 | 0 | 0 |
| | Mar-12 | 67.0 | 27 | 32.0 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 10 | 0 | 0 |
| | Sep-12 | 71.0 | 29 | 35.0 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 11 | 0 | 0 |
| | Mar-13 | 24.0 | 32 | 44.0 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 17 | 0 |
| | Aug-13 | 6.3 | 11 | 35.0 | ND | ND | ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 |

Commenced sparging Jan. 2013

| PW-2 OLD | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| | | | | | | Line Out | Wellhead | | | | | | |
| Date | Time | Compressor psi | line psi | Temp | SCFM | PSI | PSI | Notes | PW-2 S Q | PW-2 S P | PW-2 S WL | PW-2 S DO | PW-2 S T |
| 12/18/2012 | get initial conditions. Install sparge point to 27 ft bg | | | | | | | | 16 | 35 | | 1.05 | 19.1 |
| 1/18/2013 | start up of sparge system | | | | | | | | | | | | |
| 1/18/2013 | 1355 | 72 | 84 | | 16 | 5 | 6 | need temp gauge | 16 | 34 | | 1.95 | 18.7 |
| 1/18/2013 | 1453 | 45 | 52 | | 18 | 4 | 6 | | | | | | |
| 1/18/2013 | 1505 | 50 | 59 | | 17 | 4 | 6 | | | | | | |
| 1/21/2013 | 1440 | 67 | 77 | | 17 | 4 | 6 | | | | | | |
| 1/21/2013 | 1449 | 64 | 72 | | 19 | 4 | 6 | | | | | | |
| 1/21/2013 | 1453 | 61 | 70 | | 18 | 4 | 6 | | | | | | |
| 1/28/2013 | 1035 | 56 | 51 | | 16 | 3 | 4 | no air at well head | | | | | |
| 2/7/2013 | | | | | | | | traced leak in former airline 40 feet from wellhead, sched for repair | | | | | |
| 2/8/2013 | | | | | | | | hand dug to locate existing air line. Cut out bad section. Repaired with glued joint . | | | | | |
| 2/8/2013 | 1013 | 51 | 52 | | 17 | 11 | 13 | | | | | 0.98 | 18.3 |
| 2/8/2013 | 1015 | 57 | 54 | | 16 | 11 | 13 | | | | | | |
| 2/8/2013 | 1020 | 66 | 58 | | 17 | 11 | 13 | | | | | | |
| 2/15/2013 | 1440 | 62 | 70 | | 18 | 15 | 21 | have full flow to PW-2 Old | | | | | |
| 2/21/2013 | 1440 | 45 | 53 | | 18 | 18 | 22 | | | | | | |
| 2/21/2013 | 1453 | 50 | 57 | | 18 | 18 | 22 | | | | | | |
| 2/21/2013 | 1505 | 69 | 74 | | 17 | 19 | 21 | | | | | | |
| 2/25/2013 | 1125 | 110 | 112 | 85 | 9 | 24 | 22 | adjust | | | | | |
| 2/25/2013 | 1132 | 68 | 72 | 98 | 18 | 23 | | | | | | | |
| 2/25/2013 | 1134 | 48 | 52 | 100 | 18 | 19 | | | | | | | |
| 2/25/2013 | 1137 | 44 | 49 | 104 | 19 | 18 | | | | | | | |
| 3/8/2013 | 1200 | 42 | 46 | 110 | 18 | | 18 | | | | | | |
| 3/20/2013 | 1606 | 85 | 68 | 105 | na | | 19 | | | | | | |
| 3/28/2013 | 1403 | 52 | 48 | 108 | na | 18 | 19 | | 13 | 30 | | 0.77 | 18.4 |
| 4/15/2013 | 1205 | | | | | | | off on arrival, bldg very warm, moved on | | | | | |
| 4/12/2013 | 1458 | comp off, thermal tripped, o-ring bad. Leave off to await o-ring | | | | | | | 5 | 38 | water is brown, set at 8 gpm, 38 psi | | |
| 4/22/2013 | 1143 | replaced o-ring and start, comp went to 100 psi, tune | | | | | | | | | | | |
| 4/22/2013 | 1154 | 61 | 65 | 71 | | 19 | | flow meter not working | | | | | |
| 4/22/2013 | 1159 | 58 | 64 | 74 | | 19 | | | | | | | |
| 5/2/2013 | | 65 | 66 | 98 | 15 | 16.5 | 19 | | 19 | 32 | | 1.25 | 18.3 |
| 5/10/2013 | 1415 | 54 | 58 | 119 | 16 | 17 | 19 | | 17 | 29 | | 1.03 | 18.5 |
| 5/21/2013 | 1250 | 84 | 80 | 80 | 15 | 17 | 20 | comp was turned off since 5/18 | | | | | |
| 6/4/2013 | 15:15 | 64 | 59 | 91 | 15 | 19 | 13.5 | | | | | | |
| 6/11/2013 | | 59 | 63 | 110 | 16 | 17.5 | 7 | | 15 | 25 | | 0.95 | 19.4 |
| 6/20/2013 | 14:55 | 64 | 68 | 110 | 15.5 | 18 | 8 | | 15 | 24 | | 0.84 | 20.3 |
| 6/28/2013 | 15:01 | gauge broke | 64 | 121 | 15.5 | 18 | 9 | | | | | | |
| 7/8/2013 | 13:07 | gauge broke | 68 | 111 | 16 | 18.5 | 7.5 | | 14 | 24 | | 0.83 | 21.1 |
| 7/22/2013 | 14:35 | gauge broke | 62 | 108 | 16 | 19 | 7 | | | | | | |
| 7/30/2013 | 14:00 | gauge broke | 64 | 108 | 16 | 18 | 7 | | 14 | 25 | 23.4 | 0.95 | 20.6 |
| 8/9/2013 | 12:35 | gauge broke | | | | | | | 14 | 25 | 23.83 | | |
| 8/19/2013 | 14:20 | gauge broke | 56 | 120 | 15 | | | | 14 | 26 | | | |
| | | | | | | | | | | | | | |
| Note: Sparge operation and measurements performed by K. Might | | | | | | | | | | | | | |

**Attachment F**

**Biosparge Basis of Design**

# Biosparge Basis of Design

**Biosparge Basis of Design.** The basis of design provides design parameters and calculations for the biosparge system.

Summary of Items

The following items are present in the basis of design.

1. Biosparge Treatment Target Zone
2. Biosparge Flow Rate
3. Biosparge Pressure
4. Biosparge Radius of Influence
5. Groundwater Treatment and Biosparge Well Radii of Influence Overlap
6. Sparge Well Spacing
7. Pulsed Biosparge Operation
8. Biosparge Influence Monitoring
9. Ammonia Soil Gas Evaluation
10. Sparge Well Sizing, Depth, and Materials
11. Groundwater monitoring Point Sizing and Locations
12. Vapor Monitoring Point Sizing and Locations
13. Monitoring Well Sizing and Locations
14. Separating Site into Two Systems
15. Compressor Size
16. Conveyance Piping Material and Size
17. Groundwater Monitoring Program
18. Soil Gas Monitoring Program
19. System Optimization Plan
20. Remediation Timeline
21. Air Permitting Maximum Potential to Emit
22. RI-18 Boring Log and Well Construction Details

Attachment – Sparge Flow Rate and Pressure Drop Calculations

## (1) Biosparge Treatment Target Zone

The treatment zone spans generally north-south from the northern property line to the solar farm along Tibbs Ave. The purpose is to meet the Remedial Action Objective (RAO) by treating groundwater on-site within OU1 before it goes off-site into OU5.

- The northern limit extends to the northern property line in response to the presence of benzene above the remedial goal (RG) of 5 µg/L at RI-15M and RI-15D.
- The treatment zone extends between S. Minnesota St. and the northern property line due to the presence of benzene above the RG at RI-4D and pyridines above the RG of 35 µg/L for each pyridine at PW-2S, RI-4S, and RI-4D.
- The treatment zone extends between S. Minnesota St. and approximately 140 feet south of RI-6S due to the presence of benzene above the RG at PW-1D, RI-5S and RI-6S as well as the presence of pyridine above the RG at RI-5S.

The treatment zone also spans in the direction of groundwater flow by the diameter of influence of the sparge wells as well as the distance that the sparge wells overlap which is a minimum of 30 feet to allow sufficient residence time within the area of influence for treatment.

The vertical treatment zone between S. Minnesota St. and the northern property line is the groundwater that extends to the underlying shale bedrock or competent clay. The vertical treatment zone between S. Minnesota St. and approximately 140 feet south of RI-6 is the groundwater that extends to the underlying clay near the north and beneath RI-5S to the south to provide treatment of RI-5S and RI-6S.

(2) Biosparge Flow Rate

The biosparge design flow rate is 7.5 scfm. Pilot testing was successfully applied at lower and higher flow rates. This flow rate was at the lower end of the range tested and provides an abundance of oxygen to the subsurface.

For example: To raise the DO by 4 mg/L in 34,000 cft of groundwater (250,000 gallons) as described in the Pulsed Biosparge Operation section, this results in dissolving 8.3 pounds of oxygen (4 mg/L x 250,000 gal x 3.785 L/gal x 1 g/1000 mg x 1 lb/453.6 g = 8.3 lbs). In general, air consists of 20.9% oxygen and weighs approximately 0.073 lbs/cft at the site. Therefore, 540 cft of air is dissolved in groundwater (8.3 lbs x cft/0.073 lbs x 1/20.9% = 540 cft). This is approximately 5% of the 11,000 cft of air needed to distribute the dissolved oxygen by sparging 7.5 scfm for 24 hours (540 / 11,000 = 5%).

(3) Biosparge Pressure

Sparging pressure was measured during the pilot tests to be a range of 1.2 to 2.1 times the theoretical breakthrough pressure. Sparge flow rates that provided this pressure range were up to 18 standard cubic feet per minute (scfm).

For example, if the saturated thickness = 36 feet, then the breakthrough pressure is 36 feet x 1 psi / 2.31 feet = 15.6 psi. The corresponding range of sparging pressure is 19 to 33 psi.

As a contingency measure, the maximum operating pressure of a sparge well will be up to 3 times the breakthrough pressure while being tested at 15 scfm.

(4) Biosparge Radius of Influence

The radius of influence is based upon pilot testing results plus factors of safety as discussed with EPA.

- Radius of influence: ROI = 1.4 x Saturated thickness from pilot testing results.
- Factor of Safety (FOS) = 1.5 so ROI = 1.4 / 1.5 x saturated thickness = 0.93 x saturated thickness
- If saturated thickness = 36 feet then ROI = 33.5 feet
- As discussed with EPA on July 21, 2016: Use 30 sparge wells instead of calculated 24 sparge wells over the same barrier length. This leads to an additional FOS = 30/24 = 1.25
- Combined FOS = 1.5 x 1.25 = 1.875
- So ROI = saturated thickness x 1.4 / 1.5 / 1.25 = saturated thickness x 0.75
- If saturated thickness = 36 feet, then ROI = 27 feet

(5) Groundwater Treatment and Biosparge Well Radii of Influence Overlap

The half-lives of benzene and pyridines were calculated based upon pilot test results via a first order decay rate ($C = C_0e^{-kt}$).

- Benzene Decay Rate: $C_0$ = 1.4 mg/L, C = 0.10 mg/L, t = 94 days, $k = -\ln(C/C_0)/t$ so k = 0.028/day
- Benzene Half Life: $B_{1/2} = -\ln(C/C_0)/k$ where $C/C_0 = 0.5$, then t = 25 days

- Pyridines Decay Rate: $C_0$ = 2.585 mg/L, C = 0.019 mg/L, t = 367 days, $k = -\ln(C/C_0)/t$ so k = 0.013/day
- Pyridines Half Life: $P_{1/2} = -\ln(C/C_0)/k$ where $C/C_0 = 0.5$, then t = 52 days

Treatment calculations based upon the highest benzene and pyridine concentrations measured in 1Q2020.

<u>Benzene</u>

- 1Q2020 Benzene Concentration = 0.628 mg/L at RI-4D (concentration in 1Q2024 was 0.033 mg/L)
- Benzene Remediation Goal = 0.005 mg/L
- Necessary Half-Life Reductions: $HL = \ln(C_B/B_{RG}) / \ln(2) = \ln(0.628/0.005)/\ln(2) = 7.0$
- Required Treatment Time: $T_T = HL \times B_{1/2} = 7.0 \times 25$ days = 175 days
- Groundwater Velocity = 0.135 ft/day (FFS)
- Benzene Retardation Factor = 1.07 (FFS)
- Groundwater Travel Time for Treatment = 175 days x 0.135 ft/day / 1.07 = 22 ft
- Minimum Radii of Influence Overlap = 22 ft

Pyridines

- 1Q2020 Pyridine Concentration = 0.624 mg/L at RI-4D (concentration in 1Q2024 was 0.065 mg/L)
- Pyridine Remediation Goal = 0.035 mg/L
- Necessary Half-Life Reductions: HL = ln ($C_P/P_{RG}$) / ln(2) = ln(0.624/0.035)/ln(2) = 4.2
- Required Treatment Time: $T_T$ = HL x $P_{1/2}$ = 4.2 x 52 days = 218 days
- Groundwater Velocity = 0.135 ft/day (FFS)
- Pyridine Retardation Factor = 1.36 (FFS)
- Groundwater Travel Time for Treatment = 218 days x 0.135 ft/day / 1.36 = 22 ft
- Minimum Radii of Influence Overlap = 22 ft

Add a factor of safety (FOS) so that a minimum radii of influence overlap = 30 ft.

(6) Sparge Well Spacing

Sparge well spacing is such so that the overlapping radius of influence is at least 30 feet. This can be calculated using the saturated thickness of two sparge wells.

For example: SP-43 with a saturated thickness of 39.7 feet and SP-44 with a saturated thickness of 39.5 feet. The respective radii of influence are calculated by multiplying the saturated thickness by 0.75 and equal 29.8 feet and 29.6 feet, respectively. Then, the well spacing can be calculated using geometry and the Pythagorean theorem:
Well spacing = sqrt ($29.8^2 – 15^2$) + sqrt ($29.6^2 – 15^2$) = 51.3 feet.

(7) Pulsed Biosparge Operation

Biosparging elevates the dissolved oxygen (DO). Once elevated, sparging ceases and the DO decreases as aerobic microbes degrade (consume) hydrocarbons at a relatively fast rate until the dissolved oxygen is depleted at which time the degradation rate is substantially reduced. The pulsed sparge frequency can be determined from short-term pilot test results by measuring the DO increase during sparging and DO decrease after sparging ceases.

During a pilot test in the VP plant area when benzene was 1,400 µg/L (much higher than currently measured near Tibbs Ave), a sparge rate of 10 scfm was applied to a saturated thickness of 12 feet over 5.3 hours and elevated the DO from 0.27 mg/L to 5.6 mg/L with an estimated 30 foot radius of influence. After 24 hours the DO returned to near the pre-testing level. The cylinder of groundwater volume impacted with an average porosity of 30% = π (30 ft)$^2$ (12 ft) (30%) = 10,000 cft. The amount of air sparged = 10 scfm x 60 min/hr x 5.3 hrs = 3,200 cft. This resulted in an air/water ratio of 0.32. This ratio was used to calculate how much air will be needed to raise the DO for sparge wells with other depths and radii of influence.

For example: Using two significant figures. SP-43 with a saturated thickness of 40 feet. The radius of influence is 0.75 x 40 feet = 30 feet. The volume of groundwater = π (30 ft)$^2$ (40 ft) (30%) = 34,000 cft. An air/water ratio of 0.32 x 34,000 cft = 11,000 cft of air to sparge. At a sparge rate of 7.5 scfm this will take 24 hours. A 1.3 factor of safety was added to arrive at 31 hrs. Then sparging will cease for 24 hours before repeating the pulse cycle.

For weekly operational programming, sparge well operation has been allocated generally into 8 hour blocks each day. Therefore, SP-43 will operate for 4 x 8 hour sequential blocks = 32 hours. In instances when full 8 hours is not needed, then 8 hour blocks may operate for 2 or 4 hours.

The pulse operation of adjacent sparge wells was varied so not to be on the same schedule. By pulsing at different frequencies in neighboring sparge wells then the potential for preferential air channeling through the saturated zone will be minimized.

Long-term pilot testing of pulsed biosparging occurred in the VP plant area and former treatment pit. Pulsed sparging at RI-18D further reduced benzene in RI-18S to non-detect in the VP plant. Pulsed sparging at SP-32 further reduced pyridines in RI-32 to non-detect in the former treatment pit.

(8) Biosparge Influence Monitoring

Dissolved concentrations of benzene and pyridines are the main criteria for making any adjustments to the biosparge system. Groundwater monitoring of these parameters will be accomplished as described within the Remedial Action Work Plan, including the Site Wide Monitoring Plan and Field Sampling Plan. Since it takes time to receive laboratory analytical results, there is no short-term feedback to provide an indication of how successfully system adjustments have impacted the groundwater. DO can be measured as a substitute to provide short-term feedback until dissolved concentrations of benzene and pyridines are reported.

Pilot testing that elevated DO ≥2 mg/L resulted in the degradation of benzene and pyridines which led to the calculated half-lives used in the degradation calculations. This is reflective of aerobic conditions and oxygen will be the preferred electron acceptor. While it is acknowledged that degradation can occur at DO <2 mg/L, the rate is slower and not preferred as evidenced by prolonged elevated benzene and pyridine concentrations measured prior to sparging. Therefore, the sparging target is DO ≥2 mg/L. It is possible that groundwater sampling data may indicate that sufficient degradation is occurring at <2 mg/L to cease groundwater pumping and achieve the RAOs with sparging. If this occurs, then this will be documented and presented in routine quarterly reports.

Dissolved oxygen monitoring will be performed at monitoring points and monitoring wells within the anticipated sparge well radius of influence. If DO results are lower (<2 mg/L) while sparging, then this will indicate that sparging needs to increase either by extending the sparge duration, increasing the flow rate, altering the pulse cycle, and/or adding sparge wells. If DO results remain elevated while sparging is not occurring and near the end of the off-period, then this will indicate that sparging does not need to resume so soon and the period of not sparging may be increased until DO results decline to <2 mg/L.

DO monitoring will also be performed as part of the groundwater monitoring plan to determine if sparging adjustments are effective.

(9) Ammonia Soil Gas Evaluation

Biosparge pilot test data collected from testing near RI-5S has been used to calculate an ammonia concentration in soil gas. The pilot test was completed between February 2013 and September 2014. The following table identifies groundwater concentrations and calculates the dissolved ammonia concentration decrease to be 0.33 mg/L per month.

| Month | RI-5S Groundwater Concentrations | | |
|---|---|---|---|
| | Benzene (µg/L) | Pyridines (µg/L) | Ammonia (mg/L) |
| Sep 2011 | 350 | 168 | 16 |
| Mar 2012 | 350 | 294 | 32 |
| Jun 2012 | 350 | 241 | 14 |
| Sep 2012 | 330 | 307 | 14 |
| Feb 2013 (Start Sparging) | Not Sampled | | |
| Mar 2013 | 370 | 323 | 15 |
| Aug 2013 | 350 | 120 | 16 |
| Mar 2014 | 170 | 151 | 11 |
| Sep 2014 (Stop Sparging) | 86 | 140 | 11 |
| Mar 2015 | 18.6 | 54 | 12 |
| Sep 2015 | 51 | 75 | 10 |
| Mar 2016 | 31 | 67 | 9 |
| Sep 2016 | 19 | 23 | 9 |
| Mar 2024 | 12.5 | 34 | 8 |

Sparge Well ID = SP
Sparge Well Depth = 57 ft
Depth to Water = 24 ft
Saturated Thickness = 33 ft

Radius of Influence = 33 ft x 0.75 = 24.75 ft
Porosity = 25%
Effective Porosity = 18%

Monitoring Well ID = RI-5S
Ammonia concentration decrease =
(15 mg/L – 11 mg/L) / 12 months = 0.33 mg/L per month

Biosparging flow rate = 15-17 scfm

Groundwater Volume within Radius of Influence = $\pi (24.75)^2$ x 33 ft x 7.48 gal/cft x 25% = 119,000 gallons

Ammonia mass removed = 0.33 mg/L (lb / 453,600 mg) (3.785 L/gal) (119,000 gal) = 0.33 lbs / month

Sparge Flow Rate = 16 scfm x 1440 min/day x 30 day/mo = 690,000 scft / month

Ammonia soil gas concentration = 0.33 lbs x 453,600 mg/lb x 35.3 cft/$m^3$ / 690,000 cft = 7.7 mg/$m^3$
Note: This is the maximum ammonia soil gas concentration and assumes 100% volatilization. It assumes there is no aerobic biodegradation nor a general decreasing trend in ammonia concentration.

Soil Gas Residential Screening Level = 20,000 µg/$m^3$ = 20 mg/$m^3$

Factor of Safety = 20 / 7.7 = 2.6

(10) Sparge Well Sizing, Depth, and Materials

Sparge wells will be constructed of 2-inch diameter PVC equipped with 3 feet of 0.010-inch slotted screen at the bottom. These wells will be installed to a maximum depth of approximately 68 feet below ground surface (bgs) using sonic boring techniques. The subsurface geology is the basis for the sparge well depths as indicated on the Remedial Design Drawings included as Appendix A to the Remedial Action Work Plan; sparge wells extend to a lower permeability layer.

Pilot testing demonstrated that sparging within and beneath the finer grained sediments at RI-18D, screened 52.5 to 57.5 ft bgs in the deep aquifer, influenced shallow wells (<30 ft bgs) in the sand. Attached is the RI-18 boring log.

The 2-inch diameter wells will allow conventional equipment to develop the wells following installation and to provide access to the well screens in the future, if needed. Three feet of screen are used in the event that two feet become obstructed following well development from the infiltration of fine-grained material. This is not anticipated and is a contingency measure.

Following the testing of each sparge well to confirm it operates properly and pressure testing to confirm there are no leaks between the sparge equipment and the sparge well, then the sparge well will be buried. This is to prevent interferences to vehicular traffic, snow plows, mowing, and unauthorized access to pressurized lines that are beyond the site perimeter fence. The location of each sparge well will be surveyed and covered with a steel plate buried 6 inches below the ground surface so that they can be readily located in the future, if needed. The location of each spare pipe to each sparge well will also be buried and marked in the same manner.

(11) Groundwater monitoring Point Sizing and Locations

Groundwater monitoring points will be constructed in OU1 of 2-inch PVC and equipped with 10 feet of 0.010-inch slotted screen. This is a standard well construction and existing monitoring wells in OU1 are constructed of 2-inch PVC. These wells will be installed using sonic coring techniques for maximum core recovery and proper positioning as shallow and deep wells to monitor the sparge influence with depth.

Shallow (25-30 feet below ground surface, ft bgs) and deep (51-60 ft bgs) monitoring points will be installed near each other in pairs. Some of these monitoring points will be installed within the biosparge radius of influence to document the rise in dissolved oxygen and decrease in benzene and pyridines to confirm design calculations. This data will be used to document the cessation of pumping and that RAOs will be met. Other points will be located downgradient of the sparge wells near Tibbs Ave. to document treatment near the eastern limit of OU1.

In addition, temporary groundwater monitoring points will be constructed in OU1 in the same manner as permanent points. Temporary monitoring points will be installed upgradient of RI-4 which has historically been the most impacted monitoring well near the sparge barrier. The temporary points are closely spaced and screened in shallow and deep intervals to demonstrate treatment in this area. Once demonstrated, then the temporary points will be removed.

Groundwater monitoring points and temporary groundwater monitoring points will be installed in flush mount protective road boxes encased in a concrete apron to not obstruct vehicular traffic and landscaping. All points will be located on-site.

(12) Vapor Monitoring Point Sizing and Locations

Vapor monitoring points (VMPs) will be constructed in OU1 of 6-inch long, ½ inch diameter, stainless steel screen. This is a typical construction for a VMP. Two VMPs will be installed within the same borehole. The deep VMP will be positioned two feet above the highest groundwater level measured since 2011. This results in depths ranging from 13 to 15.5 ft bgs. The shallow VMP will be separated from the deep VMP by at least 5 feet of bentonite. The shallow VMP will be set a depths ranging from 6.5 to 8 ft bgs. Both of these depths qualify as deep soil gas since they are >5 ft bgs. Sampling results will be compared to deep soil gas screening levels that are identified in the Remedial Action Work Plan.

The screens will be connected to ¼-inch ID Teflon® tubing that will be extended 24 inches above grade, labeled, plugged, and coiled in a flush mount road box encased in a concrete apron to not obstruct vehicular traffic and landscaping. All points will be located on-site. Efforts will be made to keep points at least 10 feet away from underground utilities to minimize impact that utility backfill may have on the results.

(13) Monitoring Well Sizing and Locations

Monitoring wells will be constructed in OU5 of 2-inch PVC and equipped with 10 feet of 0.010-inch slotted screen. This is a standard well construction and existing monitoring wells in OU5 are constructed of 2-inch PVC. These wells will be installed using sonic coring techniques for maximum core recovery and proper positioning as shallow and deep wells to monitor the sparge influence with depth.

Shallow (30-35 ft bgs), mid-depth (60-65 ft bgs), and deep (90 ft bgs) monitoring wells (+/- 5 ft) will be installed near each other in triplets to monitor the OU5 shallow, mid-depth, and deep aquifers. The purpose of one of the well triplets is to replace RI-42S and RI-42D that were destroyed during a road construction project and to fill data gaps at other locations.

Monitoring wells will be installed in flush mount protective road boxes encased in a concrete apron and located in the right of way (ROW) for future access.

(14) Separating Site into Two Systems

The biosparge system was separated into two on-site systems: 1) Oak Park (north) property that will include 38 sparge wells, and 2) Maywood (south) property that will include 35 sparge wells. This resulted from underground and overhead utilities that are present along S. Minnesota St. and its right of ways (ROWs). Such underground utilities include a 20-inch diameter gas line, 6-inch diameter gas line, 16-inch water line, and buried communications lines. There is also a high power overhead line. By keeping both biosparge system on-site, health and safety risks associate with working around these lines are avoided as are other potential issues associated with off-site access and permitting.

(15) Compressor Size

Two rotary screw air compressors are planned for each biosparge system. The maximum pulsed sparge air demands for the Oak Park property and the Maywood property are 157.5 and 150 scfm, respectively. This amounts to 171 and 163 cfm FAD, respectively. One 40 horsepower (Hp) rotary screw air compressor can provide 184 cfm FAD. Therefore, under design conditions, one compressor will be able to satisfy the compressed air demands of the biosparge system. Operational duty will be split between the compressors to extend their life.

However, should contingency plans be enacted that result in increased sparging (flow rates, pulse frequencies, and/or additional sparge wells), then the second compressor can be utilized for this purpose. In addition, due to the shallower depth of compressed air lines, a heatless desiccant dryer will be utilized in winter months to prevent freezing. The dryer requires additional compressed air to operate which will require the second compressor.

Two compressors provide more flexibility and energy efficiency to operate the biosparge system more than one larger compressor. The combined operation of both compressors provides sufficient compressed air to operate the biosparge systems as designed in a pulsed manner with an additional capacity of approximately 75% that may be used, for example, to

accommodate pulsed operation of six additional sparge wells at 7.5 scfm plus 21 wells sparged at 15 scfm (rather than 7.5 scfm).

(16) Conveyance Piping Material and Size

As illustrated on drawings, each compressor discharges to its own receiver tank before the compressed air combines. Combined air flows through a solenoid valve, coalescing filter, desiccant dryer, particulate filter, flowmeter, and regulator with bypass piping around filters and the dryer for servicing. Compressed air is then distributed to individual flow control piping spools consisting of a flowmeter, solenoid valve, and regulator before flowing underground to the sparge well. Pressure gauges are located throughout the piping system. Remedial design drawings depict the piping and instrumentation.

Compressed air flows through galvanized steel piping, brass or bronze valves, instrumentation, and rubber hose rated for anticipated operating pressures and temperatures. All piping is visible above ground. Buried piping will consist of ½-inch DR11 IPS HDPE tubing.

Pressure drop calculations have been performed using the maximum amount of air for each pipe segment. Piping between each compressor, receiver tank, and the junction from the other compressor is 1.25-inch diameter for a maximum of 184 cfm FAD. Piping with a maximum of 368 cfm FAD is 2-inch in diameter until it splits to each individual sparge well. Piping with a maximum of 16.3 cfm FAD (15 scfm) for each sparge wells is 1/2-inch diameter until it reaches the 2-inch sparge well. The longest buried HDPE tubing run is approximately 1,000 feet.

A compressor pressure of 125 psig results in a pressure at the sparge well of 72.4 psig. As previously described, the maximum breakthrough pressure is three times the saturated thickness. With the shallowest groundwater depth of 15 feet and sparge well depth of 60 feet, this provides 45 feet of water column resulting in maximum breakthrough pressure of 58.4 psig (45 ft / 2.31 ft/psi x 3 = 58.4 psig). There will be 14 psig surplus (72.4 psig – 58.4 psig = 14 psig) at the sparge well. Pressure drop calculations are attached.

(17) Groundwater Monitoring Program

The purpose of the groundwater monitoring program is to demonstrate that sparging is effective in treating groundwater so that groundwater pumping can cease. In addition, the purpose is to document that the RAOs are achieved. Groundwater monitoring for dissolved oxygen, benzene, pyridine, and ammonia within the anticipated biosparge radius of influence is planned more frequently during the start of the sparge system. As data is collected from groundwater monitoring events, then the frequency of groundwater monitoring is reduced. Groundwater monitoring is scheduled to be performed up to seven times following system startup so that the degradation rates of benzene and pyridines can be measured to compare against design calculations and confirm that the RAOs will be achieved so that pumping can cease. This is further described in the Cessation of Groundwater Pumping section of the Remedial Action Work Plan. If the groundwater RAOs will not be achieved, then the groundwater monitoring contingency plan will be enacted.

(18) Soil Gas Monitoring Program

The purpose of the soil gas monitoring program is to determine if benzene or ammonia is present in soil gas above applicable screening levels. Soil gas monitoring is planned more frequently during the start of the sparge system. As data is accumulated from soil gas monitoring events, then the frequency of soil gas monitoring is reduced. The soil gas monitoring schedule is included in the Site-Wide Monitoring Plan. So long as soil gas concentrations are below applicable screening levels, then monitoring will progress as scheduled. If soil gas concentrations exceed applicable screening levels, then the soil gas monitoring contingency plan will be enacted.

(19) System Optimization Plan

The remediation system will be operated to achieve the RAOs. This will include sparging wells at 7.5 scfm in a pulsed manner and measuring the groundwater concentrations of benzene and pyridines in surrounding wells. In addition, DO levels will also be monitored at nearby monitoring points to provide short-term feedback in between groundwater sampling periods and while awaiting groundwater sampling results. Routine maintenance of the compressed air system will be performed to

ensure proper operation and high uptime. Remote monitoring of the system will be performed to document continued operation. If alarm conditions occur then personnel will be notified so that a prompt response can be made to address the alarm condition. System operational data will be documented in quarterly reports that will also include groundwater and soil gas sampling results. If groundwater or soil gas sampling do not indicate that the RAOs are being achieved, then groundwater or soil gas contingency measures will be enacted, respectively.

(20) Remediation Timeline

The remediation timeline has not been determined. The remediation system will operate to achieve the RAOs until upgradient groundwater is no longer impacted by benzene and pyridines above the RGs (no other compounds have been determined to be present above their RGs). Once it has been demonstrated that upgradient benzene and pyridine are no longer present above the RGs and that the RAOs will continue to be achieved, then operation of the biosparge system, or segments of the biosparge system, may cease; as approved by the USEPA.

(21) Air Permitting Maximum Potential to Emit

Calculate the maximum emissions from the biosparge barrier assuming a worse case of 100% volatilization of benzene (no biodegradation). In fact, biodegradation was measured to occur during pilot testing.

Given

- Saturated thickness = 40 feet
- Biosparge barrier length = 2,750 feet
- Groundwater velocity = 0.169 ft/day (maximum measured at RI-6 in shallow aquifer)
- Retardation factor = 1.07
- Soil porosity = 30%
- 1Q2020 Benzene Concentration = 0.628 mg/L (assumed the entire barrier as a worse case) (concentration in 1Q2024 was 0.033 mg/L)

Calculate Mass Flux of Benzene through the Barrier

- Mass = 0.628 mg/L x lb/453,600 mg x 28.3 L/cu.ft. x 40 ft x 2,750 ft x 0.169 ft/day x 30% / 1.07 = 0.21 lbs/day

IDEM Emissions Comparison

- IDEM Exemption Limit = 1 ton/year of a single HAP (326 IAC 2-1.1-3 (e)(1)(G)) x 2000 lbs/ton x year/365 days = 5.48 lbs/day
- Minimum Factor of Safety = 5.48 / 0.21 = 26

Therefore, no air discharge permitting is needed.

(22) RI-18 Boring Log and Well Construction Details

**ENSR**

## BORING LOG

Sheet 1 of 3

Project No. 5660-003-012 Date - Start 6/22/90 Finish 6/23/90 Boring BI-18

Project Name REILLY INDUSTRIES SITE Drilling Co. ATEC ASSOC.

Location INDIANAPOLIS , INDIANA Drilling Method 3 3/8 AUGER

Total Depth 94.6' Inspector L. S. EICKHOFF Reviewer L. SCHALCH EICKHOFF

Remarks

| Depth Feet | Sample Type & No. | Blows per 6 In. | Depth Range | Rec. | HNU Read. | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| 5 | S-1 | 2-1-6 | 3.5-5' | 8" | 0 | M Br. VF-C sand, some VF-F gravel, tr. silt. no odor. Dry Fill. | 0 |
| 10 | S-2 | 12-13-21 | 8.5-10' | 7" | 0 | Tan-Br. VF-M gravel and VF-VC sand, tr. C gravel (rounded). Fill | .4 |
| 15 | S-3 | 6-11-11 | 13.5-15' | 10" | 0 | M. Br. VF-C sand, some VF-F gravel, tr. silt. Fill. No odor. | .8 |
| 20 | S-4 | 12-13-21 | 18.5-20' | 8" | 0 | Moist, M-Light Br. -Tan F-M sand, little F-M gravel, little-tr. C. gravel. No odor | 65 |
| 25 | S-5 | 11-12-13 | 23.5-25' | 8" | 0 | WET SPOON , Dk. grey-Br. VF-F gravel and M-VC sand, tr. M-C gravel, little-tr. silt. Strong odor. | 60 |
| 30 | S-6 | 10-11-9 | 28.5-30' | 14" | 0 | Dk. grey-Br. VF-M gravel and VF-VC sand, some-little silt. Strong odor. | 40 |
| 35 | S-7 | 16-23-32 | 33.5-35' | 18" | 0 | Dense Br.-grey clay, tr. VC sand-VF gravel. No odor | 0 |
| | S-8 | 38-95-50/1" | 38.5-39.5' | 13" | 0 | Tan-grey VF sand, tr. silt. | 0 |

**BORING LOG** (continued)

ENSR Project REILLY INDUSTRIES Boring RI-18 Sheet 2 of 3

| Depth Feet | Sample Type & No. | Blows per 6 In. | Depth Range | Rec. | HNU reading | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 45 | S-9 | 16-22-38 | 43.5-45' | 18" | | dense gray-BR. clay, little VC sand-F gravel, little VF sand, little silt (till) | 1.5 |
| 50 | S-10 | 14-21-38 | 48.5-50' | 18" | | | |
| 55 | S-11 | 13-15-28 | 53.5-55' | 14" | | DR. brown silt, some-little clay-less than till above-reworked-lacustrine? | 0 |
| | | | | | | tan-gray VC sand-VF gravel, some F-C sand, little-tr. silt | |
| 60 | S-12 | 16-28-76 | 58.5-60' | | | tan-gray silt, some-little clay | 0 |
| 65 | S-13 | 7-21-30 | 63.5-65' | 14" | | tan M-brown silt, some little clay, tr. VF sand tr. organic matter | |
| 70 | S-14 | 10-13-28 | 68.5-70' | 18" | | DR. brown silt and clay-moist, silty clay as above | |
| 75 | S-15 | 10-14-19 | 73.5-75' | 18" | | DR. brown-gray clay | |
| 80 | S-16 | 6-8-18 | 78.5-80' | 18" | | clay and some silt, little VF sand | |
| 85 | S-17 | 13-15-27 | 83.5-85' | 18" | | DR. brown-gray silt and some clay, some-little VF sand | |
| | S-18 | 21-24-80 | 88.5-90' | | | M-Dr. brown clay, some silt-color banding<br>M Br VF-C sand and VF-M gravel, tr. M gravel, little silt/clay | |

**BORING LOG** (continued)

ENSR Project REILLY INDUSTRIES Boring RI-18 Sheet 3 of 3

| Depth Feet | Sample Type & No. | Sample Blows per 6 In. | Sample Depth Range | Sample Rec. | HNU reading | Lithologic Description | HEAD SPACE |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | M-Dr. Br. VF-M gravel and F-C sand, some clay, some -little silt | |
| 95 | S--19 | 60-103-100/1 | 93.5-95' | 13" | | | |
| | | | | | | SHALE AT END OF SPOON<br>BEDROCK REFUSAL=94.6' | |
| 100 | | | | | | | |
| 105 | | | | | | | |
| 110 | | | | | | | |
| 115 | | | | | | | |
| 120 | | | | | | | |
| 125 | | | | | | | |
| 130 | | | | | | | |
| 135 | | | | | | | |

Project No: 5660-003-012 Client: REILLY IND. Site: INDIANAPOLIS

WELL No: RI-18S

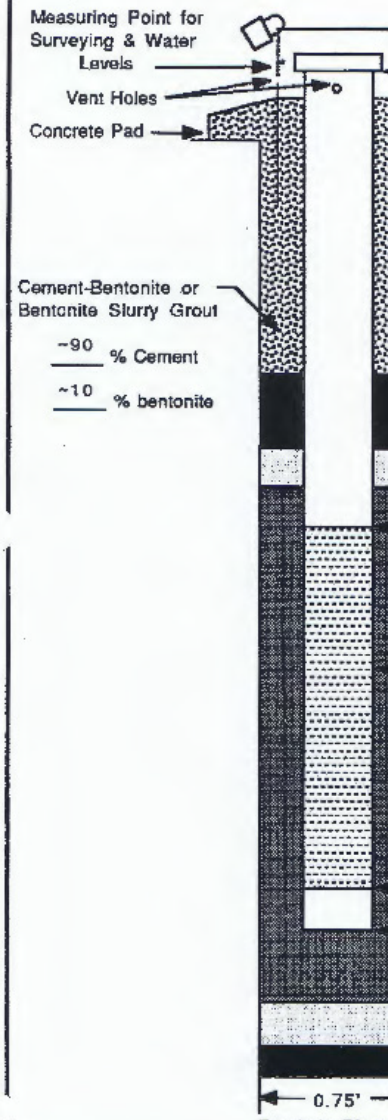
Well Location: REILLY INDUSTRIES-NORTH OF MINNESOTA STREET

Date Installed 6/23/90

Contractor: ATEC ASSOCIATES Method: 3 3/8 HSA

Inspector: L SCHALCH

## MONITORING WELL CONSTRUCTION DETAIL




| | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|
| Top of Steel Guard Pipe | 2.17 | 706.18 |
| Top of Riser Pipe | 1.97 | 705.98 |
| Ground Surface | 0.0 | 704.01 |
| Bottom of Steel Guard Pipe | 2.83 | 701.18 |
| Riser Pipe: Length 16.5; Inside Diameter 2"; Type of Material PVC | | |
| Top of Bentonite Slurry Seal | 9.5 | 694.5 |
| Top of Fine Sand | 11.5 | 692.5 |
| Top of Sand Pack | 12.5 | 691.5 |
| Top of Screen | 14.5 | 689.5 |
| Screen: Length 10'; Inside Diameter 2"; Slot size 0.010; Type of Material PVC | | |
| Type/Size of Sand: #5 QUARTZ | | |
| Bottom of Screen | 24.5 | 679.5 |
| Bottom of Tail Pipe: Length 0.46 | 25.0 | 679.0 |
| Bottom of Borehole | 25.0 | 679.0 |

* Describe Measuring Point:
Mark on riser pipe

Signature Date

ENSR

Project No: 5660-003-012 Client: REILLY IND. Site: INDIANAPOLIS

WELL No: RI-18D

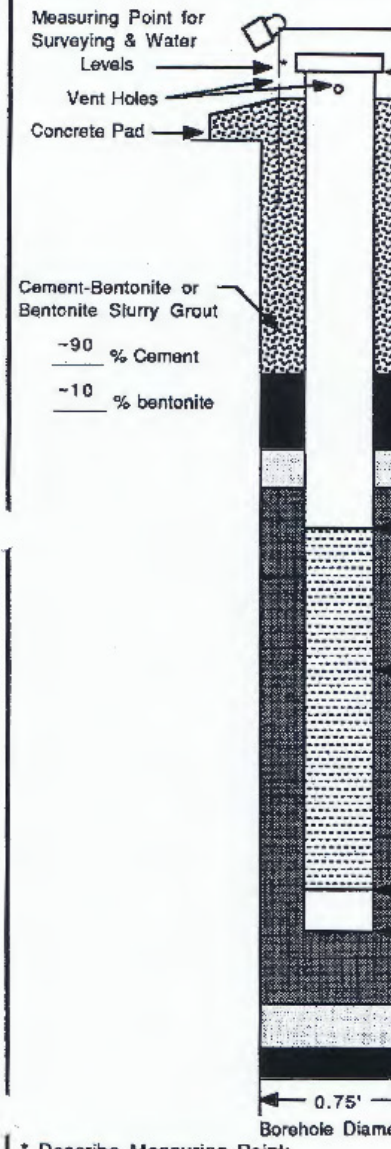
Well Location: REILLY INDUSTRIES-NORTH OF MINNESOTA STREET

Date Installed 6/25/90

Contractor: ATEC ASSOCIATES Method: 3 3/8 HSA

Inspector: L SCHALCH

## MONITORING WELL CONSTRUCTION DETAIL




| | Depth from G.S. (feet) | Elevation (NGVD) |
|---|---|---|
| Top of Steel Guard Pipe | 2.75 | 706.64 |
| Top of Riser Pipe | 2.55 | 706.44 |
| Ground Surface | 0.0 | 703.89 |
| Bottom of Steel Guard Pipe | 2.25 | 701.64 |
| Riser Pipe: Length 55.1; Inside Diameter 2"; Type of Material PVC | | |
| Top of Bentonite Slurry Seal | 47.5 | 656.4 |
| Top of Fine Sand | 49.5 | 654.4 |
| Top of Sand Pack | 50.5 | 653.4 |
| Top of Screen | 52.5 | 651.4 |
| Screen: Length 5'; Inside Diameter 2"; Slot size 0.010; Type of Material PVC | | |
| Type/Size of Sand: #5 QUARTZ | | |
| Bottom of Screen | 57.5 | 646.4 |
| Bottom of Tail Pipe: Length 0.46 | 58.0 | 645.9 |
| Bottom of Borehole | 58.0 | 645.9 |

* Describe Measuring Point:
Mark on riser pipe

Signature Date

ENSR

## Sparge Flow Rate and Pressure Drop Calculations

# Table 1 - Barrier Biosparge Well Construction Schedule

1500 South Tibbs LLC

May 16, 2025

| Sparge Well | Well Spacing (feet) | Total Distance (feet) | GW Elevation (ft ASL) | Bottom of Screen (ft ASL) | Saturated Thickness (feet) | Radius of Influence (feet) | Min. Depth to Bottom (ft BGS) |
|---|---|---|---|---|---|---|---|
| OU1 North of Minnesota Avenue (Oak Park Property) | | | | | | | |
| SP- 1 | 0 | 0 | 683.60 | 644.00 | 39.60 | 29.57 | 56 |
| SP- 2 | 41.4 | 41.4 | 683.56 | 644.00 | 39.56 | 29.53 | 56 |
| SP- 3 | 41.3 | 82.7 | 683.51 | 644.00 | 39.51 | 29.50 | 56 |
| SP- 4 | 41.3 | 124.0 | 683.47 | 644.00 | 39.47 | 29.47 | 56 |
| SP- 5 | 41.3 | 165.3 | 683.42 | 645.20 | 38.22 | 28.54 | 55 |
| SP- 6 | 40.0 | 205.3 | 683.38 | 646.40 | 36.98 | 27.61 | 54 |
| SP- 7 | 38.7 | 243.9 | 683.33 | 647.60 | 35.73 | 26.68 | 52 |
| SP- 8 | 37.4 | 281.3 | 683.29 | 648.80 | 34.49 | 25.75 | 51 |
| SP- 9 | 36.1 | 317.3 | 683.25 | 650.00 | 33.25 | 24.82 | 50 |
| SP- 10 | 34.8 | 352.1 | 683.20 | 651.20 | 32.00 | 23.89 | 49 |
| SP- 11 | 33.5 | 385.5 | 683.16 | 652.40 | 30.76 | 22.97 | 48 |
| SP- 12 | 32.2 | 417.7 | 683.11 | 653.60 | 29.51 | 22.04 | 46 |
| SP- 13 | 30.9 | 448.5 | 683.07 | 654.80 | 28.27 | 21.11 | 45 |
| SP- 14 | 29.6 | 478.1 | 683.02 | 656.00 | 27.02 | 20.18 | 44 |
| SP- 15 | 28.2 | 506.3 | 682.98 | 655.33 | 27.65 | 20.64 | 45 |
| SP- 16 | 28.9 | 535.2 | 682.94 | 654.67 | 28.27 | 21.11 | 45 |
| SP- 17 | 29.6 | 564.8 | 682.89 | 654.00 | 28.89 | 21.57 | 46 |
| SP- 18 | 30.2 | 595.0 | 682.85 | 653.33 | 29.51 | 22.04 | 47 |
| SP- 19 | 30.9 | 625.8 | 682.80 | 652.67 | 30.14 | 22.50 | 47 |
| SP- 20 | 31.5 | 657.3 | 682.76 | 652.00 | 30.76 | 22.97 | 48 |
| SP- 21 | 32.2 | 689.5 | 682.71 | 651.50 | 31.21 | 23.31 | 49 |
| SP- 22 | 32.6 | 722.1 | 682.67 | 651.00 | 31.67 | 23.65 | 49 |
| SP- 23 | 33.1 | 755.2 | 682.63 | 650.50 | 32.13 | 23.99 | 50 |
| SP- 24 | 33.6 | 788.8 | 682.58 | 650.00 | 32.58 | 24.33 | 50 |
| SP- 25 | 34.1 | 822.9 | 682.54 | 649.50 | 33.04 | 24.67 | 51 |
| SP- 26 | 34.5 | 857.4 | 682.49 | 649.00 | 33.49 | 25.01 | 51 |
| SP- 27 | 35.0 | 892.4 | 682.45 | 648.50 | 33.95 | 25.35 | 52 |
| SP- 28 | 35.5 | 927.9 | 682.40 | 648.00 | 34.40 | 25.69 | 52 |
| SP- 29 | 36.0 | 963.9 | 682.36 | 647.50 | 34.86 | 26.03 | 53 |
| SP- 30 | 36.4 | 1000.3 | 682.32 | 647.00 | 35.32 | 26.37 | 53 |
| SP- 31 | 36.9 | 1037.2 | 682.27 | 646.50 | 35.77 | 26.71 | 54 |
| SP- 32 | 37.4 | 1074.6 | 682.23 | 646.00 | 36.23 | 27.05 | 54 |
| SP- 33 | 37.9 | 1112.5 | 682.18 | 645.50 | 36.68 | 27.39 | 55 |
| SP- 34 | 38.3 | 1150.8 | 682.14 | 645.00 | 37.14 | 27.73 | 55 |
| SP- 35 | 38.8 | 1189.6 | 682.09 | 644.67 | 37.43 | 27.95 | 55 |
| SP- 36 | 39.1 | 1228.8 | 682.05 | 644.33 | 37.72 | 28.16 | 56 |
| SP- 37 | 39.4 | 1268.2 | 682.01 | 644.00 | 38.01 | 28.38 | 56 |
| SP- 38 | 39.7 | 1307.9 | 681.96 | 643.67 | 38.29 | 28.59 | 56 |
| SP- 39 | 80.0 | 1387.9 | 681.92 | 643.33 | 38.58 | 28.81 | 57 |
| SP- 40 | 40.3 | 1428.3 | 681.87 | 643.00 | 38.87 | 29.03 | 57 |
| SP- 41 | 40.6 | 1468.9 | 681.83 | 642.67 | 39.16 | 29.24 | 57 |
| SP- 42 | 40.9 | 1509.8 | 681.78 | 642.33 | 39.45 | 29.46 | 58 |
| SP- 43 | 41.2 | 1551.1 | 681.74 | 642.00 | 39.74 | 29.67 | 58 |
| SP- 44 | 41.5 | 1592.6 | 681.70 | 642.20 | 39.50 | 29.49 | 58 |
| SP- 45 | 41.3 | 1633.9 | 681.65 | 642.40 | 39.25 | 29.31 | 58 |
| SP- 46 | 41.0 | 1674.9 | 681.61 | 642.60 | 39.01 | 29.13 | 57 |
| SP- 47 | 40.8 | 1715.7 | 681.56 | 642.80 | 38.76 | 28.94 | 57 |
| SP- 48 | 40.5 | 1756.2 | 681.52 | 643.00 | 38.52 | 28.76 | 57 |
| SP- 49 | 40.3 | 1796.5 | 681.47 | 643.20 | 38.27 | 28.58 | 57 |
| SP- 50 | 40.0 | 1836.5 | 681.43 | 643.40 | 38.03 | 28.40 | 57 |
| SP- 51 | 39.8 | 1876.3 | 681.39 | 643.60 | 37.79 | 28.21 | 56 |
| SP- 52 | 39.5 | 1915.8 | 681.34 | 643.80 | 37.54 | 28.03 | 56 |
| SP- 53 | 39.2 | 1955.0 | 681.30 | 644.00 | 37.30 | 27.85 | 56 |
| SP- 54 | 39.0 | 1994.0 | 681.25 | 644.00 | 37.25 | 27.82 | 56 |
| SP- 55 | 38.9 | 2032.9 | 681.21 | 644.00 | 37.21 | 27.78 | 56 |
| SP- 56 | 38.9 | 2071.8 | 681.16 | 644.00 | 37.16 | 27.75 | 56 |
| SP- 57 | 38.8 | 2110.7 | 681.12 | 644.00 | 37.12 | 27.72 | 56 |
| SP- 58 | 38.8 | 2149.5 | 681.08 | 644.00 | 37.08 | 27.68 | 56 |
| SP- 59 | 38.8 | 2188.2 | 681.03 | 644.00 | 37.03 | 27.65 | 56 |
| SP- 60 | 38.7 | 2226.9 | 680.99 | 644.00 | 36.99 | 27.62 | 56 |
| SP- 61 | 38.7 | 2265.6 | 680.94 | 644.00 | 36.94 | 27.58 | 56 |
| SP- 62 | 38.6 | 2304.2 | 680.90 | 644.00 | 36.90 | 27.55 | 56 |
| SP- 63 | 38.6 | 2342.8 | 680.85 | 644.00 | 36.85 | 27.52 | 56 |
| SP- 64 | 38.5 | 2381.3 | 680.81 | 644.00 | 36.81 | 27.48 | 56 |
| SP- 65 | 38.5 | 2419.8 | 680.77 | 644.00 | 36.77 | 27.45 | 56 |
| SP- 66 | 38.4 | 2458.2 | 680.72 | 644.00 | 36.72 | 27.42 | 56 |
| SP- 67 | 38.4 | 2496.6 | 680.68 | 644.00 | 36.68 | 27.39 | 56 |
| SP- 68 | 38.3 | 2535.0 | 680.63 | 644.00 | 36.63 | 27.35 | 56 |
| SP- 69 | 38.3 | 2573.2 | 680.59 | 644.00 | 36.59 | 27.32 | 56 |
| SP- 70 | 38.2 | 2611.5 | 680.54 | 644.00 | 36.54 | 27.29 | 56 |
| SP- 71 | 38.2 | 2649.7 | 680.50 | 644.00 | 36.50 | 27.25 | 56 |
| SP- 72 | 38.2 | 2687.9 | 680.46 | 644.00 | 36.46 | 27.22 | 56 |
| SP- 73 | 38.1 | 2726.0 | 680.41 | 644.00 | 36.41 | 27.19 | 56 |
| Radius of Influence / Saturated Thickness = | | | | | 1.4 | | |
| Factor of Safety | | | | | 1.875 | (=1.5 x 1.25) | |
| Radius of Influence / Saturated Thickness Used = | | | | | 0.75 | | |

# Table 2 - Sparge Well Operational Schedule

1500 South Tibbs LLC

May 16, 2025

| Day of Week | MON | | | TUE | | | WED | | | THU | | | FRI | | | SAT | | | SUN | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 |
| Oak Park Property | | | | | | | | | | | | | | | | | | | | | |
| SP- 1 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 |
| SP- 2 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 |
| SP- 3 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 |
| SP- 4 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 |
| SP- 5 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 |
| SP- 6 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 |
| SP- 7 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 8 | 4 | 0 | 0 |
| SP- 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 8 |
| SP- 9 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 8 | 8 |
| SP- 10 | 0 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 |
| SP- 11 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 |
| SP- 12 | 8 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 0 | 0 |
| SP- 13 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 0 | 0 | 8 |
| SP- 14 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 0 | 0 | 8 | 4 |
| SP- 15 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 0 | 0 | 8 | 4 | 0 |
| SP- 16 | 4 | 8 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 0 | 0 | 8 | 4 | 0 | 0 |
| SP- 17 | 8 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 4 |
| SP- 18 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 4 | 8 |
| SP- 19 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 |
| SP- 20 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 0 |
| SP- 21 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 0 | 8 |
| SP- 22 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 0 | 8 | 8 |
| SP- 23 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 0 | 8 | 8 | 2 |
| SP- 24 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 0 | 8 | 8 | 2 | 0 |
| SP- 25 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 8 | 8 | 2 | 0 | 0 | 0 | 8 | 8 | 2 | 0 | 0 |
| SP- 26 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 8 | 8 | 8 | 0 |
| SP- 27 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 8 | 8 | 8 | 0 | 0 |
| SP- 28 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 |
| SP- 29 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 8 |
| SP- 30 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 8 | 4 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 |
| SP- 31 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 |
| SP- 32 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 |
| SP- 33 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 |
| SP- 34 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 |
| SP- 35 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 |
| SP- 36 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 |
| SP- 37 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 |
| SP- 38 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 |
| Total Sparge Rate (scfm) | 157.5 | 150.0 | 142.5 | 135.0 | 142.5 | 150.0 | 157.5 | 157.5 | 157.5 | 142.5 | 142.5 | 135.0 | 157.5 | 157.5 | 142.5 | 135.0 | 150.0 | 157.5 | 150.0 | 135.0 | 142.5 |

Notes:

1 The table identifies how many hours within a time period on a specific day that the sparge well will operate. Hours are sequential.

2 Total sparge flow rate is based upon the maximum flow within the 8-hour period and a flow rate of 7.5 scfm/well

# Table 2 - Sparge Well Operational Schedule

1500 South Tibbs LLC

May 16, 2025

| Day of Week | MON | | | TUE | | | WED | | | THU | | | FRI | | | SAT | | | SUN | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 |
| Maywood Property | | | | | | | | | | | | | | | | | | | | | |
| SP- 39 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 |
| SP- 40 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 |
| SP- 41 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 |
| SP- 42 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 |
| SP- 43 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 |
| SP- 44 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 |
| SP- 45 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 |
| SP- 46 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 |
| SP- 47 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 |
| SP- 48 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 |
| SP- 49 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 |
| SP- 50 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 |
| SP- 51 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 |
| SP- 52 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 |
| SP- 53 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 |
| SP- 54 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 |
| SP- 55 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 |
| SP- 56 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 |
| SP- 57 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 |
| SP- 58 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 |
| SP- 59 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 |
| SP- 60 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 |
| SP- 61 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 |
| SP- 62 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 |
| SP- 63 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 |
| SP- 64 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 |
| SP- 65 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 |
| SP- 66 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 |
| SP- 67 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 |
| SP- 68 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 |
| SP- 69 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 |
| SP- 70 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 |
| SP- 71 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 |
| SP- 72 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 |
| SP- 73 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 |
| Total Sparge Rate (scfm) | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |

Notes:

1 The table identifies how many hours within a time period on a specific day that the sparge well will operate. Hours are sequential.

2 Total sparge flow rate is based upon the maximum flow within the 8-hour period and a flow rate of 7.5 scfm/well

# Table 3 - Compressor Sizing

1500 South Tibbs LLC

May 16, 2025

| Item | Unit | Oak Park | Maywood |
|---|---|---|---|
| Sparge Wells | Quantity | 38 | 35 |
| Flow Rate Per Well | scfm | 7.5 | 7.5 |
| Pulsed Sparge Operation | Yes/No | Yes | Yes |
| Maximum Flow Rate (see Table 2) | scfm | 157.5 | 150 |
| Contingency | | | |
| 6 x Spare Wells Pulsed at 7.5 scfm | scfm | 25.7 | 25.7 |
| 21 x Wells Pulsed at 15 scfm | scfm | 90.0 | 90.0 |
| Compressed Air Leaks | scfm | 10 | 10 |
| Dryer Purge Air | scfm | 50 | 50 |
| Total Compressed Air Demand | scfm | 333.2 | 325.7 |
| Compressor Intake Elevation | ft ASL | 710 | 710 |
| Compressor Intake Pressure | psi | 14.34 | 14.34 |
| Max. Ambient Temperature | ˚ F | 100 | 100 |
| Total Compressed Air Demand | cfm FAD | 362.2 | 354.1 |
| Ingersoll Rand 40 Hp Compressor | cfm FAD | 184 | 184 |
| Number of Compressors | Quantity | 2 | 2 |
| Total Compressed Air Supply at 125 psig | cfm FAD | 368 | 368 |
| Compressed Air Supply > Demand? | Yes/No | Yes | Yes |

Notes:

1. Pulsed sparge operation at each well is based upon pilot testing data. This includes time to elevate DO based upon the volume of groundwater sparged plus time for DO to return to original concentrations. The volume of groundwater sparged is based upon the saturated thickness and radius of influence.

# Table 4 - Pressure Drop Evaluation

1500 South Tibbs LLC

May 16, 2025

| Item | | Unit | Value |
|---|---|---|---|
| Compressed Air Generation | | | |
| Compressed Air Pressure | | psig | 125 |
| Compressed Air Temperature | | ° F | 120 |
| Compressed Air Flow Rate | | cfm FAD | 184 |
| 1.25" Piping Frictional Loss | | psi/100 ft | 1.492 |
| Equivalent Length of Piping | | feet | 102 |
| Pipe | 1 ft | feet | 60 |
| 90 | 3 ft | each | 8 |
| Valve | 4 ft | each | 2 |
| Check Valve | 10 ft | each | 1 |
| Receiver Tank Pressure Drop | | psig | 2 |
| Total Pressure Drop | | psig | 3.5 |
| Compressed Air Filtering / Regulating | | | |
| Compressed Air Pressure | | psig | 121.5 |
| Compressed Air Temperature | | ° F | 100 |
| Compressed Air Flow Rate | | cfm FAD | 362 |
| 2" Piping Frictional Loss | | psi/100 ft | 0.713 |
| Equivalent Length of Piping | | feet | 242 |
| Pipe | 1 ft | feet | 80 |
| 90s | 5 ft | each | 12 |
| Tees | 4 ft | each | 8 |
| Valves | 10 ft | each | 7 |
| 1.5" Piping Frictional Loss | | psi/100 ft | 2.486 |
| Equivalent Length of Piping | | feet | 10 |
| 1.5" Reducer | 5 ft | each | 2 |
| Main Solenoid Valve Pressure Drop | | psig | 0.1 |
| Coalescing Filter Pressure Drop | | psig | 0.5 |
| Dessicant Dryer Pressure Drop | | psig | 3 |
| Particulate Filter Pressure Drop | | psig | 10 |
| Flowmeter Pressure Drop | | psig | 0.5 |
| Regulator Pressure Drop | | psig | 10 |
| Total Pressure Drop | | psig | 26.1 |
| Flow Metering and Well Connection | | | |
| Compressed Air Pressure | | psig | 95.4 |
| Compressed Air Temperature | | ° F | 100 |
| Compressed Air Flow Rate | | cfm FAD | 16.3 |
| 1/2" Piping Frictional Loss | | psi/100 ft | 1.187 |
| Equivalent Length of Piping | | feet | 81 |
| Pipe | 1 ft | feet | 10 |
| 90s | 5 ft | each | 5 |
| Tees | 4 ft | each | 4 |
| Valves | 10 ft | each | 3 |
| 3/8" Piping Frictional Loss | | psi/100 ft | 3.916 |
| Equivalent Length of Piping | | feet | 10 |
| 1/2" Reducer | 5 ft | each | 2 |
| Flowmeter Pressure Drop | | psig | 2 |
| Regulator Pressure Drop | | psig | 10 |
| Solenoid Valve Pressure Drop | | psig | 0.5 |
| Total Pressure Drop | | psig | 13.9 |
| Underground HDPE Tubing (Longest Distance to Sparge Well) | | | |
| Compressed Air Pressure | | psig | 81.6 |
| Compressed Air Temperature | | ° F | 80 |
| Compressed Air Flow Rate | | cfm FAD | 16.3 |
| 1/2" Piping Frictional Loss | | psi/100 ft | 0.896 |
| Equivalent Length of Piping | | feet | 1020 |
| Pipe | 1 ft | feet | 1000 |
| 90s | 5 ft | each | 4 |
| Total Pressure Drop | | psig | 9.1 |
| Sparge Well Pressure Supplied | | psig | 72.4 |
| Sparge Well Pressure Demand | | | |
| RI-6S Sparge Well Depth to Water | | feet | 19.5 |
| Maximum Sparge Well Depth SP-71 | | feet | 68 |
| Sparge Well Max. Saturated Thickness | | feet | 48.5 |
| Sparge Max. 3X Breakthrough Pressure | | psig | 63.0 |
| Sparge Pressure Determination | | | |
| Sparge Pressure Supply > Demand? | | Yes/No | Yes |
| Excess Pressure Supply | | psig | 9.4 |

| Pipe | Outside Diameter | Min. Wall Thickness | Max Inside Diameter | Avg. Inside Diameter |
|---|---|---|---|---|
| 1/2" DR11 HDPE | 0.840 | 0.076 | 0.688 | 0.679 |
| 3/4" DR11 HDPE | 1.050 | 0.095 | 0.860 | 0.848 |
| 3/8" Sch. 40 Galv. | 0.675 | 0.091 | X | 0.493 |
| 1/2" Sch. 40 Galv. | 0.840 | 0.109 | X | 0.622 |
| 1.25" Sch. 40 Galv. | 1.660 | 0.140 | X | 1.380 |
| 1.5" Sch. 40 Galv. | 1.900 | 0.145 | X | 1.610 |
| 2" Sch. 40 Galv. | 2.375 | 0.154 | X | 2.067 |

Note: Dimensions in inches.

Sources: Standard Pipe Schedules and Sizes Chart Table Data
https://usaindustries.com/piping-isolation-testing-products/pipe-schedule-chart/
http://www.pvcplus.com/media/website_product.pdfSpecs/en-CA/HDPE%20pipe.pdf

Pressure Drop Calculation

$dp = 7.57q^{1.85}L10^{4} / (d^{5} p)$ - uses metric units in calculation

Source: https://www.engineeringtoolbox.com/pressure-drop-compressed-air-pipes-d_852.html

1.25" Sch. 40 Galv. Pipe

| | Metric Units | | | Imperial Units | |
|---|---|---|---|---|---|
| dp | 0.105 | $kg/cm^2$ | pressure drop | 1.492 | psi |
| q | 5.21 | $m^3$/min FAD | air flow at atmospheric conditions | 184 | cfm FAD |
| L | 30 | m | length of pipe | 100 | ft |
| d | 35.1 | mm | inside diameter | 1.380 | inches |
| p | 8.81 | $kg/cm^2$ | Initial pressure (gauge) | 125 | psig |

2" Sch. 40 Galv. Pipe

| | Metric Units | | | Imperial Units | |
|---|---|---|---|---|---|
| dp | 0.050 | $kg/cm^2$ | pressure drop | 0.713 | psi |
| q | 10.26 | $m^3$/min FAD | air flow at atmospheric conditions | 362 | cfm FAD |
| L | 30 | m | length of pipe | 100 | ft |
| d | 52.5 | mm | inside diameter | 2.067 | inches |
| p | 8.56 | $kg/cm^2$ | Initial pressure (gauge) | 121 | psig |

1.5" Sch. 40 Galv. Pipe

| | Metric Units | | | Imperial Units | |
|---|---|---|---|---|---|
| dp | 0.175 | $kg/cm^2$ | pressure drop | 2.486 | psi |
| q | 10.26 | $m^3$/min FAD | air flow at atmospheric conditions | 362 | cfm FAD |
| L | 30 | m | length of pipe | 100 | ft |
| d | 40.9 | mm | inside diameter | 1.610 | inches |
| p | 8.56 | $kg/cm^2$ | Initial pressure (gauge) | 121 | psig |

1/2" Sch. 40 Galv. Pipe

| | Metric Units | | | Imperial Units | |
|---|---|---|---|---|---|
| dp | 0.084 | $kg/cm^2$ | pressure drop | 1.187 | psi |
| q | 0.46 | $m^3$/min FAD | air flow at atmospheric conditions | 16.3 | cfm FAD |
| L | 30 | m | length of pipe | 100 | ft |
| d | 15.8 | mm | inside diameter | 0.622 | inches |
| p | 6.72 | $kg/cm^2$ | Initial pressure (gauge) | 95 | psig |

3/8" Sch. 40 Galv. Pipe

| | Metric Units | | | Imperial Units | |
|---|---|---|---|---|---|
| dp | 0.276 | $kg/cm^2$ | pressure drop | 3.916 | psi |
| q | 0.46 | $m^3$/min FAD | air flow at atmospheric conditions | 16.3 | cfm FAD |
| L | 30 | m | length of pipe | 100 | ft |
| d | 12.5 | mm | inside diameter | 0.493 | inches |
| p | 6.51 | $kg/cm^2$ | Initial pressure (gauge) | 92 | psig |

1/2" DR11 HDPE Tubing

| | Metric Units | | | Imperial Units | |
|---|---|---|---|---|---|
| dp | 0.063 | $kg/cm^2$ | pressure drop | 0.896 | psi |
| q | 0.46 | $m^3$/min FAD | air flow at atmospheric conditions | 16.3 | cfm FAD |
| L | 30 | m | length of pipe | 100 | ft |
| d | 17.2 | mm | inside diameter | 0.679 | inches |
| p | 5.75 | $kg/cm^2$ | Initial pressure (gauge) | 82 | psig |

Total Pressure Drop = Equiv. Length / 100 x Frictional Loss + Components Pressure Drop
Components = Reciever Tank, Coalescing Filter, Dessicant Dryer, Particulate Filter, Coalescing Filter, Flowmeters, Regulators, and Solenoid Valves.

**Attachment G**

**Vapor Intrusion Screening**

# Vapor Intrusion Screening

**Vapor Intrusion Screening.** Results from the EPA Vapor Intrusion Screening Level (VISL) calculator to determine the target groundwater concentration that could render the vapor intrusion pathway incomplete.

(1) Benzene – Residential (Groundwater Result = 19.7 µg/L)

## Default VISL Results

1

| Variable | Value |
|---|---|
| Exposure Scenario | Resident |
| Temperature for Groundwater Vapor Concentration C | 20 |
| $ED_{res}$ (exposure duration) years | 26 |
| TR (target risk) unitless | 1E-05 |
| THQ (target hazard quotient) unitless | 1 |
| LT (lifetime) years | 70 |
| $EF_{res}$ (exposure frequency) days/year | 350 |
| $ED_{0-2}$ (mutagenic exposure duration first phase) years | 2 |
| $ED_{2-6}$ (mutagenic exposure duration second phase) years | 4 |
| $ED_{6-16}$ (mutagenic exposure duration third phase) years | 10 |
| $ED_{16-26}$ (mutagenic exposure duration fourth phase) years | 10 |
| $EF_{0-2}$ (mutagenic exposure frequency first phase) days/year | 350 |
| $EF_{2-6}$ (mutagenic exposure frequency second phase) days/year | 350 |
| $EF_{6-16}$ (mutagenic exposure frequency third phase) days/year | 350 |
| $EF_{16-26}$ (mutagenic exposure frequency fourth phase) days/year | 350 |
| $ET_{res}$ (exposure time) hours/day | 24 |
| $ET_{0-2}$ (mutagenic exposure time first phase) hours/day | 24 |
| $ET_{2-6}$ (mutagenic exposure time second phase) hours/day | 24 |
| $ET_{6-16}$ (mutagenic exposure time third phase) hours/day | 24 |
| $ET_{16-26}$ (mutagenic exposure time fourth phase) hours/day | 24 |
| $AF_{GW}$ (Attenuation Factor Groundwater) unitless | 0.001 |
| $AF_{SS}$ (Attenuation Factor Sub-Slab) unitless | 0.03 |

Output generated 11OCT2024:11:08:35

# Resident Vapor Intrusion Screening Levels (VISL)

2

**Key: I = IRIS; P = PPRTV; O = OPP; A = ATSDR; C = Cal EPA; X = PPRTV Screening Level; H = HEAST; D = DWSHA; W = TEF applied; E = RPF applied; U = user provided; G = see RSL User's Guide Section 5; CA = cancer; NC = noncancer.**

| Chemical | CAS Number | Does the chemical meet the definition for volatility? (HLC>1E-5 or VP>1) | Does the chemical have inhalation toxicity data? (IUR and/or RfC) | Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk Via Vapor Intrusion from Soil Source? ($C_{vp}$ > $C_{i,a}$,Target?) | Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk Via Vapor Intrusion from Groundwater Source? ($C_{hc}$ > $C_{i,a}$,Target?) | Target Indoor Air Concentration (TCR=1E-05 or THQ=1) MIN($C_{ia,c}$,$C_{ia,nc}$) (µg/m³) | Toxicity Basis | Target Sub-Slab and Near-source Soil Gas Concentration (TCR=1E-05 or THQ=1) $C_{sg}$,Target (µg/m³) | Target Groundwater Concentration (TCR=1E-05 or THQ=1) $C_{gw}$,Target (µg/L) | Is Target Groundwater Concentration < MCL? ($C_{gw}$ < MCL?) |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | Yes | Yes | Yes | Yes | 3.60E+00 | CA | 1.20E+02 | 1.97E+01 | No (5) |

| Pure Phase Vapor Concentration $C_{vp}$\ (20 °C)\ (µg/m³) | Maximum Groundwater Vapor Concentration $C_{hc}$\ (µg/m³) | Temperature for Maximum Groundwater Vapor Concentration (°C) | Lower Explosive Limit LEL (% by volume) | LEL Ref | IUR (ug/m³)$^{-1}$ | IUR Ref | RfC (mg/m³) | RfC Ref | Mutagenic Indicator | Carcinogenic VISL TCR=1E-05 $C_{ia,c}$ (µg/m³) | Noncarcinogenic VISL THQ=1 $C_{ia,nc}$ (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.98E+08 | 3.28E+08 | 20 | 1.20 | CRC | 7.80E-06 | I | 3.00E-02 | I | No | 3.60E+00 | 3.13E+01 |

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# Chemical Properties

3

**Output generated 11OCT2024:11:08:35**

| Chemical | CAS Number | Does the chemical meet the definition for volatility? (HLC>1E-5 or VP>1) | Does the chemical have inhalation toxicity data? (IUR and/or RfC) | MW | MW Ref | S (mg/L) | S Ref | MCL (ug/L) | HLC (atm-m$^3$/mole) | Henry's Law Constant (unitless) | Henry's Law Constant (20 ℃) (unitless) | Henry's Law Constant Used in Calcs (unitless) | H` and HLC Ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | Yes | Yes | 78.115 | PHYSPROP | 1.79E+03 | PHYSPROP | 5 | 5.55E-03 | 2.27E-01 | 1.83E-01 | 1.83E-01 | PHYSPROP |

| Enthalpy of vaporization @ groundwater temperature $\Delta H_{v,gw}$ \ (cal/mol) | Enthalpy of vaporization at the normal boiling point $\Delta H_{v,b}$ \ (cal/mol) | $\Delta H_{v,b}$ \ Ref | Normal Boiling Point BP (K) | BP Ref | Exponent for $\Delta H_{v,gw}$ | Vapor Pressure VP (mm Hg) | VP Ref | Vapor Pressure VP (20 ℃)\ (mm Hg) | Critical Temperature $T_c$ \ (K) | $T_c$ \ Ref | Lower Explosive Limit LEL (% by volume) | LEL Ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.02E+03 | 7.34E+03 | CRC | 353.15 | PHYSPROP | 0.3490017794 | 9.48E+01 | PHYSPROP | 7.53E+01 | 5.62E+02 | CRC | 1.2 | CRC |

Output generated 11OCT2024:11:08:35

(2) Benzene – Commercial (Groundwater Result = 85.8 µg/L)

## Default VISL Results

1

| Variable | Value |
|---|---|
| Exposure Scenario | Commercial |
| Temperature for Groundwater Vapor Concentration C | 20 |
| THQ (target hazard quotient) unitless | 1 |
| TR (target risk) unitless | 1E-05 |
| $AT_{com}$ (averaging time - composite worker) | 365 |
| $EF_{com}$ (exposure frequency - composite worker) day/yr | 250 |
| $ED_{com}$ (exposure duration - composite worker) yr | 25 |
| $ET_{com}$ (exposure time - composite worker) hr | 8 |
| LT (lifetime) yr | 70 |
| $AF_{gw}$ (Attenuation Factor Groundwater) unitless | 0.001 |
| $AF_{ss}$ (Attenuation Factor Sub-Slab) unitless | 0.03 |

Output generated 11OCT2024:11:09:33

# Commercial Vapor Intrusion Screening Levels (VISL)

2

**Key: I = IRIS; P = PPRTV; O = OPP; A = ATSDR; C = Cal EPA; X = PPRTV Screening Level; H = HEAST; D = DWSHA; W = TEF applied; E = RPF applied; U = user provided; G = see RSL User's Guide Section 5; CA = cancer; NC = noncancer.**

| Chemical | CAS Number | Does the chemical meet the definition for volatility? (HLC>1E-5 or VP>1) | Does the chemical have inhalation toxicity data? (IUR and/or RfC) | Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk Via Vapor Intrusion from Soil Source? ($C_{vp}$ > $C_{i,a}$,Target?) | Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk Via Vapor Intrusion from Groundwater Source? ($C_{hc}$ > $C_{i,a}$,Target?) | Target Indoor Air Concentration (TCR=1E-05 or THQ=1) MIN($C_{ia,c}$,$C_{ia,nc}$) (µg/m³) | Toxicity Basis | Target Sub-Slab and Near-source Soil Gas Concentration (TCR=1E-05 or THQ=1) $C_{sg}$,Target (µg/m³) | Target Groundwater Concentration (TCR=1E-05 or THQ=1) $C_{gw}$,Target (µg/L) | Is Target Groundwater Concentration < MCL? ($C_{gw}$ < MCL?) |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | Yes | Yes | Yes | Yes | 1.57E+01 | CA | 5.24E+02 | 8.58E+01 | No (5) |

| Pure Phase Vapor Concentration $C_{vp}$\ (20 °C)\ (µg/m³) | Maximum Groundwater Vapor Concentration $C_{hc}$\ (µg/m³) | Temperature for Maximum Groundwater Vapor Concentration (°C) | Lower Explosive Limit LEL (% by volume) | LEL Ref | IUR (ug/m³)⁻¹ | IUR Ref | RfC (mg/m³) | RfC Ref | Mutagenic Indicator | Carcinogenic VISL TCR=1E-05 $C_{ia,c}$ (µg/m³) | Noncarcinogenic VISL THQ=1 $C_{ia,nc}$ (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.98E+08 | 3.28E+08 | 20 | 1.20 | CRC | 7.80E-06 | I | 3.00E-02 | I | No | 1.57E+01 | 1.31E+02 |

Output generated 11OCT2024:11:09:33

# Chemical Properties

3

**Output generated 11OCT2024:11:09:33**

| Chemical | CAS Number | Does the chemical meet the definition for volatility? (HLC>1E-5 or VP>1) | Does the chemical have inhalation toxicity data? (IUR and/or RfC) | MW | MW Ref | S (mg/L) | S Ref | MCL (ug/L) | HLC (atm-m³/mole) | Henry's Law Constant (unitless) | Henry's Law Constant (20 °C) (unitless) | Henry's Law Constant Used in Calcs (unitless) | H` and HLC Ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | Yes | Yes | 78.115 | PHYSPROP | 1.79E+03 | PHYSPROP | 5 | 5.55E-03 | 2.27E-01 | 1.83E-01 | 1.83E-01 | PHYSPROP |

| Enthalpy of vaporization @ groundwater temperature $\Delta H_{v,gw}$ \ (cal/mol) | Enthalpy of vaporization at the normal boiling point $\Delta H_{v,b}$ \ (cal/mol) | $\Delta H_{v,b}$ \ Ref | Normal Boiling Point BP (K) | BP Ref | Exponent for $\Delta H_{v,gw}$ | Vapor Pressure VP (mm Hg) | VP Ref | Vapor Pressure VP (20 °C)\ (mm Hg) | Critical Temperature $T_C$ \ (K) | $T_C$ \ Ref | Lower Explosive Limit LEL (% by volume) | LEL Ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.02E+03 | 7.34E+03 | CRC | 353.15 | PHYSPROP | 0.3490017794 | 9.48E+01 | PHYSPROP | 7.53E+01 | 5.62E+02 | CRC | 1.2 | CRC |

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(3) Ammonia – Residential (Groundwater Result = 898,000 µg/L = 898 mg/L)

## Default VISL Results

1

| Variable | Value |
|---|---|
| Exposure Scenario | Resident |
| Temperature for Groundwater Vapor Concentration C | 20 |
| $ED_{res}$ (exposure duration) years | 26 |
| TR (target risk) unitless | 1E-05 |
| THQ (target hazard quotient) unitless | 1 |
| LT (lifetime) years | 70 |
| $EF_{res}$ (exposure frequency) days/year | 350 |
| $ED_{0-2}$ (mutagenic exposure duration first phase) years | 2 |
| $ED_{2-6}$ (mutagenic exposure duration second phase) years | 4 |
| $ED_{6-16}$ (mutagenic exposure duration third phase) years | 10 |
| $ED_{16-26}$ (mutagenic exposure duration fourth phase) years | 10 |
| $EF_{0-2}$ (mutagenic exposure frequency first phase) days/year | 350 |
| $EF_{2-6}$ (mutagenic exposure frequency second phase) days/year | 350 |
| $EF_{6-16}$ (mutagenic exposure frequency third phase) days/year | 350 |
| $EF_{16-26}$ (mutagenic exposure frequency fourth phase) days/year | 350 |
| $ET_{res}$ (exposure time) hours/day | 24 |
| $ET_{0-2}$ (mutagenic exposure time first phase) hours/day | 24 |
| $ET_{2-6}$ (mutagenic exposure time second phase) hours/day | 24 |
| $ET_{6-16}$ (mutagenic exposure time third phase) hours/day | 24 |
| $ET_{16-26}$ (mutagenic exposure time fourth phase) hours/day | 24 |
| $AF_{gw}$ (Attenuation Factor Groundwater) unitless | 0.001 |
| $AF_{ss}$ (Attenuation Factor Sub-Slab) unitless | 0.03 |

Output generated 11OCT2024:11:07:51

# Resident Vapor Intrusion Screening Levels (VISL)

2

**Key: I = IRIS; P = PPRTV; O = OPP; A = ATSDR; C = Cal EPA; X = PPRTV Screening Level; H = HEAST; D = DWSHA; W = TEF applied; E = RPF applied; U = user provided; G = see RSL User's Guide Section 5; CA = cancer; NC = noncancer.**

| Chemical | CAS Number | Does the chemical meet the definition for volatility? (HLC>1E-5 or VP>1) | Does the chemical have inhalation toxicity data? (IUR and/or RfC) | Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk Via Vapor Intrusion from Soil Source? ($C_{vp} > C_{i,a}$,Target?) | Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk Via Vapor Intrusion from Groundwater Source? ($C_{hc} > C_{i,a}$,Target?) | Target Indoor Air Concentration (TCR=1E-05 or THQ=1) MIN($C_{ia,c}$,$C_{ia,nc}$) ($\mu g/m^3$) | Toxicity Basis | Target Sub-Slab and Near-source Soil Gas Concentration (TCR=1E-05 or THQ=1) $C_{sg}$,Target ($\mu g/m^3$) | Target Groundwater Concentration (TCR=1E-05 or THQ=1) $C_{gw}$,Target ($\mu g/L$) | Is Target Groundwater Concentration < MCL? ($C_{gw}$ < MCL?) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ammonia | 7664-41-7 | Yes | Yes | Yes | Yes | 5.21E+02 | NC | 1.74E+04 | 8.98E+05 | -- |

| Pure Phase Vapor Concentration $C_{vp}$\ (20 °C)\ ($\mu g/m^3$) | Maximum Groundwater Vapor Concentration $C_{hc}$\ ($\mu g/m^3$) | Temperature for Maximum Groundwater Vapor Concentration (°C) | Lower Explosive Limit LEL (% by volume) | LEL Ref | IUR $(ug/m^3)^{-1}$ | IUR Ref | RfC ($mg/m^3$) | RfC Ref | Mutagenic Indicator | Carcinogenic VISL TCR=1E-05 $C_{ia,c}$ ($\mu g/m^3$) | Noncarcinogenic VISL THQ=1 $C_{ia,nc}$ ($\mu g/m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.88E+09 | 2.80E+08 | 20 | 16.00 | CRC | - | | 5.00E-01 | I | No | - | 5.21E+02 |

Output generated 11OCT2024:11:07:51

# Chemical Properties

3

**Output generated 11OCT2024:11:07:51**

| Chemical | CAS Number | Does the chemical meet the definition for volatility? (HLC>1E-5 or VP>1) | Does the chemical have inhalation toxicity data? (IUR and/or RfC) | MW | MW Ref | S (mg/L) | S Ref | MCL (ug/L) | HLC (atm-m$^3$/mole) | Henry's Law Constant (unitless) | Henry's Law Constant (20 ℃) (unitless) | Henry's Law Constant Used in Calcs (unitless) | H` and HLC Ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammonia | 7664-41-7 | Yes | Yes | 17.031 | PHYSPROP | 4.82E+05 | PHYSPROP | - | 1.61E-05 | 6.58E-04 | 5.81E-04 | 5.81E-04 | PHYSPROP |

| Enthalpy of vaporization @ groundwater temperature $\Delta H_{v,gw}$\ (cal/mol) | Enthalpy of vaporization at the normal boiling point $\Delta H_{v,b}$\ (cal/mol) | $\Delta H_{v,b}$\ Ref | Normal Boiling Point BP (K) | BP Ref | Exponent for $\Delta H_{v,gw}$ | Vapor Pressure VP (mm Hg) | VP Ref | Vapor Pressure VP (20 ℃)\ (mm Hg) | Critical Temperature $T_c$\ (K) | $T_c$\ Ref | Lower Explosive Limit LEL (% by volume) | LEL Ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.92E+03 | 5.58E+03 | CRC | 239.8 | PHYSPROP | 0.3215480817 | 7.51E+03 | PHYSPROP | 6.52E+03 | 4.06E+02 | CRC | 16 | CRC |

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## (4) Groundwater Results – 1Q2024 (Wells near biosparge barrier are highlighted)

### 1500 South Tibbs LLC
#### 1Q2024 Groundwater Concentrations

**OU1 / OU5 SHALLOW AQUIFER WELLS**

| Well Name | Benzene | Ammonia | Pyridine | 2-Picoline | 3/4-Picoline | 2,6-Lutidine | 2-Ethyl pyridine | 2,4/2,5-Lutidine | 2,3-Lutidine | 3-Ethyl pyridine | 4-Ethyl pyridine | 3,5-Lutidine | 3,4-Lutidine | 2-Methyl-5-ethyl pyridine | 2-Methyl-3-ethyl pyridine | 3-Ethyl-4-methyl pyridine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PW-2S | <5.0 | 15.0 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| RI-4S | <5.0 | 7.8 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | **47.7** | <9.1 | <9.1 | <9.1 | <9.1 |
| RI-6S | <5.0 | 4.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 |
| RI-8S | <5.0 | <0.50 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| RI-11S | <5.0 | <0.50 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 |
| RI-17S | <5.0 | 6.6 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 | <11.1 |
| RI-18S | **129** | 8.7 | <9.1 | 31.8 | **127** | **36.2** | **45.6** | 15.3 | 9.9 | <9.1 | <9.1 | **116** | <9.1 | <9.1 | <9.1 | <9.1 |
| RI-19S | <5.0 | 1.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| RI-25S | **24.1** | 5.4 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | 19.5 | <9.1 | 11.4 | **54.2** | <9.1 |
| RI-28S | <5.0 | 3.9 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 |
| RI-29S | <5.0 | 4.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | 17.8 | <10.0 |
| RI-30S | <5.0 | 1.5 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | 16.7 | <9.1 | 9.1 | 32.4 | <9.1 |
| RI-31S | <5.0 | 0.50 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | 9.6 | <9.1 |
| RI-32S | <5.0 | 0.59 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 | <8.3 |
| RI-33S | <5.0 | 0.95 | <10.0 | <10.0 | <10.0 | <10.0 | 26.6 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | 23.9 | <10.0 |
| RI-35S | <5.0 | 2.3 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| PW-1S | <5.0 | Note: PW-1S sampled for discharge compliance only. | | | | | | | | | | | | | | |

**OU1 DEEP / OU5 MEDIUM AQUIFER WELLS**

| Well Name | Benzene | Ammonia | Pyridine | 2-Picoline | 3/4-Picoline | 2,6-Lutidine | 2-Ethyl pyridine | 2,4/2,5-Lutidine | 2,3-Lutidine | 3-Ethyl pyridine | 4-Ethyl pyridine | 3,5-Lutidine | 3,4-Lutidine | 2-Methyl-5-ethyl pyridine | 2-Methyl-3-ethyl pyridine | 3-Ethyl-4-methyl pyridine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RI-4D | **33.4** | 14.9 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | **54.9** | <9.1 | <9.1 | 9.9 | <9.1 |
| RI-5S | **12.5** | 8.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | <10.0 | 19.4 | <10.0 | <10.0 | 14.3 | <10.0 |
| RI-11M | <5.0 | 24.2 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| RI-15M | **34.0** | 14.6 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| RI-19D | <5.0 | 2.7 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| PW-1D | **18.1** | Note: PW-1D sampled for discharge compliance only. | | | | | | | | | | | | | | |

**OU5 DEEP AQUIFER WELLS**

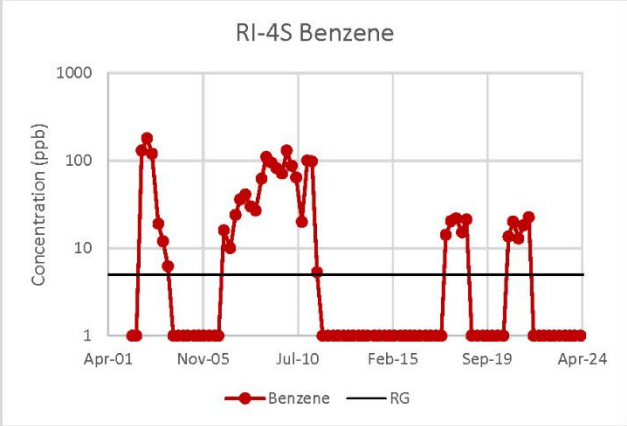
| Well Name | Benzene | Ammonia | Pyridine | 2-Picoline | 3/4-Picoline | 2,6-Lutidine | 2-Ethyl pyridine | 2,4/2,5-Lutidine | 2,3-Lutidine | 3-Ethyl pyridine | 4-Ethyl pyridine | 3,5-Lutidine | 3,4-Lutidine | 2-Methyl-5-ethyl pyridine | 2-Methyl-3-ethyl pyridine | 3-Ethyl-4-methyl pyridine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RI-11D | <5.0 | 5.9 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| RI-15D | **6.6** | 6.0 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 | <9.1 |
| Rolls PW-3 | Not sampled. Well is no longer accessible since it has been designated to only operate in emergency conditions by Rolls Royce. | | | | | | | | | | | | | | | |

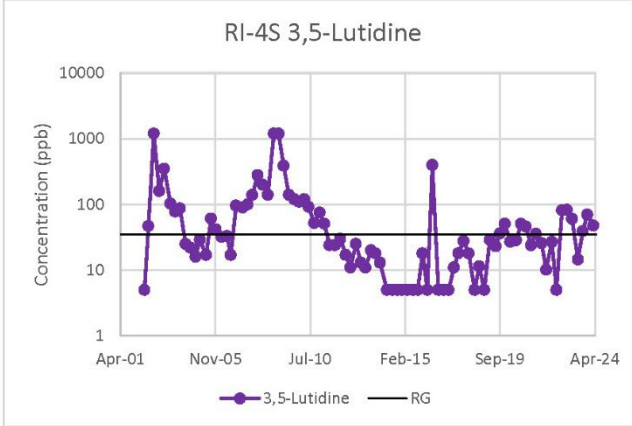
Notes:
1. All Results in ug/L except for ammonia which is in mg/L.
2. Bold and shaded text indicate result is above the cleanup objective (5 ppb for benzene, 30 ppm for ammonia, and 35 ppb for individual pyridines).
3. ND = Non-Detect
4. Samples collected on March 18 - 21, 2024.

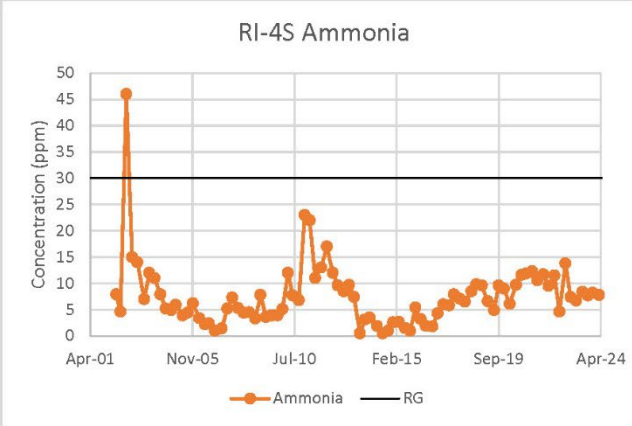
(5) Groundwater Results – Historical Graphs (Wells near biosparge barrier identified as "OU1 Perimeter Wells")

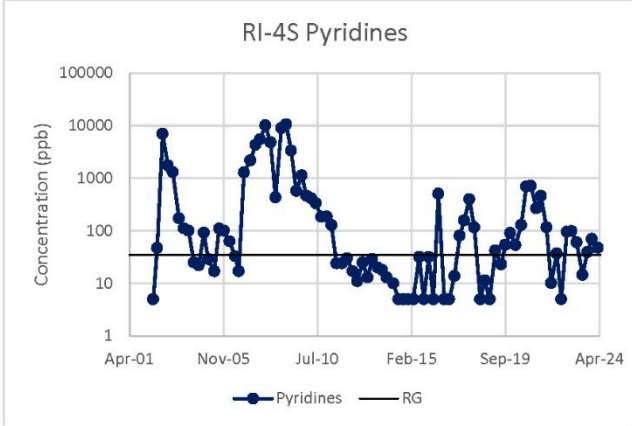
**OU1 PERIMETER WELLS**
**RI-4S GRAPHICAL ANALYSIS**

Note: Benzene and ammonia are below the RGs. Pyridines are above the RG.



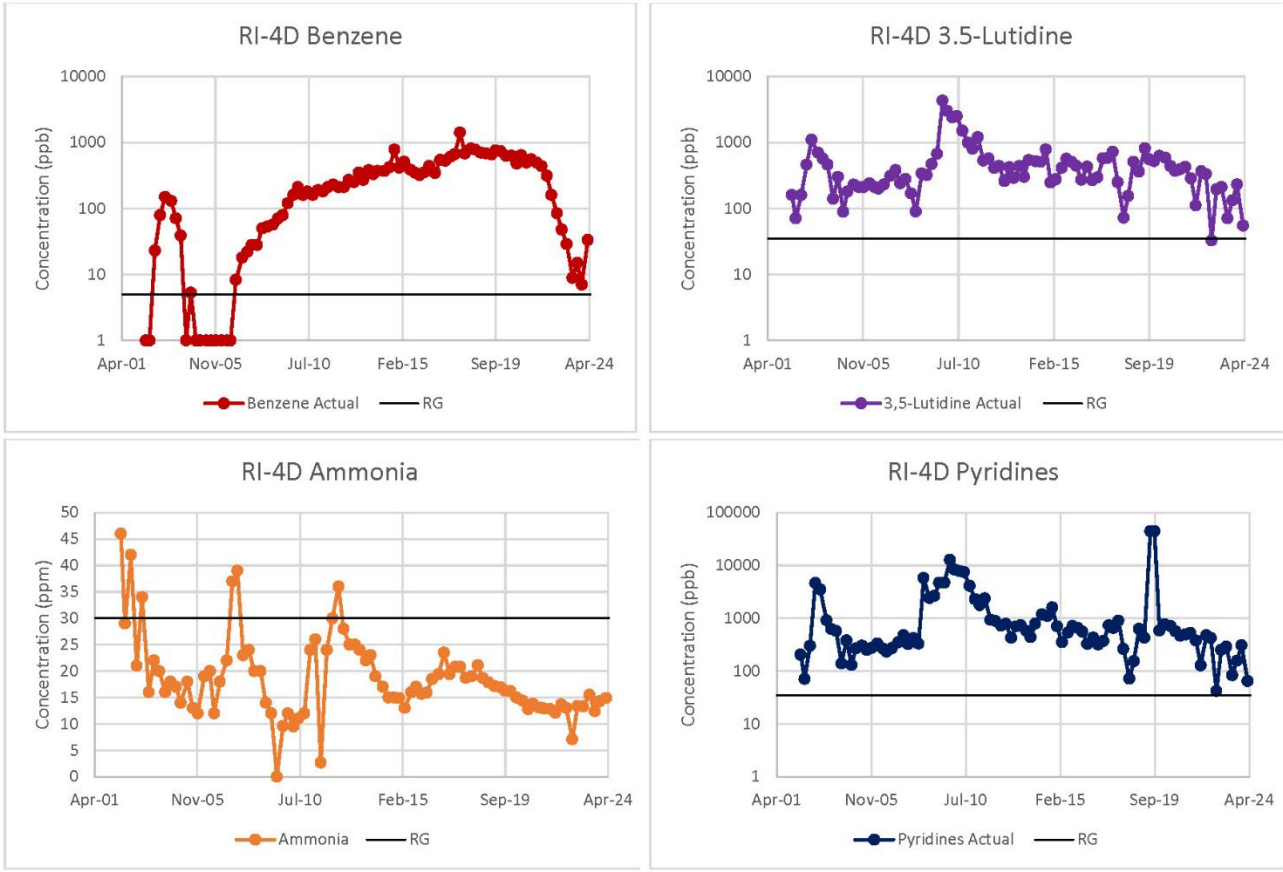




Annual Linear Regression Report – April 2024

## OU1 PERIMETER WELLS
## RI-4D GRAPHICAL ANALYSIS

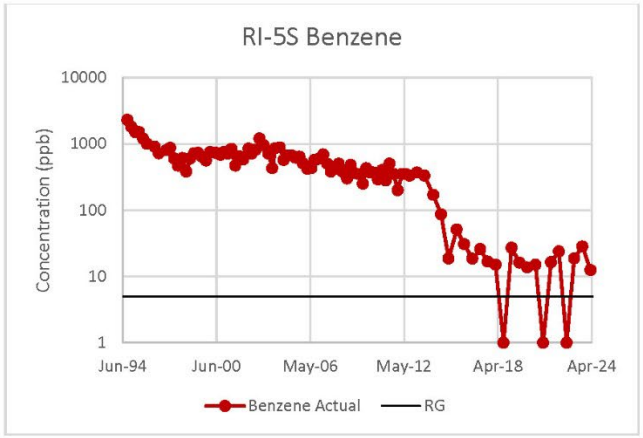
Note: Benzene and pyridine levels are above the RGs. Ammonia is below the RG.

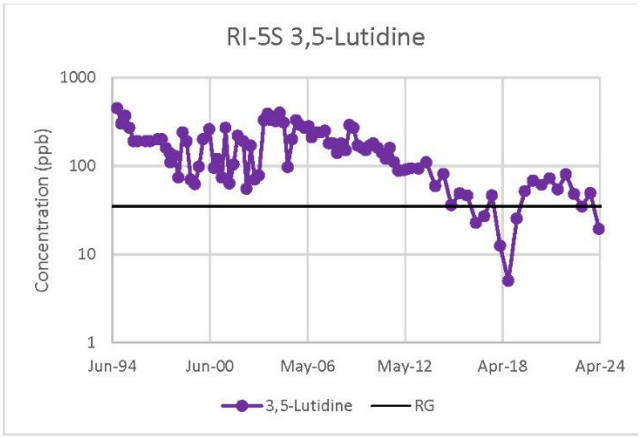


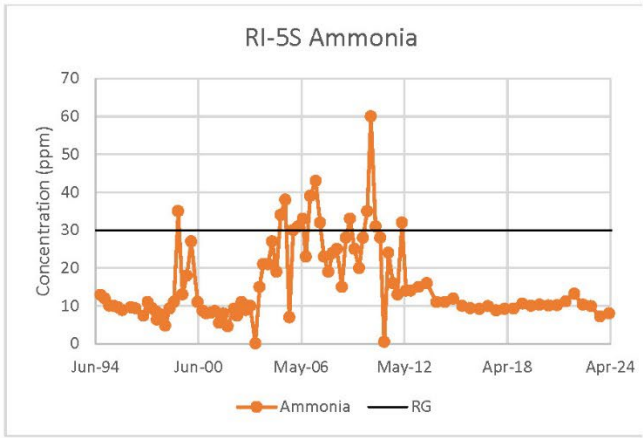

Annual Linear Regression Report – April 2024

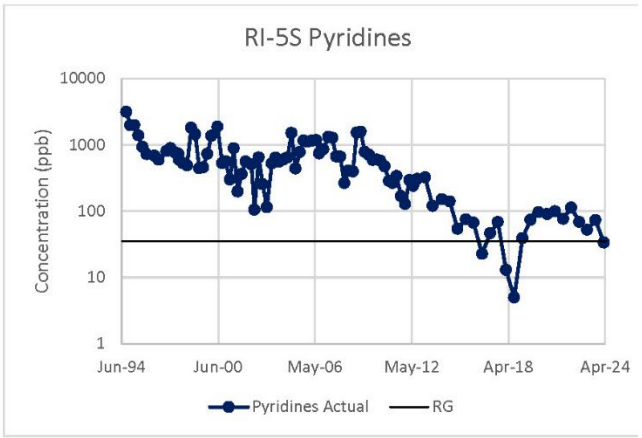
## OU1 PERIMETER WELLS
## RI-5S GRAPHICAL ANALYSIS

Note: Benzene and pyridine levels substantially decreased after sparging in this area. Ammonia is below the RG.



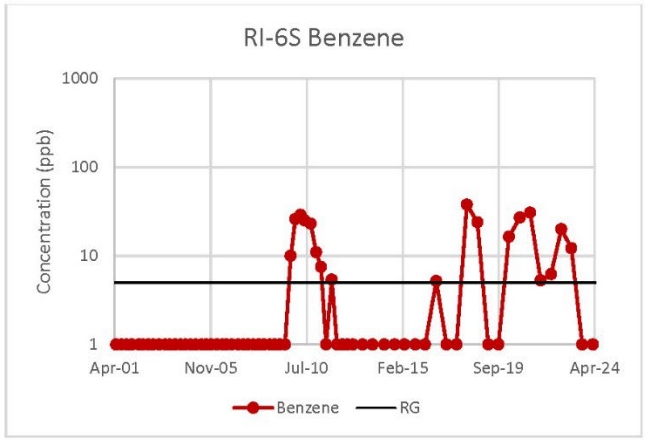



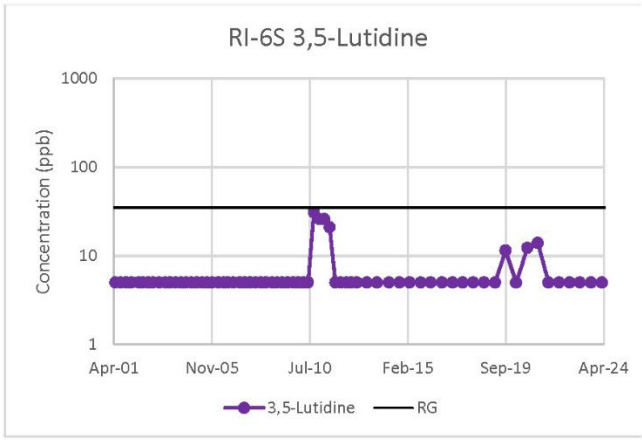



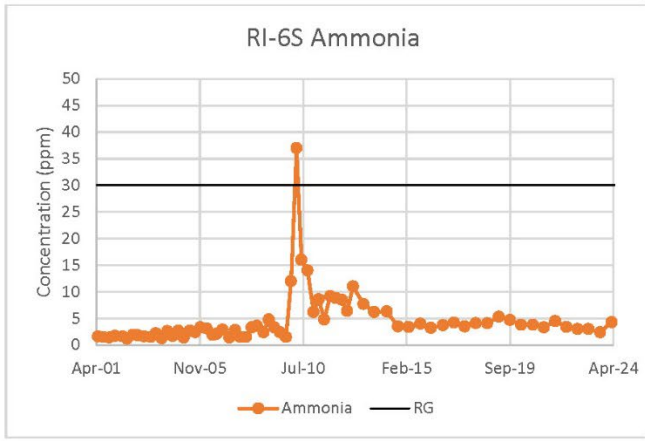



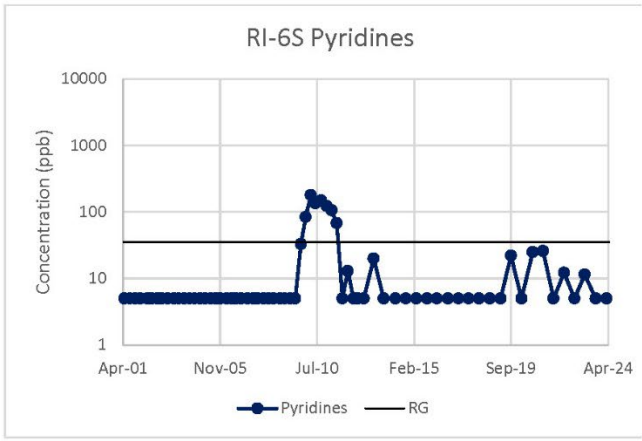
## OU1 PERIMETER WELLS
## RI-6S GRAPHICAL ANALYSIS

Note: Ammonia and pyridine levels are below the RGs; benzene increased above the RG.



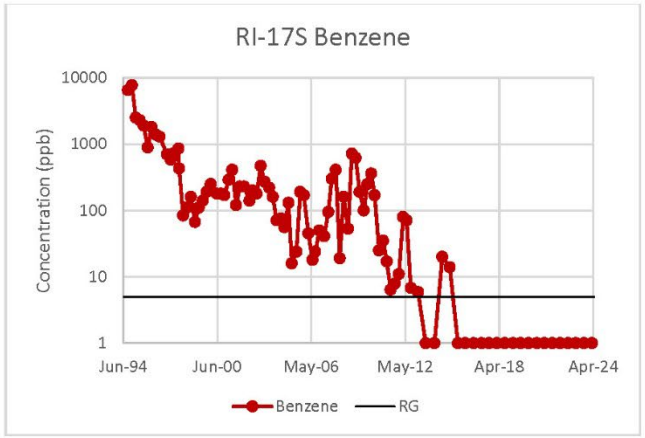



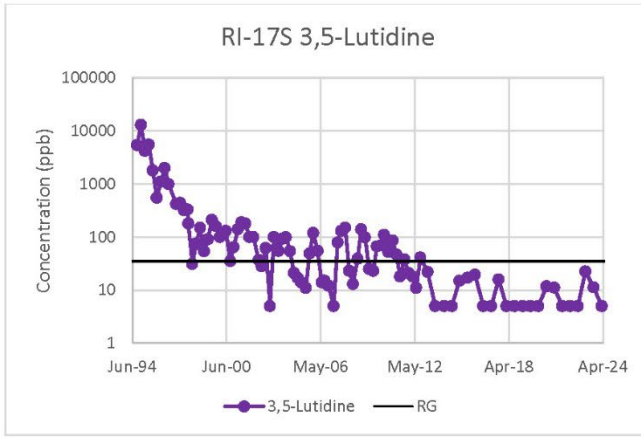



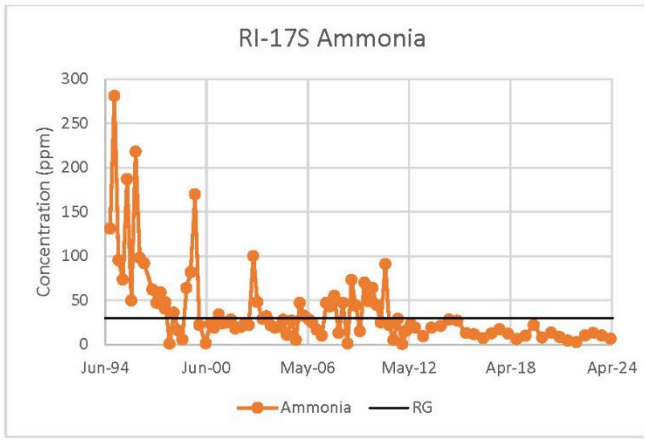



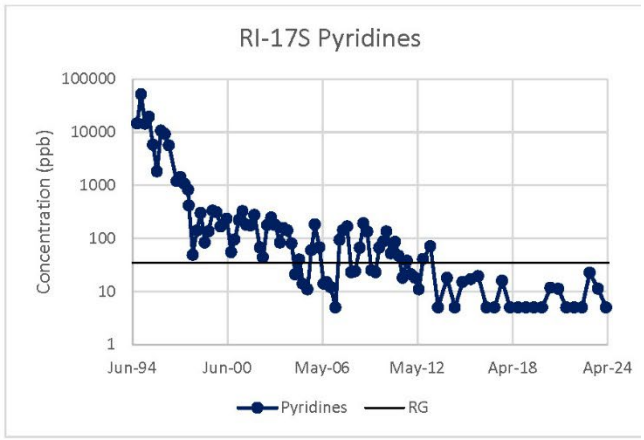
## OU1 PERIMETER WELLS
## RI-17S GRAPHICAL ANALYSIS

Note: Benzene, pyridines, and ammonia levels are below the RGs.



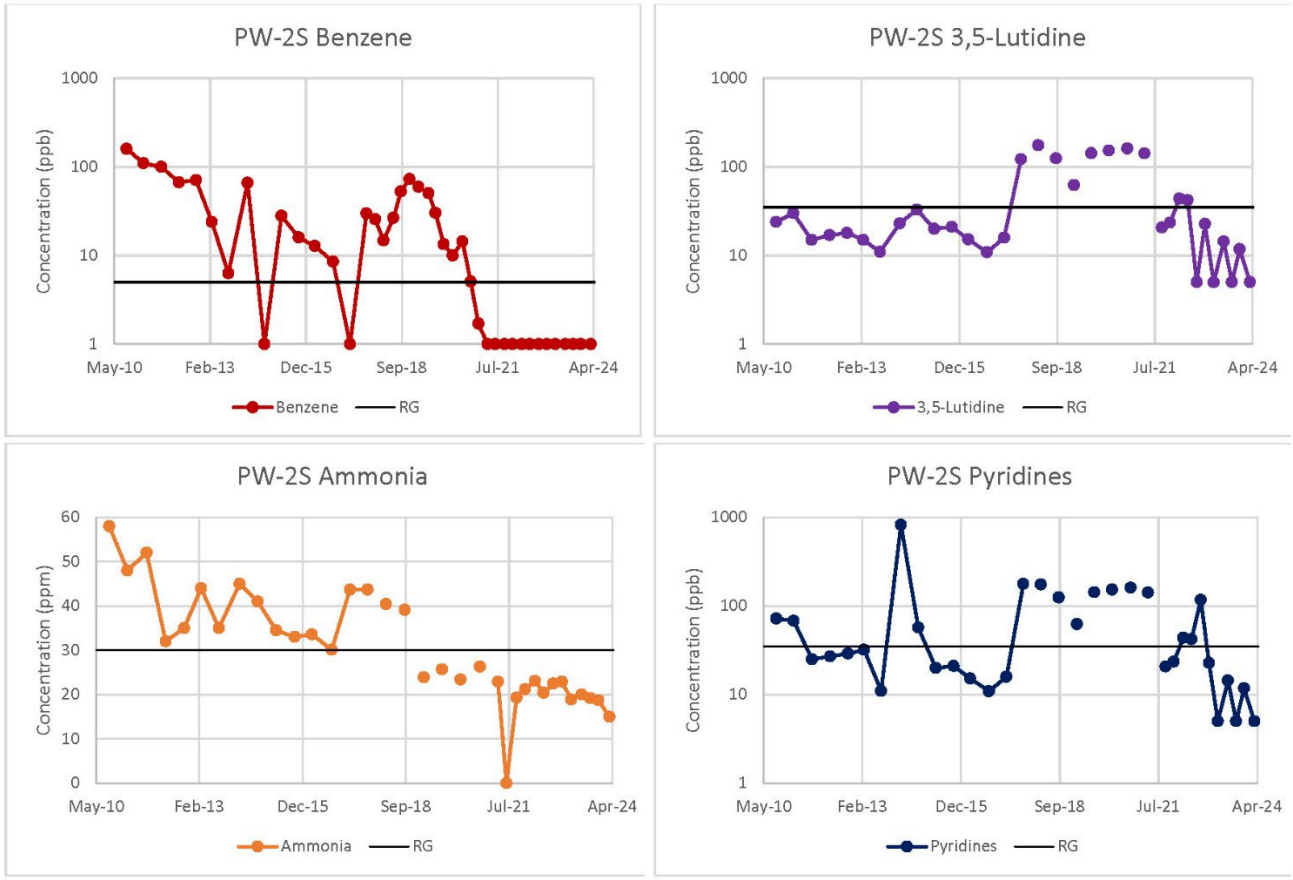



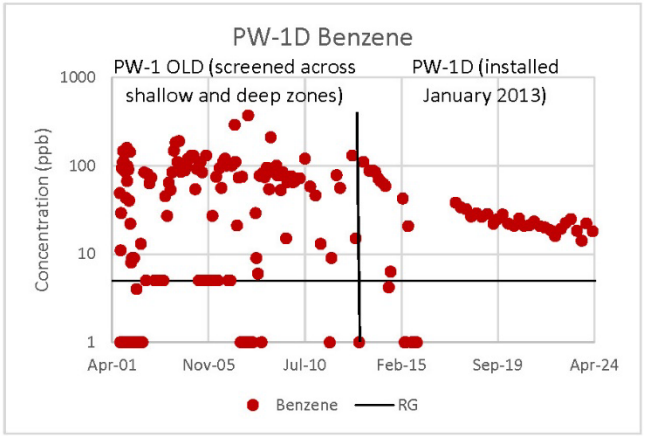
**OU1 PERIMETER WELLS**
**PW-2S GRAPHICAL ANALYSIS**

Note: Benzene, pyridines, and ammonia levels are below the RGs.



## OU1 PERIMETER WELLS
## PW-1D GRAPHICAL ANALYSIS

Note: Benzene levels measured for discharge compliance only. PW-1 Old was screened across shallow and deep zones. PW-1S and PW-1D were installed to replace PW-1 Old in January 2013. PW-1S has been non-detect and PW-1D concentrations are graphed.



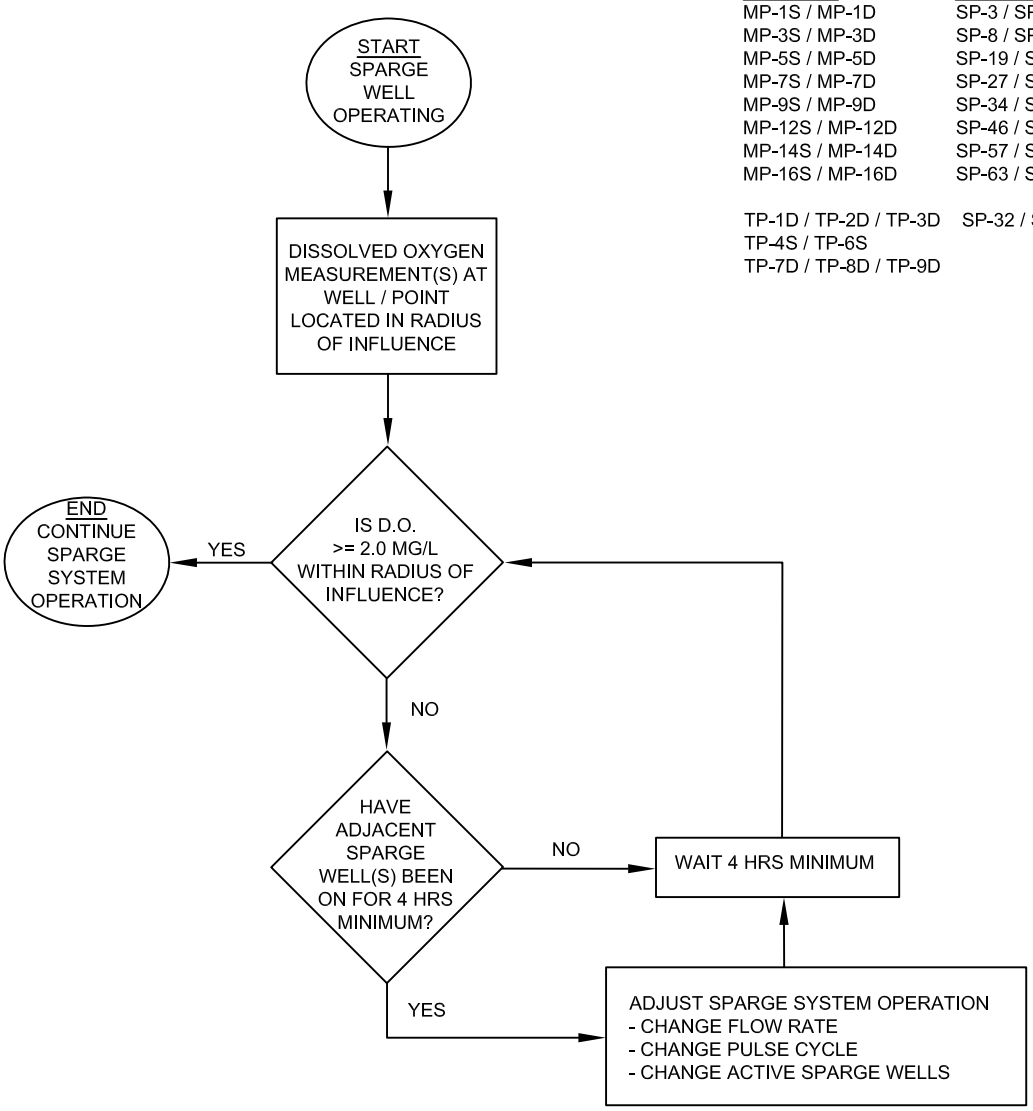
**Attachment H**

**Decision Diagrams**

1. Dissolved Oxygen Monitoring
2. Cessation of Pumping – Groundwater
3. Groundwater Monitoring Contingency Plan
4. Soil Gas Monitoring Contingency Plan
5. OU5 Groundwater Increase ≥3 Times Prior Result

**PERFORMANCE MONITORING WELL CLUSTERS**

| CLUSTER | ADJACENT SPARGE WELLS |
|---|---|
| MP-1S / MP-1D | SP-3 / SP-4 |
| MP-3S / MP-3D | SP-8 / SP-9 |
| MP-5S / MP-5D | SP-19 / SP-20 |
| MP-7S / MP-7D | SP-27 / SP-28 |
| MP-9S / MP-9D | SP-34 / SP-35 |
| MP-12S / MP-12D | SP-46 / SP-47 |
| MP-14S / MP-14D | SP-57 / SP-58 |
| MP-16S / MP-16D | SP-63 / SP-64 |
| TP-1D / TP-2D / TP-3D | SP-32 / SP-33 / SP-34 / SP-35 / SP-36 |
| TP-4S / TP-6S | |
| TP-7D / TP-8D / TP-9D | |




**NOTES**

1. DISSOLVED OXYGEN MEASURED AT EACH PERFORMANCE MONITORING CLUSTER USING A DO METER EQUIPPED WITH A PROBE DEPLOYED WITHIN THE SCREENED INTERVAL OF THE MONITORED LOCATION.

2. DO EVALUATION PERFORMED AFTER SPARGING HAS OCCURRED FOR AT LEAST 4 HOURS AT NEARBY SPARGE WELL THAT IS STILL SPARGING.

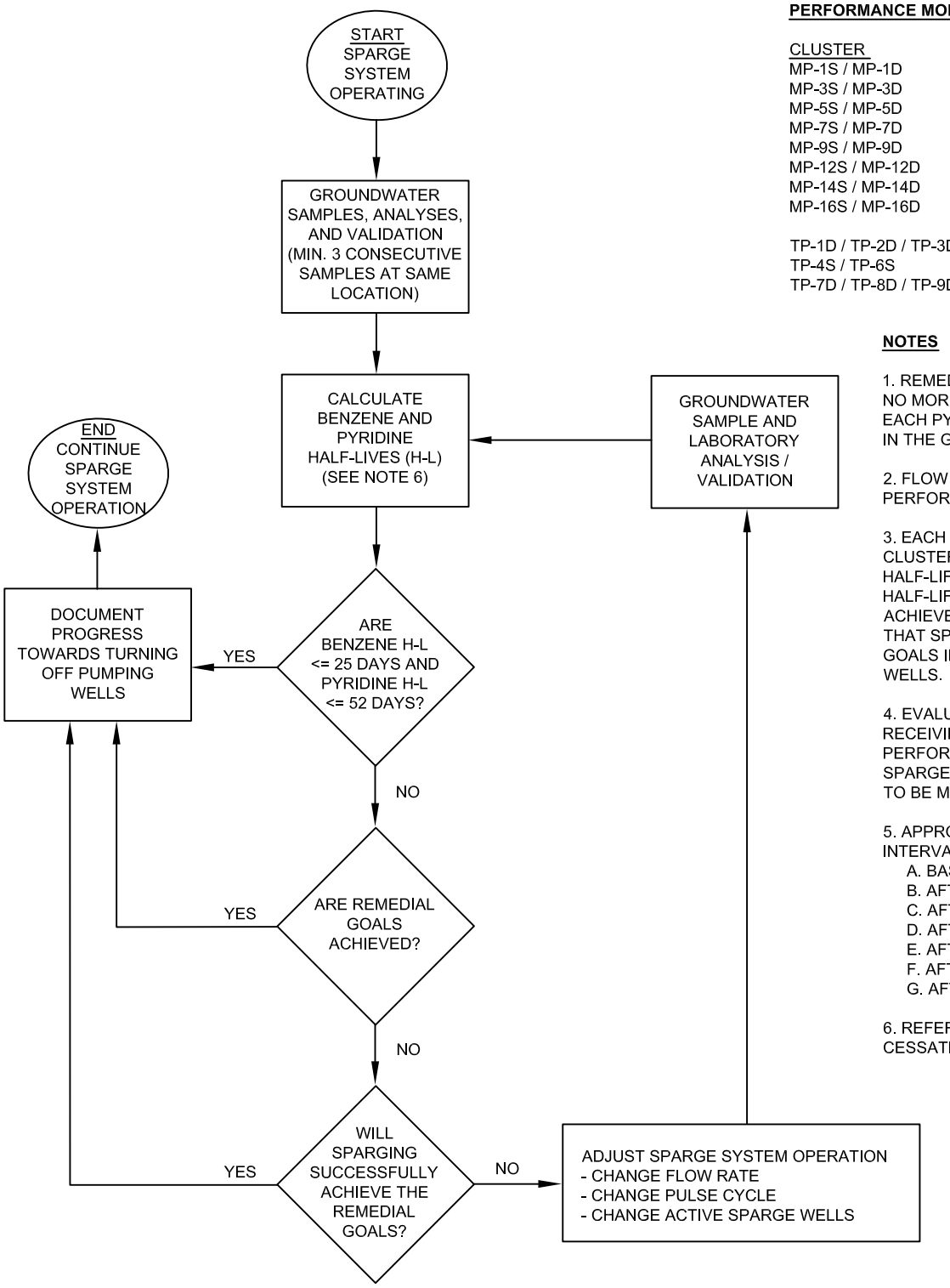
3. DO MONITORING OCCURS IN ONE DAY. IF ADJUSTMENTS ARE MADE TO SPARGE SYSTEM OPERATION, THEN DO MONITORING OCCURS DURING THE NEXT PULSE CYCLE.

4. REFERENCE: DATA QUALITY OBJECTIVE - BIOSPARGE SYSTEM OPTIMIZATION VIA DO MONITORING.

| REV. DATE: | DRAWING DATE: 05–16–2025 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

# DISSOLVED OXYGEN MONITORING DECISION DIAGRAM

| CLIENT: 1500 SOUTH TIBBS LLC | | | PM: DMP |
|---|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | | DRAWING: 1 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: RAWP/RD | |




**PERFORMANCE MONITORING WELL CLUSTERS**

| CLUSTER | ADJACENT SPARGE WELLS |
|---|---|
| MP-1S / MP-1D | SP-3 / SP-4 |
| MP-3S / MP-3D | SP-8 / SP-9 |
| MP-5S / MP-5D | SP-19 / SP-20 |
| MP-7S / MP-7D | SP-27 / SP-28 |
| MP-9S / MP-9D | SP-34 / SP-35 |
| MP-12S / MP-12D | SP-46 / SP-47 |
| MP-14S / MP-14D | SP-57 / SP-58 |
| MP-16S / MP-16D | SP-63 / SP-64 |
| TP-1D / TP-2D / TP-3D<br>TP-4S / TP-6S<br>TP-7D / TP-8D / TP-9D | SP-32 / SP-33 / SP-34 / SP-35 / SP-36 |

**NOTES**

1. REMEDIAL GOALS:
NO MORE THAN 5 µG/L (PPB) BENZENE, 35 PPB EACH PYRIDINE, AND 30 MG/L (PPM) AMMONIA IN THE GROUNDWATER.

2. FLOW CHART APPLIES TO EACH PERFORMANCE MONITORING CLUSTER.

3. EACH PERFORMANCE MONITORING CLUSTER MUST DEMONSTRATE A BENZENE HALF-LIFE <= 25 DAYS AND A PYRIDINE HALF-LIFE <= 52 DAYS FOR 2 INTERVALS, ACHIEVE THE REMEDIAL GOALS, OR PROVE THAT SPARGING WILL ACHIEVE THE REMEDIAL GOALS IN ORDER TO TURN OFF PUMPING WELLS.

4. EVALUATION PERFORMED WITHIN 5 DAYS OF RECEIVING ANALYTICAL RESULTS FROM PERFORMANCE MONITORING CLUSTERS. SPARGE SYSTEM ADJUSTMENTS, IF NEEDED, TO BE MADE WITHIN 5 DAYS OF EVALUATION.

5. APPROXIMATE GROUNDWATER SAMPLING INTERVALS:
   A. BASELINE, PRIOR TO SPARGING
   B. AFTER 30 DAYS OF SPARGING
   C. AFTER 60 DAYS OF SPARGING
   D. AFTER 120 DAYS OF SPARGING
   E. AFTER 180 DAYS OF SPARGING
   F. AFTER 240 DAYS OF SPARGING
   G. AFTER 300 DAYS OF SPARGING

6. REFERENCE: DATA QUALITY OBJECTIVE - CESSATION OF GROUNDWATER PUMPING.

| REV. DATE: | DRAWING DATE: 05–16–2025 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

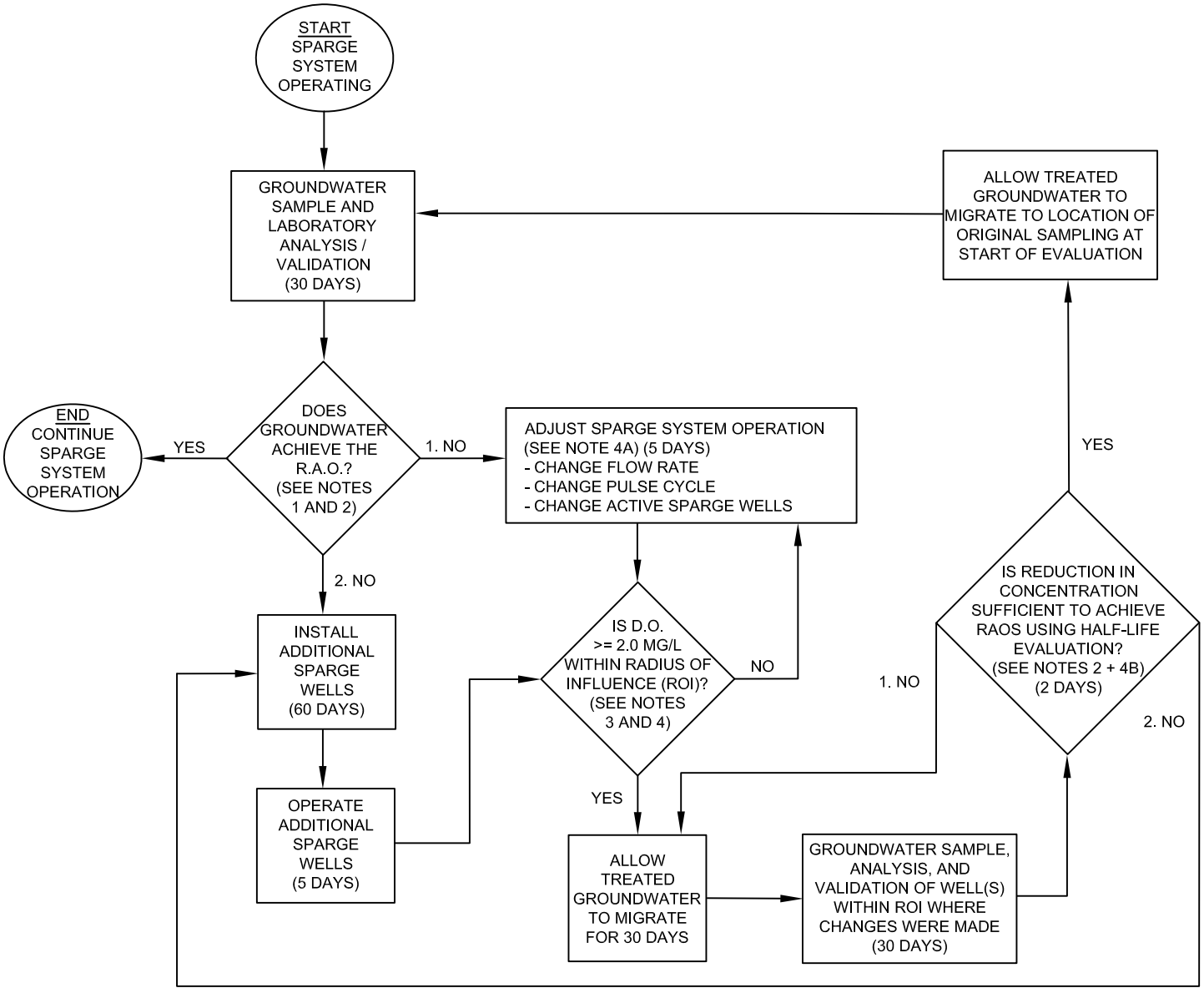
# CEASSATION OF PUMPING GROUNDWATER DECISION DIAGRAM

| CLIENT: 1500 SOUTH TIBBS LLC | | | PM: DMP |
|---|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | | DRAWING: 2 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: RAWP/RD | |

**NARRATIVE**

IT IS ANTICIPATED THAT BIOSPARGING WILL TREAT BENZENE AND PYRIDINES CONCENTRATIONS BELOW THE RG IN OU1 BEFORE GROUNDWATER MIGRATES INTO OU5. THERE ARE NUMEROUS MONITORING WELLS AND MONITORING POINTS THAT WILL BE USED TO CONFIRM THAT THIS OCCURS DURING OPERATION OF THE BIOSPARGE SYSTEM. HOWEVER, IF THIS DOES NOT OCCUR, THEN ADDITIONAL GROUNDWATER MONITORING ACTIONS WILL BE IMPLEMENTED. SUCH SEQUENTIAL ACTIONS INCLUDE:

1. CONFIRM THAT THE GROUNDWATER DATA IS VALID BY REVIEWING SAMPLING METHODS, FIELD DATA, AND LABORATORY DATA. IF THE DATA IS INVALID, THEN RESAMPLE.
2. IF VALID GROUNDWATER DATA EXCEEDS THE RG, THEN MODIFY THE SPARGE SYSTEM OPERATION BY CHANGING SPARGE FLOW RATES, CHANGING THE SPARGE OPERATIONAL PULSE CYCLE, AND/OR CHANGING SPARGE WELL OPERATION. OPERATE THE SPARGE WELLS AND MONITOR THE DO TO DETERMINE IF THE DO INCREASES TO AT LEAST 2.0 MG/L WITHIN THE SPARGE RADIUS OF INFLUENCE. IF THIS DOES NOT OCCUR, THEN CONTINUE TO MAKE CHANGES UNTIL THE DO LEVELS REACH AT LEAST 2.0 MG/L WHILE SPARGING.
3. CONTINUE TO OPERATE THE SPARGE WELLS IN THIS MANNER UNTIL TREATED GROUNDWATER HAS MIGRATED TO THE GROUNDWATER MONITORING LOCATION(S), AND THEN RESAMPLE FOR BENZENE AND PYRIDINES.
4. IF THE SAMPLES INDICATE THAT THE RG IS NOT ACHIEVED, THEN INSTALL AND OPERATE ADDITIONAL SPARGE WELLS AS APPROPRIATE BASED UPON MONITORED DATA.
5. AT ANY POINT IN THIS PROCESS, WHEN THE GROUNDWATER ACHIEVES THE RG, THEN RESPONSIVE GROUNDWATER SAMPLING WILL CEASE AND ROUTINE SCHEDULED GROUNDWATER SAMPLING WILL RESUME.




**NOTES**

1. R.A.O. = REMEDIAL ACTION OBJECTIVE, NO MORE THAN 5 µG/L (PPB) BENZENE, 35 PPB EACH PYRIDINE, AND 30 MG/L (PPM) AMMONIA BEYOND THE PROPERTY LINE.

2. DECISIONS 1 AND 2 INDICATE EACH PROGRESSIVE TIME EXCEEDING THE REMEDIAL ACTION OBJECTIVE.

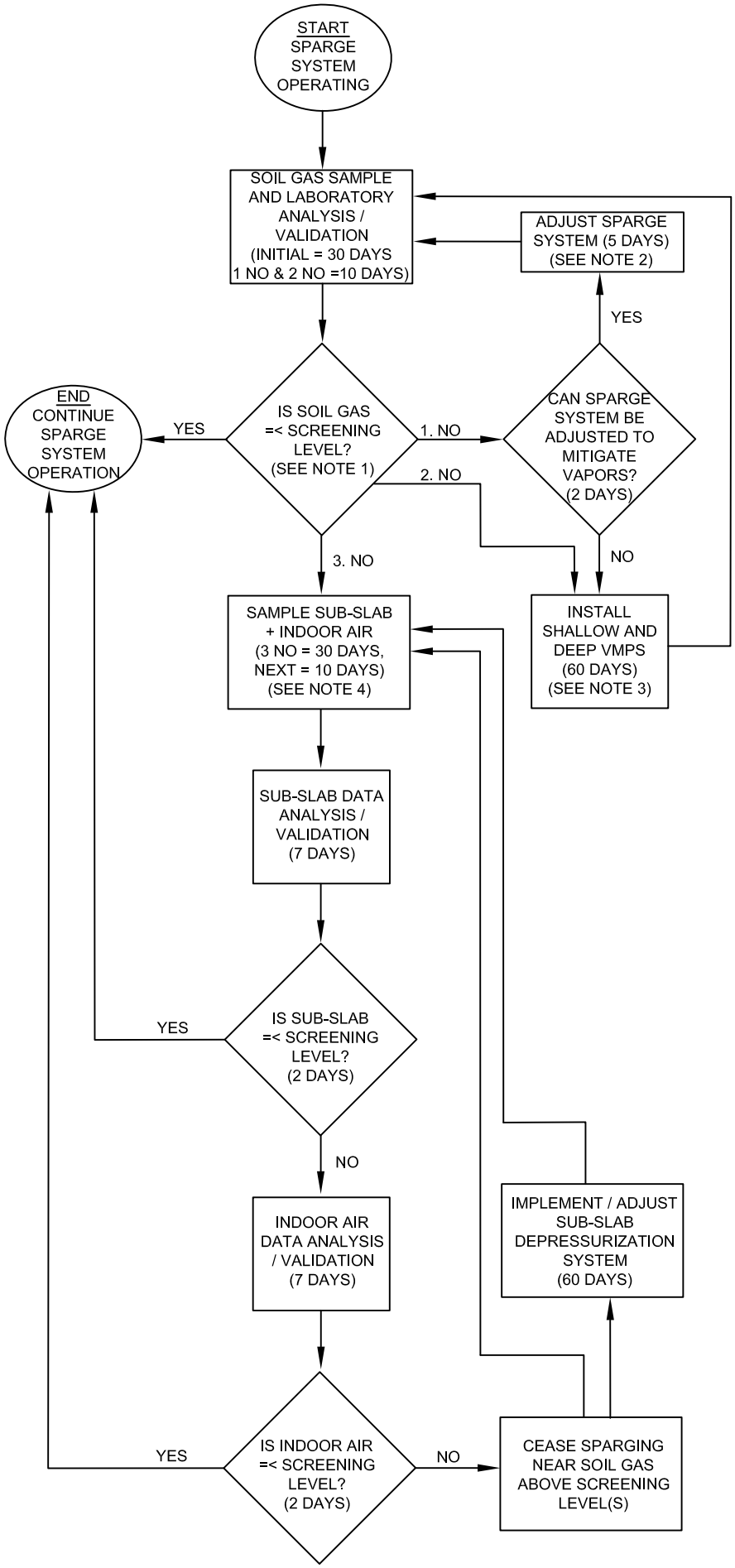
3. DO MONITORING OCCURS IN ONE DAY. IF ADJUSTMENTS ARE MADE TO SPARGE SYSTEM OPERATION, THEN DO MONITORING OCCURS DURING THE NEXT PULSE CYCLE.

4. REFERENCES:
   A. DATA QUALITY OBJECTIVE - BIOSPARGE SYSTEM OPTIMIZATION VIA DO MONITORING.
   B. DATA QUALITY OBJECTIVE - CESSATION OF GROUNDWATER PUMPING.

| REV. DATE: | DRAWING DATE: 05–16–2025 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

# GROUNDWATER MONITORING CONTINGENCY PLAN DECISION DIAGRAM

| CLIENT: 1500 SOUTH TIBBS LLC | | | PM: DMP |
|---|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | | DRAWING: 3 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: RAWP/RD | |




**NARRATIVE**

IF SOIL GAS COLLECTED FROM ANY OF THE VAPOR MONITORING POINTS (VMPS) EXCEEDS AN APPLICABLE SCREENING LEVEL, THEN ADDITIONAL MONITORING ACTIONS WILL BE IMPLEMENTED. SUCH SEQUENTIAL ACTIONS INCLUDE:

1. CONFIRM THAT THE SOIL GAS DATA IS VALID BY REVIEWING SAMPLING METHODS, FIELD DATA, AND LABORATORY DATA. PROMPTLY RESAMPLE IF DATA IS INVALID WITH RUSH 72 HR LABORATORY ANALYSIS.

2. IF THE SOIL GAS RESAMPLE IS ABOVE THE SCREENING LEVEL, AND THE SPARGE SYSTEM CAN BE ADJUSTED, THEN ADJUST THE SPARGE SYSTEM AND PROMPTLY RESAMPLE WITH RUSH 72 HR LABORATORY ANALYSIS. ADJUSTING THE SPARGE SYSTEM MAY CONSIST OF CHANGING THE SPARGE FLOW RATE, SPARGE WELL OPERATIONAL CYCLE, AND/OR CHANGING ACTIVE SPARGE WELLS.

3. IF THE SOIL GAS SAMPLE FOLLOWING SPARGE ADJUSTMENTS EXCEEDS CRITERIA, OR ADJUSTMENTS COULD NOT BE MADE TO THE SPARGE SYSTEM, THEN INSTALL PAIR(S) OF SHALLOW AND DEEP VMPS BETWEEN THE ELEVATED SOIL GAS AND THE RECEPTOR. IF VMPS ARE PLANNED TO BE INSTALLED OFF-SITE, PROMPTLY PROCURE OFF-SITE ACCESS AGREEMENT(S) WITH PROPERTY OWNER(S). PROMPTLY SAMPLE SOIL GAS IN THE ORIGINAL VMPS THAT EXCEEDED THE SCREENING LEVEL AND THE NEW VMPS WITH RUSH 72 HR LABORATORY ANALYSIS.

4. IF THE SOIL GAS IN THE NEW VMPS EXCEEDS THE SCREENING LEVEL, THEN PROCEED TO SAMPLE THE RECEPTOR, WHICH IS PRESUMED TO BE A DWELLING. SAMPLE THE SUB-SLAB OF THE DWELLING AND THE INDOOR AIR. THE SUB-SLAB SAMPLE WILL BE ANALYZED FIRST WITH RUSH 72 HR LABORATORY ANALYSIS, AND IF IT IS BELOW THE SCREENING LEVEL, THEN THE INDOOR AIR WILL NOT BE ANALYZED. IF THE SUB-SLAB SAMPLE EXCEEDS THE SCREENING LEVEL, THEN THE INDOOR AIR SAMPLE WILL BE ANALYZED WITH RUSH 72 HR LABORATORY ANALYSIS.

5. IF THE INDOOR AIR SAMPLE EXCEEDS THE SCREENING LEVEL, THEN CEASE SPARGING NEAR SOIL GAS EXCEEDING THE SCREENING LEVEL, AND IMPLEMENT OR ADJUST A SUB-SLAB DEPRESSURIZATION (SSD) SYSTEM. PROCEED TO STEP 4 AFTER SPARGING CEASES. ONCE THE SSD SYSTEM IS IMPLEMENTED, THEN PROCEED TO STEP 4.

6. AT ANY POINT IN THIS PROCESS, WHEN THE SOIL GAS OR INDOOR AIR ACHIEVES THE SCREENING LEVEL, THE RESPONSIVE SAMPLING WILL CEASE AND SCHEDULED SAMPLING WILL RESUME. IF A SUB-SLAB DEPRESSURIZATION SYSTEM HAS BEEN IMPLEMENTED, THEN OPERATION, MAINTENANCE, AND MONITORING (INDOOR AIR) WILL PROCEED AS DESCRIBED IN THE SUB-SLAB DEPRESSURIZATION SYSTEM OPERATION AND MONITORING PLAN.

**NOTES**

1. DECISIONS 1, 2, AND 3 INDICATE EACH PROGRESSIVE TIME EXCEEDING THE SOIL GAS SCREENING LEVEL.

2. SPARGE SYSTEM ADJUSTMENT OPTIONS
   A. CHANGE AIR FLOW RATE
   B. CHANGE WELL OPERATIONAL CYCLE
   C. CHANGE ACTIVE SPARGE WELLS

3. ADDITIONAL SHALLOW AND DEEP VMPS SHALL BE INSTALLED TO DELINEATE THE EXTENT OF THE VAPOR PLUME TOWARDS RECEPTOR(S) IF SOIL GAS EXCEEDS SCREENING LEVELS AT ORIGINAL SOIL GAS MONITORING LOCATIONS AFTER ADJUSTING THE SPARGE SYSTEM OPERATION .

4. SUB-SLAB AND INDOOR AIR MONITORING SHALL BE COMPLETED IF ADDITIONAL VMPS DO NOT DELINEATE THE EXTENT OF THE VAPOR PLUME.

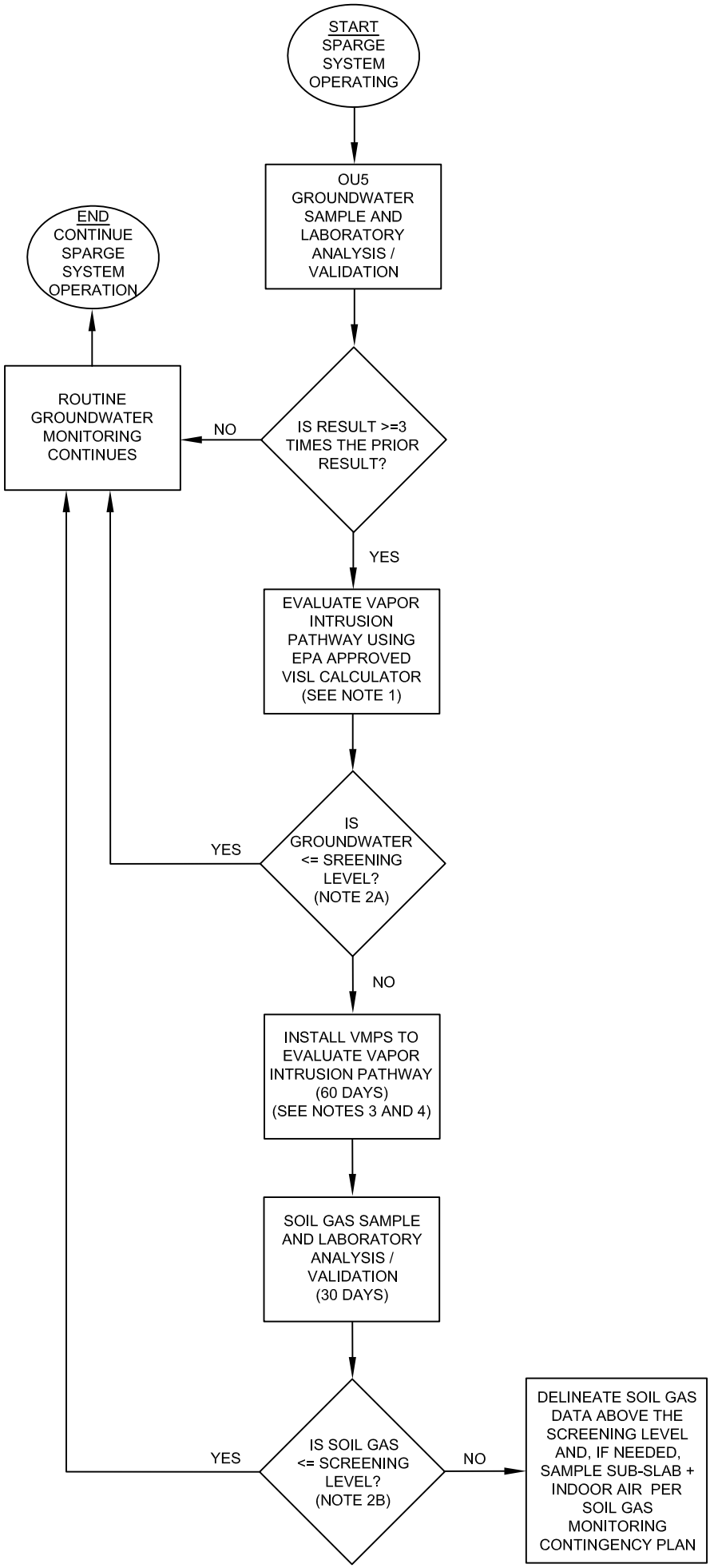
5. TIME TO PROCURE OFF-SITE ACCESS AUTHORIZATION IS NOT INCLUDED.

6. REFERENCE: DATA QUALITY OBJECTIVE - SOIL GAS VAPOR INTRUSION EVALUATION

| REV. DATE: | DRAWING DATE: 05–16–2025 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

# SOIL GAS MONITORING CONTINGENCY PLAN DECISION DIAGRAM

| CLIENT: 1500 SOUTH TIBBS LLC | | | PM: DMP |
|---|---|---|---|
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | | | DRAWING: 4 |
| DESIGNED: DMP | DETAILED: DMP | PROJECT NO.: RAWP/RD | |




**NOTES**

1. GROUNDWATER TO VAPOR INTRUSION PATHWAY EVALUATED USING VALIDATED DATA AND THE EPA VAPOR INTRUSION SCREENING LEVEL (VISL) CALCULATOR.

2. REFERENCES:
   A. DATA QUALITY OBJECTIVE - GROUNDWATER VAPOR INTRUSION EVALUATION
   B. DATA QUALITY OBJECTIVE - SOIL GAS VAPOR INTRUSION EVALUATION

3. TIME TO PROCURE OFF-SITE ACCESS AUTHORIZATION IS NOT INCLUDED.

4. OU5 MONITORING WELLS ARE >450 FT FROM BIOSPARGE WELLS. THEREFORE, THERE IS NO BIOSPARGE SYSTEM ADJUSTMENT THAT CAN BE MADE TO QUICKLY REDUCE GROUNDWATER CONCENTRATIONS AT A MONITORING WELL IN OU5, IF NEEDED. AS A RESULT, IF THE GROUNDWATER TO VAPOR INTRUSION PATHWAY COULD BE COMPLETE (AS INDICATED BY THE VISL CALCUALTOR), THEN VMPS NEED TO BE INSTALLED TO DELINEATE THE VAPOR PLUME RATHER THAN MAKE ADJUSTMENTS TO THE BIOSPARGE SYSTEM.

| REV. DATE: | DRAWING DATE: 05-16-2025 | ACAD FILE: INDY PLANT.DWG |
|---|---|---|

# OU5 GROUNDWATER INCREASE >=3 TIMES PRIOR RESULT DECISION DIAGRAM

| CLIENT: | PM: |
|---|---|
| 1500 SOUTH TIBBS LLC | DMP |
| LOCATION: 1500 S. TIBBS AVE. INDIANAPOLIS, INDIANA | DRAWING: 5 |

| DESIGNED: | DETAILED: | PROJECT NO.: |
|---|---|---|
| DMP | DMP | RAWP/RD |

**Attachment I**

**Data Quality Objectives**

1. Biosparge Well Depth and Spacing
2. Investigation Derived Waste and Surplus Excavated Soil Collection and Characterization
3. Biosparge Well Performance Testing
4. Biosparge Pipe Pressure Testing
5. Proper Biosparge System Operation
6. Biosparge System Optimization via Dissolved Oxygen Monitoring
7. Soil Gas Vapor Intrusion Evaluation
8. Cessation of Groundwater Pumping
9. OU5 Groundwater Evaluation
10. Groundwater Vapor Intrusion Evaluation

# Data Quality Objective:
# Biosparge Well Depth and Spacing

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) Biosparge Well Depth and Spacing

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1. State the Problem

A total of 73 sparge wells are planned to be installed over a distance of approximately 2,750 feet as a barrier to treat groundwater before it migrates off-site. Over this distance wells have been installed at seven general locations (RI-3, RI-17, PW-2, RI-4, PW-1, RI-5, and RI-6) between 1989 and 2003 using dual tube drilling with reverse air (air core drilling at RI-3, RI-4, RI-5 and RI-6), hollow stem augers (RI-17), and cable tool methods (PW-1 and PW-2). The sparge wells are designed to be installed to a target depth to achieve the design radius of influence. Variability between existing locations and the means and methods of installing older wells could result in a different geology than planned (i.e. depth of competent clay and/or bedrock). As a result, the depths of the sparge wells may vary from design which may also affect the radius of influence and spacing between sparge wells. In turn, locations of sparge wells may be different than planned.

2. Identify the Goals of the Project

The goals of the project are to collect high quality soil geologic data to determine the actual depth of the sparge well that can be achieved at each location so that sparge wells are installed with an overlapping radius of influence so groundwater flows not less than 30 feet through the overlap area for groundwater treatment.

3. Identify Information Inputs

Information inputs include approximately 4-inch diameter soil cores generated from sonic drill rigs.

Each sparge well will be 2-inches in diameter and contain 3 feet of 0.010 inch slotted PVC screen at the bottom. The bottom of the screen shall not be set in competent clay nor bedrock.

4. Define the Boundaries of the Study

The boundaries of the study are from SP-1 to SP-73 as illustrated on the Remedial Design Drawings. The sparge wells run parallel to Tibbs Ave. from the northern property line to the southern solar farm. The deepest sparge well is designed to be a maximum of 61 feet below ground surface (ft bgs).

5. Develop the Analytic Approach

The analytic approach is to evaluate the 10 feet long soil cores generated from sonic drill rigs. A licensed professional geologist will evaluate each soil core and log the geology in accordance with the Unified Soil Classification System (USCS).

Soil cores will be advanced to the target depth as indicated on the Remedial Design Drawings. If competent clay or bedrock is encountered prior to achieving the target depth then the sparge well will be shallower than anticipated. If the clay or bedrock is not encountered, then the soil core may be advanced deeper and the sparge well may be installed deeper.

The spacing of sparge wells will be adjusted based upon the actual sparge well depth. If the sparge well depth is within three (3) feet of the target depth, then no adjustment will be made to the sparge radius of influence nor location of the adjacent sparge well.

Sparge wells SP-56 through SP-73 were designed based upon a target depth of 59 feet below ground surface (bgs) to be set in sand and gravel. In a meeting with the USEPA on March 31, 2025 it was determined that these wells should be installed to the nearest underlying lower permeability layer that contains silt. The Remedial Design Drawings were updated to reflect these deeper wells. The spacing between these sparge wells was not increased as a result of deeper wells. Therefore, if the underlying lower permeability silt is encountered at a shallower depth, but at least 56 feet bgs (59 ft – 3 ft = 56 ft), then no adjustment to the sparge well spacing is needed.

If the depth of the sparge well is >3 feet **shallower** than the design depth, then the following procedures will be taken to determine the location of the adjacent sparge well(s). Table 1 contains the design depth and radius of influence for each sparge well.

a. Given: Sparge well design depth = $D_d$ and sparge well design radius of influence = $ROI_d$
b. Utilize the sparge well installed depth = $D_i$ to calculate the installed radius of influence = $ROI_i$
c. Calculate: $ROI_i = ROI_d – (D_d – D_i – 3\ ft) \times 0.75$
d. Given: Adjacent well design radius of influence = $ROI_a$
e. Calculate well spacing = S while allowing for overlap such that the east-west distance of overlap for wells that are separated north-south is a minimum of 30 feet to allow for treatment as groundwater passes through the sparge zone. $S = sqrt(ROI_i^2 - 225) + sqrt(ROI_a^2 - 225)$
f. Example:
    i. Sparge design depth, $D_d$ = 60 feet, sparge design radius of influence, $ROI_d$ = 28.94 feet
    ii. Installed sparge depth, $D_i$ = 54 feet. Since more than 3 feet different, calculate new spacing.
    iii. Calculate: $ROI_i = 29.84\ ft – (60\ ft – 54\ ft – 3\ ft) \times 0.75 = 27.59$ feet
    iv. Adjacent sparge well radius of influence, $ROI_a$ = 29.31 feet
    v. Calculate spacing to adjacent sparge well = $sqrt(27.59^2 – 225) + sqrt(29.31^2 – 225) = 48.33$ feet

If the depth of the sparge well is >3 feet **deeper** than the design depth, then the following procedures will be taken to determine the location of the adjacent sparge well(s). Table 1 contains the design depth and radius of influence for each sparge well.

a. Given: Sparge well design depth = $D_d$ and sparge well design radius of influence = $ROI_d$
b. Utilize the sparge well installed depth = $D_i$ to calculate the installed radius of influence = $ROI_i$
c. Calculate: $ROI_i = ROI_d + (D_i – D_d – 3\ ft) \times 0.75$
d. Given: Adjacent well design radius of influence = $ROI_a$
e. Calculate well spacing = S while allowing for overlap such that the east-west distance of overlap for wells that are separated north-south is a minimum of 30 feet to allow for treatment as groundwater passes through the sparge zone. $S = sqrt(ROI_i^2 – 225) + sqrt(ROI_a^2 – 225)$
f. Example:
    i. Sparge design depth, $D_d$ = 60 feet, sparge design radius of influence, $ROI_d$ = 28.94 feet
    ii. Installed sparge depth, $D_i$ = 66 feet. Since more than 3 feet different, calculate new spacing.
    iii. Calculate: $ROI_i = 29.84\ ft + (66\ ft – 60\ ft – 3\ ft) \times 0.75 = 32.84$ feet
    iv. Adjacent sparge well radius of influence, $ROI_a$ = 29.31 feet
    v. Calculate spacing to adjacent sparge well = $sqrt(32.84^2 – 225) + sqrt(29.31^2 – 225) = 54.39$ feet

6. Specify Performance or Acceptance Criteria

The 10 feet long soil core recovery from the sonic drill rig is ≥80%. This applies to the sand, gravel, and clay lithology that exists.

Relocating a sparge well due to the presence of clay or bedrock that results in terminating a sparge well ≤20 feet above the target depth is acceptable. If it is >20 feet, then it constitutes a project major modification.

7. Develop the Plan for Obtaining Data

Data shall be obtained in accordance with the Construction Quality Assurance and Quality Control Plan (CQA/CP).

Prior to installing sparge wells, 17 pairs of nested groundwater monitoring points (one shallow and one deep) and 8 temporary groundwater monitoring points will be installed near the sparge barrier using a sonic drill rig. Soil cores from the deep points will be evaluated by a licensed professional geologist in accordance with the USCS. The final

depths of the groundwater monitoring points, coupled with data from the existing seven locations, will serve as a guide for sparge well depths.

The sonic drill rig will start installing sparge wells near a groundwater monitoring point. Sparge wells will continue to be installed sequentially, adjacent to one another, until they are all installed. Data will be collected on Form 1 – Field Drilling Log Form, Form 2 – Field Well Construction Form, and Form 3 – Sparge Well Spacing Calculation Form.

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(2) Supporting Documentation

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| List of Tables | List of Forms |
|---|---|
| Table 1 – Sparge Well Design Parameters | Form 1 – Field Drilling Log Form |
| Table 2 – Monitoring Locations and Depths | Form 2 – Field Well Construction Form |
| | Form 3 – Sparge Well Spacing Calculation Form |

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## Table 1

## Sparge Well Design Parameters

# Table 1 - Sparge Well Design Parameters

1500 South Tibbs LLC

May 16, 2025

| Sparge Well | Well Spacing (feet) | Total Distance (feet) | GW Elevation (ft ASL) | Bottom of Screen (ft ASL) | Saturated Thickness (feet) | Radius of Influence (feet) | Min. Depth to Bottom (ft BGS) |
|---|---|---|---|---|---|---|---|
| OU1 North of Minnesota Avenue (Oak Park Property) | | | | | | | |
| SP- 1 | 0 | 0 | 683.60 | 644.00 | 39.60 | 29.57 | 59 |
| SP- 2 | 41.4 | 41.4 | 683.56 | 644.00 | 39.56 | 29.53 | 59 |
| SP- 3 | 41.3 | 82.7 | 683.51 | 644.00 | 39.51 | 29.50 | 59 |
| SP- 4 | 41.3 | 124.0 | 683.47 | 644.00 | 39.47 | 29.47 | 59 |
| SP- 5 | 41.3 | 165.3 | 683.42 | 645.20 | 38.22 | 28.54 | 58 |
| SP- 6 | 40.0 | 205.3 | 683.38 | 646.40 | 36.98 | 27.61 | 57 |
| SP- 7 | 38.7 | 243.9 | 683.33 | 647.60 | 35.73 | 26.68 | 55 |
| SP- 8 | 37.4 | 281.3 | 683.29 | 648.80 | 34.49 | 25.75 | 54 |
| SP- 9 | 36.1 | 317.3 | 683.25 | 650.00 | 33.25 | 24.82 | 53 |
| SP- 10 | 34.8 | 352.1 | 683.20 | 651.20 | 32.00 | 23.89 | 52 |
| SP- 11 | 33.5 | 385.5 | 683.16 | 652.40 | 30.76 | 22.97 | 51 |
| SP- 12 | 32.2 | 417.7 | 683.11 | 653.60 | 29.51 | 22.04 | 49 |
| SP- 13 | 30.9 | 448.5 | 683.07 | 654.80 | 28.27 | 21.11 | 48 |
| SP- 14 | 29.6 | 478.1 | 683.02 | 656.00 | 27.02 | 20.18 | 47 |
| SP- 15 | 28.2 | 506.3 | 682.98 | 655.33 | 27.65 | 20.64 | 48 |
| SP- 16 | 28.9 | 535.2 | 682.94 | 654.67 | 28.27 | 21.11 | 48 |
| SP- 17 | 29.6 | 564.8 | 682.89 | 654.00 | 28.89 | 21.57 | 49 |
| SP- 18 | 30.2 | 595.0 | 682.85 | 653.33 | 29.51 | 22.04 | 50 |
| SP- 19 | 30.9 | 625.8 | 682.80 | 652.67 | 30.14 | 22.50 | 50 |
| SP- 20 | 31.5 | 657.3 | 682.76 | 652.00 | 30.76 | 22.97 | 51 |
| SP- 21 | 32.2 | 689.5 | 682.71 | 651.50 | 31.21 | 23.31 | 52 |
| SP- 22 | 32.6 | 722.1 | 682.67 | 651.00 | 31.67 | 23.65 | 52 |
| SP- 23 | 33.1 | 755.2 | 682.63 | 650.50 | 32.13 | 23.99 | 53 |
| SP- 24 | 33.6 | 788.8 | 682.58 | 650.00 | 32.58 | 24.33 | 53 |
| SP- 25 | 34.1 | 822.9 | 682.54 | 649.50 | 33.04 | 24.67 | 54 |
| SP- 26 | 34.5 | 857.4 | 682.49 | 649.00 | 33.49 | 25.01 | 54 |
| SP- 27 | 35.0 | 892.4 | 682.45 | 648.50 | 33.95 | 25.35 | 55 |
| SP- 28 | 35.5 | 927.9 | 682.40 | 648.00 | 34.40 | 25.69 | 55 |
| SP- 29 | 36.0 | 963.9 | 682.36 | 647.50 | 34.86 | 26.03 | 56 |
| SP- 30 | 36.4 | 1000.3 | 682.32 | 647.00 | 35.32 | 26.37 | 56 |
| SP- 31 | 36.9 | 1037.2 | 682.27 | 646.50 | 35.77 | 26.71 | 57 |
| SP- 32 | 37.4 | 1074.6 | 682.23 | 646.00 | 36.23 | 27.05 | 57 |
| SP- 33 | 37.9 | 1112.5 | 682.18 | 645.50 | 36.68 | 27.39 | 58 |
| SP- 34 | 38.3 | 1150.8 | 682.14 | 645.00 | 37.14 | 27.73 | 58 |
| SP- 35 | 38.8 | 1189.6 | 682.09 | 644.67 | 37.43 | 27.95 | 58 |
| SP- 36 | 39.1 | 1228.8 | 682.05 | 644.33 | 37.72 | 28.16 | 59 |
| SP- 37 | 39.4 | 1268.2 | 682.01 | 644.00 | 38.01 | 28.38 | 59 |
| SP- 38 | 39.7 | 1307.9 | 681.96 | 643.67 | 38.29 | 28.59 | 59 |

| Sparge Well | Well Spacing (feet) | Total Distance (feet) | GW Elevation (ft ASL) | Bottom of Screen (ft ASL) | Saturated Thickness (feet) | Radius of Influence (feet) | Min. Depth to Bottom (ft BGS) |
|---|---|---|---|---|---|---|---|
| OU1 South of Minnesota Avenue (Maywood Property) | | | | | | | |
| SP- 39 | 80.0 | 1387.9 | 681.92 | 643.33 | 38.58 | 28.81 | 60 |
| SP- 40 | 40.3 | 1428.3 | 681.87 | 643.00 | 38.87 | 29.03 | 60 |
| SP- 41 | 40.6 | 1468.9 | 681.83 | 642.67 | 39.16 | 29.24 | 60 |
| SP- 42 | 40.9 | 1509.8 | 681.78 | 642.33 | 39.45 | 29.46 | 61 |
| SP- 43 | 41.2 | 1551.1 | 681.74 | 642.00 | 39.74 | 29.67 | 61 |
| SP- 44 | 41.5 | 1592.6 | 681.70 | 642.20 | 39.50 | 29.49 | 61 |
| SP- 45 | 41.3 | 1633.9 | 681.65 | 642.40 | 39.25 | 29.31 | 61 |
| SP- 46 | 41.0 | 1674.9 | 681.61 | 642.60 | 39.01 | 29.13 | 60 |
| SP- 47 | 40.8 | 1715.7 | 681.56 | 642.80 | 38.76 | 28.94 | 60 |
| SP- 48 | 40.5 | 1756.2 | 681.52 | 643.00 | 38.52 | 28.76 | 60 |
| SP- 49 | 40.3 | 1796.5 | 681.47 | 643.20 | 38.27 | 28.58 | 60 |
| SP- 50 | 40.0 | 1836.5 | 681.43 | 643.40 | 38.03 | 28.40 | 60 |
| SP- 51 | 39.8 | 1876.3 | 681.39 | 643.60 | 37.79 | 28.21 | 59 |
| SP- 52 | 39.5 | 1915.8 | 681.34 | 643.80 | 37.54 | 28.03 | 59 |
| SP- 53 | 39.2 | 1955.0 | 681.30 | 644.00 | 37.30 | 27.85 | 59 |
| SP- 54 | 39.0 | 1994.0 | 681.25 | 644.00 | 37.25 | 27.82 | 59 |
| SP- 55 | 38.9 | 2032.9 | 681.21 | 644.00 | 37.21 | 27.78 | 59 |
| SP- 56 | 38.9 | 2071.8 | 681.16 | 644.00 | 37.16 | 27.75 | 59 |
| SP- 57 | 38.8 | 2110.7 | 681.12 | 644.00 | 37.12 | 27.72 | 59 |
| SP- 58 | 38.8 | 2149.5 | 681.08 | 644.00 | 37.08 | 27.68 | 59 |
| SP- 59 | 38.8 | 2188.2 | 681.03 | 644.00 | 37.03 | 27.65 | 59 |
| SP- 60 | 38.7 | 2226.9 | 680.99 | 644.00 | 36.99 | 27.62 | 59 |
| SP- 61 | 38.7 | 2265.6 | 680.94 | 644.00 | 36.94 | 27.58 | 59 |
| SP- 62 | 38.6 | 2304.2 | 680.90 | 644.00 | 36.90 | 27.55 | 59 |
| SP- 63 | 38.6 | 2342.8 | 680.85 | 644.00 | 36.85 | 27.52 | 59 |
| SP- 64 | 38.5 | 2381.3 | 680.81 | 644.00 | 36.81 | 27.48 | 59 |
| SP- 65 | 38.5 | 2419.8 | 680.77 | 644.00 | 36.77 | 27.45 | 59 |
| SP- 66 | 38.4 | 2458.2 | 680.72 | 644.00 | 36.72 | 27.42 | 59 |
| SP- 67 | 38.4 | 2496.6 | 680.68 | 644.00 | 36.68 | 27.39 | 59 |
| SP- 68 | 38.3 | 2535.0 | 680.63 | 644.00 | 36.63 | 27.35 | 59 |
| SP- 69 | 38.3 | 2573.2 | 680.59 | 644.00 | 36.59 | 27.32 | 59 |
| SP- 70 | 38.2 | 2611.5 | 680.54 | 644.00 | 36.54 | 27.29 | 59 |
| SP- 71 | 38.2 | 2649.7 | 680.50 | 644.00 | 36.50 | 27.25 | 59 |
| SP- 72 | 38.2 | 2687.9 | 680.46 | 644.00 | 36.46 | 27.22 | 59 |
| SP- 73 | 38.1 | 2726.0 | 680.41 | 644.00 | 36.41 | 27.19 | 59 |
| Radius of Influence / Saturated Thickness = | | | | | | 1.4 | |
| Factor of Safety | | | | | | 1.875 (=1.5 x 1.25) | |
| Radius of Influence / Saturated Thickness Used = | | | | | | 0.75 | |

## Table 2

## Monitoring Locations and Depths

# Table 2 - Monitoring Locations and Depths

1500 South Tibbs LLC

May 16, 2025

### OU1 Barrier Monitoring Wells

| Monitoring Location | Operating Unit | IN East 1301 Grid System Easting | Northing | Top of Casing (ft ASL) | Screen Interval (ft BGS) |
|---|---|---|---|---|---|
| RI-17S | OU1 | 173528 | 1638419 | 699.69 | 13.5-23.5 |
| PW-2S | OU1 | 173512 | 1638230 | 700.81 | 23-25 |
| RI-4S | OU1 | 173515 | 1637705 | 700.68 | 18-28 |
| RI-4D | OU1 | 173515 | 1637688 | 700.69 | 45-55 |
| PW-1S | OU1 | 173490 | 1637371 | 705.67 | 27-31 |
| PW-1D | OU1 | 173499 | 1637354 | 705.37 | 53-58 |
| RI-5S | OU1 | 173583 | 1636959 | 703.24 | 46-56 |
| RI-6S | OU1 | 173569 | 1636267 | 703.09 | 24-34 |

### OU1 / OU5 Shallow Aquifer Monitoring

| Monitoring Location | Operating Unit | IN East 1301 Grid System Easting | Northing | Top of Casing (ft ASL) | Screen Interval (ft BGS) |
|---|---|---|---|---|---|
| PW-1 OLD | OU1 | 173525 | 1637340 | 704.81 | 31-66 |
| RI-1S | OU1 | 172238 | 1637556 | 710.15 | 20-30 |
| RI-2S | OU1 | 172884 | 1638807 | 706.46 | 16-36 |
| RI-3S | OU1 | 173229 | 1638829 | 703.91 | 18-28 |
| RI-8S | OU1 | 173537 | 1634886 | 702.24 | 26-36 |
| RI-10S | OU5 | 174157 | 1639338 | 698.65 | 19-29 |
| RI-11S | OU5 | 174929 | 1638237 | 701.96 | 27-37 |
| RI-15S | OU5 | 174082 | 1638871 | 699.17 | 18-28 |
| RI-18S | OU1 | 172999 | 1637559 | 705.98 | 14.5-24.5 |
| RI-19S | OU5 | 174298 | 1636956 | 697.00 | 19.5-34.5 |
| RI-20S | OU5 | 173725 | 1634877 | 699.18 | 21.5-31.5 |
| RI-23S | OU1 | 172300 | 1635157 | 706.97 | 18-28 |
| RI-24S | OU1 | 172313 | 1636429 | 705.70 | 18-28 |
| RI-25S | OU1 | 172749 | 1638611 | 709.43 | 16.5-26.5 |
| RI-28S | OU1 | 172792 | 1637070 | 704.78 | 18.5-28.5 |
| RI-29S | OU1 | 172906 | 1637013 | 706.03 | 20-30 |
| RI-30S | OU1 | 172913 | 1636921 | 705.59 | 18-28 |
| RI-31S | OU1 | 172877 | 1636292 | 707.48 | 20-30 |
| RI-32S | OU1 | 172998 | 1636249 | 706.32 | 20-30 |
| RI-33S | OU1 | 173080 | 1636254 | 703.69 | 17.5-27.5 |
| RI-35S | OU1 | 173456 | 1636182 | 702.02 | 21-31 |
| RI-42RS | OU5 | 174215 | 1637510 | TBD | 25-35 |
| RI-43S | OU5 | 174265 | 1638265 | TBD | 20-30 |
| RI-44S | OU5 | 173967 | 1638539 | TBD | 25-35 |
| RI-45S | OU5 | 173984 | 1636674 | TBD | 25-35 |

### OU1 Deep / OU5 Medium Aquifer Monitoring

| Monitoring Location | Operating Unit | IN East 1301 Grid System Easting | Northing | Top of Casing (ft ASL) | Screen Interval (ft BGS) |
|---|---|---|---|---|---|
| PW-2D | OU1 | 173503 | 1638216 | 701.35 | 29-44 |
| RI-1D | OU1 | 172222 | 1637556 | 710.12 | 45-55 |
| RI-2D | OU1 | 172875 | 1638785 | 707.18 | 44-54 |
| RI-3D | OU1 | 173213 | 1638830 | 703.98 | 52-57 |
| RI-10D | OU5 | 174141 | 1639338 | 698.73 | 79-89 |
| RI-11M | OU5 | 174929 | 1638254 | 701.85 | 45-55 |
| RI-15M | OU5 | 174110 | 1638871 | 699.28 | 44-54 |
| RI-17D | OU1 | 173527 | 1638406 | 699.77 | 34-44 |
| RI-19D | OU5 | 174283 | 1636956 | 696.72 | 36.5-46.5 |
| RI-20D | OU5 | 173741 | 1634878 | 699.08 | 44.5-54.5 |
| RI-23D | OU1 | 172299 | 1635142 | 706.89 | 58-68 |
| RI-24D | OU1 | 172313 | 1636443 | 708.79 | 32-42 |
| RI-25D | OU1 | 172749 | 1638597 | 709.32 | 47-57 |
| RR P8 MW-1 | OU5 | 175258 | 1635567 | 695.38 | Unknown |
| RR P8 MW-4 | OU5 | 175410 | 1635571 | 693.16 | Unknown |
| RI-42RM | OU5 | 174220 | 1637510 | TBD | 55-65 |
| RI-43M | OU5 | 174270 | 1638265 | TBD | 50-60 |
| RI-44M | OU5 | 173967 | 1638534 | TBD | 50-60 |
| RI-45M | OU5 | 173984 | 1636669 | TBD | 50-60 |

### OU5 Deep Aquifer Monitoring

| Monitoring Location | Operating Unit | IN East 1301 Grid System Easting | Northing | Top of Casing (ft ASL) | Screen Interval (ft BGS) |
|---|---|---|---|---|---|
| RI-5D | OU1 | 173568 | 1636959 | 703.82 | 72-82 |
| RI-11D | OU5 | 174928 | 1638222 | 701.99 | 87-97 |
| RI-15D | OU5 | 174096 | 1638871 | 699.60 | 79-89 |
| RR P8 PW-1 | OU5 | 174838 | 1636256 | 693.03 | 85-110 |
| RR P8 PW-2 | OU5 | 174813 | 1636576 | 691.98 | 104-114 |
| RR P8 PW-3 | OU5 | 174812 | 1636875 | 686.25 | 85-110 |
| RI-42RD | OU5 | 174225 | 1637510 | TBD | 80-90 |
| RI-43D | OU5 | 174275 | 1638265 | TBD | 80-90 |
| RI-44D | OU5 | 173967 | 1638529 | TBD | 80-90 |
| RI-45D | OU5 | 173984 | 1636664 | TBD | 80-90 |

### OU1 Groundwater Monitoring Points

| Monitoring Location | Operating Unit | IN East 1301 Grid System Easting | Northing | Top of Casing (ft ASL) | Screen Interval (ft BGS) |
|---|---|---|---|---|---|
| MP-1S | OU1 | 173397 | 1638750 | TBD | 15-25 |
| MP-1D | OU1 | 173397 | 1638745 | TBD | 49-59 |
| MP-2S | OU1 | 173559 | 1638750 | TBD | 15-25 |
| MP-2D | OU1 | 173559 | 1638745 | TBD | 49-59 |
| MP-3S | OU1 | 173470 | 1638558 | TBD | 15-25 |
| MP-3D | OU1 | 173470 | 1638553 | TBD | 44-54 |
| MP-4S | OU1 | 173560 | 1638558 | TBD | 15-25 |
| MP-4D | OU1 | 173560 | 1638553 | TBD | 44-54 |
| MP-5S | OU1 | 173473 | 1638212 | TBD | 16-26 |
| MP-5D | OU1 | 173473 | 1638207 | TBD | 41-51 |
| MP-6S | OU1 | 173562 | 1638212 | TBD | 16-26 |
| MP-6D | OU1 | 173562 | 1638207 | TBD | 41-51 |
| MP-7S | OU1 | 173503 | 1637945 | TBD | 16-26 |
| MP-7D | OU1 | 173503 | 1637940 | TBD | 45-55 |
| MP-8S | OU1 | 173565 | 1637945 | TBD | 16-26 |
| MP-8D | OU1 | 173565 | 1637940 | TBD | 45-55 |
| MP-9S | OU1 | 173476 | 1637695 | TBD | 16-26 |
| MP-9D | OU1 | 173476 | 1637690 | TBD | 48-58 |
| MP-10S | OU1 | 173566 | 1637706 | TBD | 16-26 |
| MP-10D | OU1 | 173566 | 1637701 | TBD | 48-58 |
| MP-11S | OU1 | 173580 | 1637424 | TBD | 18-28 |
| MP-11D | OU1 | 173580 | 1637429 | TBD | 50-60 |
| MP-12S | OU1 | 173520 | 1637175 | TBD | 19-29 |
| MP-12D | OU1 | 173520 | 1637170 | TBD | 50-60 |
| MP-13S | OU1 | 173580 | 1637175 | TBD | 19-29 |
| MP-13D | OU1 | 173580 | 1637170 | TBD | 50-60 |
| MP-14S | OU1 | 173520 | 1636748 | TBD | 20-30 |
| MP-14D | OU1 | 173520 | 1636743 | TBD | 49-59 |
| MP-15S | OU1 | 173580 | 1636748 | TBD | 20-30 |
| MP-15D | OU1 | 173580 | 1636743 | TBD | 49-59 |
| MP-16S | OU1 | 173520 | 1636520 | TBD | 20-30 |
| MP-16D | OU1 | 173520 | 1636515 | TBD | 49-59 |
| MP-17S | OU1 | 173580 | 1636520 | TBD | 20-30 |
| MP-17D | OU1 | 173580 | 1636515 | TBD | 49-59 |

### OU1 Temporary Groundwater Monitoring Points

| Monitoring Location | Operating Unit | IN East 1301 Grid System Easting | Northing | Top of Casing (ft ASL) | Screen Interval (ft BGS) |
|---|---|---|---|---|---|
| TP-1D | OU1 | 173446 | 1637735 | TBD | 48-58 |
| TP-2D | OU1 | 173476 | 1637735 | TBD | 48-58 |
| TP-3D | OU1 | 173506 | 1637735 | TBD | 48-58 |
| TP-4S | OU1 | 173446 | 1637695 | TBD | 16-26 |
| TP-6S | OU1 | 173506 | 1637695 | TBD | 16-26 |
| TP-7D | OU1 | 173446 | 1637655 | TBD | 48-58 |
| TP-8D | OU1 | 173476 | 1637655 | TBD | 48-58 |
| TP-9D | OU1 | 173506 | 1637655 | TBD | 48-58 |

### OU1 Vapor Monitoring Points

| Monitoring Location | Operating Unit | IN East 1301 Grid System Easting | Northing | Top of Casing (ft ASL) | Screen Interval (ft BGS) |
|---|---|---|---|---|---|
| VMP-1S | OU1 | 173250 | 1638856 | N/A | 6-6.5 |
| VMP-1D | OU1 | 173250 | 1638856 | N/A | 12.5-13 |
| VMP-2S | OU1 | 173550 | 1638519 | N/A | 6-6.5 |
| VMP-2D | OU1 | 173550 | 1638519 | N/A | 12.5-13 |
| VMP-3S | OU1 | 173447 | 1638269 | N/A | 6-6.5 |
| VMP-3D | OU1 | 173447 | 1638269 | N/A | 12.5-13 |
| VMP-4S | OU1 | 173550 | 1638166 | N/A | 6-6.5 |
| VMP-4D | OU1 | 173550 | 1638166 | N/A | 12.5-13 |
| VMP-5S | OU1 | 173550 | 1637987 | N/A | 6-6.5 |
| VMP-5D | OU1 | 173550 | 1637987 | N/A | 12.5-13 |
| VMP-6S | OU1 | 173550 | 1637868 | N/A | 6.5-7 |
| VMP-6D | OU1 | 173550 | 1637868 | N/A | 13-13.5 |
| VMP-7S | OU1 | 173550 | 1637754 | N/A | 7-7.5 |
| VMP-7D | OU1 | 173550 | 1637754 | N/A | 13-13.5 |
| VMP-8S | OU1 | 173550 | 1637613 | N/A | 6.5-7 |
| VMP-8D | OU1 | 173550 | 1637613 | N/A | 13.5-14 |
| VMP-9S | OU1 | 173581 | 1637372 | N/A | 6.5-7 |
| VMP-9D | OU1 | 173581 | 1637372 | N/A | 13.5-14 |
| VMP-10S | OU1 | 173581 | 1637197 | N/A | 7-7.5 |
| VMP-10D | OU1 | 173581 | 1637197 | N/A | 14-14.5 |
| VMP-11S | OU1 | 173577 | 1637021 | N/A | 7-7.5 |
| VMP-11D | OU1 | 173577 | 1637021 | N/A | 14-14.5 |
| VMP-12S | OU1 | 173576 | 1636710 | N/A | 7.5-8 |
| VMP-12D | OU1 | 173576 | 1636710 | N/A | 15-15.5 |

Notes:

1. TBD = To be determined following installation.
2. N/A = Not applicable since tubing is present.
3. All RI-, MP-, TP-, and RR- are 2-inch diameter PVC.
4. All VMP- are 1/2-inch diameter, 6-inch long SS screens.

## Form 1

## Field Drilling Log Form

# CENCOR, Inc.

Indianapolis, Indiana 46239 • (317) 862-3280

# Drilling Log

Project _____ Owner _____

Location _____ W.O. Number _____

Well Number _____ Total Depth _____ Diameter _____

Surface Elevation _____ Water Level: Initial _____ 24-hrs. _____

Screen: Dia. _____ Length _____ Slot Size _____

Casing: Dia. _____ Length _____ Type _____

Drilling Company _____ Drilling Method _____

Driller _____ Log By _____ Date Drilled _____

Sketch Map

Notes

| Depth (Feet) | VOC Field Reading | Well Construction | Sample Number | Description/SoilClassification (Color, Texture, Structures) |
|---|---|---|---|---|
| | | | | |

Page _____ of _____

## Form 2

## Field Well Construction Form

# 1500 SOUTH TIBBS LLC

## Well Completion Report

Site Number: _____ County: _____

Site Name: _____ Well #: _____

State _____ o ' " o ' "

Plane Coordinate: X _____ Y _____ (or) Latitude: ____ ____ ____ Longitude: ____ ____ ____ Borehole #: _____

Surveyed by: _____ IL Registration #: _____

Drilling Contractor: _____ Driller: _____

Consulting Firm: _____ Geologist: _____

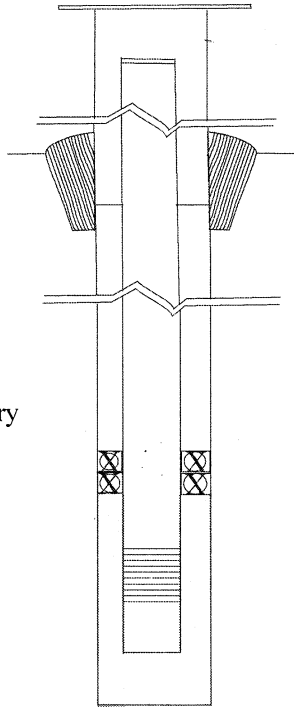
Drilling Method: _____ Drilling Fluid (Type): _____

Logged By: _____ Date Started: _____ Date Finished: _____

Report Form Completed By: _____ Date: _____

---

## ANNULAR SPACE DETAILS



Type of Surface Seal: _____

Type of Annular Sealant: _____

Installation Method: _____

Setting Time: _____

Type of Bentonite Seal - - Granular, Pellet, Slurry
(Choose One)

Installation Method: _____

Setting Time: _____

Type of Sand Pack: _____

Grain Size: _____ (Sieve Size)

Installation Method: _____

Type of Backfill Material: _____
(if applicable)

Installation Method: _____

| | Elevations (MSL)* | Depths (BGS) | (.01ft.) |
|---|---|---|---|
| | _____ | _____ | Top of Protective Casing |
| | _____ | _____ | Top of Riser Pipe |
| | _____ | _____ | Ground Surface |
| | _____ | _____ | Top of Annular Sealant |
| | _____ | _____ | Static Water Level (After Completion) |
| | _____ | _____ | Top of Seal |
| | _____ | _____ | Top of Sand Pack |
| | _____ | _____ | Top of Screen |
| | _____ | _____ | Bottom of Screen |
| | _____ | _____ | Bottom of Well |
| | _____ | _____ | Bottom of Borehole |

* Referenced to a National Geodetic Datum

### WELL CONSTRUCTION MATERIAL

(Choose one type of material for each area)

| | |
|---|---|
| Protective Casing | SS304, SS316, PTFE, PVC, or Other |
| Riser Pipe Above W.T. | SS304, SS316, PTFE, PVC, or Other |
| Riser Pipe Below W.T. | SS304, SS316, PTFE, PVC, or Other |
| Screen | SS304, SS316, PTFE, PVC, or Other |

### CASING MEASURMENTS

| | |
|---|---|
| Diameter of Borehole (inches) | |
| ID of Riser Pipe (inches) | |
| Protective Casing Length (feet) | |
| Riser Pipe Length (feet) | |
| Bottom of Screen to End Cap (feet) | |
| Screen Length (1st slot to last slot) (feet) | |
| Total Length of Casing (feet) | |
| Screen Slot Size ** | |

**Hand-Slotted Well Screens are Unacceptable

## Form 3

## Sparge Well Spacing Calculation Form

# Sparge Well Spacing Calculation Form

1500 South Tibbs LLC

May 16, 2025

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Sparge Well Design Depth | $D_d$ | | feet |
| Sparge Well Installed Depth | $D_i$ | | feet |
| Difference in Depth | $D_d - D_i$ | | feet |
| If Difference is >3 ft? | Yes / No | | |
| Sparge Well Design ROI | $ROI_d$ | | feet |
| Calculated Sparge Well Installed ROI | $ROI_i$ | | feet |
| If shallower: $ROI_i = ROI_d - (D_d - D_i - 3\ ft) \times 0.75$ | | | |
| If deeper: $ROI_i = ROI_d + (D_i - D_d - 3\ ft) \times 0.75$ | | | |
| Adjacent Sparge Well ID | SP- | | |
| Adjacent Sparge Well ROI | $ROI_a$ | | feet |
| Calculated Sparge Well Spacing | S | | feet |
| $S = sqrt\ (ROI_i^2 - 225) + sqrt\ (ROI_a^2 - 225)$ | | | |

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Sparge Well Design Depth | $D_d$ | | feet |
| Sparge Well Installed Depth | $D_i$ | | feet |
| Difference in Depth | $D_d - D_i$ | | feet |
| If Difference is >3 ft? | Yes / No | | |
| Sparge Well Design ROI | $ROI_d$ | | feet |
| Calculated Sparge Well Installed ROI | $ROI_i$ | | feet |
| If shallower: $ROI_i = ROI_d - (D_d - D_i - 3\ ft) \times 0.75$ | | | |
| If deeper: $ROI_i = ROI_d + (D_i - D_d - 3\ ft) \times 0.75$ | | | |
| Adjacent Sparge Well ID | SP- | | |
| Adjacent Sparge Well ROI | $ROI_a$ | | feet |
| Calculated Sparge Well Spacing | S | | feet |
| $S = sqrt\ (ROI_i^2 - 225) + sqrt\ (ROI_a^2 - 225)$ | | | |

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Sparge Well Design Depth | $D_d$ | | feet |
| Sparge Well Installed Depth | $D_i$ | | feet |
| Difference in Depth | $D_d - D_i$ | | feet |
| If Difference is >3 ft? | Yes / No | | |
| Sparge Well Design ROI | $ROI_d$ | | feet |
| Calculated Sparge Well Installed ROI | $ROI_i$ | | feet |
| If shallower: $ROI_i = ROI_d - (D_d - D_i - 3\ ft) \times 0.75$ | | | |
| If deeper: $ROI_i = ROI_d + (D_i - D_d - 3\ ft) \times 0.75$ | | | |
| Adjacent Sparge Well ID | SP- | | |
| Adjacent Sparge Well ROI | $ROI_a$ | | feet |
| Calculated Sparge Well Spacing | S | | feet |
| $S = sqrt\ (ROI_i^2 - 225) + sqrt\ (ROI_a^2 - 225)$ | | | |

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Sparge Well Design Depth | $D_d$ | | feet |
| Sparge Well Installed Depth | $D_i$ | | feet |
| Difference in Depth | $D_d - D_i$ | | feet |
| If Difference is >3 ft? | Yes / No | | |
| Sparge Well Design ROI | $ROI_d$ | | feet |
| Calculated Sparge Well Installed ROI | $ROI_i$ | | feet |
| If shallower: $ROI_i = ROI_d - (D_d - D_i - 3\ ft) \times 0.75$ | | | |
| If deeper: $ROI_i = ROI_d + (D_i - D_d - 3\ ft) \times 0.75$ | | | |
| Adjacent Sparge Well ID | SP- | | |
| Adjacent Sparge Well ROI | $ROI_a$ | | feet |
| Calculated Sparge Well Spacing | S | | feet |
| $S = sqrt\ (ROI_i^2 - 225) + sqrt\ (ROI_a^2 - 225)$ | | | |

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Sparge Well Design Depth | $D_d$ | | feet |
| Sparge Well Installed Depth | $D_i$ | | feet |
| Difference in Depth | $D_d - D_i$ | | feet |
| If Difference is >3 ft? | Yes / No | | |
| Sparge Well Design ROI | $ROI_d$ | | feet |
| Calculated Sparge Well Installed ROI | $ROI_i$ | | feet |
| If shallower: $ROI_i = ROI_d - (D_d - D_i - 3\ ft) \times 0.75$ | | | |
| If deeper: $ROI_i = ROI_d + (D_i - D_d - 3\ ft) \times 0.75$ | | | |
| Adjacent Sparge Well ID | SP- | | |
| Adjacent Sparge Well ROI | $ROI_a$ | | feet |
| Calculated Sparge Well Spacing | S | | feet |
| $S = sqrt\ (ROI_i^2 - 225) + sqrt\ (ROI_a^2 - 225)$ | | | |

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Sparge Well Design Depth | $D_d$ | | feet |
| Sparge Well Installed Depth | $D_i$ | | feet |
| Difference in Depth | $D_d - D_i$ | | feet |
| If Difference is >3 ft? | Yes / No | | |
| Sparge Well Design ROI | $ROI_d$ | | feet |
| Calculated Sparge Well Installed ROI | $ROI_i$ | | feet |
| If shallower: $ROI_i = ROI_d - (D_d - D_i - 3\ ft) \times 0.75$ | | | |
| If deeper: $ROI_i = ROI_d + (D_i - D_d - 3\ ft) \times 0.75$ | | | |
| Adjacent Sparge Well ID | SP- | | |
| Adjacent Sparge Well ROI | $ROI_a$ | | feet |
| Calculated Sparge Well Spacing | S | | feet |
| $S = sqrt\ (ROI_i^2 - 225) + sqrt\ (ROI_a^2 - 225)$ | | | |

Note: If $D_d - D_i > 20$ feet, notify Supervising Contractor immediately, this is a major modification to the remedial design and requries USEPA approval.

# Data Quality Objective:
# Investigation Derived Waste and Surplus Excavated Soil Collection and Characterization

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) Investigation Derived Waste and Surplus Excavated Soil Collection and Characterization

.

1. State the Problem

How to collect and characterize investigation derived waste (IDW) and surplus excavation material for lawful off-site disposal.

IDW consists of water generated from equipment decontamination, well development, and groundwater purging. Approximately 3,000 gallons of such water may be generated during the installation of wells and points associated with the biosparge system. IDW also consists of soil generated from soil borings that are drilled for the installation of the same wells and points. Approximately 22 cubic yards of such soil may be generated.

Excavation will be performed for the installation of the biosparge system. If suitable, some of the excavated material will be used for backfill. However, there will be a surplus of material that will need to be shipped off-site for lawful disposal. Approximately 500 cubic yards of surplus material may be generated.

2. Identify the Goals of the Project

Collect and characterize the water, soil cores, and surplus excavation material for lawful off-site disposal. Collection will include containerization and stockpiling both of which shall be protected from contact with storm water. Characterization will include sample collection, sample analysis, data validation, the completion of waste profile applications, and procurement of an approved waste profile from the disposal facility.

3. Identify Information Inputs

a. IDW Soil Borings

Soil borings will be completed for the installation of sparge wells, groundwater monitoring wells, groundwater monitoring points, temporary groundwater monitoring points, and vapor monitoring points. The on-site soil borings will be located on the east side of the property near Tibbs Avenue. Reportedly, historic process operations have not occupied these areas. As such, gross soil contamination is not anticipated to be encountered. Soil contamination resulting from contaminated groundwater is anticipated. Current maximum levels of dissolved benzene, pyridines, and ammonia in this area of OU1 where the biosparge system will be installed are 33.4 µg/L, 64.8 µg/L, and 15.0 mg/L, respectively, based upon the 1Q2024 report. Current maximum levels of dissolved benzene, pyridines, and ammonia in OU5 are 34.0 µg/L, <10.0 µg/L, and 24.2 mg/L, respectively, based upon the 1Q2024 report (DMP 2024a).

Soil cores will be accumulated in drums and/or a roll-off boxes. The drums and/or roll-off boxes will have a lid or be securely covered with minimum 6-mil thick plastic sheeting to protect the contents from contact with storm water during periods when the containers are not being filled.

A representative composite sample of the soil cores will be collected for laboratory analysis to generate a waste disposal profile for the facility that will receive soil cuttings and lawfully dispose of it. Since waste disposal profiles can vary by facility, exact sample requirements will be performed for the facility. Sampling will likely be performed for flashpoint, pH, Toxic Characteristic Leaching Procedure (TCLP) benzene, and TCLP pyridines. Other parameters may also need to be analyzed in accordance with the waste disposal facility requirements such as volatile organic

compounds (VOCs), semi-volatile organic compounds (SVOCs), Resource Conservation and Recovery Act (RCRA) metals, polychlorinated biphenyls (PCBs), TCLP VOCs, TCLP SVOCs, and TCLP RCRA metals.

A disposal facility for IDW soil borings is Waste Management Twin Bridges Security Landfill, 124 E. Twin Bridges Rd, Danville, IN 46122.

b. IDW Water

Current maximum levels of dissolved benzene, pyridines, and ammonia in this area of OU1 where the biosparge system will be installed are 33.4 µg/L, 64.8 µg/L, and 15.0 mg/L, respectively, based upon the 1Q2024 report. Current maximum levels of dissolved benzene, pyridines, and ammonia in OU5 are 34.0 µg/L, <10.0 µg/L, and 24.2 mg/L, respectively, based upon the 1Q2024 report (DMP 2024a). Accumulated decontamination water, development groundwater, and purged groundwater is anticipated to be lower than these maximum concentrations since sources with less impacts will be combined. Decontamination water, development groundwater, and purged groundwater will be accumulated in drums and/or storage tank(s).

Decontamination water, development groundwater, and purged groundwater may be discharged to the combined sewer, if allowed by CWA Authority via their Special Discharge Application. This is based upon the fact that groundwater has been allowed to be pumped directly to the sanitary sewer since 1994 without treatment based upon acceptable sampling results. Written approval will be required from CWA Authority before any water is discharged to the combined sewer.

If water is not allowed to be discharged to the combined sewer, then a representative composite sample of the water will be collected for laboratory analysis to generate a waste disposal profile for the facility that will receive the water. Since waste disposal profiles can vary by facility, exact sample requirements will be performed for the facility. However, based upon experience, sampling will likely be performed for flashpoint, pH, benzene, pyridines, and ammonia. Other parameters may also need to be analyzed in accordance with the waste disposal facility requirements such as VOCs, SVOCs, RCRA metals, and PCBs.

A disposal facility for decontamination water, development groundwater, and purged groundwater is Heritage Environmental Services, 1626 Research Way, Indianapolis, IN 46231.

c. Surplus Excavated Material

Surplus excavated material will be generated from trenching activities to install the biosparge system. Surplus excavated material will be accumulated stockpiles. Stockpiles will exist for paved materials (asphalt and concrete) as well as other excavated material including topsoil, sand, silt, and aggregate. Paved materials are anticipated to be largely free of topsoil, sand, silt, and aggregate. As such, these may be shipped to a facility for recycling without sampling subject to approval of the recycling facility. Stockpile(s) of non-paved excavated materials will be placed on a paved surface or on minimum 6-mil thick plastic sheeting and covered with minimum 6-mil thick plastic sheeting to prevent stormwater contact with the soils during periods when material is not being generated.

A representative composite sample of the surplus excavated material consisting of topsoil, sand, silt, and aggregate will be collected for laboratory analysis to generate a waste disposal profile for the facility that will receive and lawfully dispose of it. Since waste disposal profiles can vary by facility, exact sample requirements will be performed for the facility. Sampling will likely be performed for flashpoint, pH, TCLP benzene, and TCLP pyridines. Additional parameters may also need to be analyzed in accordance with the waste disposal facility requirements such as volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), Resource Conservation and Recovery Act (RCRA) metals, polychlorinated biphenyls (PCBs), TCLP VOCs, TCLP SVOCs, and TCLP RCRA metals.

A disposal facility for surplus excavated material is Waste Management Twin Bridges Security Landfill, 124 E. Twin Bridges Rd, Danville, IN 46122.

4. Define the Boundaries of the Study

IDW will be generated from the installation of 12 monitoring wells, 34 groundwater monitoring points, 8 temporary groundwater monitoring points, 73 sparge wells, and 24 vapor monitoring points.

Surplus excavated materials will be generated from trenching activities along the sparge barrier that extend from sparge well SP-1 at the north to SP-73 at the south.

5. Develop the Analytic Approach

The disposal facilities identified can receive non-hazardous waste. The IDW and surplus excavated material are not listed hazardous wastes (i.e. identified on the F, K, P, and U lists). IDW and surplus excavated material are not generated from within the former chemical production or storage areas and there have been no known spills of virgin material in the biosparge system area.

Solid and water samples will be submitted to Pace Analytical to test for characteristically hazardous levels published in 40 CFR 261 for:

a. Ignitability per 40 CFR 261.21,
b. Corrosivity per 40 CFR 261.22, and
c. Toxicity per 40 CFR 261.24.

Laboratory testing methods shall be in accordance with SW-846 which include:

a. Flashpoint (for ignitability) via EPA Method 1010A,
b. pH (for corrosivity) via SM 4500-H+B (water) and EPA Method 9045C (soil),
c. Toxic Characteristic Leaching Procedure (TCLP) via EPA Method 1311 for:
    i. benzene (waste code D018) via EPA Method 8260C, and
    ii. pyridine (waste code D038) via EPA Method 8270C.

Additional laboratory testing may be required depending upon the disposal facility waste profile requirements for:

a. Benzene or total VOCs (including benzene) via EPA Method 8260C.
b. Pyridine or total SVOCs (including pyridine and pyridine derivatives) via EPA Method 8270C.
c. Ammonia via Method SM 4500-NH3 G (water).
d. Total RCRA Metals via EPA Method 6010B (arsenic, barium, cadmium, chromium, lead, selenium, and silver in solids and water) and EPA Method 7470A (mercury in water) or EPA Method 7471B (mercury in solids).
e. PCBs via EPA Method 8082A.
f. TCLP via EPA Method 1311 for:
    i. total VOCs (including benzene) via EPA Method 8260.
    ii. total SVOCs (including pyridine and pyridine derivatives) via EPA Method 8270.
    iii. total RCRA Metals via EPA Method 6010B (arsenic, barium, cadmium, chromium, lead, selenium, and silver) and EPA Method 7470A (mercury).

Data validation of IDW and surplus excavated material will be completed by the Quality Assurance (QA) Officer to, at minimum, Stage 1 validation. Stage 1 validation of the laboratory analytical data package consists of verification and validation checks for the compliance of sample receipt conditions, sample characteristics, and analytical results (with associated information). The following minimum baseline checks will be performed on the laboratory analytical data package received for a Stage 1 validation label:

a. Documentation identifies the laboratory receiving and conducting analyses, and includes documentation for all samples submitted by the project or requester for analyses.
b. Requested analytical methods were performed and the analysis dates are present.
c. Requested target analyte results are reported along with the original laboratory data qualifiers and data qualifier definitions for each reported result.
d. Requested target analyte result units are reported.
e. Requested reporting limits for all samples are present and results at and below the required reporting limits are clearly identified (including sample detection limits if required).
f. Sampling dates (including times if needed), date and time of laboratory receipt of samples, and sample conditions upon receipt at the laboratory (including preservation, pH and temperature) are documented.

The QA Officer shall also review field documentation (notes, sketches, and any other records) to confirm consistency with the completion of the chain of custody and requirements of this data quality objective.

Once validated, then results will be compared to acceptance criteria required by the disposal facility. So long as analytical results meet the acceptance criteria, then the Supervising Contractor Project Manager will complete a waste profile application for the disposal facility using validated data. The Project Coordinator for 1500 South Tibbs LLC will review and waste profile application and sign the application as the waste generator. The disposal facility will review the waste profile application and either approve it, request additional information, or deny it. The Supervising Contractor and Project Coordinator will work together to respond to any additional information requests from the disposal facility.

6. Specify Performance or Acceptance Criteria

Laboratory analytical results shall be at levels that do not render the solid or water characteristically hazardous waste per 40 CFR 261 including, but not limited to:

a. Flashpoint >140˚F
b. 2 < pH <12.5
c. TCLP benzene (D018) <0.5 mg/L
d. TCLP pyridine (D038) <5 mg/L

| Target Analyte | CAS# | Method | Units | MDL | RL | TCLP Limit(1) | LCS Limits (% Rec.) | MS Limits (% Rec.) | RPD (Max %) |
|---|---|---|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | 1311/8260C | mg/L | 0.01 | 0.05 | 0.5 | 74-124 | 65-137 | 20 |
| Pyridine | 110-86-1 | 1311/8270C | mg/L | 0.05 | 0.1 | 5 | 10-61 | 11-66 | 20 |

(1) Reference: 40 CFR 261.24
(2) Definitions: MDL = Method Detection Limit, RL = Reporting Limit, LCS = Laboratory Control Sample, MS = Matrix Spike, RPD = Relative Percent Difference, Rec. = Recovery

Laboratory analytical results shall meet the acceptance criteria of the off-site disposal facility so that written authorization is provided by the facility to accept the waste material.

7. Develop the Plan for Obtaining Data

Samples will be collected for laboratory analysis at Pace Analytical according to the following schedule:

a. IDW soil – after all drilling activities have been completed; the estimated quantity is 22 CY.
b. IDW water – after all drilling activities have been completed and all excavation equipment has been decontaminated; the estimated quantity is 3,100 gallons.
c. Surplus material – after all trenching / excavation activities have been completed; the estimated quantity is 500 CY.

The following table summarizes the type and frequency of samples that will be collected. Grab samples will be collected for benzene/VOC analysis and pH analysis. Composite samples will be collected for all other analyses, including TCLP analysis.

| Container | Grab Samples | Composite Sample Aliquots | Composite Samples |
|---|---|---|---|
| IDW Soil Drum | 1 per drum | 1 per drum | 1 for up to 10 drums |
| IDW Soil Roll-off Box | 1 per 5 CY | 1 per 5 CY | 1 per 25 CY |
| IDW Water Drum | 1 per drum | 1 per drum | 1 for up to 10 drums |
| IDW Water Storage Tank | 1 per 1,000 gallons | 1 per 1,000 gallons | 1 per 5,000 gallons |
| Surplus Material Stockpile | 1 per 100 CY | 1 per 100 CY | 1 per 500 CY |

One duplicate sample will be collected for each media (soil, water, surplus material) for every 20 samples that are collected. At a minimum, there will be one duplicate grab sample and one duplicate composite sample.

Each soil / solid material grab sample of the two grab sample analyses (benzene/VOC and pH) will be collected in a discrete 4 or 8 ounce soil jar provided by Pace Analytical. Each composite sample aliquot will be a minimum of 16 ounces and placed in a clean plastic bucket with other aliquots and thoroughly mixed either by hand (while wearing clean nitrile gloves) and/or by using a clean plastic or stainless steel spoon/rod/pipe. Appropriate soil jars provided by Pace Analytical will be filled for a composite sample.

Each water grab sample of the two grab sample analyses (benzene/VOC and pH) will be collected in discrete sample container(s) for that analysis. Each benzene/VOC sample will include three 40 mL vials with a septum cap pre-preserved with hydrochloric acid and each pH sample will be a minimum 100 milliliter (mL) unpreserved poly bottle. Sample containers will be provided by Pace Analytical. Each composite sample aliquot will be a minimum of 1 liter and placed in a clean plastic bucket with other aliquots, thoroughly mixed either by hand (while wearing clean nitrile gloves) and/or by using a clean plastic or stainless steel spoon/rod/pipe. Appropriate pre-preserved water bottles provided by Pace Analytical will be filled for a composite sample.

Sample containers shall be labeled and the chain of custody shall be mostly completed prior to sample collection. Upon collection, then samples shall promptly be placed in a cooler containing loose ice sufficient to lower the temperature of the samples to 6˚C. Following proper chilled storage of samples, then the chain of custody shall be promptly completed. Prior to 5 pm each working day the sample collected that day shall be delivered by hand to Pace Analytical in Indianapolis following chain of custody protocols.

During sample collection, the field sampler shall document:

a. Volume of material being sampled and calculated number of samples required.
b. Field sketch identifying the locations where grab samples and composite aliquots are collected. The sketch shall also document the depth of sample collection. Grab samples and composite aliquots shall be collected to be representative of the media being sampled.
c. A description of each grab sample and composite aliquot collected including, but not limited to, method of collection, soil type, texture, color, odor, and moisture content.
d. All appropriate information on the chain of custody for the analyses required by the disposal facility. The Project Manager will be responsible for providing this information to the Field Manager who will convey it to the field sampler.

Standard Operating Procedures (SOPs) provided as Attachment 2 to the Quality Assurance Project Plan (QAPP) provide additional information:

a. SOP F-03: Recordkeeping, Sample Labeling, and Chain of Custody
b. SOP F-04: Sample Handling, Storage, and Shipping
c. SOP F-05: Investigation Derived Waste Management
d. SOP F-06: Equipment Decontamination
e. SOP F-12: Monitoring Well Installation
f. SOP F-13: Monitoring Well Development
g. SOP F-14: Monitoring Well Sampling

Standard Operating Procedures (SOPs) utilized by Pace Analytical are presented in the following table and attached.

| Pace Analytical Standard Operating Procedures (SOPs) | | | | | |
|---|---|---|---|---|---|
| **Reference Number** | **Title** | **Revision Date** | **Revision Number** | **Matrix** | **Analytical Group** |
| ENV-SOP-IND1-0034 | Volatiles by SW-846 8260C | 10-16-2023 | V03 | Water and Soil | Volatile Organic Compounds (VOCs) |
| ENV-SOP-IND1-0057 | Semivolatiles by SW-846 8270C | 12-27-2022 | V02 | Water and Soil | Semivolatile Organic Compounds (SVOCs) |
| ENV-SOP-IND1-0049 | PCBs by SW-846 8082A | 10-09-2024 | V03 | Water and Soil | Polychlorinated Biphenyls (PCBs) |
| ENV-SOP-IND1-0025 | Metals by SW-846 6010B | 04-22-2024 | V03 | Water and Soil | RCRA Metals (As, Ba, Cd, Cr, Pb, Se, Ag) |

| | | | | | |
|---|---|---|---|---|---|
| ENV-SOP-IND1-0044 | Mercury by SW-846 7470A, 7471A | 04-22-2024 | V05 | Water (7470A) and Soil (7471A) | RCRA Metal (Hg) |
| ENV-SOP-IND1-0139 | Ammonia Nitrogen (Gas Diffusion) by EPA 350.1, SM 4500-NH3 G | 06-29-2023 | V02 | Water | Ammonia |
| ENV-SOP-IND1-0030 | pH by SM 4500-H+B | 08-27-2024 | V04 | Water | pH |
| ENV-SOP-IND1-0058 | Soil & Waste pH by SW-846 9045C | 11-07-2024 | V04 | Soil | pH |
| ENV-SOP-IND1-0043 | Flashpoint by SW-846 1010A | 10-24-2024 | V04 | Water and Soil | Flashpoint |
| ENV-SOP-IND1-0055 | TCLP by SW-846 1311 | 04-13-2023 | V02 | Water and Soil | Toxic Characteristic Leaching Procedure (TCLP) |
| Note: No SOPs have been modified for project work. | | | | | |

Sample containers, preservation, and holding times in the Pace Analytical SOPs are presented in the following table. Sample containers will be provided by Pace Analytical for field collection of samples.

**Sample Containers, Preservation, and Hold Times**

| Analytical Group | Matrix | Analytical Method | Minimum Sample Volume and Containers | Preservation and Storage Requirements | Maximum Holding Time |
|---|---|---|---|---|---|
| VOCs | Water | 8260C | (3) VOA vials | HCl to pH<2 Cool to ≤6˚C | Analyze in 14 days |
| | Soil | | (1) 4 oz or 8 oz glass jar and one container for % moisture | Cool to ≤6˚C | |
| SVOCs, including Pyridines | Water | 8270C | (2) 100 mL amber glass with Teflon-lined lid | | Extract in 7 days, Analyze 40 days thereafter |
| | Soil | | 300 g in (1) 8 oz glass jar | | Extract in 14 days, Analyze 40 days thereafter |
| PCBs | Water | 8082A | (1) 100 mL amber glass | | Extract in 1 yr, Analyze 40 days thereafter |
| | Soil | | >100 g in (1) 4 oz glass jar | | |
| RCRA Metals | Water | 6010B / 7470A | (1) 500 mL plastic bottle | HNO3 to pH<2 Cool to ≤6˚C | Hg: Analyze in 28 days, Others Analyze in 180 days |
| | Soil | 6010B / 7471A | 150 g in (1) 4 oz or 8 oz glass jar | Cool to ≤6˚C | |
| Ammonia | Water | SM 4500-NH3G | (1) 250 mL plastic bottle | $H_2SO_4$ to pH<2 Cool to ≤6˚C | Analyze in 28 days |
| pH | Water | SM 4500-H+B | (1) 100 mL plastic bottle | Ambient | As soon as possible |
| | Soil | Method 9045C | >20 g in (1) 4 oz glass jar | | |
| Flashpoint | Water | 1010A | (1) 200 mL glass jar | Cool to ≤6˚C | None listed. |
| | Soil | | (1) 8 oz glass jar | | |
| TCLP | Water | 1311 | (2) 1 L glass containers | | TCLP Extract in 14 (VOCs, SVOCs), 28 (Hg), and 180 (Metals) days. Analyze extract per water times. |
| | Soil | | >500 g in (1) 8 oz glass jar | | |

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(2) Supporting Documentation

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Reference Materials

Attachment 1 – CWA Authority Special Discharge Application

Attachment 2 – Soil / Surplus Material Waste Profile Application – Waste Management Twin Bridges Security Landfill, 124 E. Twin Bridges Rd, Danville, IN 46122

Attachment 3 – Water Waste Profile Application – Heritage Environmental Services, 1626 Research Way, Indianapolis, IN 46231

Attachment 4 – Pace Analytical SOPs

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**Attachment 1**

**CWA Authority Special Discharge Application**

# SPECIAL DISCHARGE AGREEMENT APPLICATION CHECKLIST

May 2024

Pursuant to CWA Authority, Inc. ("Authority") Resolution No. CWA 2-2011, this application form must be completed by applicants seeking permission for temporary discharges to the Authority's wastewater collection system ("System") in Indianapolis. As a part of the process, the Authority evaluates the quantity and quality of the wastewater to be discharged to ensure that the System, including the collection system and Belmont and Southport Advanced Wastewater Treatment (AWT) Plants, and its employees are protected, and prevent the introduction of pollutants into the System that may interfere with the normal operation of the System. Visit www.citizensenergygroup.com/pretreatment to review Resolution No. CWA 2-2011, information on the pretreatment program and the current sewer discharge rates.

The following items must be attached to the Special Discharge Agreement Application:

- ☐ Completed Application and any supporting documents signed by the Authorized Representative.
- ☐ Safety Data Sheets for chemical additives if any such additives are used.
- ☐ Analytical data representative of the wastewater to be discharged, analyzed using methods promulgated by U.S. EPA at 40 CFR Part 136 or equivalent.
- ☐ Completed Hazardous Waste Statement (at end of application).
- ☐ A $150.00 industrial discharge application fee ("fee"). The fee should be submitted via check made payable to CWA Authority, Inc. and mailed to the address below.

Upon submittal of a complete Special Discharge Agreement Application, the Authority's review may require up to 14 days. Failure to fully complete all sections of this application or submit the required fee will result in a delay of approval processing.

If you have any questions regarding the completion of the Special Discharge Agreement Application, you may contact any one of the persons listed below.

| | | |
|---|---|---|
| Beth Noel | 317-927-1019 | bnoel@Citizensenergygroup.com |
| Nathaniel Berg | 317-927-1018 | nberg@Citizensenergygroup.com |
| Jeff Guinn | 317-927-4394 | jguinn@Citizensenergygroup.com |

The completed application may be submitted via e-mail to Pretreatment@Citizensenergygroup.com to initiate process; however, the Authority will not issue a Special Discharge Agreement without the signed original application and the $150.00 application fee which must be mailed to:

CWA Authority, Inc.
ATTN: Industrial Pretreatment Program
2020 North Meridian Street
Indianapolis, IN 46202

**Please note: Pursuant to the Sewage Disposal Service Tariff, Terms and Conditions for Sewage Disposal Service within Marion County, Indiana, and Contiguous Areas (Terms and Conditions) approved by the Indiana Utility Rate Commission, the appropriate sewage disposal rate, including any appropriate excessive strength surcharges, will be applied to the discharge.**

CWA AUTHORITY, INC.
2020 N. Meridian St. | Indianapolis, IN | 46202

# SPECIAL DISCHARGE AGREEMENT APPLICATION

CWA Authority, Inc. (the "Authority") is the owner and operator of the wastewater collection and treatment system in the Indianapolis sanitary sewer system (the "System"). Through approvals and delegations by the United States Environmental Protection Agency and the Indiana Department of Environmental Management, the Authority is charged with monitoring and control over the direct discharge of pollutants to waterways consistent with the Authority's Industrial Pretreatment Program ("IPP"). All pertinent information related to the Industrial Pretreatment Program is available at: www.citizensenergygroup.com/pretreatment.

If this application results in a Special Discharge Agreement, Applicant agrees to indemnify, defend, and hold harmless, including attorney fees, CWA Authority, Inc. against any and all claims, damages, losses, costs, or other expenses or liabilities resulting from CWA Authority, Inc.'s acceptance of the Applicant's wastewater.

| **APPLICANT INFORMATION (Who is responsible for the discharge?)** | | | | | |
|---|---|---|---|---|---|
| Applicant's Name: | | | | | |
| Applicant's Address: | | | | | |
| City: | | State: | | Zip Code: | |
| Contact Person: | | Phone: | | Email: | |

| **PROJECT LOCATION (include project address and nearest major intersection)** |
|---|
| |
| |

| **HOW WILL THE WASTEWATER BE DISCHARGED? (Check one)** | | | |
|---|---|---|---|
| ☐ | Discharged to Sewer? | Manhole # (Attach map if available): | |
| | | Maximum rate of discharge (gallons per minute): | |
| | | Total volume of discharge (gallons): | |
| | | Expected timeframe for discharge: | |
| | | | |
| ☐ | Hauled to Belmont AWT? | Name of Authority Permitted Hauler: | |
| | | Hauler Contact: | |
| | | Hauler Phone: | |
| | | Hauler Email: | |

| **DESCRIBE BUSINESS ACTIVITY GENERATING THE WASTEWATER TO BE DISCHARGED** |
|---|
| |
| |

CWA AUTHORITY, INC.
2020 N. Meridian St. | Indianapolis, IN | 46202

SPECIAL DISCHARGE AGREEMENT APPLICATION

| **MATERIALS AT THIS LOCATION THAT COULD REACH THE SEWER OR BE DISCHARGED IN THE WASTEWATER (include Safety Data Sheets for chemicals at the facility that may be in the wastewater)** |
|---|
| |
| |

| **WILL ANY WASTEWATER TREATMENT OCCUR PRIOR TO DISCHARGE (check one)?** | **No** | ☐ | **Yes** | ☐ |
|---|---|---|---|---|

**If yes, provide a description of the wastewater treatment process, include process equipment, design capacity, and operating conditions. Attach a wastewater flow diagram.**
*Attach additional sheets if necessary*

| |
|---|
| |
| |

| **ANALYTICAL DATA** |
|---|
| Attach laboratory analytical data of the wastewater to be discharged to the sewer system. Provide an explanation of where and when the sample was taken, what type of sample was taken (grab/composite) and how many samples were analyzed. Analytical methods shall conform to 40 CFR Part 136 or equivalent. |
| |
| |

**AUTHORIZED REPRESENTATIVE**

**This application must be signed by the Authorized Representative as defined in Resolution No. CWA 2-2011**

| | | | | | |
|---|---|---|---|---|---|
| Name: | | Title: | | | |
| Company: | | | | | |
| Mailing Address: | | | | | |
| City: | | State: | | Zip Code: | |
| Phone: | | E-mail: | | | |

**AUTHORIZED REPRESENTATIVE CERTIFICATION**

I CERTIFY UNDER THE PENALITY OF LAW THAT THIS DOCUMENT AND ALL ATTACHMENTS WERE PREPARED UNDER MY DIRECTION OR SUPERVISION IN ACCORDANCE WITH A SYSTEM DESIGNED TO ASSURE THAT QUALIFIED PERSONNEL PROPERLY GATHER AND EVALUATE THE INFORMATION SUBMITTED. BASED ON MY INQUIRY OF THE PERSON OR PERSONS WHO MANAGE THE SYSTEM, OR THOSE PERSONS DIRECTLY RESPONSIBLE FOR GATHERING INFORMATION, THE INFORMATION SUBMITTED IS, TO THE BEST OF MY KNOWLEDGE AND BELIEF, TRUE, ACCURATE, AND COMPLETE. I AM AWARE THAT THERE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF FINE AND IMPRISONMENT FOR KNOWING VIOLATIONS.

| | |
|---|---|
| | |
| PRINTED NAME | DATE |
| | |
| SIGNATURE | |

CWA AUTHORITY, INC.
2020 N. Meridian St. | Indianapolis, IN | 46202



# INDUSTRIAL PRETREATMENT PROGRAM
# HAZARDOUS WASTE STATEMENT

Regulations at 40 CFR part 403.12(p) and Resolution No. CWA 2-2011, Chapter 3, Section 3.13 require that Industrial Users ("IUs") report any substance discharged to the CWA Authority, Inc. ("Authority") sewer system which, if otherwise disposed of, would be considered a Resource Conservation and Recovery Act ("RCRA") hazardous waste as set forth at 40 CFR part 261. IUs are required periodically to complete the Hazardous Waste Statement to confirm their discharge status.

**INSTRUCTIONS:** Facilities that do not discharge wastewater that, if otherwise disposed, would be considered a hazardous waste should complete Part A of this Hazardous Waste Statement. All other facilities must complete Part B of this Hazardous Waste Statement.

| | |
|---|---|
| **Facility Name** | |
| **Facility Address (Street)** | |
| **Facility Address (City, State, ZIP)** | |
| **Contact Name** | |
| **Contact E-Mail Address** | |
| **Contact Phone Number** | |
| **RCRA Identification No. (If One is Issued to the Facility)** | |

**PART A: APPLICABLE TO FACILITIES THAT DO NOT DISCHARGE WASTEWATER THAT, IF OTHERWISE DISPOSED, WOULD BE CONSIDERED A HAZARDOUS WASTE**

☐ The above-named facility does not discharge wastewater that, if otherwise disposed, would be considered a hazardous waste. Check the box to confirm this statement and have the Authorized Representative sign the certification statement below.

*I certify under the penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly under my responsibility for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.*

Authorized Representative Signature: _____ Date: _____

Authorized Representative Name (Printed): _____

Title: _____

**PART B: FACILITIES THAT DISCHARGE WASTEWATER THAT, IF OTHERWISE DISPOSED, WOULD BE CONSIDERED A HAZARDOUS WASTE MUST COMPLETE THIS SECTION**

☐ The above-named facility discharges wastewater that, if otherwise disposed, would be considered a hazardous waste. Check the box to confirm this statement, complete the table below and have the Authorized Representative sign the certification statement below.

| Name of Hazardous Waste | EPA Hazardous Waste Number (P-, U-, K-, D-, F- Codes) | Type of Discharge (Continuous, Batch or Other) |
|---|---|---|
| | | |
| | | |
| | | |

*Note: If additional rows are needed, attach another page.*

If the discharge is greater than 100 kilograms (20.5 pounds) per calendar month, this notification must include the following information to the extent known and readily available:

1. Identification of hazardous constituents in the waste(s);
2. Estimates of mass and concentration of constituents discharged during that calendar month; and,
3. Estimation of the mass of constituents in the waste stream expected to be discharged during the following 12 months.

Any changes to the Hazardous Waste constituents that are to be discharged must be reported to CWA Authority, Inc. pursuant to 40 CFR 403.12(j).

If notification is made under 40 CFR 403.12(p), the Industrial User shall certify that it has a program in place to reduce volume and toxicity of hazardous waste generated to the degree it has determined to be economically practical as follows:

*Pursuant to 40 CFR part 403.12(p)(4), I certify that _____. (Facility Name) has a program in place to reduce the volume and toxicity of hazardous waste generated to be economically achievable.*

*I certify under the penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly under my responsibility for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.*

Authorized Representative Signature: _____ Date: _____

Authorized Representative Name (Printed): _____

Title: _____

**Attachment 2**

**Soil / Surplus Material Waste Profile Application**
**Waste Management Twin Bridges Security Landfill, 124 E. Twin Bridges Rd, Danville, IN 46122**

# EZ Profile™

Requested Facility: _____ ❑ Unsure Profile Number: _____

❑ Multiple Generator Locations (Attach Locations) ❑ Request Certificate of Disposal ❑ Renewal? Original Profile Number: _____

## A. GENERATOR INFORMATION (MATERIAL ORIGIN)

1. Generator Name: _____
2. Generator Site Address: _____
   (City, State, ZIP) _____
3. County: _____
4. Contact Name: _____
5. Email: _____
6. Phone: _____ 7. Fax: _____
8. Generator EPA ID: _____ ❑ N/A
9. State ID: _____ ❑ N/A

## B. BILLING INFORMATION ❑ SAME AS GENERATOR

1. Billing Name: _____
2. Billing Address: _____
   (City, State, ZIP) _____
3. Contact Name: _____
4. Email: _____
5. Phone: _____ 6. Fax: _____
7. P.O. Number: _____
8. Payment Method: ❑ Credit Account ❑ Cash ❑ Credit Card at Gate

## C. MATERIAL INFORMATION

1. Common Name: _____
   Describe Process(es) Generating Material: ❑ See Attached
2. Material Composition and Contaminants: ❑ See Attached

| | |
|---|---|
| 1. | |
| 2. | |
| 3. | |
| 4. | |
| Total comp. must be equal to or greater than 100% | ≥100% |

3. State Waste Codes: _____ ❑ N/A
4. Color: _____
5. Physical State at 70˚F: ❑ Solid ❑ Liquid ❑ Other: _____
6. Free Liquid Range Percentage: _____ to _____ ❑ N/A
7. pH: _____ to _____ ❑ N/A
8. Strong Odor: ❑ Yes ❑ No Describe: _____
9. Flash Point: ❑ <140˚F ❑ 140˚–199˚F ❑ ≥200˚ ❑ N/A

## D. REGULATORY INFORMATION

1. EPA Hazardous Waste? ❑ Yes* ❑ No
   Code: _____
2. State Hazardous Waste? ❑ Yes ❑ No
   Code: _____
3. Is this material non-hazardous due to Treatment, Delisting, or an Exclusion? ❑ Yes* ❑ No
4. Contains Underlying Hazardous Constituents? ❑ Yes* ❑ No
5. Does the material contain benzene? ❑ Yes* ❑ No
6. Facility remediation subject to 40 CFR 63 GGGGG? ❑ Yes* ❑ No
7. CERCLA or State-mandated clean-up? ❑ Yes* ❑ No
8. NRC, State-regulated, NORM or TENORM waste? ❑ Yes* ❑ No

***If Yes, see Addendum (page 2) for additional questions and space.**

9. Contains PCBs? → If Yes, answer a, b and c. ❑ Yes ❑ No
   a. Regulated by 40 CFR 761? ❑ Yes ❑ No
   b. Remediation under 40 CFR 761.61? ❑ Yes ❑ No
   c. Were PCBs imported into the US? ❑ Yes ❑ No
10. Regulated and/or Untreated Medical/Infectious Waste? ❑ Yes ❑ No
11. Contains Asbestos? ❑ Yes ❑ No
    → If Yes: ❑ Non-Friable ❑ Non-Friable - Regulated ❑ Friable
12. Contains Dioxins? (If Yes, please attach analysis) ❑ Yes ❑ No

## E. ANALYTICAL AND OTHER REPRESENTATIVE INFORMATION

1. Analytical attached ❑ Yes
   Please identify Lab Report(s) and list specific representative Sample ID#s:
2. Other information attached (such as SDS)? ❑ Yes

## F. SHIPPING AND DOT INFORMATION

1. ❑ One-Time Event ❑ Repeat Event/Ongoing Business
2. Estimated Annual Quantity/Unit of Measure: _____
   ❑ Tons ❑ Yards ❑ Drums ❑ Gallons ❑ Other _____
3. Container Type and Size: _____
4. USDOT Proper Shipping Name ❑ N/A
5. Estimated Start Date _____
6. Transportation Needed? ❑ Yes* ❑ No

## G. GENERATOR CERTIFICATION (PLEASE READ AND CERTIFY BY SIGNATURE)

By signing this Waste Management ("WM") Profile, I hereby certify that all information submitted in this and all attached documents contain true and accurate descriptions of this material, and that all relevant information necessary for proper material characterization and to identify known and suspected hazards has been provided. Any analytical data attached was derived from a sample that is representative as defined in 40 CFR 261 - Appendix 1 or by using an equivalent method. All changes occurring in the character of the material (i.e., changes in the process or new analytical) will be identified by the Generator and be disclosed to WM prior to providing the material to WM. I am aware that there are significant penalties for knowingly submitting false information.

❑ I am authorized to sign on behalf of the Generator and I have confirmed with the Generator that information contained in this profile, as well as supporting documents provided, are accurate and complete.

❑ I am a duly authorized employee of Generator holding a position of technical responsibility with direct knowledge of the waste stream and the information contained in this profile, and I confirm that information contained in this profile, as well as supporting documents are accurate and complete.

Name (Print): _____

Title: _____

Company: _____

Date: _____

**Certification Signature**

**QUESTIONS? CALL 800 963 4776 FOR ASSISTANCE**

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# EZ Profile™ Addendum

**Only complete this Addendum if prompted by responses on EZ Profile™ (page 1) or to provide additional information. Sections and question numbers correspond to EZ Profile™.**

Profile Number:_____

## C. MATERIAL INFORMATION

Describe Process Generating Material (Continued from page 1): If more space is needed, please attach additional pages.

| |
|---|
| |

Material Composition and Contaminants (Continued from page 1): If more space is needed, please attach additional pages.

| | |
|---|---|
| 5. | |
| 6. | |
| 7. | |
| 8. | |
| 9. | |
| Total composition must be equal to or greater than 100% | ≥100% |

## D. REGULATORY INFORMATION

**Only questions with a "Yes" response in Section D on the EZ Profile™ form (page 1) need to be answered here.**

1. EPA Hazardous Waste
   a. Please list all USEPA listed and characteristic waste code numbers:

| |
|---|
| |

   b. Is the material subject to the Alternative Debris standards (40 CFR 268.45)? ❑ Yes ❑ No
   c. Is the material subject to the Alternative Soil standards (40 CFR 268.49)? → If Yes, complete question 4. ❑ Yes ❑ No
   d. Is the material exempt from Subpart CC Controls (40 CFR 264.1083)? ❑ Yes ❑ No
      → If Yes, please check one of the following:
      ❑ Waste meets LDR or treatment exemptions for organics (40 CFR 264.1082(c)(2) or (c)(4))
      ❑ Waste contains VOCs that average <500 ppmw (CFR 264.1082(c)(1)) – will require annual update.
   e. Form Code: _____ f. Source Code: _____
2. State Hazardous Waste → Please list all state waste codes:_____
3. For material that is Treated, Delisted, or Excluded → Please indicate the category, below:
   ❑ Delisted Hazardous Waste ❑ Excluded Waste under 40 CFR 261.4 → Specify Exclusion:_____
   ❑ Treated Hazardous Waste Debris ❑ Treated Characteristic Hazardous Waste → If checked, complete question 4.
4. Underlying Hazardous Constituents → Please list all Underlying Hazardous Constituents:

| |
|---|
| |

5. a. Are you an industry regulated under Benzene NESHAP? (Petroleum refineries, chemical manufacturing plants, coke by-product, and TSDFs.) ❑ Yes ❑ No
   b. Are you a TSDF? → If yes, please complete Benzene NESHAP questionnaire. If not, continue. ❑ Yes ❑ No
   c. What is the flow weighted average benzene concentration? _____ ppmw
   d. What is your facility's current total annual benzene quantity in Megagrams? ❑ <1 Mg ❑ 1–9.99 Mg ❑ ≥10 Mg
   e. Is this waste soil from a remediation? ❑ Yes ❑No
      1. If yes, what is the benzene concentration in remediation waste? _____ ppmw
   f. Does the waste contain >10% water/moisture? ❑ Yes ❑No
   g. Has material been treated to remove 99% of the benzene or to achieve <10 ppmw? ❑ Yes ❑No
   h. Is material exempt from controls in accordance with 40 CFR 61.342? ❑ Yes ❑No
      → If yes, specify exemption:_____
   i. Based on your knowledge of your waste and the BWON regulations, do you believe that this waste stream is subject to treatment and control requirements at an off-site TSDF? ❑ Yes ❑No
6. 40 CFR 63 GGGGG → Does the material contain <500 ppmw VOHAPs at the point of determination? ❑ Yes ❑No
7. CERCLA or State-Mandated clean up → Please submit the Record of Decision or other documentation with process information to assist others in the evaluation for proper disposal. A "Determination of Acceptability" may be needed for CERCLA wastes not going to a CERCLA approved facility.
8. NRC, State-regulated radioactive, NORM or TENORM? →
   a. Please select all that apply:
   ❑ Nuclear Regulatory Commission (NRC) Radioactive ❑ Technologically Enhanced Naturally Occurring Radioactive Material (TENORM)
   ❑ State-Regulated Radioactive ❑ Naturally Occurring Radioactive Material
   b. Testing, per individual waste stream, for applicable isotopes and/or other supporting information attached? ❑ Yes ❑ No



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# Additional Profile Information

Profile Number:_____

## C. MATERIAL INFORMATION

Material Composition and Contaminants (Continued from page 2): If more space is needed, please attach additional pages.

| | |
|---|---|
| 10. | |
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| 33. | |
| 34. | |
| 35. | |
| 36. | |
| 37. | |
| 38. | |
| 39. | |
| 40. | |
| Total composition must be equal to or greater than 100% | ≥100% |

## D. REGULATORY INFORMATION

1. EPA Hazardous Waste
   a. Please list all USEPA listed and characteristic waste code numbers (Continued from page 2):



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# Additional Profile Information

Profile Number:_____

## F. SHIPPING AND DOT INFORMATION

4. USDOT Proper Shipping & Technical Name (Continued from page 1):

| | |
|---|---|
| 2. | ❑ N/A |
| 3. | ❑ N/A |
| 4. | ❑ N/A |
| 5. | ❑ N/A |
| 6. | ❑ N/A |
| 7. | ❑ N/A |
| 8. | ❑ N/A |
| 9. | ❑ N/A |
| 10. | ❑ N/A |
| 11. | ❑ N/A |
| 12. | ❑ N/A |
| 13. | ❑ N/A |
| 14. | ❑ N/A |
| 15. | ❑ N/A |
| 16. | ❑ N/A |
| 17. | ❑ N/A |
| 18. | ❑ N/A |
| 19. | ❑ N/A |
| 20. | ❑ N/A |
| 21. | ❑ N/A |
| 22. | ❑ N/A |
| 23. | ❑ N/A |
| 24. | ❑ N/A |
| 25. | ❑ N/A |
| 26. | ❑ N/A |
| 27. | ❑ N/A |
| 28. | ❑ N/A |
| 29. | ❑ N/A |
| 30. | ❑ N/A |
| 31. | ❑ N/A |
| 32. | ❑ N/A |
| 33. | ❑ N/A |
| 34. | ❑ N/A |
| 35. | ❑ N/A |
| 36. | ❑ N/A |
| 37. | ❑ N/A |
| 38. | ❑ N/A |
| 39. | ❑ N/A |
| 40. | ❑ N/A |

7. Transportation Requested: ❑ WM Hauled ❑ Third Party

8. Contact Name: _____

9. Email: _____



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# Additional Profile Information

Profile Number: _____

## C. MATERIAL INFORMATION

3. State Waste Codes (Continued from page 1):

| |
|---|
| 2. |
| 3. |
| 4. |
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**Attachment 3**

**Water Waste Profile Application**
**Heritage Environmental Services, 1626 Research Way, Indianapolis, IN 46231**

Heritage Environmental was unable to provide a timely waste profile application form for water so this alternate form is provided.

Profile #:

*Note: Standard templates may be available online for various common waste streams, Universal Waste, Recyclable Goods, and Lab Packs. To see a list of templates click HERE.*

## A. GENERATOR/CUSTOMER INFORMATION *(If foreign generator, complete Waste Import Supplement)*

1. **Generator:**
2. **Site Address:** **City:** **Phone:** **State:** **Zip:** **Country:**
3. **Mailing Address:** **City:** **State:** **Zip:** **Country:**
4. **Technical Contact:**
5. **Phone:** **Email:**

☐ **Invoicing information is the same as generator mailing address**

☐ **P.O. required for payment?** *If yes, include:*

8. **Invoicing Company:**
9. **Invoicing Address:** **City:** **State:** **Zip:** **Country:**
10. **Customer Contact:**
11. **Phone:** **Email:**

6. **Generator Status:** ○ SQG ○ LQG ○ VSQG/CESQG *(If yes, complete Certification Supplement)* ○ Not Applicable
7. **EPA ID #:** **NAICS CODE:** **State ID #:** *(If applicable)*

## B. WASTE/MATERIAL STREAM *(For assistance completing this document, click HERE)*

1. **Common Name:**

*(Please provide a site history for Remediation & IDW sites. Use additional form if necessary.)*

2. **Generating Process:**
3. **Source Code:** **Form Code:**

## C. SHIPPING/PACKAGING INFORMATION

1. **DOT Hazardous Materials?** ○ Yes ○ No **Proper Shipping Name:**
2. **Additional Description:** *(49 CFR 172.203, e.g. "Lead" or "D008")*
3. **RQ:** ○ Yes ○ No **RQ Reason:** **RQ Threshold:** **UN/NA #:**
   **Packing Group:** **ERG #:** **Hazard Class:** Select #1 Select #2 Select #3
4. **DOT Special Permit?** ○ Yes ○ No **Permit #:**
5. **24-Hour Emergency Phone:**
6. **DOT Inhalation Hazard?** ○ Yes ○ No
7. **Container Type:** ☐ Bulk ☐ Totes ☐ Pallet ☐ Boxes ☐ Drums ☐ Cylinder **Container Size:**
   ☐ Lab Pack *(If 40 CFR 264.316/49CFR 173.12(b) Lab Pack Inventory lists required)*
   ☐ Combination Containers (e.g., inner containers), **Describe:**
   ☐ Other, **Describe:**
8. **Volume/Frequency:** **Volume:** **Units:**
   **Frequency:** ○ Year ○ Quarterly ○ Monthly ○ 1 Time ○ Other, **Describe:**

## D. PHYSICAL PROPERTIES *(Use additional form if necessary)*

1. **Physical Description** *(e.g. soil, water, PPE, debris, sorbent, etc. Include 100% of container content. If debris, provide dimensions & weight.)*

| Description | Typical (%) | Min (%) | Max (%) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

2. **Odor:** ○ None ○ Slight ○ Strong
   **Odor Type:** ☐ Ammonia ☐ Amines ☐ Mercaptans ☐ Sulfur ☐ Organic Acid ☐ Other, **Describe:**
3. **Physical State:** *(at 70°F)* ☐ Solid ☐ Dust/Powder ☐ Debris ☐ Sludge/Slurry ☐ Liquid ☐ Gas/Aerosol ☐ Varies
4. **Color:** Primary Color Secondary Color
5. **Liquid phases:** ○ Single ○ Double Layer ○ Multi-layer ○ N/A
6. **Is it solid using the paint filter test?** *(40 CFR Part 264.314(b))* ○ Yes *(Solid)* ○ No *(Not Solid)*
   **Is there a possibility of incidental liquids from transportation?** ○ Yes ○ No
7. **pH:** *(If solid, provide estimated pH if mixed 50:50 with water)* ☐ ≤ 2 ☐ 2.1 - 4.9 ☐ 5 - 10 ☐ 10.1 - 12.4 ☐ ≥ 12.5
8. **Flash Point:** °F and/or ☐ < 90°F ☐ 90 - 139°F ☐ 140 - 199°F ☐ ≥ 200°F ☐ Does Not Flash ☐ Flammable Solid
   **BTU /lb. Value:** and/or ○ <5000 BTU ○ ≥5000 BTU
9. **Are there any known handling/treatment issues involving this material? (*i.e. Describe whether the waste stream has ever been the direct or suspected cause of a fire or other reaction, and whether there are any specific controls you use to prevent any adverse reactions?*)**
   ○ Yes ○ No *If yes*, **Describe:**

## E. CHARACTERIZATION & CHEMICAL COMPOSITION *(Use additional form if necessary)*

**1. US Ecology Texas Customers - Waste/Material Type:** ○ Industrial ○ Non-Industrial ○ N/A **TX State Code:**
**Pennsylvania Residual Waste:** ○ Yes ○ No **PA State Code(s):**

**2. State Waste Codes:** ☐ None

**3. RCRA Waste Codes:** ☐ None

**If None, is it exempt from the definition of "Solid Waste" or "Hazardous Waste"?** ○ Yes ○ No
*If yes, list reference from 40 CFR Part 261.2, 3, or 4:*

**4. If F006-F009, F012, or F019, are Cyanides used in the process?** ○ Yes ○ No *(If yes, Total and Amenable CN (9010/9012) analysis required)*

**5. Knowledge is from:** ☐ Lab analysis *(requires attachment)* ☐ SDS/MSDS *(requires attachment)* ☐ Process/generator knowledge

**6. Chemical Composition** *(include all applicable UHC's, TRI Section 313 chemicals, OSHA Hazardous Materials, PFAS Constituents, etc.)*

| Constituent | Units | TCLP | Totals | Typical | Min | Max | UHC | Exceeds LDR |
|---|---|---|---|---|---|---|---|---|
| | Select | ○ | ○ | | | | ☐ | ☐ |
| | Select | ○ | ○ | | | | ☐ | ☐ |
| | Select | ○ | ○ | | | | ☐ | ☐ |
| | Select | ○ | ○ | | | | ☐ | ☐ |
| | Select | ○ | ○ | | | | ☐ | ☐ |
| | Select | ○ | ○ | | | | ☐ | ☐ |
| | Select | ○ | ○ | | | | ☐ | ☐ |
| | Select | ○ | ○ | | | | ☐ | ☐ |

## F. ADDITIONAL PROPERTIES ☐ None Apply *(Through Question F23)*

| | | | |
|---|---|---|---|
| **1. Explosive:** ○ Yes ○ No | **2. Reactive Sulfides:** ____ **ppm** ○ Yes ○ No |
| **3. Shock Sensitive:** ○ Yes ○ No | **4. Reactive Cyanides:** ____ **ppm** ○ Yes ○ No |
| **5. Radioactive:** ○ Yes ○ No *(If yes, complete Radioactive Waste Acceptance Supplement)* | **6. Reactive Other:** ○ Yes ○ No **Describe:** |
| **7. Medical/Infectious/Biohazard Waste:** ○ Yes ○ No | **8. Polychlorinated Biphenyls (PCB):** ○ Yes ○ No *(If yes, complete PCB Supplement)* |
| **9. Dioxins and/or Furans:** ○ Yes ○ No | **10. Metal Fines/Powder/Paste:** ○ Yes ○ No *(Including Aluminum)* |
| **11. Pyrophoric:** ○ Yes ○ No | **12. Temperature Controlled:** ○ Yes ○ No *(For Transportation Only)* |
| **13. Thermally Unstable:** ○ Yes ○ No | **14. Biodegradable Sorbents:** ○ Yes ○ No |
| **15. Compressed Gas:** ○ Yes ○ No *(If yes, complete Compressed Gas Cylinder Supplement)* | **16. Used Oil:** (per 40 CFR Part 279) ○ Yes ○ No *(If yes, complete Used Oil Supplement)* |
| **17. Oxidizer:** *(List in Section E6)* ○ Yes ○ No | **18. Tires:** *(If yes, must be quartered for landfill)* ○ Yes ○ No |
| **19. Organic Peroxide:** ○ Yes ○ No | **20. Beryllium:** ○ Yes ○ No |
| **21. Ammonia/Ammonia Compounds:** ○ Yes ○ No | **22. Per-and Polyfluoroalkyl Substances (PFAS):** ○ Yes ○ No |

**23. Asbestos:** ○ Yes ○ No **If Yes:** ○ Friable ○ Non-Friable *(If friable, material must be packaged per 40 CFR Part 61.150)*

**24. Hazardous Secondary Material:** *(Per 40 CFR Part 260.10)* ○ Yes ○ No
*If yes,* ☐ I certify that this waste/material meets all requirements of legitimate recycling of Hazardous Secondary Materials under 40 CFR Part 260.43 and/or I am complying with the conditions for generators using one verified recycler exclusion.

**25. Are pharmaceutical wastes profiled under this approval subject to a prescription?** ○ Yes ○ No ○ N/A
*(If yes, complete Pharmaceutical Certification Supplement)*

## G. REGULATORY INFORMATION

**1. Volatile Organic Concentration:** *(Per 40 CFR Part 264.1083 & 265.1084)* ◯ <500 ppmw ◯ ≥500 ppmw

**2. Has the material been treated after the initial point of generation?** ◯ Yes ◯ No *If yes,* **Describe:**

**3. If RCRA Hazardous:** ◯ None Apply

- ◯ Wastewater *WW=<1% TSS & TOC; 40 CFR Part 268.2*
- ◯ Non-wastewater *TSS/TOC>WW*
- ◯ Alternative Treatment Standards for soil *> 50% soil; 40 CFR Part 268.49*
- ◯ Alternative Treatment Standards for debris *40 CFR Part 268.2(g) & (h); >50% of waste is >2.5 inch size*
  - ☐ I confirm debris cannot reasonably be separated from non-debris by simple physical or mechanical means.
  - ☐ I confirm debris has not been mixed/diluted with non-debris as prohibited in *40 CFR Part 268.3.*
- ◯ Waste meets LDR Treatment Standards

**4. Treatment subcategory:** *(if applicable)*

**5. Is the site or waste/material, subject to NESHAP/MACT standard(s)?** ◯ Yes ◯ No
*If yes,* **Please choose the applicable Part:** ◯ **61** ◯ **62** ◯ **63 Subpart** ____ **of NESHAP/MACT standards** ◯ **N/A**

**6. Is the waste/material RCRA Hazardous containing Benzene and originating at a petroleum refinery (SIC 2911), chemical manufacturing plant (SIC 2800 thru 2899) or Coke by-product recovery plant (SIC 3312)?**
◯ Yes ◯ No (*If yes, complete the Benzene Waste Operations Supplement and if applicable the Thermal Supplement.*)

## H. GENERATOR'S CERTIFICATION

**1. Is a specific facility or treatment technology requested?** ◯ Yes ◯ No

**2. Requested Technology:**

**3. Thermal processing:** ◯ Yes ◯ No *(If yes, complete Thermal Supplement)*

**4. Other specific restrictions requested:**

**5. Requested US Ecology Facility:**

*(If US Ecology Chicago, complete Illinois Disposal Supplement)*

I certify that all information (including attachments) is complete, factual and is an accurate representation of the known and suspected hazards pertaining to waste/material described herein. I authorize US Ecology's personnel to add supplemental information to the Waste/Material Profile Form, provided I am contacted and grant permission to do so. US Ecology may require re-submittal of the Waste/Material Profile Form if substantial changes are determined necessary. I authorize US Ecology's personnel to obtain a sample from any waste/material shipment for purposes of verification and confirmation and understand that waste/material that does not conform to specifications described in this Waste/Material Profile Form may be rejected by US Ecology. I certify that I am familiar with the waste/material described herein through analysis and/or process knowledge and that all information is true, accurate, representative and complete and that this Waste/Material Profile Form was completed in accordance with the instructions provided.

***If I am an agent acting on behalf of the generator, I also certify that I have permission to sign any and all waste/material characterization paperwork on the generator's behalf and that I can produce such certification in writing upon request.***

**Print Name:** **Signature:**

**Title:** **Company:**

**Date:**

**Attachment 4**

**Pace Analytical SOPs**

| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0034 v03_Volatiles by SW-846 8260C** |
| | **Effective Date: 10/16/2023** |

**Management Approval:**
Elizabeth Schrage Approved on 10/13/2023 3:23:17 PM
Sarah Potts Approved on 10/16/2023 10:57:09 AM
Steven Sayer Approved on 10/13/2023 3:48:05 PM
Anne Troyer Approved on 10/16/2023 11:06:36 AM

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## 1.0 SCOPE AND APPLICATION

1.1 The purpose of this SOP is to provide a laboratory specific procedure for determining Volatile Organic Compounds (VOCs) in environmental samples. The laboratory utilizes purge-and-trap GC/MS and bases these documented procedures on those listed in SW-846 Method 8260C, 5030A, 5030B, and 5035A.

1.2 This method is applicable to most organic compounds that have boiling points below 200 ºC and are insoluble or slightly soluble in water. Volatile water-soluble compounds may also be determined although quantitation limits are typically higher due to their hydrophilic properties (e.g. ketones, oxygenates).

1.3 This method is applicable to most water and solid samples, regardless of moisture content. Matrices are groundwater, surface water, soil, sediment, and waste. Procedures may need to be adapted to address limitations in the method or equipment that might hinder or interfere with sample analysis.

1.4 The list of target compounds and reporting limits is found in Table 1. Refer to the LIMS for method detection limits.

1.5 Reporting limits, control limits, volumes/weights used, standard concentrations, vendors, instrumentation, equipment, and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

Volatile organic compounds are introduced into the gas chromatograph by a purge-and trap method. The analytes are purged from a sample aliquot or extract using an inert gas. The purged analytes are collected on an absorbent trap. At the completion of the purge time, the trap is rapidly heated and back flushed to drive out the trapped analytes. The analytes are transferred into the inlet of a capillary gas chromatography column. The carrier gas flow through the column is controlled and the temperature is increased according to a set program to achieve optimum separation of purged analytes. The mass spectrometer is operated in a repetitive scan mode. Analytes are identified by the GC/MS retention times and by a comparison of their mass spectra with spectra of authentic standards. Analytes are quantified by comparing the response of a selected primary ion relative to an internal standard against a calibration curve.

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## 3.0 INTERFERENCES

3.1 Major contaminant sources are volatile materials in the laboratory and impurities in the inert purging gas and in the absorbent trap. Many common solvents, most notably acetone and methylene chloride, are frequently found in laboratory air at low levels. The use of polytetrafluoroethylene (PTFE, Teflon) as thread sealants, tubing, or in flow controllers is highly recommended since other materials can be sources of contamination which may concentrate in the trap during the purging.

3.2 A common source of interfering contamination is carryover. This may occur when a sample containing low concentrations of volatile organic compounds is analyzed immediately after a sample containing high concentrations of volatile organic compounds. The preventive action to this condition is rinsing the purging apparatus and sample syringes with organic free water between samples. Analyze one or more blanks to check for contamination prior to sample analysis. If the sample immediately following the high concentration sample does not contain the compounds present in the high-level sample, freedom from carryover contamination has been established.

3.3 Samples can be contaminated by diffusion of volatile organics (particularly methylene chloride and fluorocarbons) through the septum seal of the sample container into the sample during shipment and storage. A trip blank prepared from organic-free reagent water and carried through the sampling, handling, and storage protocols can serve as a check on such contamination.

3.4 Since methylene chloride and acetone are common laboratory solvents, special precautions must be taken. The volatiles analysis and sample storage area must be located as far as possible from areas where these solvents are used or stored. Where possible, the volatiles analysis and sample storage area should be served by a separate HVAC system and maintained under positive pressure to prevent intrusion of contaminants. Laboratory clothing previously exposed to methylene chloride fumes during extraction procedures can contribute to sample contamination.

## 4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

The distribution of printed or electronic copies of this document outside of the PAS electronic document management system (eDMS) is not controlled or tracked. PAS employees must ensure any copy used for daily work, if not accessed directly from PAS eDMS, is the current version of the document.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **5030B Aqueous** | Minimum (3) VOA vials<br>Additional sample is required if MS/MSD is requested. | Acidified w/ 1:1 HCl to pH<2, no headspace<br>(pH<2 may not be appropriate if 2-Chloroethyl vinyl ether, Acrolein, Acrylonitrile are target compounds – Refer to SW-846 Chapter 4) | Cool to ≤6°C | pH>2: Analysis must be completed within 7 days of collection date.<br>pH<2: Analysis must be completed within 14 days of collection date.<br>(pH determined post-analysis) |
| **5035A Solid Terra Core Kits (Preferred)** | One (1) container for % moisture<br>**AND**<br>Two (2) 5-g portions in vials with magnetic stir bar and 5.0mL reagent water plus one (1) 5 g portion in a vial with 5.0mL methanol<br>**OR**<br>Two (2) 10-g portions in vials with 10mL methanol.<br>Additional sample is required if MS/MSD is requested. | Either no preservative or methanol as a preservative. | Cool to ≤6°C for no more than 48 hours from collection then freeze at -7°C to -20°C.<br>Methanol vials may be stored at ≤6°C. | Analysis must be completed within 48 hours if samples are not frozen or preserved with methanol prior to the expiration of the 48-hour period.<br>The holding time may be extended to 14 days if the sample is frozen or preserved with methanol prior to the expiration of the 48-hour period. |

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| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **5035A Solid Coring Devices (Alternate)** | One (1) container for % moisture<br>**AND**<br>Two (2) EnCore, TerraCore or similar sampling tubes.<br>Additional sample is required if MS/MSD is requested. | No preservative<br>Sample is extruded into a vial with a magnetic stir bar and 5.0mL reagent water. | Freeze at -7°C to -20°C within 48 hours of collection. | Analysis must be completed within 14 days of collection date. |
| **5030A Solid Bulk Jars** | One (1) container for % moisture<br>**AND**<br>One bulk sample jar, usually 4 oz. or 8 oz. | No preservative<br>Sample is weighed into a vial with a magnetic stir bar and 5.0mL reagent water. | Cool to ≤6°C | Analysis must be completed within 14 days of collection date |

## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| Gas Chromatograph | Agilent 6850, 6890, 8890, or equivalent |
| Mass Spectrometer | Agilent 5973, 5975, 5977, or equivalent |
| P&T Concentrators | EST Analytical Encon or Evolution, or equivalent |
| Analytical Columns | J&W Scientific DB-624, 20m x 0.18mm x 1um, or equivalent |
| Trap | Supelco Trap K, or equivalent |
| Autosampler | EST Analytical Centurion, Centurion W/S, or equivalent |
| Data System | Agilent Chemstation, or equivalent |

### 7.2 Supplies

| Supplies | Description |
|---|---|
| Gas tight syringes | Hamilton or equivalent, various sizes |
| Volumetric flasks | Class A, various sizes |
| Standard vials | Supelco or equivalent vials with stop/go (mininert) caps |
| Sample vials | C&G #V54-A000-A01A-P01, or equivalent 40mL vials; pre-cleaned |
| pH paper | School Masters Science #46809, or equivalent |
| Analytical Balances | Capable of measuring to the nearest 0.001g/0.01g |
| Magnetic stir bars | Cleaned with soap/water, tap water, methanol, reagent water and baked for one hour. |

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## 8.0 REAGENTS AND STANDARDS

### 8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Reagent water | Volatile-free water |
| Methanol | Purge-and trap grade or equivalent |
| Sand | Or equivalent material to be used as a simulated soil matrix. |

### 8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| Stock VOA calibration standards | Phenova cat# ALO-180007, 180024, 180025, 180003, and Restek cat# 30287; or equivalent standards | Manufacturer's expiration date | Manufacturer's storage conditions |
| Stock Gas calibration standards | Phenova cat# ALO-180002,180018 and Restek cat# 578538, or equivalent standards | Manufacturer's expiration date | Manufacturer's storage conditions |
| Intermediate VOA calibration standard | Refer to Section 8.3.1 | Solution good for 1 month from preparation | Same as stock standard |
| Intermediate Gas calibration standard | Refer to Section 8.3.2 | Solution good for 1 week from preparation | Same as stock standard |
| Working VOA calibration standards | Refer to Section 8.3.3 | One-time use | Not applicable |
| Stock VOA ICV/Spiking standards | Restek cat# 577455, 578536, 30216, 30646, 577454, 577451, 577452, 577453, and 578541; or equivalent standards | Manufacturer's expiration date | Manufacturer's storage conditions |
| Intermediate VOA ICV/Spiking standard | Refer to Section 8.3.4 | Solution good for 1 month from preparation | Same as stock standard |
| Working ICV/Spiking standard | Refer to Section 8.3.5 | One-time use | Not applicable |
| Stock VOA Tune/ Surrogate standard | Restek; cat# 30240, 2500ug/mL or equivalent | Manufacturer's expiration date | Manufacturer's storage conditions |
| Stock VOA Internal standards | Restek; cat# 30241, 2500ug/mL or equivalent | Manufacturer's expiration date | Manufacturer's storage conditions |
| Working Tune/Surrogate/Internal standard mix | Refer to Section 8.3.6 | Solution good for 1 month from preparation | Stored on autosampler under pressure in a 5mL vial |

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8.3 Standard Preparation Procedures

Note: for all calibration standards, opened stock vials must be used within one week or be discarded. Opened stock vials of internal standard and surrogate are transferred to a screw-cap vial and stored in the freezer until exhausted or the manufacturer's expiration date.

8.3.1 Intermediate VOA Calibration Standard Preparation

Using gas-tight syringes, add the following standard volumes to a 5mL stop/go vial and dilute to 5.0mL by adding 2.625mL methanol for a final concentration of 25-1000mg/L (larger or smaller final volume of standard may be prepared if components are proportional):

| Standard | Catalog # | Volume (uL) | Volume (mL) |
|---|---|---|---|
| 8260REACT-STK | ALO-180007 | 125 | 0.125 |
| 8260CAL-STK | ALO-180024 | 125 | 0.125 |
| 8260ADD1-STK | ALO-180025 | 125 | 0.125 |
| 8260ELEV-STK | ALO-180003 | 125 | 0.125 |
| 8260Dioxane | 30287 | 1875 | 1.875 |

8.3.2 Intermediate Gas Calibration Standard Preparation

Using gas-tight syringes, add the following standard volumes to a 5mL stop/go vial and dilute to 5.0mL by adding 3.875mL methanol for a final concentration of 50-1000mg/L (larger or smaller final volume of standard may be prepared if components are proportional):

| Standard | Catalog # | Volume (uL) | Volume (mL) |
|---|---|---|---|
| 8260GAS-STK | ALO-180002 | 125 | 0.125 |
| 8260ACRR-STK | 578538 | 500 | 0.500 |
| 8260VACE-STK | ALO-180018 | 500 | 0.500 |

8.3.3 Working VOA Calibration Standards Preparation

The following are examples of one-time use calibration standards prepared in reagent water and could vary based on requirements, calibration range may vary.

8.3.3.1 Working Calibration Standards – Regular Level (examples only):

| Standard | Int. Calibration Std Volume | Int. Gas Std. Volume | Final Total Volume | Nominal Final Concentration |
|---|---|---|---|---|
| CAL1* | 3uL | 3uL | 200mL | 0.75 ug/L |
| CAL2 | 2uL | 2uL | 50mL | 2 ug/L |
| CAL3 | 5uL | 5uL | 50mL | 5 ug/L |
| CAL4 | 10uL | 10uL | 50mL | 10 ug/L |

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| Standard | Int. Calibration Std Volume | Int. Gas Std. Volume | Final Total Volume | Nominal Final Concentration |
|---|---|---|---|---|
| CAL5 | 2uL | 2uL | 5mL | 20 ug/L |
| CAL6 (CCV) | 5uL | 5uL | 5mL | 50 ug/L |
| CAL7 | 15uL | 15uL | 5mL | 150 ug/L |
| CAL8 | 30uL | 30uL | 5mL | 300 ug/L |

**CAL1 as described is primarily used to calibrate Benzene, 1,2-Dibromoethane (EDB), and Naphthalene for programs with regulatory limits below the CAL2 concentration.*

8.3.3.2 Working Calibration Standards – Low Level (examples only):

| Standard | Int. Calibration Std Volume | Int. Gas Std. Volume | Final Total Volume | Nominal Final Concentration |
|---|---|---|---|---|
| CAL1** | 2uL | 2uL | 200mL | 0.5ug/L |
| CAL2 | 2uL | 2uL | 100mL | 1ug/L |
| CAL3 | 4uL | 4uL | 100mL | 2ug/L |
| CAL4 | 10uL | 10uL | 100mL | 5ug/L |
| CAL5 | 20uL | 20uL | 100mL | 10ug/L |
| CAL6 | 40uL | 40uL | 100mL | 20ug/L |
| CAL7 (CCV) | 100uL | 100uL | 100mL | 50ug/L |
| CAL8 | 300uL | 300uL | 100mL | 150ug/L |
| CAL9 | 600uL | 600uL | 100mL | 300ug/L |

***CAL1 as described is primarily used to calibrate Vinyl chloride, Acrolein, Acrylonitrile, and Vinyl acetate for programs with regulatory limits below the CAL2 concentration.*

8.3.4 Intermediate VOA ICV/Spiking Standard Preparation (Example)

Using gas-tight syringes, add the following standard volumes to a 5mL stop/go vial and dilute to 5.0mL by adding 2.625mL methanol for a final concentration of 50-1000mg/L (larger or smaller final volume of standard may be prepared if components are proportional):

| Standard | Catalog # | Volume (uL) | Volume (mL) |
|---|---|---|---|
| 8260REAC-RES | 577455 | 125 | 0.125 |
| 82602CEVE-ST | 578536 | 125 | 0.125 |
| 8260VACER-ST | 30216 | 500 | 0.500 |
| 8260ACROR-ST | 30646 | 1000 | 1.0 |
| 8260GASR-STK | 577454 | 125 | 0.125 |
| 8260MEGAR-ST | 577451 | 125 | 0.125 |
| 8260ELV1R-ST | 577452 | 125 | 0.125 |
| 8260ELV2R-ST | 577453 | 125 | 0.125 |
| 8260ADD1R-ST | 578541 | 125 | 0.125 |

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8.3.5 Working ICV/Spiking Standard Preparation (Example)

**Water/Soil Systems:** Add 5uL of the Intermediate ICV/Spiking standard to 5mL reagent water for a final nominal ICV concentration of 50ug/L.

**Water Systems:** Dilute 50uL of the Intermediate ICV/Spiking standard to 50mL reagent water and transfer to a 40mL vial for a final nominal ICV concentration of 50ug/L.

8.3.6 Working Tune/Surrogate/Internal Standard Preparation (Example only, may vary)

Add together 100uL of Restek #30240 plus 100uL of Restek #30241 plus 4.8mL of methanol for a final concentration of 50mg/L.

## 9.0 PROCEDURE

9.1 Equipment Preparation

9.1.1 Configure the purge & trap system and GC/MS system per manufacturer's instructions.

9.1.2 Tune Verification: At the beginning of each analytical sequence, prior to the analysis of any standards or samples, the mass spectrometer must be hardware tuned by injecting ≤50ng of 4-Bromofluorobenzene (BFB). This is done by analyzing a standard containing BFB. The BFB and calibration verification standard may be combined provided both tuning and calibration verification acceptance criteria are met without interferences. Use the BFB mass intensity criteria in the table below as tuning acceptance criteria. Alternate tuning criteria may be used provided method performance is not adversely affected.

| Mass (m/z) | Ion Abundance criteria |
|---|---|
| 50 | 15 to 40% of m/z 95 |
| 75 | 30 to 60% of m/z 95 |
| 95 | Base peak, 100% relative abundance |
| 96 | 5 to 9% of m/z 95 |
| 173 | <2% of m/z 174 |
| 174 | >50% of m/z 95 |
| 175 | 5 to 9% of m/z 174 |
| 176 | 95 to 101% of m/z 174 |
| 177 | 5 to 9% of m/z 176 |

9.1.3 The mass spectrum of BFB may be obtained by averaging three scans, the peak apex scan and the scans immediately preceding and following the apex. Background subtraction is required using this approach and must be accomplished using a single scan no more than 20 scans prior to the elution of BFB. Do not background subtract part of the BFB peak. Alternatively, the analyst may use other approaches suggested:

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9.1.3.1 A single scan within the BFB peak with background subtraction of a single scan no more than 20 scans prior to the elution of BFB

9.1.3.2 An average of multiple scans within the BFB peak with background subtraction of a single scan no more than 20 scans prior to the elution of BFB.

9.1.4 Refer to Section 11.1 for corrective actions.

9.2 Initial Calibration (ICAL)

9.2.1 Initial Calibration standards are introduced into the GC/MS from the lowest to highest concentration of each working calibration standard. The lowest calibration standard must be at or below the required reporting limit. Five calibration points, at a minimum, are analyzed to evaluate linearity.

9.2.2 Initial Calibration Evaluation

9.2.2.1 The response factor (RF) is calculated for each compound for each calibration standard as follows:

$$RF = \frac{(A_x)(C_{IS})}{(A_{IS})(C_x)}$$

where: $A_x$ = Area of the quantitation ion for the compound being measured
$A_{IS}$ = Area of the quantitation ion for the internal standard
$C_{IS}$ = Concentration of the internal standard
$C_x$ = Concentration of the compound being measured

9.2.2.2 For each calibration standard, all reported compounds that appear in Table 3 must meet the minimum response factor criteria shown.

9.2.2.3 The average response factor ($RF_{avg}$) is determined by averaging the response factors at the different concentrations for each target analyte.

9.2.2.4 The percent relative standard deviation (%RSD) of the response factors is calculated as follows:

$$\%RSD = \frac{(SD)}{RF_{avg}} \times 100$$

where: SD = Standard deviation of average RF for a compound
$RF_{avg}$ = Mean of RFs for a compound

9.2.2.5 If the percent relative standard deviation (%RSD) of the RFs for a compound is $\leq$20% over the calibration range, then the slopes of the lines for each standard are sufficiently close to one another and the $RF_{avg}$ may be used to determine sample concentrations.

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9.2.2.6 If the %RSD for any compound is >20%, the analyst may employ a linear regression equation, non-weighted or weighted 1/x or $1/x^2$, that does not pass through the origin. The regression calculation will generate a correlation coefficient (r) that is the measure of the "goodness of fit" of the regression line to the data. To be used for quantitative purposes, the correlation coefficient must be >0.99.

9.2.2.7 Individual analyte calibration levels may be removed from the lowest and/or highest levels of the calibration curve provided the number of remaining calibration points meet the minimum requirements and the quantitation range is adjusted, as necessary.

9.2.2.8 Removal of interior calibration levels is not permitted unless a standard introduction error or preparation error can be documented.

9.2.2.9 A calibration level may be replaced provided that the replacement calibration standard is analyzed within 24 hours of the original analysis and all analytes are replaced.

9.2.2.10 For compounds evaluated using linear curve fit (Section 9.2.2.6), the laboratory must evaluate Relative Error:

$$\%\ Relative\ Error = \frac{x_i^{'} - x_i}{x_i}\ x\ 100$$

Where: $x_i$ = True value of the calibration standard
$x'_i$ = Measured concentration of the calibration standard

Determine %RE by back-calculating two (2) initial calibration levels, the standard at the midpoint and the standard at the lowest point. %RE must be ≤30% (70-130% Recovery) for the midpoint standard and ≤50% (50-150% Recovery) for the lowest point.

9.2.2.11 If compounds fail to meet the criteria in Sections 9.2.2.1 – 9.2.2.10, the calibration fit must be set to average response factor. Sample concentrations may be determined for failing compounds, but they must be reported as estimated. To report non-detects for a failing compound, the compound must have been detected with a response greater than zero in the initial calibration standard that corresponds to the reporting limit.

9.2.2.12 Each day that analysis is performed, the calibration standard(s) should be evaluated to determine if the chromatographic system is operating properly. Questions that should be asked are: Do the peaks look normal? Is the response obtained comparable to the response from previous calibrations? Are the retention times consistent over the range of calibration for each compound? Careful examination of the standard chromatogram can indicate whether the column is still performing acceptably.

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Additionally, examination of signal-to-noise ratio of analytes in low-level standards may be a useful diagnostic tool to monitor instrument performance. Signal-to-noise ratio is defined as the ratio of the analyte signal to the noise measured on a blank. It is recommended but not required that the signal-to-noise ratio be at least three to confirm detection.

9.2.2.13 Refer to Section 11.1 for corrective actions.

9.2.3 Initial Calibration Verification (ICV)

9.2.3.1 In addition to meeting the response and linearity criteria, any new calibration curve must be assessed for accuracy of the values generated. To assess the accuracy of the calibration, a single standard from a secondary source must be analyzed and the results obtained must be compared to the known true value. This step is referred to as the Initial Calibration Verification. The ICV must be from an alternative vendor or, in the event an alternative vendor is not available, from a different lot from the same vendor. The ICV is analyzed immediately following the initial calibration curve.

9.2.3.2 Calculate the percent recovery for each analyte using the equation:

$$\%\ Recovery = \frac{Observed\ Concentration}{Theoretical\ Concentration} \times 100$$

The acceptance limits for the ICV are 70-130% recovery for all reported compounds, except the following compounds with acceptance limits of 50-150% recovery:

| | |
|---|---|
| Acetone | Acrolein |
| Allyl chloride | Bromomethane |
| tert-Butyl alcohol | Chloromethane |
| Dichlorodifluoromethane | 1,4-Dioxane |
| Iodomethane | Isobutyl alcohol |
| Methyl acetate | Vinyl acetate |

9.2.3.3 Refer to Section 11.1 for corrective actions.

9.3 Continuing Calibration Verification (CCV)

9.3.1 The initial calibration is verified every 12 hours by analyzing a BFB tune that must meet the criteria in Section 9.1.2, followed by a Continuing Calibration Verification (CCV) standard.

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9.3.2 All target compounds in the CCV must be evaluated using a +/-20% variability criterion. Use percent difference when the average RF model calibration has been used. Use percent drift when a regression fit model has been used.

$$\%\ Difference\ (\%D) = \frac{Calculated\ conc. - Expected\ conc.}{Expected\ conc.} \times 100$$

$$\%\ Drift = \frac{Calculated\ conc. - Theoretical\ conc.}{Theoretical\ conc.} \times 100$$

9.3.3 If the percent difference or percent drift for a compound is ≤20%, then the initial calibration for that compound is considered valid and sample analysis can continue. If the criterion is not met for more than 20% of the compounds included in the calibration, then corrective action must be taken prior to sample analysis.

In cases where compounds are >20% difference or drift, they may still be reported as non-detects if the compound was detected with a response greater than zero in the initial calibration standard that corresponds to the reporting limit. When a failed compound is present in samples at or above the reporting limit, reported concentration must be qualified as estimated. Alternatively, the sample may be reanalyzed.

9.3.4 All reported compounds that appear in Table 3 must meet the minimum response factor criteria shown. If the minimum response factors are not met, the system should be evaluated, and corrective action should be taken before sample analysis begins.

9.3.5 The internal standard areas in the CCV must be -50% to +100% of the internal standard areas of the corresponding standard in the initial calibration. In addition, the retention time of the internal standards in the CCV cannot shift by more than 10 seconds from the corresponding standard in the initial calibration. Failure in either of these two areas requires the analyst to evaluate their system and perform maintenance if necessary.

9.3.6 Refer to Section 11.1 for corrective actions.

9.4 Sample Preparation and Handling

9.4.1 Refer to Section 6 for additional information regarding sample handling.

9.4.2 Aqueous Samples

9.4.2.1 Evaluate sample vials for presence of headspace. If a bubble >6 mm in diameter is present, analyze from another vial without headspace if available. If all vials contain headspace >6 mm, appropriately qualify on the batch work list/sequence log and in LIMS.

9.4.2.2 Water samples analyzed using the Centurion water system autosampler require no sample preparation and are loaded as full 40mL vials, unless dilution is required.

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9.4.2.3 Water samples to be analyzed on the Centurion Water/Soil autosampler are prepared by quickly measuring a 5mL aliquot of the sample using a 5mL gastight syringe and transferring it to a clean 40mL vial. This is done as quickly as possible to minimize analyte loss. The syringe is thoroughly rinsed inside and out with reagent water before measuring each sample. If only one vial is available for a sample, prepare two aliquots of the sample in the event the sample needs to be reanalyzed. Do not reuse a vial that has already been sampled and has significant headspace unless no other unused vials are available.

9.4.2.4 Dilutions on aqueous samples must be prepared in a volumetric fashion. Sample aliquots are measured in either a volumetric pipet or gas-tight syringe and brought to volume in either a volumetric flask or gas-tight syringe.

9.4.2.5 After analysis is complete or at the time of 5mL sample preparation, check the residue in the vial using pH paper. The pH should be <2 if HCl-preserved vials were used. Holding time for water samples with pH >2 is 7 days. Appropriately qualify on the sequence log and in LIMS any sample not meeting the pH requirement and/or holding time requirement.

9.4.2.6 Aqueous Method Blank Preparation:

9.4.2.6.1 Water/Soil Systems: The Method Blank consists of a 40mL vial containing 5mL reagent water.

9.4.2.6.2 Water Systems: The Method Blank consists of an HCl-preserved 40mL vial filled completely with reagent water.

9.4.2.7 Aqueous LCS Preparation:

9.4.2.7.1 Water/Soil Systems: Add 5uL of the Intermediate ICV/Spiking standard to 5mL reagent water for a nominal LCS concentration of 50ug/L.

9.4.2.7.2 Water Systems: Dilute 50uL of the Intermediate ICV/Spiking standard to 50mL reagent water and transfer to a 40mL vial for a nominal LCS concentration of 50ug/L.

9.4.2.8 Aqueous MS Preparation:

9.4.2.8.1 Water/Soil Systems: Add 5uL of the Intermediate ICV/Spiking standard to 5mL sample for a nominal MS concentration of 50ug/L.

9.4.2.8.2 Water Systems: Inject 40uL of the Intermediate ICV/Spiking standard directly into the 40mL vial containing the sample.

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9.4.3 Low-Level Soil Samples

9.4.3.1 Preferably, samples received for low level analysis should be contained in pre-weighed Terra Core vials with reagent water. Prior to analysis the sample weight must be determined and recorded by weighing the vial and recording the weight. Subtract the tare weight indicated on the vial and correct for the label weight to determine the sample weight. The sample is ready for analysis.

9.4.3.2 Alternatively, samples received in coring devices, such as Encore, must be extruded into a pre-weighed vial either with or without 5mL reagent water and a stir bar. Record the weight of the vial after the sample has been placed into it. Subtract the tare weight determined initially to determine the sample weight. The sample is ready for analysis.

9.4.3.3 Samples received in bulk soil jars are sub-sampled into a vial. Place an empty vial on the balance pan and tare the balance. Quickly add 5.0–5.5g of sample to the vial. Record the sample weight. Add 5mL of reagent water and a stir bar and cap the vial. The sample is ready for analysis.

9.4.3.4 Low-Level Soil Method Blank Preparation: The Method Blank consists of a 40mL vial containing 5.0–5.5g simulated soil matrix, 5mL reagent water, and a stir bar.

9.4.3.5 Low-Level Soil LCS Preparation: Place 5.0–5.5g of simulated soil matrix, 5mL reagent water, and a stir bar into a vial. Add 5uL of the Intermediate ICV/Spiking standard for a nominal LCS concentration of 50ug/kg.

9.4.3.6 Low-Level Soil MS Preparation: Place 5.0–5.5g of sample, 5mL reagent water, and a stir bar into a vial. Add 5uL of the Intermediate ICV/Spiking standard for a nominal MS concentration of 50ug/kg.

9.4.4 Medium-Level Soil Samples

9.4.4.1 Preferably, samples received for medium-level analysis should be received in pre-weighed Terra Core vials with methanol as a preservative. Prior to analysis the sample weight must be determined and recorded by weighing the vial and recording the weight. Subtract the tare weight indicated on the vial and correct for the label weight to determine the sample weight. The sample is mixed well on a vortex mixer and allowed to settle.

9.4.4.2 Alternatively, samples received in coring devices, such as Encore, must be extruded into a pre-weighed vial with 5mL methanol. Add 5mL methanol to a vial and screw on the lid. Weigh the vial with methanol and record this initial weight. Extrude the sample into the vial and record the weight of the vial with the extruded sample. Subtract the weight determined initially to determine the sample weight. The sample is mixed well on a vortex mixer and allowed to settle.

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9.4.4.3 Samples received in bulk soil jars are sub-sampled into a 40mL vial. Place an empty vial on the balance pan and tare the balance. Quickly add 5.0–5.5g of sample to the vial. Record the sample weight. Add 5mL methanol and cap the vial. The sample is mixed well on a vortex mixer and allowed to settle or may be centrifuged.

9.4.4.4 Medium-Level Dilutions: Medium-level sample dilutions are made in a volumetric fashion. Transfer a portion of the methanol extract using a gastight syringe to a vial containing 5mL reagent water for analysis on a water/soil instrument or to a volumetric flask containing reagent water for a water instrument, bringing the volumetric flask to volume after the addition of the extract. The amount of methanol extract transferred is based on the desired dilution. A maximum of 100uL of methanol extract per 5mL reagent water is used for analysis.

9.4.4.5 Medium-Level Soil Method Blank Preparation: Medium-Level soils may be analyzed/batched with aqueous samples. Refer to Section 9.4.2.5 for Method Blank preparation.

9.4.4.6 Medium-Level Soil LCS Preparation: Medium-Level soils may be analyzed/batched with aqueous samples. Refer to Section 9.4.2.6 for LCS preparation.

9.4.4.7 Medium-Level Soil MS Preparation:

9.4.4.7.1 Water/Soil Systems: place a maximum of 200uL methanol sample extract into a vial and add enough reagent water to bring the final volume to 5mL. Add 5uL of the Intermediate ICV/Spiking standard.

9.4.4.7.2 Water Systems: Inject 80uL of the Intermediate ICV/Spiking standard directly into the 40mL vial containing the sample dilution.

9.5 Sample Analysis

9.5.1 All samples must be analyzed at room temperature and the system must be calibrated and free of contamination before samples are analyzed.

9.5.2 The purge & trap system and GC/MS system configuration settings used for sample analysis must be the same as from initial calibration.

9.5.3 Autosampler automatically adds a constant volume of internal standard/surrogate mix to each injection.

9.5.4 Load vials into the autosampler in the desired order and start the sequence. Example sequence is below:

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BFB Tune (12-hour clock starts)
CCV (CCV may also be used as the tune to start the 12-hour clock)
LCS
Blank (optional)
Method Blank
Samples (all samples must be injected within 12 hours of the tune)

## 10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Qualitative Analysis

Analytes of interest are identified as present when the following criteria are met:

10.1.1 The relative retention time (RRT) for the analyte must compare within +/- 0.06 RRT units of the RRT for that analyte in the CCV.

10.1.2 The intensities of the characteristic ions of a compound must maximize in the same scan or within one scan of each other. Refer to Table 2 for the characteristic ions.

10.1.3 The relative intensities of the characteristic ions agree within 30% of the relative intensities of these ions in the reference spectrum.

10.1.4 If the acquired mass spectrum is contaminated or if identification is ambiguous, an experienced mass spectrometrist must determine the presence or absence of the compound.

10.2 Quantitative Analysis: When an analyte has been identified, quantitation of that analyte is based on the integrated response of the primary characteristic ion (quant ion). Calculate the concentration using the response factor (RF) or regression equation established with initial calibration.

10.3 Samples with target compound concentrations that exceed the calibration range must be reanalyzed at a dilution or qualified as estimated.

10.4 Refer to the Manual Integrations SOP for guidance on performing and documenting manual integrations.

10.5 Calculations

10.5.1 Calculate the final concentration in the sample as follows:

Aqueous Sample (ug/L) = $(X_s)(D)$ Solid Sample (ug/kg) = $\frac{(X_s)(V_f)(D)}{(W_s)}$

Where: $X_s$ = Concentration of the analyte from the instrument, ug/L
$V_f$ = Final volume, L
D = Dilution factor (Final Volume/Initial Volume)
$W_s$ = Weight of solid sample, kg

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$$\text{Moisture corrected concentration} = \frac{\text{(Final concentration as received)}}{\text{(100 - \%Moisture)}} \times 100$$

10.5.2 LCS calculation:

$$R = (C / S) \times 100$$

Where: R = Percent Recovery
C = Observed LCS concentration
S = True LCS concentration

10.5.3 MS calculation:

$$R = \frac{(C_s - C)}{S} \times 100$$

Where: R = Percent Recovery
$C_s$ = Observed MS concentration
C = Sample concentration
S = True spike concentration

10.5.4 RPD calculation:

$$RPD = \frac{|D_1 - D_2|}{[(D_1 + D_2)/2]} \times 100$$

Where: RPD = Relative Percent Difference
$D_1$ = First Sample Result
$D_2$ = Second Sample Result

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## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

### 11.1 Instrument Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Tune** | BFB | Every 12 hours of instrument operation | Refer to Sections 9.1.2 and 9.1.3 | Reanalyze the BFB tune. If the tune still fails the criteria, instrument maintenance, and/or preparation of new standards must be considered. |
| **Initial Calibration** | Applicable target analytes | As needed | Refer to Section 9.2 | Analyze a new initial calibration curve. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed initial calibration must be reanalyzed or affected data must be qualified. |
| **Initial Calibration Verification (ICV)** | Second Source Standard | Immediately following initial calibration of the instrument | 70-130% Recovery<br><br>50-150% Recovery for compounds noted in Section 9.2.3.2. | Reanalyze an ICV. If the second ICV also exceeds the acceptance range, a new initial calibration should be prepared. Samples associated with a failed ICV must be reanalyzed or affected data must be qualified.<br>*Exception:* If the ICV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |
| **Continuing Calibration Verification (CCV)** | Primary Source Standard | Every 12 hours of continuous instrument operation | Refer to Section 9.3 | Reanalyze a CCV. If the second CCV also fails, a new initial calibration should be prepared. Samples associated with a failed CCV must be reanalyzed or affected must be qualified.<br>*Exception:* If the CCV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |

### 11.2 Batch Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Method Blank (MB)** | Reagent water | One per preparation batch of up to 20 samples, per matrix. | Target analytes must be less than reporting limits. | Reanalyze method blank. If target compound is still >RL in method blank and associated samples, reanalyze samples.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, the reported method blank and samples must be qualified.<br>2) If a contaminant is present only in the method blank and not the samples, no action is required.<br>3) If contaminant is present in the sample at a concentration >10x the method blank, sample may be reported with qualification. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Laboratory Control Standard (LCS)** | Applicable target analytes | One per preparation batch of up to 20 samples, per matrix. | Lab-generated %Recovery limits<br>Refer to the LIMS for acceptance limits.<br>Refer to Section 11.3 for allowable marginal exceedances. | Reanalyze the LCS. If LCS is still outside acceptance limits, reanalyze all associated samples. Refer to Section 11.3 for allowable marginal exceedances.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported data must be qualified.<br>2) If LCS recovery is >QC limits and sample results are non-detect, the sample data may be reported. The LCS data must be qualified.<br>3) If allowed by program or client, an associated matrix spike that meets LCS acceptance limits may be used in place of the LCS. LCS must be reported and qualified. |
| **Matrix Spike/ Matrix Spike Duplicate (MS/MSD)** | Applicable target analytes | One MS/MSD set per preparation batch of up to 20 samples, per matrix. | Lab-generated %Recovery limits<br>RPD ≤20%<br>Refer to the LIMS for acceptance limits. | No corrective actions necessary for spiked compounds or surrogates. If LCS recovery is in range, the system is considered in-control and the out-of-control MS/MSD must be qualified appropriately. |
| **Sample Duplicate (DUP)** | Sample | One sample duplicate per batch of up to 20 samples if no MS/MSD. | RPD ≤20% | Qualify duplicate appropriately if RPD is out-of-control. |
| **Surrogates** | Applicable surrogate compounds | Added to each standard, sample, and method blank. | Lab-generated %Recovery limits<br>Refer to the LIMS for acceptance limits. | Samples with surrogate failures must be reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported surrogate data must be qualified.<br>2) If surrogate result is >QC limits, and sample results are non-detect, the sample results may be reported without qualifiers. The surrogate must be qualified.<br>3) If there is obvious visible chromatographic interference with a surrogate, results may be reported but must be qualified. |
| **Internal Standards Evaluation for Samples (Only if required by client or program)** | Applicable Internal Standard compounds | Added to each standard, sample, and method blank. | Sample ISTD areas must be -50% to +100% of the areas of the CCV.<br>Sample ISTD RTs must be +/-10 seconds from CCV. | If required by client or program, samples with ISTD failures must be re-analyzed at the same dilution or more concentrated.<br>*Exceptions:*<br>1) If internal standards are low, indicating high bias to results, and sample is non-detect, the sample results may be reported but must be qualified.<br>2) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported data must be qualified. |

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11.3 **Allowable Marginal Exceedances**: If large numbers of analytes are in the LCS, it becomes statistically likely that a few will be outside control limits. A marginal exceedance (ME) is defined as being beyond the LCS control limit of +/-3 standard deviations, but within the ME limits of +/-4 standard deviations around the mean. The number of allowable MEs is based on the number of analytes in the LCS. If more analytes exceed the LCS control limits than is allowed, or if any one analyte exceeds the ME limits, the LCS fails, and correction action is necessary. If analytes exceed the upper marginal exceedance limit, indicating high bias, associated samples determined to be <RL may be reported. If the same analyte exceeds the LCS control limit consecutively, it is an indication of a systemic problem. The source of the error shall be located, and corrective action taken.

The number of allowable marginal exceedances is as follows:

| Number of Analytes in LCS | Number Allowed as Marginal Exceedances |
|---|---|
| > 90 | 5 |
| 71 – 90 | 4 |
| 51 – 70 | 3 |
| 31 – 50 | 2 |
| 11 – 30 | 1 |
| < 11 | 0 |

NOTE: As allowed by client or program, the LCS may be outside the control limits but ≥10% recovery for up to four additional volatile compounds except benzene, toluene, ethylbenzene, m&p-xylene, o-xylene, total xylenes and any requested oxygenate, without corrective action.

11.4 Method Validation

Refer to the SOP for Method Validation and Instrument Verification for the procedures used for initial method validation. Method Detection Limits (MDL) must be determined per the procedure in 40CFR Part 136, Appendix B.

11.5 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

## 12.0 Data Review And Corrective Action

12.1 Data Review

The analyst must perform primary review of data and calculated results for accuracy. Secondary review of the data and calculated results must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

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12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

## 14.0 MODIFICATIONS

14.1 GC columns and chromatographic conditions may differ from those recommended.

14.2 Calibration solutions are purchased as certified standards.

## 15.0 RESPONSIBILITIES

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

## 16.0 ATTACHMENTS

16.1 Table 1: Method 8260C Target Compounds and Reporting Limits

16.2 Table 2: Characteristic Ions and Internal Standard Association of Target Compounds

16.3 Table 3: Minimum Average Response Factor Criteria

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## 17.0 REFERENCES

17.1 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Methods 8000D, 8260C, 5030A, 5030B, and 5035A.

17.2 Pace Analytical Quality Manual; latest revision.

17.3 NELAC/TNI Standards; Quality Systems section; 2003, 2009, and 2016.

## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 6.0 | Added language to 5030B preservation that pH<2 may not be appropriate for specific compounds. |
| 7.1, 7.2 | Updated to reflect current equipment and supplies. |
| 8.2 | Updated standard manufacturers and catalog numbers to those currently in use. |
| 8.3 | Updated standard preparation to match current practice. |
| 9.2.3.2 | Updated list of ICV compounds with limits of 50-150% to account for all poor performers. |
| 9.3.5 | Updated internal standard criteria for clarity. |
| 9.4.2 | Added headspace evaluation. Updated terminology and procedures for clarity. |
| 9.4.4 | Updated procedures for clarity. Added centrifugation as an option for samples received in bulk jars. |
| 9.5.3 | Added statement that surrogate/ISTD is added by autosampler. |
| 9.5.4 | Added example sequence. |
| 11.2 | Updated internal standard criteria and corrective actions for clarity. |
| Table 1 | Updated default reporting limits for some compounds. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0034 | Volatiles by GC/MS (8260C) | 02 |

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## Table 1
## Method 8260C Target Compounds and Reporting Limits[1]

| Analyte | Water (ug/L) | Low-Level Water (ug/L) | Low-Level Soil (ug/kg) | Medium-Level Soil (ug/kg) |
|---|---|---|---|---|
| 1,1,1,2-Tetrachloroethane | 5 | 1 | 5 | 50 |
| 1,1,1-Trichloroethane | 5 | 1 | 5 | 50 |
| 1,1,2,2-Tetrachloroethane | 5 | 1 | 5 | 50 |
| 1,1,2-Trichlorotrifluoroethane | 5 | 1 | 5 | 50 |
| 1,1,2-Trichloroethane | 5 | 1 | 5 | 50 |
| 1,1-Dichloroethane | 5 | 1 | 5 | 50 |
| 1,1-Dichloroethene | 5 | 1 | 5 | 50 |
| 1,1-Dichloropropene | 5 | 1 | 5 | 50 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | 5 | 1 | 5 | 50 |
| 1,1-Dichloroethene | 5 | 1 | 5 | 50 |
| 1,2,3-Trichlorobenzene | 5 | 1 | 5 | 50 |
| 1,2,3-Trichloropropane | 5 | 1 | 5 | 50 |
| 1,2,4-Trichlorobenzene | 5 | 1 | 5 | 50 |
| 1,2,4-Trimethylbenzene | 5 | 5 | 5 | 50 |
| 1,2-Dibromo-3-chloropropane (DBCP) | 10 | 10 | 10 | 100 |
| 1,2-Dibromoethane (EDB) | 5 | 1 | 5 | 50 |
| 1,2-Dichlorobenzene | 5 | 1 | 5 | 50 |
| 1,2-Dichloroethane | 5 | 1 | 5 | 50 |
| 1,2-Dichloropropane | 5 | 1 | 5 | 50 |
| 1,3,5-Trimethylbenzene | 5 | 5 | 5 | 50 |
| 1,3-Dichlorobenzene | 5 | 1 | 5 | 50 |
| 1,3-Dichloropropane | 5 | 1 | 5 | 50 |
| 1,4-Dichlorobenzene | 5 | 1 | 5 | 50 |
| 1,4-Dioxane (p-Dioxane) | 200 | 200 | 500 | 10000 |
| 1-Methylnaphthalene | 10 | 20 | 10 | 250 |
| 2,2-Dichloropropane | 5 | 1 | 5 | 50 |
| 2-Butanone (MEK) | 25 | 20 | 25 | 250 |
| 2-Chloroethyl vinyl ether | 50 | 50 | 50 | 500 |
| 2-Chlorotoluene | 5 | 1 | 5 | 50 |
| 2-Hexanone | 25 | 20 | 100 | 1000 |
| 2-Methylnaphthalene | 10 | 20 | 10 | 100 |
| 4-Chlorotoluene | 5 | 1 | 5 | 50 |
| 4-Isopropyltoluene (p-Isopropyltoluene) | 5 | 1 | 5 | 50 |
| 4-Methyl-2-pentanone (MIBK) | 25 | 20 | 25 | 250 |
| Acetone | 100 | 20 | 100 | 1000 |

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| Analyte | Water (ug/L) | Low-Level Water (ug/L) | Low-Level Soil (ug/kg) | Medium-Level Soil (ug/kg) |
|---|---|---|---|---|
| Acetonitrile | 100 | 100 | 100 | 1000 |
| Acrolein | 50 | 20 | 100 | 1000 |
| Acrylonitrile | 100 | 100 | 100 | 1000 |
| Allyl chloride | 5 | 20 | 10 | 100 |
| Benzene | 5 | 1 | 5 | 50 |
| Bromobenzene | 5 | 1 | 5 | 50 |
| Bromochloromethane | 5 | 1 | 5 | 50 |
| Bromodichloromethane | 5 | 1 | 5 | 50 |
| Bromoform | 5 | 1 | 5 | 50 |
| Bromomethane (Methyl bromide) | 5 | 5 | 5 | 50 |
| Carbon Disulfide | 10 | 5 | 10 | 100 |
| Carbon Tetrachloride | 5 | 1 | 5 | 50 |
| Chlorobenzene | 5 | 1 | 5 | 50 |
| Chlorodibromomethane (Dibromochloromethane) | 5 | 1 | 5 | 50 |
| Chloroethane | 5 | 2 | 5 | 50 |
| Chloroform | 5 | 1 | 5 | 50 |
| Chloromethane (Methyl chloride) | 5 | 2 | 5 | 50 |
| Chloroprene | 100 | 100 | 100 | 1000 |
| cis-1,2-Dichloroethene | 5 | 1 | 5 | 50 |
| cis-1,3-Dichloropropene | 5 | 1 | 5 | 50 |
| Cyclohexane | 100 | 20 | 100 | 1000 |
| Dibromomethane | 5 | 1 | 5 | 50 |
| Dichlorodifluoromethane | 5 | 2 | 5 | 50 |
| Diethyl ether (Ethyl ether) | 20 | 20 | 50 | 50 |
| Ethyl acetate | 100 | 25 | 1000 | 10000 |
| Ethyl Methacrylate | 100 | 20 | 100 | 1000 |
| Ethylbenzene | 5 | 1 | 5 | 50 |
| Hexachlorobutadiene | 5 | 1 | 5 | 50 |
| Iodomethane | 10 | 5 | 100 | 1000 |
| Isobutanol (Isobutyl alcohol) | 100 | 100 | 100 | 2500 |
| Isopropylbenzene (Cumene) | 5 | 1 | 5 | 50 |
| Methacrylonitrile | 100 | 100 | 100 | 1000 |
| Methyl acetate | 50 | 25 | 50 | 10000 |
| Methyl methacrylate | 100 | 20 | 100 | 100 |
| Methyl tert-butyl ether (MTBE) | 4 | 4 | 5 | 50 |
| Methylcyclohexane | 50 | 20 | 50 | 50 |
| Methylene Chloride (Dichloromethane) | 5 | 5 | 20 | 200 |
| m&p-Xylene | 5 | 2 | 5 | 50 |

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| Analyte | Water (ug/L) | Low-Level Water (ug/L) | Low-Level Soil (ug/kg) | Medium-Level Soil (ug/kg) |
|---|---|---|---|---|
| Naphthalene | 5 | 1 | 5 | 50 |
| n-Butylbenzene | 5 | 1 | 5 | 50 |
| n-Hexane | 5 | 5 | 5 | 50 |
| n-Propylbenzene | 5 | 1 | 5 | 50 |
| o-Xylene | 5 | 1 | 5 | 50 |
| Propionitrile | 100 | 100 | 100 | 1000 |
| sec-Butylbenzene | 5 | 1 | 5 | 50 |
| Styrene | 5 | 1 | 5 | 50 |
| tert-Butyl alcohol | 50 | 10 | 50 | 500 |
| tert-Butylbenzene | 5 | 1 | 5 | 50 |
| Tetrachloroethene | 5 | 1 | 5 | 50 |
| Tetrahydrofuran | 100 | 20 | 100 | 1000 |
| Toluene | 5 | 1 | 5 | 50 |
| trans-1,2-Dichloroethene | 5 | 1 | 5 | 50 |
| trans-1,3-Dichloropropene | 5 | 1 | 5 | 50 |
| trans-1,4-Dichloro-2-butene | 100 | 100 | 100 | 1000 |
| Trichloroethene | 5 | 1 | 5 | 50 |
| Trichlorofluoromethane | 5 | 2 | 5 | 50 |
| Vinyl acetate | 50 | 20 | 100 | 1000 |
| Vinyl chloride | 2 | 1 | 5 | 50 |
| Xylene (Total) | 10 | 3 | 10 | 100 |

[1]*Target Compounds and Reporting Limits are subject to change. List may not represent all calibrated compounds.*

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## Table 2: Characteristic Ions and Internal Standard Association of Target Compounds[2]

| Analyte | Primary Ion | Secondary Ion |
|---|---|---|
| **Group 1 – Fluorobenzene (IS)** | **96** | **-** |
| Dichlorodifluoromethane | 85 | 87 |
| Chloromethane (Methyl chloride) | 50 | 52 |
| Vinyl Chloride | 62 | 64 |
| Bromomethane (Methyl bromide) | 94 | 96 |
| Chloroethane | 64 | 66 |
| Trichlorofluoromethane | 101 | 103 |
| Diethyl ether (Ethyl ether) | 74 | 45 |
| Acrolein | 56 | 55 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | 101 | 151 |
| 1,1-Dichloroethene | 96 | 61 |
| Acetone | 43 | 58 |
| Iodomethane | 142 | 127 |
| Carbon Disulfide | 76 | 78 |
| Acetonitrile | 39 | 40 |
| Allyl chloride | 41 | 76 |
| Methyl acetate | 43 | 74 |
| Methylene Chloride | 84 | 49 |
| tert-Butyl alcohol | 59 | 41 |
| Acrylonitrile | 53 | 52 |
| Methyl tert-butyl ether | 73 | 57 |
| trans-1,2-Dichloroethene | 96 | 61 |
| n-Hexane | 57 | 55 |
| 1,1-Dichloroethane | 63 | 65 |
| Vinyl Acetate | 43 | 86 |
| Chloroprene | 53 | 88 |
| 2-Butanone (MEK) | 43 | 72 |
| 2,2-Dichloropropane | 77 | 97 |

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| Group 1 – Fluorobenzene (IS) continued | 96 | - |
|---|---|---|
| cis-1,2-Dichloroethene | 96 | 61 |
| Propionitrile | 54 | 52 |
| Ethyl acetate | 88 | 61 |
| Methacrylonitrile | 41 | 67 |
| Bromochloromethane | 49 | 128 |
| Tetrahydrofuran | 42 | 71 |
| Chloroform | 83 | 85 |
| Dibromofluoromethane (Surr) | 113 | 111 |
| 1,1,1-Trichloroethane | 97 | 99 |
| Cyclohexane | 56 | 84 |
| Carbon Tetrachloride | 117 | 119 |
| 1,1-Dichloropropene | 75 | 77 |
| Isobutanol (Isobutyl alcohol) | 43 | 41 |
| Benzene | 78 | 52 |
| 1,2-Dichloroethane | 62 | 64 |
| Trichloroethene | 95 | 130 |
| Methylcyclohexane | 55 | 69 |
| 1,2-Dichloropropane | 63 | 62 |
| Dibromomethane | 93 | 95 |
| 1,4-Dioxane (p-Dioxane) | 88 | 58 |
| Methyl methacrylate | 69 | 41 |
| Bromodichloromethane | 83 | 85 |
| **Group 2 – Chlorobenzene-d5 (IS)** | **117** | **82** |
| 2-Chloroethylvinyl ether | 63 | 65 |
| cis-1,3-Dichloropropene | 75 | 77 |
| 4-Methyl-2-pentanone (MIBK) | 43 | 58 |
| Toluene-d8 | 98 | 100 |
| Toluene | 91 | 92 |
| trans-1,3-Dichloropropene | 75 | 77 |
| Ethyl Methacrylate | 69 | 99 |

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| Group 2 – Chlorobenzene-d5 (IS) continued | 117 | 82 |
|---|---|---|
| 1,1,2-Trichloroethane | 83 | 85 |
| Tetrachloroethene | 166 | 168 |
| 1,3-Dichloropropane | 76 | 78 |
| 2-Hexanone | 43 | 58 |
| Dibromochloromethane (Chlorodibromomethane) | 129 | 127 |
| 1,2-Dibromoethane (EDB) | 107 | 109 |
| Chlorobenzene | 112 | 114 |
| 1,1,1,2-Tetrachloroethane | 131 | 133 |
| Ethylbenzene | 106 | 91 |
| m&p-Xylene | 106 | 91 |
| o-Xylene | 106 | 91 |
| Styrene | 104 | 78 |
| Isopropylbenzene (Cumene) | 105 | 120 |
| 4-Bromofluorobenzene (Surr) | 95 | 174 |
| Bromobenzene | 77 | 156 |
| trans-1,4-Dichloro-2-butene | 53 | 88 |
| **Group 3 – 1,4-Dichlorobenzene-d4 (IS)** | **152** | **150** |
| Bromoform | 173 | 175 |
| 1,1,2,2-Tetrachloroethane | 83 | 85 |
| 1,2,3-Trichloropropane | 110 | 75 |
| n-Propylbenzene | 91 | 120 |
| 2-Chlorotoluene | 91 | 126 |
| 1,3,5-Trimethylbenzene | 105 | 120 |
| 4-Chlorotoluene | 126 | 91 |
| tert-Butylbenzene | 119 | 91 |
| 1,2,4-Trimethylbenzene | 105 | 120 |
| sec-Butylbenzene | 105 | 134 |
| 1,3-Dichlorobenzene | 146 | 148 |
| p-Isopropyltoluene | 119 | 134 |
| 1,4-Dichlorobenzene | 146 | 148 |

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| Group 3 – 1,4-Dichlorobenzene-d4 (IS) | 152 | 150 |
|---|---|---|
| n-Butylbenzene | 91 | 92 |
| 1,2-Dichlorobenzene | 146 | 148 |
| 1,2-Dibromo-3-chloropropane | 155 | 75 |
| 1,2,4-Trichlorobenzene | 180 | 182 |
| Hexachlorobutadiene | 225 | 223 |
| Naphthalene | 128 | 127 |
| 1,2,3-Trichlorobenzene | 180 | 182 |
| 2-Methylnaphthalene | 142 | 141 |
| 1-Methylnaphthalene | 142 | 141 |

[2]*Internal standard association and/or characteristic ions are subject to change.*

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## Table 3: Minimum Average Response Factor Criteria

| Analyte | Minimum Response Factor (RF) |
|---|---|
| Dichlorodifluoromethane | 0.100 |
| Chloromethane | 0.100 |
| Vinyl Chloride | 0.100 |
| *Bromomethane | 0.05 |
| Chloroethane | 0.100 |
| Trichlorofluoromethane | 0.100 |
| Methylene Chloride | 0.100 |
| 1,1-Dichloroethene | 0.100 |
| trans-1,2-Dichloroethene | 0.100 |
| 1,1-Dichloroethane | 0.200 |
| cis-1,2-Dichloroethene | 0.100 |
| Chloroform | 0.200 |
| 1,1,1-Trichloroethane | 0.100 |
| Cyclohexane | 0.100 |
| Carbon Tetrachloride | 0.100 |
| Benzene | 0.500 |
| 1,2-Dichloroethane | 0.100 |
| *Trichloroethene | 0.100 |
| 1,2-Dichloropropane | 0.100 |
| Bromodichloromethane | 0.200 |
| Toluene | 0.400 |
| 1,1,2-Trichloroethane | 0.100 |
| *Tetrachloroethene | 0.100 |
| Dibromochloromethane (Chlorodibromomethane) | 0.100 |
| 1,2-Dibromoethane (EDB) | 0.100 |
| Chlorobenzene | 0.500 |

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| Analyte | Minimum Response Factor (RF) |
|---|---|
| Ethylbenzene | 0.100 |
| m&p-Xylene | 0.100 |
| o-Xylene | 0.300 |
| Styrene | 0.300 |
| Bromoform | 0.100 |
| Isopropylbenzene (Cumene) | 0.100 |
| 1,1,2,2-Tetrachloroethane | 0.300 |
| 1,3-Dichlorobenzene | 0.600 |
| 1,4-Dichlorobenzene | 0.500 |
| 1,2-Dichlorobenzene | 0.400 |
| 1,2,4-Trichlorobenzene | 0.200 |
| trans-1,3-Dichloropropene | 0.100 |
| cis-1,3-Dichloropropene | 0.200 |
| *Acetone | 0.010 |
| *2-Butanone (MEK) | 0.010 |
| *4-Methyl-2-pentanone (MIBK) | 0.050 |
| *2-Hexanone | 0.050 |
| Methyl tert-butyl ether | 0.100 |
| Carbon Disulfide | 0.100 |
| 1,2-Dibromo-3-chloropropane | 0.050 |
| Methylcyclohexane | 0.100 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | 0.100 |
| Methyl acetate | 0.100 |

**Alternate minimum average RF criteria based on compound performance.*

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## 1.0 SCOPE AND APPLICATION

1.1 This standard operating procedure (SOP) describes the laboratory procedure for the determination of semivolatile organic compounds in sample extracts while meeting the requirements specified in EPA method 8270C.

1.2 This method can be used to quantitate most neutral, acidic, and basic organic compounds that are soluble in methylene chloride and capable of being eluted without derivatization from a gas chromatographic fused-silica capillary column coated with a slightly polar silicone. Such compounds include polynuclear aromatic hydrocarbons, chlorinated hydrocarbons and pesticides, phthalate esters, organophosphate esters, nitrosamines, haloethers, aldehydes, ethers, ketones, anilines, pyridines, quinolines, aromatic nitro compounds, phenols, and nitrophenols.

1.3 The following compounds may require special treatment when being determined by this method. Benzidine can be subject to oxidative losses during solvent extraction and exhibits poor chromatographic behavior. Hexachlorocyclopentadiene is subject to thermal decomposition in the inlet of the gas chromatograph, chemical reaction in acetone solution, and photochemical decomposition. N-nitrosdiphenylamine decomposes in the gas chromatographic inlet and cannot be separated from diphenylamine. Pentachlorophenol, 2,4-dinitrophenol, 4-nitrophenol, 4,6-dinitro-2-methylphenol, 4-chloro-3-methylphenol, benzoic acid, 2-nitroaniline, 3-nitroaniline, 4-chloroaniline, and benzyl alcohol are subject to erratic chromatographic behavior, especially if the GC system is contaminated with high boiling material.

1.4 The following compounds are analyzed using this procedure but are not 8270C listed compounds: Carbazole, Biphenyl (Diphenyl), Caprolactam, Atrazine, Benzaldehyde, Diethyl Aniline, 2,3-Dichloroaniline, 1-Methylnaphthalene, 4-Chlorobenzotrifluoride, n-Octadecane, and Pentachloroethane.

1.5 The following Appendix IX compounds may require special treatment when being determined by this method. 3,3'-Dimethylbenzidine, Famphur, Kepone, Hexachlorophene, p-Phenylenediamine, and a,a-Dimethylphenylethylamine break down easily in the calibration mix and may not be detected in low concentration standards.

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1.6 The list of compounds and reporting limits analyzed by this laboratory using method 8270C is found in Table 1 and Table 3. Other analytes may be analyzed by this method but must have quality control documentation to support the performance of this method for those analytes. Refer to LIMS for method detection limits.

1.7 Reporting limits, control limits, volumes used, standard concentrations, vendors, instrumentation, equipment and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

Semivolatile compounds are introduced into a gas chromatograph by injection of a sample extract onto a narrow-bore capillary column for analysis. The column is temperature programmed to separate the analytes that are then detected with a mass spectrometer. Identification of the analytes is made by comparing their mass spectra with spectra of known standards. Quantitation is accomplished by comparing the response of a major ion relative to the internal standard response using a multi-point calibration curve.

Method 8270C provides chromatographic conditions for the detection of semivolatile compounds in organic extracts of groundwater, surface water, soil and sediment. Aqueous samples are extracted by using SW-846 method 3510 Separatory Funnel Extraction or other applicable method. Solid samples are extracted using SW-846 method 3546 Microwave Extraction or other applicable method.

## 3.0 INTERFERENCES

Glassware for the preparatory steps for this method should be thoroughly cleaned and rinsed. Soap products can leave phthalates on the glassware that may interfere chromatographically. Hits for phthalates should be closely scrutinized and continuous hits should warrant checking the cleanliness of all reagents and supplies.

Contamination by carryover can occur whenever high-concentration and low-concentration samples are sequentially analyzed. All samples analyzed after high-concentration samples should be evaluated for carryover.

## 4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

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The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Aqueous** | Amber glass container with Teflon-lined lid, 100mL widemouth | No preservation required | Cool to ≤6°C | Sample must be extracted within 7 days of collection date and extract must be analyzed within 40 days of extraction date. |
| **Solid** | 200 grams in 4oz or 8oz glass jar | No preservation required | Cool to ≤6°C | Sample must be extracted within 14 days of collection date and extract must be analyzed within 40 days of extraction date. |

**Note:** Store extracts at or below -10°C, protected from light, in sealed vials with unpierced PTFE-lined septa.

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## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Vendor | Model / Version | Description / Comments |
|---|---|---|---|
| Gas Chromatographs | Agilent | Lab uses models 6890 and 7890 | Or equivalent system |
| Mass Spectrometers | Agilent | Lab uses models 5973 and 5975 | Or equivalent system |
| Autosamplers | Agilent | | Or equivalent system |
| Data Systems | Agilent | | Or equivalent system |
| Analytical Columns | Restek | Rti-5 Sil MS | 15m x 0.25mm, or equivalent column |
| | Phenomenex | ZB semivolatiles | 15m x 0.25mm, or equivalent |

### 7.2 Supplies

| Supplies | Description |
|---|---|
| Gas tight syringes | Hamilton or equivalent, various sizes |
| Syringe valves | Supelco 2-way with Luer ends or equivalent |
| Standard vials | Supelco 2mL stop/go vials (clear vials) or equivalent |
| Autosampler vials | 1.8mL volume (clear vials) with PTFE-lined crimp tops or equivalent |

## 8.0 REAGENTS AND STANDARDS

### 8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Methylene Chloride | Pesticide grade or equivalent |
| Acetone | Pesticide grade or equivalent |
| Methanol | Pesticide grade or equivalent |

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8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| Internal Standard, Surrogate, and Tune Mixes | | | |
| Stock 8270 Internal Standards | Restek; catalog # 31006; 4000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Working 8270 LVE Internal Standards | Refer to Section 8.3.1 | Solution expires 6 months from date of preparation. | Refrigerate |
| Stock 8270 Surrogate Standards | Accustandard; catalog #M-8270-SS; 4000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock DFTPP Tuning Standard | Sigma; catalog #47387, 50ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Standard Compound List Mixes | | | |
| Stock 8270 Mega Mix Calibration Standard | Restek; catalog # 31850; 1000 ug/mL or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock 8270 Mix #1 Calibration Standard | Restek; catalog #578513, 2000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock 8270 Mix #2 Calibration Standard | Restek; catalog #572448, 2000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock Benzidine Mix Calibration Standard | Restek; catalog #31834, 2000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Intermediate 8270 Calibration Standard | Refer to Section 8.3.2 | Solution expires 6 months from date of preparation. | Refrigerate |
| Working 8270/Intermediate 8270 LVE Calibration Standards | Refer to Section 8.3.3 | Solution expires 6 months from date of preparation. | Refrigerate |
| Working 8270 LVE Calibration Standards | Refer to Section 8.3.4 | Solution expires 6 months from date of preparation. | Refrigerate |
| Stock 8270 ICV Standard-Stock A | NSI; catalog #C-701, 1000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |

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| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| Stock 8270 ICV Standard-Stock B | NSI; catalog #C-402, 2000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock 8270 ICV Standard-Stock C | NSI; catalog #C-639, 2000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock 8270 ICV Standard-Stock D | NSI; catalog #541H, 2000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock 8270 ICV Standard-Stock E | NSI; catalog #C-601, 2000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock 8270 ICV Custom Mix #1 | AccuStandard; catalog #S-95594, 2000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock 8270 ICV Standard-Lilly ICV | Crescent; catalog #CCS-2579, 1000 ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Working 8270/Intermediate 8270 LVE ICV Standard | Refer to Section 8.3.5 | Solution expires 6 months from date of preparation. | Refrigerate |
| Working 8270 LVE ICV Standard | Refer to Section 8.3.6 | Same expiration date as Intermediate 8270 LVE ICV standard. | Refrigerate |
| Appendix IX Compound List Mixes | | | |
| Stock APP IX Calibration Standard Mix 1 | Restek; catalog #32459, 2000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock APP IX Calibration Standard Mix 2 | Restek; catalog #31806, 1000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock APP IX Calibration Standard Mix 3 | Restek; catalog #32419, 2000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock APP IX Methapyrilene Calibration Standard | Restek; catalog #32460, 2000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock APP IX Dinoseb Calibration Standard | Restek; catalog #32251, 1000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |

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| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| Stock APP IX Hexachlorophene Calibration Standard | Restek; catalog #31811, 2000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Intermediate APP IX Calibration Standard | Refer to Section 8.3.7 | Solution expires 6 months from date of preparation. | Refrigerate |
| Working APP IX Calibration Standards | Refer to Section 8.3.8 | Solution expires 6 months from date of preparation. | Refrigerate |
| Working APP IX LVE Calibration Standards | Refer to Section 8.3.9 | Same expiration date as Working APP IX Calibration standards. | Refrigerate |
| Stock APP IX ICV Standard Mix 1 | NSI; catalog #C-731, 2000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock APP IX ICV Standard Mix 2 | NSI; catalog #C-732, 1000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock APP IX ICV Standard Mix 3 | NSI; catalog #C-417, 2000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock APP IX ICV Standard Mix 4 | NSI; catalog #323, 2000ug/mL, or equivalent. | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Stock APP IX Methapyrilene ICV Standard | Phenova; catalog #AL0-101650, 1000ug/mL, or equivalent | Manufacturer's recommended expiration date. | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Working APP IX ICV Standard | Refer to Section 8.3.10 | Solution expires 6 months from date of preparation. | Refrigerate |
| Working APP IX LVE ICV Standard | Refer to Section 8.3.11 | Same expiration date as Working APP IX ICV. | Refrigerate |

## 8.3 Standard Preparation Procedures

### 8.3.1 Working LVE Internal Standards Preparation

Dilute 300uL of the Stock internal standards (4000 ug/mL) to 3mL with methylene chloride for a final concentration of 400 ug/mL.

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8.3.2 Intermediate 8270 Calibration Standard

Dilute 1000uL of Stock 8270 MegaMix calibration standard (1000 ug/mL), 500uL of Stock 8270 Mix #1 (2000 ug/mL), 500uL of Stock 8270 Mix #2 (2000 ug/mL), 500uL of Benzidine Mix (2000ug/mL), and 250uL of Stock Surrogate standard (4000 ug/mL) to 5mL with Methylene Chloride for a final concentration of 200 ug/mL.

8.3.3 Working 8270/Intermediate 8270 LVE Calibration Standards

The following are examples of calibration standard amounts and could vary based on requirements.

| Standard | Intermediate 8270 Calibration Standard Amount | Final Volume in Methylene Chloride | Final Nominal Calibration Standard Concentration | Stock Internal Standard amount added to Calibration Standard | Internal Standard Concentration |
|---|---|---|---|---|---|
| 8270 CAL1 | 25uL | 1000uL | 5 ug/mL | 10uL | 40 ug/mL |
| 8270 CAL2 | 50uL | 1000uL | 10 ug/mL | 10uL | 40 ug/mL |
| 8270 CAL3 | 100uL | 1000uL | 20 ug/mL | 10uL | 40 ug/mL |
| 8270 CAL4 | 250uL | 1000uL | 50 ug/mL | 10uL | 40 ug/mL |
| 8270 CAL5 | 400uL | 1000uL | 80 ug/mL | 10uL | 40 ug/mL |
| 8270 CAL6 | 500uL | 1000uL | 100 ug/mL | 10uL | 40 ug/mL |
| 8270 CAL7 | 750uL | 1000uL | 150 ug/mL | 10uL | 40 ug/mL |

8.3.4 Working 8270 LVE Calibration Standards

Prepare using the Working 8270/Intermediate 8270 LVE Calibration Standards from Section 8.3.3. The following are examples of calibration standards and could vary based on requirements:

| Standard | Calibration Standard ID from Section 8.3.3 | Intermediate Calibration Standard Amount | Final Volume in Methylene Chloride | Final Calibration Standard Concentration | Internal Standard Concentration |
|---|---|---|---|---|---|
| 8270 LVE CAL1 | 8270 CAL1 | 100uL | 1mL | 0.5 ug/mL | 4 ug/mL |
| 8270 LVE CAL2 | 8270 CAL2 | 100uL | 1mL | 1.0 ug/mL | 4 ug/mL |
| 8270 LVE CAL3 | 8270 CAL3 | 100uL | 1mL | 2.0 ug/mL | 4 ug/mL |
| 8270 LVE CAL4 | 8270 CAL4 | 100uL | 1mL | 5.0 ug/mL | 4 ug/mL |
| 8270 LVE CAL5 | 8270 CAL5 | 100uL | 1mL | 8.0 ug/mL | 4 ug/mL |
| 8270 LVE CAL6 | 8270 CAL6 | 100uL | 1mL | 10 ug/mL | 4 ug/mL |
| 8270 LVE CAL7 | 8270 CAL7 | 100uL | 1mL | 15 ug/mL | 4 ug/mL |

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8.3.5 Working 8270/Intermediate 8270 LVE ICV Standard Preparation

Dilute 50uL of 8270 ICV Standard-Stock A (1000 ug/mL), 25uL of 8270 ICV Standard-Stock B (2000 ug/mL), 25uL of 8270 ICV Standard-Stock C (2000 ug/mL), 25uL of 8270 ICV Standard-Stock D (2000 ug/mL), 25uL of 8270 ICV Standard-Stock E (2000 ug/mL), 25uL of 8270 ICV Custom Mix #1 (2000ug/mL), 50uL of 8270 ICV Standard-Lilly ICV (1000 ug/mL), and 25uL of Stock Surrogate Standard (4000 ug/mL) to 1mL with methylene chloride for a final concentration of 50-100 ug/mL.

8.3.6 Working 8270 LVE ICV Standard Preparation

Dilute 100uL of the Intermediate 8270 LVE ICV Standard (50-100 ug/mL) to 1mL with methylene chloride for a final concentration of 5-10 ug/mL.

8.3.7 Intermediate APP IX Calibration Standard Preparation

Dilute 250uL of Stock APP IX Calibration Standard Mix 1 (2000ug/mL), 500uL of Stock APP IX Calibration Standard Mix 2 (1000ug/mL), 250uL of Stock APP IX Calibration Standard Mix 3 (2000ug/mL), 250uL of Stock APP IX Methapyrilene Calibration Standard (2000ug/mL), 500uL of Stock APP IX Dinoseb Calibration Standard (1000ug/mL), and 1500uL of Stock APP IX Hexachlorophene Calibration Standard (2000ug/mL) to 4mL with methylene chloride for a final concentration of 125-750ug/mL.

8.3.8 Working APP IX Calibration Standards Preparation

The following are examples of calibration standards and could vary based on requirements:

| Standard | Intermed. APP IX Calibration Standard Amount | Final Volume in Methylene Chloride | Final Nominal Calibration Standard Concentration | Working Internal Standard amount added to Calibration Standard | Internal Standard Concentration |
|---|---|---|---|---|---|
| APP IX CAL1 | 80uL | 1mL | 10 ug/mL | 10uL | 4000 ug/mL |
| APP IX CAL2 | 160uL | 1mL | 20 ug/mL | 10uL | 4000 ug/mL |
| APP IX CAL3 | 400uL | 1mL | 50 ug/mL | 10uL | 4000 ug/mL |
| APP IX CAL4 | 640uL | 1mL | 80 ug/mL | 10uL | 4000 ug/mL |
| APP IX CAL5 | 800uL | 1mL | 100 ug/mL | 10uL | 4000 ug/mL |
| APP IX CAL6 | 1000uL | 1mL | 125 ug/mL | 10uL | 4000 ug/mL |

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8.3.9 Working APP IX LVE Calibration Standards Preparation

Prepare using the Working APP IX Calibration Standards from Section 8.3.7. The following are examples of calibration standards and could vary based on requirements:

| Standard | Calibration Standard ID from Section 8.3.7 | Calibration Standard Amount | Final Volume in Methylene Chloride | Final Calibration Standard Concentration | Internal Standard Concentration |
|---|---|---|---|---|---|
| APP IX LVE CAL1 | APP IX CAL1 | 100uL | 1mL | 1 ug/mL | 400 ug/mL |
| APP IX LVE CAL2 | APP IX CAL2 | 100uL | 1mL | 2 ug/mL | 400 ug/mL |
| APP IX LVE CAL3 | APP IX CAL3 | 100uL | 1mL | 5 ug/mL | 400 ug/mL |
| APP IX LVE CAL4 | APP IX CAL4 | 100uL | 1mL | 8 ug/mL | 400 ug/mL |
| APP IX LVE CAL5 | APP IX CAL5 | 100uL | 1mL | 10 ug/mL | 400 ug/mL |
| APP IX LVE CAL6 | APP IX CAL6 | 100uL | 1mL | 12.5 ug/mL | 400 ug/mL |

8.3.10 Working APP IX ICV Standard Preparation

Dilute 50uL of Stock APP IX ICV Standard Mix 1 (2000ug/mL), 100uL of Stock APP IX ICV Standard Mix 2 (1000ug/mL), 50uL of Stock APP IX ICV Standard Mix 3 (2000ug/mL), 50uL of Stock APP IX ICV Standard Mix 4 (2000ug/mL), and 100uL of Stock APP IX Methapyriline Standard (1000ug/mL) to 1mL with methylene chloride for a final concentration of 100ug/mL.

8.3.11 Working APP IX LVE ICV Standard Preparation

Dilute 100uL of Working APP IX ICV Standard (100ug/mL) to 1mL with methylene chloride for a final concentration of 10ug/mL.

## 9.0 PROCEDURE

9.1 Equipment Preparation

9.1.1 Gas Chromatography conditions: Configure the GC/MS per manufacturer's instructions

9.1.2 DFTPP Tune Verification: At the beginning of each analytical sequence, prior to the analysis of any standards or samples, the mass spectrometer must be hardware tuned using a 50ng injection of DFTPP. Analysis must not begin until the tuning criteria are met. Use the DFTPP mass intensity criteria in the table below as tuning acceptance criteria. Alternate tuning criteria may be used provided that method performance is not adversely affected. The 12-hour window during which standards and samples may be analyzed begins with the injection of DFTPP. All subsequent standards, samples MS/MSDs, and blanks associated with a DFTPP analysis must use the identical mass spectrometer instrument conditions.

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| Mass (m/z) | Ion Abundance criteria |
|---|---|
| 51 | 30-60% of mass 198 |
| 68 | <2% of mass 69 |
| 70 | <2% of mass 69 |
| 127 | 40-60% of mass 198 |
| 197 | <1% of mass 198 |
| 198 | Base peak, 100% relative abundance |
| 199 | 5-9% of mass 198 |
| 275 | 10-30% of mass 198 |
| 365 | >1% of mass 198 |
| 441 | Present but less than mass 443 |
| 442 | >40% of mass 198 |
| 443 | 17-23% of mass 442 |

The mass spectrum of DFTPP may be obtained by averaging three scans, the peak apex scan and the scans immediately preceding and following the apex. Background subtraction is required using this approach and must be accomplished using a single scan no more than 20 scans prior to the elution of DFTPP. Do not background-subtract part of the DFTPP peak. Alternatively, the analyst may use other approaches suggested below:

1) A single scan within the DFTPP peak with background subtraction of a single scan no more than 20 scans prior to the elution of DFTPP.

2) An average of multiple scans within the DFTPP peak with background subtraction of a single scan no more than 20 scans prior to the elution of DFTPP.

9.2 Initial Instrument Calibration

9.2.1 Initial calibration standards are introduced into the GC/MS from the lowest to highest concentration, by direct injection of each working calibration standard. The lowest calibration standard must be at or below the required reporting limit. Five calibration points, at a minimum, are analyzed to evaluate linearity. Refer to the Quality Manual for more information regarding calibration curves.

9.2.2 The response factor (RF) is calculated for each compound for each calibration standard as follows:

$$RF = \frac{(A_x)(C_{IS})}{(A_{IS})(C_x)}$$

*Where:* $A_x$ = *Area of the quantitation ion for the compound being measured*
$A_{IS}$ = *Area of the quantitation ion for the internal standard*
$C_{IS}$ = *Concentration of the internal standard*
$C_x$ = *Concentration of the compound being measured*

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9.2.3 The average response factor ($RF_{avg}$) is determined by averaging the response factors at the different concentrations for each target analyte.

9.2.4 The percent relative standard deviation (%RSD) of the response factors is calculated as follows:

$$\%RSD = \frac{SD}{RF_{avg}} \times 100$$

*Where:* $SD$ = *Standard deviation of the RFs for a compound*
$RF_{avg}$ = *Mean of RFs for a compound*

9.2.5 System Performance Check Compounds (SPCCs) are checked for a minimum average response factor ($RF_{avg}$) to determine potential instability and/or degradation caused by deterioration of instrument conditions or standard material. The minimum $RF_{avg}$ for the semivolatile SPCCs are as follows:

| | |
|---|---|
| N-nitroso-di-n-propylamine | 0.050 |
| Hexachlorocyclopentadiene | 0.050 |
| 2,4-Dinitrophenol | 0.050 |
| 4-Nitrophenol | 0.050 |

If the minimum response factors are not met, the system must be evaluated and corrective action must be taken before sample analysis begins. Instrument maintenance or preparation of new standards may be necessary. The SPCC criteria must be met for sample analysis to begin. Calibration Check Compounds (CCCs) are evaluated to confirm integrity of the system. High %RSD of these compounds may indicate system leaks or reactive sites on the column. The %RSD of the $RF_{avg}$ for each individual CCC *should* be ≤15%, but *must* be ≤30%. If the RSD of any CCC is >30%, then the chromatographic system is too reactive and instrument maintenance and/or preparation of new standards may be necessary before attempting recalibration. The CCCs are:

| **Base/Neutral Fraction** | **Acid Fraction** |
|---|---|
| Acenaphthene | 4-Chloro-3-methylphenol |
| 1,4-Dichlorobenzene | 2,4-Dichlorophenol |
| Hexachlorobutadiene | 2-Nitrophenol |
| Diphenylamine | Phenol |
| Di-n-octyl phthalate | Pentachlorophenol |
| Fluoranthene | 2,4,6-Trichlorophenol |
| Benzo(a)pyrene | |

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9.2.6 Evaluation of retention times: The relative retention time (RRT) of each target analyte in each calibration standard should agree within 0.06 RRT units.

9.2.7 Linearity of target analytes: If the %RSD of the RFs for a compound is ≤15% over the calibration range, then linearity through the origin is assumed and the $RF_{avg}$ may be used to determine sample concentrations.

9.2.8 If the %RSD of the RFs for any compound is >15%, the analyst may employ a regression equation that does not pass through the origin. The regression calculation will generate a correlation coefficient (r) that is the measure of the "goodness of fit" of the regression line to the data. In order to be used for quantitative purposes, the correlation coefficient must be $\geq$ 0.99.

9.2.9 Non-linear or quadratic calibration: A non-linear or quadratic calibration model can only be used if the compound(s) have historically exhibited a non-linear response and cannot be used to extend the calibration range for any compound that normally exhibits a linear response in a narrower range. The non-linear regression calibration curve is derived from a least squares regression analysis of the calibration points. A calibration curve based on this technique will have the format of: $y= ax^2+bx+c$. In order to use this curve fit technique, a minimum of 6 calibration points must be available and the origin cannot be included as one of the points. Because the non-linear regression is not forced through the origin, very low levels of contaminants below the response of the lowest calibration point may generate erroneous reportable results. The "goodness of fit" of the polynomial equation is evaluated by calculating the coefficient of the determination (COD) or $r^2$. The COD or $r^2$ from the regression equation must be $\geq$ 0.99. Refer to Method 8000D for additional information regarding calibration.

*Note: These Appendix IX compounds are always non-linear: Famphur, Kepone, Hexachlophene, 3,3'-Dimethylbenzidine. Any detects for these compounds need to be qualified that information is for qualitative use only.*

9.2.10 For calibration compounds that required the linear regression model or the quadratic model, a minimum quantitation check on the viability of the calibration standard that corresponds to the reporting limit should be performed by re-fitting the response from the calibration standard that corresponds to the reporting limit back into the curve. The recalculated concentration of the reporting limit standard should be within +/-50% of the standard's true concentration. Compounds that fail this criterion and are reported at a concentration that is <2x the reporting limit in associated samples must be qualified as estimated. Alternatively, the reporting limit can be raised to the level of a calibration standard that meets the criteria when re-fitted against the curve.

9.2.11 Individual analyte calibration levels may be removed from the lowest and/or highest levels of the calibration curve provided the number of remaining calibration points meet the minimum requirements and the quantitation range is adjusted as necessary.

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9.2.12 Removal of interior calibration levels is not permitted unless a standard introduction error or preparation error can be documented.

9.2.13 A calibration level may be replaced provided that the replacement calibration standard is analyzed within the same calibration event.

9.2.14 For compounds evaluated using $RF_{avg}$, the RSD is the measure of Relative Error. For compounds evaluated using correlation coefficient (r), the laboratory must evaluate Relative Error:

**Relative Error (%RE)**

$$\%\ Relative\ Error = \frac{x_i^{'} - x_i}{x_i}\ x\ 100$$

Where: $x_i$ = True value of the calibration standard
$x'_i$ = Measured concentration of the calibration standard

9.2.15 Calculate %RE by back-calculating two (2) initial calibration levels, the standard at the midpoint and the standard at the lowest point. %RE must be ≤30% (70-130% Recovery) for the midpoint standard and ≤50% (50-150% Recovery) for the lowest standard.

9.2.16 Refer to Section 11.1 for corrective actions.

9.3 Initial Calibration Evaluation

9.3.1 Each day that analysis is performed, the calibration standard(s) should be evaluated to determine if the chromatographic system is operating properly. Questions that should be asked are: Do the peaks look normal? Is the response obtained comparable to the response from previous calibrations? Are the retention times consistent over the range of calibration for each compound? Careful examination of the standard chromatogram can indicate whether the column is still performing acceptably. Additionally, examination of signal-to-noise ratio of analytes in low-level standards may be a useful diagnostic tool to monitor instrument performance. Signal-to-noise ratio is defined as the ratio of the analyte signal to the noise measured on a blank. It is recommended but not required that the signal-to-noise ratio be at least three to confirm detection.

9.4 Initial Calibration Verification (ICV)

9.4.1 In addition to meeting the response and linearity criteria, any new calibration curve must be assessed for accuracy of the values generated. To assess the accuracy of the calibration, a single standard from a secondary source must be analyzed and the results obtained must be compared to the known true value. This step is referred to as the Initial Calibration Verification.

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The ICV must be from an alternative vendor or, in the event an alternative vendor is not available, from a different lot from the same vendor. The accuracy of the standard is assessed as percent recovery (%R) of the observed ICV response compared to the true value as prepared, according to the following equation:

$$\%\ Recovery = \frac{Observed\ Concentration}{Theoretical\ Concentration} \times 100$$

9.4.2 The ICV is analyzed immediately following the initial calibration curve. The ICV recoveries are evaluated against a default acceptance range of 70-130% recovery. Alternative acceptance limits may be appropriate for some compounds if approved by manager/supervisor.

9.4.3 Refer to Section 11.1 for corrective actions.

9.5 Continuing Calibration Verification (CCV)

9.5.1 The initial calibration is verified every 12 hours by analyzing a DFTPP tune verification as described in Section 9.1.2, followed by a Continuing Calibration Verification (CCV) standard. The 12-hour clock during which standards and samples may be analyzed begins with the injection of the tune.

9.5.2 The CCV is prepared using the same standard solution used for the initial calibration. The response factors for all SPCCs in the CCV standard must meet the criteria in Section 9.2.5. If the % Difference (%D) or % Drift for each CCC is ≤20%, then the initial calibration is assumed to be valid. The % difference (%D) or % Drift for each non-CCC compound should be ≤40%. If compounds fail to meet these criteria, the concentrations above the reporting limit in associated samples must be qualified as estimated.

$$\%\ Difference = [RF_v - RF_{avg}] / RF_{avg} * 100$$

*Note: For Appendix IX compounds Famphur, Kepone, Hexachlophene, 3,3'-Dimethylbenzidine, if they are non-linear and/or CCVs outside of non-CCC limits, any detects for these compounds need to be qualified that information is for qualitative use only.*

9.5.3 The internal standard areas in the CCV must be between 50%-200% of the internal standard areas of the corresponding standard in the initial calibration. In addition, the retention time of the internal standards in the CCV cannot shift by more than 30 seconds from the corresponding standard in the initial calibration. Failure in either of these two areas requires the analyst to evaluate their system and perform maintenance if necessary.

9.5.4 Refer to Section 11.1 for corrective actions.

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9.6 Sample Analysis

9.6.1 All sample extracts must be analyzed at room temperature. The system must be tuned and calibrated, and free of contamination before samples are analyzed.

9.6.2 Gas Chromatography conditions: The GC/MS configuration settings used for sample analysis must be the same as from initial calibration.

9.6.3 The extract obtained from sample preparation for 8270 should be fortified with the appropriate amount of internal standard just prior to analysis.

9.6.4 Load vials in sequence on the autosampler, and analyze each extract by injecting an appropriate volume onto the column corresponding to the extraction technique used.

## 10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Qualitative Analysis

Analytes of interest are identified as present when the following criteria are met:

10.1.1 The relative retention time (RRT) of the sample component must compare within +/- 0.06 RRT units of the RRT of the CCV component.

10.1.2 The intensities of the characteristic ions of a compound must maximize in the same scan or within one scan of each other. See Table 2 and Table 4 for primary and secondary ions.

10.1.3 The relative intensities of the characteristic ions agree within 30% of the relative intensities of these ions in the reference spectrum.

10.1.4 If the acquired mass spectrum is contaminated or if identification is ambiguous, an experienced spectrometrist should determine the presence or absence of the compound.

10.2 Quantitative Analysis

When an analyte has been identified, quantitation of that analyte is based on the integrated response of the primary characteristic ion (quant ion). Calculate the concentration using the response factor (RF) or regression equation established with initial calibration.

10.2.1 When concentrations exceed the calibration range, the sample extract should be rerun at a dilution or the result must be qualified as estimated. Additional internal standards must be added to the diluted extract to maintain the same concentration as the calibration standards.

10.2.2 Refer to the Manual Integrations SOP for guidance on performing and documenting manual integrations.

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10.3 Calculations

10.3.1 Calculate the final concentration in the sample as follows:

$$\text{Aqueous Sample (ug/L)} = \frac{(X_s)(V_f)(D)}{(V_i)} \qquad \text{Solid Sample (ug/kg)} = \frac{(X_s)(V_f)(D)}{(W_s)}$$

Where: $X_s$ = On-column concentration of the analyte, ug/mL
$V_f$ = Final volume of sample extract, mL
D = Dilution factor of extract (final volume/initial volume)
$V_i$ = Volume of aqueous sample extracted, L
$W_s$ = Weight of solid sample extracted, kg

$$\text{Moisture corrected concentration} = \frac{\text{(Final concentration as received)}}{\text{(100 - \%Moisture)}} \times 100$$

10.3.2 LCS calculation:

$$R = (C / S) \times 100$$

Where: R = Percent Recovery
C = Observed LCS concentration
S = True LCS concentration

10.3.3 MS/MSD calculation:

$$R = \frac{(C_s - C)}{S} \times 100$$

Where: R = Percent Recovery
$C_s$ = Observed MS concentration
C = Sample concentration
S = True spike concentration

10.3.4 RPD equation:

$$RPD = \frac{|D_1 - D_2|}{[(D_1 + D_2)/2]} * 100$$

Where: RPD = Relative Percent Difference
$D_1$ = First Sample Result
$D_2$ = Second Sample Result

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## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

### 11.1 Instrument Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Tune** | DFTPP | Every 12 hours of instrument operation | Refer to Section 9.1.2 | Reanalyze the DFTPP tune, If the DFTPP still fails the criteria, autotune adjustment, instrument maintenance, and/or preparation of new standards must be considered. |
| **Initial Calibration (ICAL)** | All target analytes | As needed | Refer to Section 9.2 | Analyze a new initial calibration curve. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed initial calibration must be reanalyzed. |
| **Initial Calibration Verification Standard (ICV)** | Second Source Standard | Immediately following initial calibration of the instrument | 70-130% Recovery | Reanalyze the ICV. If the second ICV also exceeds the acceptance range, a new initial calibration must be analyzed. Results associated with a QC failure must be qualified appropriately. Alternatively, the allowance for use of the ICV when the criterion is not met is documented and is at the discretion of the Department Manager, Quality Manager, General Manager or designee.<br>*Exception:* If the ICV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |
| **Continuing Calibration Standard (CCV)** | All target analytes | Every 12 hours of instrument operation | Refer to Section 9.5 | Check instrument operating conditions, and if necessary, restore them to the original settings. Inject another aliquot of the CCV. If the response still fails the acceptance criteria, perform system maintenance and analyze a new CCV, or a new initial calibration must be prepared. Samples associated with a failed CCV must be reanalyzed or qualified.<br>*Exception:* If the CCV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |

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11.2 Batch Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Method Blank (MB)** | Reagent water | One per preparation batch of up to 20 samples, per matrix. | Target analytes in the method blank must be less than reporting limits. | Reanalyze method blank. If target compound is still >RL, re-extract and reanalyze samples.<br>*Exceptions:*<br>1) If the method blank concentration is less than 1/10 of the amount measured in the sample, corrective action is not required, affected data must be qualified.<br>2) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, the reported method blank and samples must be qualified.<br>3) If a contaminant is present only in the method blank and not the samples, no action is required. |
| **Laboratory Control Standard (LCS)** | Target analytes | One per preparation batch of up to 20 samples, per matrix. | Lab-generated limits<br>Refer to the LIMS for acceptance limits.<br>Refer to Section 11.3 for additional information. | Reanalyze the LCS. If LCS is still outside acceptance limits, re-extract and reanalyze all associated samples.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported data must be qualified.<br>*2)* If LCS recovery is >QC limits and sample results are non-detect, the sample data may be reported without qualifiers. The LCS data must be qualified. |
| **Matrix Spike /Matrix Spike Duplicate (MS/MSD)**<br>**(When sufficient sample volume provided)** | Target analytes | One MS/MSD set per preparation batch of up to 20 samples, per matrix. | Lab-generated limits<br>Refer to the LIMS for acceptance limits. | No corrective action necessary. If LCS recovery is in range, the system is considered in-control and the out-of-control MS/MSD must be qualified appropriately. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Surrogates** | Applicable surrogate compounds | Added to each standard, sample, and method blank. | Lab-generated limits<br>Refer to the LIMS for acceptance limits. | Samples with surrogate failure must be re-extracted and reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported data must be qualified.<br>2) If surrogate result is >QC limits, and sample or method blank results are non-detect, the sample or method blank results may be reported without qualifiers. The surrogate must be qualified.<br>3) If the surrogate outside of QC limits does not correspond to any target analytes (i.e. acid or base/neutral extractables), the sample may be reported without qualifiers. The failing surrogate must be qualified.<br>4) MS/MSD surrogate recovery failures do not constitute the re-extraction or reanalysis of samples but the surrogate data must be qualified. |
| **As required by client or program only:**<br>**Internal Standards** | Applicable Internal Standard compounds | Added to each standard, sample, and method blank. | Sample ISTD areas must be -50% to +100% from CCV.<br>Sample ISTD RTs must be +/-0.5 minutes from CCV. | Samples with internal standard failures must be reanalyzed undiluted or more concentrated. The laboratory may only dilute a sample prior to reanalysis if matrix interference is present.<br>*Exception:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported data must be qualified. |

11.3 **Allowable Marginal Exceedances:** If a large number of analytes are in the LCS, it becomes statistically likely that a few will be outside control limits. A marginal exceedance (ME) is defined as being beyond the LCS control limit of +/-3 standard deviations, but within the ME limits of +/-4 standard deviations around the mean. The number of allowable MEs is based on the number of analytes in the LCS. If more analytes exceed the LCS control limits than is allowed, or if any one analyte exceeds the ME limits, the LCS fails and correction action is necessary. If the same analyte exceeds the LCS control limit consecutively, it is an indication of a systemic problem. The source of the error shall be located and corrective action taken.

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The number of allowable marginal exceedances is as follows:

| Number of Analytes in LCS | Number Allowed as Marginal Exceedances |
|---|---|
| > 90 | 5 |
| 71 – 90 | 4 |
| 51 – 70 | 3 |
| 31 – 50 | 2 |
| 11 – 30 | 1 |
| < 11 | 0 |

**NOTE:** As allowed by client, the LCS shall be allowed to be outside the control limits but ≥10% for hexachlorocyclopentadiene, N-nitrosodimethylamine, pentachlorophenol, 2,4-dinitrophenol, 4-nitrophenol, benzoic acid, 4-chloro-3-methylphenol, 2-nitroaniline, 3-nitroaniline, and 4-chloroaniline without corrective action. The LCS shall be allowed to be outside the control limits but >10% for up to four additional compounds, with the exception of any PAH, without corrective action.

11.4 Method Performance

11.4.1 Method Validation

Refer to the SOP for Method Validation and Instrument Verification for the procedures used for initial method validation. Method Detection Limits (MDL) must be determined per the procedure in 40CFR Part 136, Appendix B.

11.5 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

## 12.0 DATA REVIEW AND CORRECTIVE ACTION

12.1 Data Review

The analyst must perform primary review of data and calculated results for accuracy. Secondary review of the data and calculated results must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

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12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

## 14.0 MODIFICATIONS

14.1 Microwave method SW846 3546 is used for the preparation of solid samples for analysis by 8270C.

14.2 Phenol-d5 is used as a surrogate instead of phenol-d6.

14.3 Extract final volumes, volume of internal standards added to extracts, and volume of extract injected into the instrument may vary from those identified in SW846 8270C.

## 15.0 RESPONSIBILITIES

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

## 16.0 ATTACHMENTS

16.1 Table 1: Target Compounds and Default Reporting Limits

16.2 Table 2: Characteristic Ions and Internal Standard Association of Target Compounds

16.3 Table 3: Appendix IX Target Compounds and Default Reporting Limits

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16.4 Table 4: Characteristic Ions and Internal Standard Association of Appendix IX Compounds

16.5 Table 5: Target Compounds Common for Quadratic Curve Fit

## 17.0 REFERENCES

17.1 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Methods 8000D and 8270C.

17.2 Pace Analytical Quality Manual; latest revision.

17.3 NELAC/TNI Standards; Quality Systems section; 2003, 2009, and 2016.

## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 1.5 | Added 3,3'-Dimethylbenzidine |
| 3.0 | Expanded potential sources of phthalates contamination; added language on carryover contamination. |
| 6.0 | Added note detailing extract storage conditions. |
| 7.2 | Added PTFE-lined crimp tops to autosampler vial description. |
| 8.2 | Updated and added various standards to match current practice. |
| 8.3.2, 8.3.5, 8.3.10 | Added components of standard preps to match current practice. |
| 9.1.2 | Moved tune corrective action steps to 11.1 |
| 9.2.5, 9.2.6 | Changed order of sections and added language to match 8270C description of CCCs. |
| 9.2.7 | Added to ICAL evaluation section. |
| 9.2.10 | Updated reference to 8000D and added note listing non-linear Appendix IX analytes. |
| 9.2.12-9.2.16 | Added language for current calibration policy and evaluation of relative error. |
| 9.4.2 | Added approval requirement for use of alternate acceptance limits. |
| 9.5.2 | Added note listing non-linear Appendix IX analytes to be qualified as qualitative only. |
| 10.1.4 | Added evaluation by experience spectrometrist. |
| 11.1 | Updated corrective action language for ICV & CCV to match current practice. Added exception to allow reporting of <RL results if ICV biased high. |
| 11.2 | Noted that MS/MSD can only be performed when adequate sample volume is provided; added exception to corrective actions for Surrogates to allow reporting unqualified result if a failing surrogate does not correspond to target analyte(s). |

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| Section | Description of Change |
|---|---|
| 14.0 | Removed statement that standards are purchased; current method reference includes this option. |
| 16.5 | Added Table 5. |
| 17.3 | Added reference to 2016 TNI Standard. |
| Tables 1-4 | Edited all to match current target analyte lists. |
| Table 5 | Added. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0057 | Semivolatile Organic Compounds by GC/MS 8270C | 01 |

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## Table 1
## Target Compounds and Default Reporting Limits[1]

| Analyte | RL water (ug/L) | RL soil (ug/kg) |
|---|---|---|
| N-Nitrosodimethylamine | 10 | 330 |
| Pyridine | 10 | 1670 |
| 2-Picoline | 50 | 1670 |
| 4-Chlorobenzotrifluoride | 10 | N/A |
| Benzaldehyde | 50 | 1670 |
| Phenol | 10 | 330 |
| Aniline | 10 | 330 |
| Bis (2-chloroethyl) ether | 10 | 330 |
| 2-Chlorophenol | 10 | 330 |
| n-Decane | 10 | 330 |
| 1,3-Dichlorobenzene | 10 | 330 |
| 1,4-Dichlorobenzene | 10 | 330 |
| Benzyl Alcohol | 20 | 660 |
| 1,2-Dichlorobenzene | 10 | 330 |
| 2-Methylphenol (o-Cresol) | 10 | 330 |
| Bis (2-chloroisopropyl)ether | 10 | 330 |
| 3&4-Methylphenol (m&p-Cresol) | 20 | 660 |
| Acetophenone | 10 | 330 |
| N-Nitroso-di-n-propylamine | 50 | 330 |
| Hexachloroethane | 10 | 330 |
| Nitrobenzene | 10 | 330 |
| Isophorone | 10 | 330 |
| 2-Nitrophenol | 10 | 330 |
| 2,4-Dimethylphenol | 10 | 330 |
| Benzoic Acid | 50 | 1670 |
| Bis(2-chloroethoxy)methane | 10 | 330 |
| 2,4-Dichlorophenol | 10 | 330 |
| 1,2,4-Trichlorobenzene | 10 | 330 |
| Naphthalene | 10 | 330 |
| alpha-Terpineol | 10 | N/A |
| 4-Chloroaniline | 20 | 660 |
| Hexachlorobutadiene | 10 | 330 |
| Caprolactam | 10 | 330 |
| Diethyl Aniline | 10 | 330 |
| 4-Chloro-3-methylphenol | 20 | 660 |
| 1-Methylnaphthalene | 10 | 330 |
| 2-Methylnaphthalene | 10 | 330 |

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| Analyte | RL water (ug/L) | RL soil (ug/kg) |
|---|---|---|
| Hexachlorocyclopentadiene | 10 | 330 |
| 2,3-Dichloroaniline | 10 | 330 |
| 2,4,6-Trichlorophenol | 10 | 330 |
| 2,4,5-Trichlorophenol | 10 | 330 |
| Biphenyl (Diphenyl) | 10 | 330 |
| 2-Chloronaphthalene | 10 | 330 |
| 2-Nitroaniline | 50 | 1670 |
| Dimethyl phthalate | 10 | 330 |
| 1,3-Dinitrobezene | 50 | 1670 |
| 2,6-Dinitrotoluene | 10 | 330 |
| Acenaphthylene | 10 | 330 |
| 3-Nitroaniline | 10 | 330 |
| Acenaphthene | 10 | 330 |
| 2,4-Dinitrophenol | 50 | 1670 |
| 4-Nitrophenol | 50 | 1670 |
| Dibenzofuran | 10 | 330 |
| 2,4-Dinitrotoluene | 10 | 330 |
| 2,3,4,6-Tetrachlorophenol | 10 | 330 |
| Diethyl phthalate | 10 | 330 |
| 4-Chlorophenyl phenyl ether | 10 | 330 |
| Fluorene | 10 | 330 |
| 4-Nitroaniline | 20 | 670 |
| 4,6-Dinitro-2-methylphenol | 20 | 670 |
| N-Nitrosodiphenylamine | 10 | 330 |
| Diphenylamine | 10 | 330 |
| Azobenzene | 10 | 330 |
| 1,2-Diphenylhydrazine | 10 | 330 |
| 4-Bromophenyl phenyl ether | 10 | 330 |
| Hexachlorobenzene | 10 | 330 |
| Atrazine | 10 | 330 |
| Pentachlorophenol | 50 | 1670 |
| n-Octadecane | 10 | 330 |
| Phenanthrene | 10 | 330 |
| Anthracene | 10 | 330 |
| Carbazole | 10 | 330 |
| Di-n-butyl phthalate | 10 | 330 |
| Fluoranthene | 10 | 330 |
| Benzidine | 20 | 670 |
| Pyrene | 10 | 330 |

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| Analyte | RL water (ug/L) | RL soil (ug/kg) |
|---|---|---|
| Butyl benzyl phthalate | 10 | 330 |
| 3,3'-Dichlorobenzidine | 20 | 670 |
| Benzo(a)anthracene | 10 | 330 |
| Chrysene | 10 | 330 |
| Bis(2-ethylhexyl)phthalate | 10 | 330 |
| Di-n-octyl phthalate | 10 | 330 |
| Benzo(b)fluoranthene | 10 | 330 |
| Benzo(k)fluoranthene | 10 | 330 |
| Benzo(a)pyrene | 10 | 170 |
| Indeno(1,2,3-cd)pyrene | 10 | 330 |
| Dibenz(a,h)anthracene | 10 | 170 |
| Benzo(g,h,i)perylene | 10 | 330 |

***[1] Target Compounds and Reporting Limits are subject to change.***

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## Table 2
## Characteristic Ions and Internal Standard Association of Target Compounds[2]

| Analyte | Primary Ion | Secondary Ion(s) |
|---|---|---|
| **Group 1 - 1,4-Dichlorobenzene-d4 (IS)** | 152 | 150, 115 |
| N-Nitrosodimethylamine | 42 | 74,44 |
| Pyridine | 79 | 52 |
| 2-Picoline | 93 | 66, 92 |
| 4-Chlorobenzotrifluoride[3] | 180 | 161,182 |
| 2-Fluorophenol (S) | 112 | 64 |
| Phenol-d5 (S) | 99 | 71, 42 |
| Benzaldehyde[3] | 77 | 105, 106 |
| Phenol | 94 | 65.66 |
| Aniline | 93 | 66, 65 |
| Bis(2-Chloroethyl) ether | 93 | 63.95 |
| 2-Chlorophenol | 128 | 64,130 |
| n-Decane[3] | 57 | 43, 142 |
| 1,3-Dichlorobenzene | 146 | 148, 111 |
| 1,4-Dichlorobenzene | 146 | 148, 111 |
| Benzyl alcohol | 108 | 79, 77 |
| 1,2-Dichlorobenzene | 146 | 148, 111 |
| 2-Methylphenol | 108 | 107, 79 |
| Bis(2-chloro-1-methylethyl) ether[3]; 2,2'-Oxybis(1-chloropropane); Bis(2-chloroisopropyl) ether | 45 | 77, 121 |
| 3&4-Methylphenol (m&p cresol) | 108 | 107,77 |
| Acetophenone | 105 | 77, 120 |
| N-Nitroso-di-n-propylamine | 70 | 130, 101 |
| Hexachloroethane | 117 | 201, 199 |
| **Group 2 - Naphthalene-d8 (IS)** | 136 | 68 |
| Nitrobenzene-d5 (S) | 82 | 128, 54 |
| Nitrobenzene | 77 | 123, 65 |
| Isophorone | 82 | 95, 138 |
| 2-Nitrophenol | 139 | 109, 65 |
| 2,4-Dimethylphenol | 122 | 107, 121 |
| Bis(2-chloroethoxy) methane | 93 | 95, 123 |
| Benzoic Acid | 105 | 122, 77 |
| 2,4-Dichlorophenol | 162 | 164, 98 |
| 1,2,4-Trichlorobenzene | 180 | 182, 145 |
| Naphthalene | 128 | 129, 102 |
| alpha-Terpineol[3] | 59 | 93, 121 |

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| Analyte | Primary Ion | Secondary Ion(s) |
|---|---|---|
| 4-Chloroaniline | 127 | 65, 92 |
| Hexachlorobutadiene | 225 | 223, 227 |
| Caprolactam[3] | 113 | 55, 56 |
| Diethyl Aniline[3] | 134 | 106, 77 |
| 4-Chloro-3-methylphenol | 107 | 144, 142 |
| 2-Methylnaphthalene | 142 | 141, 115 |
| 1-Methylnaphthalene[3] | 142 | 141, 115 |
| **Group 3 - Acenaphthene-d10 (IS)** | 164 | 160, 162 |
| Hexachlorocyclopentadiene | 237 | 235, 272 |
| 2,3-Dichloroaniline[3] | 161 | 163, 90 |
| 2,4,6-Trichlorophenol | 196 | 198, 200 |
| 2,4,5-Trichlorophenol | 196 | 198, 200 |
| 2-Fluorobiphenyl (S) | 172 | 171 |
| 2-Chloronaphthalene | 162 | 127, 164 |
| 2-Nitroaniline | 65 | 92, 138 |
| Dimethylphthalate | 163 | 194, 164 |
| 1,3-Dinitrobenzene | 168 | 76, 50 |
| 2,6-Dinitrotoluene | 165 | 63, 89 |
| Acenaphthylene | 152 | 150, 153 |
| 3-Nitroaniline | 138 | 108, 92 |
| Biphenyl (Diphenyl)[3] | 154 | 153, 152 |
| Acenaphthene | 153 | 154, 152 |
| 2,4-Dinitrophenol | 184 | 154, 63 |
| 4-Nitrophenol | 109 | 139, 65 |
| 2,4-Dinitrotoluene | 165 | 63, 89 |
| Dibenzofuran | 168 | 139, 169 |
| 2,3,4,6-Tetrachlorophenol | 232 | 131, 230 |
| Diethylphthalate | 149 | 177, 150 |
| 4-Chlorophenyl-phenylether | 204 | 206, 141 |
| Fluorene | 166 | 165, 139 |
| 4-Nitroaniline | 138 | 108, 65 |
| **Group 4 - Phenanthrene-d10 (IS)** | 188 | 80,94 |
| 4,6-Dinitro-2-methylphenol | 198 | 51,105 |
| N-Nitrosodiphenylamine | 169 | 168, 167 |
| Diphenylamine | 169 | 168, 167 |
| Azobenzene[3] | 77 | 182, 105 |
| 1,2-Diphenylhydrazine | 77 | 105, 182 |
| 2,4,6-Tribromophenol (S) | 330 | 332, 141 |
| 4-Bromophenyl-phenyl ether | 248 | 250, 141 |
| Hexachlorobenzene | 284 | 142, 249 |

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| Analyte | Primary Ion | Secondary Ion(s) |
|---|---|---|
| Atrazine[3] | 200 | 215, 202 |
| Pentachlorophenol | 266 | 264, 268 |
| n-Octadecane[3] | 57 | 43, 71 |
| Phenanthrene | 178 | 179, 176 |
| Anthracene | 178 | 176, 179 |
| Carbazole[3] | 167 | 166, 139 |
| Di-n-butylphthalate | 149 | 150, 104 |
| Fluoranthene | 202 | 101, 203 |
| Benzidine | 184 | 92, 185 |
| **Group 5 - Chysene-d12 (IS)** | 240 | 120, 236 |
| Pyrene | 202 | 101, 203 |
| p-Terphenyl-d14 (S) | 244 | 122, 212 |
| Butylbenzylphthalate | 149 | 91, 206 |
| 3,3'-Dichlorobenzidine | 252 | 254, 126 |
| Bis(2-Ethylhexyl) phthalate | 149 | 167, 279 |
| Benzo(a)athracene | 228 | 229, 226 |
| Chrysene | 228 | 226, 229 |
| **Group 6 - Perylene-d12 (IS)** | 264 | 260, 265 |
| Di-n-ocytlphthalate | 149 | 279, 43 |
| Benzo(b)fluoranthene | 252 | 253, 125 |
| Benzo(k)fluoranthene | 252 | 253, 125 |
| Benzo(a)pyrene | 252 | 253,125 |
| Indeno(1,2,3-cd)pyrene | 276 | 138, 277 |
| Dibenz(a,h)athracene | 278 | 139, 279 |
| Benzo(g,h,i)perylene | 276 | 138, 277 |

*[2] Target Compounds are subject to change. Primary & secondary ions are subject to change for method optimization.*

*[3] Compound is not listed in Method 8270C.*

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## Table 3
## Appendix IX Target Compounds and Reporting Limits[1]

| Analyte | RL water (ug/L) | RL soil (ug/kg) |
|---|---|---|
| 2-Acetylaminofluorene | 10 | 330 |
| 4-Aminobiphenyl | 10 | 330 |
| Aramite | 50 | 1670 |
| Chlorobenzilate | 10 | 330 |
| Diallate | 10 | 330 |
| 2,6-Dichlorophenol | 10 | 330 |
| Dimethoate | 10 | 330 |
| p-Dimethylaminoazobenzene | 10 | 330 |
| 7,12-Dimethylbenz(a)anthracene | 20 | 330 |
| 3,3'-Dimethylbenzidine | 20 | 670 |
| a,a-Dimethylphenylethylamine | 20 | 330 |
| Dinoseb | 10 | 330 |
| Disulfoton | 10 | 330 |
| Ethyl methanesulfonate | 10 | 330 |
| Famphur | 200 | 6700 |
| Hexachlorophene | 200 | 6700 |
| Hexachloropropene | 10 | 330 |
| Isodrin | 10 | 330 |
| Isosafrole | 10 | 330 |
| Kepone | 200 | 6700 |
| Methapyrilene | 10 | 330 |
| 3-Methylcholanthrene | 10 | 330 |
| Methyl methanesulfonate | 10 | 330 |
| Methyl parathion | 10 | 330 |
| 1-Naphthalenamine | 10 | 330 |
| 2-Naphthalenamine | 10 | 330 |
| 1,4-Naphthoquinone | 20 | 670 |
| 4-Nitroquinoline-n-oxide | 10 | 330 |
| N-Nitrosodiethylamine | 10 | 330 |
| N-Nitroso-di-n-butylamine | 10 | 330 |
| N-Nitrosomethylethylamine | 10 | 330 |
| N-Nitrosomorpholine | 10 | 330 |
| 5-Nitro-o-toluidine | 10 | 330 |
| N-Nitrosopiperidine | 10 | 330 |
| N-Nitrosopyrrolidine | 10 | 330 |
| Parathion (Ethyl parathion) | 10 | 330 |
| Pentachlorobenzene | 10 | 330 |

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| Analyte | RL water (ug/L) | RL soil (ug/kg) |
|---|---|---|
| Pentachloroethane | 10 | 330 |
| Pentachloronitrobenzene | 10 | 330 |
| Phenacetin | 10 | 330 |
| p-Phenylenediamine | 200 | 6700 |
| Phorate | 10 | 330 |
| Pronamide | 10 | 330 |
| Safrole | 10 | 330 |
| Sulfotep | 50 | 1670 |
| 1,2,4,5-Tetrachlorobenzene | 10 | 330 |
| Thionazin | 10 | 330 |
| o,o,o-Triethylphosphorothioate | 10 | 330 |
| o-Toluidine | 10 | 330 |
| 1,3,5-Trinitrobenzene | 20 | 670 |

***[1] Target Compounds and Reporting Limits are subject to change.***

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## Table 4
## Characteristic Ions and Internal Standard Association of Appendix IX Compounds[2]

| Analyte | Primary Ion | Secondary Ion(s) |
|---|---|---|
| **Group 1 - 1,4-Dichlorobenzene-d4 (IS)** | 152 | 150, 115 |
| 2-Fluorophenol (S) | 112 | 64 |
| Phenol-d5 (S) | 99 | 71, 42 |
| N-Nitrosomethylethylamine | 88 | 42, 43 |
| Methyl methanesulfonate | 80 | 79, 65 |
| N-Nitrosodiethylamine | 102 | 42, 57 |
| Ethyl methanesulfonate | 79 | 109, 97 |
| Pentachloroethane[3] | 167 | 165, 169 |
| N-Nitrosopyrrolidine | 100 | 41, 42 |
| N-Nitrosomorpholine | 56 | 116, 86 |
| o-Toluidine | 106 | 107, 77 |
| **Group 2 - Naphthalene-d8 (IS)** | 136 | 68 |
| Nitrobenzene-d5 (S) | 82 | 128, 54 |
| N-Nitrosopiperidine | 114 | 42, 55 |
| o,o,o-Triethylphosphorothioate | 198 | 121, 115 |
| a,a-Dimethylphenylethylamine | 58 | 91, 65 |
| 2,6-Dichlorophenol | 162 | 164, 63 |
| Hexachloropropene | 213 | 211, 215 |
| N-Nitrosodi-n-butylamine | 84 | 57, 41 |
| p-Phenylenediamine | 108 | 80, 53 |
| Safrole | 162 | 104, 77 |
| **Group 3 - Acenaphthene-d10 (IS)** | 164 | 160, 162 |
| 2-Fluorobiphenyl (S) | 172 | 171 |
| 1,2,4,5-Tetrachlorobenzene | 216 | 179, 108 |
| Isosafrole | 162 | 131, 104 |
| 1,4-Naphthoquinone | 158 | 104, 102 |
| Pentachlorobenzene | 250 | 248, 252 |
| 2-Naphthalenamine | 143 | 115, 116 |
| 1-Naphthalenamine | 143 | 115, 89 |
| Thionazin | 96 | 97, 143 |
| 5-Nitro-o-toluidine | 152 | 77, 79 |
| Sulfotep | 322 | 202, 266 |
| 1,3,5-Trinitrobenzene | 75 | 74, 213 |
| Diallate | 86 | 234. 43 |

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| Analyte | Primary Ion | Secondary Ion(s) |
|---|---|---|
| **Group 4 - Phenanthrene-d10 (IS)** | 188 | 80,94 |
| 2,4,6-Tribromophenol (S) | 330 | 332, 141 |
| Phorate | 121 | 97, 93 |
| Phenacetin | 108 | 180, 179 |
| Dimethoate | 87 | 93, 125 |
| 4-Aminobiphenyl | 169 | 168, 170 |
| Pentachloronitrobenzene | 237 | 142, 214 |
| Pronamide | 173 | 175, 145 |
| Disulfoton | 88 | 97, 89 |
| Dinoseb | 211 | 163, 147 |
| Methyl parathion | 109 | 125 |
| Parathion (Ethyl parathion) | 109 | 125 |
| 4-Nitroquinoline-n-oxide | 190 | 163, 160 |
| Methapyrilene | 97 | 50, 191 |
| Isodrin | 193 | 66, 195 |
| **Group 5 - Chrysene-d12 (IS)** | 240 | 120, 236 |
| p-Terphenyl-d14 (S) | 244 | 122, 212 |
| Aramite | 185 | 191, 139 |
| p-Dimethylaminoazobenzene | 120 | 225, 77 |
| Chlorobenzilate | 251 | 139, 253 |
| Famphur | 218 | 125, 217 |
| 3,3'-Dimethylbenzidine | 212 | 106, 196 |
| Kepone | 272 | 274, 270 |
| 2-Acetylaminofluorene | 181 | 180, 223 |
| **Group 6 - Perylene-d12 (IS)** | 264 | 260, 255 |
| 7,12-Dimethylbenz(a)anthracene | 256 | 241, 239 |
| Hexachlorophene | 196 | 198, 209 |
| 3-Methylcholanthrene | 268 | 252, 126 |

[2] ***Target Compounds are subject to change. Primary & secondary ions are subject to change for method optimization.***

[3] ***Compound is not listed in Method 8270C.***

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## Table 5
## Target Compounds Common for Quadratic Curve Fit[1]

| | |
|---|---|
| Benzaldehyde | p-Phenylenediamine |
| Benzoic Acid | 1,4-Naphthoquinone |
| Hexachlorocyclopentadiene | 5-Nitro-o-toluidine |
| 2,4-Dinitrophenol | Sulfotep |
| 4-Nitrophenol | 1,3,5-Trinitrobenzene |
| Pentachlorophenol | Dinoseb |
| n-Decane | 4-Nitroquinoline-n-oxide |
| n-Octadecane | Methapyrilene |
| Butylbenzylphthalate | Aramite |
| a,a-Dimethylphenylethylamine | |

[1]***Subject to change.***

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| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0049 v03_PCBs by SW-846 8082A** |
| | **Effective Date: 10/09/2024** |

**Management Approval:**
Rubina Dalal Approved on 10/7/2024 10:41:52 AM
Sarah Potts Approved on 10/7/2024 4:13:48 PM
Steven Sayer Approved on 10/9/2024 8:24:28 AM
Anne Troyer Approved on 10/9/2024 8:37:58 AM

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## 1.0 SCOPE AND APPLICATION

The purpose of this SOP is to provide a laboratory specific procedure for determining the concentration of polychlorinated biphenyls (PCBs) in sample extracts while meeting the requirements specified in EPA method 8082A.

1.1 This method is applicable to extracts of aqueous, solid, oil, waste, and wipe samples.

1.2 The list of reporting limits is found in Table 1. Reporting limits may vary as a function of volume or weight of sample extracted and extract final volume. Refer to LIMS for method detection limits.

1.3 Reporting limits, control limits, volumes/weights used, standard concentrations, vendors, instrumentation, equipment, and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

2.1 Aqueous samples are extracted using Method 3510C, Separatory Funnel Extraction or other appropriate technique. Solids are extracted using Method 3546 Microwave Extraction or other appropriate technique. Non-aqueous wastes/oils are prepared for analysis using Method 3580, Waste Dilution or other appropriate technique. Refer to the *Extraction of Wipes for PCBs* SOP for preparation of wipes.

2.2 Cleanup steps may be applied to the extract, depending on the nature of the matrix interferences and the target analytes.

2.3 After cleanup, if applicable, the extract is analyzed by a gas chromatograph fitted with an electron capture detector (ECD). Aroclor identification is confirmed by a secondary column.

2.4 Aroclors are multi-component mixtures. When samples contain more than one Aroclor, a higher level of analyst expertise is required to attain acceptable levels of qualitative and quantitative analysis. The same is true of Aroclors that have been subjected to environmental degradation (“weathering”) or degradation by treatment technologies. Such weathered multi-component mixtures may have significant differences in peak patterns than the peak patterns of Aroclor standards.

## 3.0 INTERFERENCES

3.1 Matrix interferences may be caused by contaminants in solvents, reagents, glassware and other sample processing hardware. These interferences can lead to discrete artifacts or elevated baselines in gas chromatograms. Routinely, all of these materials must be demonstrated to be free from interferences under the conditions of the analysis by running reagent blanks.

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3.2 Interferences caused by phthalate esters can pose a major problem in PCB analysis. Common flexible plastics contain varying amounts of phthalates, which are easily extracted during lab operations. Avoiding the use of plastics in the lab can best minimize interferences from phthalates.

3.3 Matrix interferences may be caused by contaminants that are co-extracted from the sample. The extent of matrix interferences will vary considerably from source to source, depending upon the nature of the site being sampled. Cleanup procedures may be used to remove such interferences. Refer to the appropriate cleanup SOPs if extract cleanup to remove interferences is required.

## 4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

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| Sample type | Collection per sample | Preservation | Storage | Holding time* |
|---|---|---|---|---|
| **Aqueous** | 100mL in widemouth amber glass bottle | None required | Cool to ≤6°C | Extract within 1 year of collection and analyze within 40 days of extraction. |
| **Solid** | >100g in 4oz. glass jar. | None required | Cool to ≤6°C | Extract within 1 year of collection and analyze within 40 days of extraction. |
| **Oil / Waste** | >10 grams in a glass container. | None required | Cool to ≤6°C or ambient | Extract within 1 year of collection and analyze within 40 days of extraction. |
| **Wipe** | One wipe per glass container. | None required | Cool to ≤6°C or ambient | Extract within 1 year of collection and analyze within 40 days of extraction. |

*The holding time above is a recommendation. PCBs are very stable in a variety of matrices and holding time of the extract may be as long as a year.

## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| Gas Chromatograph | Agilent 7890A, LTM module optional, equipped with dual ECD detectors, dual columns, autosampler and data system, or equivalent system. |
| GC Columns | Restek DB5-MS or DB35-MS, fused silica; 30m x 0.32mm x 0.25um, or equivalent |
| | Restek RTX-CLP1 and RTX-CLP2, fused silica; 30m x 0.32mm x 0.32um, and 30m x 0.32mm x 0.25um or equivalent |
| LTM GC Columns | Restek, DB-35-MS LTM and DB5-MS LTM, fused silica; 15m x 0.32mm X 0.25um and 15m x 0.32mm x 0.25um, or equivalent |

### 7.2 Supplies

| Supplies | Description |
|---|---|
| Glass syringes | Various sizes |
| Glass vials | 20mL volume with Teflon lined caps |
| Volumetric flasks | Class A, various sizes |
| Autosampler vials | 2mL volume with Teflon lined crimp tops |
| Micro-inserts | Various sizes |

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## 8.0 REAGENTS AND STANDARDS

### 8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Hexane | Pesticide grade or equivalent |

### 8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| Stock 1016/1260 Calibration Standards | Agilent, 1000ug/mL each, or equivalent:<br>1016 cat# EPA-1282,<br>1260 cat# EPA-1362 | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Intermediate 1016/1260 Calibration Standard | Refer to Section 8.3.1 | Solution good for 6 months from preparation. | Refrigerate |
| Working 1016/1260 Calibration Standards | Refer to Section 8.3.2 | Solutions good for 6 months from preparation. | Refrigerate |
| Stock Single Point PCB Calibration Standards | Agilent, 1000ug/mL each, or equivalent:<br>1221 cat# EPA-1292,<br>1232 cat# EPA-1302,<br>1242 cat# EPA-1312,<br>1248 cat# EPA-1342,<br>1254 cat# EPA-1352,<br>1262 cat# EPA-1372,<br>1268 cat# EPA-1382. | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Working Single Point PCB Calibration Standards | Refer to Section 8.3.3 | Solution good for 6 months from preparation. | Refrigerate |
| Stock 1016/1260 ICV standard | Restek 1016/1260 cat#32039, **or** Phenova 1016/1260 cat#AL0-101455, 1000ug/mL each, or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions. Refrigerate after opening. |
| Working 1016/1260 ICV standard | Refer to Section 8.3.4 | Solution good for 6 months from preparation. | Refrigerate |
| Stock Surrogate Standard | Agilent catalog #ISM-320; TCMX 200ug/mL, or equivalent. | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions. Refrigerate after opening. |

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8.3 Standard Preparation Procedures

8.3.1 Intermediate 1016/1260 Calibration Standard Preparation

Dilute 100uL of the Stock Aroclor 1016 Calibration standard (1000ug/mL), 100uL of the Stock Aroclor 1260 Calibration standard (1000ug/mL) and 50uL of the Stock PCB Surrogate standard (200ug/mL) to 50mL with Hexane for a final Aroclor 1016/1260 concentration of 2ug/mL and a final surrogate concentration of 0.2ug/mL. This recipe can also be used to prepare an intermediate calibration standard for other Aroclors.

8.3.2 Working 1016/1260 Calibration Standards Preparation

The following are examples of calibration standards prepared in hexane using the Intermediate 1016/1260 Calibration Standard (2000ug/L). Concentrations could vary based on requirements.

| Standard | Intermediate 1016/1260 Calibration Standard amount | Final Volume in Hexane | Final Concentration of each PCB | Final Concentration of surrogate |
|---|---|---|---|---|
| CAL1 | 5uL | 5mL | 2 ug/L | 0.2 ug/L |
| CAL2 | 12.5uL | 5mL | 5 ug/L | 0.5 ug/L |
| CAL3 | 25uL | 5mL | 10 ug/L | 1.0 ug/L |
| CAL4 | 125uL | 5mL | 50 ug/L | 5.0 ug/L |
| CAL5 | 250uL | 5mL | 100 ug/L | 10 ug/L |
| CAL6 (CCV) | 1250uL | 5mL | 500 ug/L | 50 ug/L |
| CAL7 | 1875uL | 5mL | 750 ug/L | 75 ug/L |
| CAL8 | 2500uL | 5mL | 1000 ug/L | 100 ug/L |

8.3.3 Working Single Point PCB Calibration Standard Preparation

The following are examples of working single point calibration standards and could vary based on requirements:

| Standard | Stock Single Point PCB Calibration Standard amount | Stock PCB Surrogate amount | Final Volume in Hexane | Final Concentration of each PCB | Final Concentration of Surrogate |
|---|---|---|---|---|---|
| Working 1221/1254 | 10uL each | 5uL | 20mL | 0.5 ug/mL | 0.05 ug/mL |
| Working 1232/1262 | 10uL each | 5uL | 20mL | 0.5 ug/mL | 0.05 ug/mL |
| Working 1242/1268 | 10uL each | 5uL | 20mL | 0.5 ug/mL | 0.05 ug/mL |
| Working 1248 | 10uL | 5uL | 20mL | 0.5 ug/mL | 0.05 ug/mL |

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8.3.4 Working ICV Standard Preparation

Dilute 10uL of the Stock ICV standard (1000ug/mL) and 5uL of the Stock Surrogate standard (200ug/mL) to 20mL with hexane for a final Aroclor 1016/1260 concentration of 0.5ug/mL and a final surrogate concentration of 0.05ug/mL. This recipe can also be used to prepare an ICV standard for other Aroclors.

## 9.0 PROCEDURE

9.1 Initial Instrument Calibration

9.1.1 Configure the GC system per manufacturer's instructions.

9.1.2 Before initial calibration, it is advisable to perform routine injection port and column maintenance due to the sensitivity of the ECD detector.

9.1.3 Initial calibration standards are introduced into the GC from the lowest to highest concentration by direct injection. Five calibration points, at a minimum, are analyzed to evaluate linearity. The lowest calibration standard must be at or below the required reporting limit.

9.1.3.1 A mixture of Aroclor 1016 and 1260 will include many of the peaks represented in the other Aroclor mixtures. Thus, such a standard may be used to demonstrate the linearity of the detector and that a sample does not contain peaks that represent any one of the Aroclors. This standard can also be used to determine the concentrations of either Aroclor 1016 or Aroclor 1260, should they be present in a sample. An initial calibration is performed using the mixture of Aroclors 1016 and 1260.

9.1.3.2 Standards of the other Aroclors are necessary for pattern recognition. Assuming the Aroclor 1016/1260 standards have been used to demonstrate the linearity of the detector, these single standards of the remaining Aroclor may be used to determine a single-point calibration factor for each Aroclor. The standards for these other Aroclors should be analyzed before the analysis of any samples, and before the analysis of the Aroclor 1016/1260 initial calibration curve.

9.1.3.3 In situations where only one or a few Aroclors are of interest for a specific project, the analyst may employ an initial calibration of each of the Aroclors of interest in lieu of the 1016/1260 mixture and the pattern recognition standards.

9.1.4 Record the peak area (or height) for each Aroclor peak to be used for quantitation. A minimum of 3 peaks must be chosen for each Aroclor, preferably 5 peaks are used. Choose peaks in the Aroclor standards that are at least 25% of the height of the largest Aroclor peak. A book of reference chromatograms for each Aroclor has been created for each instrument. Refer to these books for the preferred peaks used for calibration of each Aroclor.

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9.1.5 Calculate the Calibration Factor (CF) for each characteristic Aroclor peak in each of the initial calibration standards using the calculation below:

$$CF = \frac{Peak\ Area\ or\ Height\ in\ the\ Standard}{Mass\ of\ the\ Standard\ Injected,\ ng}$$

Calibration factors will be generated for each of the peaks chosen for the Aroclor 1016/1260 mixture at each calibration level. The single standard for each of the other Aroclors will generate a minimum of 3 calibration factors, one for each selected peak.

9.1.6 The percent relative standard deviation (%RSD) of the calibration factors is calculated as follows:

$$\%RSD = \frac{Standard\ deviation\ of\ calibration\ factors}{Average\ of\ calibration\ factors} \times 100$$

9.1.7 If the RSD of the CFs is ≤20% over the calibration range, then the slopes of the lines for each standard are sufficiently close to one another and the average CF may be used to determine sample concentrations.

9.1.8 If the RSD is >20%, the analyst may employ a linear regression equation, non-weighted or weighted 1/x or $1/x^2$, that does not pass through the origin. The regression calculation will generate a correlation coefficient (r) that is the measure of the "goodness of fit" of the regression line to the data. In order to be used for quantitative purposes, the correlation coefficient must be ≥ 0.99. Refer to Method 8000D for additional information regarding calibration.

9.1.9 When the Aroclor 1016/1260 mixture is used to demonstrate the detector response, the calibration model chosen for this mixture must be applied to the other 5 Aroclors for which only single standards are analyzed. If multi-point calibration is performed for individual Aroclors, use the calibration factors from those standards to evaluate linearity.

9.1.10 Non-linear or quadratic calibration: A non-linear or quadratic calibration model can only be used if the compound(s) have historically exhibited a non-linear response and cannot be used to extend the calibration range for any compound that normally exhibits a linear response in a narrower range. The non-linear regression calibration curve is derived from a least squares regression analysis of the calibration points. A calibration curve based on this technique will have the format of: $y= ax^2+bx+c$. In order to use this curve fit technique, a minimum of 6 calibration points must be available and the origin cannot be included as one of the points. Because the non-linear regression is not forced through the origin, very low levels of contaminants below the response of the lowest calibration point may generate erroneous reportable results. The "goodness of fit" of the polynomial equation is evaluated by calculating the coefficient of the determination (COD) or $r^2$. The COD or $r^2$ from the regression equation must be ≥0.99. Refer to Method 8000D for additional information regarding calibration. Continue to Section 9.2 for additional evaluation requirements.

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9.1.11 For compounds evaluated using $CF_{avg}$, the RSD is the measure of Relative Error. For compounds that required the linear regression model or the quadratic model, the laboratory must evaluate Relative Error:

$$\%\ Relative\ Error = \frac{Calculated\ concentration - Theoretical\ concentration}{Theoretical\ concentration}\ x\ 100$$

Calculate %RE for two (2) initial calibration levels, the standard at the mid-point and the standard at the lowest point. %RE for the mid-point must be ± 30% (70-130% Recovery), the lowest point must be ±50% (50-150% Recovery).

For compounds that required the linear regression model or the quadratic model for calibration: if the %RE limit is exceeded for the lowest calibration level, analytes reported at a concentration that is <2x the reporting limit in associated samples must be qualified as estimated. Alternatively, the reporting limit can be raised to the level of a calibration standard that meets the criteria when re-fitted against the curve.

9.1.12 Individual analyte calibration levels may be removed from the lowest and/or highest levels of the calibration curve provided the number of remaining calibration points meet the minimum requirements and the quantitation range is adjusted, as necessary.

9.1.13 Removal of interior calibration levels is not permitted unless a standard introduction error or preparation error can be documented.

9.1.14 A calibration level may be replaced provided that the replacement calibration standard is analyzed within the same calibration event.

9.1.15 Refer to Section 11.1 for acceptance criteria and corrective actions.

9.2 Initial Calibration Evaluation

Each day that analysis is performed, the calibration standard(s) should be evaluated to determine if the chromatographic system is operating properly. Questions that should be asked are: Do the peaks look normal? Is the response obtained comparable to the response from previous calibrations? Are the retention times consistent over the range of calibration for each compound?

Careful examination of the standard chromatogram can indicate whether the column is still performing acceptably. Additionally, examination of signal-to-noise ratio of analytes in low-level standards may be a useful diagnostic tool to monitor instrument performance. Signal-to-noise ratio is defined as the ratio of the analyte signal to the noise measured on a blank. It is recommended but not required that the signal-to-noise ratio be at least three to confirm detection.

9.3 Initial Calibration Verification (ICV)

9.3.1 In addition to meeting the response and linearity criteria, any new calibration curve must be assessed for accuracy of the values generated. A single standard from a secondary source must be analyzed and the results obtained must be compared to the known true value.

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This step is referred to as the Initial Calibration Verification. The ICV must be from an alternative vendor or, in the event an alternative vendor is not available, from a different lot from the same vendor. The accuracy of the standard is assessed as percent recovery (%R) of the observed ICV response compared to the true value as prepared, according to the following equation:

$$\%\ Recovery = \frac{Observed\ Concentration}{Theoretical\ Concentration}\ x\ 100$$

9.3.2 The ICV is analyzed immediately following the initial calibration curve. Refer to Section 11.1 for acceptance criteria and corrective actions.

9.4 Continuing Calibration Verification (CCV)

9.4.1 Verify the initial calibration each 12-hour shift by injecting a Continuing Calibration Verification (CCV) standard prior to conducting any sample analyses. The CCV must also be analyzed at intervals of not less than once every 20 client samples and at the end of the analysis sequence.

9.4.2 For Aroclor analyses, the CCV standard should be a mixture of Aroclors 1016 and 1260.

9.4.3 For initial calibrations that employed average calibration factor, the calibration factor ($CF_v$) for each analyte calculated from the CCV must not exceed a %Difference (%D) of more than +/-20% when compared to the $CF_{avg}$ from the initial calibration curve.

$$\%\ Difference = [CF_v - CF_{avg}] / CF_{avg} * 100$$

9.4.4 For initial calibrations that employed a linear or quadratic calibration, the %Drift for each analyte calculated from the CCV must be within +/-20% in order to use the calibration model to quantitate sample results.

$$\%\ Drift = \frac{Calculated\ Concentration - Theoretical\ Concentration}{Theoretical\ Concentration}\ x\ 100$$

9.4.5 Refer to Section 11.1 for acceptance criteria and corrective actions.

9.4.6 At the beginning of each week, inject a single-point standard for all other Aroclors. These standards do not require assessment for recovery; they will be used for pattern recognition.

9.5 Sample Analysis

9.5.1 All sample extracts must be analyzed at room temperature and the system must be calibrated and free of contamination before samples are analyzed.

9.5.2 Load vials in the desired sequence on the autosampler. Analyze each using the same GC system configuration settings used for initial calibration.

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## 10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Qualitative Analysis

Compounds are identified as present when the following criteria are met:

10.1.1 Absolute retention times are used for the identification of PCBs as Aroclors. Retention time windows are established on both the primary and the confirmation column to compensate for minor shifts in absolute retention times as a result of sample loadings and normal chromatographic variability. The width of the retention time window should be carefully established to minimize the occurrence of both false positive and false negative results. To establish retention time windows, make three or more injections of a standard over the course of a 72-hour period, at a minimum. Record the retention time in minutes for the major peaks and surrogate to three decimal places. Calculate the mean and standard deviation of the absolute retention times of the standard. The retention time window is defined as +/-3 times the standard deviation of the mean absolute retention time established during the 72-hour period or 0.03 minutes, whichever is greater.

10.1.2 Establish the center of the retention time window for each major peak and surrogate by using the absolute retention time for each major peak and surrogate from the calibration verification standard at the beginning of the analytical shift. For samples run during the same shift as an initial calibration, use the retention time of the mid-point standard of the initial calibration.

10.1.3 It may also be useful to establish the center of the retention time window for single point standards by using the absolute retention time for each major peak and surrogate from the single point standards analyzed at the beginning of the analytical shift. For samples run during the same shift as an initial calibration, use the retention time of the single point standards analyzed with the initial calibration.

10.1.4 Tentative identification of a PCB compound is made when peaks from the sample extract fall within the established retention time windows for Aroclor peaks. The result of a single column/single injection analysis may be confirmed, if necessary, on a second, dissimilar, GC column. In order to be used for confirmation, retention time windows must have been established for the second GC column. In addition, the analyst must demonstrate the sensitivity of the second column analysis. This demonstration must include the analysis of a standard of the target analyte at a concentration at least as low as the concentration estimated from the primary analysis.

When the dual-column approach is employed, the target Aroclors are identified and confirmed when they meet the identification criteria on both columns. When confirmation is made on a second column, that analysis should meet all of the QC criteria described above for calibration, retention times, etc.

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10.1.5 A book of reference chromatograms for each Aroclor has been created for each instrument. Refer to this book for the preferred peaks and ratios between peaks that are characteristic of each Aroclor. When interferences are present, degradation has occurred, or multiple Aroclors are suspected, the following tools are helpful for proper identification:

- Overlays of the sample chromatogram with chromatograms of Aroclor standards
- Comparison of characteristic peak retention times with Aroclor standards
- Comparison of the ratio between characteristic peaks with ratios of Aroclor standards
- Comparison with historical results, if available
- Analyst judgment and consultation with other experienced analysts
- Consistent application of evaluation tools

10.2 Quantitative Analysis

10.2.1 The quantitation of PCB residues as Aroclors is accomplished by comparison of the sample chromatogram to that of the most similar Aroclor standard. A choice must be made as to which Aroclor is most similar to that of the residue and whether that standard is truly representative of the PCBs in the sample.

10.2.2 Once the Aroclor pattern has been identified, compare the responses of 3 to 5 major peaks in the calibration standard for that Aroclor with the peaks observed in the sample extract. The amount of Aroclor is calculated using the individual calibration factor for each of the 3 to 5 characteristic peaks chosen and the calibration model established from the multi-point calibration of 1016/1260. A concentration is determined using each of the characteristic peaks and then those 3 to 5 concentrations are averaged to determine the concentration of that Aroclor.

10.2.3 When interferences are present or degradation has occurred, peaks yielding concentrations or areas that are dissimilar to the others may be excluded. When multiple co-eluting Aroclors are suspected, quantitation of Aroclor(s) should be based on the best match with established Aroclor patterns as determined using the tools outlined in Section 10.1.5.

10.3 Each sample analysis must be preceded by an acceptable initial calibration and must be bracketed by acceptable continuing calibration verification standards, or calibration standards interspersed within the samples. The results from these bracketing standards must meet the calibration verification criteria in Sections 9.4 and 11.1.

10.4 When concentrations exceed the calibration range, the sample extract should be rerun at a dilution or the result must be qualified as estimated.

10.5 When the result between a quantitation and confirmation column disagree by >40% Relative Percent Difference (RPD), the chromatograms should be checked for any obvious reasons for the differences. This could be overlapping or co-eluting peaks, poor baseline integration, or a system more sensitive to interferences in the samples.

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If no anomalies are noted and there are no chromatographic problems, then SW846-8000D section 11.10.4.2 advises to report the lower of the two results. The determination to report the lower result or the higher result may rest with the group supervisor or their designee. Where the higher result is reported, the reasoning should be well documented. In either case, the client must be informed of the disparity between the results on the final report.

10.6 Refer to the Manual Integrations SOP for guidance on performing and documenting manual integrations.

10.7 Extract cleanup may be necessary when interference is indicated. Refer to cleanup SOPs for details.

10.8 Calculations

10.8.1 Calculate the final concentration in the sample as follows:

**Aqueous (ug/L)** = $\frac{(X_s)(V_f)(D)}{(V_i)} \times 1000$ **Solid (ug/kg)** = $\frac{(X_s)(V_f)(D)}{(W_i)} \times 1000$

Where: $X_s$ = On-column concentration of the analyte, ug/mL
$V_f$ = Final volume of sample extract, L
D = Dilution factor of extract (final volume/initial volume)
$V_i$ = Volume of aqueous sample extracted, L
$W_i$ = Weight of solid sample extracted, kg

Moisture corrected concentration = $\frac{\text{(Final concentration as received)}}{\text{(100 - \%Moisture)}} \times 100$

**Oil (mg/kg)** = $\frac{(X_s)(V_f)(D)}{(W_s)}$ **Wipe (Total ug)** = $(X_s)(V_f)(D)$

Where: $X_s$ = On-column concentration of the analyte in ug/mL
$V_f$ = Final volume of extract in milliliters
D = Dilution factor of extract (final volume/initial volume)
$W_s$ = Weight of oil sample extracted in kilograms

10.8.2 LCS calculation:

$R = (C / S) \times 100$

Where: R = Percent Recovery
C = Observed LCS concentration
S = True LCS concentration

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10.8.3 MS calculation:

$$R = \frac{(C_s - C)}{S} \times 100$$

Where: R = Percent Recovery
$C_s$ = Observed MS concentration
C = Sample concentration
S = True spike concentration

10.8.4 RPD equation:

$$RPD = \frac{|D_1 - D_2|}{[(D_1 + D_2)/2]} * 100$$

Where: RPD = Relative Percent Difference
$D_1$ = First Sample Result
$D_2$ = Second Sample Result

## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

11.1 Instrument Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration** | Applicable target analytes | As needed | Refer to Sections 9.1 – 9.3 | If the initial calibration curve does not meet specified criteria, a new initial calibration curve must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed initial calibration must be reanalyzed. |
| **Initial Calibration Verification Standard (ICV)** | Second Source Standard | Immediately following initial calibration of the instrument | 70-130% Recovery | Reanalyze an ICV. If the second ICV also exceeds the acceptance range, a new initial calibration should be prepared. Alternatively, the allowance for use of the ICV when the criterion is not met is documented and is at the discretion of the Department Manager, Quality Manager, General Manager or designee.<br>Samples associated with a failed ICV must be reanalyzed or must be qualified.<br>*Exception:* If the ICV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Continuing Calibration Standard (CCV)** | Applicable target analytes | Every 12 hours of instrument operation, every 20 client samples, and at the end of the sequence | Avg CF ± 20% Diff. from Initial Calibration<br><br>Linear calib ± 20% Drift from Initial Calibration | Check instrument operating conditions, and if necessary, restore them to the original settings. Reanalyze a CCV. If the response still fails the acceptance criteria, perform corrective actions such as instrument maintenance or prep of a new standard, then re-analyze a CCV. If this CCV also fails, a new initial calibration must be analyzed.<br>Samples associated with a failed CCV must be reanalyzed or qualified.<br>*Exception:* If the CCV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |

11.2 Batch Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Method Blank (MB)** | Reagent water or simulated soil matrix | One per preparation batch of up to 20 samples, per matrix. | Target analytes must be less than reporting limits. | Reanalyze method blank. If target compound is still >RL in method blank and associated samples, re-extract and reanalyze samples.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, the reported method blank and samples must be qualified.<br>2) If a contaminant is present only in the method blank and not the samples, no action is required. |
| **Laboratory Control Standard (LCS)** | Applicable target analytes | One per preparation batch of up to 20 samples, per matrix. | Lab-generated limits<br>Refer to the LIMS for acceptance limits. | Reanalyze the LCS. If LCS is still outside acceptance limits, re-extract and reanalyze all associated samples.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported data must be qualified.<br>2) If LCS recovery is >QC limits and sample results are non-detect, the sample data may be reported without qualifiers. The LCS data must be qualified. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Matrix Spike /Matrix Spike Duplicate (MS/MSD)** | Applicable target analytes | One MS/MSD set per preparation batch of up to 20 samples, per matrix. | Lab-generated limits<br>Refer to the LIMS for acceptance limits. | No corrective actions necessary. If LCS recovery is in range, the system is considered in-control and the out-of-control MS/MSD must be qualified appropriately. |
| **Surrogates** | Applicable surrogate compounds | Added to each standard, sample, and method blank. | Lab-generated limits<br>Refer to the LIMS for acceptance limits. | Samples with surrogate failure must be re-extracted and reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported surrogate data must be qualified.<br>2) If surrogate result is >QC limits, and sample results are non-detect, the sample results may be reported without qualifiers. The surrogate must be qualified.<br>3) MS/MSD surrogate recovery failures do not constitute the re-extraction or reanalysis of samples but the surrogate data must be qualified. |

11.3 Method Validation

Refer to the SOP for Method Validation and Instrument Verification for the procedures used for initial method validation. Method Detection Limits (MDL) must be determined per the procedure in 40CFR Part 136, Appendix B.

11.4 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

## 12.0 Data Review And Corrective Action

12.1 Data Review

The analyst must perform primary review of data and calculated results for accuracy. Secondary review of the data and calculated results must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

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12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual. ***Samples with a PCB concentration ≥50 ppm must be disposed of as hazardous waste.***

## 14.0 MODIFICATIONS

14.1 Extracts are not stored in the dark. Sample extracts are analyzed within a few days of extraction and are not exposed to light for an extended period of time.

14.2 A standard of the DDT analogs is not analyzed and evaluated because interference from DDT and its breakdown components is more applicable to congener analysis than Aroclor analysis. Analysis of the DDT analogs is not considered a method requirement.

14.3 Single point Aroclor standards may be combined in the same way that Aroclors 1016 and 1260 are combined.

## 15.0 RESPONSIBILITIES

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

## 16.0 ATTACHMENTS

16.1 Table 1: Analytes and Reporting Limits for the Analysis of PCBs by 8082A

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## 17.0 REFERENCES

17.1 "Test Methods for Evaluating Solid Wastes" EPA SW-846 Methods 8082A (February 2007) and 8000D.

17.2 Pace Analytical Quality Manual; latest revision.

17.3 NELAC/TNI Standards; 2003, 2009, and 2016.

## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 9.1 | Added relative error evaluation. Added allowance for dropping and/or replacing calibration points according to calibration policy. |
| 9.4.6 | Added weekly injection of single-point Aroclor standards. |
| 10.5 | Added description of reporting decision rationale when results from both columns are not confirming. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0049 | Polychlorinated Biphenyls (PCBs) by Gas Chromatography | 02 |

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## Table 1
## Analytes and Reporting Limits for the Analysis of PCBs by 8082A[1]

| Analyte | CAS# | RL Water, ug/L | RL Soil, ug/kg | RL Oil, mg/kg | RL Wipe, Total ug |
|---|---|---|---|---|---|
| PCB-1016 (Aroclor 1016) | 12674-11-2 | 0.1 | 100 | 1 | 0.5 |
| PCB-1221 (Aroclor 1221) | 11104-28-2 | 0.1 | 100 | 1 | 0.5 |
| PCB-1232 (Aroclor 1232) | 11141-16-5 | 0.1 | 100 | 1 | 0.5 |
| PCB-1242 (Aroclor 1242) | 53469-21-9 | 0.1 | 100 | 1 | 0.5 |
| PCB-1248 (Aroclor 1248) | 12672-29-6 | 0.1 | 100 | 1 | 0.5 |
| PCB-1254 (Aroclor 1254) | 11097-69-1 | 0.1 | 100 | 1 | 0.5 |
| PCB-1260 (Aroclor 1260) | 11096-82-5 | 0.1 | 100 | 1 | 0.5 |
| PCB-1262 (Aroclor 1262) | 37324-23-5 | 0.1 | 100 | 1 | 0.5 |
| PCB-1268 (Aroclor 1268) | 11100-14-4 | 0.1 | 100 | 1 | 0.5 |
| PCB, Total (Aroclor) | 1336-36-3 | 0.1 | 100 | 1 | 0.5 |

[1] Target Compounds and Reporting Limits are subject to change.

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| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0025 v03_Metals by SW-846 6010B** |
| | **Effective Date: 04/22/2024** |

**Management Approval:**
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## 1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide a laboratory specific procedure for determining the concentration of metals in aqueous and solid environmental samples while meeting the requirements specified in SW-846 method 6010B.

1.1 This method is applicable to the determination of most trace elements, including metals, in groundwater, surface water, wastewater, extract, leachate, soil, sediment, sludge, wipes, and other solid samples.

1.2 Reporting limits, control limits, volumes/weights used, standard concentrations, vendors, instrumentation, equipment and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

Prior to analysis, samples must be solubilized or digested using appropriate sample preparation methods. When analyzing groundwater samples for dissolved constituents, acid digestion is not necessary if the samples are filtered and acid preserved prior to analysis.

This method describes multielement determinations by Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES). The instrument measures characteristic emission spectra by optical spectrometry. Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by radio-frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and the intensities of the emission lines are monitored by photosensitive devices.

Background correction may be required to compensate for spectral interferences. Background is measured adjacent to analyte lines at a wavelength selected to be free of spectral interference and which reflects the same change in background intensity as occurs at the wavelength measured. Background correction is not required in cases of line broadening where a correction would actually degrade the analytical result.

## 3.0 INTERFERENCES

3.1 Spectral interferences: Overlap of emission lines from another element, unresolved overlap of molecular band spectra, background contribution from continuous or recombination phenomena and stray light can contribute to spectral interferences. These interferences can typically be minimized by careful selection of quantitation wavelengths, inter-element corrections, and background correction.

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3.2 Physical interferences: Changes in sample viscosity, surface tension, or other effects associated with sample transport and nebulization can produce significant inaccuracies, especially in samples containing high concentrations of dissolved solids and acids. Dissolved solids may build up on the nebulizer tip, altering the sample flow rate and causing instrument drift. These effects can be minimized by sample dilution or use of a specially designed high-solids nebulizer.

3.3 High Salt Concentrations: high salt concentrations in sample digestates can cause signal suppression and confuse interference tests

3.4 Chemical interferences: Molecular compound formation, ionization effects, and solute vaporization effects are typically not significant with ICP determinations. If observed, they can be minimized by careful selection of plasma and spectrometer operating parameters.

3.5 Memory interferences: Sample deposition on the nebulizer tubing, spray chamber, and plasma torch can cause apparent sample carryover. Memory interferences can be minimized by flushing the system with rinse blanks between samples. If memory interference is suspected for a sample, the sample must be re-analyzed after a sufficient rinse period.

## 4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

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## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Aqueous - Total** | 250mL in plastic container | $HNO_3$ to pH <2<br>Samples received at pH >2 must be preserved to pH <2 with $HNO_3$ and allowed to equilibrate in the original container for 24 hours before being prepared for analysis. Record date/time of acidification in the Sample Preservation logbook. Additional acid added may not exceed 1% of the total container volume. Data is qualified if sample cannot be properly preserved. | Ambient or cool to ≤6°C | Must be analyzed within 6 months of the collection date. |
| **Aqueous-Dissolved Field Filtered** | 250mL in plastic container | Filter on site using 0.45um filter then add $HNO_3$ to pH<2.<br>Samples received at pH >2 must be preserved to pH <2 with $HNO_3$ and be allowed to equilibrate in the original container for 24 hours before digestion. Record date/time of acidification in Sample Preservation logbook. Additional acid added may not exceed 1% of the total container volume. Data is qualified if sample cannot be properly preserved. | Ambient or Cool to ≤6°C | Must be analyzed within 6 months of the collection date. |
| **Aqueous-Dissolved Lab Filtered** | 250mL in plastic container | Unpreserved samples are lab filtered using 0.45um filter then preserved to pH<2 with $HNO_3$ and allowed to equilibrate for 24 hours before being digested.<br>Date/time of filtration and preservation is recorded in the metals digestion prep log. Volume of acid added may not exceed 1% of the sample volume. Data is qualified if sample cannot be properly preserved. | Ambient or Cool to ≤6°C | Must be analyzed within 6 months of the collection date. |
| **Aqueous – TCLP/SPLP Leachates** | 250mL in plastic container | $HNO_3$ to pH <2 immediately prior to digestion for an aliquot of leachate to be analyzed.<br>Spiking solution for matrix spike must be added to an aliquot of the leachate prior to preservation with $HNO_3$ to pH<2, followed by digestion. | Ambient | Must be analyzed within 6 months of the leachate extraction date. |
| **Solid** | 50g in glass or plastic container | None | Ambient or Cool to ≤6°C | Must be analyzed within 6 months of the collection date. |

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| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Aqueous – 6010 WASTE acode only** | Misc. plastic or glass container | No preservation required. | Ambient or Cool to ≤6°C | Must be analyzed within 6 months of the collection date. |
| **Wipe – 6010 I acode only** | Individual wipe in plastic or glass container | None | Ambient or Cool to ≤6°C | Must be analyzed within 6 months of the collection date. |

## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| ICP-AES | Thermo-Fisher iCAP6500 or equivalent, equipped with autosampler and data system |

### 7.2 Supplies

| Supplies | Description |
|---|---|
| Volumetric flasks | Class A, various capacities |
| Mechanical pipets | Eppendorf or equivalent, various sizes |
| Graduated cylinders | Class A, various capacities |
| pH strips | Fisher or equivalent, full range |
| 0.45 um filters | Environmental Express FlipMate filters or equivalent. Used only for dissolved metals determination. |
| Autosampler vials | Environmental Express or equivalent |
| Analytical balance | Capable of weighing to 0.01g |

## 8.0 REAGENTS AND STANDARDS

### 8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Reagent water | ASTM Type II water or equivalent |
| Argon | High purity, liquefied |
| Nitric acid | Concentrated, trace metal analyzed or equivalent |
| Hydrochloric acid | Concentrated, trace metal analyzed or equivalent |
| Diluent | Add 50mL nitric acid and 20mL hydrochloric acid to 500mL reagent water in a 1L volumetric flask and dilute to volume with reagent water. Mix well. |

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8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| Stock Calibration Standards | SPEX; catalog #'s MIXSTD1-100; MIXSTD2-100; MIXSTD3-100; MIXSTD4-100; MIXSTD5-100; PLS19-2Y; CLSN2-2Y; CLTI9-2Y; PLLI-2Y; PLP9-3Y; CLAG2-2Y; PLSR2-2Y or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Working Calibration Standards | Refer to Section 8.3.2 | Must be prepared fresh weekly | Same as stock standards |
| Stock ICV Standard | SPEX; catalog #s SXFMN-26-250A, SXFMN-27-250A, and SXFMN-28-250A or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Stock ICV Standard | Inorganic Ventures; catalog #s PA-STD1B, PA-STD2B, and PA-STD3B or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Working ICV Standard | Refer to Section 8.3.4 | Must be prepared fresh weekly | Same as stock standard |
| Working Spiking Solution | Refer to Section 8.3.5 | Expires 6 months from date of preparation. | Same as stock standard |
| Stock Interference Check Standard A | HPS; catalog # ICL500-6 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Working Interference Check Standard A (ICSA) | Refer to Section 8.3.6 | Must be prepared fresh weekly | Same as stock standards |
| Stock Interference Check Standard AB | HPS; catalog #ICL500-6, SPEX XFSMN-26-250A (mix 1B), XFSMN-27-250A (mix 2B), or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Working Interference Check Standard AB (ICSAB) | Refer to Section 8.3.8 | Must be prepared fresh weekly | Same as stock standards |
| Stock CRDL standard | SPEX; catalog #XPACEMN-115-100, or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Working CRDL standard | Refer to Section 8.3.10 | Must be prepared fresh weekly | Same as stock standards |
| Stock Internal Standard | SPEX; catalog # PLY2-2X; 1000mg/L yttrium or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Working Internal Standard | Refer to Section 8.3.11 | Must be prepared fresh weekly | Same as stock standards |

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8.3 Standard Preparation Procedures

**NOTE:** In all standard preparations, volumes and/or final concentrations may vary if alternate stock standards are used.

8.3.1 Stock Calibration Standard Details

The following table shows the seven stock standard mixes that may be used to prepare the initial calibration and calibration check standards.

| Analyte | Concentration (mg/L) |
|---|---|
| *Mix #1: Catalog # MIXSTD1-100* | |
| Lead | 500 |
| Selenium | 200 |
| Cadmium | 150 |
| Zinc | 150 |
| Manganese | 100 |
| Beryllium | 50 |
| *Mix #2: Catalog # MIXSTD2-100+PLSR2-2Y* | |
| Iron | 10,000 |
| Barium | 100 |
| Cobalt | 100 |
| Copper | 100 |
| Vanadium | 100 |
| Strontium | 100 |
| *Mix #3: Catalog # MIXSTD3-100 + silicon PLSI9-2Y* | |
| Arsenic | 500 |
| Molybdenum | 100 |
| Silicon | 100 |
| *Mix #4: Catalog #MIXSTD4-100* | |
| Calcium | 1000 |
| Potassium | 400 |
| Aluminum | 200 |
| Sodium | 200 |
| Chromium | 20 |
| Nickel | 20 |
| *Mix #5: Catalog #MIXSTD5-100* | |
| Magnesium | 1000 |
| Antimony | 200 |
| Thallium | 200 |
| Boron | 100 |
| Silver | 50 |
| *Mix #6: CLSN2-2Y+CLTI9-2Y+PLLI-2Y+PLP9-3Y* | |
| Lithium | 1000 |
| Phosphorus | 10,000 |
| Tin | 1000 |
| Titanium | 1000 |
| *Mix #7: Catalog #CLAG2-2Y* | |
| Silver | 1000 |

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8.3.2 Working Calibration Standards Preparation

Prepared fresh weekly from the stock standard mixes listed and dilute to volume with diluent.

| Working Std. ID | Stock Standard | Vol. of Stock Std. | Final Volume in Diluent |
|---|---|---|---|
| Calibration Std. Mix 1 | MIXSTD1-100 | 2mL | 100mL |
| Calibration Std. Mix 2 | MIXSTD2-100<br>Strontium PLSR2-2Y | 1mL<br>0.1mL | 100mL |
| Calibration Std. Mix 3 | MIXSTD3-100<br>Silicon PLSI9-2Y | 2mL<br>0.8mL | 100mL |
| Calibration Std. Mix 4 | MIXSTD4-100 | 5mL | 100mL |
| Calibration Std. Mix 5 | MIXSTD5-100 | 2mL | 100mL |
| Calibration Std. Mix 6 | Lithium PLLI-2Y<br>Phosphorus PLP9-3Y<br>Tin CLSN2-2Y<br>Titanium CLTI9-2Y | 1mL<br>0.1mL<br>1mL<br>1mL | 100mL |
| Calibration Std. Mix 7 | Silver CLAG2-2Y | 0.2mL | 100mL in 10% HCl solution |

8.3.3 Stock ICV Standard Details

The following table shows the concentrations of the stock standards purchased from SPEX or Inorganic Ventures as three mixes:

| Analyte | Concentration (mg/L) | Concentration (mg/L) |
|---|---|---|
| | ***SPEX XFSMN-26-250A*** | ***Inorg. Vent. PA-STD1B*** |
| Arsenic | 100 | 200 |
| Barium | 100 | 200 |
| Beryllium | 100 | 200 |
| Cadmium | 100 | 200 |
| Cobalt | 100 | 200 |
| Chromium | 100 | 200 |
| Copper | 100 | 200 |
| Manganese | 100 | 200 |
| Nickel | 100 | 200 |
| Phosphorus | 100 | 200 |
| Lead | 100 | 200 |
| Selenium | 100 | 200 |
| Thallium | 100 | 200 |
| Lithium | 100 | 200 |
| Strontium | 100 | 200 |
| Vanadium | 100 | 200 |
| Zinc | 100 | 200 |

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| Analyte | Concentration (mg/L) | Concentration (mg/L) |
|---|---|---|
| | ***SPEX XFSMN-27-250A*** | ***Inorg. Vent. PA-STD2B*** |
| Silicon | 500 | 1000 |
| Boron | 100 | 200 |
| Molybdenum | 100 | 200 |
| Antimony | 100 | 200 |
| Tin | 100 | 200 |
| Titanium | 100 | 200 |
| Zirconium | 100 | 200 |
| Silver | 50 | 100 |
| | ***SPEX XFSMN-28-250A*** | ***Inorg. Vent. PA-STD3B*** |
| Aluminum | 1000 | 2000 |
| Calcium | 1000 | 2000 |
| Iron | 1000 | 2000 |
| Potassium | 1000 | 2000 |
| Magnesium | 1000 | 2000 |
| Sodium | 1000 | 2000 |

8.3.4 Working ICV Standard Preparation

Add 0.5mL of each Inorganic Ventures Second-Source Stock Standard (200-2000mg/L) mix to a 100mL volumetric flask and dilute to volume with diluent. If using the SPEX Second-Source Stock Standards (100-1000mg/L), use 1.0mL of each.

8.3.5 Working Spiking Standard Preparation

Add 25.0 mL of each Inorganic Ventures Second-Source Spiking Stock Standard (200-2000mg/L) mix to a 100 mL volumetric flask and dilute to volume with reagent water. If using SPEX Second-Source Stock Standards (100-1000mg/L), mix together 25mL of each standard with reagent water.

8.3.6 Stock Interference Check Standard A (ICSA) Details

| ***HPS Interference Check Standard A (ICSA), mg/L*** | |
|---|---|
| Aluminum | 5000 |
| Calcium | 5000 |
| Magnesium | 5000 |
| Iron | 2000 |

8.3.7 Working Interference Check Standard A (ICSA) Preparation

Dilute 10mL of the Stock ICSA Standard to 100mL with diluent.

8.3.8 Stock Interference Check Standard AB (ICSAB) Details

| ***Interference Check Standard AB (ICSAB), mg/L*** | |
|---|---|
| ***HPS ICL500-6*** | |
| Al, Ca, Mg | 5000 |
| Fe | 2000 |

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| *Interference Check Standard AB (ICSAB), mg/L* | |
|---|---|
| ***SPEX XFSMN-26-250A (Mix 1B)*** | |
| As, Ba, Be, B, Cd, Co, Cr, Cu, Mn, Ni, Pb, Se, Tl, V, Zn, Li, P | 100 |
| ***SPEX XFSMN-27-250A (Mix 2B)*** | |
| Mo, Sb, Sn, Ti, B | 100 |
| Ag | 50 |
| Si | 500 |

8.3.9 Working Interference Check Standard AB (ICSAB) Preparation

Dilute 10mL of the stock ICSA standard and 0.5mL each stocks Mix 1B and Mix 2B to 100mL with diluent.

8.3.10 Stock CRDL Standard Detail

When specified by client or program requirements, a low-level check standard, also known as a CRDL standard, must be analyzed prior to sample analysis and at the end of each analytical batch to bracket the client samples. The Stock CRDL standard is as follows:

| Element | Conc. (ug/mL) | Element | Conc. (ug/mL) |
|---|---|---|---|
| Aluminum | 20 | Manganese | 1 |
| Antimony | 1.2 | Molybdenum | 2 |
| Arsenic | 1 | Nickel | 1 |
| Barium | 1 | Phosphorus | 100 |
| Beryllium | 0.6 | Potassium | 100 |
| Boron | 10 | Selenium | 2 |
| Cadmium | 0.2 | Silicon | 40 |
| Calcium | 100 | Silver | 1 |
| Chromium | 1 | Sodium | 100 |
| Cobalt | 0.6 | Strontium | 2 |
| Copper | 1 | Thallium | 2 |
| Iron | 10 | Tin | 2 |
| Lead | 1 | Titanium | 2 |
| Lithium | 1.6 | Vanadium | 2 |
| Magnesium | 100 | Zinc | 2 |

8.3.11 Working CRDL Standard Preparation

Dilute 0.5mL of the stock CRDL Standard to 100mL with diluent. Final concentrations are shown below:

| Element | Final Conc. (ug/L) | Element | Final Conc. (ug/L) |
|---|---|---|---|
| Aluminum | 100 | Molybdenum | 10 |
| Antimony | 6 | Nickel | 5 |
| Arsenic | 5 | Phosphorus | 500 |

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| Element | Final Conc. (ug/L) | Element | Final Conc. (ug/L) |
|---|---|---|---|
| Barium | 5 | Potassium | 500 |
| Beryllium | 3 | Selenium | 10 |
| Boron | 50 | Silicon | 200 |
| Cadmium | 1 | Silver | 5 |
| Calcium | 500 | Sodium | 500 |
| Chromium | 5 | Strontium | 10 |
| Cobalt | 3 | Thallium | 10 |
| Copper | 5 | Tin | 10 |
| Iron | 50 | Titanium | 10 |
| Lead | 5 | Vanadium | 10 |
| Lithium | 8 | Zinc | 10 |
| Magnesium | 500 | Zirconium | 5 |
| Manganese | 5 | | |

8.3.12 Working Internal Standard Preparation

Dilute 5mL of yttrium stock standard (1000mg/L) to 1L with a reagent water solution that is 2% nitric acid for a final concentration of 5mg/L.

## 9.0 PROCEDURE

9.1 Initial Calibration (ICAL)

9.1.1 Calibrate the ICP each working day according to the instrument manufacturer's recommended procedures. Flush the system with the calibration blank solution prepared by acidifying reagent water to the same concentrations of the acids found in the standards and samples. The calibration curve must consist of a minimum of a calibration blank and a standard.

9.1.2 Initial Calibration Verification (ICV)

In addition to meeting the linearity requirement, any new calibration curve must be assessed for accuracy in the values generated. To assess the accuracy, a single standard from a secondary source must be analyzed and the results obtained must be compared to the known value of the standard. This step is referred to as Initial Calibration Verification. The ICV is analyzed immediately following an initial calibration curve. Refer to Section 11.1 for acceptance criteria and corrective action.

9.1.3 Initial Calibration Blank (ICB)

The ICB consists of diluent. An ICB must be analyzed immediately following the ICV. Refer to Section 11.1 for acceptance criteria and corrective action.

9.2 Continuing Calibration

9.2.1 Continuing Calibration Verification (CCV): A CCV must be analyzed after every 10 samples, and at the end of the analytical batch, to verify the system is still calibrated. Refer to Section 11.1 for acceptance criteria and corrective action.

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9.2.2 Continuing Calibration Blank (CCB): The CCB consists of diluent. A CCB must be analyzed after every 10 samples, and at the end of the analytical batch, following the CCV. Refer to Section 11.1 for acceptance criteria and corrective action.

9.2.3 Contract Required Detection Limit (CRDL) Standard: A CRDL standard must be analyzed with each analytical run, at a minimum, after calibration. If required by client or program, another CRDL standard must be analyzed after samples – not to exceed 8 hours between CRDL analyses. Refer to Section 11.1 for acceptance criteria and corrective action.

9.2.4 Interference Check Standard A (ICSA): An ICSA must be analyzed at the beginning of each analytical run. If required by client or program, an ICSA may also be required to close out the preparation batch. Refer to Section 11.1 for acceptance criteria and corrective action.

9.2.5 Interference Check Standard AB (ICSAB): If required by client or program, an ICSAB must be analyzed at the beginning of each analytical run and may also be required to close out the preparation batch. Refer to Section 11.1 for acceptance criteria and corrective action.

9.3 Analytical Determination

9.3.1 Prior to analysis of samples, there must be data available documenting initial demonstration of performance. The required data document the selection criteria of background correction points; analytical dynamic ranges; the applicable equations, and the upper limits of those ranges; the method and instrument detection limits; and the determination and verification of inter-element correction equations or other routines for correcting spectral interferences. This data must be generated using the same instrument, operating conditions and calibration routine to be used for sample analysis.

9.3.2 Configure the ICP per manufacturer's instructions and allow it to become thermally stable.

9.3.3 Pour approximately 10mL portions of each standard, method blank, LCS, sample and MS/MSD into autosampler tubes for analysis.

9.3.4 Prepare a Post Digestion Spike (PDS) by adding 0.2mL of the Working Second-Source Spiking Standard to 10mL of sample.

9.3.5 Prepare a Serial Dilution (SD) of a sample by diluting 2mL of sample to 10mL with diluent.

9.3.6 Establish initial calibration as described in Section 9.1.

9.3.7 Once initial calibration is established, analyze each sample, method blank, LCS and MS/MSD. An example sequence may be as follows:

Initial calibration blank
Mix 1
Mix 2
Mix 3
Mix 4
Mix 5

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Mix 6
Mix 7
ICV
ICB
CRDLA
ICSA
ICSAB (if required)
Method blank
LCS
Client samples
MS/MSD
PDS/SD
CCV
CCB
Client samples
CCV
CCB
Client samples
CCV
CCB
CRDLA (if required)
ICSA (if required)
ICSAB (if required)

9.3.8 The instrument performs two replicate readings for each analysis and the average of the two readings is used to derive the concentration. For samples, the difference between the two readings must be ≤20% RSD for values that are >4x the reporting limit. If the RSD is >20% for values that are >4x the reporting limit, the sample must be reanalyzed.

9.3.9 Samples with analyte concentrations ≥90% of the linear range must be diluted and reanalyzed or the over range results must be qualified as estimated.

9.3.10 **For OH VAP samples only:** results subject to potential high bias or potential low bias, indicated by internal standard response, must include a qualifier or narrative that indicates the potential bias to the data user.

9.3.11 **For TCLP extract only:** perform the method of standard additions if (1) analyte concentration is between 80-100% of the regulatory limit (refer to Table 3) **AND** (2) MS recovery is <50%.

Refer to *MSA Calculation – TCLP ICP Metals F-IN-I-525* spreadsheet or current replacement for detailed directions.

9.3.11.1 Prepare four aliquots spiked at 0%, 50%, 100%, and 150% of the measured sample concentration. If necessary, dilute the spiked aliquots to obtain results within the linear range for the analyte(s) of concern. Analyze the spiked aliquots.

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9.3.11.2 Use linear regression to generate a calibration curve using results from the spiked aliquots. Back-calculate the unspiked sample result from this calibration curve. This back-calculated result is reported as the sample result. Qualify the result (MA) to indicate that it was derived by the method of standard additions.

***NOTE:*** *If the analyte concentration in the TCLP extract is above the regulatory limit (refer to Table 3), the method of standard additions is not required.*

## 10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Calculations

10.1.1 Calculate the final concentration in **aqueous** samples as follows:

$$\text{Aqueous Sample (ug/L)} = \frac{(X_s)(V_f)(D)}{(V_i)}$$

Where: $X_s$ = Element concentration from instrument, ug/L
$V_f$ = Final volume of digestate, L
D = Dilution factor (final volume / initial volume)
$V_i$ = Initial sample volume of aqueous sample digested, L

10.1.2 Calculate the final concentration in **soli**d samples as follows:

$$\text{Solid Sample (ug/kg)} = \frac{(X_s)(V_f)(D)}{(W_i)}$$

Where: $X_s$ = Element concentration from instrument, ug/L
$V_f$ = Final volume of digestate, L
D = Dilution factor (final volume / initial volume)
$W_i$ = Initial weight of solid sample digested, kg

$$\text{Moisture corrected concentration} = \frac{\text{(Final concentration as received)}}{\text{(100 - \%Moisture)}} \times 100$$

10.1.3 Calculate the final concentration in **wip**e samples as follows:

$$\text{Wipe Sample (total ug)} = (X_s)(0.050\ \text{L/wipe})(D)$$

Where: $X_s$ = Element concentration from instrument, ug/L
D = Dilution factor (final volume / initial volume)

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10.1.4 LCS calculation:

$$R = (C / S) \times 100$$

Where: R = Percent Recovery
C = Observed LCS concentration
S = True LCS concentration

10.1.5 MS calculation:

$$R = \frac{(C_s - C)}{S} \times 100$$

Where: R = Percent Recovery
$C_s$ = Observed MS concentration
C = Sample concentration
S = True spike concentration

10.1.6 RPD calculation:

$$RPD = \frac{|D_1 - D_2|}{[(D_1 + D_2)/2]} \times 100$$

Where: RPD = Relative Percent Difference
$D_1$ = First Sample Result
$D_2$ = Second Sample Result

10.1.7 Hardness calculation: automated within LIMS using Ca and Mg results according to the equation:

Hardness, mg/L equivalent $CaCO_3$/L = 2.497 [Ca, mg/L] + 4.118 [Mg, mg/L]

10.1.8 Silica ($SiO_2$) calculation: automated within LIMS using Si results according to the equation:

SiO2 (mg/L) = 2.1393 [Si, mg/L]

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## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

11.1 Instrument Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration** | All target analytes | Daily and as needed | Acceptable ICV | Analyze a new initial calibration curve. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed initial calibration must be reanalyzed. |
| **Initial Calibration Verification Standard (ICV)** | Second Source Standard | Immediately following initial calibration of the instrument | 90-110% Recovery<br><br>RSD <5% for replicate readings | Inject another aliquot of the ICV. If the second ICV also exceeds the acceptance range, a new initial calibration must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed ICV must be reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If the ICV is outside the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |
| **Initial Calibration Blank (ICB)** | Diluent | Immediately following initial calibration of the instrument | Target analyte must be <RL.<br><br>**If required by client or program:** target analyte must be <1/2 RL. | Reanalyze blank. If the second ICB is >RL, a new initial calibration must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed ICB must be reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If a contaminant is present only in the blank and not the samples, no action is required.<br>3) Samples associated with a failed ICB must be re-analyzed unless the concentration of the target analyte is greater than 10 times the absolute value of the ICB result.<br>**If required by client or program:** If the ICB result exceeds ½ the RL, the ICB is considered to be unacceptable. Only samples determined to be <RL are reportable. **BP samples:** If the absolute value of a negative concentration exceeds twice the established MDL, the ICB is considered to be unacceptable. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Continuing Calibration Standard (CCV)** | All target analytes | Every 10 samples and at end of sequence | 90-110% Recovery<br>RSD <5% for replicate readings | Check instrument operating conditions, and if necessary, restore them to the original settings. Analyze another aliquot of the CCV. If the second CCV still exceeds the acceptance criteria, then a new initial calibration must be analyzed. Samples must be bracketed by acceptable ICV/CCVs in order to be reportable. Samples associated with a failed CCV must be reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If the CCV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |
| **Continuing Calibration Blank (CCB)** ***(cont. next page)*** | Diluent | Every 10 samples and at end of sequence | Target analyte must be <RL.<br><br>**If required by client or program:** target analyte must be <1/2 RL. | Reanalyze blank. If the second CCB is also >RL, a new initial calibration must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed CCB must be reanalyzed. |
| **Continuing Calibration Blank (CCB)** ***(cont. from previous page)*** | | | | *Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If a contaminant is present only in the blank and not the samples, no action is required.<br>3) Samples associated with a failed CCB must be re-analyzed unless the concentration of the target analyte is greater than 10 times the absolute value of the CCB result**.**<br>**If required by client or program:** If the CCB result exceeds ½ the RL, the CCB is considered to be unacceptable. Only samples determined to be <RL are reportable. **BP samples:** If the absolute value of a negative concentration exceeds twice the established MDL, the CCB is considered to be unacceptable. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Contract Required Detection Limit (CRDL)** | Applicable target analytes | Must be analyzed after calibration, at minimum.<br>**If required by client or program**, CRDL must be analyzed after samples – not to exceed 8 hours between CRDL analyses. | 50-150% Recovery<br><br>Other acceptance criteria may apply based on client or program. | Reanalyze CRDL. If second CRDL fails a new initial calibration must be analyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If the CRDL is outside of the upper control limit, indicating high bias, associated samples determined to be <RL are reportable without qualification. |
| **Interference Check Standard A (ICSA)** | Applicable target analytes | Must be analyzed after calibration, at minimum.<br>**If required by client or program:** ICSA must be analyzed after samples – not to exceed 8 hours between ICSA analyses. | 80-120% Recovery for elements in the mix<br><br>Non-ICSA elements within +/-2x the RL | If the ICSA fails the acceptance criteria, another ICSA may be analyzed. If the second ICSA fails, a new calibration curve must be analyzed. Instrument maintenance and/or preparation of new standards must also be considered. Samples associated with a failed ICSA must be reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If the ICSA is >120% for any element in the mix or if any non-ICSA element is >2x the reporting limit, indicating high bias, associated samples determined to be <RL are reportable. |
| **Interference Check Standard AB (ICSAB)**<br><br>**If required by client or program** | Applicable target analytes | **If required by client or program:** At the beginning and end of the sequence, at minimum | 80-120% Recovery for elements in the mix | If an ICSAB is required by client or program and the ICSAB fails the acceptance criteria, another ICSAB may be analyzed. If the second ICSAB fails, then a new calibration curve must be analyzed. Instrument maintenance and/or preparation of new standards must also be considered. Samples associated with a failed ICSAB must be reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If the ICSAB is >120% for any element in the mix, indicating high bias, associated samples determined to be <RL are reportable. |

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11.2 Batch Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Method Blank (MB)** | Reagent water or boiling chips | One per preparation batch of up to 20 samples, per matrix. | Target analyte must be <RL.<br><br>**If required by client or program:** target analyte must be <1/2 RL. | Reanalyze blank. Re-digest and reanalyze if target compound is still >RL (or ½ RL) in method blank and associated samples.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, the reported method blank and samples must be qualified.<br>2) If a contaminant is present only in the method blank and not the samples, no action is required.<br>3) If sample concentration is >10x blank level, sample and method blank may be reported, but sample must be qualified (Not applicable to OH VAP projects). |
| **Laboratory Control Standard (LCS)** | Applicable target analytes | One per preparation batch of up to 20 samples, per matrix. | 80-120% Recovery | Re-analyze LCS. If LCS is still outside acceptance limits, re-prepare and reanalyze all associated samples.<br>*Exceptions:*<br>1) If no additional sample remains for re-analysis or if re-analysis cannot take place within holding time, reported data must be qualified.<br>2) If LCS recovery is >QC limits and sample results are non-detect, the sample data may be reported without qualifiers. The LCS data must be qualified.<br>3) If the batch's associated MS or MSD recovery falls within LCS acceptance limits, associated samples may be reported. The LCS data must be qualified (Not applicable to OH VAP or other specified client samples). |
| **Matrix Spike/ Matrix Spike Duplicate (MS/MSD)** | Applicable target analytes | One MS/MSD set per preparation batch of up to 20 samples, per matrix. | 75-125% Recovery<br>≤20% RPD | No corrective action necessary. If LCS recovery is in range, the system is considered in-control and the out-of-control MS/MSD must be qualified appropriately.<br>If no sample received for MS/MSD (wipe matrix), add qualifier. |
| **Internal Standard** | Yttrium | Automatically added to each sample, blank, and standard as part of the analysis. | 60-140% Recovery | Re-analyze sample at a dilution. Qualify sample results if dilution does not resolve failed recovery. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Post-Digestion Spike (PDS) and Serial Dilution (SD) (optional, or if required by client or program)** | Sample | One PDS (at 10X-100X IDL) and one SD per batch. | **PDS:** 75-125% Recovery<br><br>**SD:** +/-10% difference between 1X and 5X sample results | No corrective action required. Interference should be suspected if PDS and/or SD do not meet acceptance criteria. Results may be qualified. |

11.3 Method Validation

Refer to the SOP for Method Validation and Instrument Verification for the procedures used for initial method validation. Method Detection Limits (MDL) must be determined per the procedure in 40CFR Part 136, Appendix B.

11.4 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

11.5 Linear Dynamic Range Study: A linear dynamic range study must be conducted for each element by analyzing increasing concentrations of at least three, preferably five different concentration standards across the range. One of these should be near the upper limit of the range. The upper range limit should be an observed signal no more than 10% below the level extrapolated from lower standards. Samples determined to be $\geq$90% of the upper range limit must be diluted and reanalyzed. New dynamic ranges should be determined whenever there is a significant change in instrument response. For those analytes that periodically approach the upper limit, the range should be checked every six months. Refer to Section 7.2.5.4 of Method 6010B for more information.

11.6 Inter-element Correction Factors must be verified and updated every 6 months or when an instrumentation change occurs. Refer to Section 3.1 of Method 6010B for more information.

## 12.0 Data Review And Corrective Action

12.1 Data Review

The analyst must perform primary review of data and calculated results for accuracy. Secondary review of the data and calculated results must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

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12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 Pollution Prevention And Waste Management

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

## 14.0 Modifications

14.1 Instrument conditions may vary from those stated in the method.

14.2 Mixed standard solutions are purchased as certified standards.

14.3 Calibration blanks are evaluated to the reporting limit and not to three times the IDL.

## 15.0 Responsibilities

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

## 16.0 Attachments

16.1 Table 1: Target Elements and Default Reporting Limits

16.2 Table 2: Target Element Wavelengths

16.3 Table 3: TCLP Regulatory Levels

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## 17.0 REFERENCES

17.1 "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA SW-846, latest revision, Methods 6010B, 1311.

17.2 Pace Analytical Quality Manual; latest revision.

17.3 NELAC/TNI Standards; 2003, 2009, and 2016.

## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 1.1, 6.0 | Added Wipe matrix. |
| 9.3.11 | Added standard additions process for TCLP samples. |
| 10.1 | Separated aqueous and solid calculation sections. Added wipe calculation. |
| 16.3 | Added Table 3. |
| 17.1 | Added reference to SW846 1311. |
| Table 1 | Added wipe RLs. |
| Table 3 | Added. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0025 | Metals by SW846 6010B | 02 |

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## Table 1

## Target Elements and Default Reporting Limits (subject to change)

| Element | Aqueous (µg/L) | Solid (mg/kg) | Wipe (ug) |
|---|---|---|---|
| Aluminum – Al | 200 | 50 | 50 |
| Antimony – Sb | 6 | 1 | 2 |
| Arsenic – As | 10 | 1 | 2 |
| Barium – Ba | 10 | 1 | 0.5 |
| Beryllium – Be | 4 | 0.5 | 0.4 |
| Boron – B | 100 | 5 | 10 |
| Cadmium – Cd | 2 | 0.5 | 0.5 |
| Calcium – Ca | 1000 | 50 | 20 |
| Chromium – Cr | 10 | 1 | 0.5 |
| Cobalt – Co | 10 | 1 | 0.5 |
| Copper – Cu | 10 | 1 | 1 |
| Iron – Fe | 100 | 50 | 10 |
| Lead – Pb | 10 | 1 | 1 |
| Lithium – Li | 20 | 5 | N/A |
| Magnesium – Mg | 1000 | 50 | 20 |
| Manganese – Mn | 10 | 1 | 0.5 |
| Molybdenum – Mo | 10 | 1 | 2 |
| Nickel – Ni | 10 | 1 | 1 |
| Phosphorus – P | N/A | 50 | N/A |
| Potassium – K | 1000 | 50 | 100 |
| Selenium – Se | 10 | 1 | 2 |
| Silicon – Si | 200 | N/A | N/A |
| Silver – Ag | 10 | 0.5 | 1 |
| Sodium – Na | 1000 | 50 | 100 |
| Strontium – Sr | 10 | 1 | 0.5 |
| Thallium – Tl | 10 | 1 | 4 |
| Tin – Sn | 10 | 5 | 5 |
| Titanium – Ti | 10 | 1 | 0.5 |
| Vanadium – V | 10 | 1 | 0.5 |
| Zinc – Zn | 20 | 1 | 4 |
| Hardness, Calcium | 10,000 | N/A | N/A |
| Hardness, Magnesium | 10,000 | N/A | N/A |
| Hardness, total | 10,000 | N/A | N/A |
| Silica – SiO2 | 450 | N/A | N/A |

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## Table 2

## Target Element Wavelengths (subject to change)

| Element | Wavelength (nm) |
|---|---|
| Aluminum – Al | 308.215 |
| Antimony – Sb | 206.833 |
| Arsenic – As | 189.042 |
| Barium – Ba | 455.403 |
| Beryllium – Be | 313.042 |
| Boron – B | 249.678 |
| Cadmium – Cd | 228.802 |
| Calcium – Ca | 315.887 |
| Chromium – Cr | 267.716 |
| Cobalt – Co | 228.616 |
| Copper – Cu | 324.754 |
| Iron – Fe | 271.441 |
| Lead – Pb | 220.353 |
| Lithium – Li | 670.784 |
| Magnesium – Mg | 279.079 |
| Manganese – Mn | 257.610 |
| Molybdenum – Mo | 202.030 |
| Nickel – Ni | 231.604 |
| Phosphorus | 177.495 |
| Potassium – K | 766.490 |
| Selenium – Se | 196.090 |
| Silicon – Si | 288.158 |
| Silver – Ag | 328.068 |
| Sodium – Na | 589.592 |
| Strontium – Sr | 407.771 |
| Thallium – Tl | 190.856 |
| Tin – Sn | 189.989 |
| Titanium – Ti | 337.280 |
| Vanadium – V | 292.464 |
| Zinc – Zn | 206.200 |

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## Table 3

## TCLP Regulatory Levels

| Element | TCLP Regulatory Level (mg/L) | Concentration range (mg/L) requiring Method of Standard Additions if MS <50%R |
|---|---|---|
| Arsenic | 5.0 | 4.0 – 5.0 |
| Barium | 100 | 80 – 100 |
| Cadmium | 1.0 | 0.80 – 1.0 |
| Chromium | 5.0 | 4.0 – 5.0 |
| Lead | 5.0 | 4.0 – 5.0 |
| Selenium | 1.0 | 0.80 – 1.0 |
| Silver | 5.0 | 4.0 – 5.0 |

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# Test Method Standard Operating Procedure (SOP): Pace® Analytical Services

| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0044 v05_Mercury by SW-846 7470A, 7471A** |
| | **Effective Date: 04/22/2024** |

**Management Approval:**
Reghan McCoskey Approved on 4/22/2024 10:33:53 AM
Sarah Potts Approved on 4/19/2024 10:24:56 AM
Steven Sayer Approved on 4/18/2024 1:05:47 PM
Anne Troyer Approved on 4/22/2024 10:48:42 AM

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## 1.0 SCOPE AND APPLICATION

1.1 The purpose of this Standard Operating Procedure (SOP) is to provide a laboratory specific procedure for determining total mercury concentration while meeting the requirements specified in EPA method 7470A for aqueous samples and method 7471A for solid samples.

1.2 This SOP is applicable for the measurement of mercury in groundwater, surface waters, domestic and industrial wastes, TCLP extracts, soil, sediment, bottom deposits, and sludge-type materials.

1.3 The default reporting limits for mercury are 0.002 mg/L for aqueous samples and 0.20 mg/kg for solid samples. Refer to the LIMS for method detection limits.

1.4 Reporting limits, control limits, volumes/weights used, standard concentrations, vendors, instrumentation, equipment, and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

Prior to analysis, all samples are digested by heating with appropriate acids and oxidizing agents to dissolve and oxidize mercury contents.

This cold-vapor method is based on the absorption of radiation at 253.7nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) is measured as a function of mercury concentration.

## 3.0 INTERFERENCES

3.1 High concentrations of sulfide may interfere in some water or solid samples. Potassium permanganate is added during digestion to eliminate sulfide interference. Concentrations as high as 20mg/L have been demonstrated to cause no interference in spiked samples.

3.2 High concentrations of copper have been reported to interfere with mercury determinations. Concentrations as high as 10mg/L in water or 10mg/kg in soil have been demonstrated to cause no interference in spiked samples.

3.3 High concentrations of chloride present in samples may require additional potassium permanganate or dilution. The free chlorine produced during digestion should be removed with excess hydroxylamine hydrochloride solution.

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## 4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Aqueous** | 250mL in plastic container | -$HNO_3$ to pH<2<br>-Samples received at pH >2 must be preserved to pH <2 with $HNO_3$ and equilibrate in the original container for 24 hours before digestion. Record date/time of acidification in Sample Preservation logbook. Additional acid added may not exceed 1% of the total sample volume. Data must be qualified if sample cannot be properly preserved. | Ambient | Must be analyzed within 28 days of collection. |

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| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Aqueous-Dissolved Field Filtered** | 250mL in plastic container | -Field filter using 0.45um filter within 15 minutes of collection, then add $HNO_3$ to pH<2.<br>-Samples received at pH >2 must be preserved to pH <2 with $HNO_3$ and equilibrate in the original container for 24 hours before digestion. Record date/time of acidification in Sample Preservation logbook. Additional acid added may not exceed 1% of the total sample volume. Data must be qualified if sample cannot be properly preserved. | Ambient | Must be analyzed within 28 days of collection. |
| **Aqueous-Dissolved Lab Filtered** | 250mL in plastic container | -Unpreserved samples are lab filtered using 0.45um filter then preserved to pH<2 with $HNO_3$ and allowed to equilibrate for 24 hours before being digested.<br>-Date/time of filtration and preservation is recorded in the metals digestion prep log. Additional acid added may not exceed 1% of the total sample volume. Data must be qualified if sample cannot be properly preserved. | Ambient | Must be analyzed within 28 days of collection. |
| **Solid** | 100g in 4oz glass container | None | Cool to ≤6°C | Must be analyzed within 28 days of collection. |

## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| Automated Mercury Analyzer | CETAC/Teledyne M-7500, M-6100, M-7600 or equivalent; to include an atomic absorption spectrophotometer, mercury lamp, absorption cell, air pump, flow meter, drying tube, autosampler and data system. |
| Hot Block | Environmental Express 56-well or equivalent; adjustable and capable of maintaining a temperature of 90°C to 95°C. |
| Balance | Capable of reading to 0.01g |
| Vacuum pump | Gast diaphragm compressor/vacuum pump, or equivalent |

### 7.2 Supplies

| Supplies | Description |
|---|---|
| Volumetric flasks | Class A, 1L |
| Graduated cylinder | Class A, 25mL |
| Mechanical pipets | Eppendorf or equivalent, various sizes |
| Digestion cups | Environmental Express 50mL and 100 mL capacity, volumetrically certified, or equivalent |

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| Supplies | Description |
|---|---|
| Autosampler tubes | Moldpro 17x100 mm, or equivalent |
| Plunger filters | Environmental Express or equivalent, for use with digestion cups |
| 0.45um Flipmate filters | Environmental Express or equivalent, for use with vacuum pump and 100mL digestion cups |

## 8.0 REAGENTS AND STANDARDS

### 8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Reagent water | ASTM Type II water or equivalent |
| Sulfuric acid | Concentrated, trace metal grade or equivalent |
| Hydrochloric acid | Concentrated, trace metal grade or equivalent |
| Hydrochloric acid (3%) | Dilute 30mL of concentrated HCl to 1L with reagent water. Used for dilution preparation. |
| Nitric acid | Concentrated, trace metal grade or equivalent |
| Aqua Regia | Carefully add one volume of nitric acid to three volumes of hydrochloric acid. Must be prepared in a hood and must be prepared immediately before use each day. |
| Stannous Chloride | Powder, reagent grade or equivalent |
| Stannous Chloride solution | Add 100g stannous chloride and 70 mL conc. HCl in reagent water and dilute to 1L. This solution is good for up to 3 days. Refrigerate when not in use, per manufacturer's recommendation. |
| Sodium Chloride | Granular, reagent grade or equivalent |
| Hydroxylamine hydrochloride | Granular, reagent grade or equivalent |
| Sodium Chloride/ Hydroxylamine Hydrochloride solution | Dissolve 120g sodium chloride and 120g hydroxylamine hydrochloride in reagent water and dilute to 1L. This solution is good for 6 months from preparation (hydroxylamine sulfate may be substituted for hydroxylamine hydrochloride). |
| Potassium permanganate solution (5%) | Commercially purchased Mercury-free, 5% solution (w/v) |
| Potassium persulfate | Granular, reagent grade or equivalent |
| Potassium persulfate solution | Dissolve 50g potassium persulfate in reagent water and dilute to 1L.<br>Expires 6 months from the date of preparation. May be stored at room temperature. |
| Rinse/Probe Wash Solution | Place approximately 500mL reagent water in a 1L flask. Add 25mL HNO3 and 10mL HCl, and dilute to 1L with reagent water. |
| Plastic beads | Environmental Express or equivalent, to be used as a simulated soil matrix. |

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8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| Stock Mercury Calibration standard | Environmental Express; cat # HP100033-1; 1000mg/L or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Intermediate #1 Mercury Calibration standard | Refer to Section 8.3.1 | Solution expires 6 months from date of preparation. | Same as for stock standard. |
| Intermediate #2 Mercury Calibration standard | Refer to Section 8.3.2 | Must be prepared fresh daily. | Not applicable |
| Working Mercury Calibration standards | Refer to Section 8.3.3 | One-time use standards. | Not applicable |
| Stock Mercury ICV/Spiking standard | SPEX; catalog # PLHG4-2Y; 1000mg/L or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Intermediate #1 Mercury ICV/Spiking standard | Refer to Section 8.3.4 | Solution expires 6 months from date of preparation. | Same as for stock standard. |
| Intermediate #2 Mercury ICV/Spiking standard | Refer to Section 8.3.5 | Must be prepared fresh daily. | Not applicable |
| Working Mercury ICV standard | Refer to Section 8.3.6 | One-time use standard. | Not applicable |

8.3 Standard Preparation Procedures

Refer to the standard preparation logbook or database for specific instructions regarding preparation of standards for Mercury analysis.

8.3.1 Intermediate #1 Mercury Calibration Standard Preparation

Dilute 1mL of the Stock Mercury Calibration Standard (1000mg/L) to 100mL with 2% $HNO_3$ for a final concentration of 10mg/L.

8.3.2 Intermediate #2 Mercury Calibration Standard Preparation

Dilute 1mL of the well-homogenized Intermediate #1 Mercury Calibration Standard (10mg/L) to 100mL with 2% $HNO_3$ for a final concentration of 100ug/L.

8.3.3 Working Mercury Calibration Standards Preparation

Working calibration standards are prepared by diluting the Intermediate #2 Mercury Calibration Standard (100ug/L) with reagent water. Examples of possible calibration standards are as follows but may vary:

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Aqueous:

| Standard ID | Amount of Intermediate #2 | Final Volume in reagent water | Final Concentration |
|---|---|---|---|
| CAL0 (ICB/CCB) | 0 mL | 30mL | 0.0ug/L |
| CAL1 (CRDL) | 0.06mL | 30mL | 0.2ug/L |
| CAL2 | 0.3mL | 30mL | 1.0ug/L |
| CAL3 | 0.6mL | 30mL | 2.0ug/L |
| CAL4 (CCV) | 1.5mL | 30mL | 5.0ug/L |
| CAL5 | 2.25mL | 30mL | 7.5ug/L |
| CAL6 | 3.0mL | 30mL | 10.0ug/L |

Solid:

| Standard ID | Amount of Intermediate #2 | Final Volume in reagent water | Final Concentration |
|---|---|---|---|
| CAL0 (ICB/CCB) | 0 mL | 50mL | 0.0ug/L |
| CAL1 (CRDL) | 0.1mL | 50mL | 0.2ug/L |
| CAL2 | 0.5mL | 50mL | 1.0ug/L |
| CAL3 | 1.0mL | 50mL | 2.0ug/L |
| CAL4 (CCV) | 2.5mL | 50mL | 5.0ug/L |
| CAL5 | 3.75mL | 50mL | 7.5ug/L |
| CAL6 | 5.0mL | 50mL | 10.0ug/L |

8.3.4 Intermediate #1 Mercury ICV/Spiking Standard Preparation

Dilute 1mL of the Stock Mercury ICV/Spiking Standard (1000mg/L) to 100mL with 2% $HNO_3$ for a final concentration of 10mg/L.

8.3.5 Intermediate #2 Mercury ICV/Spiking Standard Preparation

Dilute 1mL of the well-homogenized Intermediate #1 Mercury ICV/Spiking Standard (10mg/L) to 100mL with 2% $HNO_3$ for a final concentration of 100ug/L. This standard is also used to prepare the LCS and MS/MSD.

8.3.6 Working Mercury ICV Standard Preparation

Aqueous: Dilute 1.5mL of the Intermediate #2 Mercury ICV Standard (100ug/L) to 30mL with reagent water for a standard concentration of 5.0ug/L.

Solid: Dilute 2.5mL of the Intermediate #2 Mercury ICV Standard (100ug/L) to 50mL with reagent water for a standard concentration of 5.0ug/L.

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## 9.0 PROCEDURE

9.1 Aqueous Sample Preparation

9.1.1 Transfer a 30mL aliquot of well-mixed sample to a 50mL graduated digestion cup.

9.1.2 Prepare a Method Blank by adding 30mL of reagent water to a digestion cup.

9.1.3 Prepare an LCS by adding 1.5mL of the Intermediate #2 Mercury ICV/Spiking Standard (100ug/L) to a digestion cup and diluting to 30mL with reagent water for a spike concentration of 5.0ug/L.

9.1.4 Prepare an MS/MSD set by transferring 30mL aliquots of well-mixed sample to separate digestion cups and adding 1.5mL of the Intermediate #2 Mercury ICV/Spiking Standard (100ug/L) for a spike concentration of 5.0ug/L.

9.1.5 Add 0.75mL concentrated nitric acid to each digestion cup, then add 1.5mL concentrated sulfuric acid acid to each digestion cup. Mix after each addition.

9.1.6 Add 5mL potassium permanganate solution to each digestion cup. Swirl to mix. Ensure that equal amounts of permanganate solution are added to Method Blank and LCS.

9.1.7 Add 2.5mL potassium persulfate solution to each digestion cup.

9.1.8 Cap loosely and heat samples for 2 hours in the Hot Block at 95°C. If the purple color does not persist after 15 minutes of being heated, start over at Section 9.1.1 using a diluted aliquot of sample.

9.1.9 If the purple color does not persist for the entire 2-hour digestion period, qualify the reported result. **For WI DNR compliance samples:** If the purple color does not persist for the entire 2-hour digestion period, start over at Section 9.1.1 using a diluted aliquot of the sample.

9.1.10 Cool samples and add 1.8mL of the sodium chloride/hydroxylamine hydrochloride solution to each sample to reduce the excess potassium permanganate. **CAUTION:** perform this addition in a fume hood, as chlorine gas could be produced.

9.1.11 Adjust the digestate volumes to 30mL with reagent water and mix. Proceed to Section 9.4. If needed, a plunger filter may be used to filter the digestate. The Method Blank and LCS must also be filtered if any client samples are filtered in the batch. Alternatively, reduce the effect of particulates by centrifuging samples for approximately 5 minutes at 3500rpm.

9.1.12 All sample volumes, reagent volumes, spiking standard volumes, standard/reagent ID numbers, hot block ID numbers, hot block temperature, thermometer ID number, and preparation date and time must be recorded in the electronic prep log.

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9.2 Solid Sample Preparation

9.2.1 Weigh 0.3g of sample into a labeled 50mL digestion cup. To ensure the sample is representative of the entire container, the analyst should weigh out three 0.1g aliquots from different parts of the same container.

9.2.2 Prepare a Method Blank by placing several boiling chips into a labeled digestion cup.

9.2.3 Prepare an LCS by placing several boiling chips into a labeled digestion cup and adding 1.5mL of the Intermediate #2 Mercury ICV/Spiking Standard (100ug/L) for a final concentration of 0.5mg/kg.

9.2.4 Prepare an MS and MSD by weighing 0.3g portions of a sample into separate labeled digestion cups and adding 1.5mL of Intermediate #2 Mercury ICV/Spiking Standard (100ug/L) for a spike concentration of 0.5mg/kg.

9.2.5 Add 5mL of reagent water to each digestion cup.

9.2.6 Add 2.5mL of aqua regia to each digestion cup.

9.2.7 Heat samples for 2 minutes in the Hot Block at 95°C.

9.2.8 Cool samples and add 25mL reagent water then add 7.5mL of 5% potassium permanganate solution. Swirl to mix and let sample stand at least 15 minutes. If the purple color does not persist after 15 minutes, then start over at Section 9.2.1 using a reduced portion of sample.

9.2.9 Return the samples to the Hot Block and heat for 30 minutes at 95°C.

9.2.10 Cool samples again and add 3mL of the sodium chloride/hydroxylamine hydrochloride solution to each sample to reduce the excess potassium permanganate. **CAUTION**: perform this addition in a fume hood, as chlorine gas could be produced.

9.2.11 Adjust the digestate volumes to 50mL with reagent water and mix. Proceed to Section 9.4. If needed, a plunger filter may be used to filter the digestate. The Method Blank and LCS must also be filtered if any client samples are filtered in the batch. Alternatively, reduce the effect of particulates by centrifuging samples for approximately 5 minutes at 3500rpm.

9.2.12 All sample volumes, reagent volumes, spiking standard volumes, standard/reagent ID numbers, hot block ID numbers, hot block temperature, thermometer ID number, and preparation date and time must be recorded in the electronic prep log.

9.3 Calibration Standard Preparation:

9.3.1 Prepare calibration standards in 50mL digestion cups per the instructions in Section 8.3.3.

9.3.2 Follow steps in Section 9.1 to prepare calibration standards for aqueous matrix.

9.3.3 Follow steps in Section 9.2 to prepare calibration standards for solid matrix.

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9.3.4 All sample volumes, reagent volumes, spiking standard volumes, standard/reagent ID numbers, hot block ID numbers, hot block temperature, thermometer ID number, and preparation date and time must be recorded in the electronic prep log.

9.4 Equipment Preparation

Configure the instrument according to manufacturer's recommendations. Allow the colorimeter and recorder to warm up. Run a baseline with all reagents, using reagent water to flush the tubing. Whenever new tubing is used, allow ample time to flush the tubing.

9.5 Initial Calibration (ICAL)

9.5.1 Analyze a blank and a minimum of 5 calibration standards. The lowest calibration standard must be at or below the reporting limit. A new initial calibration curve with freshly prepared standard is analyzed on each working day.

9.5.2 Initial Calibration Evaluation

9.5.2.1 Using the instrumentation software, prepare a standard curve by plotting absorbance versus mercury concentration of each calibration standard. The analyst may employ a regression equation that does not pass through the origin. The regression calculation will generate a correlation coefficient (r) that is the measure of the "goodness of fit" of the regression line to the data. Refer to Section 11.1 for acceptance criteria and corrective actions.

9.5.2.2 Individual analyte calibration levels may be removed from the lowest and/or highest levels of the calibration curve provided the number of remaining calibration points meet the minimum requirements and the quantitation range is adjusted as necessary.

9.5.2.3 Removal of interior calibration levels is not permitted unless a standard introduction error or preparation error can be documented.

9.5.2.4 A calibration level may be replaced provided that the replacement calibration standard is analyzed within the same calibration event.

9.5.2.5 Evaluate the Relative Error of the calibration by one of the following options:

**Option 1: Relative Error (%RE)**

$$\%\ Relative\ Error = \frac{x_i^{'} - x_i}{x_i} x\ 100$$

Where: $x_i$ = True value of the calibration standard
$x'_i$ = Measured concentration of the calibration standard

Calculate %RE for two (2) initial calibration levels, the standard at the mid-point and the standard at the lowest point.

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**Option 2: Relative Standard Error (%RSE)**

$$\%\text{RSE} = 100\,x\sqrt{\sum_{i=1}^{n}\frac{\left[\frac{x_i' - x_i}{x_i}\right]^2}{(n-p)}}$$

Where: $x_i$ = True value of the calibration level i
$x'_i$ = Measured concentration of calibration level i
p = Number of terms in the fitting equation (avg.=1, linear=2)
n = Number of calibration points

Refer to Section 11.1 for acceptance criteria and corrective actions.

9.5.2.6 Initial Performance and Recovery (IPR) at the mid-point of the calibration curve (5 ug/L) and CRDL at the lowest calibration point (0.2 ug/L) will be analyzed immediately after calibration to verify %RE in instances where software limitations do not allow for %RSD calculation.

9.5.3 Initial Calibration Verification (ICV)

In addition to meeting the linearity requirement, any new calibration curve must be assessed for accuracy in the values generated. To assess the accuracy, a single standard from a secondary source must be analyzed and the results obtained must be compared to the known value of the standard. This step is referred to as Initial Calibration Verification. The ICV is prepared per Sections 8.3.6 and 9.1 analyzed immediately following an initial calibration curve. Refer to Section 11.1 for acceptance criteria and corrective actions.

9.5.4 Initial Calibration Blank (ICB)

The ICB consists of reagent water that is prepared per Sections 8.3.3 and 9.1. An ICB must be analyzed immediately following the ICV. Refer to Section 11.1 for acceptance criteria and corrective actions.

9.6 Continuing Calibration Verification (CCV)

9.6.1 Continuing Calibration Verification (CCV): A CCV must be analyzed after every 10 samples and at the end of the analytical batch to verify the system is still calibrated. The CCV should be from the same material as the curve standards and is prepared per Sections 8.3.3 and 9.1. Refer to Section 11.1 for acceptance criteria and corrective actions.

9.6.2 Continuing Calibration Blank (CCB): The CCB consists of reagent water that is prepared per Sections 8.3.3 and 9.1. A CCB must be analyzed after each CCV. Refer to Section 11.1 for acceptance criteria and corrective actions.

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9.6.3 Reporting Limit Verification Standard (CRDL): The CRDL is an optional check standard at or below the concentration of the reporting limit. The CRDL is prepared per Sections 8.3.3 and 9.1. If required by client or program, the CRDL must be analyzed at the beginning and the end of the analytical run. Refer to Section 11.1 for acceptance criteria and corrective actions.

9.7 Determination of Mercury

9.7.1 Instrument configuration must be the same for sample analysis as for initial calibration.

9.7.2 Pour approximately 10mL portions of each standard, Method Blank, LCS, sample and MS/MSD into autosampler tubes for analysis.

9.7.3 Once initial calibration is established, analyze each sample, Method Blank, LCS and MS/MSD. An example sequence may be as follows:

Initial calibration standards
IPR (if required)
ICV
ICB
CRDL (if required)
Method blank
LCS
Client samples 1-10
MS/MSD
CCV
CCB
Client samples 11-20
MS
CCV
CCB
CRDL (if required)

9.7.4 Any sample with a mercury concentration that exceeds the linear range of the calibration curve must be diluted with 3% HCl solution and re-analyzed, or over range results must be qualified as estimated. Alternatively, the sample can be re-digested at a dilution.

9.7.5 **WI DNR samples only:** Any sample digestate with a Hg concentration >90% of the linear range of the calibration must be diluted and reanalyzed.

9.7.6 **OH VAP samples only:** results subject to potential high bias or potential low bias must include a qualifier or narrative that indicates the potential bias to the data user.

9.7.7 **For TCLP extract only:** perform the method of standard additions if (1) analyte concentration is between 0.16-0.20mg/L **AND** (2) MS recovery is <50%.

Refer to *MSA Calculation – TCLP Hg F-IN-I-526* spreadsheet or current replacement for detailed directions.

9.7.7.1 Prepare four aliquots spiked at 0%, 50%, 100%, and 150% of the measured sample concentration. If necessary, dilute the spiked aliquots to obtain results within the linear range for the analyte(s) of concern. Analyze the spiked aliquots.

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9.7.7.2 Use linear regression to generate a calibration curve using results from the spiked aliquots. Back-calculate the unspiked sample result from this calibration curve. This back-calculated result is reported as the sample result. Qualify the result (MA) to indicate that it was derived by the method of standard additions.

**NOTE:** If the analyte concentration in the TCLP extract is above the regulatory limit (0.2mg/L), the method of standard additions is not required.

9.7.8 Flush all lines with a 20% nitric acid solution for several minutes, followed by a DI water rinse several minutes. Remove lines from rinse and pump until dry.

## 10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Calculations

10.1.1 The instrument software calculates the Mercury concentration in the sample aliquot as follows:

$$X_s = (y - b)/a$$

Where: $X_s$ = Concentration of the analyte
y = Total area or response of the analyte
a = slope of the line (the coefficient of x)
b = intercept of the line

10.1.2 Calculate the final concentration in the samples as follows:

$$\text{Aqueous Sample (ug/L)} = \frac{(X_s)(V_f)(D)}{(V_i)} \qquad \text{Solid Sample (mg/kg)} = \frac{(X_s)(V_f)(D)}{(W_s)} \times 1000$$

Where: $X_s$ = Mercury concentration from instrument in ug/L
$V_f$ = Final sample volume of digestate in Liters
D = Dilution factor of the digestate
$V_i$ = Initial volume of aqueous sample digested, in Liters
$W_s$ = Weight of solid sample digested, mg

$$\text{Moisture-corrected concentration} = \frac{\text{(Final concentration as received)}}{\text{(100 - \%Moisture)}} \times 100$$

10.1.3 LCS calculation:

$$R = (C / S) \times 100$$

Where: R = Percent Recovery
C = Observed LCS concentration
S = True LCS concentration

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10.1.4 MS calculation:

$$R = \frac{(C_s - C)}{S} \times 100$$

Where: R = Percent Recovery
$C_s$ = Observed MS concentration
C = Sample concentration
S = True spike concentration

10.1.5 RPD calculation:

$$RPD = \frac{|D_1 - D_2|}{[(D_1 + D_2)/2]} \times 100$$

Where: RPD = Relative Percent Difference
$D_1$ = First Sample Result
$D_2$ = Second Sample Result

## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

11.1 Instrument Quality Control*

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration** | Applicable target analyte | Each day of analysis and as needed | r ≥ 0.995<br><br>%RE:<br>Lowest point: +/-50%<br>Midpoint: +/-10%<br>**--OR--**<br>%RSE: ≤20% | Analyze a new initial calibration curve. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed initial calibration must be reanalyzed. |
| **Initial Calibration Verification Standard (ICV)** | Second Source Standard | Immediately following initial calibration of the instrument | 90-110% Recovery | Reanalyze ICV. If the second ICV also exceeds the acceptance range, a new initial calibration must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed ICV must be reanalyzed or qualified.<br>*Exception:* If the ICV is outside the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration Blank (ICB)**<br><br>**Continuing Calibration Blank (CCB)** | Reagent water | ICB Immediately following an ICV.<br><br>CCB Immediately following each CCV. | Target analyte must be <RL.<br><br>If required by client or program: ICB/CCB must be <1/2 the RL.<br><br>**WI DNR compliance samples:** ICB/CCBs must be evaluated to the most current MDL (LOD). | Reanalyze ICB/CCB. If the second ICB/CCB is also >RL, a new initial calibration must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed ICB/CCB must be reanalyzed or qualified.<br>*Exception:* If the ICB/CCB is >RL, associated samples determined to be <RL are reportable.<br>*WI DNR:* If the absolute value of an ICB/CCB result exceeds the established MDL but is <RL (LOQ), associated samples are reportable but must be qualified to indicate that an associated blank exceeds the MDL (LOD). |
| **Continuing Calibration Standard (CCV)** | Applicable target analyte | Every 10 samples and at end of run | 90-110% Recovery | Check instrument operating conditions, and if necessary, restore them to the original settings. Reanalyze CCV. If the second CCV still exceeds the acceptance criteria, then a new initial calibration must be analyzed. Samples associated with a failed CCV must be reanalyzed or qualified.<br>*Exception:* If the CCV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |
| **Reporting Limit Verification Standard (CRDL)** | Applicable target analyte | If required by client or program: At the beginning of the run and at end of run. | 50-150% Recovery<br>Acceptance range may vary; refer to client-specific technical requirements. | If the CRDL is required by client or program and fails the acceptance criteria, another CRDL may be analyzed. If the second CRDL fails, associated samples must be qualified.<br>*Exception:* If the CRDL is outside of the upper control limit, indicating high bias, associated samples determined to be <RL are reportable without qualification. |

*NOTE: Failure of the initial calibration, ICV, CCV, ICB, CCB, or CRDL due to instrument malfunction requires the instrument to be restored to proper working order and the reanalysis of samples associated with the failed QC.

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11.2 Batch Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Method Blank (MB)** | Reagent water or simulated soil matrix | One per preparation batch of up to 20 samples, per matrix. | Target analyte must be less than the reporting limit. | Reanalyze method blank. Re-digest and reanalyze if target compound is still >RL in method blank and associated samples.<br>*Exceptions:*<br>1) If the method blank concentration is less than 1/10 of the amount measured in the sample, corrective action is not required, affected data must be qualified. This allowance is not applicable to samples associated with some state programs or client technical specifications<br>2) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, the reported method blank and samples must be qualified.<br>3) If a contaminant is present only in the method blank and not the samples, no action is required. |
| **Laboratory Control Standard (LCS)** | Applicable target analyte | One per preparation batch of up to 20 samples, per matrix. | 80-120% Recovery | Re-analyze LCS. Re-digest and re-analyze associated samples if LCS is still outside acceptance limits.<br>*Exceptions:*<br>1) If no additional sample remains for re-analysis or if re-extraction/re-analysis cannot take place within holding time, reported data must be qualified.<br>2) If LCS recovery is >QC limits and sample results are non-detect, the sample data may be reported without qualifiers. The LCS data must be qualified.<br>3) If LCS recovery is outside of QC limits but a matrix spike recovers within LCS recovery limits, the sample data may be reported without qualifiers. The LCS data must be qualified with "L5". This allowance is not applicable for samples associated with some state programs or client technical specifications. |
| **Matrix Spike/ Matrix Spike Duplicate (MS/MSD)** | Applicable target analyte | One MS/MSD set per preparation batch. | 75-125% Recovery<br>≤20% RPD | No corrective action necessary. If LCS recovery is in range, the system is considered in-control and the out-of-control MS/MSD must be qualified appropriately. |

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11.3 Method Validation

Refer to the SOP for Method Validation and Instrument Verification for the procedures used for initial method validation. Method Detection Limits (MDL) must be determined per the procedure in 40CFR Part 136, Appendix B.

11.4 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

## 12.0 Data Review And Corrective Action

12.1 Data Review

The analyst must perform primary review of data and calculated results for accuracy. Secondary review of the data and calculated results must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 Pollution Prevention And Waste Management

13.1 Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

## 14.0 Modifications

14.1 Digestion procedure modified to use digestion cups in a hot block instead of BOD bottles in a water bath.

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14.2 Standards and some reagents purchased as certified solutions.

14.3 Stannous Chloride solution not stirred continually because it is a solution and not a suspension.

14.4 Stannous Chloride solution is prepared per instrument manufacturer's instructions.

14.5 Interference tests and MSA from method 7000A Sections 8.6 and 8.7 are not routinely performed.

## 15.0 RESPONSIBILITIES

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

## 16.0 ATTACHMENTS

Not applicable to this SOP.

## 17.0 REFERENCES

17.1 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Methods 7000A, 7470A, 7471A, and 1311.

17.2 Pace Analytical Quality Manual; latest revision.

17.3 NELAC/TNI Standards; 2003, 2009, and 2016.

## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 9.7.6 | Added language referring to Ohio VAP samples. |
| 9.7.7 | Added standard additions process for TCLP samples. |
| 17.1 | Added reference to SW846 1311. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0044 | Mercury by SW-846 7470A, 7471A | 04 |

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| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0139 v02_Ammonia Nitrogen (Gas Diffusion) by EPA 350.1, SM 4500-NH3 G** |
| | **Effective Date: 06/29/2023** |

**Management Approval:**
Megan Stephenson Approved on 6/27/2023 11:14:59 AM
Sarah Potts Approved on 6/29/2023 12:05:25 PM
Steven Sayer Approved on 6/26/2023 3:39:39 PM
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## 1.0 SCOPE AND APPLICATION

1.1 This standard operating procedure (SOP) describes the laboratory procedure for the determination of Ammonia Nitrogen by Gas Diffusion Separation in aqueous samples, while meeting the requirements specified in EPA method 350.1, revision 2.0 and Standard Method 4500-$NH_3$ G, 2011.

1.2 This method is applicable to the measurement of ammonia nitrogen in ground water, surface waters, and wastewaters.

1.3 The default reporting limit is 0.1mg/L. Refer to the LIMS for method detection limits.

1.4 Reporting limits, control limits, volumes used, standard concentrations, vendors, instrumentation, equipment and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

The ammonia is separated from the matrix in a diffusion cell across a hydrophobic semi-permeable membrane and absorbed by a flowing acceptor stream. When ammonia in the acceptor is heated with salicylate and hypochlorite in an alkaline phosphate buffer, an emerald green color is produced that is proportional to the ammonia concentration. The green color formed is intensified with sodium nitroprusside and measured colorimetrically at 660nm.

## 3.0 INTERFERENCES

3.1 In alkaline solution, calcium and magnesium can interfere by forming a precipitate, which scatters light or which can cause clogs. In this method, precipitate is excluded from the chemistry by the use of a hydrophobic membrane. Additionally, EDTA is added to the alkaline donor to prevent this interference.

3.2 Residual chlorine must be removed by pretreatment of the sample prior to analysis.

3.3 Lauryl sulfate, detergents, oils and greases can cause low ammonia recoveries by wetting the membrane.

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## 4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Aqueous** | 250 mL in plastic container | $H_2SO_4$ to pH<2 | Cool to ≤6°C | Samples must be analyzed within 28 days of collection date. |

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## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| Autoanalyzer | Lachat Quikchem 8500 or equivalent, equipped with an autosampler, heating unit, diffusion cell, flow cell, 660nm filter, and data reduction system. Must use PVC pump tubing for this method. |
| Analytical Balance | Capable of weighing to the nearest 0.01g |

### 7.2 Supplies

| Supplies | Description |
|---|---|
| Volumetric flasks | Class A, various sizes |
| Mechanical pipets | Eppendorf or equivalent, various sizes |
| Magnetic stir plate and stir bars | For mixing reagents |
| Autosampler tubes | Disposable glass or plastic, for use with Lachat autosampler |
| Disposable Beakers | 50mL or equivalent |
| Syringe filters | Environmental Express 0.45um or equivalent |
| Syringes | 10mL disposable |
| Chlorine Test Strips | Supelco MQuant, or equivalent. Store in refrigerator. |

## 8.0 REAGENTS AND STANDARDS

### 8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Reagent water | ASTM Type II water or equivalent |
| Helium gas | For degassing reagents |
| Sodium Hydroxide (NaOH) | Reagent grade pellets |
| Sulfuric Acid ($H_2SO_4$) | Concentrated, reagent grade |
| Sodium Thiosulfate | Reagent grade crystals |

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| Reagent | Concentration / Description |
|---|---|
| Sodium Thiosulfate Solution 0.025N | In a 500mL volumetric flask containing about 300mL of reagent water, dissolve 1.75g Sodium Thiosulfate. Dilute to volume with reagent water and mix. Prepare fresh weekly. |
| Disodium ethylenediamine tetraacetate ($Na_2EDTA$) | Reagent grade crystals |
| Boric Acid ($HBO_3$) | Reagent grade crystals |
| Sodium Phosphate Dibasic Heptahydrate ($Na_2HPO_4*7H_2O$) | Reagent grade crystals |
| Sodium Salicylate ($C_6H_4(OH)(COO)Na$) | Reagent grade crystals |
| Sodium Nitroprusside ($Na_2Fe(CN)_5NO*2H_2O$) | Reagent grade crystals |
| Sodium Dichloroisocyanurate | Reagent grade crystals |
| Alkaline Donor Reagent | To a 2L volumetric flask, add approximately 1600mL reagent water and 60g EDTA. Mix with a magnetic stirrer. Add 24.8g Boric Acid. While mixing, add 80g NaOH pellets. Dilute to volume with reagent water. The pH of this solution will be approximately 13. This solution can be stored in a plastic bottle at room temperature for one month. |
| Buffer | In a 1L volumetric flask containing about 500mL of reagent water, dissolve 15g NaOH pellets, 12.5g EDTA, and 33.5g Sodium Phosphate Dibasic. Dilute to volume with reagent water and mix. This solution can be stored in a plastic bottle at room temperature for six months. |
| Salicylate - Nitroprusside Color Reagent | In a 1L volumetric flask containing about 800mL of reagent water, dissolve 350g Sodium Salicylate and 3.5g Sodium Nitroprusside. Dilute to volume with reagent water and mix. Store in a light proof bottle. Prepare fresh weekly or more frequently if the solution turns blue. |
| DCIC Reagent (Hypochlorite Generator) | In a 1L volumetric flask containing about 600mL of reagent water, dissolve 5g of NaOH pellets and 5g Sodium Dichloroisocyanurate (DCIC). Stir to mix then dilute to volume with reagent water. This reagent should be made daily. Degas solution 5-30min with helium before use. |
| Carrier and Diluent Solution | In a 2L volumetric flask containing about 1L of reagent water, add 4mL concentrated Sulfuric Acid. Dilute to volume with reagent water and stir to mix. This solution is used as the diluents for standards and samples. This solution can be stored in a plastic bottle at room temperature for six months. |

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8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| Stock Ammonia Calibration Standard | SPEX; catalog # AS-NH3N9-2Y; 1000mg/L Ammonia as N, or equivalent. | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Intermediate Ammonia Calibration Standard | Refer to Section 8.3.1 | Expires 1 month from date of preparation. | Same as stock standard. |
| Working Ammonia Calibration Standards | Refer to Section 8.3.2 | Must be prepared fresh daily. | Not Applicable |
| Stock Ammonia ICV Standard | Hach; catalog # 24065-49; 100mg/L Ammonia as N, or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| Working Ammonia ICV Standard | Refer to Section 8.3.3 | Must be prepared fresh daily. | Not Applicable |

8.3 Standard Preparation Procedures

8.3.1 Intermediate Ammonia Calibration Standard Preparation

Dilute 1mL of the Stock Ammonia Calibration Standard (1000mg/L) to 50mL with reagent water for a concentration of 20mg/L.

8.3.2 Working Ammonia Calibration Standard Preparation

Working calibration standards must be prepared fresh daily by diluting the Intermediate Ammonia Calibration Standard (100mg/L) to 100mL with reagent water. Examples of possible calibration standards are as follows:

| Standard | Amount of Standard | Standard Used | Final Volume | Final Concentration |
|---|---|---|---|---|
| CAL0 | 0mL | N/A | 10mL | 0mg/L |
| CAL1 | 1.0mL | CAL3 | 10mL | 0.10mg/L |
| CAL2 | 0.50mL | CAL5 (CCV) | 10mL | 0.50mg/L |
| CAL3 | 1.0mL | CAL5 (CCV) | 10mL | 1.0mg/L |
| CAL4 | 2.5mL | Intermediate | 10mL | 5.0mg/L |
| CAL5 (CCV) | 1mL | Stock | 100mL | 10mg/L |
| CAL6 | 10mL | Intermediate | 10mL | 20mg/L |

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8.3.3 Working Ammonia ICV Standard Preparation

Dilute 0.5mL of the Stock Ammonia ICV standard (100mg/L) to 10mL with reagent water for a concentration of 5mg/L. This standard must be prepared fresh daily.

## 9.0 PROCEDURE

9.1 Preliminary Sample Evaluation

9.1.1 Water samples for NPDES compliance must be analyzed using gas diffusion or must be distilled prior to analysis. Refer to 40CFR Part 136, Table 1B for requirements.

9.1.2 Water samples with significant suspended solids content or samples that contain soaps, oils or greases may not be appropriate for analysis by gas diffusion. Samples may require dilution prior to analysis to minimize interferences. Otherwise, distillation may be a more appropriate option, refer to SOP-ENV-IND1-0046 or current replacement.

9.1.3 Check samples for chlorine using a chlorine test strip. If positive, add 0.025N Sodium Thiosulfate solution dropwise until subsequent test strips are negative for chlorine. Samples may require dilution prior to chlorine removal; if chlorine content is very high distillation may be a more appropriate option, refer to SOP-ENV-IND1-0046 or current replacement.

9.2 Initial Calibration (ICAL)

9.2.1 Configure the instrument according to manufacturer's instructions. Allow the heating unit, colorimeter, and recorder to warm up. Run a baseline with all reagents, using reagent water to flush the tubing. Whenever new tubing is used, allow ample time to flush residual compounds from the tubing.

9.2.2 A minimum of five initial calibration standards and a calibration blank are analyzed in decreasing order of concentration. The lowest calibration standard must be at or below the reporting limit. A new initial calibration curve is run on each working day. Refer to the Quality Manual for more information regarding calibration curves.

9.2.3 Initial Calibration Evaluation

9.2.3.1 Using the Lachat software, prepare a standard curve by plotting area versus concentration. The analyst may employ a regression equation that does not pass through the origin. Weighting factors of $1/x$ or $1/x^2$ may be used to gain accuracy at lower concentrations.

9.2.3.2 The regression calculation will generate a correlation coefficient (r) that is the measure of the "goodness of fit" of the regression line to the data. Refer to Section 11.1 for acceptance criteria and corrective action.

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9.2.3.3 Individual analyte calibration levels may be removed from the lowest and/or highest levels of the calibration curve provided the number of remaining calibration points meet the minimum requirements and the quantitation range is adjusted, as necessary.

9.2.3.4 Evaluate the Relative Error of each calibration point. The instrument software back-calculates the concentration of each calibration point as Det. Conc (mg/L). Refer to Section 11.1 for acceptance criteria and corrective action.

9.2.4 Initial Calibration Verification (ICV)

9.2.4.1 In addition to meeting the linearity requirement, any new calibration curve must be assessed for accuracy in the values generated. To assess the accuracy, a single standard from a secondary source must be analyzed and the results obtained must be compared to the known value of the standard. This step is referred to as Initial Calibration Verification. The ICV is analyzed immediately following an initial calibration curve.

9.2.4.2 The ICV is evaluated by calculating the percent difference or percent recovery, as follows:

$$\%\ Difference = \frac{Calculated\ concentration - Theoretical\ concentration}{Theoretical\ concentration} \times 100$$

$$\%\ Recovery = \frac{Calculated\ concentration}{Theoretical\ concentration} \times 100$$

9.2.4.3 Refer to Section 11.1 for acceptance criteria and corrective action.

9.2.5 Initial Calibration Blank (ICB): The ICB consists of diluent. An ICB must be analyzed after each ICV. Refer to Section 11.1 for acceptance criteria and corrective action.

9.3 Continuing Calibration Verification (CCV)

9.3.1 A CCV must be analyzed after every 10 samples and at the end of the analytical batch to verify the system is still calibrated. The CCV should be prepared from the same material as the initial calibration standards. Refer to Section 11.1 for acceptance criteria and corrective action.

9.3.2 Continuing Calibration Blank (CCB): The CCB consists of diluent. A CCB must be analyzed after each CCV. Refer to Section 11.1 for acceptance criteria and corrective action.

9.4 Sample Analysis

9.4.1 Samples with small amounts of solids should be filtered using a 0.45um syringe filter.

9.4.2 Prepare a Method Blank consisting of reagent water.

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9.4.3 Prepare an LCS: add 0.5mL of the Stock Ammonia ICV Standard (100mg/L) to 10mL of reagent water for a spike concentration of 5mg/L.

9.4.4 Prepare a Matrix Spike: add 0.5mL of the Stock Ammonia ICV Standard (100mg/L) to 10mL of sample for a spike concentration of 5mg/L.

9.4.5 Once initial calibration is established, analyze 10mL portions of each sample, Method Blank, LCS and MS/MSD. An example sequence may be as follows:

ICAL Standards
ICV
ICB
Method blank
LCS
Client samples
CCV
CCB
Client samples
CCV
CCB

9.4.6 Sample concentrations that exceed the calibration range must be diluted and reanalyzed, or the result must be qualified as estimated.

9.4.7 For Ohio VAP samples only: Analytical results subject to potential high bias or potential low bias must include a qualifier or narrative that indicates the potential bias to the data user.

9.4.8 When analysis is complete, flush all lines with reagent water, then air. Turn off pump and Lachat.

## 10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Calculations

10.1.1 Calculate the final concentration in the samples as follows:

Aqueous Sample (mg/L) = $(X_s)(D)$

Where: $X_s$ = Ammonia concentration, mg/L
D = Dilution factor (Final volume / Initial volume)

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10.1.2 LCS calculation:

$$R = (C / S) \times 100$$

Where: R = Percent Recovery
C = Observed LCS concentration
S = True LCS concentration

10.1.3 MS calculation:

$$R = \frac{(C_s - C)}{S} \times 100$$

Where: R = Percent Recovery
$C_s$ = Observed MS concentration
C = Sample concentration
S = True spike concentration

10.1.4 RPD calculation:

$$RPD = \frac{|D_1 - D_2|}{[(D_1 + D_2)/2]} \times 100$$

Where: RPD = Relative Percent Difference
$D_1$ = First Sample Result
$D_2$ = Second Sample Result

## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

11.1 Instrument Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration** ***(continued on next page)*** | Applicable target analyte | Daily | r ≥ 0.995 for Linear Calibration<br>**Relative error:**<br>**EPA 350.1**:<br>Lowest curve point +/- 50%;<br>Mid-point of curve: +/- 10% | Analyze a new initial calibration curve. If the second curve attempt does not meet the acceptance criteria, the analyst must consult the department manager. Instrument maintenance and/or preparation of new calibration standards must be considered. Samples associated with a failed initial calibration must be reanalyzed. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration *(cont.)*** | | | **SM 4500-NH3 G**: Lowest curve point +/- 50%;<br>All other curve points +/- 10% | *(see previous page)* |
| **Initial Calibration Verification Standard (ICV)** | Second Source Standard | Immediately following initial calibration | 90-110% Recovery or ±10% Difference | Analyze another ICV. If the response still fails the acceptance criteria, a new initial calibration must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed ICV must be reanalyzed.<br>*Exception:* If the ICV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |
| **Initial Calibration Blank (ICB)** | Reagent water | Immediately following the ICV | **Method 350.1:** Target analyte must be less than MDL.<br>**Method 4500-NH3 G:** Target analyte must be less than RL. | Reanalyze blank. If target compound is still > MDL/RL in blank and associated samples, a new initial calibration must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed ICB must be reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If a contaminant is present only in the blank and not the samples, no action is required. |
| **Continuing Calibration Standard (CCV)** | Applicable target analyte | Every 10 samples, and at end of run | 90-110% Recovery | Analyze another CCV. If the response still fails the acceptance criteria, then a new initial calibration must be analyzed. Samples associated with a failed CCV must be reanalyzed.<br>*Exception:* If the CCV is outside of the upper control limit, indicating high bias, associated samples determined to be <RL may be reported. |
| **Continuing Calibration Blank (CCB)** | Reagent water | Every 10 samples, and at end of run | **Method 350.1:** Target analyte must be less than MDL.<br>**Method 4500-NH3 G:** Target analyte must be less than RL. | Reanalyze blank. If target compound is still > MDL/RL in blank and associated samples, a new initial calibration must be analyzed. Instrument maintenance and/or preparation of new calibration standards should also be considered. Samples associated with a failed CCB must be reanalyzed.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis, or if reanalysis cannot take place within holding time, the sample results must be qualified.<br>2) If a contaminant is present only in the blank and not the samples, no action is required. |

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11.2 Batch Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Method Blank (MB)** | Reagent water | One per preparation batch of up to 20 samples. | **Method 350.1:** Target analyte must be less than MDL.<br>**Method 4500-NH3 G:** Target analyte must be less than RL. | Reanalyze blank. Reanalyze associated samples if target compound is still >MDL / RL in method blank and associated samples.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, the reported method blank and samples must be qualified.<br>2) If a contaminant is present only in the method blank and not the samples, no action is required.<br>3) If the method blank concentration is less than 1/10 of the amount measured in the sample, corrective action is not required, affected data must be qualified. |
| **Laboratory Control Standard (LCS)** | Applicable target analyte | One per preparation batch of up to 20 samples. | 90-110% Recovery | Reanalyze LCS. Reanalyze associated samples if LCS is still outside acceptance limits.<br>*Exceptions:*<br>1) If no additional sample remains for reanalysis or if reanalysis cannot take place within holding time, reported data must be qualified.<br>2) If LCS recovery is >QC limits and sample results are non-detect, the sample data may be reported without qualifiers. The LCS data must be qualified. |
| **Matrix Spike/ Matrix Spike Duplicate (MS/MSD)** | Applicable target analyte | One MS/MSD set per batch plus an additional MS if >10 samples in the batch. | 90-110% Recovery<br>≤20% RPD | No corrective action necessary. If LCS recovery is in range, the system is considered in-control and the out-of-control MS/MSD must be qualified appropriately. |

11.3 Method Validation

Refer to the SOP for Method Validation and Instrument Verification for the procedures used for initial method validation. Method Detection Limits (MDL) must be determined per the procedure in 40CFR Part 136, Appendix B.

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11.4 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

## 12.0 DATA REVIEW AND CORRECTIVE ACTION

12.1 Data Review

The analyst must perform primary review of data and calculated results for accuracy. Secondary review of the data and calculated results must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

## 14.0 MODIFICATIONS

14.1 Procedure modified for use with Gas Diffusion cell with hydrophobic membrane.

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## 15.0 RESPONSIBILITIES

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

## 16.0 ATTACHMENTS

Not applicable to this SOP.

## 17.0 REFERENCES

17.1 USEPA, Method 350.1, “Methods for Chemical Analysis of Water and Wastes”, EPA-600/4-79-020, Revision 2.0, August 1993.

17.2 Standard Methods for the Examination of Water and Wastewater; Method 4500-NH3 G, 1997, editorial revisions 2011.

17.3 Lachat Method No. 10-107-06-5-J, Rev. 2.0, January 16, 2015.

17.4 Pace Analytical Quality Manual; latest revision.

17.5 NELAC/TNI Standards; Quality Systems section; 2003, 2009, and 2016.

## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 7.2 | Updated supplies to match current practice. |
| 8.1 | Updated storage and shelf life of several reagents to match Lachat method directions and/or current practice. |
| 8.3 | Updated standard prep directions to match current practice. |
| 9.1.2, 9.1.3 | Added reference to distilled ammonia procedure that may be used when samples matrix is not suitable for gas diffusion. |
| 9.2.3 | Added allowance for dropping calibration points to match current calibration policy. Updated description of relative error evaluation. |
| 9.2.4.2 | Added equations for evaluation of ICV. |
| 9.2.5, 9.3.2 | Defined ICB/CCB as diluent. |
| 9.4.7 | Added Ohio VAP language. |
| 11.1 | Updated ICAL acceptance criteria based on applicable method reference. |

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This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0139 | Ammonia Nitrogen by Gas Diffusion Separation | 01 |
| ENV-SOP-IND1-0122 | Ammonia Nitrogen by Gas Diffusion Separation (Ohio VAP) | 00 |

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| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0030 v04_pH by SM 4500-H+ B** |
| | **Effective Date: 08/27/2024** |

**Management Approval:**
Sarah Potts Approved on 8/21/2024 7:08:09 AM
Steven Sayer Approved on 8/27/2024 8:33:43 AM
Anne Troyer Approved on 8/27/2024 9:16:25 AM

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## 1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) describes the laboratory procedure for the determination of pH in aqueous samples while meeting the requirements specified in Standard Method 4500-$H^+$ B; 2021.

1.1 This procedure is applicable to the measurement of pH in groundwater, surface water, and domestic and industrial wastes.

1.2 Determination of pH cannot be made accurately in nonaqueous media, suspensions, colloids, or high-ionic-strength solutions.

1.3 Determined values for pH are reported to the nearest 0.1 pH units.

1.4 Reporting limits, control limits, volumes used, vendors, instrumentation, equipment, and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

The pH of a sample is determined electrometrically using either a glass electrode in combination with a reference potential or a combination electrode. The measuring device is calibrated using a series of standard solutions of known pH.

## 3.0 INTERFERENCES

3.1 Coatings of oily material or particulate matter on the electrode can impair response. This can be minimized by gently wiping off the electrode or washing with detergent followed by reagent water. An additional treatment with hydrochloric acid (1:9 ratio) may be necessary to remove any remaining film.

3.2 Samples with very low or very high pH may give incorrect readings on the pH meter. This error can be minimized by using a low-sodium-error electrode.

3.3 Temperature can have effects on results. To compensate for temperature interferences, the analyst should always calibrate the pH meter at the same temperature as the samples and they should record the sample temperature and pH at the time of analysis. Alternately, an automatic temperature compensating pH meter can be used.

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## 4.0 DEFINITIONS

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## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Aqueous** | 100mL in plastic container | None required | Ambient | 15 minutes** |

** Analysis can only be performed as soon as possible after receipt by the lab. A qualifier is applied to all results from pH analysis initiated more than 15 minutes after sample collection.

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## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| pH/Ion meter | Orion Star A214, Accumet AB15, Accumet AB150, or equivalent, equipped with a combination pH probe and temperature sensor. |

### 7.2 Supplies

| Supplies | Description |
|---|---|
| Magnetic stirrer | With Teflon coated stir bars |
| Disposable beakers | 50mL capacity |

## 8.0 REAGENTS AND STANDARDS

### 8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Reagent water | ASTM Type II water or equivalent |

### 8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| pH 2 buffer | SPEX, catalog #VPACEMN-98-4L, or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 4 buffer | Control Co, catalog # 06-664-259 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 7 buffer (CCV) | Control Co, catalog # 06-664-260 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 10 buffer | Control Co, catalog # 06-664-261 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 12 buffer | SPEX, catalog # VPACEMN-100-4L or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 7 buffer (ICV) | Ricca catalog #1551.4 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |

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## 9.0 PROCEDURE

9.1 Calibration

9.1.1 Refer to manufacturer's instructions for pH electrode and meter. If using a refillable electrode, uncover the fill hole on the pH electrode and add the appropriate fill solution to the electrode up to the fill hole. The level of the fill solution must always be above the reference junction. The fill hole should remain open when the electrode is in use. Store electrode in KCl filling solution when not in use.

9.1.2 Each instrument/electrode system must be calibrated each day of use with a minimum of three calibration points that bracket the expected pH of the samples. Place the appropriate buffer solution into a clean beaker using sufficient volume to cover the sensing elements of the electrode and temperature probe, and to give the magnetic stir bar some clearance to move. Use fresh buffer solutions daily.

9.1.3 Refer to Attachments for calibration instructions based on the specific meter being used.

9.1.4 The slope after calibration must be ≥90%.

9.1.5 Once the meter has been calibrated and is in measurement mode, proceed to Step 9.1.6.

9.1.6 Measure the pH of each of the buffers used for calibration and record the readings. Readings must be within +/-0.1 pH units of the true value of each buffer.

9.1.7 Check calibration with a second source pH 7 buffer (ICV). Record the pH. Results must be within +/-0.1 pH units of the true value.

9.1.8 If the requirements of steps 9.1.4, 9.1.6, and 9.1.7 are not met, repeat the meter calibration using fresh buffers. If either of the requirements are still not met, replace electrode filling solution, and clean the electrode or replace the electrode.

9.1.9 Once calibrated, the meter is ready to analyze samples when in the measurement mode.

9.2 Sample Analysis

9.2.1 Allow samples to reach room temperature.

9.2.2 Place the well-mixed sample or buffer solution in a sample cup using a sufficient volume to cover the sensing elements of the electrode and temperature probe, and to allow clearance for the magnetic stir bar.

9.2.3 Immerse the electrode and temperature probe into the sample and stir gently at a constant rate. Record the sample pH to the nearest 0.1 pH units and record the temperature when the meter indicates the reading is stable.

9.2.4 If the pH of the sample exceeds the calibration range (i.e. between 4 and 10), an additional pH buffer solution must be analyzed to confirm the accuracy of the pH meter beyond the calibration range. Results must be within +/-0.1 pH units. If the pH of the additional buffer is not within +/-0.1 pH units, re-calibrate the pH meter using buffers that bracket the pH range of the samples and reanalyze the samples.

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9.2.5 Measure and record the pH of the calibration source pH 7 buffer (CCV) at the beginning of the analytical sequence, after every 10 samples, and at the end of the sequence. Results must be within +/-0.1 pH units. If the pH reading of the CCV is not within +/-0.1 pH units of the true value, repeat the CCV measurement using fresh CCV. If CCV still fails, replace electrode filling solution, and clean the electrode or replace the electrode and repeat calibration per Section 9.1. Repeat any samples that are not bracketed by acceptable buffer readings.

9.2.6 Thoroughly rinse the electrode with reagent water between sample measurements. Gently shake off excess water or dab gently with a Kimwipe.

**NOTE:** Certain customer technical specifications may stipulate that their samples must be analyzed within 4 hours of the calibration.

## 10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Calculations

10.1.1 Report sample pH results directly from meter readings without corrections.

10.1.2 RPD equation:

$$RPD = \frac{|D_1 - D_2|}{[(D_1 + D_2)/2]} * 100$$

Where: RPD = relative percent difference
$D_1$ = first sample result
$D_2$ = second sample result

## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

11.1 Instrument Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration** | pH | Daily | Slope ≥90%<br><br>Readback of each buffer ±0.10 pH units of the certified value | Repeat calibration using fresh buffer solutions. If calibration still doesn't pass, pH electrode maintenance may be required and may include replacing electrode filling solution, cleaning electrode, or replacing electrode. Samples associated with a failing initial calibration must be reanalyzed. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration Verification Standard (ICV)** | Second Source Standard | Immediately following initial calibration of the instrument | ±0.10 pH units of the certified value | Reanalyze an ICV using fresh buffer solution. If criteria still not met, recalibrate meter. If criteria not met, pH electrode maintenance may be required and may include replacing electrode filling solution, cleaning electrode, or replacing electrode. Samples associated with a failing ICV must be reanalyzed. |
| **Continuing Calibration Standard (CCV)** | pH | Beginning of analytical sequence, every 10 samples, and end of sequence. | ±0.10 pH units of the certified value | Reanalyze CCV using fresh buffer solution. If criteria still not met, recalibrate meter. If criteria not met, pH electrode maintenance may be required and may include replacing electrode filling solution, cleaning electrode, or replacing electrode. Samples associated with a failing CCV must be reanalyzed. |
| **Extended-range low calibration check (if needed)** | pH 2 buffer | Once per batch if any sample result is below pH 4 | ±0.10 pH units of the certified value | Recalibrate the meter using buffers that bracket the pH range of the sample(s) and reanalyze the sample(s). |
| **Extended-range high calibration check (if needed)** | pH 12 buffer | Once per batch if any sample result is above pH 10 | ±0.10 pH units of the certified value | Recalibrate the meter using buffers that bracket the pH range of the sample(s) and reanalyze the sample(s). |

11.2 Batch Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Sample Duplicate (DUP)** | Sample | One Sample Duplicate per 10 or fewer samples. | ≤2% RPD | Consult with supervisor to see if another sample should be duplicated, or report samples with the appropriate qualifier. |

11.3 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

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## 12.0 DATA REVIEW AND CORRECTIVE ACTION

12.1 Data Review

The analyst must perform primary review of data for accuracy. Secondary review of the data and must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

## 14.0 MODIFICATIONS

14.1 Buffers are purchased from commercial suppliers and not prepared from dry chemicals in the lab.

## 15.0 RESPONSIBILITIES

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

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## 16.0 ATTACHMENTS

16.1 Attachment 1: Orion Star A214 Calibration Instructions

16.2 Attachment 2: Accumet AB 15 Calibration Instructions

16.3 Attachment 3: Accumet AB150 Calibration Instructions

## 17.0 REFERENCES

17.1 Standard Methods for the Examination of Water and Wastewater, Method 4500 H+ B-2021.

17.2 Orion Star A214 User Manual, Rev.A 0811.

17.3 Accumet AB-15 User Manual, Rev.3 Aug 06.

17.4 Accumet AB150 User Manual, Rev.0 July 2012.

17.5 Pace Analytical Quality Manual; latest revision.

17.6 NELAC/TNI Standards; 2003, 2009, and 2016.

## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 1.0, 17.1 | Updated method citation to 2021 revision. |
| 1.1 | Updated matrices analyzed. |
| 7.1 | Updated equipment to match current. |
| 8.2 | Updated standards to match current practice. |
| 9.1.2 | Specified that fresh buffer solutions are used daily. |
| 9.2.6 | Added removal of excess rinse water by gently shaking electrode or using a Kimwipe. |
| 16, 17 | Added calibration directions and user manual for Accumet AB150 meter. |
| Att.3 | Added. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0030 | Aqueous pH | 03 |

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# Attachment 1
# Orion Star A214 Calibration Instructions

## Chapter 4 pH, RmV and ORP Calibration

The Orion Star A200 and Star A300 series pH meters can perform a one to five point pH calibration, one point relative mV calibration and one point ORP calibration. Step-by-step instructions and prompts are displayed on the meter to assist operators with the calibration menus. The meter can save up to 10 calibrations in the log and calibration data can be exported from the meter to a printer or computer.

### pH Calibration

One to five pH buffers can be used for calibration. Always use fresh pH buffers and select buffers that bracket the sample pH and are one to four pH units apart. Prepare the pH electrode according to the instructions in the electrode use guide. Connect the pH electrode and any other electrodes to be used (stirrer probe, ATC probe, reference electrode) to the meter. Power on the meter and set the measurement mode to pH.

*Note: In most calibration screens, press **f1 (esc)** to return to the measurement mode without saving the calibration.*

1. In the measurement mode, press ***f1 (cal)***.
2. Rinse the pH electrode and any other electrodes in use with distilled water, blot dry with a lint-free tissue and place into the pH buffer.
3. When the electrode and buffer are ready, press ***f3 (start)***. If using a Star A214 benchtop meter and stirrer probe, the stirrer probe will automatically start stirring at the speed selected in the setup menu once ***f3 (start)*** is pressed and stop stirring once the reading stabilizes.
4. Wait for the pH value on the meter to stabilize and stop flashing and perform one of the following actions:
    a. Press ***f2 (accept)*** to accept the displayed value.
    b. Press ***f3 (edit)*** to access the numeric entry screen and edit the value.
        i. Press ▲, ▶, ▼ or ◀ to highlight a number, decimal point or negative sign; press ***f3 (enter)*** to select the highlighted item and repeat until the value at the measured temperature is shown above the numeric entry screen.
        ii. Press ***f2 (done)*** to exit the numeric entry screen.
        iii. Press ***f2 (accept)*** to accept the entered value.
5. Press ***f2 (next)*** to proceed to the next buffer and repeat steps 2 through 4 or press ***f3 (cal done)*** to save and end the calibration. If five buffers are used, the calibration will save and end once the fifth value is accepted.
    a. If a one point calibration is performed, press ***f2 (accept)*** to accept the displayed slope value or press ***f3 (edit)*** to access the numeric entry screen, enter the slope value and press ***f2 (accept)***.
6. The meter will display the calibration summary including the average slope and export the data to the calibration log. Press ***f1 (meas)*** to proceed to the measurement mode or press ***f2 (print)*** to proceed to the measurement mode and export the data to a printer or computer.

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# Attachment 2
# Accumet AB 15 Calibration Instructions

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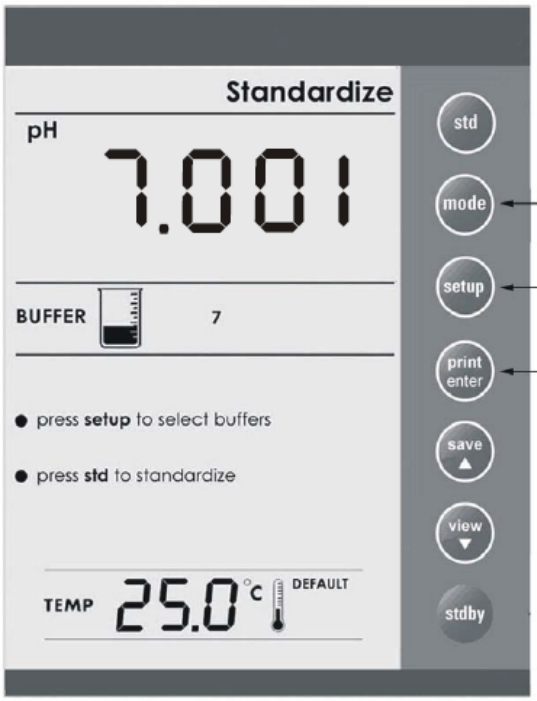
## 5 STANDARDIZATION

### 5.1 Standardization Procedure

Because electrodes vary in their response, you must standardize or calibrate your pH meter and electrode to compensate for electrode variation. The more frequently you standardize or calibrate, the more accurate your measurements. Standardize at least daily, or more often, for accurate results. The Accumet AB 15/ 15+ meter has auto buffer recognition for up to 5/6 buffer values from choice of either 1 of the 3 buffer groups available or 6 custom pH buffer values selected from any of these 3 buffer groups (Depending on buffer selection).




AB15+ screen & display keys

1. Press and release the mode key until your digital display indicates pH mode. This key toggles between pH, mV and Rel mV modes.
2. Press the setup key twice and then press enter key to clear an existing standardization. (See USING SETUP on Pg 9 if the calibration done)

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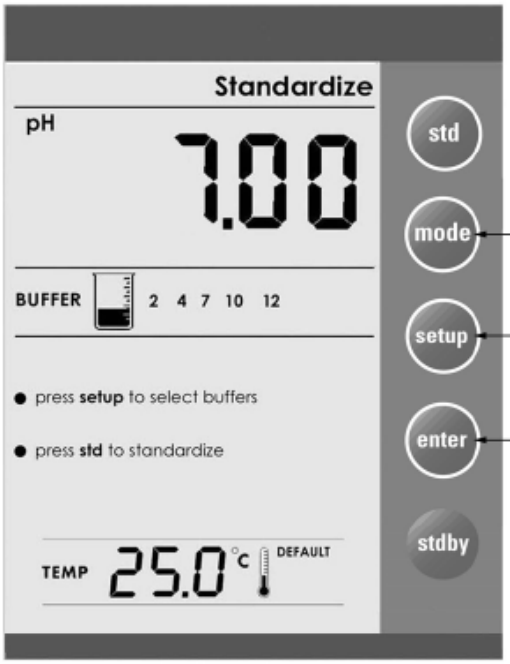


**AB15 screen & display keys**

1. Press and release the mode key until your digital display indicates pH mode. This key toggles between pH, mV and Rel mV modes.

2. Press the **setup** key twice and then press **enter** key to clear an existing standardization. (See USING SETUP on Pg 9 if the calibration done)

3. Immerse the rinsed electrode(s) into a buffer from the selected group. Stir, moderately,

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4. Press **std** to access the Standardize mode.

The selected buffer group is displayed briefly.

5. Do wait for reading to stabilize.

6. Press **std** again to initiate standardization. The meter will automatically recognize the buffer.

and then meter returns to the Measure screen.

Press **mode** key while in the standardization mode to return to measurement without accepting calibration.

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7. Repeat steps 3-6 with a second and subsequent buffers.

When the ATC probe is connected, the meter will continually adjust for temperature. Therefore the buffer values may vary slightly from the nominal values because of temperature variations.

It is good to standardize your meter using at least 2 buffers.

When the meter accepts the second buffer, it will briefly display the percent slope associated with the electrode's performance prior to returning to the Measure mode.

If the electrode is within the range of 90-102%, the GOOD ELECTRODE message will appear.

GOOD ELECTRODE

If the electrode is outside this range, the meter will display the ELECTRDOE ERROR message, and will not return to the Measure screen until the user presses **enter**.

ELECTRODE ERROR

The meter will permit the user to use an electrode outside the recommended range, but the ERROR message will persist.

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## 6 MEASUREMENT

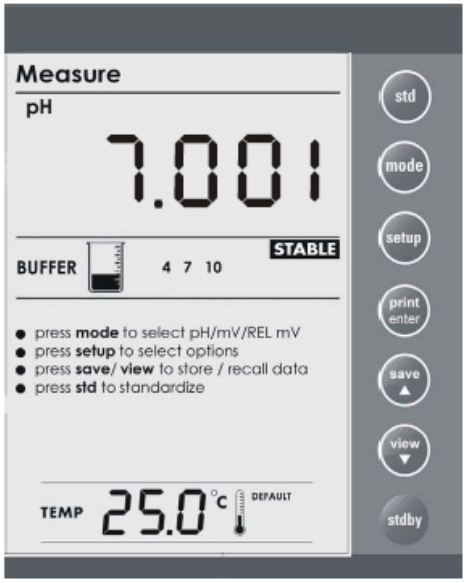
### 6.1 Measurement Procedure

1. Immerse the electrode (along with temperature probe if available for the measurement of pH) into the sample solution. Stir moderately.

Make sure that the meter is in the Measure mode.

2. When the meter senses that the reading has stabilized, the stable icon will appear under the reading. The reading may be recorded at this time.

STABLE icon will only appear provided that it has been set to 'On' mode in setup. See Section 4.1.6: Stability Indicator (Only available in AB15+), Pg 17.




AB15+ screen & display keys

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# Attachment 3
# Accumet AB150 Calibration Instructions

## 5. pH Standardization (With Preset Buffer Group)

For best results, periodic standardization (calibration) with known accurate standards is recommended prior to measurement. Use standards that bracket your intended measuring range while including a neutral point (7.00, 6.86, or 6.79). For example, if you expect to measure samples from pH 6.2 to 9.5, calibration with 4.01, 7.00, and 10.01 will work well.

The following pH calibration buffers in the groups listed below are automatically recognized:

| Buffer Group | pH Values |
|---|---|
| USA | 2.000, 4.010, 6.997, 10.013, 12.000 |
| NIST | 1.678, 4.010, 6.865, 9.184, 12.460 |
| DIN 19267 | 1.090, 3.060, 4.650, 6.790, 9.230, 12.750 |
| FSCI | 1.000, 3.000, 6.000, 8.000, 10.000, 13.000 |

To eliminate temperature errors associated with the pH electrode, attach the automatic temperature compensation (ATC) probe for best accuracy. Without temperature compensation, pH accuracy will decrease as samples deviate from 25 °C and pH 7.

If the pH electrode has been stored dry, soak in storage solution for 10 minutes before standardization to saturate the pH electrode surface and minimize drift. If storage solution is not available, use a neutral pH buffer. Do not reuse buffer solutions after calibration.

1) Turn meter on, press **MODE** if needed for pH measurement mode.
2) Rinse the pH and ATC electrodes with clean water then submerse in your first pH standard buffer.
3) Press **STD** to enter standardization mode.

If the meter is password protected, you will be prompted to enter a password.

4) The AB meter automatically searches for the appropriate standard from the chosen buffer group in the secondary display. This value will blink when the '**Stable**' indicator appears. Selecting **CLEAR** will clear existing calibration values.

5) Press **STD** to accept the value of the measured buffer. If successful, the Standardization Report will show the accepted value along with other data. The percentage slope is visible after two or more calibration points have been completed.
6) Repeat Steps 4 & 5 with additional pH buffers.

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## 16. Standardization Report

The Standardization Report provides detailed information on the most recent calibration. It includes date & time, calibration standard(s), offset, temperature, number of days calibration is overdue, and slope information.

The Standardization Report is automatically displayed every time a standard has been successfully accepted.

**Important Note For pH Standardization:**

If the calculated pH slope is not within 80.0 % - 110.0 %, the value is rejected and returns to standardization mode after the following message is displayed;

*"**Slope Error!** Allowable limit is 80 % to 110 %"*

If the calculated pH slope is within 80.0 % - 110.0 %, but not within 90.0 % - 102.0 %, the value is accepted after the following message is displayed;

*"**Warning:** Slope is not within 90-102 %.*
*Check electrode / buffer / temperature or clear values."*

**Important Note For ISE Standardization:**

The allowable limit for ISE slope is 15 to 90 mV per decade.

To view the calibration report at any time, press **REPORT** from the desired measurement screen. To send the calibration report data to a printer or PC, press **PRINT/ENTER key**.

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| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0058 v04_Soil & Waste pH by SW-846 9045C** |
| | **Effective Date: 11/07/2024** |

**Management Approval:**
Derek Gormon Approved on 11/7/2024 12:26:19 PM
Sarah Potts Approved on 11/7/2024 1:40:25 PM
Steven Sayer Approved on 11/7/2024 1:53:13 PM
Anne Troyer Approved on 11/7/2024 2:38:01 PM

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## 1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) describes the laboratory procedure for the determination of pH in solid samples while meeting the requirements specified in EPA method 9045C.

1.1 This procedure is applicable to soils, sludges, solid wastes, or non-aqueous liquids. If water is present, it must be less than 20% of the total volume of the sample.

1.2 Reporting limits, control limits, volumes/weights used, standard concentrations, vendors, instrumentation, equipment and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

The sample is mixed with reagent water and then the pH of the mixture is determined electrometrically using either a glass electrode in combination with a reference potential or a combination electrode. The measuring device is calibrated using a series of standard solutions of known pH.

## 3.0 INTERFERENCES

3.1 Coatings of oily material or particulate matter on the electrode can impair response. This can be minimized by gently wiping off the electrode or washing with detergent followed by reagent water. An additional treatment with hydrochloric acid (1:9 ratio) may be necessary to remove any remaining film.

3.2 Samples with very low or very high pH may give incorrect readings on the pH meter. This error can be minimized by using a low-sodium-error electrode.

3.3 Temperature can have effects on results. To compensate for temperature interferences, the analyst should always calibrate the pH meter at the same temperature as the samples and they should record the sample temperature and pH at the time of analysis. Alternately, an automatic temperature compensating pH meter can be used.

## 4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

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The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Solid** | >20g in 4oz glass jar | None required | Ambient | Analyze immediately** |

** There is no holding time requirement listed in the method. SW-846 Chapter Three lists the holding time as “analyze immediately.” All samples will be qualified as being analyzed outside recommended holding time.

## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| pH/Ion meter | Orion Star A214, Accumet AB15, Accumet AB150, or equivalent equipped with a combination pH probe and temperature sensor. |
| Analytical balance | Capable of weighing to 0.1g |

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7.2 Supplies

| Supplies | Description |
|---|---|
| Magnetic stirrer | With Teflon coated stir bars. Fisher or equivalent |
| Disposable beakers | 50mL capacity. Fisher or equivalent |
| Graduated cylinder | Class A for measuring 20mL reagent water volume. |
| Digestion tubes | 50mL capacity with lids, Environmental Express or equivalent |
| Filter paper | Fisher P4 or equivalent |
| Tumbling apparatus | |

## 8.0 REAGENTS AND STANDARDS

8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Reagent water | ASTM Type II water or equivalent |

8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| pH 2 buffer | SPEX, catalog #VPACEMN-98-4L, or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 4 buffer | Control Co, catalog # 06-664-259 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 7 buffer (CCV) | Control Co, catalog # 06-664-260 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 10 buffer | Control Co, catalog # 06-664-261 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 12 buffer | SPEX, catalog # VPACEMN-100-4L or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |
| pH 7 buffer (ICV) | Ricca catalog #155141 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |

## 9.0 PROCEDURE

9.1 Calibration

9.1.1 Refer to manufacturer's instructions for pH electrode and meter. If using a refillable electrode, uncover the fill hole on the pH electrode and add the appropriate fill solution to the electrode up to the fill hole. The level of the fill solution must always be above the reference junction. *The fill hole should remain open when the electrode is in use.* Store electrode in KCl filling solution when not in use.

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9.1.2 Each instrument/electrode system must be calibrated on each analysis day with a minimum of two calibration points that bracket the expected pH of the samples. The two points should be at least three pH units apart. Place the appropriate buffer solution into a clean beaker using sufficient volume to cover the sensing elements of the electrodes and to give the magnetic stir bar some clearance to move. Use fresh buffer solutions daily.

9.1.3 If meter does not indicate pH mode, press and release the **mode** key until the digital display indicates pH mode.

9.1.4 Press the **setup** key twice and then press the **enter** key to clear an existing standardization.

9.1.5 Rinse the electrode with reagent water and immerse the rinsed electrode into the first buffer solution while gently stirring the buffer.

9.1.6 Press **std** to access Standardization mode. Wait for the reading to stabilize. Press **std** again to initiate standardization. The meter will automatically recognize the buffer and then return to the Measure screen. Rinse off the electrode with reagent water and gently wipe dry.

9.1.7 Repeat steps 9.1.5-9.1.6 for each of the remaining buffer solutions.

9.1.8 When the three buffers have been standardized, record the slope from the meter. The slope must be 90-102%.

9.1.9 Read each buffer solution used for calibration. Readings should be +/-0.1 pH units from the listed values for the buffer solutions.

9.1.10 Check calibration with a second source pH 7 buffer (ICV). Record the pH. Results must be within +/-0.1 pH units of the true value.

9.1.11 If either of the requirements of steps 9.1.8 or 9.1.9 are not met, repeat the meter calibration using fresh buffers. If either of the requirements are still not met, replace electrode filling solution and clean the electrode or replace the electrode.

9.1.12 Once calibrated, the meter is ready to analyze samples when in the Measure mode.

9.2 Sample Analysis

9.2.1 Place 20g of sample into a 50mL digestion tube and add 20mL of reagent water. Cap the tube and tumble the suspension continuously for 5 minutes. Additional dilutions are allowed for problematic samples.

9.2.2 Filter or centrifuge the sample to separate the aqueous phase.

9.2.3 Decant the aqueous portion of prepared sample or transfer to a disposable beaker.

9.2.4 Immerse the electrode into the sample and stir gently at a constant rate. Record the sample pH to the nearest 0.01 pH units and record the temperature to the nearest ˚C when **STABLE** appears on the screen. For normal use, the pH meter Stability Criteria is set to slow, allowing the highest precision.

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9.2.5 If the pH of the sample exceeds the calibration range (i.e. between 4 and 10), an additional pH buffer solution must be analyzed to confirm the accuracy of the pH meter beyond the calibration range. Results should be within +/-0.1 pH units. If the pH of the additional buffer is not within +/-0.1 pH units, re-standardize the pH meter using buffers that bracket the pH range of the samples and reanalyze the samples.

9.2.6 Measure and record the pH of the calibration source pH 7 buffer (CCV) at the beginning and ending of each analytical sequence and after every 10 samples. Results should be within +/-0.1 pH units. If the pH reading of the CCV is not within +/-0.1 pH units of the true value, repeat the CCV measurement using fresh CCV. If CCV still fails, replace electrode filling solution and clean the electrode or replace the electrode and repeat calibration per Section 9.1. Repeat any samples that are not bracketed by acceptable buffer readings.

9.2.7 Thoroughly rinse and gently blot the electrode between sample measurements. Gently shake off excess water or dab gently with a Kimwipe.

## 10.0 Data Analysis And Calculations

10.1 Calculations

10.1.1 Report sample results directly from meter readings without corrections.

10.1.2 RPD equation:

$$RPD = \frac{|D_1 - D_2|}{[(D_1 + D_2)/2]} * 100$$

Where: RPD = relative percent difference
$D_1$ = first sample result
$D_2$ = second sample result

## 11.0 Quality Control and Method Performance

11.1 Instrument Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration** | pH | Daily | Slope 90-102%<br>Each buffer ±0.10 pH units of the certified value | Repeat calibration using fresh buffer solutions. If calibration still doesn't pass, pH electrode maintenance may be required and may include replacing electrode filling solution, cleaning electrode, or replacing electrode. Samples associated with a failing initial calibration must be re-analyzed. |

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| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Initial Calibration Verification Standard (ICV)** | Second Source Standard | Immediately following initial calibration of the instrument | ±0.10 pH units of the certified value | Reanalyze ICV using fresh buffer solution. If criteria still not met, recalibrate meter. If criteria not met, pH electrode maintenance may be required and may include replacing electrode filling solution, cleaning electrode, or replacing electrode. Samples associated with a failing ICV must be re-analyzed. |
| **Continuing Calibration Standard (CCV)** | pH | Beginning of analytical sequence, every 10 samples, and end of sequence. | ±0.10 pH units of the certified value | Reanalyze CCV using fresh buffer solution. If criteria still not met, recalibrate meter. If criteria not met, pH electrode maintenance may be required and may include replacing electrode filling solution, cleaning electrode, or replacing electrode. Samples associated with a failing CCV must be re-analyzed. |
| **Extended-range low calibration check** | pH 2 buffer | Once per batch if any sample result is below pH 4 | ±0.10 pH units of the certified value | Re-standardize the meter using buffers that bracket the pH range of the sample(s) and reanalyze the sample(s). |
| **Extended-range high calibration check** | pH 12 buffer | Once per batch if any sample result is above pH 10 | ±0.10 pH units of the certified value | Re-standardize the meter using buffers that bracket the pH range of the sample(s) and reanalyze the sample(s). |

11.2 Batch Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Sample Duplicate (DUP)** | Sample | One Sample Duplicate per 10 or fewer samples. | ≤2% RPD | Consult with supervisor to see if another sample should be duplicated, or report samples with the appropriate qualifier. |

11.3 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

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## 12.0 Data Review And Corrective Action

12.1 Data Review

The analyst must perform primary review of data and calculated results for accuracy. Secondary review of the data and calculated results must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 Pollution Prevention And Waste Management

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

## 14.0 Modifications

14.1 Samples are gently stirred during pH measurement.

14.2 Acceptance criteria for ongoing calibration buffers is +/-0.1 standard units based on SM 4500-$H^+$ B recommendations, instead of +/-0.05 standard units recommended in 9045C.

14.3 Buffers are purchased as certified standards.

## 15.0 Responsibilities

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

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## 16.0 ATTACHMENTS

Not applicable to this SOP.

## 17.0 REFERENCES

17.1 "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods"; EPA SW-846, Method 9045C.

17.2 Standard Methods for the Examination of Water and Wastewater, Method 4500-$H^+$ B-2021.

17.3 Orion Star A214 User Manual, Rev.A 0811.

17.4 Accumet AB-15 User Manual, Rev.3 Aug 06.

17.5 Accumet AB150 User Manual, Rev.0 July 2012.

17.6 Pace Analytical Quality Manual; latest revision.

17.7 NELAC/TNI Standards; 2003, 2009, and 2016.

## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 7.1 | Updated for equipment currently in use. |
| 8.2 | Updated to standards currently in use. |
| 9.1.2 | Specified that fresh buffers are to be used daily. |
| 9.2.7 | Added that excess water is removed from electrode. |
| 17.0 | Added pH meters currently in use. Updated to current approved SM 4500-H+ B reference. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0058 | Soil and Waste pH | 03 |

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# Test Method Standard Operating Procedure (SOP): Pace® Analytical Services

| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0043 v04_Flashpoint by SW-846 1010A** |
| | **Effective Date: 10/24/2024** |

**Management Approval:**
Derek Gormon Approved on 10/21/2024 2:54:32 PM
Sarah Potts Approved on 10/23/2024 4:54:02 PM
Steven Sayer Approved on 10/21/2024 1:32:37 PM
Anne Troyer Approved on 10/24/2024 8:15:35 AM

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## 1.0 Scope And Application

This standard operating procedure (SOP) describes the laboratory procedure for the determination of flash point (ignitability) in liquid samples while meeting the requirements specified in EPA method 1010A, Pensky-Martens Closed-Cup Method for Determining Ignitability.

1.1 Flashpoint temperature is used to classify materials as flammable or combustible. Check regulations for precise definitions.

1.2 This procedure is applicable to liquids including those that tend to form a surface film under test conditions. Liquids containing non-filterable, suspended solids shall also be tested using this method. The method has been adapted for the analysis of soils and other solid samples.

1.3 Vendors, instrumentation, equipment, and supplies are subject to change.

## 2.0 Summary of Method

The sample is heated at a slow constant rate while stirring. A small flame is directed into the cup at regular intervals with simultaneous interruption of stirring. The flash point is the lowest temperature at which application of the test flame ignites the vapor above the sample.

## 3.0 Interferences

Not applicable to this SOP.

## 4.0 Definitions

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 Health and Safety

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

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Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Liquid** | 200mL in a glass jar | None required | Cool to ≤6°C<br>Samples should be stored where the temperature is at least 32°F below the expected flashpoint. | None listed in methods |
| **Solid** | 8 oz. in a glass jar | None required | Cool to ≤6°C<br>Samples should be stored where the temperature is at least 32°F below the expected flashpoint. | None listed in methods |

## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| Automated Pensky-Martens closed cup apparatus | Tanaka apm-100 or equivalent. Unit consists of a brass test cup, test cover and shutter, stirring device, heating source, ignition source device, air bath, top plate, thermometer, barometer and operating software. |
| Manual Pensky-Martens closed cup apparatus | Apparatus consists of a brass test cup, test cover and shutter, stirring device, heating source, ignition source device, air bath and top plate. |

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7.2 Supplies

| Supplies | Description |
|---|---|
| Thermometer | ASTM Model 9F or equivalent. Range of 20-230°F, with 1°F increments. Tanaka apm-100 includes a built-in thermometer. |
| Fuel source | Bottled propane |
| Ignition source | Grill lighter or equivalent |
| Barometer | For determining barometric pressure for flashpoint correction. Tanaka apm-100 includes a built-in barometer. |

## 8.0 Reagents And Standards

8.1 Reagents: Not applicable to this SOP.

8.2 Standards

| Standard Type | Description | Expiration | Storage |
|---|---|---|---|
| p-Xylene | Fisher/ catalog # 05082-4 or equivalent | Manufacturer's recommended expiration date | Manufacturer's recommended storage conditions |

## 9.0 Procedure

9.1 Calibration and Standardization

9.1.1 The performance of the flash point apparatus is verified using a standard of p-xylene. The standard is analyzed according to the procedure below and corrected for barometric pressure. The expected flashpoint of this standard is 81°F +/- 2°F.

9.1.2 The thermometer used shall be calibrated against a NIST-traceable thermometer annually. For the automated instrument, the calibration must be repeated if the temperature sensor is changed prior to the annual date.

9.2 Analysis using Manual Apparatus

9.2.1 Sample size should be about 75mL for this procedure. Samples should not be opened until analysis to minimize loss of volatile components that could affect the results.

9.2.2 Prepare the flashpoint apparatus in accordance with manufacturer's instructions.

9.2.3 Make sure all parts of the test cup are clean and dry before proceeding with analysis.

9.2.4 Fill the test cup with sample to the mark inside the cup. The temperature of the test cup and sample should be at least 32°F below the expected flash point. Place the test cover on the test cup and place the assembly into the flashpoint apparatus.

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9.2.5 Insert the thermometer into its holder. Light the test flame and adjust it to a diameter of about 3-5 mm. **Warning**: the analyst should exercise extreme caution when operating this equipment and performing this method. The analyst must monitor gas pressure and use extreme care when working with unknown samples.

9.2.6 Apply heat at such a rate that the temperature increases no more than 9-11°F per minute for liquids or no more than 2-3°F per minute for solids.

9.2.7 For liquid samples, turn the stirring device at 90-120 rpm, stirring in a downward direction. **Do not stir solid samples**.

9.2.8 Discontinue the stirring of the sample, check the thermometer reading, and apply the ignition source when the temperature is at ambient temperature.

9.2.9 Apply the ignition source by operating the mechanism on the test cover which controls the shutter so that the ignition source is lowered into the vapor space of the test cup in 0.5 s, left in its lowered position for 1s, and quickly raised to its upward position.

9.2.10 Resume stirring (liquid samples only) and heat to within 32-50°F of the expected flash point of the sample. Discontinue stirring and apply ignition source. Repeat the application of the ignition source thereafter at temperature increments of 2°F, up to a maximum sample temperature of 200°F.

9.2.11 Record the reading on the thermometer at the time ignition source application causes a distinct flash in the interior of the test cup. This is the observed flashpoint. Do not confuse this flash with the blue halo that sometimes surrounds the test flame shortly before the actual flash.

9.2.12 When a flashpoint is detected on the first application, the test shall be discontinued and the test repeated with a fresh test sample. The first application of the ignition source with the fresh sample shall be at least 32-50°F below the temperature at which the first flash was detected.

9.2.13 When the flashpoint apparatus has cooled to a safe handling temperature, remove the cover and test cup and clean per manufacturer's recommendations.

9.3 Analysis using Automated Apparatus

9.3.1 Liquid Samples

9.3.1.1 Sample size should be about 75mL for this procedure. Samples should not be opened until analysis to minimize loss of volatile components that could affect the results.

9.3.1.2 Prepare the flashpoint apparatus in accordance with manufacturer's instructions.

9.3.1.3 Make sure all parts of the test cup are clean and dry before proceeding with analysis.

9.3.1.4 Allow the instrument to cool.

9.3.1.5 Fill the test cup with a fresh aliquot of the sample.

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9.3.1.6 Set the method to **d93b water F**. Set the **EXP FP** (expected flash point) to 120°F.

*Note: When running the xylene standard, set the EXP FP to 81°F.*

9.3.1.7 Press **START.** Allow instrument to complete the sequence.

9.3.1.8 If no flash is detected, analysis is complete.

9.3.1.9 If a flash is detected allow the instrument to cool to at least 32°F below the temperature of the flash. Repeat steps 9.3.1.6 to 9.3.1.7 with a fresh aliquot of sample, with the EXP FP set to the detected flash temperature.

9.3.2 Solid Samples

9.3.2.1 Sample size should fill the test cup to the line for this procedure. Samples should not be opened until analysis to minimize loss of volatile components that could affect the results.

9.3.2.2 Prepare the flashpoint apparatus in accordance with manufacturer's instructions.

9.3.2.3 Make sure all parts of the test cup are clean and dry before proceeding with analysis.

9.3.2.4 Allow the instrument to cool.

9.3.2.5 Fill the test cup with a fresh aliquot of the sample.

9.3.2.6 Set the method to **d93b soil F**. Set the **EXP FP** (expected flash point) to 120°F.

9.3.2.7 Press **START.** Allow instrument to complete the sequence.

9.3.2.8 If no flash is detected, analysis is complete.

9.3.2.9 If a flash is detected allow the instrument to cool to at least 32°F below the temperature of the flash. Repeat steps 9.3.2.6 to 9.3.2.7 with a fresh aliquot of sample, with the EXP FP set to the detected flash temperature.

## 10.0 Data Analysis And Calculations

10.1 If using the manual Pensky-Martens apparatus, correct flashpoint results for barometric pressure using the following equation:

Corrected flashpoint = F + 0.06(760-P)

Where: F = observed flashpoint in degrees Fahrenheit
P = ambient barometric pressure in mm Hg, not corrected to sea level

10.2 If using the automated apparatus, report the flashpoint temperature obtained directly from the instrument, from the re-analysis in Section 9.3.1.9 or 9.3.2.9.

10.3 Round temperature to nearest whole degree F.

10.4 If no flash point was detected, report as **>200°F** ("greater than" 200 degrees Fahrenheit).

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## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

### 11.1 Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Laboratory Control Sample (LCS)** | p-Xylene | One per batch | 79 - 83°F | If LCS fails it can be repeated. If second LCS fails, consult a supervisor for assistance. |
| **Duplicate** | Sample duplicate | One per batch if any sample has a flash point <200°F | Liquids: +/-5°F<br>Solids: +/-9°F | Repeat sample determination or qualify results appropriately. |

### 11.2 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document acceptable accuracy and precision by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

## 12.0 DATA REVIEW AND CORRECTIVE ACTION

### 12.1 Data Review

The analyst must perform primary review of data and calculated results for accuracy. Secondary review of the data and calculated results must be performed by another qualified analyst, the department supervisor, or the Quality Manager prior to release for reporting. Refer to the SOP for Data Review Process for more information.

### 12.2 Corrective Action

Corrective action is expected any time QC is not within acceptance criteria, when sample results exceed the calibration range, and when carryover is suspected. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

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## 13.0 Pollution Prevention And Waste Management

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

*Note: Mark any sample found to have a flashpoint <140°F for disposal as flammable waste. This includes the portion used for flashpoint testing.*

## 14.0 Modifications

14.1 Procedure A of ASTM D93 is used for all liquids.

14.2 This method has been adapted for the analysis of solids. Procedure A of ASTM D93 is used, except material is not stirred.

## 15.0 Responsibilities

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

## 16.0 Attachments

Not applicable to this SOP.

## 17.0 References

17.1 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods; EPA SW-846, Method 1010A.

17.2 Test Methods for Flash Point by Pensky-Martens Closed Tester, ASTM D93-80 and D93-99c.

17.3 Tanaka Scientific Limited; Model apm-8 Instruction Manual, Rev. 2.00 131203.

17.4 Pace Analytical Quality Manual; latest revision.

17.5 NELAC/TNI Standards; 2003, 2009, and 2016.

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## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| All | Updated for use of new automated instrument. |
| 9.3.1 | Removed optional preliminary screening procedure and directions for reportable analysis based on result of a prescreen. |
| 9.3.2, 14.2 | Updated soil analysis to Procedure A of ASTM D93. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0043 | Flashpoint by 1010A | 03 |

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# Test Method Standard Operating Procedure (SOP): Pace® Analytical Services

| | |
|---|---|
| Pace ANALYTICAL SERVICES | **ENV-SOP-IND1-0055 v02_TCLP by SW-846 1311** |
| | **Effective Date: 04/13/2023** |

**Management Approval:**
Felicia Walker Approved on 4/13/2023 11:47:43 AM
Sarah Potts Approved on 4/13/2023 12:22:02 PM
Steven Sayer Approved on 4/13/2023 11:40:12 AM
Anne Troyer Approved on 4/13/2023 4:05:32 PM

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## 1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide a laboratory specific procedure for extracting organic and inorganic compounds from samples using the Toxicity Characteristic Leaching Procedure (TCLP) as stated in EPA SW-846 Method 1311.

1.1 The TCLP is designed to determine the mobility of organic and inorganic constituents present in liquid, solid and multiphasic wastes. This SOP is applicable for all waste matrices.

1.2 If a total analysis of the waste sample demonstrates that individual analytes are not present or are at such low levels that the regulatory limits will not be exceeded, the TCLP need not be run.

1.3 If the analysis of any liquid fraction of the waste shows analytes of concern at such high concentrations that, even after accounting for dilution from the other fractions of the extract, the concentration would be above the regulatory limit for that compound, then the remaining fractions do not need to be analyzed.

1.4 Extraction using the Zero Headspace Extractor (ZHE) for volatiles is not necessary if an analysis of the bottle extract shows a concentration of a regulated volatile compound above the regulatory limit for a compound. The bottle extract cannot be used to demonstrate that the concentrations of volatile compounds are below regulatory limits.

1.5 Extract resulting from the use of the ZHE shall not be used to evaluate the mobility of nonvolatile analytes (metals, SVOAs, etc.).

1.6 Volumes/weights used, standard concentrations, vendors, instrumentation, equipment and supplies are subject to change.

## 2.0 SUMMARY OF METHOD

2.1 An aliquot of waste sample is tumbled in a sealed vessel containing extraction fluid to leach out compounds of interest from the sample. The leachate is then the sample that is analyzed by the required determinative method.

2.2 Bottle extractors are used for non-volatile analytes and a special ZHE extraction device is used to facilitate extraction of samples for volatile analysis.

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2.3 Liquid wastes, those containing <0.5% solid material, after filtration through a 0.6 to 0.8um glass filter, are defined as the TCLP extract.

2.4 For wastes containing ≥0.5% solids, the liquid portion, if any, is separated from the solid phase and stored for later analysis. The solid phase is extracted with an amount of the appropriate extraction fluid equal to 20 times the weight of the solid phase.

2.5 If compatible, the initial liquid phase and the extracted water from the solid phase are combined and analyzed as one sample. If the wastes are not compatible, they are analyzed separately and results are mathematically combined to give a volume-weighted average concentration.

## 3.0 INTERFERENCES

No significant interferences are listed for the preparation of the TCLP extracts. Potential interferences during analyses are discussed in the individual determinative method SOPs.

## 4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

## 5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handling these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

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## 6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory and data quality objectives for the project.

| Sample type | Collection per sample | Preservation | Storage | Holding time |
|---|---|---|---|---|
| **Solids and Semi-solids** | **Non-volatiles:** >200g preferably in a glass container (to avoid phthalates in SVOA analysis).<br><br>**Volatiles:** >50g in a glass container. | No preservation required. | Cool to ≤6˚C unless refrigeration causes irreversible physical change. | **Volatile:** TCLP extraction within 14 days of collection date and VOA analysis within 14 days of TCLP extraction date.<br><br>**Non-Volatile:** TCLP extraction within 14 days of collection date, SVOA extraction within 7 days of TCLP extraction date SVOA analysis within 40 days of SVOA extraction date.<br><br>**Mercury:** TCLP extraction within 28 days of collection date and Hg analysis within 28 days of TCLP extraction date.<br><br>**Metals:** TCLP extraction within 180 days of collection date and metals analysis within 180 days of TCLP extraction date. |
| **Aqueous and Liquid** | **Non-volatiles:** Minimum 1L preferably in a glass container.<br><br>**Volatiles:** Minimum 1L preferably in a glass container. | No preservation required. | Cool to ≤6˚C unless refrigeration causes irreversible physical change. | **Volatile:** TCLP extraction within 14 days of collection date and VOA analysis within 14 days of TCLP extraction date.<br><br>**Non-Volatile:** TCLP extraction within 14 days of collection date, SVOA extraction within 7 days of TCLP extraction date SVOA analysis within 40 days of SVOA extraction date.<br><br>**Mercury:** TCLP extraction within 28 days of collection date and Hg analysis within 28 days of TCLP extraction date.<br><br>**Metals:** TCLP extraction within 180 days of collection date and metals analysis within 180 days of TCLP extraction date. |

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## 7.0 EQUIPMENT AND SUPPLIES

### 7.1 Equipment

| Equipment | Description / Comments |
|---|---|
| Zero Headspace Extraction (ZHE) vessels | Used for volatile extractions; must have an internal volume of 500-600mL and be equipped to accommodate a 90-110mm filter. ZHEs contain o-rings that should be replaced frequently. The piston within the ZHE should be able to be moved with approx. 15psi or less. Refer to Attachment 1. |
| Bottle Extraction vessels | Used for non-volatile extractions; borosilicate glass bottles of sufficient size to fit into the agitation apparatus. Plastic bottles shall not be used if organics are to be determined. |
| Agitation apparatus | Device capable of rotating the extraction vessels in an end-over-end fashion at 30 ± 2rpm. Refer to Attachment 1. |
| Filtration Device | For non-volatile extractions; the filtration device should have a minimum internal volume of 300mL, be able to accommodate a minimum filter size of 47mm, must be capable of exerting pressures of up to 50psi or more and shall be constructed of inert material. |
| pH meter | Accurate to ± 0.05 units at 25°C |
| Gas-tight syringes | Used for ZHE extract transfer |
| Analytical balance | Accurate to within ± 0.01g |
| Magnetic stirrer | Including stir bars |
| Water Bath | Capable of maintaining water temperature at 50 ± 5°C |
| Thermometer | Capable of recording minimum and maximum temperatures of the room while samples are tumbled |

### 7.2 Supplies

| Supplies | Description |
|---|---|
| Graduated cylinders | Class A, glass, various sizes |
| Filters | Filters shall be made of borosilicate glass fiber, shall contain no binder material, and shall have an effective pore size of 0.6 to 0.8um, or equivalent. |
| Glass vials | 40mL, for ZHE extract collection |
| Tedlar bags (optional) | For ZHE extract collection |
| Plastic cups and lids | 5-oz or equivalent |

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## 8.0 REAGENTS AND STANDARDS

### 8.1 Reagents

| Reagent | Concentration / Description |
|---|---|
| Reagent water | ASTM Type II water or equivalent |
| Hydrochloric acid, HCl | 1N, Fisher item #SA481 reagent grade, or equivalent |
| Sodium Hydroxide, NaOH | 1N, Fisher item #SS266-4 reagent grade, or equivalent |
| Acetic acid, $CH_3COOH$ | Glacial, reagent grade, Fisher, or equivalent |
| Extraction Fluid #1 | Add 5.7mL of glacial acetic acid to 500mL of reagent water then add 64.3mL of 1N sodium hydroxide and dilute to 1L with reagent water. **When correctly prepared, the pH of this fluid will be 4.93 ± 0.05. The pH should be checked prior to use. If the pH is not 4.93 ± 0.05, the fluid shall be discarded and fresh extraction fluid prepared. Expires 6 months from preparation date.** |
| Extraction Fluid #2 | Dilute 5.7mL of glacial acetic acid to 1L with reagent water. **When correctly prepared, the pH of this fluid will be 2.88 ± 0.05. The pH should be checked prior to use. If the pH is not 2.88 ± 0.05, the fluid shall be discarded and fresh extraction fluid prepared. Expires 6 months from preparation date.** |

### 8.2 Standards

| Reagent | Concentration / Description |
|---|---|
| pH 2 Calibration Buffer | Fisher #SB96-1, or equivalent |
| pH 4 Calibration Buffer | Fisher #SB101-4, or equivalent |
| pH 7 Calibration Buffer | Fisher #SB107-4, or equivalent |
| pH 10 Calibration Buffer | Fisher #SB115-4, or equivalent |
| pH 12 Calibration Buffer | Ricca #1615.3-2, or equivalent |
| pH 7 ICV Buffer | Ricca #1551.4-1, or equivalent |

## 9.0 PROCEDURE

### 9.1 Preliminary Evaluations

Preliminary evaluations must be made on a 100g aliquot of the waste sample. If a minimum of 100g of sample is not available, the client must be contacted for their consent to perform the extraction using less than 100g. Before the extraction can proceed, the client must return a signed copy of the TCLP Deficiency Release, as seen in Attachment III.

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Preliminary evaluations include determination of the percent solids of the sample; determination of whether the waste sample contains insignificant solids and is therefore its own TCLP extract after filtration; determination if there is a need for particle size reduction; and determination of which of the two extraction fluids are required when non-volatile TCLP is requested. Refer to Attachment II for additional information.

Refer to the Sample Homogenization, Subsampling, and Compositing SOP for guidelines to obtain a well-mixed sample portion for all preliminary evaluations, and for TCLP extraction.

9.1.1 Percent Solids Determination

If the waste will obviously yield no liquid when subjected to pressure filtration, indicating that the waste is 100% solids, then skip to Section 9.1.2.

If the sample is a liquid or is multiphasic, separation to make a preliminary determination of percent solids is required. Filter the sample as follows, and record all measurements in the *TCLP Percent Solids and Add-back Calculations* spreadsheet. See Attachment V.

9.1.1.1 Pre-weigh the filter to be used and the container that will collect the filtrate.

9.1.1.2 Assemble the filtering device per manufacturer's specifications and place the filter on the support screen.

9.1.1.3 Weigh out a well-mixed subsample of the waste, 100g minimum, by recording initial and final sample container weights per the *TCLP Percent Solids and Add-back Calculations* spreadsheet. The spreadsheet will calculate the exact weight used.

9.1.1.4 Allow slurries to stand to permit the solid phase to settle.

9.1.1.5 If using pressure filtration, quantitatively transfer the sample to the filtration device. Spread the sample evenly over the surface of the filter. Begin applying gentle vacuum or pressure to the filtration device of 1-10psi until air or pressurized gas moves through the filter. If air does not pass through the filter or if no additional liquid comes through in a 2-minute period, slowly increase the pressure in 10psi increments to a maximum of 50psi until liquid flow has ceased.

**NOTE:** If >1% of the sample material has adhered to the container used to transfer the sample to the filtration apparatus, determine the weight of this residue and subtract it from the sample weight determined in Section 9.1.1.3.

9.1.1.6 The material in the filter holder is defined as the solid phase of the waste and the filtrate is defined as the liquid phase.

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**NOTE:** Some samples such as oily wastes and some paint wastes, will obviously contain some material that appears to be a liquid, but even after applying vacuum or pressure filtration, this material may not filter. In this case, the material within the filtration device is defined as the solid. Do not replace the original filter with a new filter under any circumstances. Use only one filter.

9.1.1.7 Determine the weight of the liquid phase by subtracting the weight of the filtrate container from the total weight of the filtrate-filled container. Determine the weight of the solid phase by subtracting the weight of the liquid phase from the total weight of sample used. Record the weight of the liquid and solid phases and calculate the percent solids as follows:

$$Percent\ solids = \frac{weight\ of\ solid\ phase}{total\ weight\ of\ sample} \times 100$$

**NOTE:** The *TCLP Percent Solids and Add-back Calculation* spreadsheet will automatically calculate these values. See Attachment V.

9.1.1.8 If the percent solids determined in Section 9.1.1.7 is ≥0.5%, then proceed either to Section 9.1.2 to determine if the material requires particle size reduction or to Section 9.1.1.10 if it is noticed that an amount of the filtrate is entrained in wetting of the filter.

9.1.1.9 If the percent solids determined in Section 9.1.1.7 is <0.5%, then the filtered sample is defined as the TCLP extract. If non-volatile TCLP is to be performed, filter adequate sample volume for all requested analyses, then proceed to Section 9.2.10. If volatile TCLP is to be performed proceed to Section 9.3 with a fresh portion of the waste.

9.1.1.10 If it appears that the filtrate is entrained in wetting of the filter and the calculated percent solids is between 0.5% – 2%, determine the percent dry solids. Remove the solid phase and filter from the filtration apparatus and place them into an oven located in a fume hood. Dry the solid phase and filter at 100 ± 20°C. Cool filter to room temperature, then record the final weight. Calculate the percent dry solids as follows:

$$Percent\ dry\ solids = \frac{(weight\ of\ dry\ waste + filter) - tared\ wt.\ of\ filter}{Initial\ weight\ of\ waste} \times 100$$

**NOTE:** The *TCLP Percent Solids and Add-back Calculation* spreadsheet will automatically calculate this value.

Repeat step 9.1.1.10 a second time if calculated dry solids is still greater than 0.5% on a second, separate spreadsheet with the sample number and “(2)” designation.

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9.1.1.11 If the percent dry solids determined is <0.5%, then the filtered sample is defined as the TCLP extract. If non-volatile TCLP is to be performed, filter adequate sample volume for all requested analyses, then proceed to Section 9.2.10. If volatile TCLP is to be performed proceed to Section 9.3 with a fresh portion of the waste.

9.1.1.12 If the percent dry solids are ≥0.5%, and if non-volatile TCLP is to be performed, proceed to the Section 9.1.2 with a fresh portion of waste. If only volatile TCLP is to be performed, proceed to Section 9.3 with a fresh portion of the waste.

9.1.2 Particle Size Reduction Determination

This is required unless the solid portion of the sample is capable of passing through a minimum 9.5mm sieve or is smaller than 1 cm in its narrowest dimension. If it will not pass through, the sample must be ground, crushed or cut until it will pass through. Contact PM if particle reduction cannot be done in-house.

9.1.3 Extraction Fluid Determination for Non-Volatile TCLP

For determining pH, refer to ENV-SOP-IND1-0030 *pH by SM 4500-H⁺ B* or its replacement. The pH meter must be calibrated to bracket the range of use according to the SOP or manufacturer's instructions each day of use.

The same 100g sample portion used for percent solids determination can be used for the extraction fluid determination process and the extraction process if the sample is not 100% solid.

For non-volatile TCLP, the following steps are used to determine the appropriate fluid:

9.1.3.1 If the sample was found to have greater >0.5% solids, weigh out a 5g aliquot of the solid phase of the waste into a plastic cup.

9.1.3.2 Add 96.5mL of reagent water to the cup and stir for 5 minutes using a magnetic stirrer. Determine the pH and record it on the TCLP bench sheet (See Attachment IV). If the pH is <5.0, use extraction fluid #1. Proceed to Section 9.2.

9.1.3.3 If the pH is >5.0, add 3.5mL of 1N HCl, stir briefly and cover with a plastic lid. Heat without stirring in water bath to 50 ± 5°C and hold at 50 ± 5°C for 10 minutes.

9.1.3.4 Let the solution cool to room temperature in an ice bath for approximately 10 minutes. Determine the pH and record it on the TCLP bench sheet. If the pH is <5.0, use extraction fluid #1. If the pH is >5.0, use extraction fluid #2. Proceed to Section 9.2.

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9.2 Extraction Procedure for Non-volatile Analysis

9.2.1 A minimum sample size of 100g (solid + liquid phases) is recommended. In some cases, a larger sample size may be appropriate, depending on solids content of the waste sample, whether the initial liquid phase of the waste will be miscible with the aqueous extract of the solid, and whether inorganics and organics are analytes of concern. Enough solids should be generated for extraction such that the volume of TCLP extract will be sufficient to support all of the analyses required. If the amount of extract generated by a single TCLP extraction is insufficient, additional extractions may be performed and the extracts from each combined and aliquoted for analysis. Refer to Attachment II for additional information.

9.2.2 If the waste will obviously yield no liquid when subjected to pressure filtration, indicating that the waste is 100% solids, transfer a minimum 100g well-mixed aliquot of the waste directly into an extractor bottle and proceed to Section 9.2.4.

9.2.3 If the sample is liquid or multiphasic, separation is required per the filtration procedure described in Section 9.1.1. Transfer the solid material resulting from the filtration procedure, including the filter, into the bottle extractor and proceed to Section 9.2.4. Refer to Section 9.2.9 regarding handling of the filtrate.

9.2.4 Determine the amount of extraction fluid to add to the extraction vessel as follows:

$$Weight\ of\ extraction\ fluid = \frac{20\ x\ percent\ solids\ x\ unfiltered\ sample\ weight}{100}$$

Use the *TCLP Percent Solids Determination and Add-back* spreadsheet to complete this calculation. See Attachment V.

9.2.5 Slowly add this amount of the appropriate extraction fluid to the extractor bottle. Close the bottle tightly with a lid.

9.2.6 Secure the sealed extractor bottle in the agitation device and rotate at 30 ± 2 rpm for 18 ± 2 hours. The temperature of the room where TCLP extractions are performed shall be maintained at 23 ± 2°C during the extraction period.

**NOTE:** As agitation continues, pressure may build up within the extractor bottle. To relieve excess pressure, the extractor bottle may be periodically opened and vented into a hood.

9.2.7 Following the 18 ± 2 hours tumble, record the min/max temperatures of the room during the entire tumbling period on the TCLP bench sheet (See Attachment IV). Separate the material in the extractor bottle by filtration, using a clean glass filter. More than one filter may be used to facilitate final filtering of the TCLP extract, if necessary. Filters shall be acid rinsed with 1N nitric acid if metals are to be determined, or use an acid pre-washed filter from supplier.

9.2.8 If the original waste contained no liquid, then the tumbled and filtered extract is defined as the TCLP extract.

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9.2.9 If the original waste contained an initial liquid phase that is compatible to mix with the tumbled extract, combine the liquid extract resulting from Section 9.2.7 with the initial liquid phase of the waste obtained in Section 9.2.3. Use the *TCLP Percent Solids Determination and Add-back Calculation* spreadsheet to determine amounts of each liquid to combine. This combined liquid is then defined as the TCLP extract. If the two liquid fractions are not compatible, analyze the two fractions separately and combine their results mathematically using the equation in Section 9.2.13.

9.2.10 Following collection of the TCLP extract, the pH of the extract should be determined and recorded on the TCLP bench sheet. Refer to ENV-SOP-IND1-0030 *pH by SM 4500-$H^+$ B* or its replacement for pH determination procedures. The pH meter must be calibrated to bracket the range of use according to the SOP or manufacturer's instructions each day of use.

9.2.11 Fill labeled containers appropriate for the analyses requested (pre-preserved if applicable) with TCLP extract. An aliquot for metals analysis may be stored at room temperature in the metals lab until digestion takes place. All other aliquots must be stored under refrigeration until analyzed. The TCLP extract shall be prepared and analyzed according to the appropriate analytical method.

9.2.12 TCLP extracts to be analyzed for metals must undergo acid digestion, unless the analysis of the undigested aliquot produces results for metallic analytes above the regulatory limits. Data on undigested extracts alone cannot be used to demonstrate that the waste is not hazardous.

9.2.13 If the individual phases are to be analyzed separately, determine the volume of the individual phases (to ± 0.5%), conduct the appropriate analysis, and combine the results mathematically by using a simple volume-weighted average:

$$\text{Final analyte concentration} = \frac{(V1)\,(C1) + (V2)\,(C2)}{V1 + V2}$$

Where: V1 = The volume of the first phase, L
C1 = The concentration of the analyte of concern in the first phase, mg/L
V2 = The volume of the second phase, L
C2 = The concentration of the analyte of concern in the second phase, mg/L

9.2.14 Transfer all documentation from the TCLP bench sheet into the electronic TCLP logbook. Autopost logbook into Epic.

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9.3 Extraction Procedure for Volatile Analysis

9.3.1 Use the ZHE device to obtain the TCLP extract for analysis of volatile compounds. The ZHE device has approximately a 500mL internal capacity and can accommodate a maximum of 25g of solid. Charge the ZHE with sample only once and do not open the device until the final extract has been collected. Repeated filling of the ZHE to obtain 25g of solid is not permitted. Do not allow the waste, the initial liquid phase, or the extract to be exposed to the atmosphere for any more time than is absolutely necessary. Any manipulation of these materials should be done when cold to minimize loss of volatiles.

9.3.2 All samples for TCLP Volatiles analysis must be prepared by means of extraction and/or filtration through the ZHE apparatus. Refer to Attachment II for additional information.

9.3.3 See 9.1.2 for particle size reduction if solids are not capable of passing through a minimum 9.5mm sieve. If reduction of the waste is necessary, exposure of the waste to the atmosphere should be avoided to the extent possible. Sieving of the waste is not recommended due to the possibility that volatiles may be lost.

9.3.4 Pre-weigh the filtrate collection container and set aside.

9.3.5 Before use each ZHE extractor must be pressure tested. Fully assemble each ZHE extractor without the piston and charge to 50psi. The ZHE vessel must maintain pressure at 50psi for one hour in order to be suitable for use.

9.3.6 Place the ZHE piston within the body of the ZHE to a height that minimizes the distance the piston must move once the ZHE is charged with sample. Secure the glass fiber filter between the support screens and set aside.

9.3.7 If the waste is 100% solids, weigh out a well-mixed subsample of a maximum of 25g. Record the weight and proceed to Section 9.3.9.

9.3.8 If the waste contains <0.5% solids, the liquid portion of the waste, after filtration, is defined as the TCLP extract. Follow the procedure described in Sections 9.3.10 – 9.3.13 to filter enough of the sample so that the amount of filtered liquid will support all of the volatile analyses required. Then proceed to Section 9.3.20.

9.3.9 For wastes containing ≥0.5% solids, use the percent solids information obtained in Section 9.1.1 to determine the optimum sample size to charge into the ZHE. The recommended sample size is as follows:

9.3.9.1 For wastes containing <5% solids, weigh out a well-mixed 500g subsample of waste and record the weight on the TCLP bench sheet (See Attachment IV).

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9.3.9.2 For wastes containing >5% solids, determine the amount of waste to charge into the ZHE as follows:

$$\text{Weight of waste to charge ZHE} = \frac{25}{\text{Percent Solids}} \times 100$$

9.3.9.3 Weigh out a well-mixed subsample of the waste of the appropriate size and record the weight on the TCLP bench sheet.

9.3.10 Quantitatively transfer the entire sample, liquid and solid phases, quickly to the ZHE. Secure the filter and support screens then secure the top flange. Carefully tighten all ZHE fittings by hand; over-tightening can break fittings.

9.3.11 Attach the gas line to the gas inlet/outlet valve on the bottom flange making sure the liquid inlet/outlet valve on the top flange is CLOSED. Begin applying gentle pressure of 1-10psi (or more if necessary to a maximum of 50psi). In a fume hood, slowly open the valve to force all headspace slowly out of the ZHE. At the first appearance of liquid from the liquid inlet/outlet valve, quickly close the valve and discontinue pressure.

9.3.12 If the waste sample in the ZHE contains a liquid phase, record the weight of an empty filtrate collection container on the *TCLP Percent Solids Determination and Add-back Calculation* spreadsheet. Attach the container to the liquid inlet/outlet valve and open the valve. Begin applying gentle pressure of 1-10psi to ZHE. Attach the container to the liquid inlet/outlet valve and slowly open the valve. The pressure will force the liquid phase of the sample into the filtrate collection container. If no additional liquid has passed through the filter in any 2-minute period, slowly increase the pressure in 10psi increments to a maximum of 50 psi until liquid flow has ceased. Close the liquid inlet/outlet valve, discontinue pressure to the piston and disconnect and weigh the filtrate collection container.

9.3.13 The material in the ZHE is defined as the solid phase of the waste and the filtrate, if any, is defined as the liquid phase. If the original waste contained <0.5% solids, the filtrate is defined as the TCLP extract and is analyzed directly. The liquid phase may now be either analyzed immediately or refrigerated under minimal headspace conditions until the time of analysis.

9.3.14 Determine the weight of extraction fluid #1 to add to the ZHE as follows:

$$\text{Weight of extraction fluid \#1} = 20 \times \frac{\text{percent solids} \times \text{weight of waste filtered}}{100}$$

Use the *TCLP Percent Solids Determination and Add-back Calculation* spreadsheet to complete this calculation. See Attachment V.

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9.3.15 With the ZHE in the vertical position, release gas pressure on the ZHE piston and deliver the appropriate amount of extraction fluid #1 into the ZHE through the liquid inlet/outlet valve. Once the extraction fluid has been added, immediately close the liquid inlet/outlet valve. Check the ZHE to ensure that all valves are closed. Manually rotate the ZHE in an end-over-end fashion 2 or 3 times. With the ZHE in the vertical position, pressurize the ZHE to 5-10psi. Place the ZHE in a fume hood and slowly open the liquid inlet/outlet valve to bleed off any headspace. Close the valve at the first appearance of liquid from the valve. Re-pressurize the ZHE with 5-10 psi and check all ZHE fittings to ensure that they are closed. Record an initial pressure in the electronic TCLP logbook.

9.3.16 Place the ZHE in the agitation apparatus and rotate the ZHE for 18 ± 2 hours at 30 ± 2 rpm. Temperature of the room where tumbling occurs shall be maintained at 23 ± 2°C.

9.3.17 Following the 18 ± 2 hours agitation period, record the min/max temperatures of the room during the entire tumbling period on the TCLP bench sheet (See Attachment IV). Record the final pressure on the ZHE in the electronic TCLP logbook. If no pressure has been maintained (pressure gauge reads zero) and no gas release is noted, perform the extraction again with a new aliquot of waste.

9.3.18 Filter the extract through the glass fiber filter using the ZHE device as discussed in Section 9.3.12. All extract should be filtered and collected if the extract is multiphasic or if the waste contained an initial liquid phase. If the original waste contained no initial liquid phase, the filtrate is defined as the TCLP extract. If the waste contained an initial liquid phase, the filtrate and the initial liquid phase are collectively defined as the TCLP extract.

9.3.19 Following collection of the TCLP extract, immediately prepare the extract for analysis and store refrigerated with minimal headspace. If the individual phases are to be analyzed separately, determine the volume of the individual phases, conduct the analysis and combine the results mathematically using the equation shown in Section 9.2.13.

9.3.20 Transfer all documentation from the TCLP bench sheet into the electronic TCLP logbook. Autopost logbook into Epic.

## 10.0 DATA ANALYSIS AND CALCULATIONS

Refer to calculations in Section 9.

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## 11.0 QUALITY CONTROL AND METHOD PERFORMANCE

11.1 Quality Control

| QA Sample | Component | Frequency | Acceptance Criteria | Corrective Action |
|---|---|---|---|---|
| **Extraction (Tumble) Blank** | Extraction fluid | **Volatile ZHE Vessel:** Minimum of 1 blank per 20 extractions per extraction vessel unless a tumble blank is required per batch by program/client.<br>**Non-Volatile Glass Vessel:** Minimum of 1 blank per 20 extractions per reusable glass extraction vessel unless a tumble blank is required per batch by program/client.<br>**Disposable Glass/Plastic Vessels:** Minimum of 1 blank per lot number received. | Target analytes must be less than reporting limits. | Re-tumble associated samples if blank result is >RL. If sample cannot be re-tumbled, blank and samples must be qualified.<br>**Exception:** If blank result is >RL but associated sample(s) are ND, no action is required. |

11.2 The required rotation speed of the agitation device is 30 ± 2rpm. The rotation speed is checked monthly and recorded on a monitoring sheet. A supervisor should be alerted if the rotation speed is unacceptable and corrective actions must be taken.

11.3 The minimum room temperature and maximum room temperature over the duration of each tumbling event is recorded. If the room temperature exceeds the required 23 ± 2°C, samples tumbled during that event must be qualified (T9) or re-prepared and re-tumbled.

11.4 Analyst Qualifications and Training

Employees that perform this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must document proficiency by completing an initial demonstration of capability (DOC). Analysts must document on-going DOCs on an annual basis.

## 12.0 CORRECTIVE ACTION

Refer to Section 11 for a complete summary of QC, acceptance criteria, and recommended corrective actions.

## 13.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Procedures for handling waste generated during this analysis are addressed in Waste Handling and Management, or other applicable SOP. All wastes are accumulated, managed, and disposed of in accordance with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

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## 14.0 MODIFICATIONS

Not applicable to this SOP.

## 15.0 RESPONSIBILITIES

Pace employees that perform any part of this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP. If an employee is unable to follow the procedures in this SOP, they must consult with their supervisor for guidance.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

## 16.0 ATTACHMENTS

16.1 Attachment I: Diagram of agitation apparatus and ZHE apparatus

16.2 Attachment II: TCLP Preliminary Evaluations Flow Diagram

16.3 Attachment III: TCLP Deficiency Release Form

16.4 Attachment IV: Examples TCLP Preparation Bench Sheets

16.5 Attachment V: TCLP Percent Solids and Add-back Calculation spreadsheet

## 17.0 REFERENCES

17.1 “Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,” SW-846 Method 1311, Toxicity Characteristic Leaching Procedure, 3rd edition, December 1996.

17.2 Pace Analytical Quality Manual; latest revision.

17.3 NELAC/TNI Standards; Quality Systems section; 2003, 2009 and 2016.

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## 18.0 REVISION HISTORY

This Version:

| Section | Description of Change |
|---|---|
| 1.5 | Added statement that sample prepared by ZHE cannot be used to analyze for non-volatile components. |
| 6.0 | Corrected SPLP typos in hold time column. |
| 9.1.1.3 | Added use of TCLP Percent Solids and Add-Back Calculation spreadsheet. |
| 9.1.1.9; 9.1.1.11 | Clarified that filtered sample is TCLP extract when solids/dry solids <0.5% and corrected section number for next step in non-volatile prep. |
| 9.1.1.10 | Added cooling filter to room temp prior to weighing. |
| 9.1.2 | Added that PM is contacted if particle-size reduction cannot be done in-house. |
| 9.1.3.4 | Added approximate cooling time. |
| 9.2.7; 9.3.17 | Changed 16-20 hours to 18+/- 2 hours for consistency. |
| 9.2.10 | Added reference to pH SOP. |
| 9.2.11 | Expanded description of containers used for extract. |
| 9.2.14; 9.3.20 | Added description of recordkeeping process. |
| 9.3.8 | Clarified sections to follow when solids <0.5%. |
| 9.3.10-9.3.12 | Added details to filtration steps for clarity and for current process. |
| 17.3 | Added reference to 2016 TNI Standard. |
| Att. III, IV | Updated examples to forms currently in use. |

This document supersedes the following document(s):

| Document Number | Title | Version |
|---|---|---|
| ENV-SOP-IND1-0055 | Toxicity Characteristic Leaching Procedure (TCLP) | 01 |

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## Attachment I: Diagram of Agitation Apparatus and ZHE Apparatus

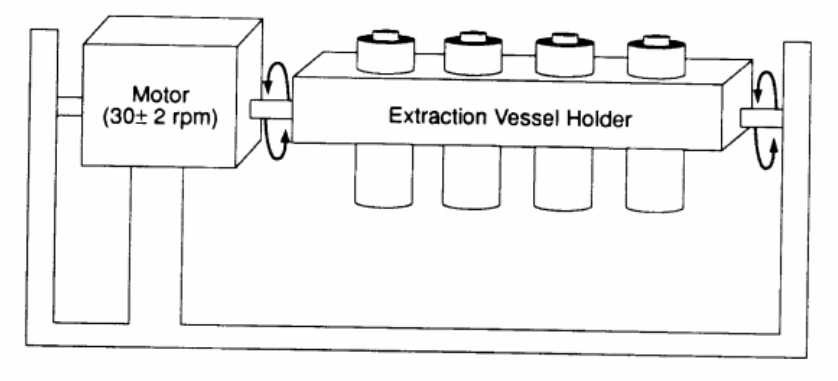


Figure 1. Rotary Agitation Apparatus

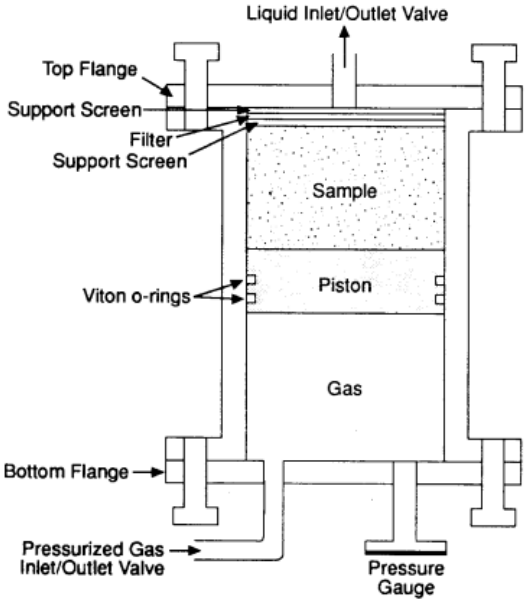


Figure 2. Zero-Headspace Extractor (ZHE)

CD-ROM 1311- 33 Revision 0
July 1992

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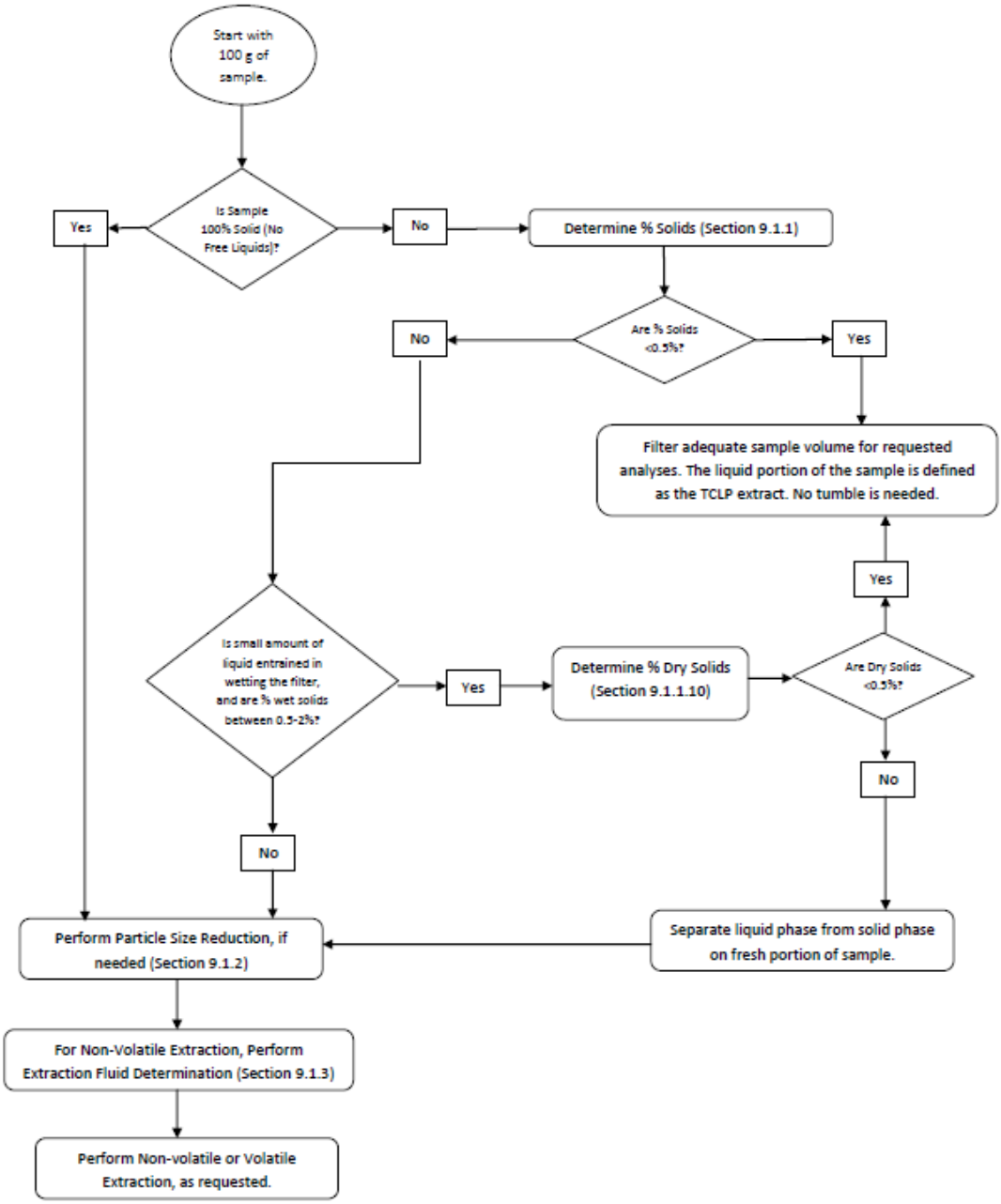
## Attachment II: TCLP Preliminary Evaluations Flow Diagram

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## Attachment III: TCLP Deficiency Release Form

*Pace Analytical Services, LLC*
***7726 Moller Road***
***Indianapolis, IN 46268***
***Phone: 317-228-3100***
*Fax: 317-872-6189*

### TCLP DEFICIENCY RELEASE

DATE:

TO:

RE: NOTE OF TCLP DEFICIENCY

This memo is in notice of a deficiency in the TCLP extraction for the sample identified:

**PROJECT#** **LAB#:**

**CLIENT ID:**

In accordance with the TCLP Method 1311, the required weight to be used with a sample is 100 grams. The sample identified above does not have sufficient weight to comply with this requirement. In order to proceed with the TCLP extraction, your written approval is needed. The sample will then be processed with a reduced weight and the extraction fluid volume adjusted accordingly.

Test method compliance would not be met, and data may be qualified if the method volume requirement is not adhered to.

Should your decision be to provide additional sample for extraction, please contact your customer service representative to request containers, evaluate holding time constraints, or specify turnaround time needs.

Thank you.

Approval to proceed with TCLP extraction using reduced weight has been granted by:

**Signature:** _____

**Name (Print):** _____

**Date:** _____

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# Attachment IV: Examples TCLP Preparation Bench Sheets

Analyst _____ Pace Analytical Services - Indianapolis Batch _____

Date_____ Benchsheet HBN _____

TCLP(1311) ☐ SPLP (1312) ☐ Neutral Leachates (ASTM D3987-12) ☐

| Sample ID | Analysis | Filtered? If yes, refer to % solids sprdsht for details | % Solids * | Size Reduction? | Passed Sieve? 1 mm | Passed Sieve? 9.5 mm | Fluid determ. weight (g) | Initial pH | Adj. pH | Fluid Solution pH**/ Solution ID | Extracted Sample (g) | Buffer Solution (mL) | Extract Filtered (mL) | Aq Add back (mL) | Final pH | Glass/ Plastic Vessel ID or Lot # | Client/ Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |
| | Metals | Yes | | Yes | Yes | Yes | | | | | | | | | | | |
| | SVOA | No | | No | No | No | | | | | | | | | | | |

*If < 0.5% solid, sample is not tumbled. Proceed to final pH column. **Check daily before use.

Start Date/Time _____ Stop Date /Time_____ Total Hours Tumbled_____ Final Filtration Date_____ 1N HCl ID_____

pH Meter: **50MET: 1 2 6 7** Balance ID: **SC-34 and SC-23** Water Bath Thermometer:_____ Room Therm.:_____ Corrected R.T. *Min*_____ *Max*_____

0.7um Flipmate ID _____ Cup ID _____ 125mm ID_____ 150mm ID_____ 500mL Glass Bottle ID _____ 1L Glass Bottle ID _____ Tumbler ID _____

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Analyst _____ Pace Analytical Services - Indianapolis Batch _____

Date_____ Benchsheet HBN _____

TCLP(1311)☐ SPLP (1312)☐ Neutral Leachates (ASTM D3987-12)☐

| Sample ID | Analysis | Filtered? If yes, refer to % solids sprdsht for details | * % Solids | Size Reduction? | Passed Sieve? 9.5 mm | Fluid Solution pH**/ Solution ID | Extracted Sample (g) | Buffer Solution (mL) | Extract Filtered (mL) | Aq. Addback (mL) | ZHE Vessel ID | Client/ Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |
| | ZHE | Yes No | | Yes No | Yes No | | | | | | | |

*If < 0.5% solid, sample is not tumbled. **Check daily before use.

Start Date/Time _____ Stop Date /Time_____ Total Hours Tumbled_____ Final Filtration Date_____

pH Meter: **50MET: 1 2 6 7** Balance ID: **SC-34 and SC-23** Room Thermometer: _____ Corrected R.T. *Min*_____ *Max*_____

90mm ID_____ 40mL Vial ID _____ Tumbler ID _____

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## Attachment V: TCLP Percent Solids and Add-back Calculation spreadsheet

| Pace Analytical | 7726 Moller Road<br>Indianapolis, IN 46268 | Document Name:<br>TCLP Percent Solids Determination and Add-back Calculation | Date Revised:<br>January 21, 2020 |
|---|---|---|---|
| | | Document Number:<br>F-IN-M-441-rev.02 | Issuing Authority:<br>Pace Indianapolis Quality Department |

Analyst
Date
EPIC sample #
Client name
Batch #
HBN #

**Percent Solids Determination:**

| | | | |
|---|---|---|---|
| A. container 1 + sample (g) | | g | (container with sample) |
| B. container 1 (g) | | g | |
| C. filter (g) | | g | |
| D. sample used (g) | 0.000 | g | [ A - B ] |
| E. container 2 (g) | | g | (container to hold filtrate) |
| F. container 2 + filtrate (g) | | g | |
| G. filtrate (g) [=initial liquid phase] | 0.000 | g | [ F - E ] |
| H. wet solids (g) | 0.000 | g | [ D - G ] |
| I. % solids (wet) | #DIV/0! | % | [ (H/D)*100 ] |
| J. % liquid | #DIV/0! | % | [ 100 - I ] |

if <0.5%, no tumble is required. <-----

STOP - Proceed only if wet solids are between 0.5% - 2%.

| | | | |
|---|---|---|---|
| C. filter (g) | 0.000 | g | |
| K. dry solids + filter (g) | | g | |
| L. dry solids (g) | 0.000 | g | [ K - C ] |
| M. % solids (dry) | #DIV/0! | % | [ (L/D)*100 ] |
| N. % liquid | #DIV/0! | % | [ 100 - M ] |

if <0.5%, no tumble is required. <-----

**Filtrate Add-back Calculations (if compatible):**

| | | | | |
|---|---|---|---|---|
| O. solids tumbled (g) | | g | | |
| P. extraction fluid added (ml) | 0.000 | ml | [ O *20 ] | |
| Q. amount of initial liquid phase to add back to tumbled TCLP extract (g) | #DIV/0! | g | [ (O*G)/H ] | (weight of initial liquid phase (G) added to the tumbled TCLP extract if all tumbled TCLP extract is to be filtered) |
| R. actual amount of tumbled TCLP extract filtered (ml) | | mL | | |
| S. amount of initial liquid phase to add back to tumbled TCLP extract (g) | #DIV/0! | g | [ (R*Q)/P ] | (weight of initial liquid phase (G) added to the amount of tumbled TCLP extract filtered (R) |

**TCLP ZHE Filtration:**

| | | | |
|---|---|---|---|
| 1. wt of 40ml vial | | g | |
| 2. wt of sample used | | g | (25g minimum) |
| 3. wt of 40ml vial + filtrate | | g | |
| 4. filtrate in vial | 0 | g | [step 3. - step 1.] |
| 5. solid in ZHE vessel | 0 | g | [step 2. - step 4.] |
| 6. amt ext fl #1 to use | 0 | ml | [step 5. x 20] |

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# Data Quality Objective:
# Biosparge Well Performance Testing

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) Biosparge Well Performance Testing

.

1. State the Problem
   Biosparge wells are designed for a flow rate of 7.5 standard cubic feet per minute (scfm) and may be operated at up to 15 scfm, if warranted, based upon biosparge system monitoring. It is necessary to demonstrate that air can be sparged through the biosparge wells before they are connected to the biosparge system. Otherwise, if a biosparge well cannot perform, substantial work would be required to replace the well.

2. Identify the Goals of the Project
   Demonstrate that each biosparge well functions properly before it is connected to the sparge system.

3. Identify Information Inputs
   Information inputs include the depth of the biosparge well and the depth to water.

4. Define the Boundaries of the Study
   All of the biosparge wells shall be tested.

5. Develop the Analytic Approach
   Calculate the theoretical breakthrough pressure.
   a. Measure sparge well depth to water (DTW) and depth to bottom (DTB).
   b. Calculate the breakthrough pressure, BP = (DTB – DTW) / 2.31 ft water / pounds per square inch (psi)
   c. Sparge pressure limit is 3 x BP.
   d. Example:
      i. Measure DTW = 18 ft and DTB = 60 ft
      ii. Calculate BP = (60 ft – 18 ft) / 2.31 ft/psi = 18.2 psi
      iii. Three times the theoretical breakthrough pressure = 3 x 18.2 psi = 54.6 psi.

6. Specify Performance or Acceptance Criteria
   Sparge 15 scfm through a sparge well for a period of no more than 15 minutes with the final sparge pressure not exceeding 3 times the theoretical breakthrough pressure.

7. Develop the Plan for Obtaining Data
   The drilling contractor shall terminate the sparge well one foot above grade and equipped with a 2-inch Sch. 80 PVC female adapter (secured using PVC primer and glue) and a threaded PVC plug.

   Data shall be obtained in accordance with the Construction Quality Assurance and Quality Control Plan (CQA/CP).

   An air compressor with a minimum capacity of 20 scfm continuously at a pressure exceeding 100 psi will be used as the source of compressed air. A pressure and flow metering pipe spool consisting of a coalescing filter, orifice plate flowmeter, regulator, valves, hoses, and gauges with a 2-inch male thread outlet will be connected to the sparge well. A pressure gauge will be present at the top of the sparge well (downstream of the regulator); this is where the sparge pressure will be recorded. The air compressor will be connected to the pressure and flow metering pipe spool.

The compressor will be started with the valves to the sparge well closed. The regulator will be confirmed to be closed and then the valves will be opened. The regulator will be slowly adjusted to increase the pressure up to three times the theoretical breakthrough pressure. When flow initiates the regulator adjustment will slow. The regulator will be adjusted so that 15 scfm is sparged over a period of no more than 15 minutes. Adjustments may need to continue to be made to the regulator over this time. The final sparge well pressure after 15 minutes shall be recorded to confirm it is less than three times the theoretical breakthrough pressure. Test data shall be documented on Form 1 – Sparge Well Testing Form.

.

(2) Supporting Documentation

.

| List of Tables | List of Forms |
|---|---|
| Table 1 – Sparge Well Design Parameters | Sparge Well Testing Form |

.

## Table 1

## Sparge Well Design Parameters

# Table 1 - Sparge Well Design Parameters

1500 South Tibbs LLC

May 16, 2025

| Sparge Well | Well Spacing (feet) | Total Distance (feet) | GW Elevation (ft ASL) | Bottom of Screen (ft ASL) | Saturated Thickness (feet) | Radius of Influence (feet) | Min. Depth to Bottom (ft BGS) |
|---|---|---|---|---|---|---|---|
| OU1 North of Minnesota Avenue (Oak Park Property) | | | | | | | |
| SP- 1 | 0 | 0 | 683.60 | 644.00 | 39.60 | 29.57 | 59 |
| SP- 2 | 41.4 | 41.4 | 683.56 | 644.00 | 39.56 | 29.53 | 59 |
| SP- 3 | 41.3 | 82.7 | 683.51 | 644.00 | 39.51 | 29.50 | 59 |
| SP- 4 | 41.3 | 124.0 | 683.47 | 644.00 | 39.47 | 29.47 | 59 |
| SP- 5 | 41.3 | 165.3 | 683.42 | 645.20 | 38.22 | 28.54 | 58 |
| SP- 6 | 40.0 | 205.3 | 683.38 | 646.40 | 36.98 | 27.61 | 57 |
| SP- 7 | 38.7 | 243.9 | 683.33 | 647.60 | 35.73 | 26.68 | 55 |
| SP- 8 | 37.4 | 281.3 | 683.29 | 648.80 | 34.49 | 25.75 | 54 |
| SP- 9 | 36.1 | 317.3 | 683.25 | 650.00 | 33.25 | 24.82 | 53 |
| SP- 10 | 34.8 | 352.1 | 683.20 | 651.20 | 32.00 | 23.89 | 52 |
| SP- 11 | 33.5 | 385.5 | 683.16 | 652.40 | 30.76 | 22.97 | 51 |
| SP- 12 | 32.2 | 417.7 | 683.11 | 653.60 | 29.51 | 22.04 | 49 |
| SP- 13 | 30.9 | 448.5 | 683.07 | 654.80 | 28.27 | 21.11 | 48 |
| SP- 14 | 29.6 | 478.1 | 683.02 | 656.00 | 27.02 | 20.18 | 47 |
| SP- 15 | 28.2 | 506.3 | 682.98 | 655.33 | 27.65 | 20.64 | 48 |
| SP- 16 | 28.9 | 535.2 | 682.94 | 654.67 | 28.27 | 21.11 | 48 |
| SP- 17 | 29.6 | 564.8 | 682.89 | 654.00 | 28.89 | 21.57 | 49 |
| SP- 18 | 30.2 | 595.0 | 682.85 | 653.33 | 29.51 | 22.04 | 50 |
| SP- 19 | 30.9 | 625.8 | 682.80 | 652.67 | 30.14 | 22.50 | 50 |
| SP- 20 | 31.5 | 657.3 | 682.76 | 652.00 | 30.76 | 22.97 | 51 |
| SP- 21 | 32.2 | 689.5 | 682.71 | 651.50 | 31.21 | 23.31 | 52 |
| SP- 22 | 32.6 | 722.1 | 682.67 | 651.00 | 31.67 | 23.65 | 52 |
| SP- 23 | 33.1 | 755.2 | 682.63 | 650.50 | 32.13 | 23.99 | 53 |
| SP- 24 | 33.6 | 788.8 | 682.58 | 650.00 | 32.58 | 24.33 | 53 |
| SP- 25 | 34.1 | 822.9 | 682.54 | 649.50 | 33.04 | 24.67 | 54 |
| SP- 26 | 34.5 | 857.4 | 682.49 | 649.00 | 33.49 | 25.01 | 54 |
| SP- 27 | 35.0 | 892.4 | 682.45 | 648.50 | 33.95 | 25.35 | 55 |
| SP- 28 | 35.5 | 927.9 | 682.40 | 648.00 | 34.40 | 25.69 | 55 |
| SP- 29 | 36.0 | 963.9 | 682.36 | 647.50 | 34.86 | 26.03 | 56 |
| SP- 30 | 36.4 | 1000.3 | 682.32 | 647.00 | 35.32 | 26.37 | 56 |
| SP- 31 | 36.9 | 1037.2 | 682.27 | 646.50 | 35.77 | 26.71 | 57 |
| SP- 32 | 37.4 | 1074.6 | 682.23 | 646.00 | 36.23 | 27.05 | 57 |
| SP- 33 | 37.9 | 1112.5 | 682.18 | 645.50 | 36.68 | 27.39 | 58 |
| SP- 34 | 38.3 | 1150.8 | 682.14 | 645.00 | 37.14 | 27.73 | 58 |
| SP- 35 | 38.8 | 1189.6 | 682.09 | 644.67 | 37.43 | 27.95 | 58 |
| SP- 36 | 39.1 | 1228.8 | 682.05 | 644.33 | 37.72 | 28.16 | 59 |
| SP- 37 | 39.4 | 1268.2 | 682.01 | 644.00 | 38.01 | 28.38 | 59 |
| SP- 38 | 39.7 | 1307.9 | 681.96 | 643.67 | 38.29 | 28.59 | 59 |

| Sparge Well | Well Spacing (feet) | Total Distance (feet) | GW Elevation (ft ASL) | Bottom of Screen (ft ASL) | Saturated Thickness (feet) | Radius of Influence (feet) | Min. Depth to Bottom (ft BGS) |
|---|---|---|---|---|---|---|---|
| OU1 South of Minnesota Avenue (Maywood Property) | | | | | | | |
| SP- 39 | 80.0 | 1387.9 | 681.92 | 643.33 | 38.58 | 28.81 | 60 |
| SP- 40 | 40.3 | 1428.3 | 681.87 | 643.00 | 38.87 | 29.03 | 60 |
| SP- 41 | 40.6 | 1468.9 | 681.83 | 642.67 | 39.16 | 29.24 | 60 |
| SP- 42 | 40.9 | 1509.8 | 681.78 | 642.33 | 39.45 | 29.46 | 61 |
| SP- 43 | 41.2 | 1551.1 | 681.74 | 642.00 | 39.74 | 29.67 | 61 |
| SP- 44 | 41.5 | 1592.6 | 681.70 | 642.20 | 39.50 | 29.49 | 61 |
| SP- 45 | 41.3 | 1633.9 | 681.65 | 642.40 | 39.25 | 29.31 | 61 |
| SP- 46 | 41.0 | 1674.9 | 681.61 | 642.60 | 39.01 | 29.13 | 60 |
| SP- 47 | 40.8 | 1715.7 | 681.56 | 642.80 | 38.76 | 28.94 | 60 |
| SP- 48 | 40.5 | 1756.2 | 681.52 | 643.00 | 38.52 | 28.76 | 60 |
| SP- 49 | 40.3 | 1796.5 | 681.47 | 643.20 | 38.27 | 28.58 | 60 |
| SP- 50 | 40.0 | 1836.5 | 681.43 | 643.40 | 38.03 | 28.40 | 60 |
| SP- 51 | 39.8 | 1876.3 | 681.39 | 643.60 | 37.79 | 28.21 | 59 |
| SP- 52 | 39.5 | 1915.8 | 681.34 | 643.80 | 37.54 | 28.03 | 59 |
| SP- 53 | 39.2 | 1955.0 | 681.30 | 644.00 | 37.30 | 27.85 | 59 |
| SP- 54 | 39.0 | 1994.0 | 681.25 | 644.00 | 37.25 | 27.82 | 59 |
| SP- 55 | 38.9 | 2032.9 | 681.21 | 644.00 | 37.21 | 27.78 | 59 |
| SP- 56 | 38.9 | 2071.8 | 681.16 | 644.00 | 37.16 | 27.75 | 59 |
| SP- 57 | 38.8 | 2110.7 | 681.12 | 644.00 | 37.12 | 27.72 | 59 |
| SP- 58 | 38.8 | 2149.5 | 681.08 | 644.00 | 37.08 | 27.68 | 59 |
| SP- 59 | 38.8 | 2188.2 | 681.03 | 644.00 | 37.03 | 27.65 | 59 |
| SP- 60 | 38.7 | 2226.9 | 680.99 | 644.00 | 36.99 | 27.62 | 59 |
| SP- 61 | 38.7 | 2265.6 | 680.94 | 644.00 | 36.94 | 27.58 | 59 |
| SP- 62 | 38.6 | 2304.2 | 680.90 | 644.00 | 36.90 | 27.55 | 59 |
| SP- 63 | 38.6 | 2342.8 | 680.85 | 644.00 | 36.85 | 27.52 | 59 |
| SP- 64 | 38.5 | 2381.3 | 680.81 | 644.00 | 36.81 | 27.48 | 59 |
| SP- 65 | 38.5 | 2419.8 | 680.77 | 644.00 | 36.77 | 27.45 | 59 |
| SP- 66 | 38.4 | 2458.2 | 680.72 | 644.00 | 36.72 | 27.42 | 59 |
| SP- 67 | 38.4 | 2496.6 | 680.68 | 644.00 | 36.68 | 27.39 | 59 |
| SP- 68 | 38.3 | 2535.0 | 680.63 | 644.00 | 36.63 | 27.35 | 59 |
| SP- 69 | 38.3 | 2573.2 | 680.59 | 644.00 | 36.59 | 27.32 | 59 |
| SP- 70 | 38.2 | 2611.5 | 680.54 | 644.00 | 36.54 | 27.29 | 59 |
| SP- 71 | 38.2 | 2649.7 | 680.50 | 644.00 | 36.50 | 27.25 | 59 |
| SP- 72 | 38.2 | 2687.9 | 680.46 | 644.00 | 36.46 | 27.22 | 59 |
| SP- 73 | 38.1 | 2726.0 | 680.41 | 644.00 | 36.41 | 27.19 | 59 |
| Radius of Influence / Saturated Thickness = | | | | | | 1.4 | |
| Factor of Safety | | | | | | 1.875 (=1.5 x 1.25) | |
| Radius of Influence / Saturated Thickness Used = | | | | | | 0.75 | |

## Sparge Well Testing Form

# Sparge Well Testing Form

1500 South Tibbs LLC

May 16, 2025

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Depth to Water | DTW | | feet |
| Depth to Bottom | DTB | | feet |
| Difference in Depth | DTB - DTW | | feet |
| Caculated Breakthrough Pressure | BP | | psi |
| BP = (DTB - DTW) / 2.31 | | | |
| Sparge Pressure Limit ($P_L$ = BP x 3) | $P_L$ | | psi |
| Test Flow Rate | Q | 15 | scfm |
| Sparge Pressure after 15 minutes | P | | psi |
| Is P ≤ $P_L$ | Yes / No | | |

If Yes, then PASS. If No, then clean / redevelop well and retest.

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Depth to Water | DTW | | feet |
| Depth to Bottom | DTB | | feet |
| Difference in Depth | DTB - DTW | | feet |
| Caculated Breakthrough Pressure | BP | | psi |
| BP = (DTB - DTW) / 2.31 | | | |
| Sparge Pressure Limit ($P_L$ = BP x 3) | $P_L$ | | psi |
| Test Flow Rate | Q | 15 | scfm |
| Sparge Pressure after 15 minutes | P | | psi |
| Is P ≤ $P_L$ | Yes / No | | |

If Yes, then PASS. If No, then clean / redevelop well and retest.

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Depth to Water | DTW | | feet |
| Depth to Bottom | DTB | | feet |
| Difference in Depth | DTB - DTW | | feet |
| Caculated Breakthrough Pressure | BP | | psi |
| BP = (DTB - DTW) / 2.31 | | | |
| Sparge Pressure Limit ($P_L$ = BP x 3) | $P_L$ | | psi |
| Test Flow Rate | Q | 15 | scfm |
| Sparge Pressure after 15 minutes | P | | psi |
| Is P ≤ $P_L$ | Yes / No | | |

If Yes, then PASS. If No, then clean / redevelop well and retest.

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Depth to Water | DTW | | feet |
| Depth to Bottom | DTB | | feet |
| Difference in Depth | DTB - DTW | | feet |
| Caculated Breakthrough Pressure | BP | | psi |
| BP = (DTB - DTW) / 2.31 | | | |
| Sparge Pressure Limit ($P_L$ = BP x 3) | $P_L$ | | psi |
| Test Flow Rate | Q | 15 | scfm |
| Sparge Pressure after 15 minutes | P | | psi |
| Is P ≤ $P_L$ | Yes / No | | |

If Yes, then PASS. If No, then clean / redevelop well and retest.

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Sparge Well ID | SP- | | |
| Depth to Water | DTW | | feet |
| Depth to Bottom | DTB | | feet |
| Difference in Depth | DTB - DTW | | feet |
| Caculated Breakthrough Pressure | BP | | psi |
| BP = (DTB - DTW) / 2.31 | | | |
| Sparge Pressure Limit ($P_L$ = BP x 3) | $P_L$ | | psi |
| Test Flow Rate | Q | 15 | scfm |
| Sparge Pressure after 15 minutes | P | | psi |
| Is P ≤ $P_L$ | Yes / No | | |

If Yes, then PASS. If No, then clean / redevelop well and retest.

# Data Quality Objective:
# Biosparge Pipe Pressure Testing

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

## (1) Biosparge Pipe Pressure Testing

1. State the Problem
   Leaks in the compressed air system will reduce the amount of air that can be sparged. Therefore, leaks are not acceptable. While each compressed air system is designed for 10 scfm of leaks, buried piping needs to be tested to confirm it is not leaking since such leaks would not be able to be easily identified and repaired during and following construction.
2. Identify the Goals of the Project
   Document the absence of buried piping compressed air leaks.
3. Identify Information Inputs
   Compressed air starting pressure and final pressure.
4. Define the Boundaries of the Study
   Buried piping to each of the biosparge wells and for each of the 12 spare biosparge pipes shall be pressure tested.
5. Develop the Analytic Approach
   Subtract the starting pressure from the final pressure measured after a period of 15 minutes.
6. Specify Performance or Acceptance Criteria
   Starting Pressure – Final Pressure ≤ 2 psi
7. Develop the Plan for Obtaining Data
   a. Close the compressed air supply valve at the sparge well.
   b. Connect the compressed air source to the other end of the HDPE piping that is exposed above ground.
   c. Pressurize the piping to 100 psi and close an isolation valve between the compressed air source and HDPE piping. The pressure gauge must be located between the isolation valve and the sparge well.
   d. After 10 minutes record the starting pressure (this may be slightly less than 100 psi depending upon the expansion of the HDPE pipe and other factors).
   e. After another 15 minutes record the final pressure.
   f. Test data shall be documented on the Pipe Pressure Testing Form in the Construction Quality Assurance and Quality Control Plan (CQA/CP).

## (2) Supporting Documentation

List of Forms
Pipe Pressure Testing Form

## Pipe Pressure Testing Form

# Pipe Pressure Testing Form

1500 South Tibbs LLC

May 16, 2025

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Pipe end location | | | |
| Pipe end location | | | |
| Pipe material tested | | | |
| Pipe distance (estimated) | | | feet |
| Pipe initial pressure | $P_0$ | | psi |
| Starting Time | | | (hr:min) |
| Pipe pressure after 10 minutes | $P_{10}$ | | psi |
| Time | | | (hr:min) |
| Pipe pressure after 25 minutes | $P_{25}$ | | psi |
| Finish Time | | | (hr:min) |
| Pressure drop | $\Delta P = P_{25} - P_{10}$ | | psi |

If $\Delta P \leq 2$ psi, then PASS. If No, then identify leak, repair, and retest.

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Pipe end location | | | |
| Pipe end location | | | |
| Pipe material tested | | | |
| Pipe distance (estimated) | | | feet |
| Pipe initial pressure | $P_0$ | | psi |
| Starting Time | | | (hr:min) |
| Pipe pressure after 10 minutes | $P_{10}$ | | psi |
| Time | | | (hr:min) |
| Pipe pressure after 25 minutes | $P_{25}$ | | psi |
| Finish Time | | | (hr:min) |
| Pressure drop | $\Delta P = P_{25} - P_{10}$ | | psi |

If $\Delta P \leq 2$ psi, then PASS. If No, then identify leak, repair, and retest.

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Pipe end location | | | |
| Pipe end location | | | |
| Pipe material tested | | | |
| Pipe distance (estimated) | | | feet |
| Pipe initial pressure | $P_0$ | | psi |
| Starting Time | | | (hr:min) |
| Pipe pressure after 10 minutes | $P_{10}$ | | psi |
| Time | | | (hr:min) |
| Pipe pressure after 25 minutes | $P_{25}$ | | psi |
| Finish Time | | | (hr:min) |
| Pressure drop | $\Delta P = P_{25} - P_{10}$ | | psi |

If $\Delta P \leq 2$ psi, then PASS. If No, then identify leak, repair, and retest.

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Pipe end location | | | |
| Pipe end location | | | |
| Pipe material tested | | | |
| Pipe distance (estimated) | | | feet |
| Pipe initial pressure | $P_0$ | | psi |
| Starting Time | | | (hr:min) |
| Pipe pressure after 10 minutes | $P_{10}$ | | psi |
| Time | | | (hr:min) |
| Pipe pressure after 25 minutes | $P_{25}$ | | psi |
| Finish Time | | | (hr:min) |
| Pressure drop | $\Delta P = P_{25} - P_{10}$ | | psi |

If $\Delta P \leq 2$ psi, then PASS. If No, then identify leak, repair, and retest.

| | | | |
|---|---|---|---|
| Date | | | |
| Name | | | |
| Pipe end location | | | |
| Pipe end location | | | |
| Pipe material tested | | | |
| Pipe distance (estimated) | | | feet |
| Pipe initial pressure | $P_0$ | | psi |
| Starting Time | | | (hr:min) |
| Pipe pressure after 10 minutes | $P_{10}$ | | psi |
| Time | | | (hr:min) |
| Pipe pressure after 25 minutes | $P_{25}$ | | psi |
| Finish Time | | | (hr:min) |
| Pressure drop | $\Delta P = P_{25} - P_{10}$ | | psi |

If $\Delta P \leq 2$ psi, then PASS. If No, then identify leak, repair, and retest.

# Data Quality Objective:
# Proper Biosparge System Operation

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) Proper Biosparge System Operation

.

1. State the Problem
   How to determine that the biosparge system is operating properly.

2. Identify the Goals of the Project
   Operate the biosparge system effectively to achieve the Remedial Action Objectives (RAOs) while benzene and ammonia soil gas and air concentrations are less than screening levels.

3. Identify Information Inputs
   Groundwater and soil gas monitoring data resulting from the implementation of the Site-Wide Monitoring Plan (SWMP), Field Sampling Plan (FSP), and Quality Assurance Project Plan (QAPP).

   Biosparge system operational pulse schedule and completed biosparge system operation and maintenance forms from the Operation and Maintenance Manual (OMM). Biosparge O&M forms from the OMM, including remote monitoring data.

4. Define the Boundaries of the Study
   Each compressed air system (Oak Park Property and Maywood Property), biosparge wells, and interconnecting piping, valves, and appurtenances. OU1 and OU5 groundwater and soil gas monitoring locations.

5. Develop the Analytic Approach
   Groundwater data will be compared to the remedial goals (RGs) of benzene ≤ 5 µg/L, each pyridine ≤ 35 µg/L, and ammonia ≤ 30 mg/L.

   Soil gas and indoor air levels of benzene and ammonia will be compared to screening levels.

| Compound of Concern | Location | Residential Screening Level (µg/m³) | Commercial Screening Level (µg/m³) |
|---|---|---|---|
| Benzene | Indoor Air<br>Soil Gas | 4<br>100 | 20<br>500 |
| Pyridines | Laboratory analysis of pyridine vapors is not available at Pace Analytical who analyzes all the pyridine derivatives in groundwater. Pyridine does not have an IDEM nor EPA screening level. Benzene has a vapor pressure 4.6 times higher than pyridine (Lide 1995) and the Henry's Law constant indicates benzene is more than 400 times more removable from groundwater than pyridines (NIST 2000). To the extent any volatilization occurs, benzene is much more likely to be volatilized than pyridines. Therefore, pyridine vapors will not be monitored. | | |
| Ammonia | Indoor Air<br>Soil Gas | 500<br>20,000 | 2,000<br>70,000 |

| | |
|---|---|
| | Ammonia was evaluated by the EPA Vapor Intrusion Screening Level (VISL) calculator (EPA 2020a and b). Input values included a target risk of $10^{-5}$, target hazard quotient of 1, residential exposure, chronic RfC, and a groundwater temperature of 20˚C. The resulting target groundwater concentration is 898 mg/L that exceeds existing groundwater concentrations. |

Notes:
1. Sub-slab and deep (>5 ft below ground surface) soil gas (collectively "Soil Gas") levels are calculated using an attenuation factor of 0.03.
2. Both the EPA vapor intrusion screening levels (VISLs) and IDEM screening levels (SLs) are identical to one significant figure. While EPA VISLs are published to three significant figures, the EPA VISL frequently asked question (FAQ) #11 states that EPA recommends using one significant figure.

Review of biosparge system operation and maintenance data.

6. Specify Performance or Acceptance Criteria

Groundwater concentration ≤ RGs or trending downward to achieve the RAOs.

Benzene levels in soil gas below the applicable screening level.

Air compressor operation uptime as needed to operate the biosparging wells needed to achieve the RAOs.

Operation of biosparge wells at a pulse schedule (on/off intervals) and minimum 7.5 scfm flow rate necessary to achieve the RAOs.

Equipment maintenance at intervals recommended by the manufacturer.

7. Develop the Plan for Obtaining Data

Data will be collected in accordance with the SWMP, FSP, and QAPP. In addition, if the groundwater monitoring and/or soil gas monitoring contingency plan contained within the Remedial Action Work Plan (RAWP) are/is triggered, then data will also be collected in accordance with those contingency plans.

Data will also be collected in accordance with the Operation and Maintenance Plan (OMP) and Operation and Maintenance Manual (OMM).

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# Data Quality Objective:
# Biosparge System Optimization via Dissolved Oxygen Monitoring

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) Biosparge System Optimization via Dissolved Oxygen Monitoring

.

1. State the Problem
   Biosparging will increase the dissolved oxygen within the radius of influence. After biosparging ceases, the dissolved oxygen will decrease due to microbial activity that degrades benzene and pyridine. Bioremediation of these hydrocarbons occurs best in an aerobic environment where the dissolved oxygen (DO) is ≥ 2 milligrams per liter (mg/L; ppm) as evidenced by on-site sparge pilot testing. The geology from one sparge well to the other may vary and, as such, the biosparge air flow rate may need to be adjusted or the pulse cycle (period of time the biosparge well is on) may need to be changed from well to well so that an aerobic environment is present while the biosparge well is operating. Therefore, measuring the DO is important to optimizing the biosparge system.

2. Identify the Goals of the Project
   Create an aerobic environment within the biosparge well radius of influence while the biosparge well is operating.

3. Identify Information Inputs
   Information inputs include the biosparge well flow rate and the DO level in the monitoring well or point that is located within the theoretical biosparge well radius of influence.

4. Define the Boundaries of the Study
   Monitoring locations and the associated nearby biosparge wells are presented in the following table.

| Property | Monitoring Locations | Nearby Sparge Wells |
|---|---|---|
| Oak Park Property (North of Minnesota St. | MP-1S and MP-1D | SP-3 and SP-4 |
| | MP-3S and MP-3D | SP-8 and SP-9 |
| | MP-5S and MP-5D | SP-19 and SP-20 |
| | MP-7S and MP-7D | SP-27 and SP-28 |
| | MP-9S and MP-9D | SP-34 and SP-35 |
| | TP-1D, TP-2D, TP-3D, TP-4S, TP-6S, TP-7D, TP-8D and TP-9D | SP-32, SP-33, SP-34, SP-35, and SP-36 |
| Maywood Property (South of Minnesota St.) | MP-12S and MP-12D | SP-46 and SP-47 |
| | MP-14S and MP-14D | SP-57 and SP-58 |
| | MP-16S and MP-16D | SP-63 and SP-64 |

   .

5. Develop the Analytic Approach
   Compare the measured DO level to an aerobic environment.

6. Specify Performance or Acceptance Criteria
   DO ≥ 2 mg/L within the radius of influence from an adjacent operating biosparge well that has been operating for at least 4 hours.

7. Develop the Plan for Obtaining Data
   a. Procure a dissolved oxygen meter with a probe that can fit down a 2-inch diameter PVC well. The probe may need to extend 30 feet below grade at shallow locations and 60 feet below grade at deep locations to

be within the screen interval. Therefore it is recommended that at least 70 feet of cable be connected to the probe.

b. Calibrate the dissolved oxygen meter in accordance with manufacturer specifications.
c. Deploy the calibrated dissolved oxygen meter probe down the monitored point or well into the groundwater screen interval.
d. Slowly lift and lower the probe by approximately 2 inches and observe the DO reading.
e. Record the value after the DO has stabilized.
f. The DO should be ≥2 mg/L at the monitoring location if it is within the anticipated radius of influence of the adjacent operating biosparge well and after the well has been operating for 4 hours.
g. If the DO <2 mg/L, then increase the sparge flow rate, pulse cycle (i.e. ON duration), or by turning on another nearby sparge well and repeat measurements after sufficient time has passed to affect the groundwater. During pilot testing this time period was approximately 2-4 hours.

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# Data Quality Objective:
# Soil Gas Vapor Intrusion Evaluation

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) Soil Gas Vapor Intrusion Evaluation

.

1. State the Problem
   Biosparging may liberate benzene vapors into the soil gas. Soil gas sampling is planned to determine the presence or absence of benzene and, if present, the concentration. Sparge system adjustments, the installation of additional vapor monitoring points (VMPs), sub-slab monitoring, and/or indoor air monitoring may be needed to delineate a benzene vapor plume and/or to prove that concentrations are not above screening levels.

2. Identify the Goals of the Project
   Confirm that the soil gas to vapor intrusion pathway to sensitive receptors including neighboring homes and businesses is incomplete.

3. Identify Information Inputs
   Data collected in accordance with the Site-Wide Monitoring Plan (SWMP), Field Sampling Plan (FSP), and Quality Assurance Project Plan (QAPP). This may consist of soil gas data, sub-slab soil gas data, indoor air data, and ambient air data.

4. Define the Boundaries of the Study
   Soil gas measurements will be collected at VMP-1S, VMP-1D, VMP-2S, VMP-2D, VMP-3S, VMP-3D, VMP-4S, VMP-4D, VMP-5S, VMP-5D, VMP-6S, VMP-6D, VMP-7S, VMP-7D, VMP-8S, VMP-8D, VMP-9S, VMP-9D, VMP-10S, VMP-10D, VMP-11S, VMP-11D, VMP-12S, and VMP-12D. If additional VMPs are installed, then they will be included with the study. Any results from sub-slab soil gas monitoring, indoor air monitoring, and ambient air monitoring will also be included.

   As described in the Remedial Action Work Plan (RAWP), benzene and ammonia screening levels will be used.

   Laboratory analysis of pyridine vapors is not available at Pace Analytical who analyzes the pyridine derivatives in groundwater. Pyridine does not have an IDEM nor EPA screening level. Benzene has a vapor pressure 4.6 times higher than pyridine (Lide 1995) and the Henry's Law constant indicates benzene is more than 400 times more removable from groundwater than pyridines (NIST 2000). To the extent any volatilization occurs, benzene is much more likely to be volatilized than pyridines. Therefore, pyridine vapors will not be monitored.

5. Develop the Analytic Approach
   Compare sampling results to screening levels.

| Compound of Concern | Location | Residential Screening Level (µg/m³) | Commercial Screening Level (µg/m³) |
|---|---|---|---|
| Benzene | Indoor Air<br>Soil Gas | 4<br>100 | 20<br>500 |
| Ammonia | Indoor Air<br>Soil Gas | 500<br>20,000 | 2,000<br>70,000 |

Notes:
1. Sub-slab and deep (>5 ft below ground surface) soil gas (collectively "Soil Gas") levels are calculated using an attenuation factor of 0.03.
2. Both the EPA vapor intrusion screening levels (VISLs) and IDEM screening levels (SLs) are identical to one significant figure. While EPA VISLs are published to three significant figures, the EPA VISL frequently asked question (FAQ) #11 states that EPA recommends using one significant figure.

Regulatory screening levels published in the Indiana Department of Environmental Management (IDEM) Risk Based Closure Guide (RBCG) dated July 8, 2022 (IDEM 2022), Table 1 effective March 28, 2025 (IDEM 2025) use a total hazard quotient of 1 and target risk level of $10^{-5}$. IDEM screening levels are published using one significant figure. OSWER Publication 9200.2-154 dated June 2015 named Technical Guidance for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (EPA 2015b) allows use of the same hazard quotient of 1 and target risk level of $10^{-5}$ (this is the mid-point of EPA's risk range). USEPA Regional Screening Levels for ambient air dated November 2024 for resident and composite worker (i.e. commercial) use more significant figures. However, EPA recommends using one significant figure as published in the EPA vapor intrusion screening levels (VISL) frequently asked question (FAQ) #11.

The 24 VMPs are planned to be >5 feet below ground surface.

The soil gas and indoor air laboratory reporting limit for benzene identified in the QAPP is 0.6389 µg/m$^3$ which is below the identified screening levels. The soil gas and indoor air laboratory reporting limits for ammonia identified in the QAPP are a maximum of 5,000 and 300 µg/m$^3$, respectively.

.

6. Specify Performance or Acceptance Criteria
Soil gas and/or indoor air levels ≤ benzene and ammonia screening levels.

7. Develop the Plan for Obtaining Data
Data will be collected in accordance with the SWMP, FSP, and QAPP. In addition, if the soil gas monitoring contingency plan contained within the Remedial Action Work Plan (RAWP) is triggered, then data will also be collected in accordance with that contingency plan.

.

# Data Quality Objective:
# Cessation of Groundwater Pumping

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) Cessation of Groundwater Pumping

.

1. State the Problem
   Shutdown of the existing groundwater extraction well pumps at PW-1S, PW-1D, and PW-2S will be allowed once biosparging is shown to be effective (USA 2024). The method of proving that biosparging is effective needs to be determined so that groundwater pumping can cease.

2. Identify the Goals of the Project
   Prove that biosparging is effective so that the pumps in groundwater pumping wells (PW-1S, PW-1D, and PW-2S) can be turned off and removed from service.

3. Identify Information Inputs
   Groundwater and soil gas monitoring data resulting from the implementation of the Site-Wide Monitoring Plan (SWMP), Field Sampling Plan (FSP), and Quality Assurance Project Plan (QAPP).

   Dissolved oxygen data collected as described in the data quality objective for biosparge system optimization via dissolved oxygen monitoring.

4. Define the Boundaries of the Study
   Benzene and pyridine groundwater data from groundwater monitoring wells, groundwater monitoring points, and temporary groundwater monitoring points within, or very close to, the design radius of influence of the sparging wells.

| Property | Monitoring Locations | Nearby Sparge Wells | Nearby Pumping Well |
|---|---|---|---|
| Oak Park Property (North of Minnesota St. | MP-1S and MP-1D | SP-3 and SP-4 | PW-2S |
| | MP-3S and MP-3D | SP-8 and SP-9 | |
| | MP-5S and MP-5D | SP-19 and SP-20 | |
| | MP-7S and MP-7D | SP-27 and SP-28 | |
| | MP-9S and MP-9D | SP-34 and SP-35 | PW-1S and PW-1D |
| | TP-1D, TP-2D, TP-3D, TP-4S, TP-6S, TP-7D, TP-8D and TP-9D | SP-32, SP-33, SP-34, SP-35, and SP-36 | |
| Maywood Property (South of Minnesota St.) | PW-1S and PW-1D | SP-41, SP-42, and SP-43 | |
| | MP-12S and MP-12D | SP-46 and SP-47 | |
| | MP-14S and MP-14D | SP-57 and SP-58 | |
| | MP-16S and MP-16D | SP-63 and SP-64 | |

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5. Develop the Analytic Approach
   Benzene and pyridines half-lives in groundwater were determined to be 25 and 52 days, respectively, from on-site pilot testing activities.

   Data collected from groundwater sampling will be used to calculate the half-lives:
   - First order rate decay equation: $C = C_0 e^{-kt}$, where: C = final concentration (mg/L), $C_0$ = starting concentration (mg/L), t = time (days between sampling events), and k = rate decay constant (1/days; calculated by rearranging the equation: $k = - \ln(C/C_0)/t$ ).

- Half-life equation: $t_{1/2} = -\ln(C/C_0)/k$ where $t_{1/2}$ = half-life (days; calculated) and $C/C_0 = 0.5$

Data will be compared to the remedial goals (RGs) of benzene ≤ 5 µg/L and each pyridine ≤ 35 µg/L. Ammonia levels are already ≤ 30 mg/L.

Data collected from groundwater sampling will be used to demonstrate treatment within the biosparging radius of influence.

- Calculate k using two groundwater sampling events, the time between the events, and the first order rate decay equation ($k = -\ln(C/C_0)/t$).
- Determine the treatment time: $t = L / V \times R_f$, where: t = treatment time (days; calculated), L = the 30 foot minimum overlap distance of adjacent radii of influence (i.e. minimum treatment distance = 30 ft), V = groundwater velocity with no on-site pumping and consistent withdrawals at Rolls-Royce Plant 8 which was determined in the 2019 hydrogeologic modeling to be 0.133 and 0.135 feet per day (ft/day) for shallow and deep wells, respectively, near Minnesota St. and Tibbs Ave. (RI-4 area) and 0.169 and 0.157 ft/day for shallow and deep wells, respectively, near Environmental Rd. and Tibbs Ave. (RI-6 area), and $R_f$ = retardation factors of 1.07 for benzene and 1.36 for pyridines. The following table summarizes the treatment times (t).

| Location | Benzene Treatment Time (days) | Pyridine Treatment Time (days) |
|---|---|---|
| RI-4 area | | |
| Shallow | 241 | 307 |
| Deep | 238 | 302 |
| RI-6 area | | |
| Shallow | 190 | 241 |
| Deep | 204 | 260 |

- Using the RGs (5 µg/L benzene and 35 µg/L each pyridine) as the final concentration (C), then calculate the maximum untreated concentration ($C_0$) using the rearranged first order rate decay equation: $C_0 = C / e^{-kt}$, where t = treatment time (days, from above table). If the maximum untreated concentration exceeds the starting concentration (prior to sparging), then treatment will be successful. If not, then optimize the biosparge system.

For example: Benzene is measured to be 75 µg/L at MP-9D prior to starting the biosparging system and after 120 days of biosparging the concentration is measured to be 15 µg/L.

- $k = -\ln(15/75)/120 = 0.0134$ / days
- Benzene half-life $C_{1/2} = -\ln(0.5)/0.0134 = 52$ days (greater than 25 days)
- Calculate maximum untreated concentration $C_0 = 5 / e^{-(0.0134 \times 241)} = 126$ µg/L
- Since 126 µg/L ≥ 75 µg/L, then biosparging treatment will be successful.

6. Specify Performance or Acceptance Criteria

The biosparge system shall be determined to be operating properly in groundwater.

The biosparge system will be deemed to be operating properly for benzene and pyridines in groundwater once either:

- two consecutive calculations (between three data points) demonstrate half-lives less than or equal to the design (benzene $t_{1/2} \leq 25$ days and pyridines $t_{1/2} \leq 52$ days),
- concentrations are reduced to below the RGs, or
- calculations indicate that the RGs will be achieved within the sparge well radius of influence.

If the groundwater concentrations of benzene or pyridine are such that the conditions for the cessation of pumping may not be achieved, then operation of the biosparge system shall be adjusted by increasing sparging rates, adjusting the sparging duration, adjusting the sparging frequency (i.e. on and off periods), and/or installing additional

sparge wells. Implementing these measure(s) will be made until benzene and pyridines groundwater concentrations indicate the biosparge system is operating properly.

Once the biosparging system is fully operational and achieving the design objectives, including the RAOs, then groundwater pumping may cease with USEPA approval.

7. Develop the Plan for Obtaining Data

Data will be collected in accordance with the SWMP, FSP, and QAPP. In addition, if the groundwater monitoring contingency plan contained within the Remedial Action Work Plan (RAWP) is triggered, then data will also be collected in accordance with the contingency plan.

Dissolved oxygen data collected as described in the data quality objective for biosparge system optimization via dissolved oxygen monitoring.

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# Data Quality Objective:
# OU5 Groundwater Evaluation

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) OU5 Groundwater Evaluation

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1. State the Problem

The biosparge system will achieve the Remedial Action Objectives (RAOs) and a demonstration that the biosparge system is effective should take no more than one year after which time groundwater pumping will cease. The OU5 natural attenuation remedy will take several years to achieve the Remedial Goals (RGs). The problem is how to monitor OU5 groundwater to affirm that natural attenuation is continuing and will achieve the RGs within the time frame calculated by the hydrogeologic model (AECOM 2019). The model calculated 8, 9, and 19 years to achieve the pyridine, ammonia, and benzene RGs, respectively.

2. Identify the Goals of the Project

Document that natural attenuation is continuing in OU5 groundwater and whether there have been any changes to the 2019 hydrogeologic model that would indicate different times to achieve the RGs than previously identified in the model.

3. Identify Information Inputs

Groundwater data resulting from the implementation of the Site-Wide Monitoring Plan (SWMP), Field Sampling Plan (FSP), and Quality Assurance Project Plan (QAPP). This includes OU5 groundwater natural attenuation / stabilization parameters including the groundwater elevation, temperature, pH, conductivity, oxidation reduction potential, and dissolved oxygen. This also includes OU5 laboratory analytical results for benzene, pyridines, and ammonia.

4. Define the Boundaries of the Study

The boundaries of the study include the existing and future monitoring wells in OU5.

| OU5 Monitoring Wells | Shallow Aquifer | Mid-Depth Aquifer | Deep Aquifer |
|---|---|---|---|
| Existing | RI-10S<br>RI-11S<br>RI-15S<br>RI-19S<br>RI-20S<br>RI-42S<br>RR P8 MW-1<br>RR P8 MW-4 | RI-10D<br>RI-11M<br>RI-15M<br>RI-19D<br>RI-20D | RI-11D<br>RI-15D<br>RR PW-3 |
| Future | RI-42RS<br>RI-43S<br>RI-44S<br>RI-45S | RI-42RM<br>RI-43M<br>RI-44M<br>RI-45M | RI-42RD<br>RI-43D<br>RI-44D<br>RI-45D |

Groundwater data has been collected from monitoring wells in OU5 since the late 1980s / early 1990s. Since that time, the groundwater plume has been significantly reduced in both concentration and area as depicted in the OU1

ROD Addendum (EPA 2021) as a result of groundwater pumping in OU1 and natural attenuation in OU5. The following table illustrates how long OU5 wells have been below the RGs and where OU5 wells have not reached the RGs.

**OU5 Groundwater Sampling Results Summary**

| Benzene ≤5 µg/L and duration ≤5 µg/L | | Each pyridine ≤35 µg/L and duration ≤35 µg/L | | Ammonia ≤30 mg/L and duration ≤30 mg/L | | Wells with benzene >5 µg/L and 1Q2024 concentration | |
|---|---|---|---|---|---|---|---|
| RI-11S | for 24 yrs | RI-11S | for 19 yrs | RI-11S | for 30 yrs | RI-15M | 34.0 µg/L |
| RI-11M | for 4.5 yrs | RI-11M | for 6.5 yrs | RI-11M | for 4.5 yrs | RI-15D | 6.6 µg/L |
| RI-11D | for 19 yrs | RI-11D | for 24 yrs | RI-11D | for 30 yrs | | |
| RI-19S | for 21 yrs | RI-15M | for 2.5 yrs | RI-15M | for 30 yrs | | |
| RI-19D | for 14 yrs | RI-15D | for 9 yrs | RI-15D | for 27 yrs | | |
| RI-42S(1) | for 9 yrs | RI-19S | for 14.5 yrs | RI-19S | for 30 yrs | | |
| RR PW-3(2) | for 25 yrs | RI-19D | for 12 yrs | RI-19D | for 30 yrs | | |
| | | RI-42S(1) | for 4 years | RI-42S(1) | for 10 yrs | | |
| | | RR PW-3(2) | for 28 yrs | RR PW-3(2) | for 28 yrs | | |

Notes:
(1) RI-42S was destroyed by road construction and the most recent sample was collected in 2015.
(2) RR PW-3 was converted into a backup pump for emergency use only and the most recent sample was collected in 2022. Pumping wells RR PW-1, RR PW-2, and RR PW-3 are only used for measuring the groundwater level, these wells are not sampled.
(3) RI-10S, RI-10D, RI-15S, RI-20S, RI-20D, RR P8 MW-1, and RR P8 MW-4 are used only for measuring the groundwater level, these wells are not sampled.
(4) All wells in OU5 are below the pyridine and ammonia RGs and all but two wells are below the benzene RG.

Natural attenuation data has been routinely collected during groundwater sampling events since 2011 and tabulated. This natural attenuation data will serve as a basis for future data evaluation.

5. Develop the Analytic Approach

Natural attenuation has been successful in reducing benzene, pyridines, and ammonia impacts in OU5 groundwater. Groundwater sampling events include the collection of several natural attenuation / stabilization field parameters prior to collecting samples for laboratory analysis. Field parameters collected between 2011 and 2024 are presented in the annual linear regression report (DMP 2024b) and the ranges are presented in the following table. These ranges will be compared against ranges from future sampling events to provide evidence that natural attenuation is continuing.

| Well ID | Temperature (˚F) | pH (S.U.) | Conductivity (µS/cm) | Oxidation Reduction Potential (mV) | Dissolved Oxygen (mg/L) | Groundwater Elevation (ft msl) |
|---|---|---|---|---|---|---|
| **OU5 Shallow Aquifer** | | | | | | |
| RI-11S | 11.50 – 15.38 | 6.95 – 7.82 | 808 - 1170 | -34.7 – 121.8 | 0.26 – 8.42 | 673.20 – 676.72 |
| RI-19S | 13.90 – 16.30 | 7.02 – 7.42 | 849 - 1304 | -90.3 – 158.2 | 0.18 – 2.12 | 676.33 – 680.10 |
| RI-42S(1) | 12.83 – 17.93 | 6.58 – 7.55 | 1120 - 1600 | -137.4 – 42.6 | 015 – 2.44 | 677.24 – 679.14 |
| Range | 11.50 – 17.93 | 6.58 – 7.82 | 808 - 1600 | -137.4 – 158.2 | 0.15 – 8.42 | 673.20 – 680.10 |
| **OU5 Mid-Depth Aquifer** | | | | | | |
| RI-11M | 12.63 – 15.70 | 7.15 – 8.08 | 942 - 1995 | -153.9 – 162.1 | 0.05 – 2.46 | 672.63 – 676.34 |
| RI-15M | 13.16 – 15.72 | 6.62 – 8.07 | 771 - 1504 | -204.6 – 216.3 | 0 – 6.31 | 678.71 – 675.62 |
| RI-19D | 13.84 – 16.70 | 6.08 – 7.56 | 968 - 2514 | -152.7 – 238.9 | 0.19 – 2.21 | 675.50 – 679.81 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Range | 12.63 – 16.70 | 6.08 – 8.08 | 771 - 2514 | -204.6 – 238.9 | 0 – 6.31 | 672.63 – 679.81 |
| **OU5 Deep Aquifer** | | | | | | |
| RI-11D | 12.37 – 15.79 | 7.08 – 7.69 | 857 - 1315 | -74.8 – 143.0 | 0.15 – 3.71 | 669.87 – 674.43 |
| RI-15D | 12.68 – 17.60 | 6.78 – 7.76 | 868 - 1509 | -170.3 – 180.6 | 0.03 – 2.26 | 677.72 – 674.08 |
| Range | 12.37 – 17.60 | 6.78 – 7.76 | 857 - 1509 | -170.3 – 180.6 | 0.03 – 3.71 | 669.87 – 674.43 |

Notes:
(1) RI-42S was destroyed by road construction and the most recent sample was collected in 2015.
(2) RR PW-3 was converted into a backup pump for emergency use only the most recent sample was collected in 2022. Since RR PW-3 was a pumping well, natural attenuation parameters were not collected to determine stabilization when a sample was collected.
(3) RI-10S, RI-10D, RI-15S, RI-20S, and RI-20D are only used for measuring the groundwater level, they are not sampled.

OU5 groundwater laboratory analytical data will also be used to compare benzene, pyridines, and ammonia to the RGs. Results will be graphed to identify any trends in concentration. At locations where OU5 groundwater concentrations are above the RGs (such as RI-15M and RI-15D), cleansed groundwater may take several years to reach such areas that are hundreds of feet downgradient from the biosparge barrier. The 2019 hydrogeologic model calculated the groundwater velocity near RI-4 to be up to 0.135 ft/day with no on-site pumping and consistent withdrawals at Rolls-Royce Plant 8.

6. Specify Performance or Acceptance Criteria

Natural attenuation parameters will continue to be measured to determine when the groundwater has stabilized and a groundwater sample can be collected in accordance with the low flow sampling procedure.

Natural attenuation parameters measured from existing wells will be compared to the ranges previously measured. Natural attenuation will be evidenced as continuing so long as the parameters remain in the same ranges for that well.

Natural attenuation parameters measured from future wells will be compared to the ranges for the shallow, mid-depth, and deep wells. Natural attenuation will be evidenced as continuing so long as the parameters remain in the same ranges for wells at similar depths (i.e. shallow, mid-depth, and deep).

Natural attenuation will also be evidenced as occurring so long as concentrations above the RGs are reducing or concentrations below the RGs remain below the RGs. These trends will be evaluated in the annual linear regression report.

7. Develop the Plan for Obtaining Data

Groundwater data will be collected in accordance with the Site-Wide Monitoring Plan (SWMP), Field Sampling Plan (FSP), and Quality Assurance Project Plan (QAPP).

In addition, if the groundwater monitoring contingency plan contained within the Remedial Action Work Plan (RAWP) is triggered and results in additional data collected from OU5, then that data will also be utilized.

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# Data Quality Objective:
# Groundwater Vapor Intrusion Evaluation

**Data Quality Objectives.** Data Quality Objectives (DQOs) are utilized to ensure that representative data is collected using a systematic approach. The DQO is a seven step planning process that addresses the problem(s) (or issues) that will be encountered during the project: 1) state the problem, 2) identify the goals of the project, 3) identify information inputs, 4) define the boundaries of the study, 5) develop the analytic approach, 6) specify performance or acceptance criteria, and 7) develop the plan for obtaining data.

(1) Groundwater Vapor Intrusion Evaluation

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1. State the Problem
   Dissolved benzene, pyridine, and ammonia in groundwater could cause a completed vapor intrusion pathway to indoor air in OU1 between the biosparge system radius of influence and South Tibbs Avenue as well as in OU5. A method needs to be developed to evaluate whether this could occur.

2. Identify the Goals of the Project
   Determine whether the groundwater to indoor air vapor intrusion pathway could be complete.

3. Identify Information Inputs
   Groundwater monitoring data collected in accordance with the Site-Wide Monitoring Plan (SWMP), Field Sampling Plan (FSP), and Quality Assurance Project Plan (QAPP).

4. Define the Boundaries of the Study
   Existing and future groundwater monitoring wells and groundwater monitoring points in OU1 between the biosparge system radius of influence and South Tibbs Avenue as well as existing and future groundwater monitoring wells in OU5 are presented in the following table.

| Aquifer | Approximate Elevation Range (ft msl) | OU1 Wells | OU5 Wells |
|---|---|---|---|
| OU1 and OU5 Shallow | 670 – 700 | RI-4S, RI-6S, MP-2S, MP-4S, MP-6S, MP-8S, MP-10S, MP-11S, MP-13S, MP-15S, MP-17S | RI-11S, RI-19S, RI-42RS, RI-43S, RI-44S, RI-45S |
| OU1 Deep and OU5 Mid-Depth | 640 – 670 | RI-4D, RI-5S, MP-2D, MP-4D, MP-6D, MP-8D, MP-10D, MP-11D, MP-13D, MP-15D, MP-17D | RI-11M, RI-15M, RI-19D, RI-42RM, RI-43M, RI-44M, RI-45M |
| OU5 Deep | 610 – 640 | None | RI-11D, RI-15D, RI-42RD, RI-43D, RI-44D, RI-45D |

   Although data from all aquifers may be evaluated, data is only applicable to the OU1 and OU5 shallow aquifer. This is because the mid-depth and deep aquifers are not in contact with soil gas. The mid-depth aquifer is located beneath 10-15 feet of water in the shallow aquifer. The deep aquifer is located beneath an additional 30 feet of water in the mid-depth aquifer.

5. Develop the Analytic Approach
   Utilize groundwater sampling results (temperature) as an input to the EPA Vapor Intrusion Screening Level (VISL) calculator (EPA 2020a and b). The VISL calculator is available on-line: https://epa-visl.ornl.gov/cgi-bin/visl_search

   Default values shall be used unless site-specific values are measured. Default values include a target risk of $10^{-5}$, target hazard quotient of 1, chronic reference concentration (RfC), default residential exposure values, default commercial exposure values, and groundwater attenuation factor of 0.001. The resulting calculated target

groundwater concentration (i.e. screening level) shall then be compared to results from the shallow aquifer. If groundwater concentrations do not exceed the screening level, then the groundwater vapor intrusion pathway to indoor air is incomplete.

The following table presents the screening levels from the VISL calculator assuming the groundwater temperature is 20˚C. Lower temperatures result in higher groundwater screening levels.

| Target Analyte | CAS# | Remedial Goal | Residential Screening Level | Commercial / Industrial Screening Level |
|---|---|---|---|---|
| Benzene | 71-43-2 | 5 µg/L | 19.7 µg/L | 85.8 µg/L |
| Pyridine | 110-86-1 | 35 µg/L each pyridine derivative | Not applicable, no inhalation toxicology information. | |
| Ammonia | 7664-41-7 | 30 mg/L | 898 mg/L | 3770 mg/L |

Notes:
1. If the groundwater concentration does not exceed the screening level, then the groundwater vapor intrusion pathway to indoor air is incomplete.
2. A groundwater temperature of 20˚C has been used to calculate the screening levels.
3. Benzene has a vapor pressure 4.6 times higher than pyridine (Lide 1995) and the Henry's Law constant indicates benzene is more than 400 times more removable from groundwater than pyridines (NIST 2000). To the extent any volatilization occurs, benzene is much more likely to be volatilized than pyridine.

If a result from the mid-depth and/or deep aquifer indicates a possible completed pathway (i.e. above the screening level), and there is no corresponding result in the shallow aquifer, then a nearby well screened in the shallow aquifer may be sampled to compare to the screening level.

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6. Specify Performance or Acceptance Criteria

Groundwater concentration in the shallow aquifer does not exceed the screening level.

If the groundwater concentration exceeds the screening level, then a soil gas vapor intrusion evaluation to indoor air may be performed as described in the Remedial Action Work Plan (RAWP) and the corresponding data quality objective and decision diagrams.

7. Develop the Plan for Obtaining Data

Data will be collected in accordance with the SWMP, FSP, and QAPP.

In addition, if the groundwater monitoring contingency plan contained within the RAWP is triggered, then data will also be collected in accordance with that contingency plan.

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# Remedial Action Work Plan for OU1
# Certification

## Settling Defendant: 1500 South Tibbs LLC

1500 S. Tibbs Ave.
Indianapolis, IN 46241

May 16, 2025

Prepared by: David M. Peterson, PE, PC

# Remedial Action Work Plan Certification

**Certification**. All deliverables that require compliance with this paragraph must be signed by the Settling Defendant's Project Coordinator, or other responsible official of Settling Defendant, and must contain the following statement.

(1) Settling Defendant Certification

I certify under penalty of perjury that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I have no personal knowledge that the information submitted is other than true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature

Printed Name Chet Chiles Date 05-16-2025

Company Aurorium Title Global EHS Director

Settling Defendant 1500 South Tibbs LLC Title Project Coordinator

(2) Professional Engineer Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature Date 05-16-2025

Printed Name David M. Peterson, PE License# PE19600105

Company David M. Peterson, PE, PC Role Supervising Contractor

Title President

Stamp

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# Remedial Action Work Plan for OU1
# Remedial Design Overview

## Settling Defendant: 1500 South Tibbs LLC

1500 S. Tibbs Ave.
Indianapolis, IN 46241

May 16, 2025

Prepared by: David M. Peterson, PE, PC

## Remedial Design Overview

**Remedial Design for OU1 and Updated Sitewide Supporting Deliverables**. Settling Defendant shall submit the Remedial Design for OU1 and updated sitewide Supporting Deliverables within 30 days of receiving EPA comments to the 95% Remedial Design. Comments were received from EPA on November 15, 2024, March 13, 2025, and May 5, 2025 and this Remedial Action Work Plan / Remedial Design addresses those comments. Per the Consent Decree Statement of Work (USA 2024), the Remedial Design must include:

(1) A complete set of construction drawings and specifications that are: (1) certified by a registered professional engineer; (2) suitable for procurement; and (3) follow the Construction Specifications Institute's MasterFormat 2020.

Appendix A and Appendix B to the Remedial Action Work Plan (RAWP) contain remedial design drawings and specifications, respectively, that meet these criteria. Appendix C to the RAWP contains the remedial action construction schedule.

(2) A survey and engineering drawings showing existing Site features, such as elements, property borders, easements, and Site conditions.

Appendix D to the RAWP is a site survey containing such features. Appendix A contains remedial design drawings illustrating site features and underground utilities based upon reviewing site drawings, having utilities marked by Indiana 811, and using a private utility contractor to identify utilities.

(3) Final versions of the same elements and deliverables as are required for the 95% Remedial Design

The 95% Remedial Action Work Plan and Remedial Design submitted July 3, 2024 contained drawings, specifications, and work plans as required by the Consent Decree Statement of Work (USA 2024). Comments were received from EPA on November 15, 2024 and responded to on December 16, 2024. Additional comments were received from EPA on March 13, 2025. These elements have been updated based upon those comments and are included in the Remedial Action Work Plan including attachments and appendices.

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|---|---|
| Appendix A – Remedial Design Drawings<br>Appendix B – Remedial Design Specifications<br>Appendix C – Remedial Action Construction Schedule<br>Appendix D – Site Survey<br>Appendix E – Photographic Documentation Plan<br>Appendix F – Permitting Plan<br>Appendix G – Site-Wide Monitoring Plan (SWMP)<br>Appendix H – Field Sampling Plan (FSP)<br>Appendix I – Quality Assurance Project Plan (QAPP) | Appendix J – Construction Quality Assurance and Control Plan (CQA/CP)<br>Appendix K – Transportation and Off-Site Disposal Plan (TODP)<br>Appendix L – Emergency Response Plan (ERP)<br>Appendix M – Community Impacts Mitigation Plan (CIMP)<br>Appendix N – Operation and Maintenance Plan (OMP)<br>Appendix O – Operation and Maintenance Manual (OMM)<br>Appendix P – Health and Safety Plan (HASP) |

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(4) A specification for photographic documentation of the Remedial Action

Appendix E to the RAWP contains a Photographic Documentation Plan (PDP).

(5) Updates of all supporting deliverables required to accompany the Preliminary (30%) Remedial Design, including an update to the OU1 O&M Plan.

The RAWP contains updates to all supporting deliverables. The OU1 O&M Plan has been updated via the Operation and Maintenance Plan (OMP) that applies to OU1, OU2, OU3, OU4, and OU5 (Appendix N). The OU1 biosparge system Operation and Maintenance Manual (OMM) has also been updated (Appendix O).

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