From:	Casbon-Scheller, Angela M
To:	Fracetti, Juliana
Cc:	Liberge, Thierry
Subject:	Southern Indiana Gas and Electric Company F.B. Culley Generating Station West Ash Pond (SW Program ID 87-UP-14) \\ Revised Bedrock Characterization Work Plan
Date:	Thursday, April 18, 2024 2:31:33 PM
Attachments:	image003.png SIGECO F.B. Culley West Ash Pond (SW Program ID 87-UP-14) Bedrock Characterization Work Plan Rev 1_2024 April.pdf

Ms. Fracetti,

Please find attached a revised Bedrock Characterization Work Plan for the Southern Indiana Gas and Electric Company (SIGECO) West Ash Pond, as requested by IDEM during a virtual meeting on April 2, 2024.

Thank you,

CenterPoint. Energy

Angie Casbon-Scheller
Director, Generation Compliance and Carbon Policy | Environmental Department
812.491.4787 w.
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CenterPoint Energy

Angela Casbon-Scheller
Director, Generation Compliance and Carbon Policy
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P.O. Box 209
Evansville, IN 47702-0209
812-491-4787

April 18, 2024

Submitted via Email to:
JFracett@idem.IN.gov

Indiana Department of Environmental Management
Office of Land Quality
100 North Senate Avenue
Indianapolis, IN 46204

Re: Revised Work Plan for Bedrock Characterization
Southern Indiana Gas and Electric Company
F.B. Culley Generating Station – West Ash Pond
Newburgh, Warrick County, Indiana
SW Program ID: 87-UP-14

Dear Ms. Fracetti,

Southern Indiana Gas and Electric Company (SIGECO) submitted the Work Plan for Bedrock Characterization at the F.B. Culley Generating Station – West Ash Pond (Plan) on January 18, 2024 along with a response to the Indiana Department of Environmental Management (IDEM) comments pertaining to the May 2023 Semiannual Groundwater Monitoring Report. IDEM provided comments on the Plan on March 4, 2024. During a follow up virtual meeting on April 2, 2024, IDEM clarified the Plan was acceptable and requested the Plan be updated to cite Rules 312 IAC 13-8-3 and 329 IAC 10-21-4 as discussed during the meeting.

Please see the enclosed response to comments which contains Revision 1 of the Work Plan for Bedrock Characterization at the F.B. Culley Generating Station.

If you have any questions, please contact me at Angela.Casbon-Scheller@centerpointenergy.com or 812-491-4787.

Sincerely,

Angela Casbon-Scheller
Director, Generation Compliance and Carbon Policy
Environmental Affairs

Enclosures

Cc: Plant File

www.haleyaldrich.com

WORK PLAN FOR
BEDROCK CHARACTERIZATION
F.B. CULLEY GENERATING STATION
WEST ASH POND
WARRICK COUNTY, INDIANA

by
Haley & Aldrich, Inc.
Greenville, South Carolina

for
Southern Indiana Gas and Electric Company
Evansville, Indiana

File No. 0129420
Revised: April 2024
Submitted: January 2024

HALEY & ALDRICH, INC.
400 AUGUSTA ST.
SUITE 100
GREENVILLE, SC 29601
864.214.8771

SIGNATURE PAGE FOR

WORK PLAN FOR
BEDROCK CHARACTERIZATION
F.B. CULLEY GENERATING STATION
WEST ASH POND
WARRICK COUNTY, INDIANA

PREPARED FOR
SOUTHERN INDIANA GAS AND ELECTRIC COMPANY
EVANSVILLE, INDIANA

PREPARED BY:

Todd Plating
Senior Geologist
Haley & Aldrich, Inc.

REVIEWED AND APPROVED BY:

Neal Kochis
Senior Project Manager
Haley & Aldrich, Inc.

Table of Contents

List of Tables

List of Figures

List of Appendices

1. Introduction

1.1 BACKGROUND

Haley & Aldrich, Inc. (Haley & Aldrich) has prepared this *Bedrock Characterization Work Plan* (Work Plan) for the West Ash Pond (WAP) at the F.B. Culley Generating Station located in Warrick County, Indiana (the "Site") on behalf of Southern Indiana Gas and Electric Company (SIGECO). The Site is identified in the Indiana Department of Environmental Management (IDEM) Solid Waste Program as ID #87-UP-14.

A *Semiannual Groundwater Monitoring Report – May 2023 Sampling Event* was prepared by Haley & Aldrich and submitted to IDEM on September 20, 2023 (VFC # 83537298). IDEM responded in a comment letter dated 20 November 2023 requesting additional evaluation of the vertical extent of constituents in groundwater and the no-flow boundary associated with shale bedrock beneath the former WAP, as noted below:

> "In response to our request for vertical delineation of the N&E of GWPS exceedances, the facility states that unconsolidated material is underlain by shale offering a no-flow boundary; therefore, eliminating the need to investigate groundwater contamination vertically below the unconsolidated material. Thick, continuous, competent shale may provide a zone of low hydraulic conductivity preventing downward contaminant migration. However, the facility needs to demonstrate that there exists a competent thick shale throughout the site that will provide such a boundary. Please provide as much detail as possible about the shale's characteristics, including composition, fractures, thickness, etc. throughout the facility boundaries and immediate surrounding areas in your next groundwater monitoring report (updated cross-sections would offer valuable visual aid)."

This Work Plan proposes activities necessary to assist in assessing the extent and effects of the plume and address IDEM's comment.

1.2 PROJECT OBJECTIVES

The overall objective of the proposed scope of work is to confirm bedrock characteristics beneath the Former WAP including extent, competency, fracture occurrence, and hydraulic conductivity. Results of this evaluation will confirm the presence of a no-flow boundary. Bedrock characteristics and methods included in this scope of work to evaluate those characteristics are summarized in the table below.

Bedrock Characteristic	Method
Thickness	Rock coring and core logging to a depth of 30 feet past top of bedrock
Competency	Rock Quality Designation (RQD) in general accordance with ASTM D6032
Fracture occurrence	Visual observation and core logging, RQD
Hydraulic conductivity	Packer testing discrete borehole intervals using straddle packer system; slug testing in general accordance with OP3016
Hydraulic conductivity	Hydraulic conductivity laboratory testing ASTM D5084
Hydraulic conductivity	Slug testing (if applicable) in general accordance with OP3016

2. Project Tasks

The work activities described below have been designed to address the objectives identified in Section 1.2 and outline the proposed activities and procedures.

2.1 TECHNICAL APPROACH

Up to three bedrock borings are proposed to provide Site-specific information to confirm characteristics of the bedrock lithology beneath the Former WAP. Bedrock borings are proposed to be advanced at three existing monitoring well clusters (CCR-WAP-4, CCR-WAP-7, and CCR-WAP-9), one boring per location as shown on Figure 1. Groundwater monitoring wells will be installed in borings if constituent concentrations in the overlying monitoring well are greater than a groundwater protection standard and if core logging observations and hydraulic testing identify a water-bearing zone with sufficient yield to support monitoring. Planned boring specifications and estimated well construction details (if warranted) are summarized in Table 1.

Rationale and objectives of the proposed borings are summarized below:

- WAP-4 – Statistically significant levels of boron and molybdenum have been identified at the WAP-4 cluster. WAP-4 is located in an area that provides information along the southern boundary of the former WAP and upgradient of the Ohio River. A bedrock boring and monitoring well (if appropriate) are proposed to evaluate physical and hydraulic characteristics of the bedrock underlying the former WAP; specifically, lithology, thickness, fracture characteristics (if observed), and hydraulic conductivity.
- WAP-7 – Statistically significant levels of boron, lithium, and molybdenum have been identified at the WAP-7 cluster. WAP-7 is located along the western boundary of the former WAP and adjacent to the western property boundary. A bedrock boring and monitoring well (if appropriate) are proposed to evaluate physical and hydraulic characteristics of the bedrock underlying the former WAP; specifically, lithology, thickness, fracture characteristics (if observed), and hydraulic conductivity.
- WAP-9 – Elevated concentrations of molybdenum have been identified at the WAP-9 cluster. WAP-9 is located southwest of the former WAP, adjacent to the property boundary to the west and the Ohio River to the south. A bedrock boring and monitoring well (if appropriate) are proposed to evaluate physical and hydraulic characteristics of the bedrock underlying the former WAP, specifically lithology, thickness, fracture characteristics (if observed), and hydraulic conductivity.

Proposed testing to be completed with the bedrock borings is summarized in Table 1. Those tests and observations during drilling will be used to determine if a water-bearing zone is present to support installation of a groundwater monitoring well. Monitoring well design, if necessary, will be determined in the field based on field observations. Resulting data will be used to refine the conceptual site model and improve the understanding of groundwater flow and constituent transport at the Site.

2.2 FIELD PREPARATION

2.2.1 Health and Safety

Work will be performed in accordance with the procedures outlined in the Site-specific Health and Safety Plan. Prior to the start of each day of field work, a Daily Tailgate Meeting will be conducted by Haley & Aldrich to review the scope of work for that day, perform a Job Safety Analysis, and to review pertinent safety issues (including access routes and work near water) and emergency plans. In addition, a meeting will be held prior to the start of fieldwork to review project scope, schedule, potential hazards, and strategies to mitigate those hazards.

2.2.2 Permits

Haley & Aldrich's review of potentially applicable permits indicates that permits are not required to perform the proposed work. Because the work will not involve disturbance of river sediments, placement of fill, discharge of water to the river, or installation of monitoring devices or structures within the floodway, we do not believe that United States Army Corps of Engineers or Indiana Department of Natural Resources permitting is required.

2.3 FIELD PROCEDURES

As discussed with IDEM during a virtual meeting on 2 April 2024, boring and monitoring well installation will be completed in accordance with the Water Well Driller and Pump Installer Rule 312 IAC 13-8-3 (monitoring wells), and procedures detailed in the Solid Waste Land Disposal Facility Rule 329 IAC 10-21-4 (groundwater monitoring well and piezometer construction and design), where applicable. Where applicable, sampling and documentation will be completed in accordance with the IDEM-approved *Sampling and Analysis Plan and Quality Assurance Project Plan* (SAP/QAPjP) prepared by Haley & Aldrich, July 2021 and approved by IDEM on February 18, 2022.

2.3.1 Utility Locate and Soft Digging

Prior to the start of the field investigation, Haley & Aldrich will contact Indiana 811 (utility notification center). Haley & Aldrich will engage with SIGECO to review Site plans and review proposed locations to verify that known utilities are not present. If warranted, Haley & Aldrich will retain a qualified subcontractor to conduct a private utility locate using electromagnetic and ground-penetrating radar tools in a 25-foot-diameter area surrounding each planned drilling location. Non-mechanized or soft dig methods (hand auger, air jet, or vacuum) will be used to confirm the absence of utilities to a depth of 5 feet at each location. The width of soft dig excavations will be equal or greater than the width of the planned boring at each location.

2.3.2 Borehole drilling

Bedrock boring and monitoring well installation (if necessary) will be completed by an Indiana-licensed well driller using hollow stem auger and standard coring techniques to an assumed depth up to 180 feet (or 30 feet into bedrock). Bedrock borings will be advanced through shallow soils and saprolite using a larger-diameter hollow stem auger to refusal. A rotary bit will be used to advance the boring approximately 5 feet into competent rock where a temporary conductor casing will be installed to isolate the bedrock zone from the overlying groundwater. The boring will be advanced beyond the bottom of the conductor casing using standard coring methods to approximately 30 feet into competent bedrock. Haley & Aldrich will provide technical oversight of all drilling activities.

The drilling contractor will decontaminate downhole equipment between drilling locations. Bedrock boreholes will remain open until hydraulic conductivity testing is completed. Final well screen intervals, if necessary, will be selected to target hydraulically active fractures identified using the downhole testing results.

Soil sampling will be conducted at the boring locations by advancing a 2-foot-long split spoon sampling device in advance of the auger. A minimum of one split spoon sample per 10 feet of borehole will be collected. Soil recovered from each sample interval will be visually characterized for color, texture, and moisture content.

2.3.3 Soil Characterization

Haley and Aldrich will collect soil samples from each of the three proposed borings that correspond with depth intervals for the existing shallow and deep flow zone monitoring wells. The samples will be submitted for laboratory analysis including:

- Sequential extraction (ACZ, Laboratories); ½ gallon zip-lock bag per sample;
- Microcosm and desorption testing (Ursus Remediation Testing and Technologies); 2 x ½ gallon vacuum-sealed bags per sample;
- Total metals (Eurofins); 1 x 4-ounce jar per sample.

Estimated sample collection intervals and proposed testing are summarized in Table 1.

2.3.4 Packer Testing

Hydraulic straddle packer testing will be performed on up to three depth-discrete intervals in each open bedrock borehole as needed to estimate the hydraulic conductivity of those discrete zones and determine if monitoring well installation is appropriate. The packer assembly will isolate an approximately 10-foot vertical interval in the bedrock borehole. Falling head or rising head hydraulic conductivity testing will be completed to estimate hydraulic conductivity and evaluate which intervals may be suitable for monitoring well installation.

2.3.5 Well Installation

If necessary, monitoring wells will be constructed in accordance with the Water Well Driller and Pump Installer Rule 312 IAC 13-8-3 (monitoring wells), and procedures detailed in the Solid Waste Land Disposal Facility Rule 329 IAC 10-21-4 (groundwater monitoring well and piezometer construction and design), where applicable. If no water-producing fractures or other indications of groundwater flow are observed (a dry hole), a monitoring well will not be installed, and the borehole will be abandoned in accordance with 312 IAC 13-10- 2 and 329 IAC 10-21-1.

In general, wells will be constructed using 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) pipe and will be screened over a 5- to 10- foot interval with 0.010-inch machine-slotted PVC screen. The approximate proposed boring depths and screen intervals are presented in Table 1 and may be modified in the field based on drilling observations and packer testing. The depth of bedrock monitoring well screen intervals will be selected based on results from downhole testing and observations, if hydraulically active fractures are indicated. In general, the bedrock monitoring well screen interval will target the most transmissive fracture zone in the bedrock.

Open bedrock boreholes will be backfilled with bentonite pellets or chips to a depth of approximately 1 foot below the selected screen interval. Bentonite pellets or chips will be used to fill the annular space from the top of the sand pack up to at least 2 feet into the 6-inch outer casing. After allowing ample time for the bentonite to fully hydrate, the remaining annular space will be tremie-grouted to the surface.

A stickup surface completion will be installed at each well location. A 2-foot by 2-foot concrete pad with protective bollards will be installed around the completed well.

2.3.6 Well Development

Each new monitoring well will be developed by pumping with a submersible pump at the maximum rate that can be sustained by the well. If wells are pumped dry, they will be allowed to recover and pumped again a minimum of three times. Development will continue until the turbidity is reduced to 10 nephelometric turbidity units or less and pH and conductivity measurements have stabilized, or until the well has been purged for two hours, whichever comes first. The rate, quantity, and water quality parameters of groundwater removed from each monitoring well during development will be recorded on a field form.

2.3.7 Surveying

SIGECO will coordinate the survey of newly installed groundwater monitoring wells. The survey by an Indiana-licensed surveyor will include:

- Horizontal coordinates (x, y location);
- Ground surface elevation;
- Well pad elevation; and
- Top of casing elevation.

2.3.8 Groundwater Sampling

If bedrock monitoring wells are installed, two rounds of groundwater samples will be collected. Sampling procedures will be completed in accordance with the IDEM-approved SAP/QAPjP. Groundwater samples will be collected for analysis of Appendix III and Appendix IV constituents. Those constituents, analytical methods, reporting limits, and method detection limits are summarized in Table 2.

Microbial testing of groundwater is planned at the WAP-7S and WAP-4S groundwater monitoring wells to compliment solid phase sampling in preparation for evaluation of potential corrective measures and in support of a selection of remedy. Specifically, microbial testing can identify natural processes that are actively reducing constituent concentrations in groundwater. Those processes may be naturally sufficient or could be enhanced to achieve corrective measures objectives. Those samples are collected on filters in the field and supplied by the laboratory, Microbial Insights.

2.3.9 Slug Testing

Slug tests assess the horizontal hydraulic conductivity of a water-bearing zone. Slug tests are accomplished by stressing the screened water-bearing zone through an “instantaneous” displacement of water (with a slug) or removal of water (with a bailer) and subsequently measuring the water level response in the well over time. A very rapid change in the water level in a well can be created by inserting and rapidly withdrawing a solid dense object (a.k.a. a slug). Slug testing at each bedrock monitoring well will be completed in accordance with Haley & Aldrich Standard Operating Procedure OP3016 included in Appendix A.

2.3.10 Investigation-Derived Waste Management

Solid investigation-derived waste (IDW), including soil and rock cuttings, will be contained and transported to a location approved by SIGECO for disposal. Waste personal protective equipment and sampling supplies (e.g., used tubing), will be placed in regular solid waste containers at the F.B. Culley Generating Station.

Liquid IDW, consisting of drilling fluids, equipment decontamination wash water, and groundwater from well development, purging and sampling activities, will be contained at the wellhead or decontamination station as it is generated, then transported to a location approved by SIGECO for disposal or discharged to the ground surface for infiltration.

2.3.11 Quality Assurance/Quality Control Procedures

Quality assurance/quality control samples, including trip blanks, equipment blanks, blind duplicates, and matrix spike/matrix spike duplicate samples will be collected in accordance with the IDEM-approved SAP/QAPjP.

3. Reporting and Schedule

3.1 REPORTING

Results of bedrock boring testing and field observations will be summarized and included in subsequent Semiannual Groundwater Monitoring Reports. If groundwater monitoring wells are installed, a monitoring well installation report detailing the procedures used for drilling and installing the monitoring wells will be prepared and submitted to IDEM within 60 days after the completion of field activities.

The monitoring well installation report will comply with 329 Indiana Administrative Code (IAC) 10-21-4 and D3 of the 20 December 2019 IDEM approval letter and will contain the following:

- Figure(s) showing the location of newly installed monitoring wells;
- Description of drilling procedures;
- Soil boring and construction logs;
- Well development information; and
- Detailed hydraulic conductivity testing.

The monitoring well installation report will include the horizontal and vertical survey information with ground surface elevation measured to the nearest 0.1 foot and the referenced top of casing mark measured to the nearest 0.01 foot. The results of hydraulic conductivity testing will be summarized in tables. The installation report for all the monitoring wells will also be included in the 2024 Annual Report and placed in the operating record as stated by §257.90(e)(2) and §257.91(e)(1).

3.2 SCHEDULE

A proposed conceptual schedule, contingent on IDEM approval, for this scope of work is presented in the table below.

Task	Proposed Date
Bedrock boring, packer testing, and monitoring well installation	March to April 2024
Slug testing and groundwater sampling (if applicable	April to May 2024
Analytical testing	April to June 2024
Reporting (monitoring well construction report if applicable)	May 2024
Reporting (testing results evaluation in Semiannual Groundwater Monitoring Report)	August to September 2024

The actual schedule for this scope of work will be developed upon approval to proceed and will be dependent upon contractor availability.

TABLE

TABLE 1
PROPOSED SCOPE OF WORK SUMMARY
F.B. CULLEY GENERATING STATION
WEST ASH POND
WARRICK COUNTY, INDIANA

Well ID	Hydrogeologic Unit	Estimated Depth to Bedrock (ft bgs)	Estimated Borehole Depth (ft bgs)	Screen Interval (ft bgs)	Outer Casing Depth (ft bgs)	Solid Phase Testing: Total metals (Fe, Mn, Al, Mo, Li, TOC) [1] (4 oz. jar)	Solid Phase Testing: Sequential extraction (Fe, Mn, Al, Mo) [2] - (1/2 kg) from fine grained/clay interval	Solid Phase Testing: Kd, linear isotherm [3] (1 kg from sand unit if possible) - vacuum seal	Solid Phase Testing: MNA + Evaluation [3] (1 kg from sand unit if possible) - vacuum seal	Solid Phase Testing: Rock core permeability/hydraulic conductivity	Aqueous Phase Testing: Packer Hydraulic Test	Aqueous Phase Testing: Slug Test	Aqueous Phase Testing: Groundwater Sample
Proposed Bedrock Borings and Monitoring Wells						**Proposed sample interval**							
WAP-4BR	Bedrock	126	156	TBD - TBD	131	(49-51), (79-81)	~40-45	~50-55	~50-55	TBD	X	*	*
WAP-7BR	Bedrock	85	115	TBD - TBD	90	(54-56), (72-74)	~40-45	~50-55	~50-55	TBD	X	*	*
WAP-9BR	Bedrock	126	156	TBD - TBD	131	(59-61), (84-86)	~40-45	~55-60	~55-60	TBD	X	*	*

Notes:

Depths listed for proposed monitoring wells are estimates and may change based on field observations
-- indicates not applicable
** slug testing and groundwater sampling to be completed if bedrock monitoring well is necessary and groundwater yield is sufficient*
ft bgs = feet below ground surface
ft MSL = feet above mean seal level
ft bTOC = feet below top of casing
TBD = to be determined
[1] *Ground surface for proposed wells estimated based on nearby wells*
[2] *ACZ Laboratories, Inc.*
[3] *Ursus Remediation Testing*

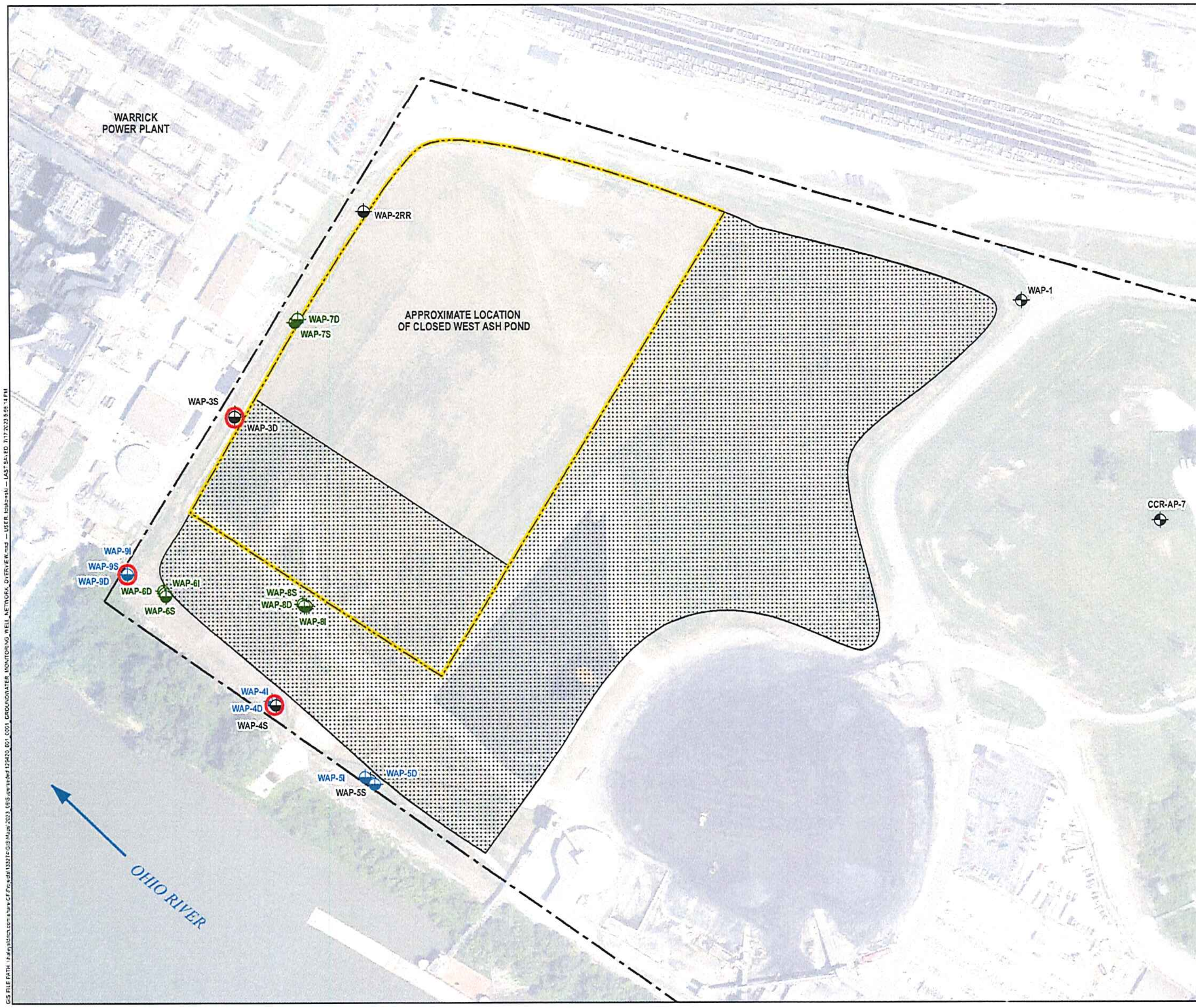
TABLE 2
SUMMARY OF ANALYTES, ANALYTICAL METHODS, LABORATORY REPORTING LIMITS, AND METHOD DETECTION LIMITS
F.B.CULLEY GENERATING STATION
WEST ASH POND
WARRICK COUNTY, INDIANA

Analyte Group	Analyte	Analytical Method	Reporting Limit	Method Detection Limit
Detection Monitoring - EPA Appendix III Constituents - 40 CFR Part 257				
Inorganics	Boron	EPA 6020A	0.5	0.04
Inorganics	Calcium	EPA 6020A	0.0005	0.0001
Anions	Chloride	EPA 9056A	1.0	0.08
Anions	Fluoride	EPA 9056A	0.1	0.05
Anions	Sulfate	EPA 9056A	1.0	0.2
Wet Chemistry	pH [f]	EPA 9040C	N/A	N/A
Wet Chemistry	Total Dissolved Solids	SM 2540C	30	10
Assessment Monitoring - EPA Appendix IV Constituents - 40 CFR Part 257				
Inorganics	Antimony	EPA 6020A	0.005	0.001
Inorganics	Arsenic	EPA 6020A	0.005	0.002
Inorganics	Barium	EPA 6020A	0.005	0.001
Inorganics	Beryllium	EPA 6020A	0.002	0.0002
Inorganics	Boron [a]	EPA 6020A	0.5	0.04
Inorganics	Cadmium	EPA 6020A	0.002	0.0002
Inorganics	Chromium	EPA 6020A	0.005	0.002
Inorganics	Cobalt	EPA 6020A	0.002	0.0002
Inorganics	Hexavalent Chromium [b]	[d]	--	--
Inorganics	Lead [e]	EPA 6020A	0.003	0.0006
Inorganics	Lithium	EPA 6020A	0.00500	0.00107
Inorganics	Molybdenum	EPA 6020A	0.005	0.001
Inorganics	Selenium	EPA 6020A	0.005	0.002
Inorganics	Thallium	EPA 6020A	0.002	0.00006
Inorganics	Trivalent Chromium [b]	-- [c]	-- [c]	-- [c]
Inorganics	Mercury	EPA 7470A	0.0002	0.00003
Anions	Fluoride	EPA 9056A	0.1	0.05
Radiochemistry	Radium 226 and 228 combined	EPA 903.0/904.0	1 pCi/L	N/A

Notes:
Units in mg/L except where noted
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
mg/L = milligrams per liter
pCi/L = picocuries per liter
SM = Standard Method
N/A = not applicable

[a] IDEM-only requirement
[b] Will only be analyzed if chromium is greater than the groundwater protection standard.
[c] Trivalent Chromium is a calculated value of total chromium minus hexavalent chromium.
[d] In the event that sampling for hexavalent chromium needs to occur, the laboratory methodology will be chosen in consultation with IDEM.
[e] Lead is regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. The action level for lead is 0.015 mg/L
[f] The criteria for pH is within the range of 6.5 - 8.5 pH units.

FIGURE



LEGEND

- UPGRADIENT CCR COMPLIANCE MONITORING WELL
- DOWNGRADIENT CCR COMPLIANCE MONITORING WELL
- DOWNGRADIENT WELL TO ASSESS NATURE AND EXTENT OF APPENDIX IV SSLs
- DOWNGRADIENT WELL TO COMPLY WITH IDEM APPROVAL OF CLOSURE/POST CLOSURE PLAN
- APPROXIMATE LIMITS OF WEST ASH POND FINAL COVER
- APPROXIMATE LIMITS OF WEST ASH POND CCR REMOVAL
- WEST ASH POND
- APPROXIMATE F.B. CULLEY PROPERTY BOUNDARY
- PROPOSED BEDROCK CHARACTERIZATION BORING

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. AERIAL IMAGERY SOURCE: HEXAGON 21 JULY 2022

0 200 400
SCALE IN FEET

HALEY ALDRICH

F.B. CULLEY GENERATING STATION
WEST ASH POND
NEWBURGH, INDIANA

PROPOSED BEDROCK CHARACTERIZATION BORING LOCATIONS

JANUARY 202

FIGURE 1

APPENDIX A
Haley & Aldrich Standard Operating Procedure OP3016

OPERATING PROCEDURE: OP3016

SLUG TESTS

PREPARATION AND APPROVALS

VERSION	AUTHORED/DATE	REVIEWED / DATE	REVIEWED / DATE	REVIEWED / DATE	APPROVED / DATE
Ver. 0.0	MGB	DBK/ 02-03			JAK/ September 2003

Total Pages: 14

HALEY & ALDRICH

TABLE OF CONTENTS

OPERATING PROCEDURE: OP3016

SLUG TESTS

1. PURPOSE

1.1 Introduction

This operating procedure (OP) describes the protocol for performing slug tests (in-situ hydraulic conductivity tests, rising-head tests, falling-head tests) including preparation, collection of valid field data, and preliminary evaluation of the data.

A slug test is performed to assess the horizontal hydraulic conductivity of a water-bearing zone. Slug tests are accomplished by stressing the screened water-bearing zone through an "instantaneous" displacement of water (with a slug) or removal of water (with a bailer) and subsequently measuring the water level response in the well over time. A very rapid change in the water level in a well can be created using one of these field methods:

- Inserting and rapidly withdrawing a solid dense object (a.k.a. a slug). Solid slugs are the preferred option;
- Removing water using a bailer. Bailers should be used to remove water only if using a slug is not possible;
- Changing the air pressure in a well causing displacement of well fluids (pneumatic displacement method)

The method chosen will depend on project needs, equipment availability, water disposal/treatment options, pertinent laws and regulations, and operator experience.

The protocols that follow assume that field staff can effectively perform one of these methods for rapidly changing the water level in a well at the start of a slug test, and can then use either a manual or automatic procedure for measuring water level response over time. When practical strive to measure slug test response with automatic datalogger devices.

This OP provides only a guideline for performing slug tests. There are many factors that go into performing slug tests in the field and just as many factors that can affect the quality of the data collected. An experienced hydrogeologist or groundwater specialist should be consulted before preparing a slug test program or performing a slug test.

1.2 Considerations

Certain conditions or activities should be avoided when performing slug tests. In general, a person should **not** conduct any type of slug tests in a well if:

- The well contains a pipe, tube, or other obstruction in the depth range where the water level is anticipated to change
- The casing diameter in a well varies in the depth range where the water level is anticipated to change
- The water level in a well has not yet recovered to nearly static conditions (i.e., 90% or more) after a prior disturbance, (e.g., drilling, purging, development, previous well tests, etc.)
- Non-aqueous phase liquid (NAPL) is present in a well
- The water level in the well cannot be appreciably changed due to minimal slug size or volume, large well casing diameter, etc.

A ***rising-head*** test should generally **not** be conducted:

- If the slug or amount of water to be removed cannot be removed nearly instantaneously (i.e., if removal takes over 5% of the "90%-recovery" time)
- By pumping to remove water, unless the amount of water to be removed by the pump can be removed nearly instantaneously and any back-flush can be eliminated;
- By using bailers. If a bailer must be used, avoid:
  - using a bailer that has a leaky check valve
  - bailing multiple times instead of creating an instantaneous water level change
  - using a bailer with a diameter so close to that of the casing that groundwater is suctioned into the well while the bailer is raised.

Falling-head tests are generally not recommended due to inherent problems associated with reproducibility, the introduction of fluids, and general application restrictions. They are recommended in circumstances when no other option is available. Consult with the Project Manager or an experienced hydrogeologist before undertaking a falling-head test program.

2. EQUIPMENT & SUPPLIES

- A battery-operated water level measurement probe, marked in 0.01-foot increments
- Field books, appropriate field forms (See Appendix C), clipboards, rulers, graph paper, calculator, etc.
- Site maps (property lines, wells, topography, etc.), as needed
- Site-access and well-cap keys, as needed
- A clean bailer or a solid or sealed slug
- Clean rope or string for raising and lowering a bailer or slug
- Appropriate container for withdrawn groundwater and/or decontamination fluids
- Tools necessary for well access (shovel, bolt-cutters, etc.)
- For flowing artesian wells: duct tape, couplings, and extra casing of appropriate diameter for increasing casing height so as to enable measurement of a SWL. (NOTE: Tests on artesian wells are identical to other testing if the casing can be raised to a level above the well's static water level surface. If not, alternative methods such as measurement of pressure may be performed. Appropriate literature or methodologies should be consulted when performing such alternative testing.)
- Data logger and laptop computer with fully charged battery (if required)
- Pressure transducer of appropriate pressure range for the depths of water to be tested, if needed
- Clamps, tape, cable ties, or rope to secure the transducer cable to the well casing

3. PROCEDURE

3.1 Pre-testing Preparatory Activities

There are a number of preliminary steps that should be taken prior to conducting slug tests. These include, at a minimum, the following:

- Review requirements of the project Work Plan and Health & Safety Plan to assure compliance with any applicable requirements or regulations.
- Clear all necessary access issues (permission, physical access, permits, etc.).

- Gather all necessary equipment, materials, and tools necessary to adequately perform the tests.
- Identify the monitoring wells, piezometers, or other monitoring points to be used in tests.
- Gather all necessary installation information on the well to be tested and all monitoring.
- Decontaminate all necessary equipment before entering the site or performing tests in accordance with the Work Plan, if required. As necessary or required, decontaminate all impacted equipment prior to tests, between test locations, and after testing is completed. If decontamination cannot or will not be performed and dedicated equipment will not be used then proceed with testing from the least contaminated to most contaminated locations to minimize cross-contamination.
- Determine the most appropriate method to dispose of decontamination water in accordance with the Work Plan, if required. If potentially contaminated, the water should be containerized for subsequent characterization and proper disposal or treatment in accordance with applicable regulations.
- Synchronize all time devices including watches, computer clocks, datalogger and transducer clocks, etc.

Other information potentially needed for proper slug test data interpretation includes:

- Depth-interval of screen or open section in well
- Sandpack porosity (if water levels intersect screen)
- Sandpack diameter (if water levels intersect screen)
- Stratigraphic horizon materials and elevations
- Hydraulic conductivity of bounding low-hydraulic conductivity units, if present
- Ground-surface elevation
- Typical or historical groundwater elevations or depths-to-water

3.2 Procedure

The steps for conducting a slug test are as follows. An attempt to utilize dataloggers to collect water level measurements should be made if at all possible. Manual measurements should only be used if absolutely necessary or to collect back-up data.

1. Follow all required "Pre-Test Preparatory Activities", as warranted.
2. Measure and record the Static Water Level (SWL) of the well to be tested, in accordance with the Water Level Measurement OP3008.

3. Test the pressure transducer and data logger, and obtain well-bottom pressures/water column heights and SWL pressures, using the following steps. **NOTE**: attention must be paid to the maximum allowable immersion depth (i.e., the manufacturer specifications for acceptable pressure range of the transducer, where 1 psi = 2.311 feet of water):

   - Place the pressure transducer at least several feet below the top of water as well as below the projected depth of the lowest part of the bailer or slug to be used.
   - Make pressure readings until three uniform values are read consecutively.
   - Raise the datalogger one (1) foot from its original position. View the pressure reading to confirm that the change in position was accurately reported by the transducer.
   - Lower the pressure transducer to the base of the well, and measure and record the pressure/height of water column. Again, refer to note above regarding maximum allowable immersion depth.
   - Return the transducer to its original position and secure the suspension cable to the well casing. Again, make pressure readings until three uniform values are read consecutively. Compare with the original readings to make sure no drift occurs.

4. Perform the following pre-test activities for a ***rising-head*** test:

   - Allow the slug (or bailer) that will be used to move down into the groundwater. (Fully immerse the bailer if possible. If there is not enough water in the well for the bailer to be fully immersed, then let the bottom of the bailer gently come to rest on the well bottom, or a few inches above the well bottom. Prevent agitation of sediment on the bottom of the well, as sediment in the bailer may keep the check valve from properly sealing.) I don't see how it can ever get to the bottom if the transducer is supposed to be below it
   - Measure falling pressures during recovery using the pressure transducer until the water level in the well re-equilibrates. IMPORTANT: the water level in the well should be allowed to return to near-static conditions (within 0.02 feet) before initiating test.
   - Set the pressure transducer below the base of the immersed bailer or slug. Isn't it already supposed to be in place? See 3, above.

5. Start the slug test by creating a nearly instantaneous displacement in water level:

   - Pull the bailer or slug rapidly upwards, either removing it from the well or securing/suspending it within the well several feet above the SWL.
   - Simultaneously pull bailer and to displacing the water, initiate the datalogger, beginning the measuring/recording of rising water levels in the well at the predetermined time frequencies (a logarithmic time scale is usually employed).

- If a bailer is used, listen for cascading water while the bailer is being raised or is suspended. This is a sign of check-valve failure. If failure occurs, clean and repair the valve and start over.

- If a bailer is used, measure the volume of water removed by the bailer after retrieval.

6. Continue measuring the water levels as they change over time until the water in the well rises or falls to the limit specified in the Project Work Plan (usually 90% recovery or one hour, whichever comes first). A pre-set logarithmic sampling interval, with increasing intervals of time, is ideal, usually predetermined by the datalogger's default setup.

7. Compare the volume of groundwater recovered in the bailer, if one is used, with the volume of groundwater estimated to have been removed from the well (V) based on the initial recorded water-level displacement (H) and borehole radius (r), (e.g., $V=H\pi r^2$). If, for a rising-head test, the static water level lies within the screened section of the well, then the sandpack porosity (n) and radius (R) should be accounted for also in the volume calculation, (e.g., $V=H\pi r^2 + nH\pi(R-r)^2$). A similar comparison can be performed if a slug is used in a falling-head test. If the volume recovered and the calculated volume does not reasonably correlate, based on site-specific conditions, the test should be performed again.

8. Record all general and pertinent test data in a field book or on appropriate forms.

9. Decontaminate all necessary equipment in accordance with the Work Plan or Equipment Decontamination OPs.

10. Properly containerize and label spent decontamination fluids or groundwater removed from the well in accordance with the Work Plan or other waste characterization guidance, OPs, and/or regulations.

11. Lock all well caps and secure the site as needed.

12. Submit the slug-test data to a qualified scientist or engineer assigned by the Project Manager for interpretation. The data should be interpreted by an experienced hydrogeologist. Calculations should be based on an appropriate model for the known hydrogeologic conditions in the field.

Any variations from these procedures should first be approved by the Project Manager.

3.3 Field Documentation

The following data should be obtained prior to heading into the field and/or in the field during slug tests and recorded appropriately (either on appropriate forms, in a field book, and/or onto an electronic form copied to computer disk):

- Client name
- Site name and location
- Test company, if applicable

- Name of field staff performing the test
- Test date and time
- Well ID
- Well location
- Well casing, screen and borehole diameter
- Well screen or open-hole section diameter
- Total depth of well
- Any unusual well, weather, or hydrologic features or conditions
- Height (measured distance) of well riser or reference point above or below grade
- Test procedure used (solid slug or pneumatic)
- Storage, transport, and disposal methods for any water removed
- Well drilling method (hollow-stem auger, mud rotary, etc.)
- Decontamination procedures
- Problems and solutions to problems encountered during testing
- Static water level
- Slug volume

APPENDIX A
REFERENCES

- Bouwer, H. 1979. Groundwater Hydrology. New York: McGraw-Hill Book Company.
- Bouwer, H. 1989. The Bouwer and Rice Slug Test -- An Update. Ground Water, vol. 27, no. 3: 304-309.
- Bouwer, H., and R.C. Rice, 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resour. Res., vol. 12, no. 3: 423-428.
- Butler, J.J., Jr. 1996. Slug Tests in Site Characterization: Some Practical Considerations. Environ. Geoscience., 3: 154-163.
- Butler, J.J., Jr., and Z. Hyder. 1994. An Assessment of the Nguyen and Pinder Method for Slug Test Analysis. Ground Water Monitoring and Remediation, 14: 124-131.
- Butler, J.J., Jr., C.D. McElwee, and W.Z. Liu. 1996. Improving the Quality of Parameter Estimates Obtained from Slug Tests. Ground Water, 34: 480-490.
- Chirlin, G.R. 1989. A critique of the Hvorslev Method for Slug Test Analysis: The Fully Penetrating Well. Ground Water Monitoring Rev., 1: 365-381.
- Cooper, H.H., Jr., J.D. Bredehoeft, and I.S. Papadopulos. 1967. Response of a Finite Diameter Well to an Instantaneous Charge of Water. Water Resour. Res., 3, no. 1: 263-269.
- Cooper, H.H., Jr., J.D. Bredehoeft, and I.S. Papadopulos. 1973. On Analysis of Slug Test Data, Water Resour. Res., vol. 3, no. 4: 1087-1089.
- Domenico, P.A. and Schwartz, F.W. 1990. Physical and Chemical Hydrogeology, John Wiley & Sons, Inc. New York, 824 pp.
- Fetter, C.W. 1993. Contaminant Hydrogeology, Macmillan Publishing Co., New York, 458 pp.
- Fetter, C.W. 1994. Applied Hydrogeology, 3rd Ed., MacMillan College Publishing Company, New York, 691 pp.
- Hvorslev, M.J. 1951. Time Lag and Soil Permeability in Ground-Water Observations. Bull. No. 36, Waterways Exper. Sta., Corps of Engrs., U.S. Army, Vicksburg, Mississippi: 1-50.
- Hyder, Z. and J.J. Butler, Jr. 1995. Slug Tests in Unconfined Formations; An Assessment of the Bouwer and Rice Technique. Ground Water, vol. 33, no. 1: 16-22.

APPENDIX A
REFERENCES
(Continued)

- Hyder, Z., J.J. Butler Jr., C.D. McElwee, and W.Z. Liu. 1994. Slug Tests in Partially Penetrating Wells. Water Resour. Res., vol. 30: 2913-2919.

- Khilar, K.C. and H.S. Fogler. 1987. Colloidally induced fines migration in porous media. Rev. Chem. Eng. 4, nos. 1-2: 1-149.

- Kruseman, G.P. and N.A. de Ridder. 1990. Analysis and Evaluation of Pumping Test Data, 2nd Ed., International Institute for Land Reclamation and Improvement, the Netherlands: 377 pp.

- Prosser, Pneumatic Displacement Method.

- Shapiro, A.M. and P.A. Hsieh. 1998. How good are estimates of transmissivity from slug tests in fractured rock. Ground Water (in press).

- U.S. Department of the Interior, Bureau of Reclamation. 1985. Ground-Water Manual. United States Government Printing Office. Denver. 480 pp.

- Van der Kamp, G. 1976. Determining aquifer transmissivity by means of well response tests: the underdamped case. Water Resour. Res. 12: 71-77.

- Watson and Burnett, A.D. 1993. Hydrology, an Environmental Approach. Ft. Lauderdale: Buchanon Books. 702 pp.

- Widdowson, M.A., F.J. Molz, and J.G. Melville. 1990. An analysis technique for multilevel and partially penetrating slug test data. Ground Water. 28, no. 6: 937-945.

- Zlotnik, V. 1994. Interpretation of slug and packer tests in anisotropic aquifers. Ground Water. 32, no. 5: 761-766.

APPENDIX B
RELATED HALEY & ALDRICH PROCEDURES

- OP1009 Medical Surveillance Program
- OP1010 Health and Safety Plans
- OP 3000 General Environmental
- OP3008 Manual Water Level Measurement
- OP3015 Aquifer Parameter Testing Procedure
- OP3018 Vertical Water Quality Profiling Procedure
- OP3025 Hydraulic Conductivity
- OP3027 Decontamination Procedure

APPENDIX C
FORMS

APPENDIX D
GLOSSARY