Herman Kishner Trust B-1 and Maryland Square Shopping Center, L.L.C.

PRE-DESIGN CHARACTERIZATION WORK PLAN

Maryland Square PCE Site
Las Vegas, Nevada
Facility ID No. H-000086

Version 1.0

June 9, 2016

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CONTENTS

Acronyms, Abbreviations and definitions 4
1 Introduction 5
2 Conceptual Site Model 5
3 Objectives 7
4 Scope and Application 8
4.1 High Resolution Subsurface Characterization 8
4.1.1 Purpose 8
4.1.2 Methodology and Scope 8
4.2 Eastern DGR Area Well Pair Injection/Extraction Test 10
4.2.1 Purpose 10
4.2.2 Well Installation 10
4.2.2.1 Location Clearance 10
4.2.2.2 Drilling Procedures 11
4.2.2.3 Well Construction and Completion 11
4.2.3 Well Development 11
4.2.4 Extraction Test 12
4.2.5 Injection Test 13
5 Access, Site Control and Investigation Derived Waste Management 13
5.1 Access to Maryland Square and Boulevard Mall Properties 13
5.2 Site Control 14
5.3 Investigation Derived Waste Characterization, Storage and Disposal 14
5.3.1 Soil 14
5.3.2 Water 15
6 Proposed Schedule 15
7 References 15
8 environmental certification Jurat 16

TABLES

Table 1 Proposed MiHPT Borings

Table 2 Proposed Injection and Extraction Well Construction

FIGURES

Figure 1 Site Vicinity Map

Figure 2 NDEP Conceptual Site Model

Figure 3 Cross Section A-A'

Figure 4 Cross Section B-B'

Figure 5 Cross Section C-C'

Figure 6 Proposed MiHPT Boring Locations

Figure 7 Proposed Extraction and Injection Well Locations

Figure 8 Typical Injection/Extraction Well Construction Diagram

APPENDICES

Appendix A Geoprobe Hydraulic Profiling Tool (HPT) System Standard Operating Procedure and Geoprobe Membrane Interface Probe (MIP) Standard Operating Procedure

Appendix B Extraction Testing Procedure

Appendix C Injection Testing Procedure

ACRONYMS, ABBREVIATIONS AND DEFINITIONS

APN	Assessors Parcel Number
APS	Waterloo Advanced Profiling System
Arcadis	Arcadis U.S., Inc.
bgs	below ground surface
CSM	Conceptual Site Model
DGR	Dynamic Groundwater Recirculation
DNAPL	Dense Non-aqueous-Phase Liquid
DTW	depth to water
EPA	United States Environmental Protection Agency
ft	foot or feet
GAC	Granular Activated Carbon
HPT	Hydraulic Profiling Tool
in.	inch or inches
MiHPT	Membrane Interface Probe and Hydraulic Profiling Tool Combination
MIP	Membrane Interface Probe
MW	Monitoring Well (Groundwater)
NDEP	Nevada Division of Environmental Protection
PCE	Tetrachloroethylene/Tetrachloroethene
PID	Photoionization Detector
PVC	Polyvinyl Chloride
ROD	Record of Decision
SVOC	Semi-Volatile Organic Compound
TCLP	Toxicity Characteristic Leaching Procedure
TD	total depth
Trust	Herman Kishner Trust B-1 and Maryland Square Shopping Center, L.L.C.
µg/l	micrograms per liter or parts per billion
UIC	Underground Injection Control
VOC	Volatile Organic Compound

1 INTRODUCTION

On behalf of Herman Kishner Trust B-1 and Maryland Square Shopping Center L.L.C. (Trust), Arcadis U.S., Inc. (Arcadis) has prepared this *Draft Pre-Design Characterization Work Plan, Maryland Square PCE Site, Las Vegas, Nevada, Facility ID No. H-000086* (work plan) to collect additional data to support the design of a dynamic groundwater recirculation (DGR) remedial system at the Maryland Square PCE Site (Site). Data collected will be used to further define our understanding of the hydrogeologic framework and the extent of tetrachloroethylene (PCE) contamination beneath the Site in order to fine-tune the existing conceptual site model (CSM).

Groundwater treatment is mandated in the March 31, 2015 Record of Decision (ROD) for the Site. The ROD specifies the following:

- The preferred remedy is implementation of hydraulic containment and capture and removal of contaminant mass with aboveground treatment. The remedy is focused on accelerated reduction of the contaminant plume upgradient from the residential area to minimize potential exposure to sensitive receptors as quickly as possible.
- The cleanup goal is to reduce concentrations of PCE in groundwater to less than 100 micrograms per liter (µg/L) beneath residential areas affected by the plume based on the vapor intrusion exposure pathway and associated risk.

The investigations proposed by this work plan focus on the former Maryland Square Shopping Center (herein synonymous with source area), what is referred to in the ROD as the “West Treatment Area” (herein referred to as the western dynamic groundwater recirculation (DGR) area), and the “East Treatment Area” (herein referred to as the eastern DGR area). The investigation will incorporate a dynamic work plan approach utilizing real time evaluation of field data and collaboration with various stakeholders to guide and complete the investigation objectives in a timely and efficient manner.

Arcadis anticipates that the proposed western DGR area will satisfy the requirements of the ROD for the reduction of PCE mass without the use of either air sparge/soil vapor extraction or in situ chemical oxidation technologies. Arcadis may consider air sparge/soil vapor extraction or in situ chemical oxidation technologies should the pre-design characterization data indicate that a DGR approach is not viable, or in the event that DGR does not appear to effectively satisfy requirements of the ROD following implementation and monitoring.

2 CONCEPTUAL SITE MODEL

The CSM was developed by the Nevada Division of Environmental Protection (NDEP) and is quoted here from the ROD (NDEP 2015):

> “The conceptual site model (CSM) is based on the inhalation exposure pathway, wherein indoor air is contaminated with PCE vapors emanating from PCE-contaminated groundwater (Figure 5-1 [Figure 2 of this work plan]). Residents are exposed when they breathe the contaminated indoor air. Vapor intrusion has been confirmed at the site by sampling of soil gas and indoor air. There

is also the potential for exposure via ingestion, if actively used domestic wells intercept the plume. The latter exposure scenario assumes that groundwater wells are completed in the shallow groundwater system hosting the Maryland Square PCE plume, and that the water is used as an untreated drinking water source. This latter scenario is unlikely to occur throughout most of the plume, because homes are on a city water system throughout the neighborhood and drilling of new domestic wells is generally prohibited in Las Vegas.

The deeper drinking-water aquifers underlying the Maryland Square PCE Site have not been affected by the PCE plume. The vertical hydraulic conductivity is significantly lower than (1/100th) the horizontal hydraulic conductivity; this means the dissolved-phase PCE plume migrates laterally rather than vertically. Additionally, a thick heterogeneous sequence of interbedded clays, silts, silty sands, caliche, and gravels overlies the drinking-water aquifer.

Site conditions indicate that it is highly unlikely that contaminants in the plume will migrate vertically downward to the water-supply aquifer at 300 to 500 feet (ft) below the ground surface. Studies of the chemical composition and extent of contamination across aquitards and aquifers in the basin show that areas of contaminated shallow groundwater have not affected the deep water-supply aquifer (Leising, 2004). Dissolved-phase PCE is neutrally buoyant, so barring any strong downward hydraulic gradient, downward migration of the plume is unlikely. Pure-phase PCE, which is classified as a “dense non-aqueous-phase liquid” (DNAPL) because it has a higher specific gravity than water and can migrate downward due to density differences, has not been found at the Maryland Square PCE site.

Results of contaminant-transport modeling using calculations and a simple analytical model are consistent with what is known about the site geology, geochemistry, and hydrogeology. That is, the PCE is not degrading via reductive dechlorination, the migration of PCE is only slightly retarded (due to low organic-carbon content of site soils), and some fraction of the PCE migrates more quickly through more transmissive zones such as sand channels or stringers, while the bulk of PCE migrates slowly through fine-grained materials.

The 14-compartment model for DNAPLs (Sale & Newell, 2011) suggests the Maryland Square PCE plume is a mature plume, with secondary sources (i.e., fine-grained soils saturated with PCE) serving to sustain the dissolved-phase plume. Slow release of PCE stored in fine-grained, low-conductivity materials can sustain a plume long after the primary source (free pure-phase DNAPL) is depleted.

Although the shallow groundwater in the Las Vegas Valley is of poor quality and not generally used for drinking water or other beneficial purposes, contamination of this groundwater with volatile chemicals is a concern for several reasons. Samples of soil gas and indoor air have confirmed that PCE vapors emanating from the contaminant plume have travelled through vadose-zone soils and up into homes overlying the plume. Concentrations of PCE in samples of groundwater collected from monitoring wells within the residential neighborhood have been as high as 3,500 µg/L.

Vapor intrusion is the process by which contaminant vapors enter into, and accumulate within, the indoor air of homes and other buildings. Exposure occurs when occupants breathe the contaminated indoor air. Analytical results from testing indoor air in more than 100 homes have

found potentially unacceptable levels of PCE in indoor air in some of the homes. However, the only homes found to be adversely affected overlie groundwater with more than 100 µg/L PCE (i.e., homes outside of the 100 µg/L PCE contour in groundwater do not appear to be adversely affected by intrusion of PCE vapors)."

Arcadis evaluated and modified cross sections prepared by Tetra Tech (Tetra Tech 2013). Modified versions are shown on Figures 3, 4 and 5. The modified figures illustrate the current CSM including site lithology and distribution of PCE contaminated groundwater. Data gaps identified in Figures 3, 4, and 5 will be addressed by this work plan. The CSM will be revised and updated as needed based on the results of the investigation.

Background information on the regional hydrogeology indicates that the valley-fill deposits under the Site consist of three relatively distinct zones, each with individual water-bearing characteristics: Las Vegas Wash Aquitard, Las Vegas Springs Aquifer, and Duck Creek Aquifer (Maxey and Jameson 1948). The nomenclature for these hydrostratigraphic units is also included in Donovan (1996) and Leising (2004). The uppermost zone, the Las Vegas Wash Aquitard, is approximately 200 ft thick, but may vary locally and has generally low water yields. According to Leising (2004) after Donovan (1996), the unit is undivided and in the central and eastern areas of the Las Vegas Valley grades into fine-grained deposits.

Based on the generally fine-grained interbedded lithologies encountered at the Site, the nature of groundwater at the Site, and the location of the Site within the Las Vegas Valley, it is believed that the groundwater encountered beneath the Site is associated with the undivided members of the Las Vegas Wash Aquitard, also termed the "shallow system" (Leising 2004) and referred to hereinafter as the "shallow groundwater system". This system has been termed an aquitard from a regional perspective, especially with respect to the more conductive underlying aquifer systems (e.g., the Las Vegas Springs Aquifer), and thus use of the term "shallow aquifer" should be avoided (Leising 2004). Use of the term "aquifer" in this work plan is intended to be generic and is not a reflection of the hydraulic properties of the shallow groundwater system underlying the Site. The investigations proposed in this work plan are presumed to be focused on the Las Vegas Wash Aquitard and/or the shallow groundwater system.

3 OBJECTIVES

The objectives of the investigation are to collect high-resolution information regarding subsurface soil and aquifer physical properties, including porosity and permeability, and to further characterize the distribution and migration of PCE mass within the hydrogeologic framework, both in the source area and in the proposed DGR treatment areas.

Information obtained will be used to identify areas of mass storage and mass flux within the aquifer in order to focus remedial efforts where the greatest impact can be made with the goal of designing a system that:

- efficiently removes PCE mass from the aquifer to achieve cleanup goals in a timely manner;.
- allows for continuous evaluation and adaptive modifications to enhance the remedy as additional performance data are collected; and
- is cost effective and acceptable to NDEP.

4 SCOPE AND APPLICATION

4.1 High Resolution Subsurface Characterization

4.1.1 Purpose

The High Resolution Subsurface Characterization will provide data to assist in the DGR remedial design. The results will be used to:

- Characterize subsurface hydrostratigraphic conditions that promote mass storage (fine-grained areas) and mass flux (preferential pathways for mass transport),
- Evaluate the distribution of PCE, both vertically and laterally in the source zone and downgradient aquifer.
- Evaluate remaining PCE mass in the source area on the former Maryland Square Shopping Center property.
- Estimate PCE mass flux entering and leaving the Boulevard Mall property.
- Support the location and design of a well pair (or pairs) to test the hydraulic characteristics of the contaminated aquifer in the eastern DGR system.
- Support the design of the western and eastern DGR systems.

4.1.2 Methodology and Scope

A dynamic work plan using the following methodology will be employed:

- Direct and continuous communication between field geologists and senior staff during drilling operations and data acquisition, to quickly evaluate subsurface conditions.
- Near real-time transmission of data from field to office.
- Guidance and control of the locations and depths of borings, to maximize collection of pertinent and high quality data, while minimizing collection of redundant or non-valuable data.
- Regular communication with the client and NDEP, to keep stakeholders informed of drilling progress and to solicit input at significant decision points.

Arcadis will coordinate conference calls, as needed, to facilitate work plan progress and decision point discussions. The following are the proposed primary points of contact for dynamic work plan decision points:

- NDEP: Mary A. Siders, Ph.D., Bureau of Corrective Actions
- Herman Kishner Trust: Drew Flynn, Marsh & McLennan Agency, LLC
- Arcadis: Brad Cross

A combination of direct push and rotary drilling techniques will be employed to advance borings at the site (Figure 6). A combination membrane interface probe and hydraulic profiling tool (MiHPT) will be attached to the end of a drill string and advanced into the unconsolidated soil. The MiHPTincludes both of the following technologies:

- **The hydraulic profiling tool (HPT)** allows the user to create fast, continuous, real-time profiles of soil hydraulic properties in both fine and coarse grained material. A small volume of water is continuously injected into the formation at a rate of approximately 200 to 300 milliliters per minute. At the same time, the injection backpressure, as well as the flow rate, are measured and logged. After correction for atmospheric and hydrostatic pressure effects, the flow and pressure data are plotted as relative hydraulic conductivity by recognizing that hydraulic conductivity is proportional to flow divided by pressure.

  Once the HPT has been advanced below the water table, a “dissipation test” will be performed to verify the elevation of the water table. Tooling advancement is paused during a dissipation test and the flow of water to the HPT is turned off. The pressure response is then recorded as it returns to a stable reading consistent with ambient hydrostatic pressure. Dissipation test results are used to correct the HPT pressure curve for hydrostatic pressure effects, and accurately calculate the estimated hydraulic conductivity of the formation. A minimum of one dissipation test will be conducted per boring. The HPT will be calibrated according to the manufacturer’s standard operating procedures for the MiHPT tool (Appendix A) prior to beginning work and after each boring has been completed.

- **The membrane interface probe (MIP)** is used to detect the presence and relative concentration of volatile organic compounds (VOCs) in unsaturated and saturated subsurface soils. The MIP will be used in accordance with the manufacturer’s standard operating procedures for the MiHPT tool (Appendix A). An electrical conductivity dipole in the MiHPT will acquire measurements of the electrical conductivity of the soil, providing information related to soil composition and related physical properties. The electrical conductivity measurements will be collected in accordance with the manufacturer’s standard operating procedures for the MiHPT tool (Appendix A).

Arcadis plans to advance a minimum of 10 MiHPT borings using a combination of direct push and rotary drilling techniques. Rotary drilling will be employed in zones of caliche or where tool advancement is otherwise impeded due to subsurface soil conditions. In instances where tool advancement is impeded, the MiHPT tool will be removed from the boring. A small diameter auger will be tripped in to advance the boring. The auger will be removed from the boring when the depth of the boring exceeds the bottom of the competent soil layer, and the MiHPT will resume. The MiHPT will be advanced with direct push drilling techniques below the competent soil layer.

A summary of the proposed borings and the rationale for each boring is provided in Table 1, and the proposed boring locations are shown on Figures 3, 4, 5, and 6. Rapid acquisition of large amounts of high resolution data is expected. Data will be transmitted to the Arcadis office after collection. Based on field observations and field results, alternative boring locations and/or additional borings may be added during the investigation. Conversely, field observations and results may indicate that a proposed boring location may not be necessary and the boring will not be completed. Adding, removing, or altering the total depth of a boring will be discussed with representatives of the Trust and NDEP prior to field execution.

Arcadis may collect discrete interval grab groundwater samples for laboratory analysis to verify the results of the MIP. Grab groundwater samples will be collected in accordance with the standard operating procedures for the selected technology. Grab groundwater sampling may be conducted at selected locations as indicated in Table 1.

Utility clearance will be conducted at the proposed drilling locations with air knife to a depth of 6 feet below ground surface (ft bgs) prior to boring installations. The proposed work will be minimally intrusive, and will create only minimal surface damage. Borings will be backfilled with bentonite and the surface restored to previous condition. Minimal waste generation is expected. Waste will be characterized, stored, and disposed of as per Section 5.3 of this work plan.

If emplacement of MiHPT borings is not feasible, Arcadis will suspend the investigation and consult with representatives of the Trust and NDEP on other methods of investigation, including Nuclear Magnetic Resonance logging of selected existing monitoring wells at the Site.

4.2 Eastern DGR Area Well Pair Injection/Extraction Test

4.2.1 Purpose

A pair of wells will be installed and a groundwater injection/extraction test will be performed. The resulting confirmation data will be compared with measurements of permeability and porosity collected during the high resolution site characterization work in the eastern DGR area, and will assist in the remedial design for the full scale system. Data collected will be used to evaluate sustainable pumping rates and associated capture zones for extraction wells, to evaluate available injection capacities for injection wells, and to determine the optimal number and location of wells needed to achieve the goals of the remedy.

The wells will be located and constructed so that they can be incorporated into the full scale DGR system. Additional wells and injection/extraction tests may be conducted in the eastern or western DGR areas based on high resolution characterization results.

4.2.2 Well Installation

The proposed locations of the groundwater injection and extraction wells are illustrated on Figure 7, but may be modified depending on the results of the high resolution characterization. Two borings will be drilled and one injection and one extraction well will be installed.

4.2.2.1 Location Clearance

Prior to drilling, each proposed boring location will be cleared using a minimum of three lines of evidence. Each drilling location will be cleared by a licensed underground locator. Each boring will be hand or air knife cleared to a depth of at least 6 ft bgs or to caliche refusal, and to a diameter of 12 inches. Hand/air knife clearance deeper than 6 ft may be required if there are indications of deeply buried utilities in the vicinity of the intended boring location. Overhead clearance of at least 10 ft. is required for all aboveground utility lines. Power line clearances vary depending on the line voltage; the Arcadis guidance for utility clearance will be consulted for proper clearance distances.

4.2.2.2 Drilling Procedures

ARCADIS proposes to advance a 10 inch (in) diameter bore hole to approximately 71 ft bgs using hollow stem auger drilling technology. Drill cuttings will be observed and logged. Split-spoon samples may be collected at periodic or specific intervals to confirm or support HPT data and interpretation. Periodic measurements of the breathing zone with a PID will be performed during all drilling operations. All drill cuttings will be placed in drums or a roll off container and stored pending characterization and disposal.

4.2.2.3 Well Construction and Completion

Well construction details are summarized on Table 2 and illustrated on Figure 8. Each boring will be completed with a well casing and screen, a sounding tube, and a gravel tube, as described in more detail below. These three components will be zip-tied together and lowered into the boring.

- The well casing and screen will be constructed of 4-inch diameter stainless steel; the screen will consist of 0.040-inch slotted wire-wrap. Blank casing will be installed from ground surface to a tentative depth of approximately 20 ft bgs, with screen at tentative depths of approximately 20 to 70 ft bgs. The screen intervals and slot sizes may be modified following evaluation of the high resolution site characterization results.
- The annular sounding tube will be conducted of 1.5 in diameter Schedule 40 poly vinyl chloride (PVC).
- The gravel tube will be conducted of 1.5 in diameter Schedule 40 PVC. The gravel tube will extend from approximately ground surface to approximately 17 ft bgs, or three ft above the top of the screened intervals.

Colorado silica sand filter pack, mesh number 12-30, will be added to the annulus of the borehole from the total depth of the boring to a tentative depth of approximately 17 ft bgs, or three ft above the top of the screened intervals. The exact specifications of the filter pack may be modified following evaluation of the high resolution characterization results.

Two ft of #60 transition sand will be added on top of the sand pack to a depth of approximately 15 ft bgs, or five ft above the top of the screened intervals. Three ft of bentonite chips will be added on top of the transition sand. Water will be added to the bentonite chips, and the chips will be allowed to set for at least one hour. Following bentonite setup, a cement grout mixture will be tremmied into the boring to within 5 ft. of the surface, and the well will be left to set up for a minimum of 24 hours. The surface will be completed using a heavy traffic-rated, flush-mounted 12 in diameter well vault.

Investigative derived wastes (drill cuttings, well spoils, and decontamination water) will be stored in a roll-off bin or drums, and will be disposed of as per Section 5.3 of this work plan.

4.2.3 Well Development

Well development will occur following a 48 hour-settling period. Well development will be conducted to maximize well efficiency. Initially, a gentle, low-energy method will be employed. As the well develops, a higher energy method may be used.

For wire-wrap screens, water jetting is the preferred development method. If possible, the well may be pumped during development at a rate greater than the jetting rate to move sediment to the surface and avoid forcing fines into the formation. The submerged portions of each well screen will be developed for approximately 20 minutes per foot of submerged screen, or until the produced water is clear and free of suspended sediment.

The general procedure will be to:

1. Gauge total depth (TD) and depth to water (DTW).
2. Air lift or bail solids from the well.
3. Brush the well screen.
4. Air lift or bail solids from the well.
5. Measure DTW and TD of the well.
6. Surge using double surge blocks with concurrent air lifting. Water extraction rate will be recorded.
7. Measure DTW and TD of the well.
8. Jet well. If possible, well will be pumped during jetting.
9. Gauge well for DTW and TD.
10. Surge using double surge blocks with concurrent air lifting. Water extraction rate will be recorded.
11. Pump well until the water is clear and free of suspended material.

Both the extraction well and the injection well will be pumped at varying flow rates during well development. Well development data may be used to estimate extraction or injection rates for the constant rate extraction or injection tests (respectively). Water produced during well development will be properly characterized, stored, and disposed of as per Section 5.3 of this work plan.

4.2.4 Extraction Test

A groundwater extraction test will be performed on the newly installed extraction well EW-E-01 (see Figure 7). The well will be pumped at a constant rate for a minimum of 12 hours, and potentially up to 24 hours. The pumping rate will be determined from data obtained during the high resolution site characterization and well development. In general, the optimum pumping rate will be sufficient to stress the aquifer without resulting in excessive drawdown or significant head loss due to well inefficiency. Extraction testing procedures are included in Appendix B.

The anticipated observation well network for the EW-E-01 extraction test includes MW-20, MW-20D1, MW-20D2, MW-20D3 and MW-21 (see Figure 7). Groundwater levels may be manually measured in additional monitoring wells in the vicinity of the extraction well to supplement this network. The extraction well and each of the observation wells will have a transducer installed to record water levels (head pressure) for the test. Manual water level measurements will also be collected periodically during the test from each of these wells to verify (i.e., ground truth) the transducer measurements. Groundwater level data will be collected for approximately 24 hours prior to the test, throughout the test and for approximately 24 hours after the test. Both drawdown and recovery data will be analyzed and used to evaluate the hydraulic properties of the shallow groundwater system.

Water produced during the test will be stored in an onsite tank located within secondary containment. Ideally the tank will be located on the Boulevard Mall property adjacent to the injection/extraction well pair

during testing, but may be located on the former Maryland Square Shopping Center property, if necessary. At the end of the test, extracted water will be treated by granular activated carbon (GAC), characterized as described in Section 5.3, and stored in a second onsite tank. Assuming the GAC has removed the VOCs from the produced water and assuming proper permits are in place, the water will be recycled and injected back into the aquifer during the injection test. If the extracted water cannot be injected then the water will be stored and disposed of as described in Section 5.3.

4.2.5 Injection Test

A groundwater injection test will be performed on the newly installed injection well, IW-E-02 (see Figure 7). Arcadis proposes to inject treated groundwater (as discussed in Section 4.2.4) or municipal water under gravity flow from a temporary on-site tank at a constant rate for approximately 12 hours. Injection rate will be measured with a flow meter, monitored and controlled with a valve. The injection rate will be determined from data obtained during the high resolution site characterization, well development, and extraction testing. In general, the optimum injection rate will be sufficient to stress the well without resulting in excessive mounding in the well. Injection testing procedures are included in Appendix C.

The anticipated observation well network for the IW-E-02 injection test includes MW-19I, MW-19D1, MW-19D2, MW-19D3 and MW-19 (see Figure 7). Groundwater levels may be manually measured in additional monitoring wells in the vicinity of the extraction well to supplement this network. The injection well and each of the observation wells will have a transducer installed to record water levels (head pressure) for the test. Manual water level measurements will also be collected periodically during the test from each of these wells to verify (i.e., ground truth) the transducer measurements. Groundwater level data will be collected for approximately 24 hours prior to the test, throughout the test and for approximately 24 hours after the test. Both mounding and post-injection water level dissipation data will be analyzed and used to evaluate the hydraulic properties of the shallow groundwater system. Prior to performing an injection test Arcadis will obtain an Underground Injection Control (UIC) permit from the NDEP Bureau of Water Pollution Control.

5 ACCESS, SITE CONTROL AND INVESTIGATION DERIVED WASTE MANAGEMENT

5.1 Access to Maryland Square and Boulevard Mall Properties

The former Maryland Square Shopping Center property (APN 162-15-602-009) is owned by the Trust. Access has been granted to Arcadis for the purposes of environmental investigation and remediation for the duration of the contract between Arcadis and the Trust.

The Boulevard Mall property (APN 162-14-213-001 and 002 and APN 162-14-314-001 through 003) is owned by Boulevard Ventures L.L.C. and 2495 Rivera LP (Mall). Access for the purposes of environmental investigation and remediation is currently under negotiation between representatives of the Trust, the Attorney General of Nevada, and the Mall. Access is expected to be granted shortly.

5.2 Site Control

Drilling work will be performed during hours specified in the expected access agreement with the Mall. Work areas will be kept to a minimum footprint and noise will be minimized to the extent practical. Work areas will be barricaded and/or taped off to discourage incursions during active work. If needed, a private security company will be employed to prevent access of non-authorized personnel in work areas and protect site workers and equipment.

Outside of working hours, equipment will either be moved to the former Maryland Square Shopping Center property or to the proposed staging areas on the Mall property, as illustrated on Figure 7. Investigation derived waste will be collected prior to the end of the daily work period and moved to a secure holding area pending characterization and disposal. Tests requiring continuous monitoring and operations outside of working hours specified in the access agreement will be coordinated with the Mall to minimize business disruptions and impacts on customers.

Upon completion of the work, surfaces on the Mall property disturbed during drilling will be completed as required by the expected access agreement.

5.3 Investigation Derived Waste Characterization, Storage and Disposal

A locked, secure storage location will be installed on the former Maryland Square Shopping Center property and/or on the Mall property to temporarily store the investigation derived wastes (Figure 7). Soil will be stored in sealed steel barrels or a covered roll-off bins. Development, testing, and decontamination water will be stored in either portable “frac” tanks, poly tanks, or steel barrels pending characterization and disposal. Containers of investigation derived waste will be placed within secondary containment.

5.3.1 Soil

Composite soil samples will be collected from the soil container(s) and submitted to a Nevada-certified environmental laboratory for analysis for the purposes of determining the appropriate soil disposal options. Composite soil samples will be analyzed for the following:

- Ignitability by United States Environmental Protection Agency (EPA) Method D93/1010A,
- Corrosivity by EPA Method 9045D,
- Toxicity characteristic leaching procedure (TCLP) extraction of As, Ba, Cd, Cr, Pb, Se, and Ag by EPA method 6010B,
- TCLP extraction of Hg by EPA Method 7471A,
- TCLP extraction of Semi-volatile organic compounds (SVOCs) by EPA Method 8270C, and
- TCLP extraction of VOCs by EPA Method 8260B.

The soil container(s) will be labeled as pending analysis. Following characterization, the soil will be removed and properly disposed of by an authorized subcontractor under the oversight of Arcadis personnel. If

appropriate, manifests will be signed by a designated representative of the Trust or Arcadis personnel that have been specifically designated by letter from the Trust. Depending of the results of the waste characterization, soil will be transported to Las Vegas Paving and disposed of by incorporation into road paving material or transported to an approved, licensed treatment, storage, and/or disposal facility for disposal. .

5.3.2 Water

Development, testing and decontamination water will be stored in “frac” tanks, poly tanks or new steel drums in secondary containment at the secure storage location. If poly tanks are used, bottom drain valves will be padlocked to deter vandalism. Investigation derived liquid waste may be treated using liquid granular activated carbon prior to disposal. To determine appropriate water disposal options water will be analyzed for:

- Flashpoint by EPA Method D93/1010A,
- Corrosivity by EPA Method 9045D
- As, Ba, Cd, Cr, Pb, Se, Ag by EPA Method 6010B,
- Hg by EPA Method 7471A
- SVOCs by EPA Method 8270C, and
- VOCs by EPA Method 8260B.

The tanks or drums will be labeled as “Pending Analysis” following sampling. Upon receipt of analytical results, the water will be classified as either hazardous or non-hazardous, and the proper manifest will be prepared. The manifest will be signed by a designated representative of the Trust or Arcadis personnel that have been specifically designated by letter from the Trust.

Water will be removed under manifest from the site and properly disposed of by an EPA certified waste hauler under the oversight of Arcadis personnel.

6 PROPOSED SCHEDULE

- Mobilization for direct push boring investigation – August 2016
- Installation of an extraction and injection wells pair – September 2016
- Extraction and injection testing – October 2016

7 REFERENCES

Nevada Division of Environmental Protection, Record of Decision. Remediation of Groundwater at the Maryland Square Tetrachloroethylene (PCE) Site, Clark County, Nevada March 31, 2015

Tetra Tech, Final Corrective Action Report for Groundwater, Maryland Square Shopping Center, 3661 South Maryland Parkway, Las Vegas, Nevada Facility ID No. H-0000086, August 13, 2013

8 ENVIRONMENTAL CERTIFICATION JURAT

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances.

Description of Services: Pre-Design Characterization Work Plan, Maryland Square PCE Site, Las Vegas, Nevada. Facility ID No. H-000086.

_____ Date___06/09/2016_____

Jo Wang

CEM of Record (CEM No. 2184 (expires April 14, 2017)

Arcadis U.S., Inc.

TABLES

Table 1
Proposed MiHPT Borings
Herman Kishner Trust B-1 and Maryland Square Shopping Center L.L.C.
Maryland Square PCE Site, Las Vegas, Nevada

Boring ID	Proposed Tool	Proposed Total Depth	Location	Candidate for Grab Groundwater Sampling	Rationale
HPT-01	MiHPT	110	Source Area	Yes	● Expand lithology below existing boring MW-9. ● Evaluate permeability profile. ● Expand PCE profile below existing well MW-9
HPT-02	MiHPT	110	Source Area	No	● Expand lithology below existing boring MW-9. ● Evaluate permeability profile. ● Establish PCE profile in vicinity of sanitary sewer.
HPT-03	MiHPT	110	Western DGR	No	● Expand lithology below existing borings MW-14 and MW-15. ● Evaluate permeability profile. ● Establish PCE profile between existing wells MW-14 and MW-15. Expand PCE profile below existing wells MW-14 and MW-15.
HPT-04	MiHPT	110	Western DGR	Yes	● Expand lithology below existing boring MW-14I. ● Evaluate permeability profile. ● Expand PCE profile below existing well MW-14I.
HPT-05	MiHPT	110	Western DGR	No	● Expand lithology below existing boring MW-5. ● Evaluate permeability profile. ● Expand PCE profile below existing well MW-5.
HPT-06	MiHPT	110	Western DGR	Yes	● Expand lithology below existing boring MW-13. ● Evaluate permeability profile. ● Expand PCE profile below existing well MW-13.
HPT-07	MiHPT	110	Eastern DGR	No	● Expand lithology below existing boring MW-21. Resolve lithology of existing borings MW-20D1/MW-20D2/MW-20D3 and CMT-1. ● Evaluate permeability profile. ● Expand PCE profile below existing well MW-21.
HPT-08	MiHPT	110	Eastern DGR	Yes	● Correlate lithology with existing boring MW-19D1/MW-19D2/MW-19D3. ● Evaluate permeability profile. ● Correlate PCE profile with existing wells MW-19D1/MW-19D2/MW-19D3. Establish PCE profile between existing wells MW-19D3 and MW-20D3.
HPT-09	MiHPT	110	Eastern DGR	Yes	● Expand lithology south of existing boring MW-19D1/MW-19D2/MW-19D3. ● Evaluate permeability profile. ● Correlate PCE profile with existing wells MW-19D1/MW-19D2/MW-19D3. Establish PCE profile between existing wells MW-19D1/MW-19D2/MW-19D3 and MW-16.
HPT-10	MiHPT	110	Eastern DGR	Yes	● Expand lithology below existing boring MW-16. ● Evaluate permeability profile. ●Establish PCE profile between existing wells MW-19D1/MW-19D2/MW-19D3 and MW-16. Expand PCE profile below MW-16.
HPT-11	MiHPT	110	Eastern DGR	Yes	● Expand lithology below existing boring MW-16. ● Evaluate permeability profile. ● Establish PCE profile between boring HPT-10 and existing well MW-16.

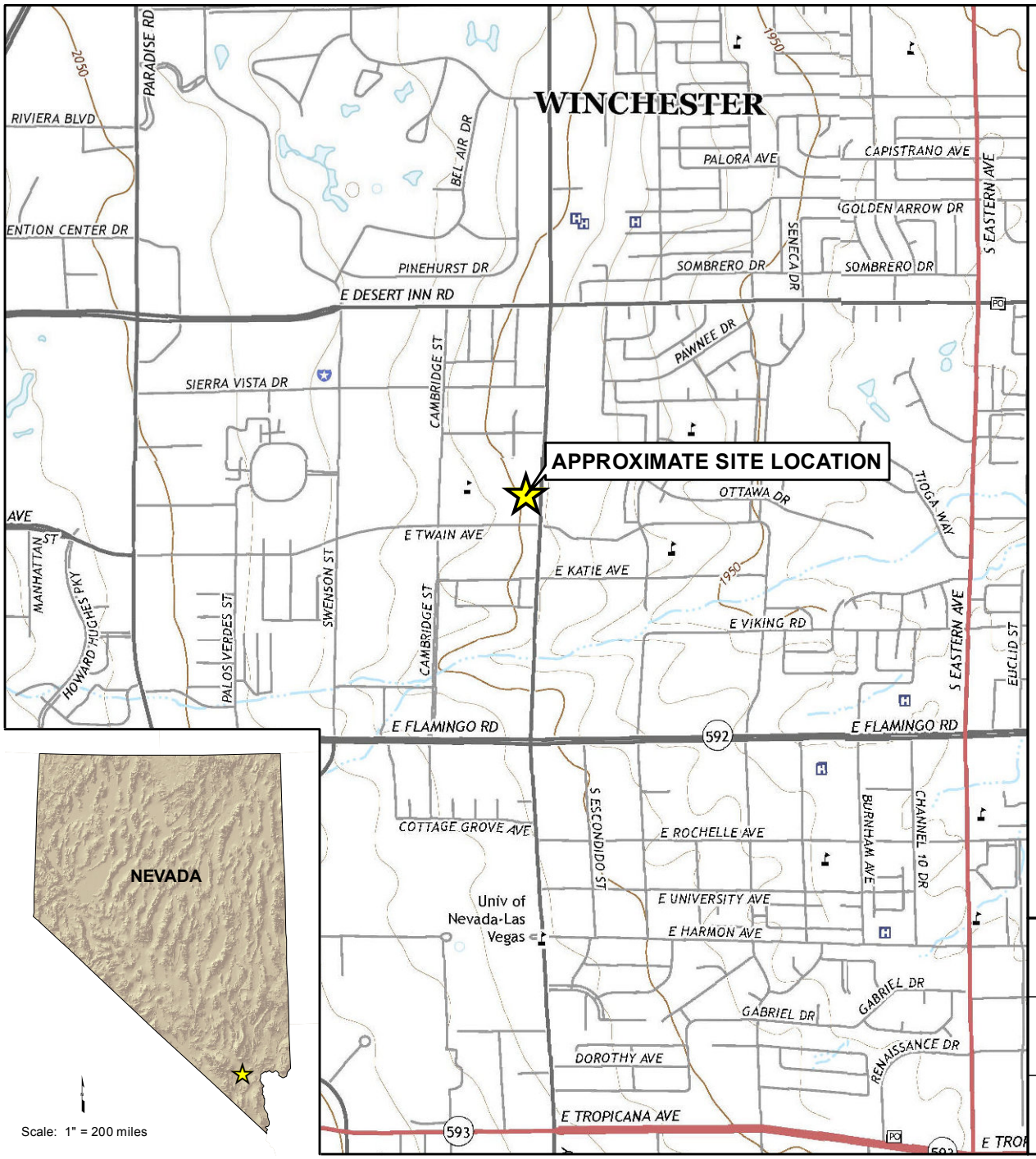
Notes:
· Proposed total depth is expressed in feet below ground surface.
· MiHPT = Membrane interface probe and hydraulic profiling tool.
· PCE = Tetrachloroethene.
· DGR = dynamic groundwater recirculation.

Table 2
Proposed Injection and Extraction Well Construction
Herman Kishner Trust B-1 and Maryland Square Shopping Center L.L.C.
Maryland Square PCE Site, Las Vegas, Nevada

Proposed Well ID	Well Type	Total Depth of Boring	Drilling Method	Approx. Borehole Diameter (inches)	Estimated Depth to Water	Screen Interval	Filter Pack Interval	Transition Sand Interval	Casing Diameter (inches)	Screen Material	Screen Slot Size (inches)	Filter Pack	Sounding Tube Diameter/ Material	Sounding Tube Screen Interval	Gravel Tube Diameter/ Material	Gravel Tube Interval
EW-E-01	Groundwater extraction well	71	Hollow stem auger	10	26	20-70	17-71	15-17	4	Stainless steel wire wrap	0.040	Colorado Silica Sand 12/30	1.5 in./Sch. 40 PVC Screen .030	20-70	1 1/2 in /Sch. 40 PVC	0-17
IW-E-02	Groundwater injection well	71	Hollow stem auger	10	26	20-70	17-71	15-17	4	Stainless steel wire wrap	0.040	Colorado Silica Sand 12/30	1.5 in./Sch. 40 PVC Screen .030	20-70	1 1/2 in /Sch. 40 PVC	0-17

Notes:
· Depth and intervals expressed in feet below ground surface unless otherwise noted.
· EW and IW well construction is proposed; actual well construction to be based on HPT results.

FIGURES



LEGEND

Approximate site location

NOTES

· Topographic map source: USGS Topo Maps (2014-15).

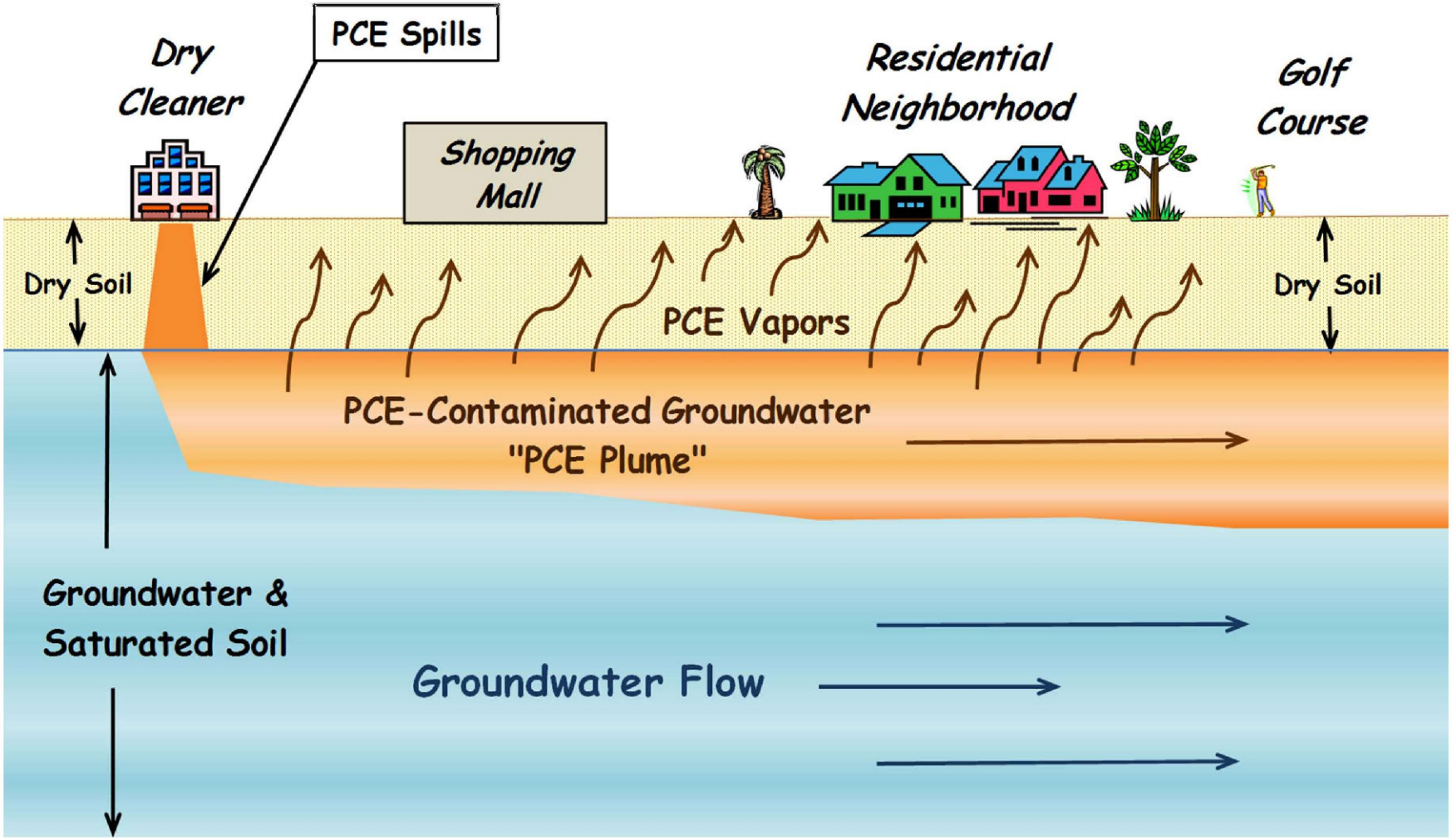
Feet
0 1,000 2,000
Scale: 1" = 2,000'

MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA
PRE-DESIGN CHARACTERIZATION WORK PLAN

SITE VICINITY MAP

ARCADIS

FIGURE
1



NOTES

· Figure 5-1: Conceptual Site Model Showing Cross-sectional Representation of Source, Migration Pathways, and Receptors, excerpted from *Record of Decision* (Nevada Department of Environmental Protection [NDEP], March 31, 2015).

MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA
PRE-DESIGN CHARACTERIZATION WORK PLAN

NDEP CONCEPTUAL SITE MODEL

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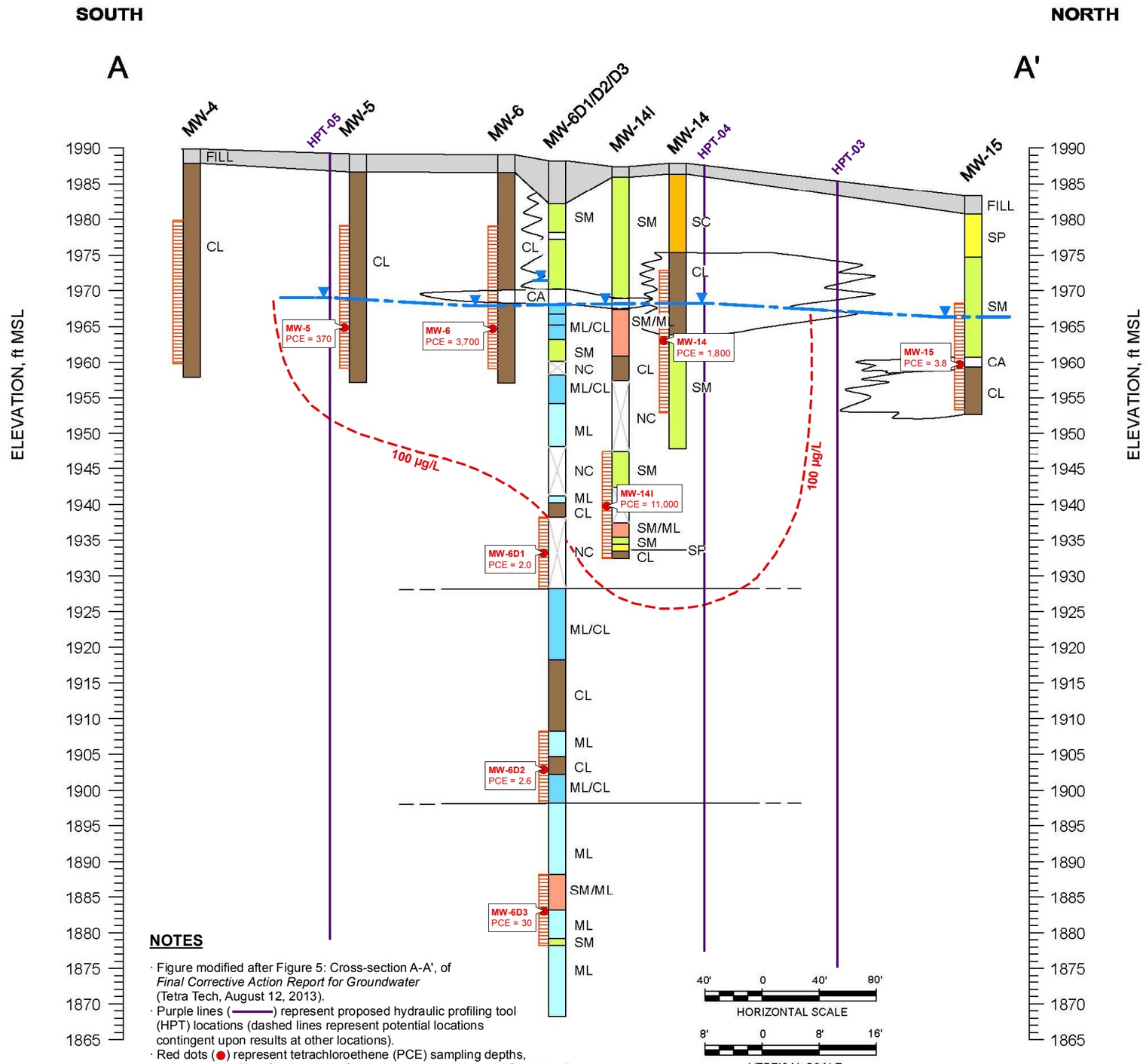
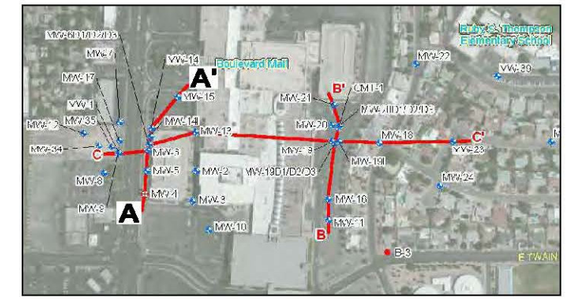
FIGURE
2





LEGEND

FILL	FILL UNDER ASPHALT
SC	CLAYEY SAND
SM	SILTY SAND
SP	POORLY GRADED SAND, SAND WITH GRAVEL
SM/ML	SILTY SAND / SANDY SILT
ML	CLAYEY SILT, SANDY SILT
CL	CLAY, SILTY CLAY, SANDY CLAY
ML/CL	SILT, CLAYEY SILT, SILT/CLAY MIXTURES
CA	CALICHE
NC	NO RECOVERY
	LITHOLOGICAL CONTACT, DASHED WHERE UNCERTAIN
	APPROXIMATE GROUNDWATER ELEVATION
	SCREEN INTERVAL
FT MSL	FEET ABOVE MEAN SEA LEVEL

NOTES

- Figure modified after Figure 5: Cross-section A-A', of *Final Corrective Action Report for Groundwater* (Tetra Tech, August 12, 2013).
- Purple lines (———) represent proposed hydraulic profiling tool (HPT) locations (dashed lines represent potential locations contingent upon results at other locations).
- Red dots (●) represent tetrachloroethene (PCE) sampling depths, as reported in *First Quarter 2016 Groundwater Monitoring and Sampling Report* (ATC, April 18, 2016); concentrations are expressed in micrograms per liter (µg/L).
- Dashed red lines (– – –·) represent inferred PCE isoconcentration contours.

40' 0 40' 80'
HORIZONTAL SCALE

8' 0 8' 16'
VERTICAL SCALE

VERTICAL EXAGGERATION = 5X

MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA
PRE-DESIGN CHARACTERIZATION WORK PLAN

CROSS-SECTION A-A'

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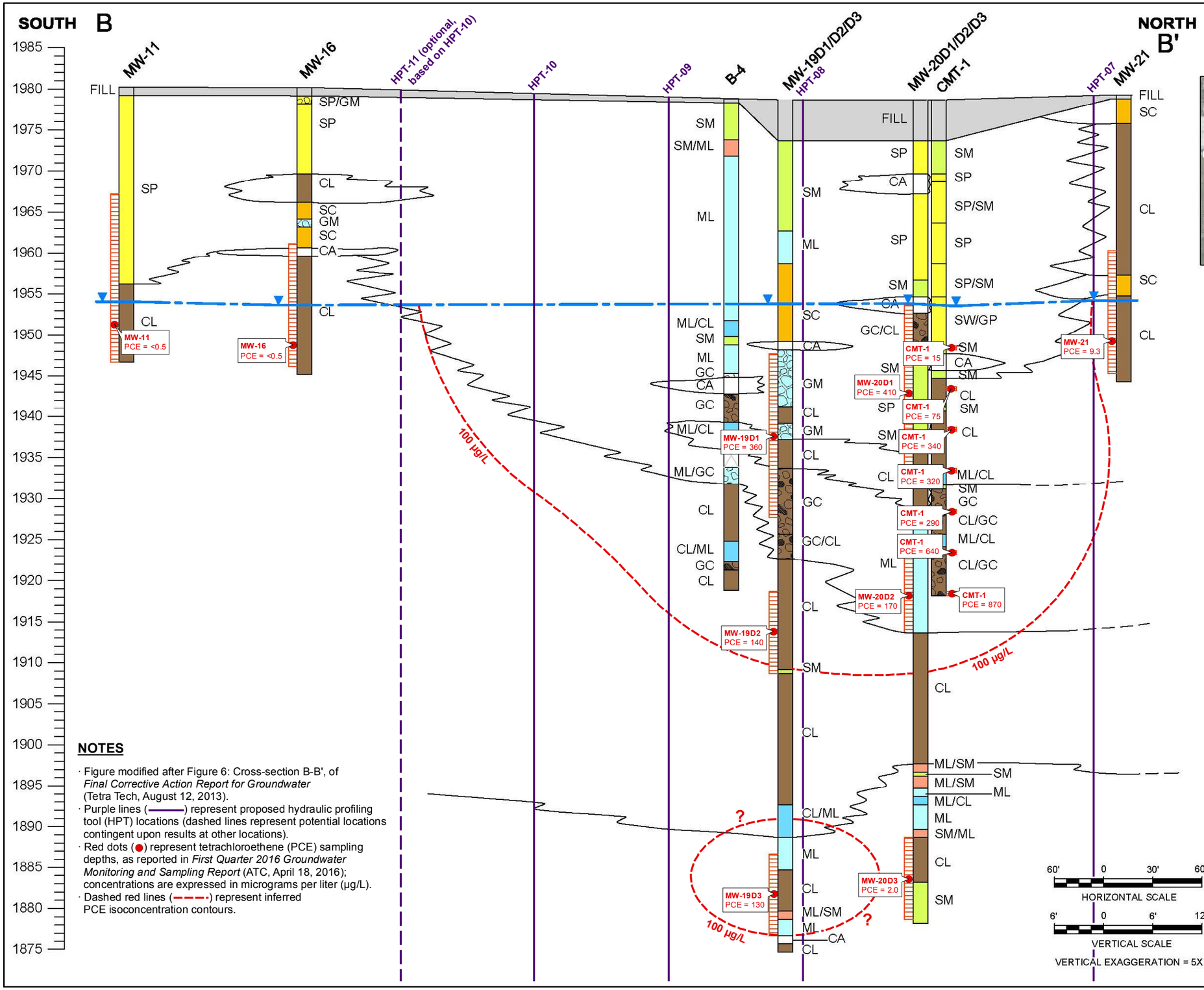
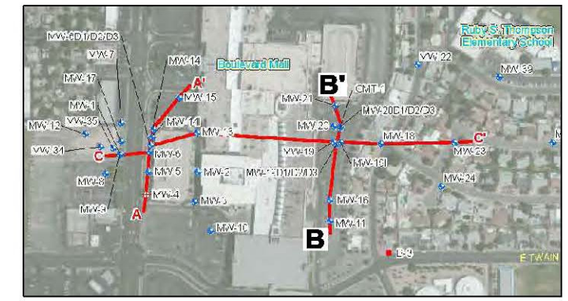
FIGURE
3

\\Scottsdale-AZ\Project\Maryland Square\GIS\Projects\Pre-design characterization WP 06-2016\Figure 3 cross-section A-A' Q1 2016.mxd 6/7/2016





LEGEND

FILL	FILL UNDER ASPHALT
SC	CLAYEY SAND
SM	SILTY SAND
SP	POORLY GRADED SAND, SAND WITH GRAVEL
SM/ML	SILTY SAND / SANDY SILT
ML	CLAYEY SILT, SANDY SILT
CL	CLAY, SILTY CLAY, SANDY CLAY
ML/CL	SILT, CLAYEY SILT, SILT/CLAY MIXTURES
GC	CLAYEY GRAVEL/ GRAVELLY CLAY
GM	GRAVEL, GRAVEL-SAND-SILT MIXTURE
CA	CALICHE
NC	NO RECOVERY
	APPROXIMATE GROUNDWATER ELEVATION
	SCREEN INTERVAL
FT MSL	FEET ABOVE MEAN SEA LEVEL

NOTES

- Figure modified after Figure 6: Cross-section B-B', of *Final Corrective Action Report for Groundwater* (Tetra Tech, August 12, 2013).
- Purple lines (———) represent proposed hydraulic profiling tool (HPT) locations (dashed lines represent potential locations contingent upon results at other locations).
- Red dots (●) represent tetrachloroethene (PCE) sampling depths, as reported in *First Quarter 2016 Groundwater Monitoring and Sampling Report* (ATC, April 18, 2016); concentrations are expressed in micrograms per liter (µg/L).
- Dashed red lines (— — —) represent inferred PCE isoconcentration contours.

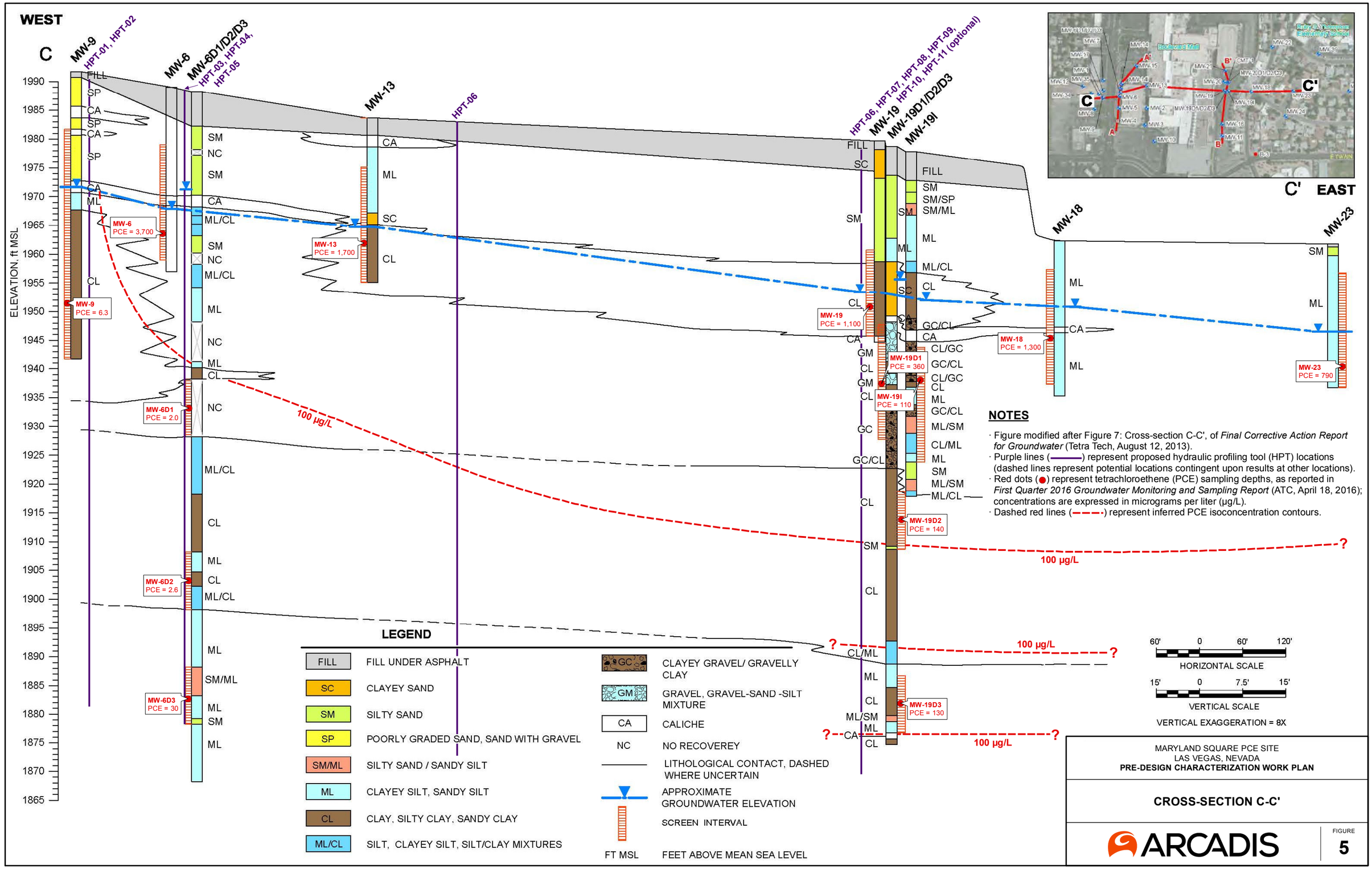
MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA
PRE-DESIGN CHARACTERIZATION WORK PLAN

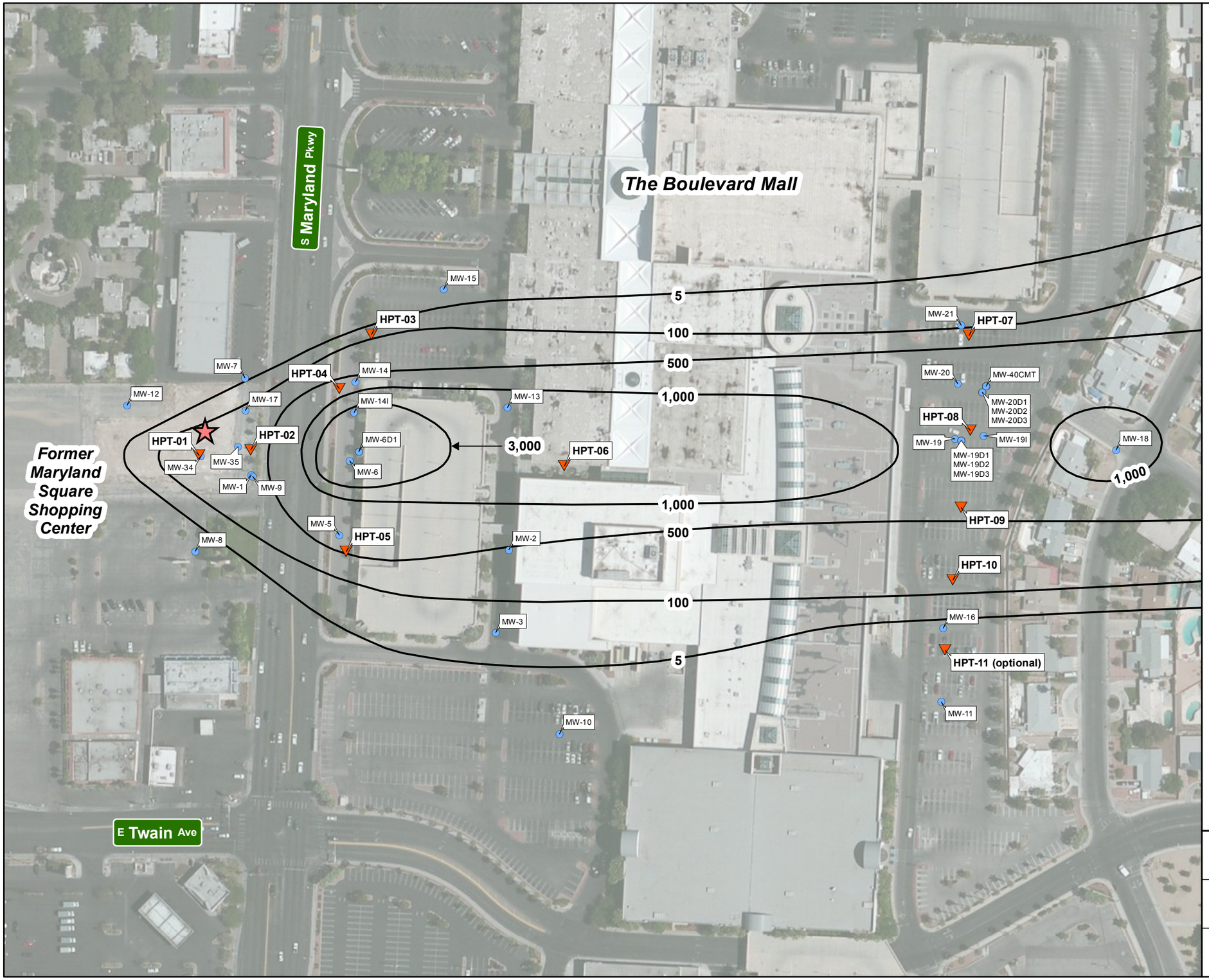
CROSS-SECTION B-B'

ARCADIS

FIGURE
4

\\Scottsdale-AZ\Project\Maryland Square\GIS\Projects\Pre-design characterization WP 06-2016\Figure 4 cross-section B-B' Q1 2016.mxd 6/6/2016


WEST
C
C' EAST
MW-9
HPT-01, HPT-02
MW-6
MW-6D1/D2/D3
HPT-03, HPT-04, HPT-05
MW-13
HPT-06
HPT-06, HPT-07, HPT-08, HPT-09, HPT-10, HPT-11 (optional)
MW-19
MW-19D1/D2/D3
MW-19I
MW-18
MW-23
ELEVATION, ft MSL
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
1920
1915
1910
1905
1900
1895
1890
1885
1880
1875
1870
1865
MW-6
PCE = 3,700
MW-9
PCE = 6.3
MW-13
PCE = 1,700
MW-19
PCE = 1,100
MW-19D1
PCE = 360
MW-19I
PCE = 110
MW-18
PCE = 1,300
MW-23
PCE = 790
MW-6D1
PCE = 2.0
MW-6D2
PCE = 2.6
MW-6D3
PCE = 30
MW-19D2
PCE = 140
MW-19D3
PCE = 130
100 µg/L
100 µg/L
100 µg/L
100 µg/L
NOTES
· Figure modified after Figure 7: Cross-section C-C', of *Final Corrective Action Report for Groundwater* (Tetra Tech, August 12, 2013).
· Purple lines (———) represent proposed hydraulic profiling tool (HPT) locations (dashed lines represent potential locations contingent upon results at other locations).
· Red dots (●) represent tetrachloroethene (PCE) sampling depths, as reported in *First Quarter 2016 Groundwater Monitoring and Sampling Report* (ATC, April 18, 2016); concentrations are expressed in micrograms per liter (µg/L).
· Dashed red lines (—·—·—) represent inferred PCE isoconcentration contours.
LEGEND
FILL — FILL UNDER ASPHALT
SC — CLAYEY SAND
SM — SILTY SAND
SP — POORLY GRADED SAND, SAND WITH GRAVEL
SM/ML — SILTY SAND / SANDY SILT
ML — CLAYEY SILT, SANDY SILT
CL — CLAY, SILTY CLAY, SANDY CLAY
ML/CL — SILT, CLAYEY SILT, SILT/CLAY MIXTURES
GC — CLAYEY GRAVEL/ GRAVELLY CLAY
GM — GRAVEL, GRAVEL-SAND -SILT MIXTURE
CA — CALICHE
NC — NO RECOVEREY
LITHOLOGICAL CONTACT, DASHED WHERE UNCERTAIN
APPROXIMATE GROUNDWATER ELEVATION
SCREEN INTERVAL
FT MSL — FEET ABOVE MEAN SEA LEVEL
60' 0 60' 120'
HORIZONTAL SCALE
15' 0 7.5' 15'
VERTICAL SCALE
VERTICAL EXAGGERATION = 8X
MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA
PRE-DESIGN CHARACTERIZATION WORK PLAN
CROSS-SECTION C-C'
ARCADIS
FIGURE
5
\\Scottsdale-AZ\Project\Maryland Square\GIS\Projects\Pre-design characterization WP 06-2016\Figure 5 cross-section C-C' Q1 2016.mxd 6/6/2016



LEGEND

- Source area
- Groundwater monitoring well*
- Proposed MiHPT boring location
- PCE concentration contour*

NOTES

- Aerial photo source: ESRI World Imagery.
- Tetrachloroethene (PCE) concentrations are expressed in micrograms per liter (µg/L).
- * = Existing well locations and PCE concentration contours are from *First Quarter 2015 Groundwater Monitoring and Sampling Report* (Cardno ATC, April 27, 2015); PCE concentration contours are based on samples collected in March 2015.

N

0 75 150 Feet

Scale: 1" = 150'

MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA
PRE-DESIGN CHARACTERIZATION WORK PLAN

PROPOSED MiHPT BORING LOCATIONS

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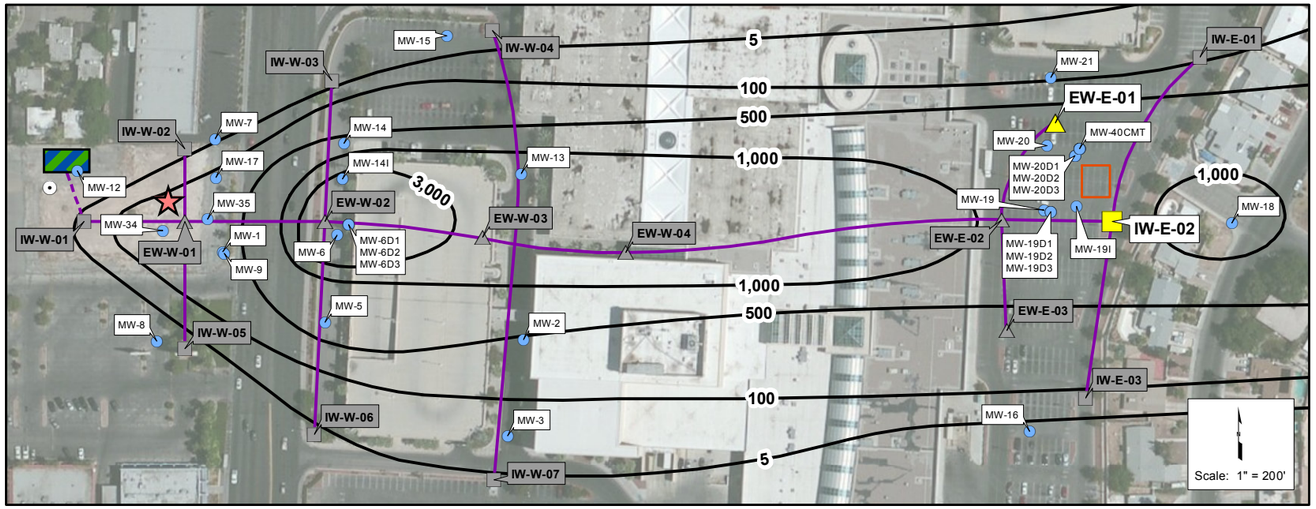
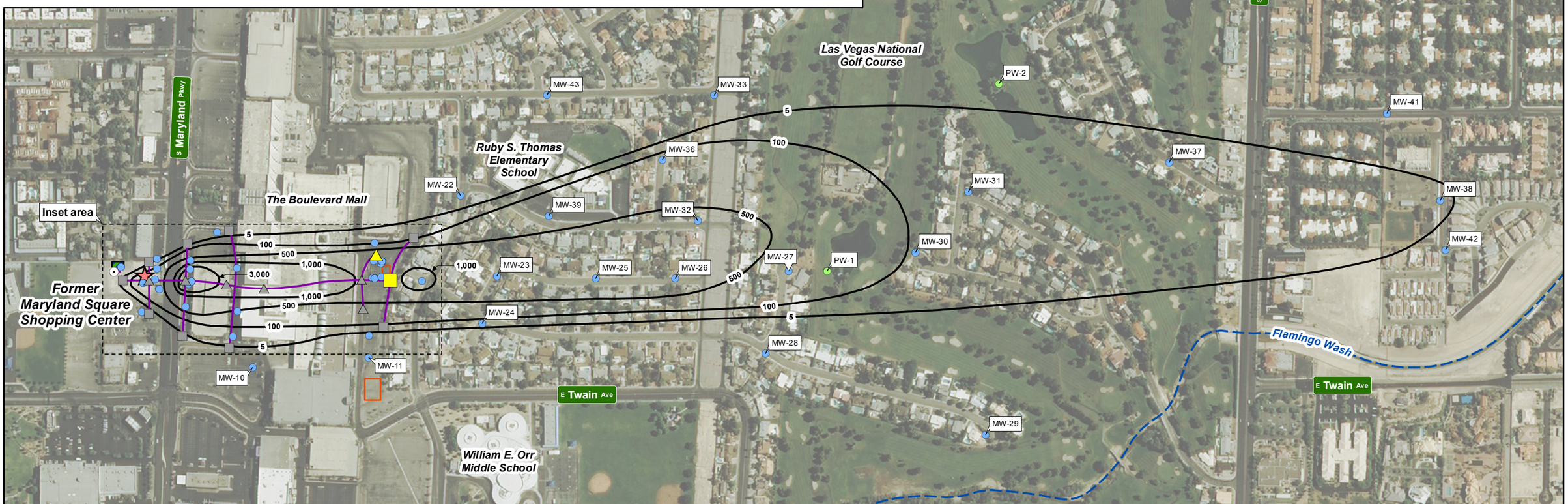
FIGURE
6

\\Scottsdale-AZ\Project\Maryland Square\GIS\Projects\Pre-remedial design hi-res SCWP 06-2016\Figure 6 proposed direct push locations.mxd 6/9/2016





LEGEND

- Source area
- Groundwater monitoring well*
- Groundwater pumping well*
- PCE concentration contour*
- Surface water feature

CONCEPTUAL DGR NETWORK

- Groundwater injection well
- Groundwater extraction well
- Treatment system compound
- Drilling and well installation storage area
- Subsurface remedial system piping (to be installed via directional boring)
- Subsurface remedial system piping (to be installed via trenching)
- Groundwater injection test well
- Groundwater extraction test well
- Existing power supply

NOTES

· Aerial photo source: ESRI World Imagery.
· Tetrachloroethene (PCE) concentrations are expressed in micrograms per liter (µg/L).
· * = Existing well locations and PCE concentration contours are from *First Quarter 2015 Groundwater Monitoring and Sampling Report* (Cardno ATC, April 27, 2015); PCE concentration contours are based on samples collected in March 2015.

N

Feet
0 250 500
Scale: 1" = 500'

MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA
PRE-DESIGN CHARACTERIZATION WORK PLAN

PROPOSED EXTRACTION AND INJECTION WELL LOCATIONS

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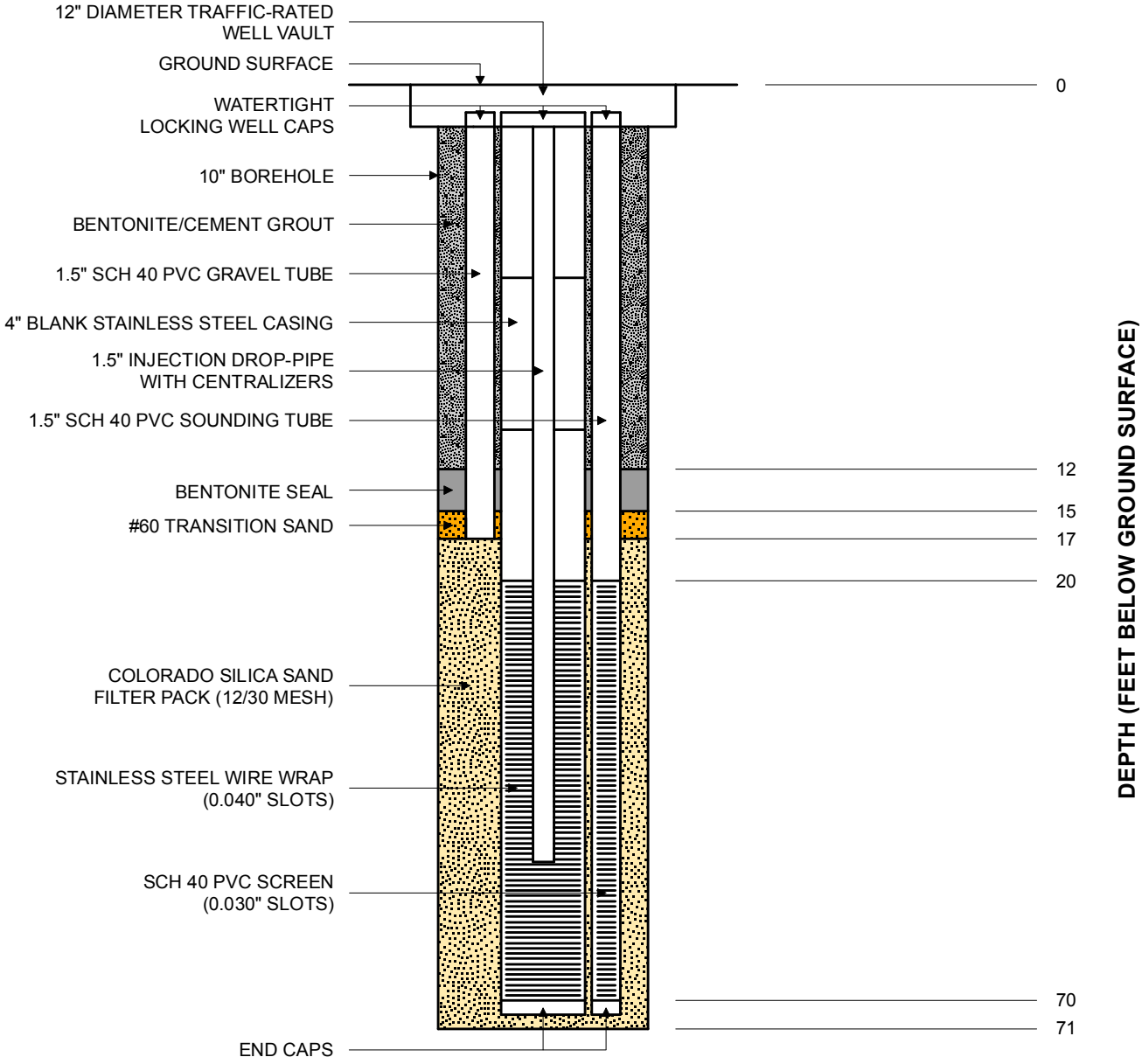
FIGURE
7

\\Scottsdale-AZ\Project\Maryland Square\GIS\Projects\Pre-remedial design hi-res SCWP 06-2016\Figure 7 proposed well installation.mxd 6/9/2016



NOTES

- Diagram is not drawn to scale.
- Details of well construction may be revised based on high-resolution information regarding subsurface soil and the physical properties of the aquifer, and/or the lithologic logging of the boring.

MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA
PRE-DESIGN CHARACTERIZATION WORK PLAN

TYPICAL INJECTION/EXTRACTION WELL CONSTRUCTION DIAGRAM

ARCADIS

FIGURE
8

\\Scottsdale-AZ\Project\Maryland Square\GIS\Projects\Pre-design characterization WP 06-2016\Figure 8 well construction diagram.mxd 6/8/2016

APPENDIX A

Geoprobe Hydraulic Profiling Tool (HPT) System Standard Operating Procedure

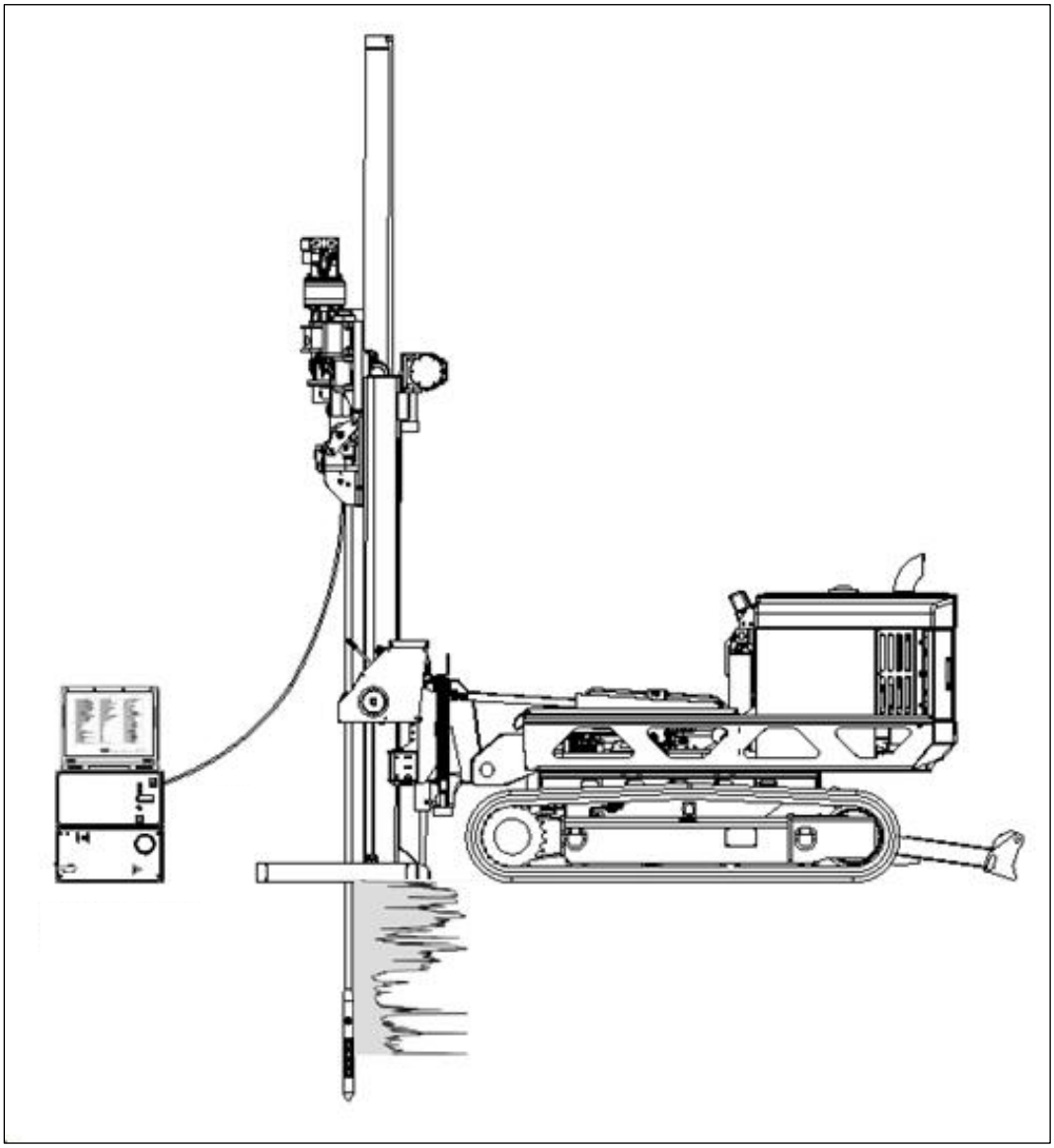
Geoprobe Membrane Interface Probe (MIP) Standard Operating Procedure

Geoprobe® Hydraulic Profiling Tool (HPT) System

Standard Operating Procedure

Technical Bulletin No. MK3137

Prepared February 6, 2013



1.0 Objective

This document serves as the standard operating procedure for the Geoprobe® Hydraulic Profiling Tool (HPT) system. In this procedure, the HPT system is used to measure the pressure response of soil to injected water for identifying potential flow paths and to assist with characterization of soil type. This document has been updated from Geoprobe Systems® Technical Bulletin No. MK3137 (March 2007) to show the use of an FI6000 field instrument for HPT system control and data acquisition.

2.0 Background

2.1 Definitions

Geoprobe®*: A brand of high quality, hydraulically-powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and testing, electrical conductivity and contaminant logging, grouting, and materials injection.

**Geoprobe® and Geoprobe Systems® are registered trademarks of Kejr, Inc., Salina, Kansas.*

Hydraulic Profiling Tool (HPT) System: A system manufactured by Geoprobe Systems® to evaluate the hydraulic behavior of subsurface soil. The tool is advanced through the subsurface at a constant rate while water is injected through a screen on the side of the probe. An in-line pressure sensor measures the pressure response of the soil to water injection. The pressure response identifies the relative ability of a soil to transmit water. Both pressure and flow rate are logged versus depth.

2.2 Introduction

The HPT system has been developed by Geoprobe Systems® for the geohydrologic characterization of soils. The HPT probe and logging system is able to quickly provide logs that are easily interpreted. HPT logs are used to indicate hydraulic conductivity, EC, hydrostatic profile, and areas of EC/permeability anomalies.

The HPT system is designed to evaluate the hydraulic behavior of unconsolidated materials. As the probe is pushed or hammered at 2 cm/s, clean water is pumped through a screen on the side of the HPT probe at a low flow rate, usually less than 300 mL/min. Injection pressure, which is monitored and plotted with depth, is an indication of the hydraulic properties of the soil. That is, a low pressure response would indicate a relatively large grain size, and the ability to easily transmit water. Conversely, a high HPT pressure response would indicate a relatively small grain size and the lack of ability to transmit water.

An electrical conductivity measurement array is built into the HPT probe. This allows the user to collect soil electrical conductivity (EC) data for lithologic interpretation. In general, the higher the electrical conductivity value, the smaller the grain size, and vice versa. However, other factors can affect EC, such as mineralogy and pore water chemistry (brines, extreme pH, contaminants). In contrast, HPT pressure response is independent of these chemical and mineralogical factors.

There are four primary components of the HPT system: the probe assembly, trunkline, HPT Flow Module (K6300 Series), and Field Instrument (FI6000 series). These primary components are shown in Figure 2.1.

The probe assembly consists of the HPT probe and connection section. This assembly houses the downhole HPT pressure transducer, water and electrical connections, and the probe body with the injection screen and electrical conductivity array.

Injecting water at a constant rate is integral to system operation. The HPT Flow Module houses the pump and associated hand crank mechanism used for adjusting the output flow of the HPT pump. The flow module also contains the HPT flow measurement and injection line pressure transducers. HPT flow can be adjusted from approximately 50 to 500 ml/min. The HPT pump is a positive displacement pumping device with minimal decrease in flow over the HPT operating pressure range. The flow module is equipped with an internal bypass that is factory set to open and return flow to the supply reservoir at a pressure of 120 psi. When the soil resistance to water injection becomes sufficiently great, the HPT Flow Module bypass will open, returning some or all of the pumped flow to the supply reservoir. The flow meter only measures flow leaving the module to the HPT probe. The HPT Flow Module is connected to the Field Instrument via a data cable.

Water and power are transmitted from the controller to the probe assembly via the HPT trunkline. The probe rods must be pre-strung with the trunkline before advancing the probe.

Data collection occurs in real time by connecting the controller to the field instrument. The field instrument collects, stores and displays transducer pressure, flow rate and electrical conductivity, line pressure, probe rate, and diagnostic parameters, with depth.

Since the HPT pressure response is analogous to the soil's ability to transmit water (and therefore the to the soil's dominant grain size), the HPT system can be used to identify potential contaminant migration pathways. Similarly, it can help identify zones for remedial material injection or provide qualitative guidance on how difficult injection may be in different zones of the formation.

The HPT system may be used to direct other investigation methods, such as soil and groundwater sampling and slug testing. HPT pressure response and EC data can help target zones of geologic and hydraulic interest, minimizing the number of soil and groundwater samples required to adequately develop a site conceptual model. When hydraulic conductivity values are required, the HPT system can also help the user identify zones to slug test, as well as the length of the screen required to adequately test the zone.

The HPT system also can be used to collect static water pressure data at discrete intervals during the logging process. These static pressure data can be used to calculate static water levels or to create a hydrostatic profile for the log.

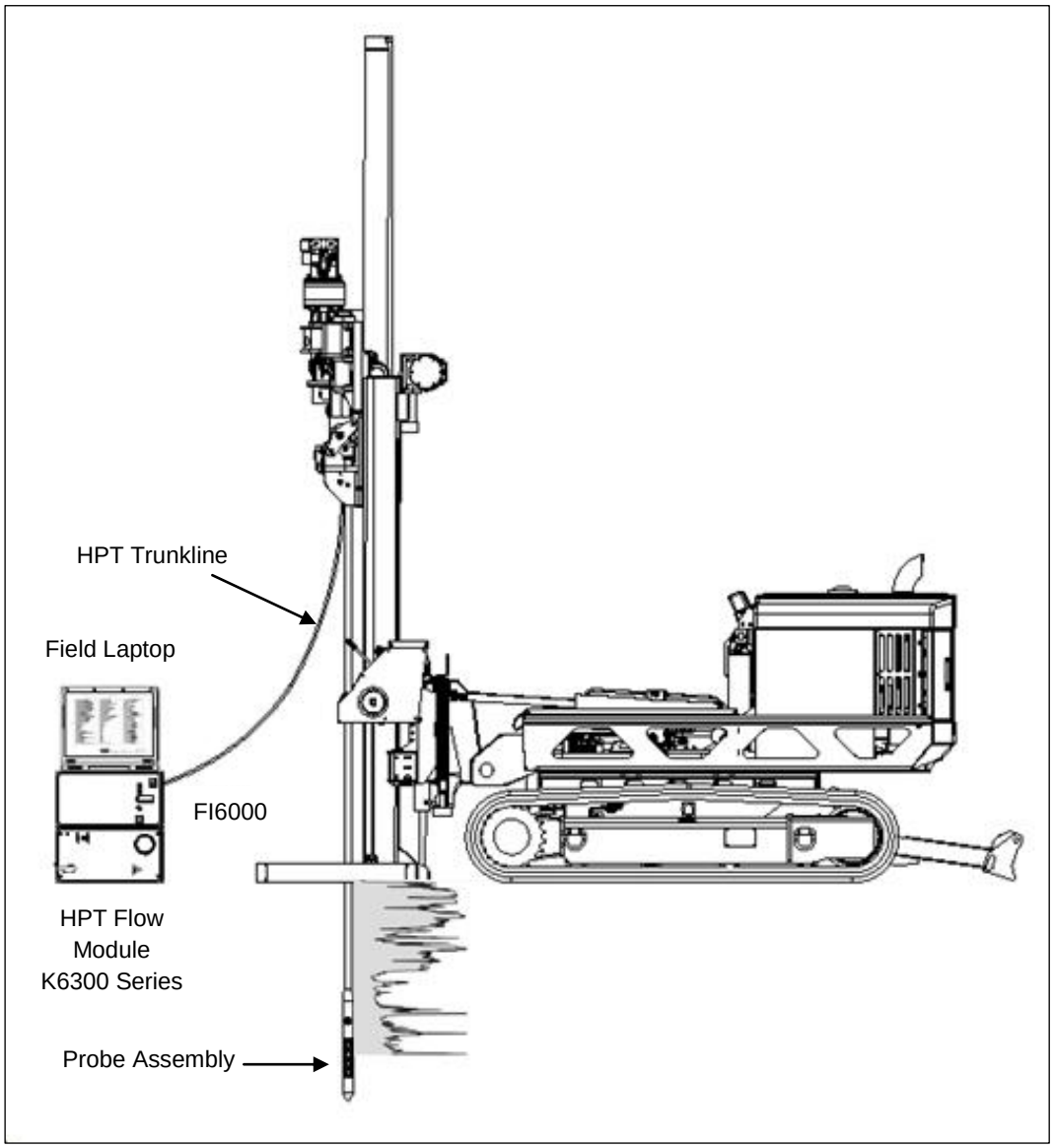


Figure 2.1: HPT Components

3.0 Tools and Equipment

The following equipment is required to perform and record an HPT log using a Geoprobe® 66- or 78-Series Direct Push Machine. Refer to Figures 3.1, 3.2, and 3.3 for identification of the specified parts.

Basic HPT System Components	Quantity	Part Number
Field Instrument, 120V	-1-	FI6000
Field Instrument, 220V	*	FI6003
HPT Acquisition Software	-1-	K6020
HPT Flow Module, 120V	-1-	K6300
HPT Flow Module, 220V	*	K6303
HPT Probe, 1.75 inch	-1-	K6050
MIP/HPT Connection Tube	-1-	31641
MIP/HPT Adapter 1.5 Pin x LB Box	-1-	20712
HPT Probe, 2.25 inch	**	K8050
2.25 Probe Rod, 24 inch	**	32656
2.25 Inch Water Seal Adapter	**	45170
2.25 Inch Water Seal Drive Head	**	48866
HPT Reference Tube 1.75 in HPT Probe	-1-	50344
HPT Reference Tube 2.25 in HPT Probe	**	50344
HPT Trunkline 150 ft.	-1-	K6415
HPT Trunkline 200 ft.	(optional)	K6420
HPT Service Kit *(contains the following)*	-1-	29028
O-Ring Pick	*-1-*	*AT102*
Term Block 4 POS Green	*-4-*	*7700*
Electrical Tape, 0.75-in. x 60-ft.	*-1-*	*6167*
Membrane Ratchet Wrench Asm	*-1-*	*48877*
Coupling 1/8 to 1/8 Tube	*-5-*	*48842*
Oetiker #7 Band Clamp 5.8 x 7mm	*-10-*	*48724*
HPT Sensor Module	*-2-*	*43327*
Silicone Dielectric Compound	*-1-*	*41274*
Butt Connector Red (10 pak)	*-2-*	*39807*
HPT Trunkline Seal Asm.	*-4-*	*37031*
Trunkline Seal Spacer (1 pair)	*-2-*	*36378*
O-Ring 120 BUNA 70	*-10-*	*3537*
HPT Screen Asm	*-4-*	*28895*
HPT Spring Washer (pkg 10)	*-1-*	*52399*
Tube Nylon 0.25 OD x 0.04 W Flexible	*-1-*	*20727*
Tubing 0.125 ID x 0.25 OD Polyur Yellow	*-1-*	*17957*
EC Probe Test Jig	-1-	SC563
EC Test Load	-1-	37785
Stringpot, 100-inch	-1-	SC160-100
Stringpot Cordset, 65-feet (19.8 m)	-1-	16401

*Use in place of 120V components if desired.

**Use in place of 1.75 inch probe and components if desired.

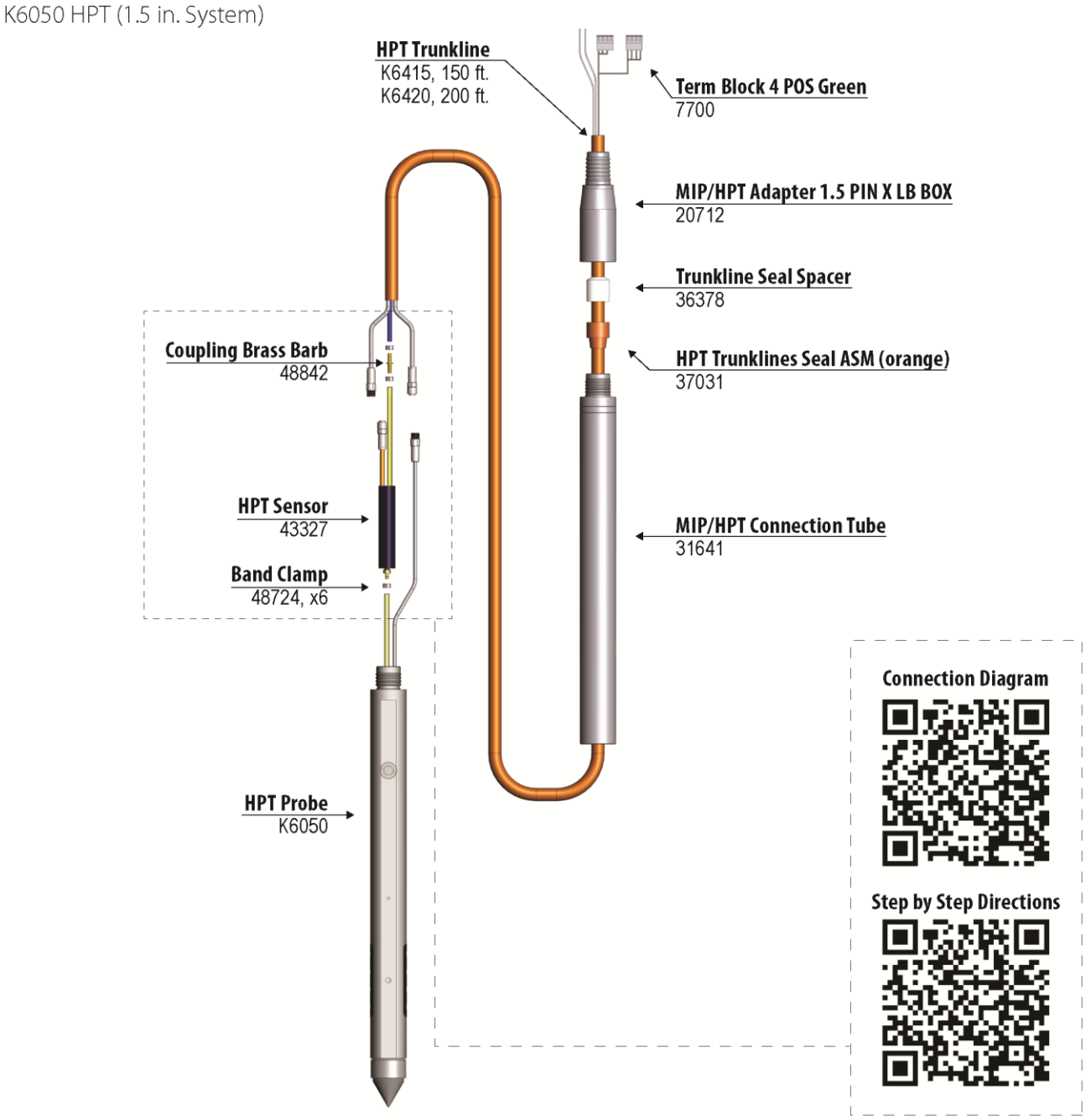


Figure 3.1 PN K6050 1.75 inch HPT Probe and components

http://geoprobe.com/tool-string-diagrams/k6050-hpt

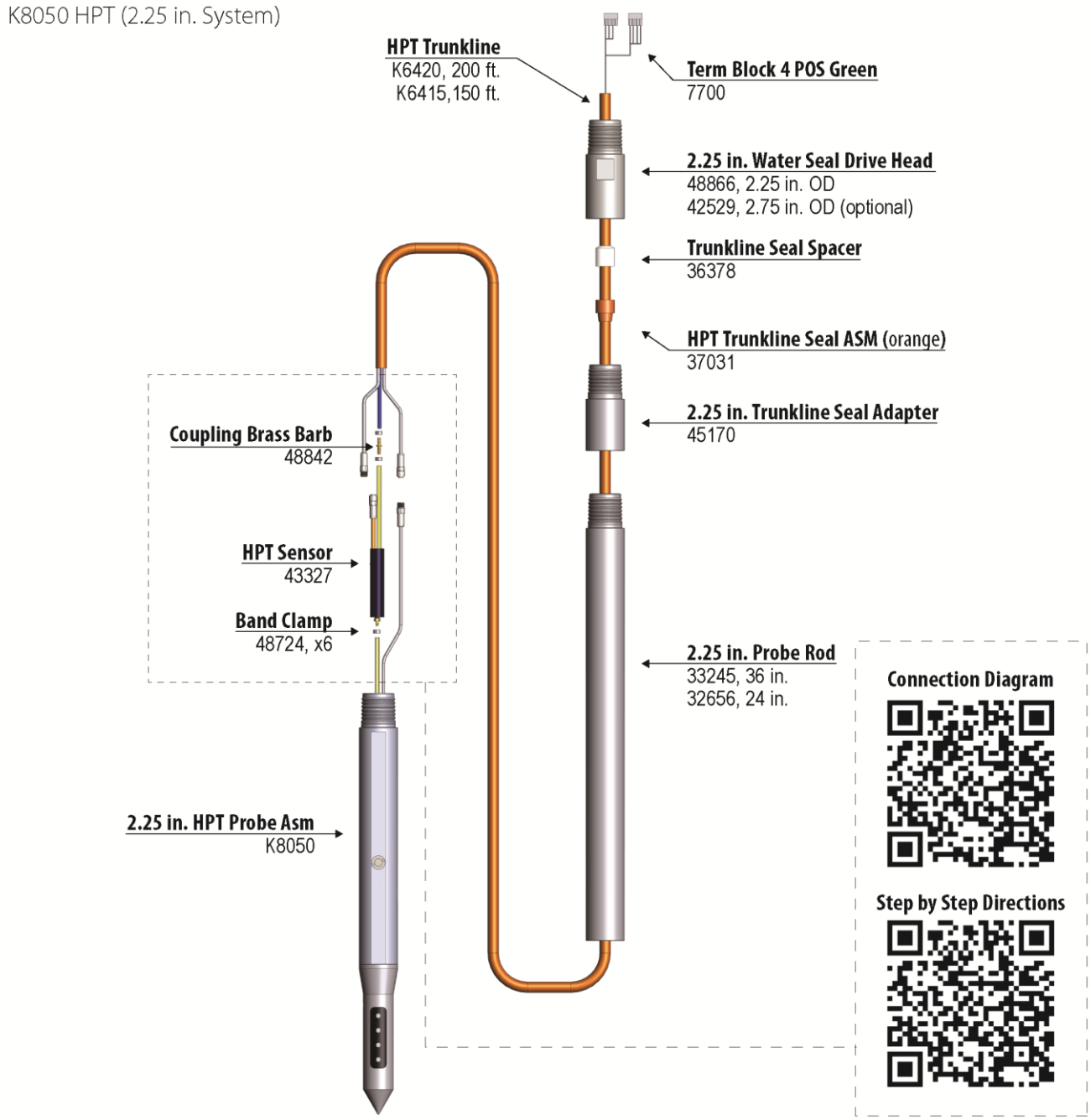


Figure 3.2 PN-K8050 2.25 inch HPT Probe and components

http://geoprobe.com/tool-string-diagrams/k8050-hpt

HPT Sensor Connection Diagram

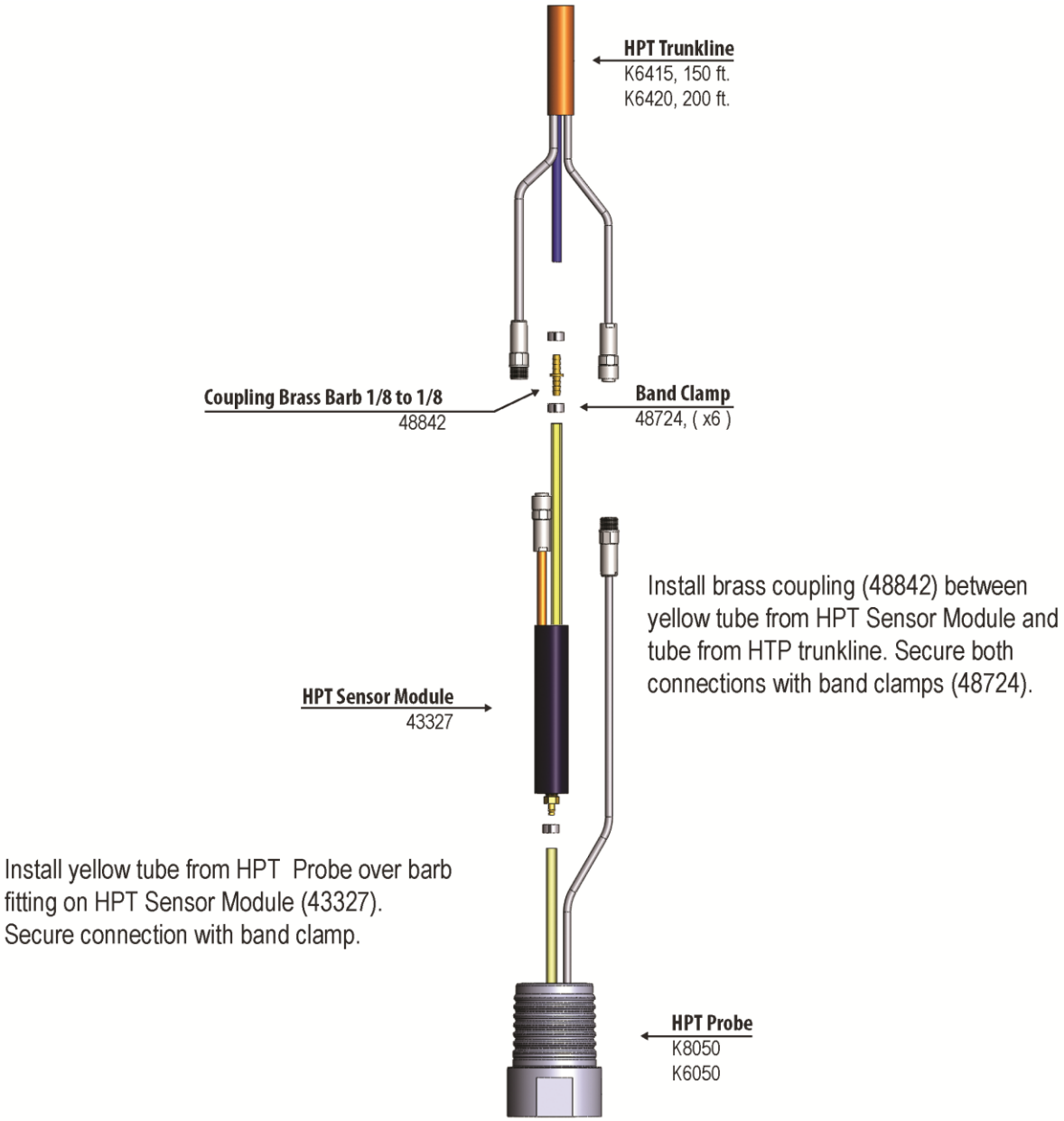


Figure 3.3 PN 43327 HPT Sensor Module Connection Diagram

http://geoprobe.com/tool-string-diagrams/hpt-sensor-connection-diagram

4.0 HPT Assembly

Refer to Appendix A

Threading the Rods

- Protect the end to be threaded through the rods with electrical tape or shrink tubing.
- Probe rods must alternate directions prior to threading the trunkline.
- The end of the HPT trunkline with chrome connectors is the downhole or probe end.
- The probe end of the trunkline will always enter the male end and exit the female end of the probe rods.
- The instrument end (no chrome connectors) will always enter the female end and exit the male end of the probe rods.
- After the trunkline is through the probe rods make sure the downhole end is threaded through the male end of the drive head and connection tube prior to connecting to the probe.
- The trunkline is now ready to connect to the instrument and HPT pressure sensor and probe.

5.0 Field Operation

5.1 Instrument Setup

1. Connect the HPT Controller (K6300), Field Instrument (FI6000) and laptop (Fig. 5.1) to an appropriate power source.

2. Connect the FI6000 to the K6300 using the 62-pin serial cable inserted into the acquisition port of each instrument.

3. Secure the EC wires into the Green terminal block connector and insert into the FI6000. The wires match to the EC dipoles in the following top down order when the probe tip is on the ground – white, black, yellow and blue (Fig 5.2).

4. Secure the HPT sensor wires to the appropriate inputs on the green terminal block connector and connect to the rear of the K6300. The top down order of the wires which is listed on the back of the instrument is: brown, orange, red and reserved (open).

5. Insert the nylon water line tubing from the trunkline into the water output connector on the back of the K6300.

6. Connect the HPT water supply hose into the input port on the rear of the K6300 and insert the filtered end of the supply line into a water supply tank. The bypass line connects to the bypass port and will follow the supply line back to the supply tank.

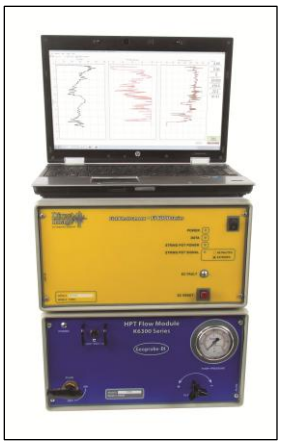


Figure 5.1: HPT Instrument Setup

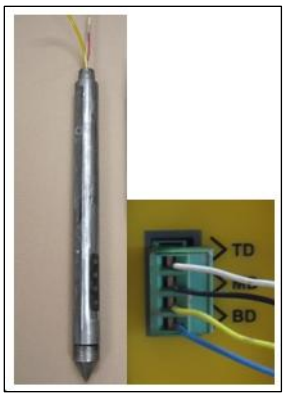


Figure 5.2: EC Wire Connections

7. Connect the USB cable between the USB interface port on the rear of the FI6000 to USB input on the field laptop computer.

8. A stringpot is required to measure depth. Bolt the stringpot onto the machine and the stringpot onto the bracket. Connect the plastic connector end of the stringpot cable to the “Stringpot” connector on the back of the Field Instrument and the metal connector to the stringpot. Pull the stringpot cable and attach to the stringpot piston weight which should be mounted to the probe machine foot and pull the keeper pin so the weight is free to move.

5.2 Starting the Software

1. Make sure the FI6000 and K6300 are connected together with the 62 pin cable, powered on and connected to the computer by the USB cable for the software to load properly.

2. Start the DI Acquisition Software which should open in HPT mode.

3. Select “Start New Log”. The software will request log information and have you browse for a storage location and create and save a file name for the log (Fig. 5.3).

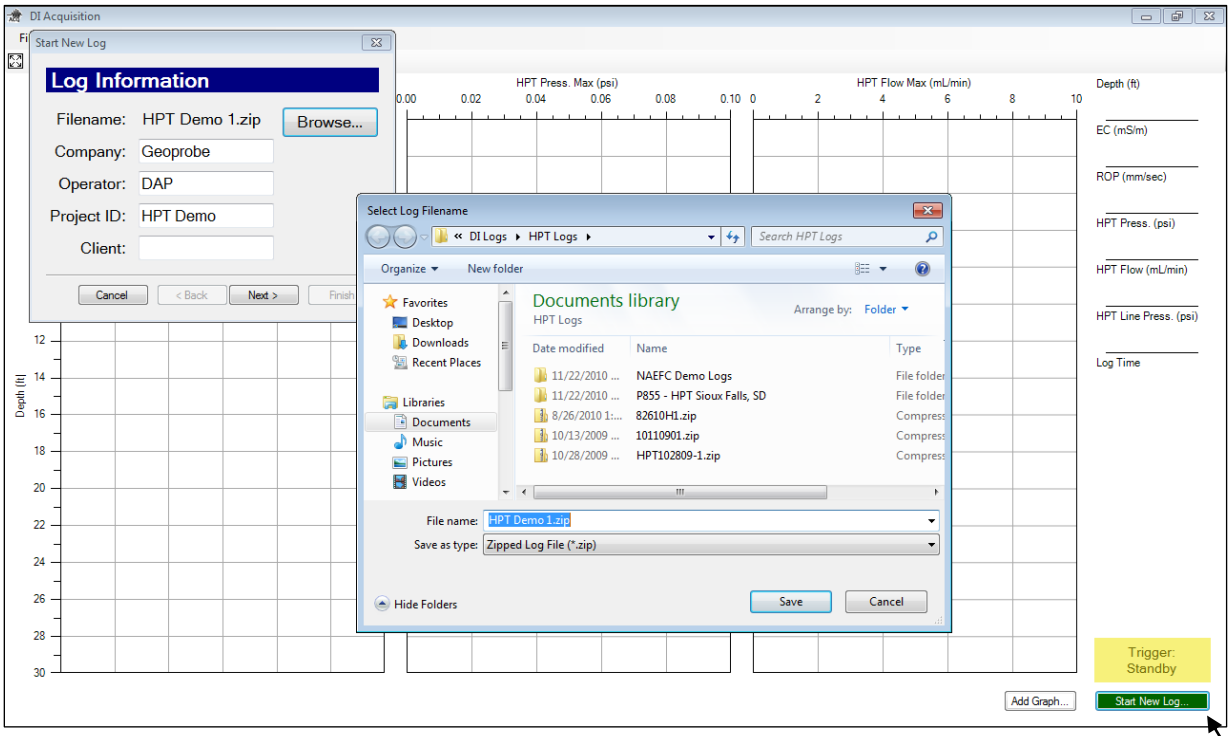


Figure 5.3: DI Acquisition Software – Start New Log Sequence

4. Select “Next”. If the software has been run before it will show a list of previous settings including Probe Type, EC Configuration, Stringpot length, rod length and HPT Transducer. If any of these have changed or you are unsure select “No” but if they are all the same select “yes”. If you select “No” the software will have you select the proper settings after the EC Load Test, if you selected “Yes” the selection of these settings will be bypassed.

5.3 QA Testing the EC and HPT Systems

Both the EC and HPT components must be tested before and after each log. This is required to ensure that the equipment is working properly and capable of generating good data before and after the log.

A. Electrical Conductivity Load Test

1. Secure the EC 3 position test load connector (37785) to the test input jack on the back of the Field Instrument.

2. Secure the EC Probe Test Jig into the input on the EC 3 position test load.

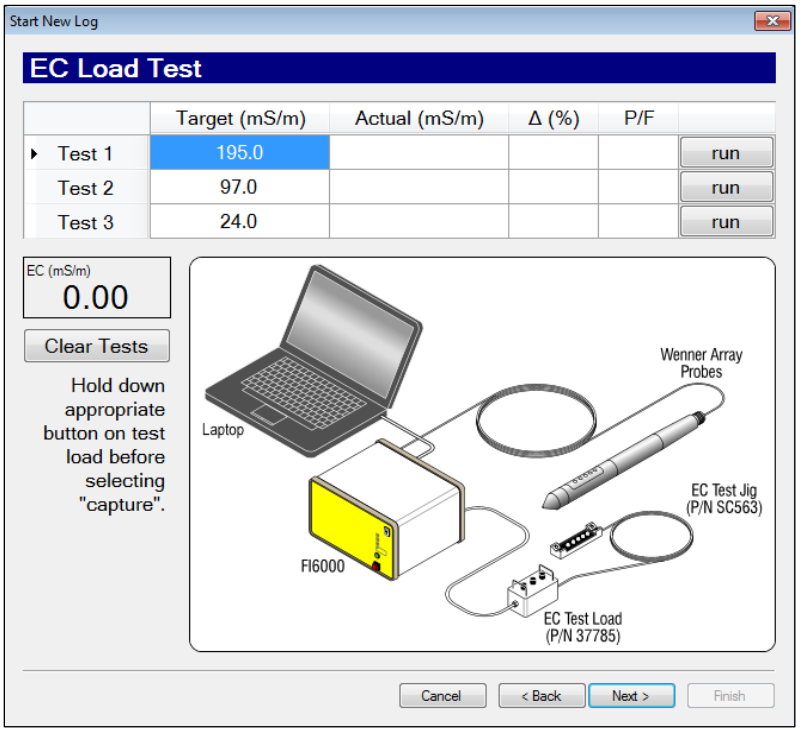


Figure 5.4: EC Load Test Screen

3. Clean and dry the EC dipoles as well as several inches of the probe body above the pins.

4. Place the EC Test Jig (SC563) so that the four springs on the test jig touch the four dipoles of the Wenner EC array (Fig. 5.4). Make sure the trunkline and test jig wires go in the same direction. The other spring on the test jig will ground the probe body above the Wenner array. Make sure the springs are pulled out far enough to make a solid contact on the dipoles.

5. When you get to the EC Load Test Screen and the EC test load and test jig are in place on the probe press down on the test 1 button on the test load and select “run” of Test 1 (Fig. 5.4). After 5 seconds the actual value will acquire and will pass if within 10% of the target value. Continue on with Test 2 and 3.

6. If any of the EC load tests fail do not pass within the allowed 10% acceptance range you can make adjustments on the test jig and rerun the test by just re-clicking the “run” button for an individual test.

7. If the tests continue to fail, select “Next” and the software will conduct the “EC Troubleshooting Tests.” The Instrument Calibration Tests (Fig. 5.5) checks of the calibration within the FI6000. If these are far out of range it will influence the EC Test load values and will need to return to Geoprobe® for repair. The “Probe Continuity and Isolation Tests” confirm each of the wires is a complete circuit and is fully isolated from one another. If a probe continuity test fails just outside the target range of <8ohms this is typically a contact issue with the test jig and the dipoles. If the continuity is in the thousands of ohms this is a break in the EC wire circuit – either in the probe, the trunkline or the connection between them.

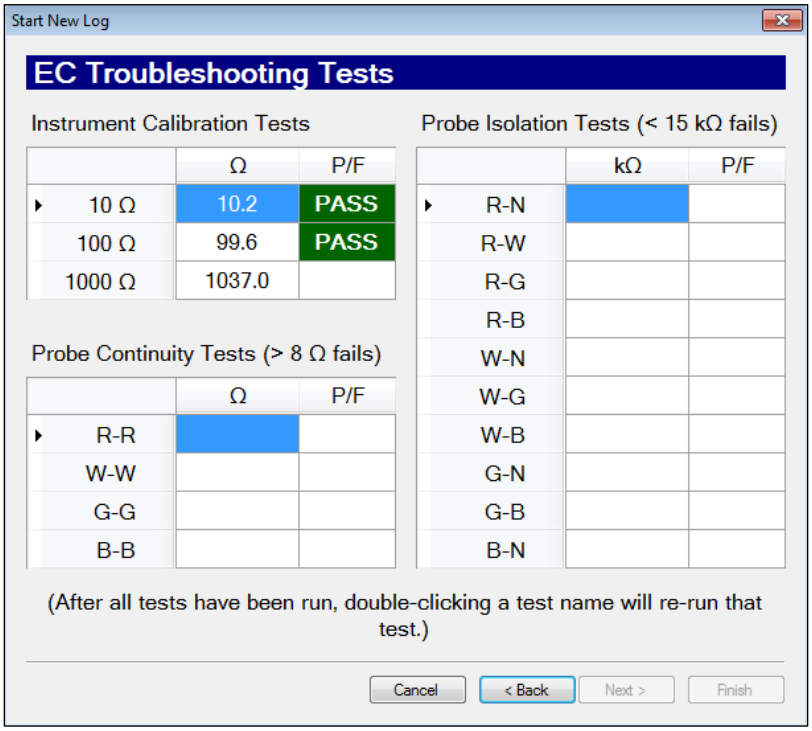


Figure 5.5: EC Troubleshooting Test Screen

8. When these tests are complete select next. In the next screen, the software will provide an EC option, if one is available. The EC Load Test will only work if EC can be operated in Wenner array meaning all of the EC wires in the continuity test pass with results <8ohms on the individual circuits. EC can be operated and collect good data in one odf the dipole areas: top, middle or bottom dipole. If the R-R test fails but the others pass the software will provide the option in the next screen to run either middle dipole or bottom dipole arrays. If R-R and G-G are both an incomplete circuit then no EC array is available to run and a new probe must be connected or the problem fixed. In the Wenner configuration it requires 2 adjacent dipoles to operate in dipole mode. If an EC array is chosen and run in this last manner then all of the EC information collected will be bad data.

B. HPT Reference Testing

Reference testing is done to ensure that the HPT pressure sensor is in working order and to evaluate the condition of the HPT injection screen. The HPT reference test calculates atmospheric pressure which is required to obtain static water level readings and to determine the estimated K values for the log in our post log processing software the DI Viewer.

Reference Test Procedure

1. Connect a clean water source to the HPT controller and turn on the pump.

2. Allow water to flow through the system long enough so that no air remains in the trunkline or probe (air in the system can cause inaccurate flow and pressure measurements).

3. Insert the probe into the HPT reference tube and allow the water to flow out the valve adjusting the flow rate to between 250-300ml/min (Fig. 5.5). Ensure that the reference tube is close to vertical.

4. With a stable pressure reading and the water flowing out of the valve select “capture” - bottom with flow (Fig. 5.6)

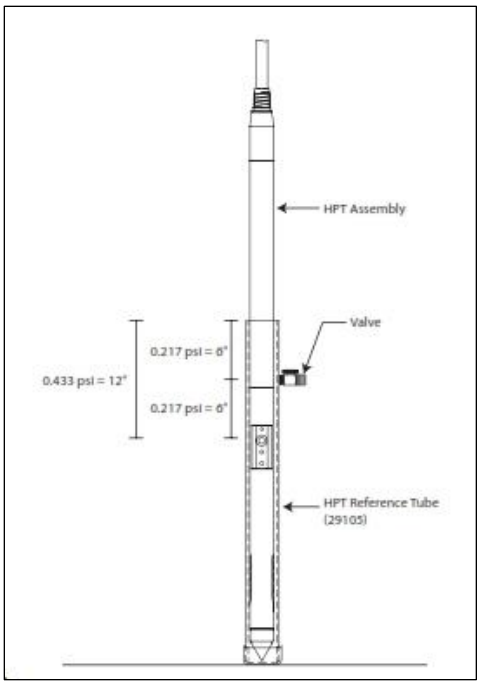


Figure 5.5: HPT Reference Test Setup

5. Close the valve and allow the water to overflow the top of the tube. When the pressure stabilizes select “capture” - top with flow.

6. Shut off the water flow. When the pressure stabilizes select “capture” - top flow = 0.

7. Open the valve and allow the water to drain out. When the pressure stabilizes select “capture” - bottom flow = 0.

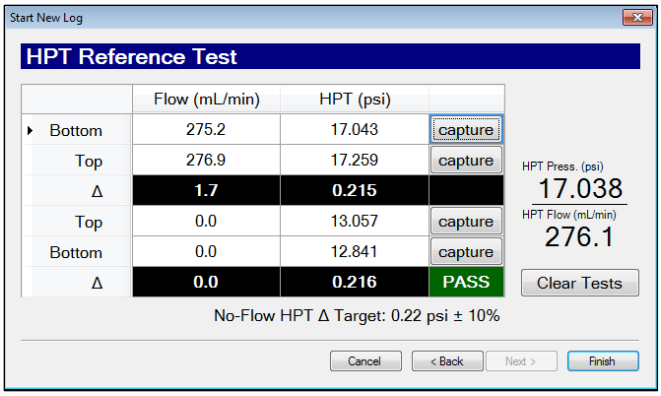


Figure 5.6: HPT Reference Test Screen

The HPT reference test reading flow = 0 is the true test of the condition of the pressure sensor and is the only sensor test to have a pass/fail reading on it. Ideally, the pressure difference between the top and bottom values will be 0.22 psi (1.52kPa). Typical pressure readings of the sensor will be in the 12PSI-15PSI (83kPa-104kPa) range.

5.4 Running an HPT Log

1. Place the rod wiper on the ground over the probing location and install the drive cushion in place of the anvil of the probing machine.

2. Place the probe tip in the center of the rod wiper, and place the slotted drive cap on top of the HPT probe.

3. Start the HPT water flow. **Note**: It is important that there is always water flowing when the probe is advanced to avoid soil particles from moving through the screen and causing problems with the pressure readings or causing a blockage behind the screen.

4. Adjust the probe so that it is vertical and advance the probe until the HPT screen is at the ground surface.

5. Click the trigger button in the lower right hand corner of computer screen. (The Trigger label will flash and the background will change from yellow to green).

9. Advance the probe at a rate of 2 cm/s. If necessary, feather the hammer to maintain this advance rate.

10. Perform a dissipation test (Section 5.4) in a zone of higher permeability indicated by lower HPT pressure.

11. After completing the log, press the trigger button again and select “Stop Log”.

12. Pull the rod string using either the rod grip pull system or a slotted pull cap. Run a post-log EC test and HPT response test (Section 5.2).

5.5 Performing a Dissipation Test

At least one dissipation test must be performed in order to calculate the static water level and estimated K readings from the log. Dissipation tests need to be performed below the water table and are best in zones of high permeability where the injection pressure can dissipate off quickly once the flow is shut off.

1. Stop in a zone of higher permeability which is indicated by lower HPT inject pressure.

2. Switch the DI Acquisition display view from the depth screen to the time screen by pressing the F10 key (F9 and F10 toggle between the depth and time screen of the acquisition software).

3. The screen will be grayed out which means that the data up to that point has not been saved. Select “Start Dissipation Test” which will turn the screen from gray to a white background indicating that you are now saving the time data.

4. Now shut the pump switch off and when the line pressure reaches zero, turn the flow valve off.

5. The HPT Pressure will begin to drop (dissipate the hydrostatic increase) and allow it to stabilize so very little visible drop in pressure is seen. When the pressure has fully dissipated turn the flow valve and the pump switch back on. When the flow and pressure are reestablished select “End Dissipation test.”

6. Select F9 to return to the depth screen and advancing the tool into the ground.

   Note: Performing a dissipation test in zones of higher permeability may only take 30 seconds or so but if the HPT pressure was higher to start with it may take a long time up to several hours to dissipate off to equilibrium. This is why targeting the most permeable zone to perform the dissipation tests is most desirable.

6.0 HPT Log Interpretation

Below is a typical HPT log, which consists of both the HPT pressure response and electrical conductivity. In general, both HPT pressure and EC values increase with decreasing grain size, and decrease with increasing grain size. The log in Figure 6.1 shows good consistency between EC and HPT pressure for the majority of the log. It is only between 32’-42’bgs that we see some divergence of the graphs with higher HPT pressure while the EC readings remained low. This can happen for reasons such as poor mineralogy of the soil. Refusal was encountered in a shale layer beginning at 75’bgs and it can be noted that as we enter this layer the HPT flow gets suppressed as the pressure reaches a maximum value of 100PSI (690kPa). The second graph of the log shows the hydrostatic profile on the secondary series of the graph. The hydrostatic profile has 2 black triangles which indicate where dissipation tests were run and used to calculate the profile. The red circle indicates the calculated water table based upon where the hydrostatic profile intersects atmospheric pressure. The fourth graph is the estimate K or groundwater flow graph. This is calculated based upon HPT pressure and HPT flow relationships. Less permeable soil will have less groundwater flow.

It is fairly common to see zones where EC readings and HPT pressure contradict one another. In cases where EC readings are low and HPT pressure trends higher as in the log in Figure 6.1 the following are possible reasons:

- Poor mineralogy of the soil particles resulting in silt and clay soils with very low EC readings. This is seen in many locations along the east coast of the United States.
- Silts intermixed with sand particles.
- Weathered bedrock may have low EC but would have low permeability.

Where we have cases of higher EC and lower HPT pressure typically is due to an ionic influence in the soil or groundwater. These higher EC readings can range from very slight to higher than typical soil readings. Very high EC readings can occur when the probe contacts metallic objects in the soil which will ground them out and typically will cause hard sharp spikes in the EC data.

- Chloride or other ionic contaminant (sea water, injection materials)
- Sea Water intrusion
- Wire, metal objects or Slag

In cases where HPT and EC do not confirm one another it is important to take confirmation soil and/or groundwater samples to help understand the difference between the two graphs.

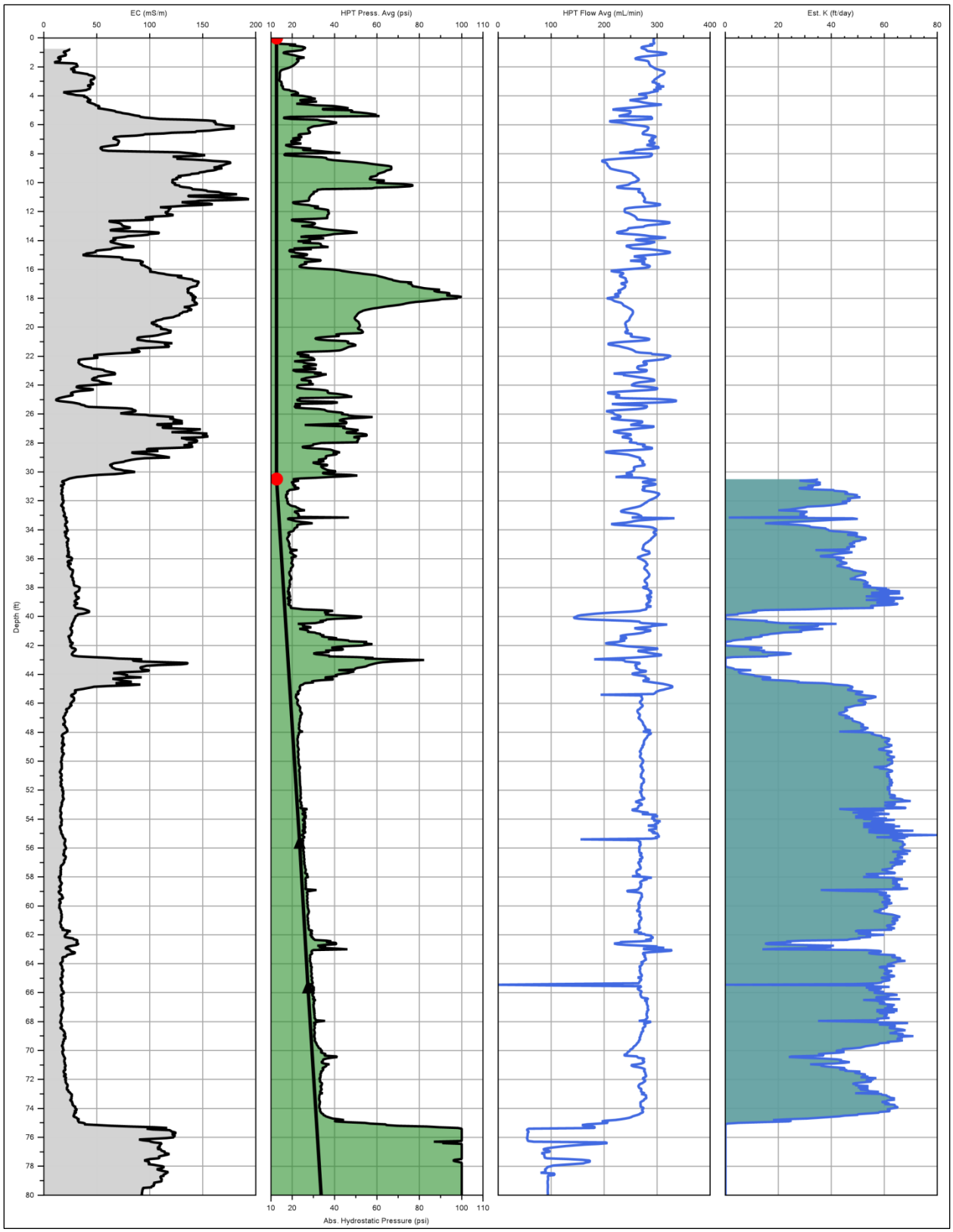


Figure 6.1: HPT Log file showing (left to right):
Electrical Conductivity (EC), HPT Injection Pressure with Hydrostatic Profile, HPT Flow, and Estimated K

7.0 Troubleshooting

7.1 Using the HPT Controller Test Load

The HPT Controller Test Load (32441) is included with the HPT Controller to help troubleshoot the HPT pressure sensor, trunkline, and controller. If there is a major problem with the HPT pressure sensor or the system wiring the system will not read anywhere close to atmospheric pressure with the probe at the surface. Commonly if the HPT sensor has broken the software will read either a maximum or minimum value which would be 100PSI or 0PSI (690kPa or 0KPa). If there is damaged wiring or nothing is connected to the controller the system typically reads 50PSI (345kPa).

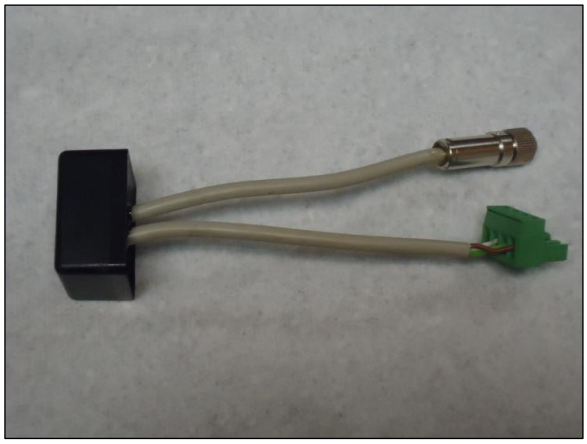


Figure 7.1: HPT Test Load PN32441

When connected to either the trunkline (in place of the pressure sensor), or the controller (in place of the trunkline and pressure sensor), the test load will cause the pressure sensor value to read a pressure ranging from approximately 25PSI-35PSI (172kPa – 241kPa).

To use the test load, set up the system as previously described. Turn on both the field instrument and HPT controller and start the HPT software. Plug the green wire connector of the test load into the HPT sensor connector on the back of the HPT controller. If the pressure sensor value reads somewhere around 30PSI (207kPa), the controller is able to properly read pressures so the problem is in the trunkline or the HPT sensor. If HPT controller has not moved from what it was reading or is way out from the expected value of the load test the HPT controller may require servicing. Contact Geoprobe Systems® for service.

Next, connect the HPT sensor wires of the trunkline to the controller with the green connector and then connect the test load to the female chrome connector on the downhole end of the trunkline in place of the pressure sensor. Again, the pressure value displayed on the field instrument should be somewhere around 30PSI (207kPa) and should be the same as what was seen with the load test connected into the controller. If the load test through the trunkline is around 30PSI (207kPa), then both the trunkline and the controller are working properly and the problem is in the HPT sensor. If it is not, the trunkline may be defective and should be replaced. Before restringing another HPT trunkline, first connect the new trunkline sensor wires into the HPT controller and the downhole end into the test load. If the system now reads in the expected test load range the trunkline needs replacing.

Finally, connect the pressure sensor to the trunkline. If it reads atmospheric pressure, approximately 12PSI-15PSI (83kPa-104kPa), then the pressure transducer is functioning properly. However, if it does not, replace the sensor with a new one and re-check the pressure reading. Be sure to enter the new sensor calibration values into the software prior to starting the new log. Additional pressure sensors purchased from Geoprobe®.

7.2 Common Problems

Problem: The pressure transducer is hooked up to the trunkline, but the software is reporting a reading of ~ 50PSI (345kPa).
Solution: Make sure that the trunkline wires are secured to the green terminal blocks and plugged in to the back of the HPT controller. Check components using the HPT Controller Test Load (Section 7.1).

Problem: The pressure transducer is hooked up to the trunkline, but the software is reporting a reading of 100PSI or 0PSI (690kPa or 0KPa).
Solution: Make sure all of the connections are good and recheck the pressure reading. If still bad connect a new HPT pressure sensor onto the trunkline and see if it reads atmospheric pressure. If not check all the components using the HPT Controller Test Load (Section 7.1).

Problem: The pressure with flow values keep drifting when water is flowing out the port or over the top of the reference tube.
Solution 1: If the trunkline was just connected and flow was just started air may still be in the lines. Allow the water to continue to flow through system which will purge out the remaining air. When it appears that most of the air is out of the lines pressing your finger over the injection screen for a few seconds can help to drive out any remaining air from the trunkline.
Solution 2: There may be debris behind the screen. Remove the HPT injection screen with the membrane wrench and turn the water flow on, place your finger over the open port to drive out debris. Replace the screen and retry the reference test with flow.
Solution 3: If the with flow pressure values continue to not settle down and provide close to the expected difference for a 6" water column then the problem may be inside the HPT control box. When you remove the cover of the HPT controller there will be a brass filter located on the left side when viewing from the front of the instrument (Fig 7.2). Particulates and precipitates can collect inside this filter causing problems with HPT pressure stability. Remove this filter and open up using appropriate wrenches. The filter can be easily cleaned by rinsing water over the screen. Reassemble and return to its proper location inside the control box. Resume reference testing the system.

Figure 7.2: Location of Inline Filter in K6300 and buildup of particulates in filter.

Problem: EC won't pass the QA tests.

Solution: Check the trunkline to probe EC connections ensuring they are tight. Run the troubleshooting tests (Section 4.3A), test EC on a new probe.

APPENDIX A

Making HPT Probe, Sensor and Trunkline Connections

http://geoprobe.com/literature/hpt-sensor-connection-tutorial

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Geoprobe® Membrane Interface Probe (MIP)

Standard Operating Procedure

Technical Bulletin No. MK3010
PREPARED: May, 2003
REVISED: January, 2015

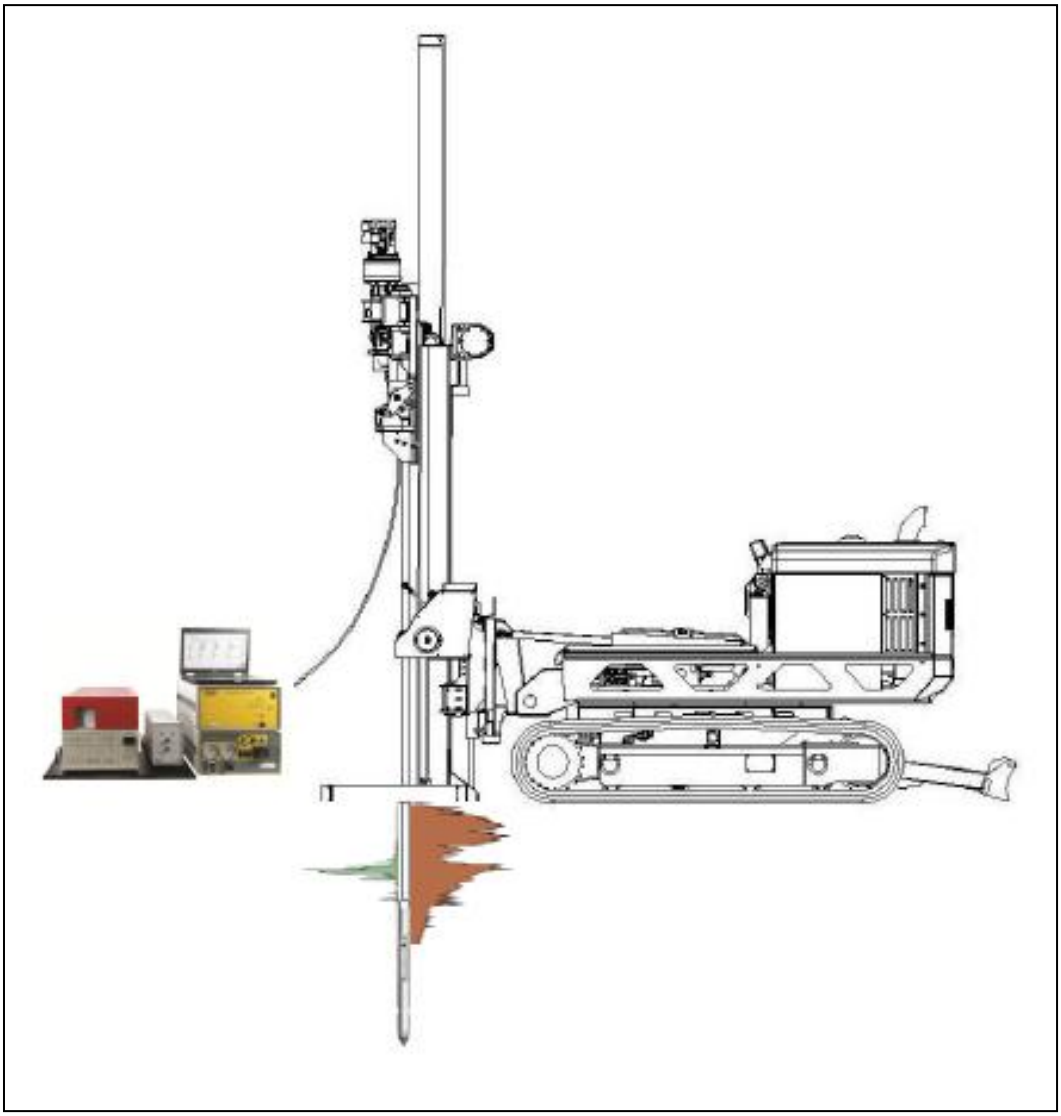

Table of Contents:

		Page
1.0	Objective	4
2.0	Background	4
3.0	MIP/EC Interferences	5
4.0	Tools and Equipment	6
4.1	Basic MIP System Components	6
4.2	Additional MiHPT System Components	8
4.3	Optional Accessories	8
5.0	Quality Assurance/Quality Control	9
5.1	MIP Chemical Response Test	9
5.2	EC Dipole Test	15
5.3	HPT Reference Test	16
6.0	Equipment Preparation for Site Work	17
7.0	Field Operation	18
7.1	Performing HPT Dissipation Test	20
7.2	Detector Gain/Software Attenuation Changes	21
8.0	Replacing a Membrane on the MIP Probe	23
Appendix I	Typical Response Test Data	24
Appendix II	Troubleshooting Guide	26
Appendix III	Membrane Performance Control Charts	30
Appendix IV	Sample Logs and Interpretation	31
Appendix V	GC1000 Configuration and Operating Parameters	34
Appendix VI	Tool Configurations	36

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1.0 Objective

This document serves as the standard operating procedure for use of the Geoprobe Systems® Membrane Interface Probe (MIP) used to detect volatile organic compounds (VOCs) at depth in the subsurface.

2.0 Background

2.1 Definitions

Geoprobe®: A brand name of high quality, hydraulically-powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and testing, soil conductivity and contaminant logging, grouting, and materials injection.
**Geoprobe® is a registered trademark of Kejr, Inc., Salina, Kansas.*

Membrane Interface Probe (MIP): A system manufactured by Geoprobe Systems® for the detection and measurement of volatile organic compounds (VOCs) in the subsurface. A heated probe carrying a permeable membrane is advanced to depth in the soil. VOCs in the subsurface cross the membrane, enter into a carrier gas stream, and are swept to gas phase detectors at ground surface for measurement.

2.2 Discussion

The MIP is an interface between contaminates in the soil and the detectors at ground surface. It is a mapping tool used to find the depth at which the contamination is located, but is not used to determine concentration of the compound. Two advantages of using the MIP are that it detects contamination in situ and can be used in all types of soil conditions.

The MIP is a logging tool used to make continuous measurements of VOCs in soil. Volatile compounds outside the probe diffuse across a membrane and are swept from the probe to a gas phase detector at ground surface. A log is made of detector response versus probe depth. In order to speed diffusion, the probe membrane is heated to approximately 121°C. (Refer to Figure 2.1).

Along with the detection of VOCs in the soil, the MIP also measures the electrical conductivity of the soil to give a probable lithology of the subsurface. This is accomplished by using a dipole measurement arrangement at the end of the MIP probe so that both conductivity and detector readings may be taken simultaneously. A simultaneous log of soil electrical conductivity is recorded with the detector response.

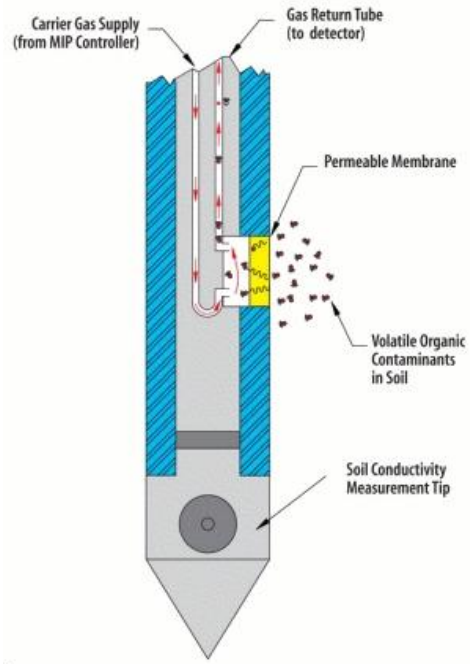


Figure 2.1: Diffusion across the membrane

Interpretation of electrical conductivity (EC) logs comes with field experience. It is very important that soil core samples are taken to confirm lithologic changes as each EC log is unique per site. As a generalization, a high conductivity reading indicates a smaller grain size and a low conductivity reading indicates a larger grain size (See Fig. 2.2).

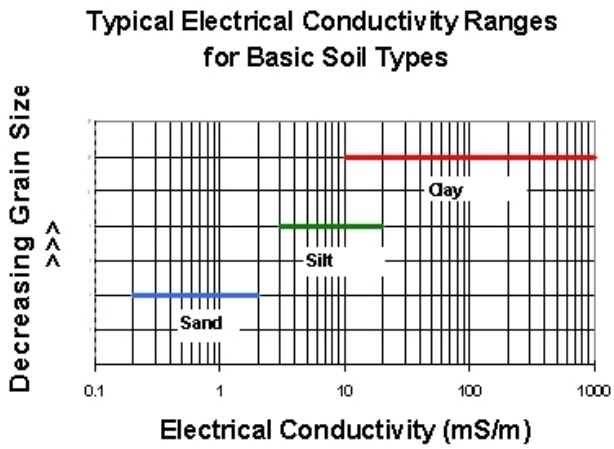


Figure 2.2: Generalized Electrical Conductivity Readings

3.0 MIP/EC Interferences

3.1 Detector saturation may require a short period of time for the detector to return to baseline after a log has been performed in higher concentrations. The MIP system can be used in free product environments with the operator monitoring and making the necessary adjustments to the detector and software gain/attenuation settings to account for the higher voltage readouts.

3.2 The MIP system can be operated in a wide range of contaminant concentrations from low dissolved phase to free phase materials. During a log and the removal of the tool string, contaminants can absorb onto the surface of the membrane and trunkline material causing elevated detector baseline signals. It is very important that the probe and trunkline system is clean enough to see the low concentrations typically used in the chemical response test. Not adequately decontaminating the probe prior to performing a response test can elevate the concentration of the standard causing an inaccurate high response to the specific concentration of standard that was prepared for the test.

3.3 Electrical conductivity can provide false positives or higher than expected readings when the soil is impacted by ionic plumes (chloride, nitrate) originating from, but not limited to: agriculture practices, seawater, salt storage, mining practices. Encountering metallic objects in the subsurface can also result in high EC readings.

3.4 Some silt and clay soils will not have the typical ionic composition that an operator may be used to for similar soils. This can result in lower than expected readings and perhaps cause misidentification of the associated soil zone based on typical response of a courser grain material. This can occasionally be found in clays that have had the minerals leached out or in intermixed silt-sand zones.

4.0 Tools and Equipment

The following equipment is needed to perform and record MIP logs. Basic MIP system components are listed in section 4.1 and shown in Figure 4.1. Additional equipment needed to run MiHPT logs is listed in section 4.2 with optional equipment listed in section 4.3. Refer to Appendix V for a detailed illustration of the GC1000 setup configuration. Appendix VI shows the common MIP probe tool string diagrams. There may be more required tools as determined by your specific model of Geoprobe® direct push machine.

4.1 Basic MIP System Components

Description	Quantity	Material Number
Field Instrument, 120V (Model FI6000)	-1-	213940
Field Instrument, 220V (Model FI6003)	*	213941
MIP Acquisition Software	-1-	214128
MIP Controller, 120V (Model MP6505)	-1-	214137
MIP Controller, 220V (Model MP6507)	*	214139
Gas Chromatograph, 120V with PID, FID and XSD	-1-	213946
Gas Chromatograph, 220V with PID, FID and XSD	*	213947
MIP Probe, 1.75 inch	-2-	214143
MIP/HPT Connection Tube	-2-	220912
MIP/HPT Drive Head 1.5in. rods	-2-	203794
Slotted 1.5” Drive Cap, Threadless	-2-	206609
MIP Probe, 2.25 inch	**	214152
2.25 Connection Tube	**	219455
2.25 Inch Water Seal Drive Head	**	212089
2.75 Inch Water Seal Drive Head	**	209796
Slotted 2.25” Drive Cap	**	211798
MIP Trunkline 100 ft.	(optional)	204077
MIP Trunkline 150 ft.	-2-	202570
MIP Trunkline 200 ft.	(optional)	204655
Agilent ADM 1000 Digital Flow Meter	-1-	600227
Hydrogen Gas Regulator	-1-	600137
Nitrogen Gas Regulator	-1-	600175
Vertical Gas Bottle Rack	-1-	214121
MIP Service Kit	-1-	214142
EC Bypass Cable	-1-	204025
Stringpot, 100-inch	-1-	214227
Stringpot Ground Plate	-1-	220775
Stringpot Cordset, 65-feet (19.8 m)	-1-	202884
Stringpot Mounting Bracket (6600/7700)	(optional)	202947
Stringpot Mounting Bracket (78 Series)	-1-	209511

Stringpot Foot Bracket (6600/7700)	(optional)	201816
Stringpot Foot Bracket (78 Series)	-1-	209533
Stringpot Piston Weight	-1-	214225
Drive Cushion (GH60)	-1-	204278
Rod Wiper, 1.25/1.5” Rods	-1-	600341
Rod Wiper Weldment	-1-	204387

4.2 Additional MiHPT System Components

Description	Quantity	Material Number
HPT Flow Module, 120V (Model K6300)	-1-	214091
HPT Flow Module, 220V (Model K6303)	*	214093
HPT Reference Tube 1.75 in HPT Probe	-1-	212689
HPT Reference Tube 2.25 in HPT Probe	**	211762
MiHPT Probe, 1.75 inch	-2-	219228
MiHPT Probe, 2.25 inch	**	214117
MiHPT Connection Tube	-2-	219594
MiHPT Drive Head for 1.5” rods	-2-	220545
MiHPT Trunkline 100 ft	(optional)	214113
MiHPT Trunkline 150 ft	-2-	214114
MiHPT Trunkline 200 ft	(optional)	214115
Coupling 1/8 to 1/8 Tube	-5-	107963
Coupling 0.135 to 0.150 Tube	-5-	220978
Oetiker Band Clamp 4.7mm x 5.7mm	-10-	220977
Oetiker Band Clamp #7	-10-	220976
HPT Sensor Module	-2-	210091
Heated Trunkline Seal Asm.	-4-	211768
HPT Test Load	-1-	206552
HPT Service Kit	-1-	205599

4.3 Optional Accessories

Description	Quantity	Material Number
Heated Trunkline Controller, 120V (Model MP7000)	-1-	214147
Heated Trunkline Controller, 220V (Model MP7003)	*	214148
MIP Heated Trunkline 100 ft.	(optional)	214150
MIP Heated Trunkline 150 ft.	-1-	214151
MIP Heated Transfer Line 8 ft.	-1-	214149
MIP Breakout Connection Panel.	-1-	211100
Roll-out Rod Rack (30-1.5in rods)	-1-	213627
Water Transport System.	-1-	203450

*Use in place of 120V components if desired.

**Use in place of 1.75 inch probe and components if desired.

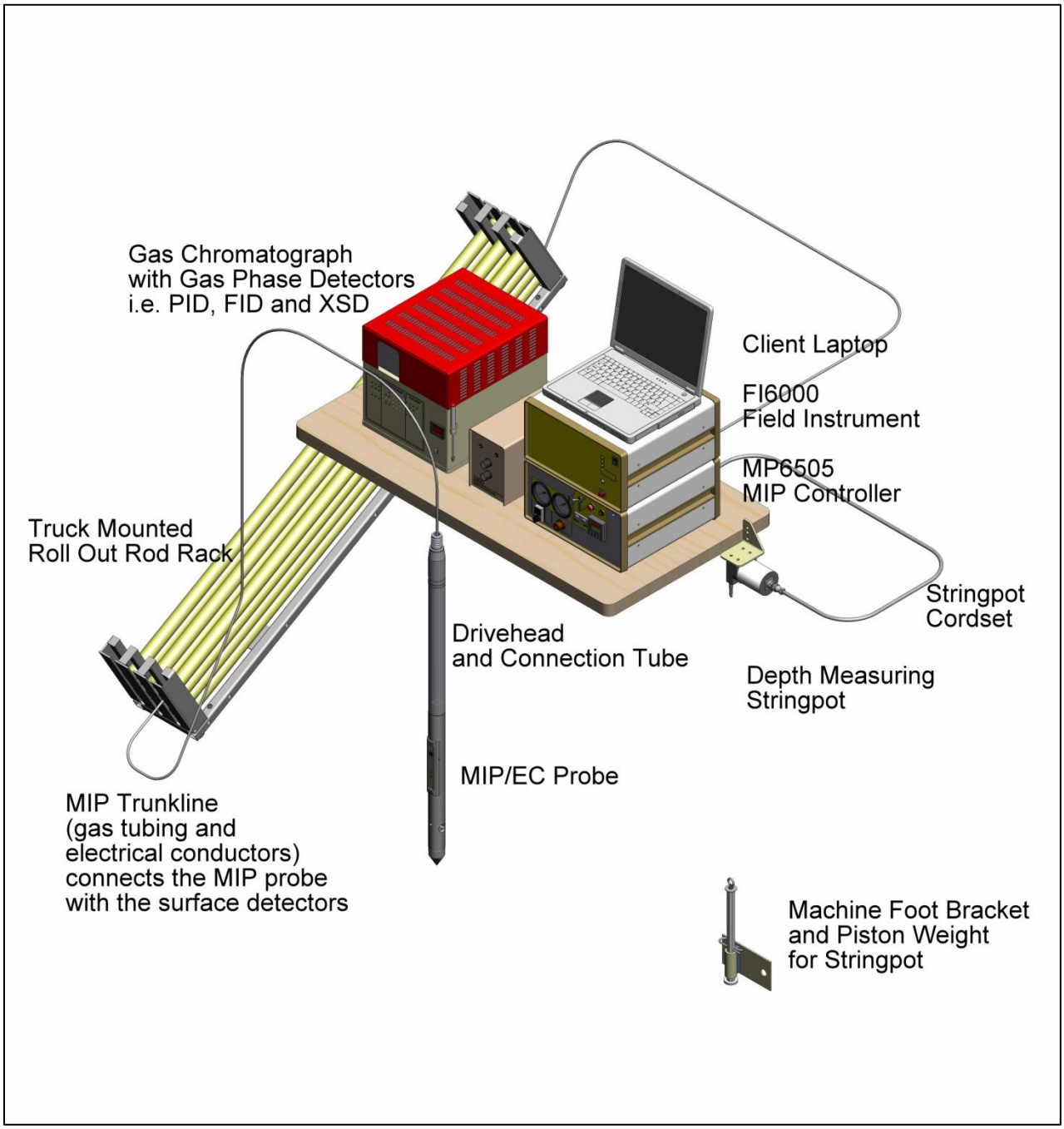


Figure 4.1: MIP System Components

5.0 Quality Assurance/Quality Control

Quality assurance (QA) testing of each of the sensors on the probe is too be performed before and after each log to validate that the equipment is capable of generating good data. The MIP tool includes chemical response tests (Section 5.1.3) which are performed to ensure that the probe membrane, trunkline and detectors are capable to providing ample signal over baseline noise to a known site contaminant at a given concentration. The electrical conductivity (EC) sensor is tested using an EC dipole test (Section 5.2) with low and high readings typical to EC values of the soil. The HPT sensor is included on the MiHPT probe and is tested using the HPT reference test (Section 5.3) which confirms the sensors ability to accurately measure a 6" column of water and provides an accurate measurement of atmospheric pressure.

Quality control (QC) is performed during and after each log is generated. Log QC will answer the following questions to ensure that the data is good and makes sense:

1. Does the log look correct? Does the elctrical conductivity appear to be in an acceptable range? Is there anything seen in the log that would make you suspect that the system wasn't working correctly, ie. a loss of temperature or gas pressure of the system.
2. Response consistency? As more logs are completed do they show general consistency of EC and contaminant response? Review a cross section of logs in the DI-Viewer (Appendix IV).
3. Repeatablity? Replicate logs may be run every 10 to 20 locations to verify repeatability.
4. Are my lithogy changes consistant with physical soil cores? Take continuous or discreet confirmation soil samples to confirm your lithogy changes in EC.
5. Do the MIP detector responses make sense for contaminant concentration. This must be verified by the collection of water or soil samples for lab analysis to confirm contaminants and their concentrations.

5.1 MIP Chemical Response Test:

Chemical response testing is an important quality assurance measure used to validate each log by proving that the integrity of the detector system is intact. With the chemical response test the operator introduces a working standard (known site contaminant of concern) at a known concentration to the membrane for a set time of 45 seconds which should match the residence or holding time at each sampling interval. Two acceptable methods of introducing the standard to the membrane are shown in Figures 5.4 and 5.5.

Typical site contaminant of concerns which are used in MIP chemical response tests include but are not limited to Benzene, Toluene, Trichloroethylene or Perchloroethylene. The stock standard should be made up from one of these or an appropriate mix of chemicals.

5.1.1 Preparation of the Stock Standard

Preparation of the stock standard is critical to the final outcome of the concentration to be placed into the testing cylinder. The following items are required for preparing the stock standard:

- Neat sample of the analyte of interest (i.e.: Benzene, Toluene, TCE, PCE, etc.) purchased from a chemical vendor
- Microliter syringes (recommended to have: 25μL, 100μL and a 500μL or 1,000μL syringes).
- 25-mL or 50-mL Graduated cylinder
- Several 40-mL VOC vials with labels
- 25mL Methanol

1. The total volume of methanol and the compound added should equal 25mL.
2. Pour methanol into graduated cylinder to the 23.5-24mL mark, the volume depends upon the compound density (Table 5.1).
3. Pour the methanol from the graduated cylinder into a 40mL VOC vial.
4. Add the appropriate volume of desired neat analyte into 40mL VOC vial containing methanol. The required volume of neat analyte for seven common compounds is listed in Column 3 of Table 5.2. The equation in table 5.1 shows how to calculate the appropriate neat analyte volume for other compounds of interest given the appropriate density.
5. Label the vial with the name of the stock standard (i.e. Benzene, Toluene, TCE, PCE), concentration (50mg/mL), date created, and created by (your name or initials).
6. Stock standards need to be kept cold in a refrigerator or freezer to ensure they can last up to one month otherwise they should be made up more frequently as often as every 3 days if there is not cooling during the summer months. The more volatile the compound the quicker it will lose its concentration.

Stock Standard Calculations

25mL (methanol) x 50mg/mL = 1250mg
1250mg x 1/density of analyte = amount of neat material to be placed with methanol to make up 25mL total volume

Example: Preparation of 50mg/mL Benzene standard.

1250mg x 1/0.8765mg/μL = 1426μL
Use 1426μL of neat Benzene in 23.5mL of Methanol to get a 50mg/mL stock standard.

Table 5.1: Stock Standard Preparation Calculations

Compound	**Density (mg/μL)**	**Volume (μL) of Neat Standard Required to prepare Working Standard (0.5 L)**
Benzene	0.876	1426
Toluene	0.867	1442
Xylenes	0.860	1453
Methylene Chloride	1.335	936
Carbon Tetrachloride	1.594	784
Chloroform	1.480	845
Trichloroethylene	1.464	854
Perchloroethylene	1.623	770

Table 5.2: Density and required volumes of neat (pure ~100%) compounds used to make a 50mg/mL stock standard into 25 ml of methanol

5.1.2 Preparation of Working Standards

The following items are required to perform response testing:

- Microliter syringes (recommended to have: 10, 25, 100 & 500µL syringes).
- Freshly made 50ml/ml Stock standard
- Testing cylinder made from a nominal 2-in. PVC pipe with a length of 24 in. or 40ml vial
- 0.5 L plastic beaker or pitcher
- Supply of fresh water, 500mL needed per test
- Stopwatch

Volume of 50mg/ml Stock Standard (µL)		Final Concentration mg/L = ppm
10		1.0
100		10
1000		100

Table 5.3: Volumes of stock standard and final concentrations

Figure 5.1: Working standard

5.1.3 Performing the Chemical Response Test

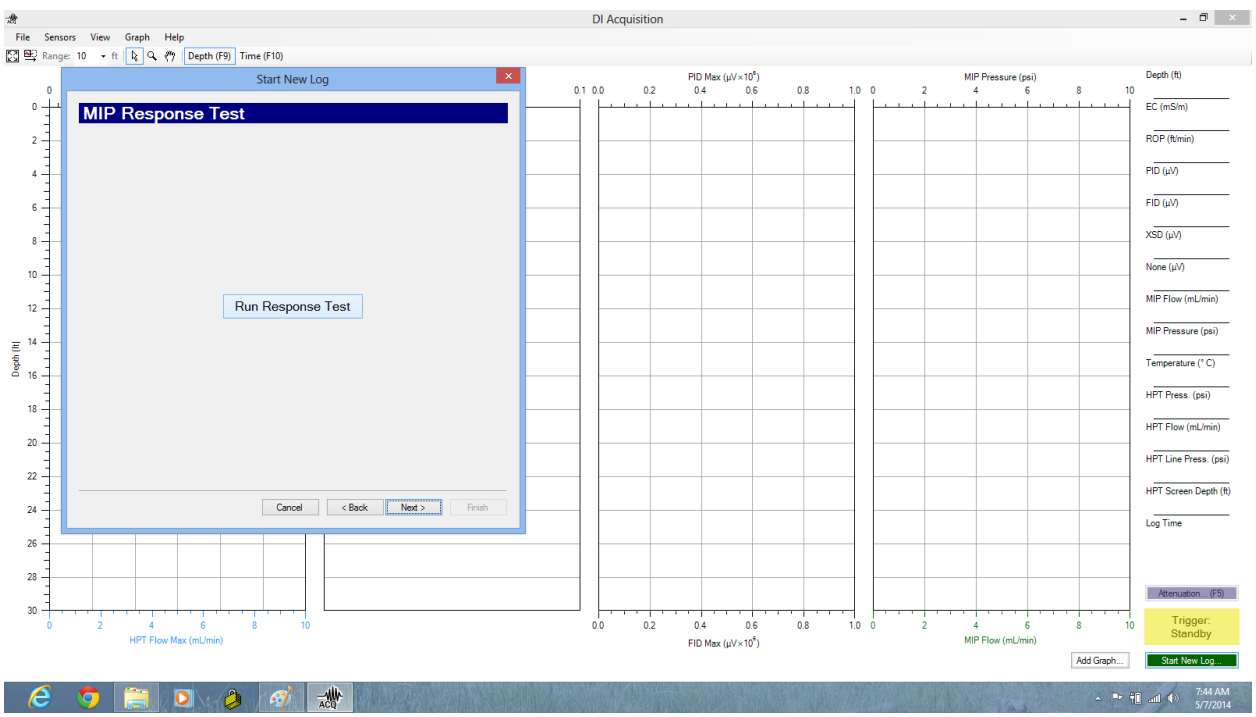


Figure 5.2: DI Acquisition Response Test Screen

1. Begin a new log in the DI-Acquisition software and proceed to the response test screen. The detector signals should be stable before proceeding with the test.
2. Measure out 500mL of tap or distilled water in a graduated beaker.
3. Using Table 5.3, determine the desired volume of stock standard to place into the 500ml measured volume of water to make up the working standard.
4. If the detector baselines have been monitored while the standard was being prepared select "Clear Response Test".
5. When ready with the working standard prepare to run the response test by exposing the membrane to the working standard. Two acceptable methods are to pour the standard into a nominal 2-inch x 24-inch PVC pipe and insert the probe into the tube (Fig. 5.4) and the other method is to pour the working standard into a 40ml/vial and invert onto the membrane (Fig. 5.5).
6. Start the response test by clicking on the "Run Response Test" button (Fig. 5.2) and immediately expose the MIP membrane to the test solution (Figures 5.4 or 5.5).

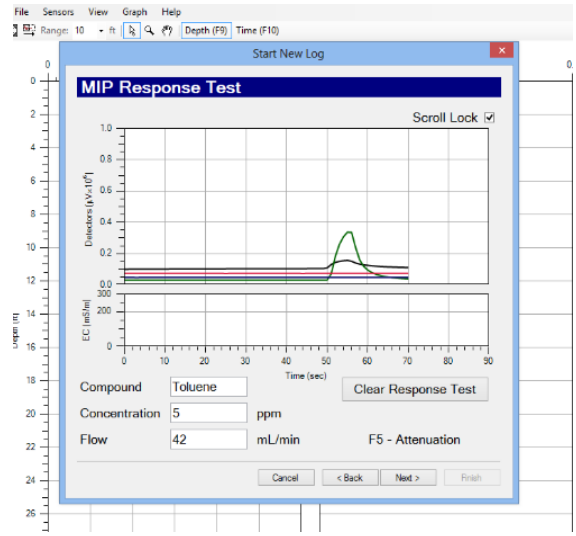


Figure 5.3: Running the Chemical Response Test

7. Leave the membrane exposed to the test solution for 45 seconds. This time is to be equal to the resonance time at each depth interval during probe advancement.
8. Starting the response test time file as the membrane is exposed to the test solution allows the trip time (Section 5.1.4) to be easily calculated by when response begins to climb which is approximately 50seconds in Fig. 5.3.
9. Fresh working standards need to be made for each test, they cannot be reused.
10. After the response has come through the detectors and adequate detector response is seen the operator may select "next" to move to the EC QA test.

Acceptable methods for performing the MIP Chemical Response Test

Figure 5.4 Probe immersed in steel or PVC pipe containing working standard

Figure 5.5: 40ml vial of working standard inverted onto membrane

5.1.4 Determination of Contaminant Trip Time:

Response testing also enables the operator to measure the chemical trip time which needs to be entered into the MIP software to accurately plot the contaminants depth position. The trip time is the time it takes for the contaminant to travel through the trunkline from the membrane to the detectors. The contaminant trip time is influenced primarily by trunkline length and carrier gas flow rates as well as the contaminant makeup specifically boiling point. The chemical response trip time can be determined from the results on the Pre-Log Response Test. Using Fig. 5.6 the Benzene trip time (TT) would be approximately 55 seconds. This response test would need to have been started right when the chemical used in the response test was exposed to the membrane. Additional typical response test graphs are located in Appendix I.

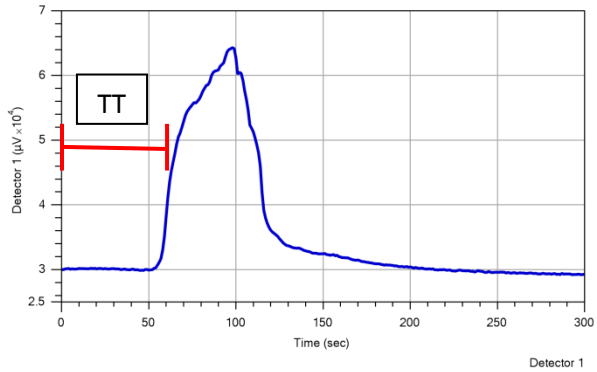


Figure 5.6: 5ppm Benzene on PID

5.1.5 Appropriate Chemical Response Test Concentrations and Response

The compound used in a chemical response test should be the site contaminant of concern or similar which will give you the most accurate response magnitude for that chemical as well as an accurate trip time. If the site objective is to delineate the extent of a dry cleaner plume then the operator should use PCE for the response tests at the lowest possible concentrations ~1ppm or less. If the site objective is to delineate the extent of the petroleum plume from a gas station then the operator should use one of the BTEX compounds or a gasoline mixture at or near the detection limit. If the site objective is to map out a plume source and high contaminant concentrations are expected then the response tests should be run at higher concentrations such as 10ppm-50ppm. This should reduce the possibility of trunkline/membrane carryover masking the chemical response tests.

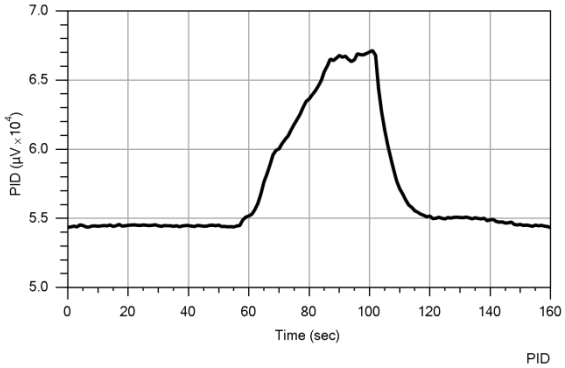


Figure 5.7: 2.5ppm Benzene on the PID

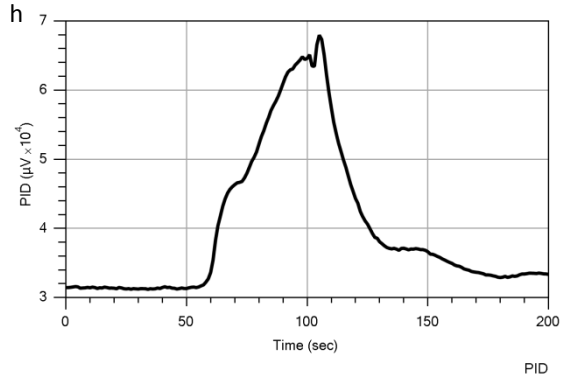


Figure 5.8: 5ppm TCE on the XSD

Figure 5.7 shows a benzene response over baseline on the PID of approximately 12,500μV on a 2.5ppm standard for a 5,000μV/1ppm. Figure 5.8 shows TCE responses over baseline on the XSD of 33,000μV on a 5ppm standard for approximately a 6,500μV/1ppm response.

5.1.6 Minimum Acceptable MIP Response Test Levels and Maintenance Tips

Geoprobe Systems specifies the following guidelines as minimum MIP response test values for performing MIP logging.

Detector systems can vary in the level of response for a given chemical concentration depending on detector age, model, and maintenance performed. However, it should be expected that the detector system would be able to provide at least a 5:1 signal to noise ratio (see Appendix I) for 1ppm of Benzene or TCE. Other compounds or concentration may be performed at the client requests however they may have different response magnitudes and signal to noise ratios at 1ppm. These specifications are required with operation of the PID and XSD (ECD or DELCD as well as alternative halogen detectors). The FID is a less sensitive detector typically used as a confirmation detector and one used for mapping natural gas components.

If the minimum response test levels are not achievable or throughout the day or project the detector sensitivity falls below these levels, the operator must stop and perform maintenance on the system to enhance the sensitivity of the detectors. Corrective actions could include:

- Changing MIP membrane (see section 9.0)
- Making a fresh chemical stock standard (see section 5.1.1). It does not take long for a volatile chemical standard to lose the original concentration.
- Decreasing trunkline carrier gas flow from 40ml/min to 30 or 20ml/min. This will lower the pressure in the trunkline and at the membrane which will increase system sensitivity. If this is corrective action is taken the operator must update the system trip time which has changed.
- Performing detector maintenance
    - Cleaning or replacing the PID bulb
    - Replacing the XSD probe assembly or reactor core
- Checking and adjusting detector gas flows - especially in the FID.
- Replacing the trunkline (an old trunkline can be a source of contaminant phase buildup. This will reduce detector sensitivity by causing contaminant dispersion in the trunkline which results in reduced response levels as well as delayed trip times).

It is wise for the MIP operator to monitor the detector response heights from the chemical response tests to evaluate membrane performance. With increased membrane footage, detector response will fall off indicating that it is time to change the membrane (see Appendix III). It may be possible to rejuvenate a MIP membrane by scrubbing with a wire brush.

5.2 EC Dipole Test

On the FI6000 and the DI-Acquisition software the EC dipole test screen (Fig. 5.10) will open up after the chemical response test is completed. When ready place the low (brass) side of the EC Dipole test jig (Fig. 5.9) between the EC dipole and body of the probe and start the low level test, hold for 5 sec until the system captures the data (Fig. 5.10). Repeat for the high (stainless steel) EC test. These tests should result in readings of 55mS/m and 290mS/m ± 10%.

Figure 5.9: EC Dipole Test Jig

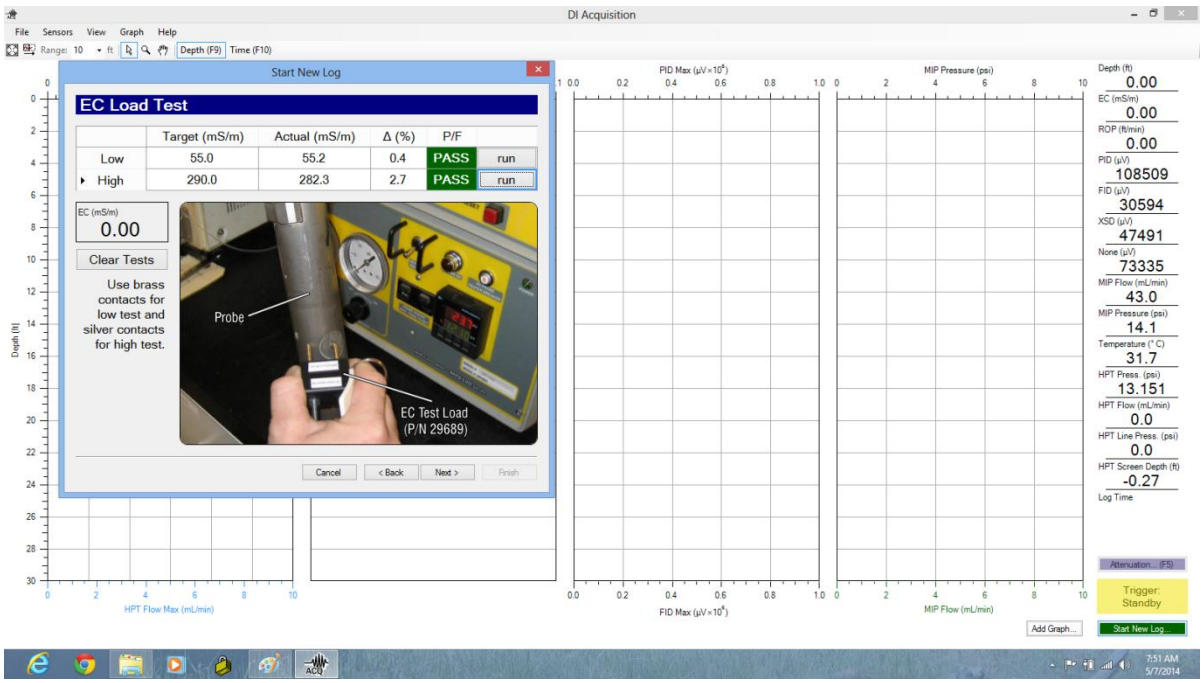


Figure 5.10: EC Dipole Test QA Screen

If the EC readings do not pass, the DI Acquisition (FI6000) software will prompt the user to proceed through a series of troubleshooting tests (Fig. 5.11). These tests will check the EC calibration (Fig. 5.12) to determine if the reason EC Test loads have failed was an issue internal to the FI6000 or if it is external in the trunkline-probe circuit. From here the operator should have an idea where to focus their attention to fix the problem.

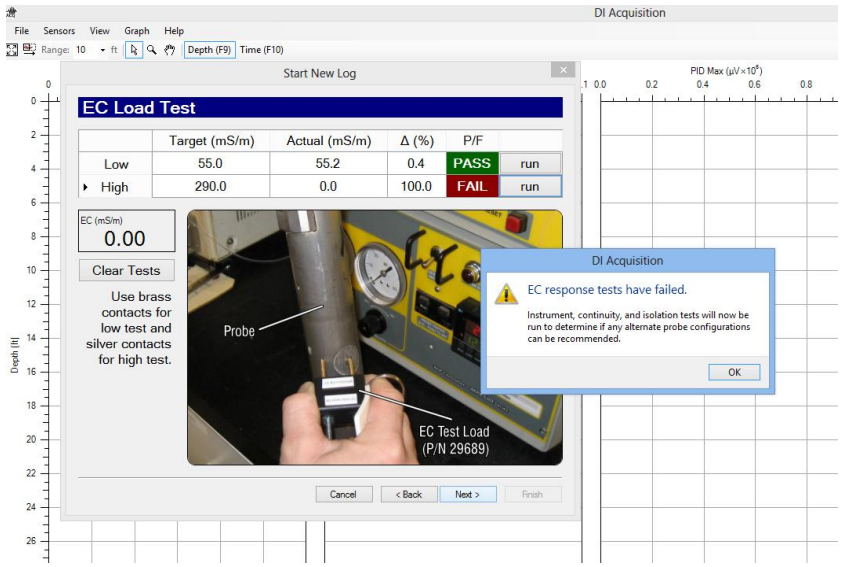


Figure 5.11: Failed EC Dipole Test Error Screen

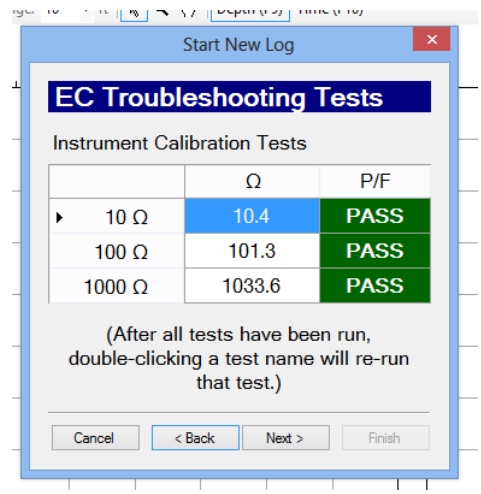


Figure 5.12: EC Calibration Check

5.3 HPT Reference Test – (MiHPT)

Reference testing is done to ensure that the HPT pressure sensor is in working order and to evaluate the condition of the HPT injection screen. The HPT reference test calculates atmospheric pressure which is required to obtain static water level readings and to determine the estimated K values for the log in our post log processing software the DI Viewer.

Reference Test Procedure

1. Connect a clean water source to the HPT controller and turn on the pump.
2. Allow water to flow through the system long enough so that no air remains in the trunkline or probe (air in the system can cause inaccurate flow and pressure measurements).
3. Insert the probe into the HPT reference tube and allow the water to flow out the valve adjusting the flow rate to between 200-300ml/min (Fig. 5.13). Ensure that the reference tube is close to vertical.
4. With a stable pressure reading and the water flowing out of the valve select “capture” - bottom with flow (Fig. 5.14)

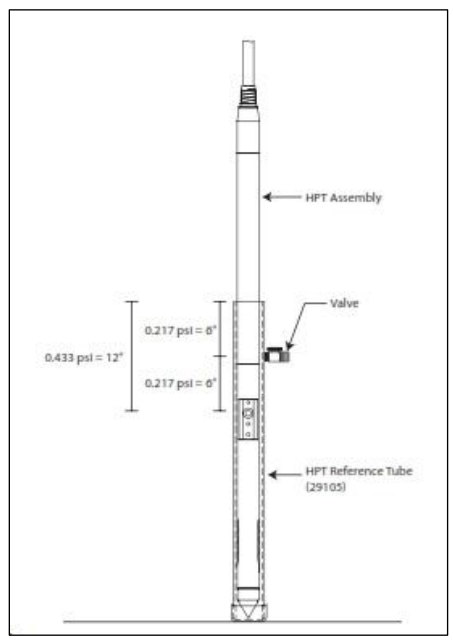


Figure 5.13: HPT Reference Test Setup

5. Close the valve and allow the water to overflow the top of the tube. When the pressure stabilizes select “capture” - top with flow.
6. Shut off the water flow. When the pressure stabilizes select “capture” - top flow = 0.
7. Open the valve and allow the water to drain out. When the pressure stabilizes select “capture” - bottom flow = 0.

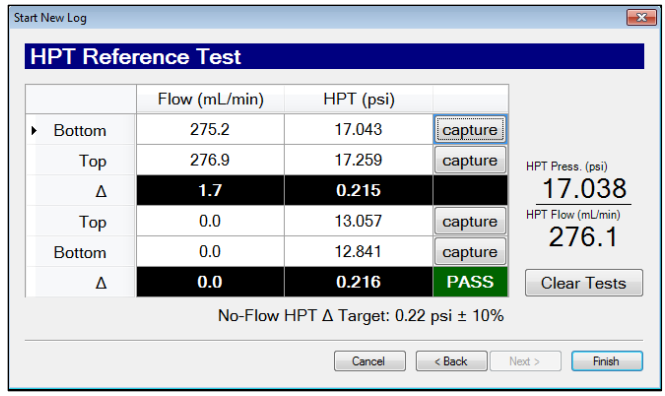


Figure 5.14: HPT Reference Test Screen

The HPT reference test reading flow = 0 is the true test of the condition of the pressure sensor and is the only sensor test to have a pass/fail reading on it. Ideally, the pressure difference between the top and bottom values will be 0.22 psi (1.52kPa). Typical pressure readings of the sensor will be in the 12PSI-15PSI (83kPa-104kPa) range.

6.0 Equipment Preparation for Site Work

The biggest issues to the performance of any specific MIP system is inadequate project preparation and system review, too heavy of a workload which reduces the ability to perform needed maintenance and inexperienced operators how do not fully understand the steps of troubleshooting.

When a MIP system is stored for a period of time between projects, operators must review the equipment and give it a full system checkup which includes checking detector gas flow rates, running response chemical response tests with known chemicals at concentrations at or near required site detection limits. This needs to be performed 1-2 weeks in advance of project work so there is time to obtain required supplies that might be needed for proper operation. A final checkout needs to be performed within 7 days of the project. If the MIP site contaminant of concern is an obscure chemical not normally tested for the operator should run some of that chemical for response tests to confirm it can be detected and to determine reasonable detection limits. The operator should be able to supply the consultant with pre-project performance data of all sensor information to be performed at the site which might include EC, MIP chemical response tests, and HPT reference test information.

If a MIP system is scheduled on a long job or has a number of jobs strung together it is in the best interest of the MIP service company to schedule a maintenance day at least every 3 weeks to allow the operator time to go through system and service the components that need attention. This will help to be able to keep to system performing well for the company and their clients. Pre project performance must still be able to be produced.

New operators will always be needed as the MIP community continues to grow, however it is imperative that operators who are running the MIP systems on their own have been properly trained by experts from their own company or at Geoprobe Systems® headquarters. An inadequately trained operator who faced difficulties onsite and does not understand the system and how to troubleshoot it will quickly bring frustration upon themselves, their company and clients. It is important that each operator is properly trained, is able to spend consistent time with the equipment and the software, and whenever possible operate of the equipment under the guidance of a mentor "MIP specialist."

7.0 MIP Field Operation

1. Power on the generator.
2. Open the gas cylinders that will be used for the MIP system (i.e. nitrogen, hydrogen, air, etc.).
3. Power on the GC and detectors and allow them to warm up (min. 20 minutes) to set temperature.
4. Power on the MIP controller, field instrument and laptop computer.
5. Check the trunkline supply and return flows of the system and MIP pressure. Compare these numbers to previous work.
6. Start the Acquisition software and start a new log.
7. Perform the chemical response test (Section 5.1.2) and record the height of the peak response and the trip time into a field notebook. Refer to Figure 5.4 and Appendix I and III.
8. Complete the EC dipole test (Section 5.3) and finish setting up the log.
9. Record the system parameters in a field notebook at this time (i.e. flow, pressure, trip time, detector baseline voltages).
10. Connect the stringpot cable to the stringpot and the stringpot wire to the weight located on the probe foot and pull keeper pin so the weight will drop to the ground.

NOTE: Do not allow the stringpot cable to snap back into the stringpot housing at a high rate of speed. This will ultimately damage the stringpot transducer.

11. Place the drive cushion onto the probing machine head.
12. Place a slotted drive cap to the MIP drive head.
13. Place the rod wiper on the ground and insert the point of the MIP probe into rod wiper opening.
14. Start the HPT water flow if running MiHPT.

    Note: It is important that there is always water flowing when the probe is moving to avoid soil particles from moving through and plugging up the screen.
15. Align the probe exactly straight and advance the probe to the starting depth: MIP membrane even with the ground surface.
16. Click the trigger button in the lower right hand corner of computer screen. (The Trigger label will flash and the background will change from yellow to green).
17. Standard advancement the probe is at a rate of 1ft/min meaning: advance 1 ft (30 cm) in 15 seconds and then hold at depth for 45 seconds, then advance to the next depth interval (1 foot) over 15 seconds and wait for 45 seconds. Do this until the predetermined log depth or until refusal is attained.

Advancement the MIP probe can be performed using a continuous push method with no stopping intervals which may be desirable in source level contamination. Data collected by this method will result in higher detection limits and is not directly comparable to data collected by the standard advancement method previously discussed.

NOTE: If the there is a loss in MIP pressure or temperature during the logging process, stop and evaluate the problem using the troubleshooting guide located in Appendix II.

NOTE: Refusal is attained when it takes longer than 1 minutes of continuous hammering to advance the probe one foot. This is the maximum time to reach one foot of probe travel.

18. Perform an HPT dissipation test (Section 7.1) in a zone of higher permeability indicated by lower HPT pressure if you are operating the MiHPT probe.
19. When the MIP log is complete, turn the trigger off and slowly return the stringpot cable into the stringpot housing.
20. Turn off the heater switch to the probe during tool string retraction so no as few contaminants as possible are diffused through the membrane and into the trunkline during retraction.
21. Raise the probe foot of the direct push machines foot assembly and place the rod wiper weldment under the foot assembly to keep it in place during rod retraction.
22. Pull the probe rod string using either the Geoprobe® rod grip pull system or a slotted pull cap.
23. When the MIP probe reaches the surface, clean the probe and membrane well with a detergent/water mix and rinse off well.
24. Now turn the probe heat back on to back off the membrane. Make sure the probe membrane and trunkline are clean of contaminants and the detector baselines are stable prior to running a post log response test. View the detector activity in the response test screen.
25. When the baselines are stable run a post log response test. These response test results should be written down in the field notes and compared to the initial test. This system check ensures the data for that log is valid.
26. When using the FI6000, the data will be saved into your designated folder on your laptop in a compact .zip file. Data from the MIP log can now be graphed and printed using the DI-Viewer software (Appendix IV).

7.1 Performing an HPT Dissipation Test

At least one dissipation test must be performed in order to calculate the static water level and estimated K readings from the HPT log. Dissipation tests need to be performed below the water table and are best in zones of high permeability where the injection pressure can dissipate off quickly once the flow is shut off. The following are the steps for running an HPT Dissipation test.

1. Stop in a zone of higher permeability which is indicated by lower HPT inject pressure.
2. Switch the DI Acquisition display view from the depth screen to the time screen by pressing the F10 key (F9 and F10 toggle between the depth and time screen of the acquisition software).

3. The screen will be grayed out which means that the data up to that point has not been saved. Select “Start Dissipation Test” which will turn the screen from gray to a white background indicating that you are now saving the time data.
   Now shut the pump switch off and when the line pressure reaches zero, turn the flow valve off.
4. The HPT Pressure will begin to drop (dissipate the hydrostatic increase) and allow it to stabilize so very little visible drop in pressure is seen. When the pressure has fully dissipated turn the flow valve and the pump switch back on. When the flow and pressure are reestablished select “End Dissipation test.”
5. Select F9 to return to the depth screen and advancing the tool into the ground.

   Note: Performing a dissipation test in zones of higher permeability may only take 60 seconds or so but if the HPT pressure was higher to start with it may take a long time up to several hours to dissipate off to equilibrium. This is why targeting the most permeable zone to perform the dissipation tests is most desirable.

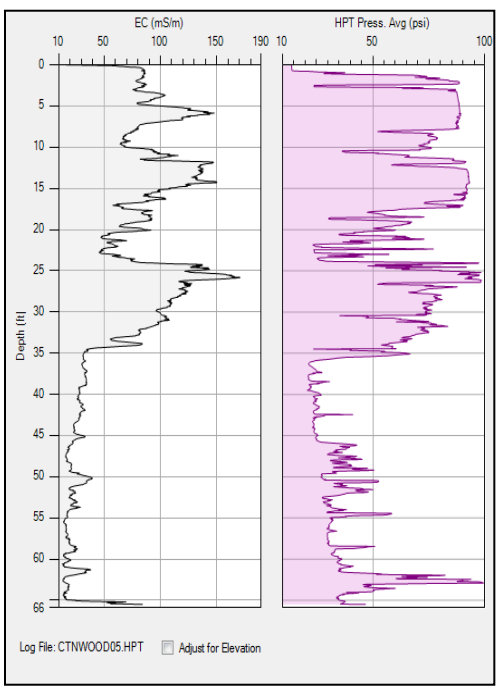


Figure 7.1: EC and HPT Pressure Graphs

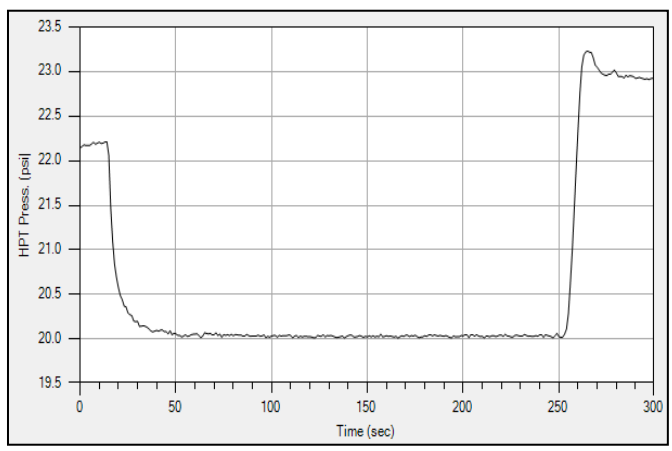


Figure 7.2: HPT Dissipation Test Screen.

The dissipation test shown in Figure 7.2 was performed in the lower pressure zones located at 39.5’ of the log shown in Figure 7.1. With HPT sands and gravels are indicated by lower injection pressure which is primarily seen below 35’ in the above log. The dissipation test in Figure 7.2 shows a higher pressure at the start of the test which falls off which is a result of shutting off the water flow. A good dissipation test will run for a period of time approximately 30-60seconds at a stabilized pressure and then turn the water flow back on during the saved log.

7.2 Detector Gain/Software Attenuation Changes

While mapping volatile contaminants with the MIP system operators commonly encounter highly contaminated/free product zones that can result in the detector signal climbing to the point of saturation or "flat lining." This occurs because the GC or detector system has a limited signal output range. What that range is varies depending upon the GC model or detector controller. Typical signal out limits for are 0-5VDC for SRI and Shimadzu GC models and 0-1VDC for HP/Agilent GCs and the OI XSD. The attenuation settings (software multipliers) for SRI and Shimadzu GCs and the XSD are based on a 10^x multiplication factor. The attenuation settings for detectors operated through an HP GC are based on a 2^x multiplication scale x = HP GC Range with the sum being the corresponding attenuation for the MIP software (Table 7.1).

As the probe is being advanced into higher concentration petroleum hydrocarbon soils the operator, if using an SRI GC, will want/need to adjust the GC gain on the PID and probably the FID from a gain setting of high to medium which takes those detector signals and divides them by a factor of 10 (Table 7.1). This reduction in the signal can be seen in the software both in the digital display as well as on the time graph. After the signal has been reduced the operator will need to select the attenuation tab/F5 in the DI Acquisition software and input a 10x multiplier in for the PID and the FID if both gain switches were changes to the medium setting.

If the operator chooses to go back to the highest sensitivity on those detectors after passing through the high contamination zone they need to first remove the multiplier in the software (F5) and then change the gain setting from medium to high on the GC – removing the signal divider. If either of these is performed in reverse fashion the log will see a very larger false positive peak because the signal is multiplied up without having a signal divider in place. The operator always wants to add the signal divider in first as they go into higher reading soils and remove it last as they come out of them.

Gain/Attenuation Settings on the GC detectors and the DI Acquisition software

HP GC* Range	DI Acq. Attenuation		SRI GC Gain	XSD Gain	DI Acq. Attenuation
0	1		High	High	1
1	2		Medium	Medium	10
2	4		Low	Low	100
3	8				

Table 7.1: GC gain/range settings and associated software multipliers.

*- The detectors on the HP GC can have attenuation settings up to a range of 7 on the GC corresponding to an acquisition software multiplication value of 128.

8.0 Replacing a Membrane on the MIP Probe

A probe membrane is considered in good working condition as long as two requirements are met:

1. Adequate signal response is achieved during the chemical response tests to see the required detection limits.
2. The difference between the supply and return flow has not increased by more than 3mL/min from the original settings. (A digital or bubble flow meter should be kept with the system at all times).

If either one of these requirements are not met, a new membrane must be installed as follows.

1. Turn the heater off and allow the block to cool to less than 50° C on the control panel readout.
2. Clean the entire heating block with water and a clean rag to remove any debris.
3. Dry the block completely before proceeding.
4. Remove the membrane using the membrane wrench (Fig. 8.1). Keep the wrench parallel to the probe while removing the membrane to ensure proper engagement with socket head cap screw.

NOTE: Do <u>not</u> leave the membrane cavity open for extended periods. Debris can become lodged in the gas openings in the plug.

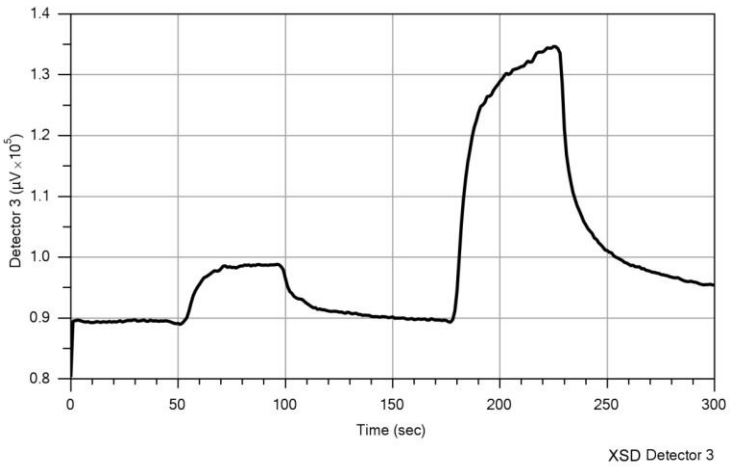
5. Remove and discard the copper washer as shown in Figure 8.2. Each new membrane is accompanied by a new copper washer. **Do not reuse the copper washer**.
6. Clean the inside of the membrane socket with a q-tip and methanol removing dirt and debris that will be present.
7. Insert the new copper washer around the brass plug making sure that it sits flat on the surface of the block.
8. Install the new membrane by threading it into the socket. Thread the membrane into the socket by hand, do not use the membrane wrench until the membrane is nearly all the way threaded. Use the membrane wrench to tighten the membrane to a snug fit. Do not over-tighten.
9. Turn the carrier gas on and leave the heater off. Apply soapy water to the membrane and surrounding area to check for leaks. If bubbles form in the water around the edges of the membrane or in the wrench holes use the membrane wrench to further tighten the membrane.
10. Use a flow meter to check carrier flow. The difference between the supply flow from the MP6505 and the return flow from the trunkline should be less than 3ml/min. Record the values in a field notebook.

Figure 8.1: Unthread the membrane from the probe block.

Figure 8.2: Remove and discard the copper washer.

APPENDIX I

Typical Response Test Data

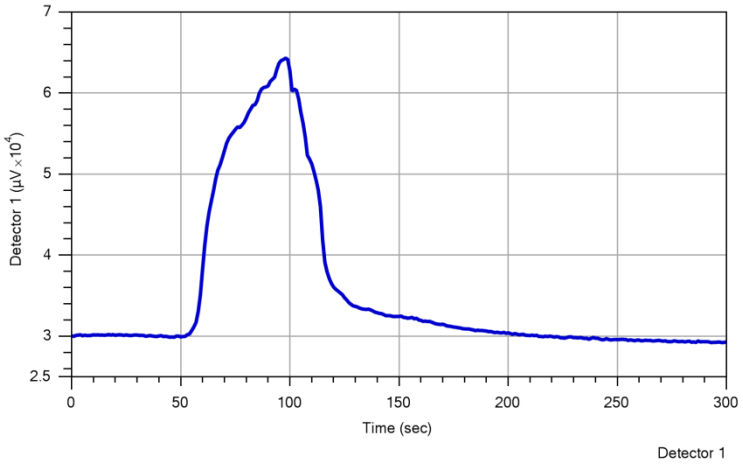


System Parameters:

MP6520 Probe with 121°C setpoint
150' PEEK Trunkline
40ml/min of Nitrogen Carrier Gas
XSD Temperature of 1,100°C

System Response:
1ppm – 9,000µV
5ppm- 45,000µV

Figure 1: Chemical Response Test: TCE 1 & 5ppm on XSD



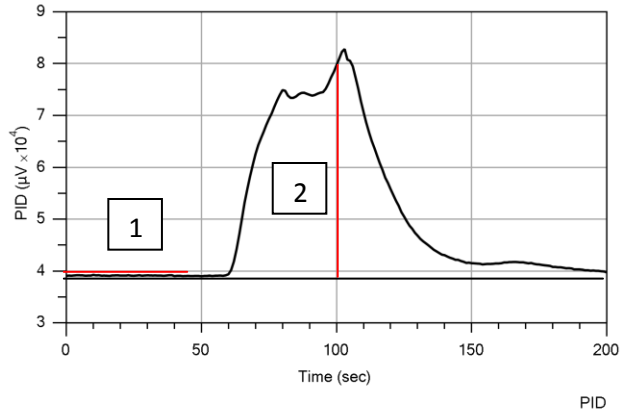
System Parameters:

MP6520 Probe with 121°C setpoint
150' PEEK Trunkline
40ml/min of Nitrogen Carrier Gas
PID Lamp intensity

System Response: 5ppm- 35,000µV

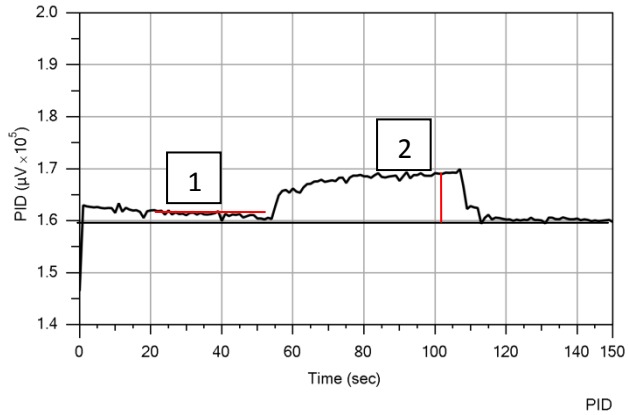
7,000µV/1ppm

Figure 2: Chemical Response Test: Benzene 5ppm on PID



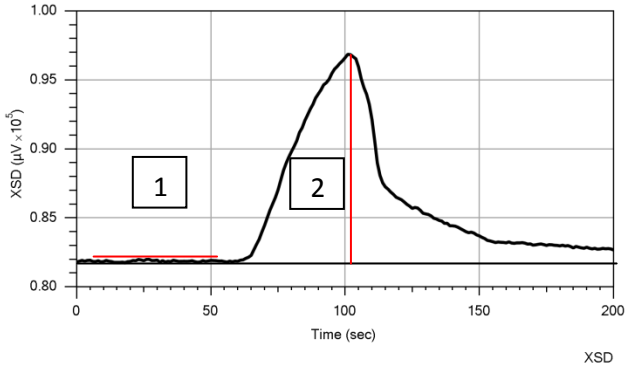
Response test - PID 5ppm Benzene
Response magnitude (2) ~40,000µV
Response/1ppm ~8,000µV
Baseline noise (1) <500µV
Parameters: 150'TL/40ml/min flow/12PSI

Acceptable response test. Response to baseline noise ratio is >5:1 at 1ppm



Response test - PID 1ppm Benzene
Response magnitude (2) ~8,000µV
Baseline noise (1) ~2,000µV
Parameters: 150'TL/39ml/min flow/12PSI

Not Acceptable response test
Response to baseline noise ratio is <5:1 for 1ppm Benzene
Quick Fix: Lowering carrier flow rate to 25-30ml/min will improve signal response 50% or more.



Response test - XSD 2.5ppm TCE
Response magnitude 15,000µV
Response/1ppm 6,000µV
Baseline noise <300µV
Parameters: 150'TL/40ml/min flow/11.4PSI
Acceptable response test, Response to baseline noise ratio >5:1 for 1ppm TCE

1. Baseline noise is the amount of variation in baseline signal over a given time.
2. Signal response is the amount of rise in baseline over the stable baseline level.

APPENDIX II

Troubleshooting Guide

Loss of Pressure 1-2 PSI

- If the pressure loss has been gradual, and your MIP controller has a flow sensor check to see if the MIP supply flow has gradually dropped over the course of the log. This can happen due to the control box warming up and will be indicated by a gradual drop of both MIP pressure and flow. To resolve this increase the mass flow controller to bring the supply flow back to its original set point.
- Punctured membrane: Are there any obvious holes in the membrane with bubbles streaming out of them? Replace membrane.
- Membrane leaking out of the face – heavy frothing of bubbles on membrane face but no obvious punctures in membrane. **With the heat off**, place your thumb over the membrane**,** if the pressure goes back up to the gas pressure prior to the boring the pressure and flow loss is due to a leak in at the membrane face. Replace the membrane.
- Swagelok fitting connecting one of the trunkline gas lines to stainless steel gas line of the probe is loose. Check with soapy water, if bubbles build, fix by slowly tighten the gas line 1/16" nut to the probe.
- Examine for cuts, kinks & cracks in the length of the observable gas line. Expect to see bubbling when MEOH or soapy water is placed on it. Cut gas line prior to this and replace nut and ferrule and reconnect onto the probes steel gas line connection.
- Broken gas line somewhere else up the trunkline. Confirmed when trunkline connections are removed from the probe and close coupled. The carrier gas supply and return should be within 2ml/min, if it is >5ml/min first check with soapy water at the connecting nuts and exposed gas line then look for cuts in throughout the trunkline and see if they will show bubbles with soapy water placed on them. If this is seen you will likely need to change the trunkline.

Loss of Pressure >5 PSI

- Large puncture in membrane. Either visible puncture or observable streaming bubble when soapy water or methanol placed on membrane. Replace membrane.
- Loosen the 1/16" Swagelok nut on gas line. Check and carefully tighten.
- Broken gas line in the probe. Compare the supply versus return flow values (should $\leq$ 2/ml/min) of trunkline connected with the probe and with a close coupled trunkline. If close coupled supply/return flow is good but connected to the probe shows a big leak, there is a break is in the probe. This may be seen with soapy water placed on the edges of the heater block or on the top of the probe where the connections come out. If this produces bubbles it confirms a broken internal line or connection point. Replace the probe.

DI Acquisition - Flash Warnings:

The DI acquisition system, operated with the FI6000 field instrument, will flash a large warning screen – MIP pressure out of Range - to the operator if the probe pressure (PSI) changes over 1 PSI from the initial starting MIP pressure of the log. This alerts the operator that something in the system has changed and the operator can take the necessary precautions for a punctured membrane, broken gasline or a plug in the system.

Increase in Pressure (clearing a blockage)

- After setting the mass flow, an increase of more than 3 PSI over the original set pressure indicates a potential blockage, especially if you can verify that the pressure first dropped a 2-5 PSI prior to rising toward 20PSI.
  - Shut off the Nitrogen carrier gas flow ASAP. Do this by turning off the black regulator knob on the MIP controller or removing the carrier gas supply line from the breakout panel or the back of the MIP controller.
  - Remove the tools from the ground.
  - Look for a hole in the membrane and water or dirt got into the up-hole gas line just behind the membrane.
  - Remove connection tube and membrane.
  - Remove the trunkline gas lines from the top of the probe. Take note of which one had the gas flow coming out because this is the line that will be plugged.
  - Look for any obvious particles in either holes behind the membrane or in the gas line at the top of the probe. If any are evident attempt to remove them.
  - Take the return gas line at the surface and connect it to the supply gas connection on the breakout panel or on the back of the MIP controller.
  - Place the probe end of this line into a jar of methanol to see if the line is clear which is evident by streaming bubbles. If there are no bubbles, increase the flow to try to expel the blockage. If this does not work you may need to cut back the trunkline.
  - To clear out the probe take a 5 ml plastic syringe (or a 3 foot section of Teflon/PEEK gas line will work) filled with methanol and attempt to inject through the plugged gas line at the top of the probe. If it clears it will shoot the methanol in an arcing stream out one of the ports in the plug that sits behind the membrane.
  - The probe must be dried of the methanol which can be accelerated by heating the probe. Don't reconnect the trunkline to the detectors until you are sure the blockage is clear and the methanol is out of the system.
  - If the blockage cannot be cleared a new probe or trunkline will need to be connected.

Blinking Temperature Light

- If the temperature light on the MP6505 begins blinking in an unreadable number, it means that there is an open thermocouple in the system.
  - To complete the log in progress, replace the thermocouple for the trunkline with a thermocouple wire and twist-tie the wires together. This will fool the system to thinking there is continuity of the thermocouple wire and allow you to finish a log. The probe will continually heat set up this way and if left on when out of the ground it will overheat. When the log is complete remove the tricked thermocouple and remove tools from the ground.

- When you have the probe out of the ground, replace the thermocouple as follows.
  - Remove the connection tube from the probe.
  - Check the crimp connections of the thermocouple wires from the trunkline to the probe.
    - If one of the crimp connections has broken then strip back the wire on both sides of the thermocouple – probe and trunkline ends and reconnect in a new crimp connection and see if the probe temperature comes back.
    - If the thermocouple connection is good, the thermocouple wire in the probe has likely broken. Cut off the crimp connections of the thermocouple wires between the probe and the trunkline Check the resistance between the red and yellow thermocouple wires coming out of the probe. A resistance reading of approximately 40ohms indicates that the thermocouple is good reconnect. If they are open (O.L.) or mega ohms then the leads are broken on the thermocouple. Replace the thermocouple.
- To check the trunkline thermocouple wires, measure each wire from top to bottom. The resistances will be different between the two colored wires but should be somewhere approximately 50 ohms – 150ohms for the length of the trunkline. The resistances will also increase with an increase in trunkline length.
  - If they are open (no resistance) then there is a break in the trunkline. Replace the trunkline.

Blinking temperature readout or
Spiking in the Pressure and/or Temperature Data

- If spikes show up in the temperature or pressure data especially when related to hammer strikes it is likely an intermittent break in the thermocouple connection. Spiking of the temperature may reach single point readings of 250°C in the data but may not be visible when watching the temperature display on the MIP controller.
  - When you check the resistance between the two thermocouple wires they may check out at approximately 40 ohms, however there likely is an intermittent break in the wire.
  - Replacing the thermocouple should eliminate the pressure and temperature data spikes.

Probe Not Reaching Temperature

- If the heater light is on but the temperature seems low (<100°C with a set point of 120°C) a heater may have broken in the probe.
  - Check the resistance of the heater wires.
    - If a heater is broken the resistance will be over 40 ohms. The probe needs to be replaced.
    - Two good heaters will read approximately 22 ohms on the MP6520, MP8520 and MK6530.
      - Check to see if the thermocouple has pulled of few inches out of the probe.
        - If the thermocouple duct has broken and pulled back away from the probe, the probe will need to be replaced and rebuilt.
        - A thermocouple can unscrew and vibrated loose out of the thermocouple duct connection if it is not secured with shrink tubing or electrical tape. Reseated back into the leur-lock connection and secure. When the thermocouple pulls away from the probe it measures the probe temperature in the wrong location.

Flash Warning:

The DI acquisition system, operated with the FI6000 field instrument, will flash a large warning screen – Temperature out of Range - to the operator if the temperature goes outside of a set range from the setpoint temperature of 121°C. This alerts the operator that something in the system has failed and the operator can take the necessary precautions for a broken probe heater or thermocouple problem.

System explanations and warnings

MIP Flow
MIP flow is the carrier gas flow set by the MIP controller. This flow is supplying carrier gas to the trunkline and probe and is typically set to approximately 42ml/min. This parameter may be monitored by the DI-Acquisition system if the operator has the necessary components in their MIP Controller. The return flow, or Flow-R, is the flow coming back to the GC up the return gas line. Flow-S and Flow-R should be within 3-4ml/min and are usually much closer.

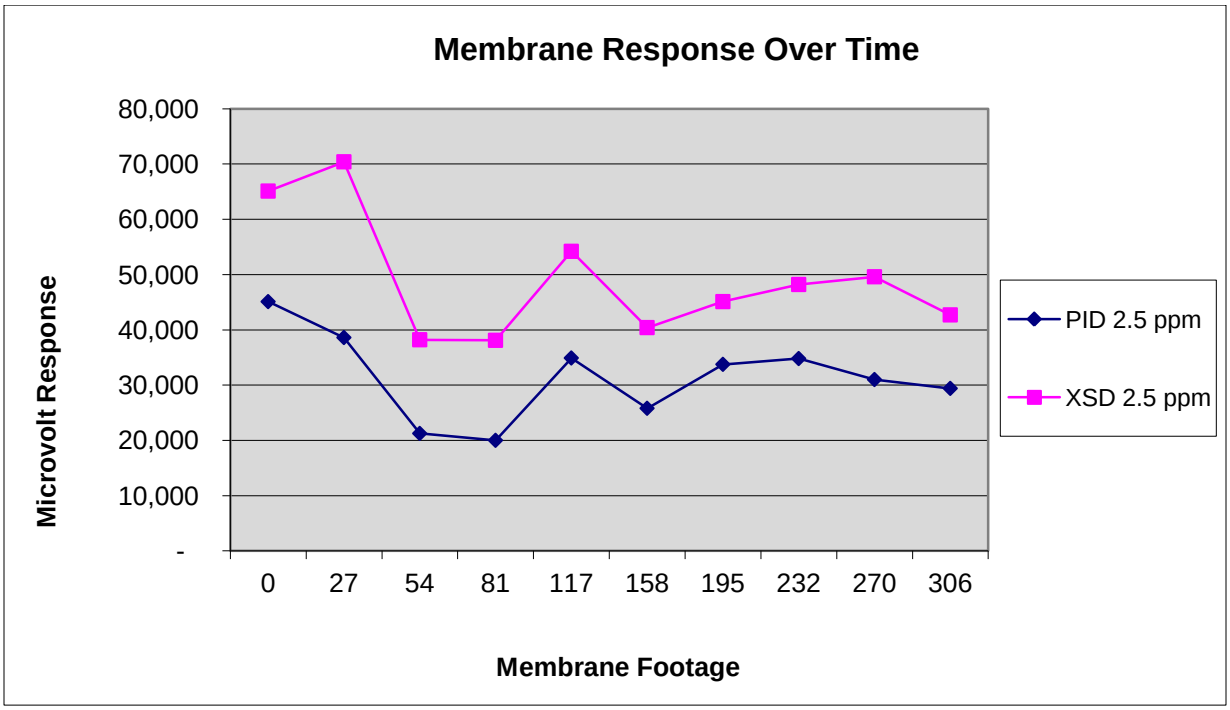
MIP Pressure
The MIP pressure is the back pressure of the carrier gas as it moves through the trunkline and probe. This is monitored digitally on the DI-Acquisition screen as well as by an analog pressure gauge on the front of the MIP controller. The MIP pressure is directly related to the MIP return flow (Flow-R) and the length of the trunkline. If the MIP pressure falls, the return flow has also dropped, if the MIP flow (Flow-S) has remained the same then there is likely a punctured membrane of problem with the gas lines.

APPENDIX III

Membrane Performance Control Charts

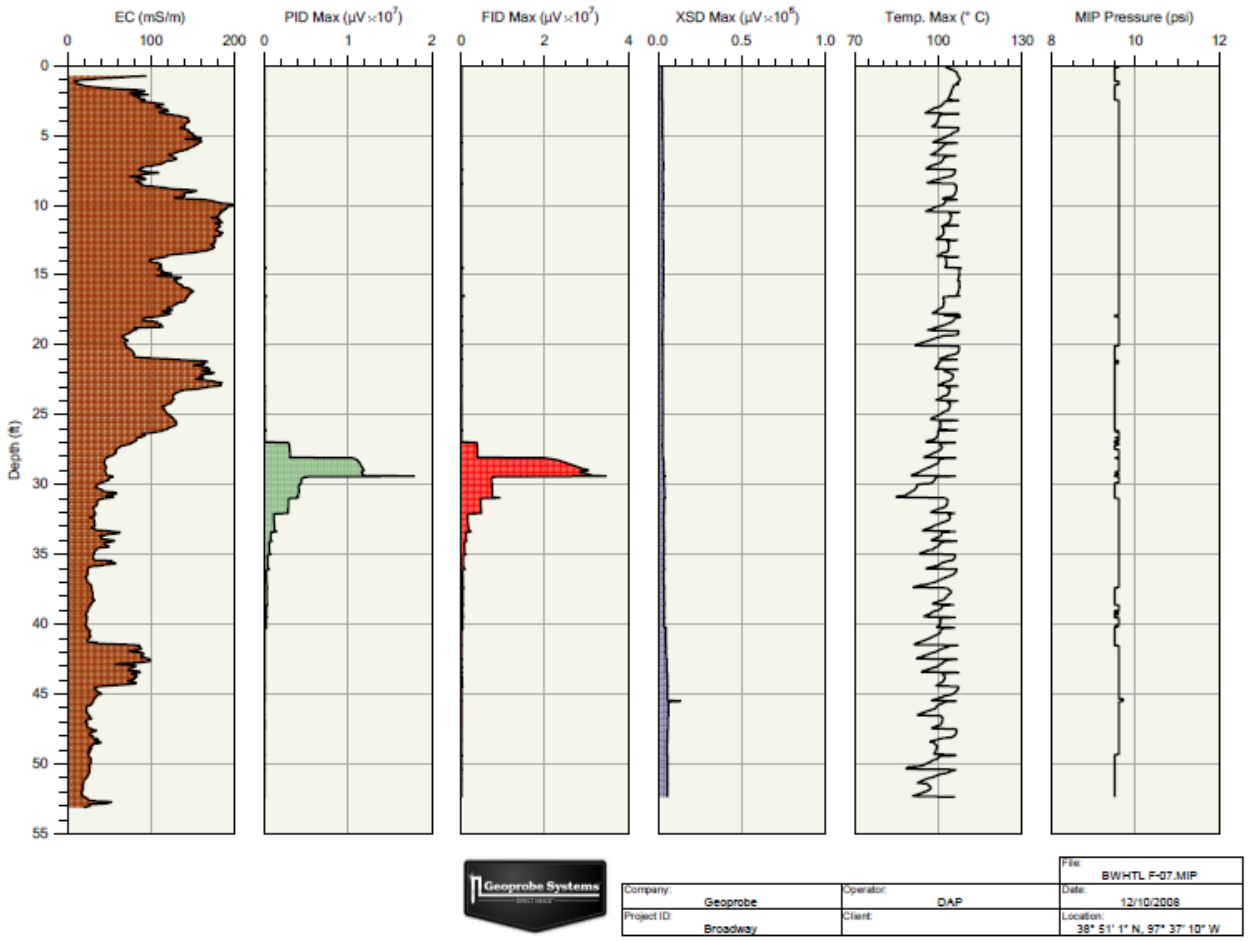
Response Tests using TCE

Pre/Post Log Response Test	Log ID:	PID Response 2.5ppm	XSD Response 2.5ppm	Log Footage	Membrane Footage
Pre-Log	MIP01	45,100	65,100	27	0
Pre-Log	MIP02	38,600	70,400	27	27
Pre-Log	MIP03	21,250	38,200	27	54
Pre-Log	MIP04	20,000	38,100	36	81
Pre-Log	MIP05	34,900	54,200	41	117
Pre-Log	MIP06	25,800	40,400	37	158
Pre-Log	MIP07	33.750	45,100	37	195
Pre-Log	MIP08	34,800	48,200	37	232
Pre-Log	MIP09	31,000	49,600	36	270
Post-Log	MIP09	29,400	42,700		306



APPENDIX IV

Sample Logs and Interpretation



Here is a MIP log with the graphs left to right: electrical conductivity, detectors (PID, FID and XSD), probe temperature and trunkline carrier gas pressure.

The above log shows contamination from 27ft to 33ft bgs. The main detector response is on the PID and FID with minimal response on the XSD (Halogen Specific Detector). This indicates that the main contaminant would not contain halogenated (Cl-, Br-, Fl-) atoms, but would likely be hydrocarbon based. The contaminants are present in the lower electrical conductivity formations which typically indicate courser grained formations of higher permeability. The temperature deflections of the MIP block heater are indicative of the probe heat cycling and the trunkline carrier gas maintains a constant stable pressure which indicates no leak or plug issues occurred with the gas line or membrane during the log.

Detector Interpretation

Standard MIP systems are able to identify compound families and determine general compound classes. The identification of individual compounds is not possible. Standard MIP systems have a continuous carrier gas flow that is brought to the detectors from the down-hole probe. To be able to effectively speciate (determine specific contaminant chemicals) the operator would need a highly modified system in place. The carrier gas stream would need to be run through a mass spectrometer or trapped and run a secondary GC onsite.

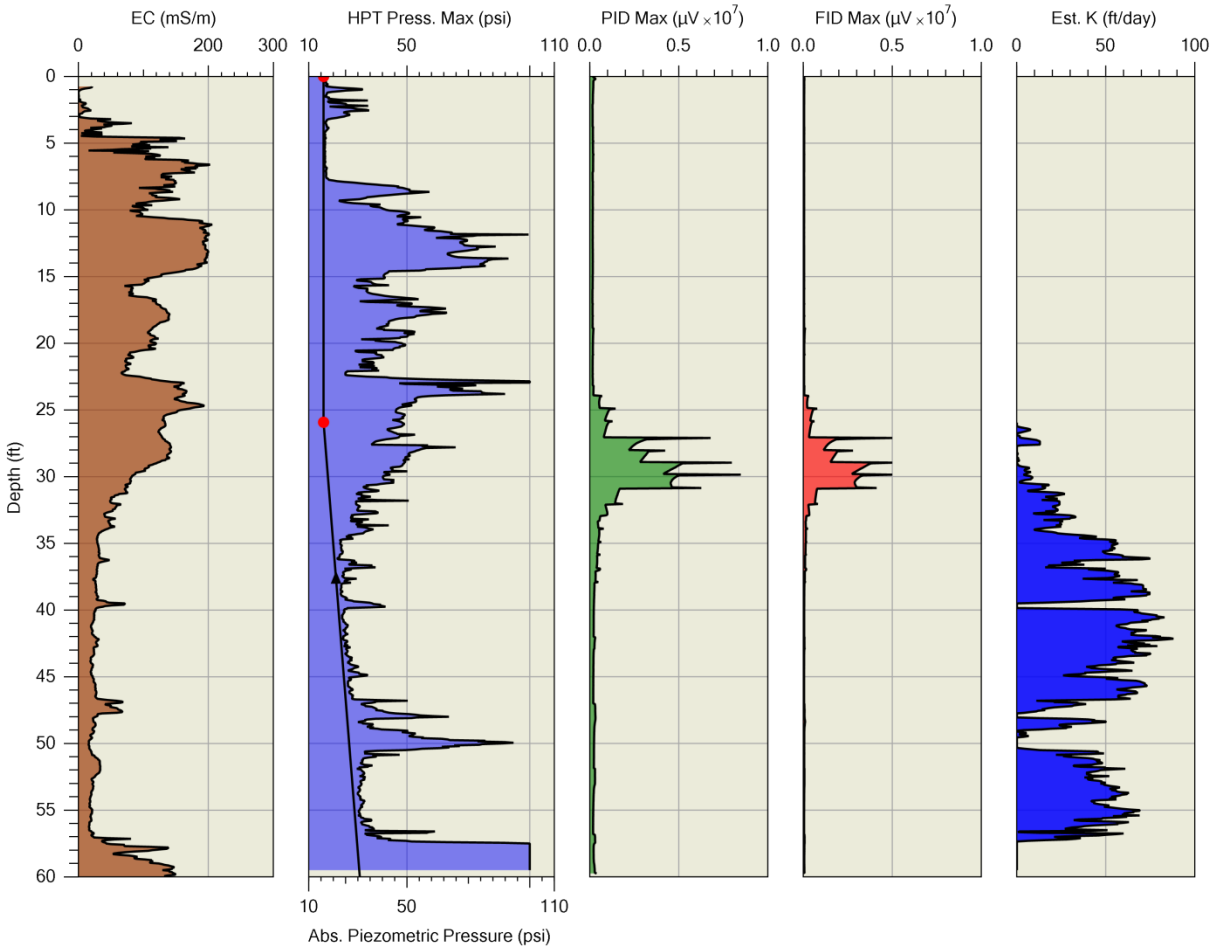
Typical standard MIP configurations use 3 gas phase detectors: a photo-ionization detector (PID), flame-ionization (FID) and a halogen specific detector (XSD). The PID responds to compounds which have an ionization potential $\leq$ electron voltage of the PID bulb. These compounds include both chlorinated and non-chlorinated hydrocarbons. A typical PID bulb has a 10.6eV lamp. The FID will respond when organic compounds (anything containing carbon) are present in the carrier gas stream in high enough concentration burn up in the flame which increases the flames ionization voltage. The XSD responds only to halogenated compounds which are made up of chlorinated (most typical halogen environmental contaminant), brominated and fluorinated compounds. Based upon which detector or detector series a contaminant responds on, we can determine if the contaminants are halogenated or petroleum based.

Petroleum hydrocarbons will respond on the PID and FID but not on the XSD. Fresh gasoline primarily contains aromatic hydrocarbons such as benzene, toluene, ethyl benzene and xylenes, which respond strongly on a photo-ionization detector (PID) and not so well on the FID. As gasoline breaks down or weathers the molecular structure changes from primarily aromatic to mainly straight chain hydrocarbons (single bonded hydrocarbons). Straight chain hydrocarbons typically do not show up on the PID do having a higher ionization potential but will respond on a flame ionization detector (FID). Weathered petroleum will still have a decent signal on the PID but may show a stronger FID signal.

Chlorinated compounds such as trichloroethylene and perchloroethylene are detected by the XSD and PID and respond in a similar profile. This is typical of the common double bonded chlorinated compounds seen in the subsurface which have an ionization potential that the PID can see. Chlorinated compounds without multiple bonds such as chloroform, methylene chloride and 1,1,1,-trichloroethane have an ionization potential higher than the PID electron voltage which results in a solid response on the XSD but will not show up on the PID.

The only sure way of determining contaminant concentration from MIP responses is to take confirmation soil and/or groundwater samples for laboratory analysis. After obtaining the results the actual concentrations can be compared to the MIP detector responses and concentrations may be estimated across the site.

MiHPT Log Example– Combined MIP & HPT



The addition of the HPT sensor to the MIP detectors and EC has provided valuable information to the subsurface lithogy encountered by the MIP operator. The above log shows graphs left to right: electrical conductivity, HPT injection pressure with the absolute piezometric pressure profile on the secondary axis, detectors (PID and FID) and estimated hydraulic conductivity (K).

The above log shows contamination from 24ft to 31ft bgs both on the PID & FID at similar magnitudes which is likely from petroleum hydrocarbons but without showing the XSD we cannot tell for sure that there are no halogenated (Cl-, Br-, Fl-) compounds present. The contaminants are present in the higher electrical conductivity and HPT pressure formations which indicate finer grained formations of lower permeability. The second graph with the Absolute Peizometric profile graph has a triangle on the increasing line at approximately 37 feet which indicates that an HPT dissipation test was performed at that depth. By taking the hydrostatic pressure at that interval and subtracting off the weight of water (0.445psi/ft) until the atmospheric pressure (calculated in the pre log HPT reference test) we can see the static water table is approximately 26 feet indicated by the red dot. Estimated hydraulic conductivity (K) is shown as the final graph which is a relationship between HPT injection pressure and HPT flow.

APPENDIX V

GC1000 Configuration and Operating Parameters

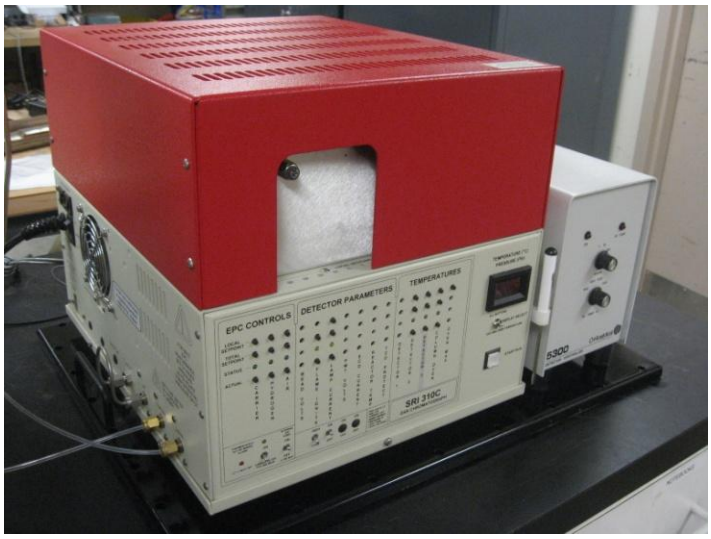


Figure 1: GC1000: SRI 310GC with XSD Controller

GC1000 Configuration

SRI310 GC with PID, FID & OI Analytical XSD
(all standalone detectors)

Flows:

TL Carrier (N_2): 40ml/min
Detector split 60:40 – 24ml/min-XSD
16ml/min-FID

Nafion Dryer (installed in GC Oven)
80ml/min (2x carrier flow rate)

A built in air compressor is split underneath the GC between the XSD & FID. The XSD & FID air supply is controlled through the GC air pressure screw control on front of GC and with different air line sizes and lengths to provide 250ml/min to the FID and 30 ml/min to the XSD.

Detectors front of GC to back: XSD, FID & PID

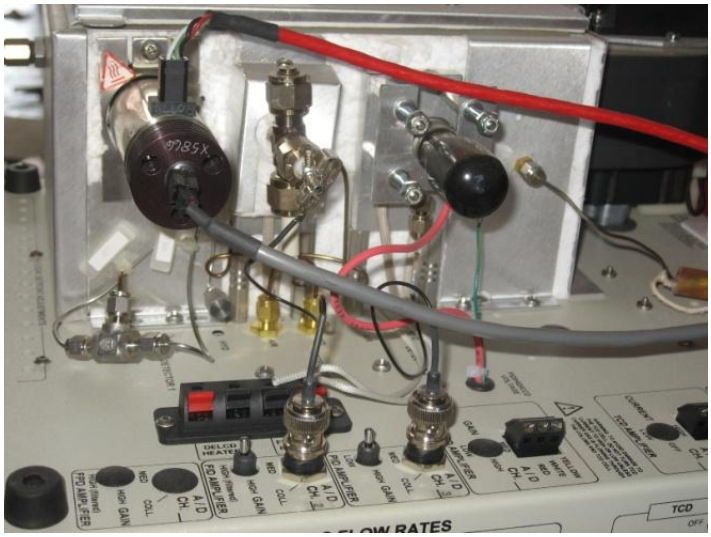


Figure 2: GC Detectors – left to right - XSD, FID, PID

SRI 310 GC Detector 1 position – XSD
(not controlled by GC)

SRI 310 GC Detector 2 position – FID

SRI 310 GC Detector 3 position – PID

Nafion dryer installed inside GC oven

GC Oven set to 85°C – 130°C max temp.

Flow comes into the GC oven via a 1/16" bulkhead fitting located in the 4th detector position furthest back (upper right inside oven) behind the PID detector. The trunkline will connect to this bulkhead and a 1/16" stainless steel line transports flow into the Nafion dryer. Silco steel takes this to the PID lamp which is inserted up to the lamp and backed off a 1/16" and tightened. A 1/16" stainless steel line brings it back into the GC oven where it is split between the FID and XSD and sent to them via a silco-steel line to the XSD and a stainless steel line to the FID.

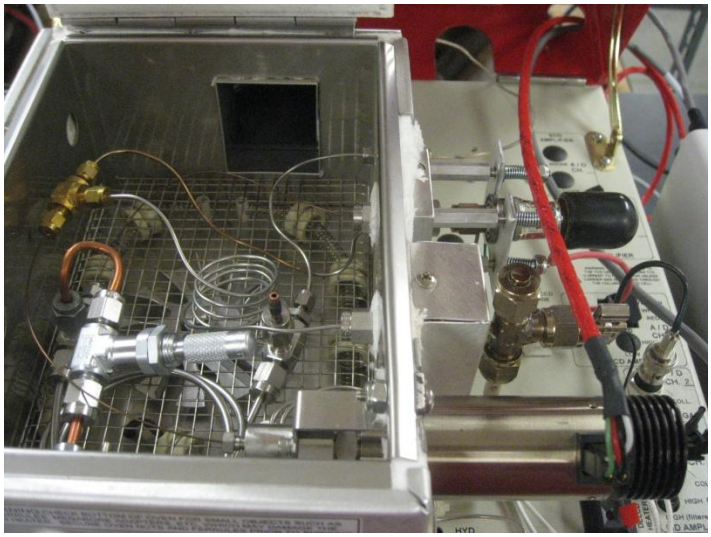


Figure 3: GC Oven Configuration

Detector Operating Parameters:

PID:

- MIP Carrier Flow (N_2) – 100% - 40ml/min
- Carrier return back into oven split between XSD & FID
- Detector Temperature setting – 150°C
- PID current 70 (0.70ma)

FID:

- Carrier N_2 MIP effluent – 40% - 16ml/min
- Hydrogen – 25ml/min
- AIR – 250ml/min
- Detector Temperature setting – 250°C
- FID igniter set at -600 (6.0V)

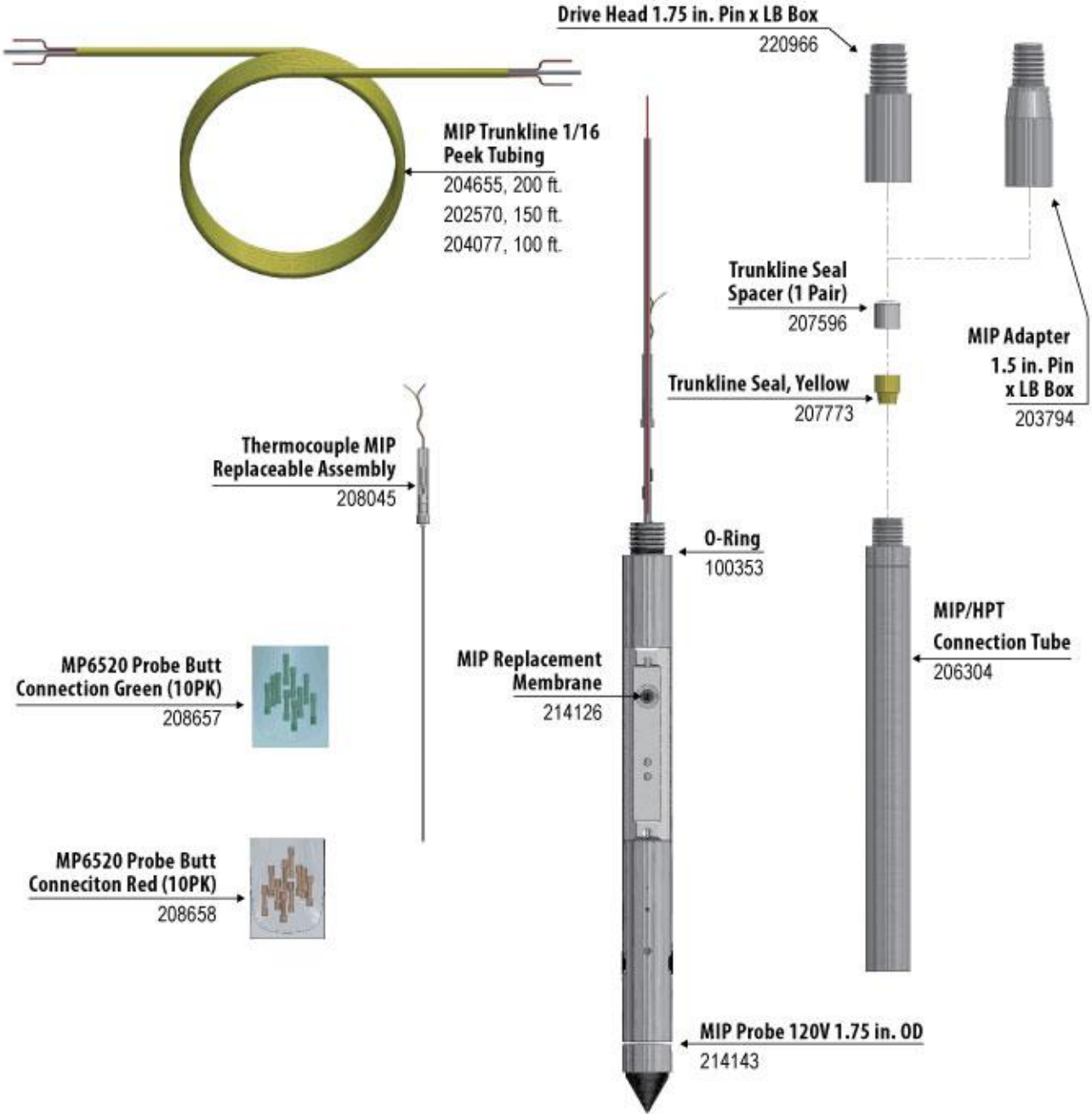
XSD:

- Carrier N_2 MIP effluent – 60% - 24ml/min
- Air – 30ml/min (split 50:50 wall & jet input of XSD)
- Detector Temperature setting – 1,100°C

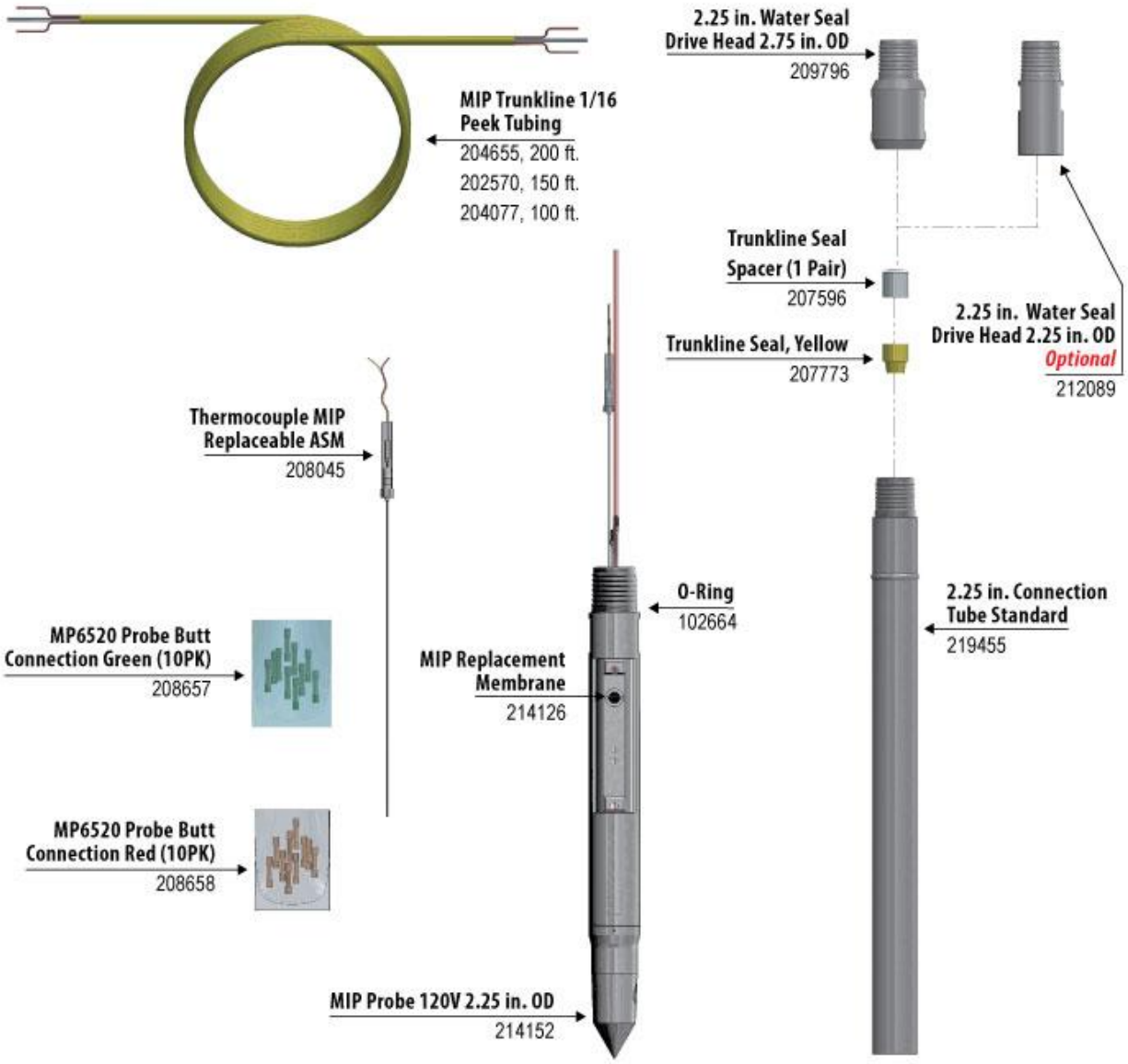
APPENDIX VI

MIP Tool Configurations

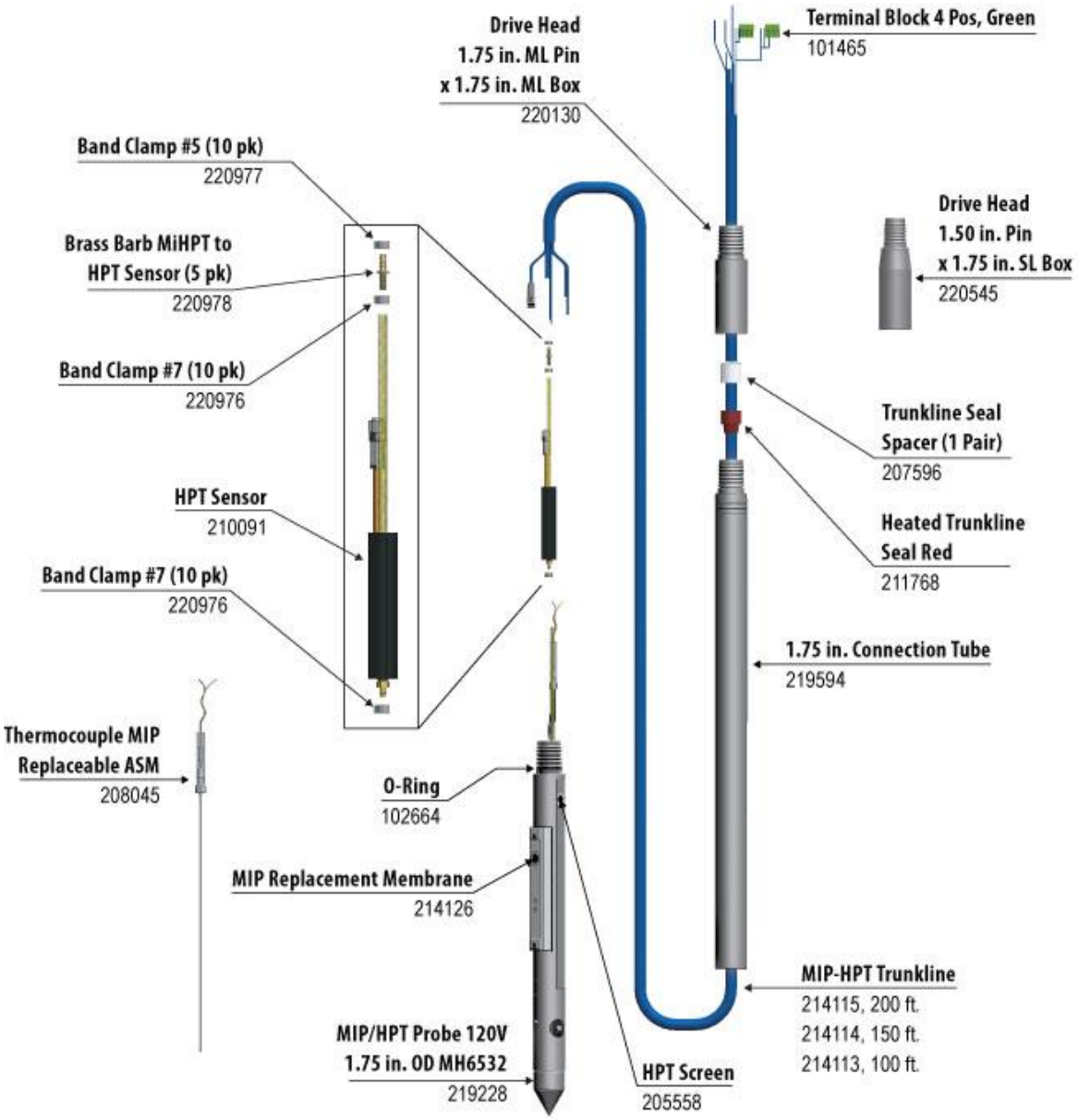
MIP - MP6520 (1.5 in. / 1.75 in. system)



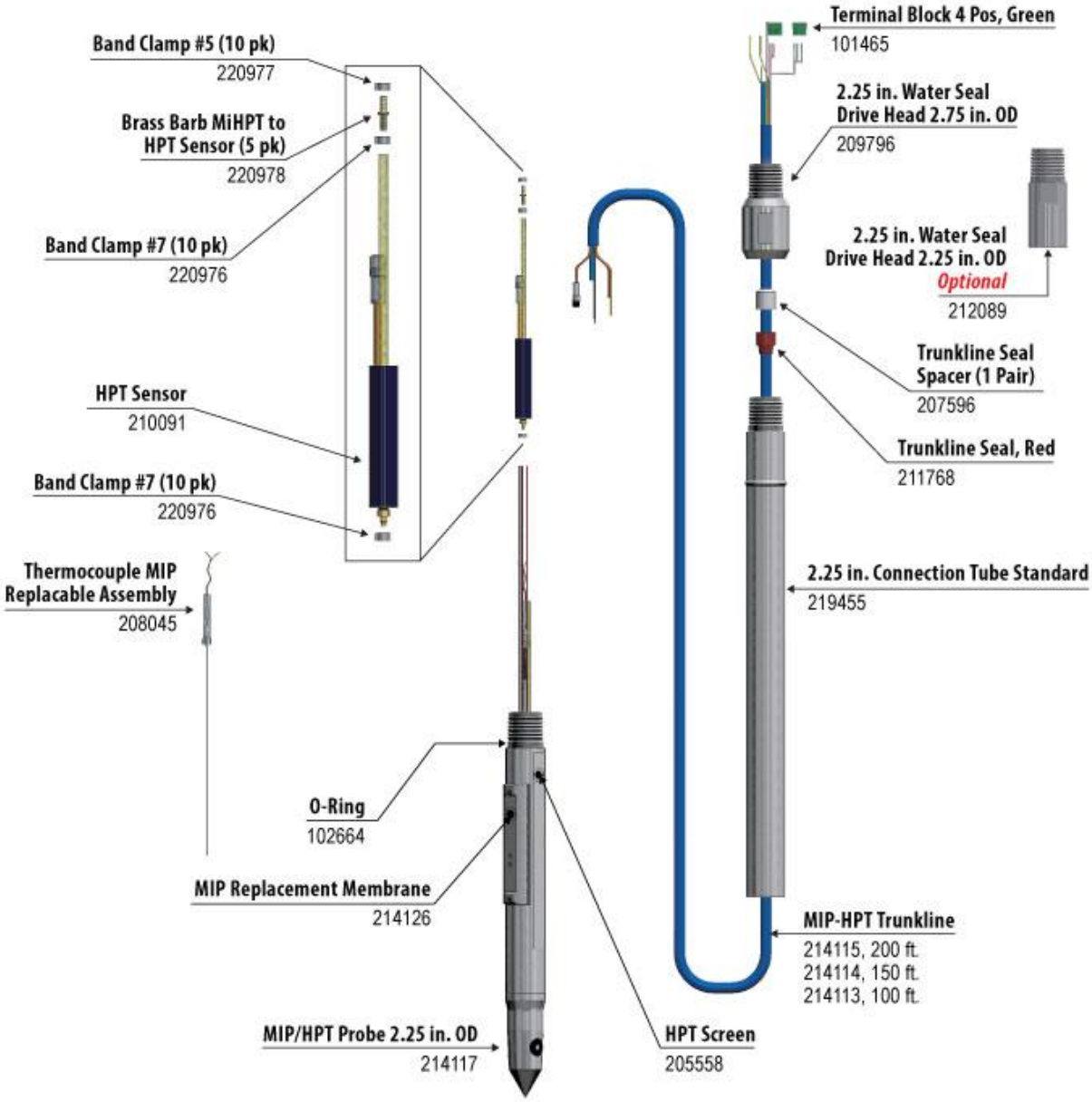
MIP – MP8520 (2.25 in. System)



MiHPT – MH6532 (1.5 in. / 1.75 in. system)



MiHPT – MH8530 (2.25 in. System)



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APPENDIX B

Extraction Testing Procedure

APPENDIX B - EXTRACTION TEST PROCEDURE

Data sets to be collected generally include background data, constant-rate test data, and recovery data. During each portion of the test, the extraction well, observation wells within the anticipated area of influence, and a background well, if available, should be monitored. Existing site monitoring wells can be used as observation wells.

Equipment

The following represents a partial list of equipment generally needed for extraction testing:

- Transducer to measure head pressure capable of measuring water columns with an accuracy of 0.01 foot.
- Electrical submersible pump rated to appropriate yield for pump depth.
- Accurate flowmeter and totalizer.
- Appropriate flow regulator.
- Water-level meter.
- Hoses sufficient to transport water from the extraction well to the water storage tanks.
- Forms for recording test information.

Observation Well Network Setup

Before transducers are installed in the extraction or in the observation wells, transducer serial numbers should be recorded and one transducer assigned to each particular well. Multi-channel transducers may be used for wells that are in close proximity to each other. All transducer internal clocks should be synchronized and all transducers programmed for appropriate data collection intervals.

As the transducers are installed in each well, the calibration of each transducer should be checked by manually raising the transducer a measured distance and checking the resulting reading. If the transducer reading does not show the same change as manually observed, the transducer's vent should be checked for obstructions. If the transducer fails a second time, another transducer should be used for the test. Once each transducer has passed the calibration check, it should be attached to the top of the well casing and securely anchored.

Background Monitoring

Background data should be collected before pumping begins. Transducers installed in the extraction well or observation wells should be programmed to collect measurements every 15 minutes for a minimum of 12 hours prior to the test. Water levels should periodically be manually measured manually as a check and backup of the automated monitoring by transducers.

Prior to the start of each constant-rate extraction test, the following information should be recorded, at a minimum:

- well identification
- location of test

- discharge point
- names of persons conducting the test
- model numbers of equipment being used
- measuring point description
- measuring point elevation
- static water level (depth below measuring point)
- depth of pump intake (below measuring point)
- methods of measuring discharge rate
- date and time pumping started

Constant-Rate Pumping Test

To the extent possible, the extraction well should be pumped at a constant rate for the duration of the test. Variation in pumping rate should be minimized as much as possible, however variation in pumping rate often occurs for one reason or another and needs to be monitored and documented. The well pump should be fitted with a check valve to prevent back flow of water in the discharge riser pipe for all extraction testing. Groundwater pumping rates should be determined based on previous aquifer testing at the site and pumping rates and drawdowns observed during well development. The optimum pumping rate will be sufficient to stress the aquifer without resulting in excessive drawdown or significant head loss due to well inefficiency. Water level measurements should be collected in accordance with the specified data collection schedule in shown in the *schedule of monitoring* section below.

Constant-Rate Test Procedures

During the test, the water level in the extraction well should be monitored with a transducer. Transducers should have direct read capability. An electric tape or other water level tape should also be used at regular intervals to collect backup water level measurements. Observations wells should also be monitored using transducers with manual backup.

Prior to shutting off the pump, field data should be evaluated to determine if the extraction test should be extended. After shutting off the pump, rising water level should be monitored at the same time intervals used during the start up of the test until the water level returns to static conditions.

Schedule for Monitoring

Water level should be measured in the extraction well with a transducer. The appropriate transducer model should be selected based upon the expected drawdown of the well. One pound per square inch (PSI) at atmospheric pressure is equivalent to approximately 2.3 feet of head (or drawdown). The minimum measurement intervals for the transducer are as follows:

Elapsed Time of Test	Maximum Water Level Measurement Interval
From 0 to 2 minutes	Every 1 seconds
From 2 to 10 minutes	Every 1 minute
From 10 to 16 minutes	Every 2 minutes
From 16 to 100 minutes	Every 5 minutes
From 100 to 720 minutes	Every 15 minutes

As a backup, manual depth to water measurements should be taken with an electronic water level meter and recorded at approximately the following intervals, if possible:

Elapsed Time of Test	Maximum Water Level Measurement Interval
From 0 to 5 minutes	Every 30 seconds or as rapidly as possible
From 5 to 15 minutes	Every minute or as rapidly as possible
From 15 to 90 minutes	Every 5 minutes
From 90 to 300 minutes	Every 10 minutes
From 300 to 720 minutes	Every 30 minutes

Water levels in observation wells should be measured with a transducer at the same intervals as the extraction well, if possible. Water levels in observation wells should be measured manually every 15 minutes for the first 300 minutes of the test, and every 60 minutes thereafter. When pumping has ceased, the elapsed time of test will be considered zero and the timing of water level measurements in the extraction and observation wells will be adjusted accordingly.

Pumping rate and depth-to-water should be measured whenever the pumping rate is adjusted. Field staff should monitor the pumping rate and note any changes. At a minimum, the pumping rate should be checked at the following intervals to ensure that the pumping rate remains steady:

Duration of Test	Discharge Measurement Interval
From 0 to 60 minutes	Every 5 minutes
From 60 to 720 minutes	Every 15 minutes

The pumping rate should be measured using an in-line pitot tube or flowmeter. The pumping rate should be maintained at a constant rate (within 10 percent if possible) for the duration of each test. Information collected in the field should be recorded in the field log book, in a field log form, or in an electronic field form. Transducer calibration and extraction test record forms should be available for use in documenting conditions in the field.

Collection of Post-Pumping Recovery Data

After completion of the constant-rate test, rising water levels in the extraction and observation wells should be measured. Transducers should remain in the extraction and observation wells

until the extraction well has recovered to at least 90 percent of its static water level or a maximum of 24 hours later.

Prior to test breakdown, a preliminary data evaluation should be performed to determine whether the test data is sufficient for analysis. If the data quality is acceptable, the transducers should be collected and the data should be downloaded to a spreadsheet file. The transducers, pump, and hoses should then be removed, disconnected, and decontaminated. All wells should then be secured.

Field Analysis

Field personnel should monitor water levels, pumping rate, and plot drawdown graphs in the field. Drawdown plots (time-drawdown and residual drawdown versus t/t' graphs) should be continuously monitored, and field personnel should continuously evaluate the effectiveness of the test.

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Freeze, Allan R., and Cherry, John A., 1979. Measurement of Parameters: Pumping Tests in Groundwater, Prentice Hall, Inc. Publisher, Englewood Cliffs, New Jersey; pp. 343-350.

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APPENDIX C

Injection Testing Procedure

APPENDIX C - INJECTION TEST PROCEDURE

Data sets to be collected generally include background data, constant-rate injection test data, and recovery data. During each portion of the test, the injection well, observation wells within the anticipated area of influence, and a background well, if available, should be monitored. Existing site monitoring wells can be used as observation wells.

Equipment

The following represents a partial list of equipment generally needed for injection testing:

- Water level transducers (transducers) capable of measuring water columns with an accuracy of 0.01 foot.
- Injection drop tube of appropriate length.
- Accurate flowmeter and totalizer.
- Appropriate flow regulator.
- Water-level meter.
- Hoses sufficient to transport water from the water storage tanks to the injection well.
- Forms for recording test information.

Observation Well Network Setup

Before transducers are installed in the injection or in an observation well, the transducer serial numbers should be recorded, and one transducer assigned to each particular well. Multi-channel transducers may be used for wells that are in close proximity to each other. All transducer internal clocks should be synchronized and all transducers programmed for appropriate data collection intervals.

As the transducers are installed in each well, the calibration of each transducer should be checked by manually raising the transducer a measured distance and checking the resulting reading. If the transducer reading does not show the same change as manually observed, the transducer's vent should be checked for obstructions. If the transducer fails a second time, another transducer should be used for the test. Once each transducer has passed the calibration check, it should be attached to the top of the well casing and securely anchored.

Background Monitoring

Background data should be collected before injection begins. Transducers installed in the injection well or observation wells should be programmed to collect measurements every 15 minutes for a minimum of 12 hours prior to the test. Water levels should periodically be manually measured manually as a check and backup of the automated monitoring by transducers.

Prior to the start of each constant-rate injection test, the following information should be recorded, at a minimum:

- well identification
- location of test

- injection point
- names of persons conducting the test
- model numbers of equipment being used
- measuring point description
- measuring point elevation
- static water level (depth below measuring point)
- depth of drop tube outlet (below measuring point)
- method of measuring injection rate
- date and time injection started

Continuous Injection Test

To the extent possible, water should be injected at a constant rate for the duration of the test. Variation in injection rate should be minimized as much as possible, however variation in injection rate often occurs for one reason or another and needs to be monitored and documented. Groundwater injection rates should be determined based on previous aquifer testing at the site, pumping rates and drawdowns observed during well development, and results from any previous injection testing occurring at the site. The optimum injection rate will be sufficient to stress the aquifer without resulting in excessive mounding or significant head gain due to well inefficiency. Water level measurements should be collected in accordance with the specified data collection schedule in shown in the *schedule of monitoring* section below.

Continuous Injection Test Procedures

During the test, the water level in the injection well should be monitored with a transducer. Transducers should have direct read capability. An electric tape or other water level tape should also be used at regular intervals to collect backup water level measurements. Observations wells should also be monitored using transducers with manual backup.

Prior to ceasing injection, field data should be evaluated to determine if the injection test should be extended. After shutting off the pump, falling water level should be monitored at the same time intervals used during the start up of the test until the water level returns to static conditions.

Schedule for Monitoring

Water level should be measured in the injection well with a transducer. The appropriate transducer model should be selected based upon the expected mounding in the well. One pound per square inch (PSI) at atmospheric pressure is equivalent to approximately 2.3 feet of head (or drawdown). The minimum measurement intervals for the transducer are as follows:

Elapsed Time of Test	Maximum Water Level Measurement Interval
From 0 to 60 minutes	Every 1 second

From 26 to 10 minutes	Every 1 minute
From 10 to 16 minutes	Every 2 minutes
From 16 to 100 minutes	Every 5 minutes
From 100 to 720 minutes	Every 15 minutes

As a backup, manual depth to water measurements should be taken with an electronic water level meter and recorded at approximately the following intervals, if possible:

Elapsed Time of Test	Maximum Water Level Measurement Interval
From 0 to 5 minutes	Every 30 seconds or as rapidly as possible
From 5 to 15 minutes	Every minute or as rapidly as possible
From 15 to 90 minutes	Every 5 minutes
From 90 to 300 minutes	Every 10 minutes
From 300 to 720 minutes	Every 30 minutes

Water levels in the observation wells should be measured with a transducer at the same intervals as in the injection well. Water levels in observation wells should be measured manually every 15 minutes for the first 300 minutes of the test, and every 60 minutes thereafter. When injection has ceased, the elapsed time of test will be considered zero and the timing of water level measurements in the injection and observation wells will be adjusted accordingly.

Injection rate and groundwater level should be measured whenever the injection rate is adjusted. Field staff should monitor the injection rate and note any changes. At a minimum, the injection rate should be checked at the following intervals to ensure it remains steady:

Duration of Test	Discharge Measurement Interval
From 0 to 60 minutes	Every 5 minutes
From 60 to 720 minutes	Every 15 minutes

The injection rate should be measured using an in-line flowmeter. The injection rate should be maintained at a constant rate (within 10 percent if possible) for the duration of the test. Information collected in the field should be recorded in the field log book, in a field log form, or in an electronic field form. Transducer calibration and injection testing forms should be available for use in documenting conditions in the field.

Collection of Post-Injection Data

After completion of the continuous injection test, falling water levels in the injection and observation wells should be measured. Transducers should remain in the injection and observation wells until groundwater mound in the injection well has decayed to at within 110 percent of its static water level or a maximum of 24 hours later.

Prior to test breakdown, a preliminary data evaluation should be performed to determine whether the test data is sufficient for analysis. If the data quality is acceptable, the transducers should be collected and the data should be downloaded to a spreadsheet file. The transducers, injection drop tube, and hoses should then be removed, disconnected, and decontaminated. All wells should then be secured.

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