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Chevron Environmental Management Company

Detention Basin No.2 Investigation Work Plan

Former Unocal Edmonds Bulk Fuel Terminal

11720 Unoco Road

Edmonds, Washington

July 29, 2011

ARCADIS

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Investigation Work Plan

Former Unocal Edmonds Bulk Fuel Terminal

11720 Unoco Road
Edmonds, Washington

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Chevron Environmental Management Company

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Date:
July 29, 2011

Figures

Appendices

ARCADIS

1. Introduction

On behalf of Chevron Environmental Management Company (Chevron), ARCADIS U.S., Inc. (ARCADIS) is pleased to submit this Detention Basin No.2 Investigation Work Plan (work plan) for the Former Unocal Edmonds Bulk Fuel Terminal (Terminal), located at 11720 Unoco Road, Edmonds, Washington. The site location is shown on **Figure 1**. This report presents a work plan for the investigation of light non-aqueous phase liquids (LNAPL) and petroleum hydrocarbon impacts in soils in the vicinity of Detention Basin No.2 (DB-2). The work plan outlines the procedures that will be used to complete investigation activities at the site. Site layout is shown on **Figure 2**.

2. Background

2.1 Site Description

The Lower Yard occupies approximately 22 acres and lies east-southeast of Burlington Northern Santa Fe Railway Company (BNSF) property, south of the Edmonds Marsh (also known as the Union Oil Marsh) and a drainage ditch (Willow Creek), and north of the Upper Yard (**Figure 2**).

At its nearest point (the southwest corner of the Lower Yard), the Lower Yard boundary is approximately 160 feet from the Puget Sound shoreline. Two storm water detention basins (Detention Basin No.1 (DB-1) and DB-2) are located along the north and northeast boundaries of the Lower Yard. DB-1 borders Edmonds Marsh and Willow Creek and acts as a retention pond for overflow from DB-2 during storm events. Detention basin DB-2 serves as a collection area from which site stormwater is discharged into Willow Creek.

Currently, a stormwater system consisting of 12 storm drains collects surface water runoff and discharges directly into DB-2 via gravity flow. From DB-2, stormwater is discharged into Willow Creek under an Industrial Stormwater General Permit (SO3-002953C), and excess stormwater is stored in DB-1. When DB-1 is full, excess water from DB-1 is pumped to the DB-2 outfall. There are currently no permanent aboveground structures at the site. A temporary storage shed is located along Unoco Road in the southern portion of the Lower Yard.

Previous structures in the Lower Yard included petroleum storage and transfer equipment (aboveground storage tanks and piping), two truck loading racks, several office buildings, a railcar loading/unloading station, a stormwater conveyance system including two 10,000-gallon stormwater detention tanks and two 500-gallon vapor recovery tanks, an air-blown asphalt plant, and an asphalt packaging warehouse.

2.2 Site History

Unocal operated the bulk fuel terminal from 1923 to 1991. Fuel was brought to the terminal on ships, pumped to the storage tanks in the Upper Yard, and loaded from the tanks into rail cars and trucks for delivery to customers. In addition, an asphalt plant operated at the Lower Yard from 1953 to the late 1970s.

In 2001, Unocal conducted an Interim Action in the Lower Yard, removing LNAPL and petroleum-impacted soil and groundwater from four areas of the Lower Yard. The results of the 2001 Interim Action are summarized in Lower Yard Interim Action As-built Report, Unocal Edmonds Terminal – Volume 1 (MFA 2002). Additional Interim Actions conducted in 2003 included soil excavations in the Southwest Lower Yard and Detention Basin No.1. The results of the 2003 Interim Action are summarized in the 2003 Lower Yard Interim Action As-Built Report, Detention Basin No. 1, Southwest Lower Yard, Metals Area 3, and Storm Drain Line Excavations – Volume 1 (MFA 2004). Previous excavations are shown on **Figure 2**.

In June 2007, Unocal entered into an Agreed Order with the Washington Department of Ecology (Ecology) to conduct an Interim Action in the Lower Yard (Ecology 2007). This Order supersedes Agreed Order No. DE 92TC-N328, dated October 25, 1993. Specific objectives of the Interim Action included:

- Removal of soil with petroleum impacts in excess of the soil remediation levels which were established in the 2001Work Plan for the Lower Yard
- Removal of LNAPL
- Extraction of groundwater that is in contact with LNAPL
- Removal of soil with arsenic concentrations in excess of the soil remediation levels which were established in the 2001 Work Plan within the Southwest Lower Yard
- Remove the sediment in the drainage ditch (Willow Creek), at locations near the Terminal’s two storm water outfalls, that failed 2003 toxicity tests

- Obtain the data necessary to determine if the remaining soil concentrations are sources of LNAPL on the groundwater table

- Obtain the data necessary to determine if the remaining soil concentrations will cause an exceedance of the groundwater CULs at the groundwater points of compliance (POCs)

- Obtain the data necessary to determine if the petroleum hydrocarbon concentrations in the groundwater beneath the lower yard will naturally attenuate to below the CULs at the groundwater POCs

The 2007 Agreed Order Interim Actions were conducted in two phases from July 2007 to April 2008 (Phase I), and July 2008 to October 2008 (Phase II). Phase I Interim Action work consisted of the removal of 108,000 tons of petroleum impacted soil for offsite disposal, and the removal of approximately 9,700 gallons of LNAPL. During Phase I construction activities, approximately 2 million gallons of groundwater were extracted, treated onsite, and discharged under a National Pollutant Discharge Elimination System (NPDES) Permit to Willow Creek. The complete results of the 2007 Phase I Interim Actions are summarized in Phase I Remedial Implementation As-Built Report, Unocal Edmonds Bulk Fuel Terminal Lower Yard (ARCADIS 2009a). Phase II Interim Action work consisted of the removal of 14,825 tons of petroleum impacted soil for offsite disposal and the removal of 131 gallons of LNAPL. During Phase II, approximately 520,000 gallons of groundwater were extracted, treated onsite, and discharged to Willow Creek under a NPDES permit. Phase II construction activities also included the removal of 2,000 tons of impacted sediments, and subsequent restoration of approximately 420 feet of Willow Creek. The complete results of the 2008 Phase II Interim Action are summarized in the FINAL – Phase II Remedial Implementation As-Built Report, Unocal Edmonds Bulk Fuel Terminal Lower Yard (ARCADIS, 2010).

In accordance with the Agreed Order, groundwater monitoring was to be conducted after remedial excavation activities. Groundwater sampling events were to be conducted every other month (bi-monthly) over a two year period at wells within three groundwater flow paths and the 21 POC wells. Groundwater flow paths were established within the interior of the site and each groundwater flow path consisted of seven monitoring wells (an upgradient well, three source area wells, and three downgradient wells). The groundwater flow paths and the frequency of groundwater monitoring events were created to provide the data to utilize Ecology's Natural Attenuation Analysis Tool Package A (Modules 1, 2 and 3).

The locations of the wells inside the three groundwater flow paths were based on the presence of LNAPL on groundwater prior to remedial activities. Prior to the 2007/2008 Interim Action remedial excavations, the groundwater flow paths fit the established model of upgradient, source area, and downgradient wells. As a result of the 2007/2008 Interim Action, remedial excavations extended beyond the mapped flow path areas, and the resulting monitoring well arrangement was no longer suitable for use with Ecology's Natural Attenuation Analysis Tool Package A. As a result of the source removal, the flow paths as previously defined do not contain monitoring wells that could provide upgradient and downgradient water quality data in relation to specific source areas, and are no longer applicable for a spatial evaluation of natural attenuation away from the source, as required for use with Ecology's Natural Attenuation Analysis Tool Package A. This change in the site conceptual model rendered the previous sampling schedule and monitoring program obsolete with respect to the planned data evaluation, and necessitated revisions to the monitoring program that were reviewed and approved by WDOE in December 2009. The current monitoring well network is sufficient to monitor and evaluate the status of the overall dissolved-phase plume; the stability of the site plume is being evaluated on a well-by-well basis, and the monitoring program needed to support this analysis was reduced accordingly. Currently, groundwater sampling events are conducted on a quarterly basis, with only POC wells sampled during first and third quarter events, and all site wells (POC and interior wells) sampled during second and fourth quarter events. LNAPL has been present in one monitoring well (MW-510) since October, 2009.

2.3 Geology

During the Phase I excavation (2007 to 2008), subsurface materials encountered from land surface to a depth of 8 to 15 feet below ground surface (bgs) were silty sands with gravel and sandy silts with gravel. The removed soils were mostly fill material placed after 1929, during the creation of the lower yard facility. Below the 1929 fill material, a poorly graded sand formation of very fine to medium sand with fine gravel was encountered, which contains organic material such as beach debris, wood, and seashells, and is considered the native soil below the terminal. Beneath many of the excavated areas throughout the Lower Yard, there is a layer approximately 6 to 12 inches thick composed of sandy silt with large amounts of peat, wood debris, and decomposing vegetation. This layer was encountered at depths of 8 to 14 feet bgs, between the 1929 fill material and the native soil, and is considered to be representative of the former marsh located at the site.

The current lithology of the Lower Yard consists primarily of backfill material that resulted from the Phase I and Phase II Interim Action work (2007 to 2008). All of the 2007 to 2008 excavations were extended to a depth considered to be native soil; this material was a poorly graded sand layer consisting of very fine to medium sand with fine gravel, which contains organic material such as beach debris, wood, and seashells, and was distinct from the overlying materials. Excavations were backfilled with poorly graded coarse gravels to 6 inches above the water table, and continued to ground surface with very fine to medium sand, trace silt, and coarse gravel material.

3. Proposed Work

The purpose of this investigation is to evaluate the nature and extent of LNAPL in the vicinity of DB-2. LNAPL baildown testing will be used to determine LNAPL hydraulic conductivity. Soil borings will be advanced to the north, south, east and west of DB-2 and on the east bank of Willow Creek to determine the extent of LNAPL-impacted soil. Piezometers will be installed in select borings to collect fluid-level data in the investigation area.

3.1 LNAPL Baildown Testing

LNAPL baildown testing is used to evaluate LNAPL hydraulic conductivity in the subsurface. Historical data indicate that the LNAPL thickness in well MW-510 has ranged from no measureable thickness to 0.13 feet. An absorbent sock is currently installed in MW-510 and will be removed a minimum of one week prior to the LNAPL baildown test to allow for LNAPL accumulation. An LNAPL baildown test will be performed on monitoring well MW-510 if a minimum of 0.10 feet of measureable LNAPL is observed. LNAPL thickness and groundwater elevation data will be collected using an oil/water interface probe. These data will be used in conjunction with analytical soil sampling, visual observations and other site data to characterize the LNAPL mobility and recoverability at the site. For the LNAPL baildown test, a disposable bailer will be fitted with a product recovery cup and used for the removal of LNAPL. Field personnel will take care to properly protect the ground surface from spills by placing plastic sheeting and oil absorbent pads around the well. The bailer will be lowered to just below the LNAPL water interface and removed from the well. The bailer may be required to be lowered several times to remove as much of the recoverable LNAPL from the well as feasible. Once LNAPL is removed, manual LNAPL thickness readings will be obtained every 30 seconds for the first 5 minutes. The frequency of LNAPL measurements and depth to water readings can be spaced accordingly following the first five minutes of readings; however, measurements will be collected at a minimum of every 30 minutes. The test will be concluded upon recovery of the initial measured thickness or after 8-hours of recovery time, whichever is sooner. To account for possible tidal influence on LNAPL recovery, depth to water/LNAPL measurements will be compared to the tide chart for the test day. Emphasis will be given to note the time at which LNAPL most quickly recovers within the well, and that time period will be compared to the stage of the tidal cycle to observe if LNAPL migrates toward the well during high or low tide more readily. The ARCADIS Standard Operating Procedure for LNAPL Baildown Testing is included as **Appendix A**.

3.2 Soil Boring Advancement

Seventeen soil borings will be advanced in the vicinity of DB-2, as shown on **Figure 3**. Eight of the borings will be advanced to the south of DB-2, between DB-2 and the 2007-2008 excavation areas A4, B6, B8 and B20. Two borings will be advanced to the north of DB-2 on the berm separating DB-2 and DB-1. Three borings will be advanced to the northwest of DB-2, between DB-2 and the 2008 Sediment Removal Excavation Area, including one boring within 10 feet of MW-510. Three of the borings to the northwest of DB-2 will be advanced on the southeast bank of Willow Creek, within the Sediment Removal Excavation Area. One soil boring will be advanced to the north of DB-2 on the access road at the north end of DB-1. This road was constructed over the north end of DB-1 during Phase II excavation activities, and is made of backfill material used during excavation activities.

Soil borings will be advanced using a direct push drill rig. A hollow stem auger rig with 8-inch hollow stem augers will be used if soil conditions do not allow the use of a direct push rig. The three soil borings to be installed on the south east slope of Willow Creek will be installed using a hand auger, due to access issues along the creek bank. The Sampling and Analysis Plan which is included as Appendix L of the 2007 Interim Action Report (Ecology 2007) and Exhibit B of Agreed Order No. DE 4460 (SLR 2007b), specifies soil borings will be advanced with a geoprobe. Use of an 8-inch diameter hollow-stem auger or a hand auger is a variance from the original plan. Soil borings will be completed to a minimum depth of 15 feet bgs in order to reach a depth greater than that reached during the 2007 to 2008 excavation activities, or until native, non-fill material is encountered. Hand auger locations on the bank of Willow Creek are approximately 7-feet below the ground elevation of the Terminal property. Total depths of hand auger borings will be approximately 6-ft bgs, or as deep as reasonably possible. It is anticipated that native or non-fill material will be encountered in close proximity to land surface. If field screening (described below) indicates petroleum-impacted soil is present at 15 feet bgs, soil borings will be advanced further to define the vertical extent of impacts. Continuous soil samples will be collected using sleeve samplers from the direct push rig or split spoon samplers from a hollow stem auger rig.

Additional soil borings may be completed to define the areal extent of impacts based on the field screening data. Potential contingent locations include areas closer to DB-2, excavation area B6, excavation area B20 or monitoring well LM-2.

Completed boreholes will either be backfilled with hydrated bentonite chips and capped with concrete or converted into 1-inch piezometers. Proper decontamination procedures will be followed and sample equipment that contacts the soil, including samplers and augers, will be decontaminated after each use. The completed soil borings and piezometers will be surveyed for horizontal coordinates by a state certified surveyor. The completed piezometers will also be surveyed for vertical coordinates of the well casings.

3.3 Sample Collection and Analysis

During soil boring installation soils will be classified using the Unified Soil Classification System (USCS). Field screening of soil samples will be done with a photoionization detector (PID), as well as, visual observations of impacted soil, visual observations for the presence of LNAPL or sheen, and/or odor. Where field screening indicates the possible presence of LNAPL, petroleum hydrocarbon related soil impacts, or PID readings in excess of 25 parts per million (ppm), soils will be sampled and submitted for laboratory analysis. Additional sampling will be focused on smear zone and saturated soils identified between 5 and 15 feet bgs based on historical groundwater gauging data. At each boring location, where sufficient soil is collected in the push probe sampling sleeve, a minimum of two soil samples (one from the approximate smear zone and another from the saturated zone) will be submitted for laboratory analysis from approximately 5 to 15 feet bgs; however up to 10 samples will be submitted per boring location. Samples will be collected for laboratory analysis and soil samples will be placed in laboratory-provided containers and stored in an ice-chilled cooler prior to delivery to the analytical laboratory. PID readings, soil types, and other pertinent geologic data will be recorded on the boring log.

The collected samples will be submitted to a state certified laboratory and analyzed for the following constituents, per the Sampling and Analysis Plan:

- Benzene by U.S. Environmental Protection Agency (EPA) Method 8021B

- Gasoline-range organics (GRO) by Ecology Method NWTPH-Gx

- Diesel and heavy oil-range organics (DRO and HO) by Ecology Method NWTPH-Dx (after silica gel cleanup)
    - Any samples that contain detectable DRO and/or HO concentrations greater than site Remedial Action Levels (RELs) will also be analyzed for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) by EPA Method 8270C

Additional geotechnical samples will be obtained from each boring within smear zone soils. Undisturbed soil samples will be collected using either an acetate liner from the direct push rig or a brass sampling tube from the hollow stem auger, capped, taped and submitted to a state certified laboratory for the following properties:

- Grain Size analysis by ASTM method D422

- Porosity by method SW 9100

These data will be used to assess LNAPL mobility and to assess remediation system designs in the feasibility study.

3.4 Piezometer Construction

Depending on field conditions/findings, a minimum of four soil borings will be converted into 1-inch piezometers upon completion to collect fluid-level data within the investigation area. The proposed piezometers will be constructed of 1-inch schedule 40 PVC pipe with 0.01-inch slotted screen. Sand packs will be constructed of 2/12 silica sand and extend from one foot above the screened interval to the total depth of the well. Each of the piezometers will be completed with hydrated bentonite chips to one foot bgs, with flush-mount well monuments set in concrete at ground surface. Upon completion, the piezometers will be surveyed by a licensed surveyor for horizontal location and vertical coordinates of the well casing. Piezometer placement will target a variety of field conditions observed during soil sampling and screening as follows:

- one piezometer will be placed in a soil boring within close proximity to MW-510

- one piezometer will be placed in a soil boring along the berm separating DB-1 and DB-2

- one piezometer will be placed in a soil boring in the area to the south of DB-2

- one piezometer will be placed in the soil boring where the greatest occurrence of LNAPL is visually confirmed within the smear zone

- piezometers will be gauged for water level and LNAPL thickness data each week for the first month after installation, once per month for the first quarter after installation, and once per quarter after the first quarter after installation.

Additional piezometers may be installed at the discretion of the field crew; however, the four locations noted above were selected to obtain data over a wide area and will be considered as the preferred locations.

4. Schedule and Reporting

LNAPL baildown testing will be conducted the week of August 15th, 2011, and is anticipated to be completed in one day. The soil boring program will be conducted the week of August 22nd, and is anticipated to take up to three days to complete. Results of this investigation will be reviewed as analytical data are obtained. Monthly Progress Reports, including a summary of data as they are received, will continue to be submitted by the 15th of each month. A comprehensive Site Assessment Report detailing these investigations results will be prepared and submitted for Ecology review by November, 2011.

5. References

ARCADIS. 2009a*. Phase I Remedial Implementation As-Built Report, Unocal Edmonds Bulk Fuel Terminal Lower Yard.*

ARCADIS. 2010. *FINAL – Phase II Remedial Implementation As-Built Report, Unocal Edmonds Bulk Fuel Terminal Lower Yard.*

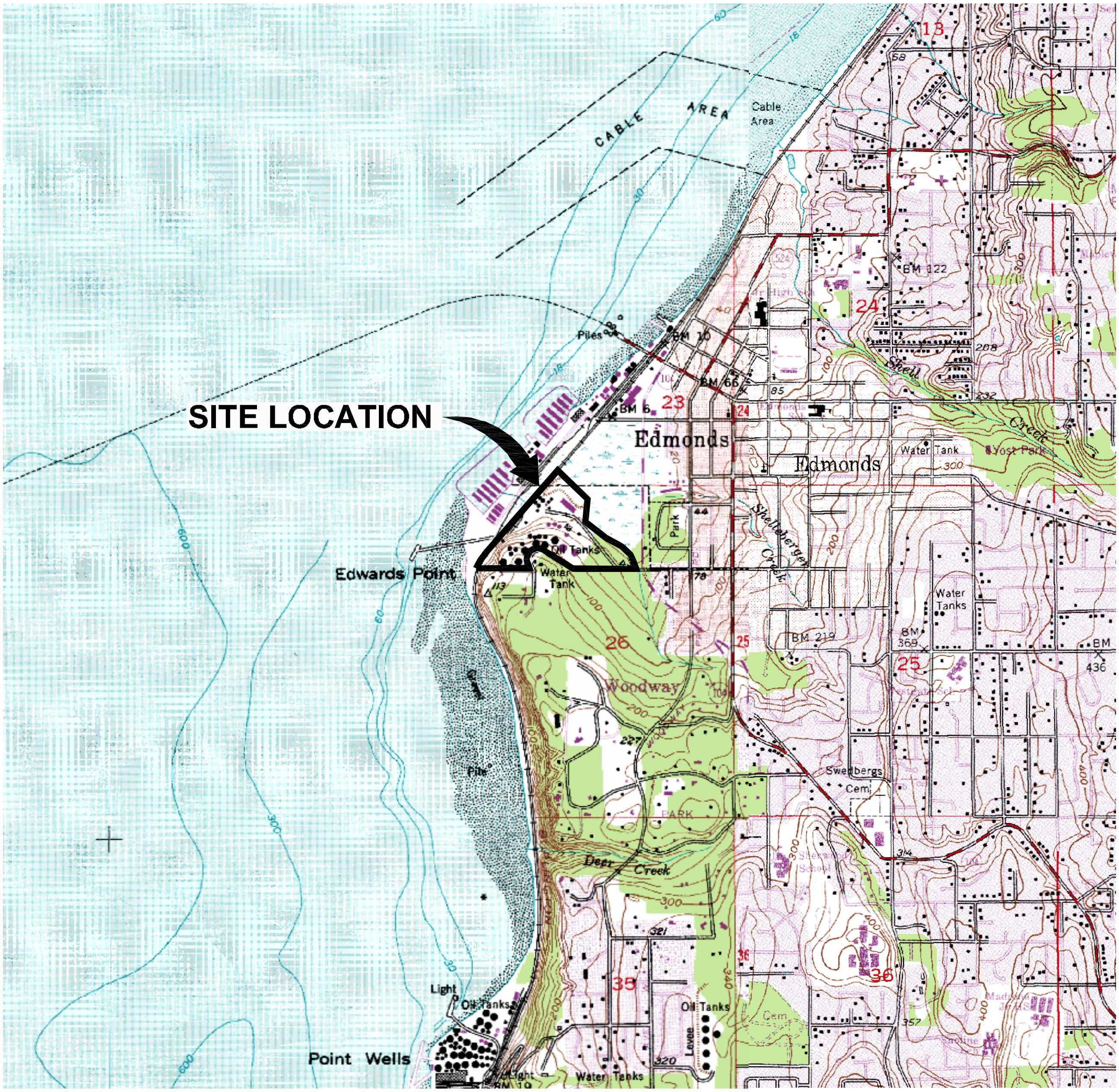
Maul Foster and Alongi, Inc. (MFA). 2002. *Lower Yard Interim Action Report – Volume 1*. November 30, 2002.

MFA. 2004. *Draft 2003 Lower Yard interim Action As-Built Report, Unocal Edmonds Terminal*. February 26, 2004.

SLR International Corporation (SLR). 2007a. *Interim Action Report - Work Plan for 2007 Lower Yard Interim Action, Unocal Edmonds Bulk Fuel Terminal*. June 25, 2007.

SLR. 2007b. *Sampling and Analysis Plan*. July 5, 2007.

Washington State Department of Ecology (Ecology) 2007. *Agreed Order for Remedial Action, Lower Yard of Unocal Edmonds Bulk Fuel Terminal, Edmonds, Washington*. State of Washington Department of Ecology, June 2007.



REFERENCE: USGS QUADS., 7.5 MIN. SERIES (TOPOGRAPHIC) - EDMONDS EAST, WASH. AND EDMONDS WEST, WASH.

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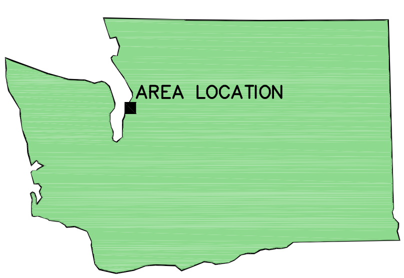
Approximate Scale: 1"=0.5 Miles



CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL TERMINAL
EDMONDS, WASHINGTON

SITE LOCATION MAP

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FIGURE
1

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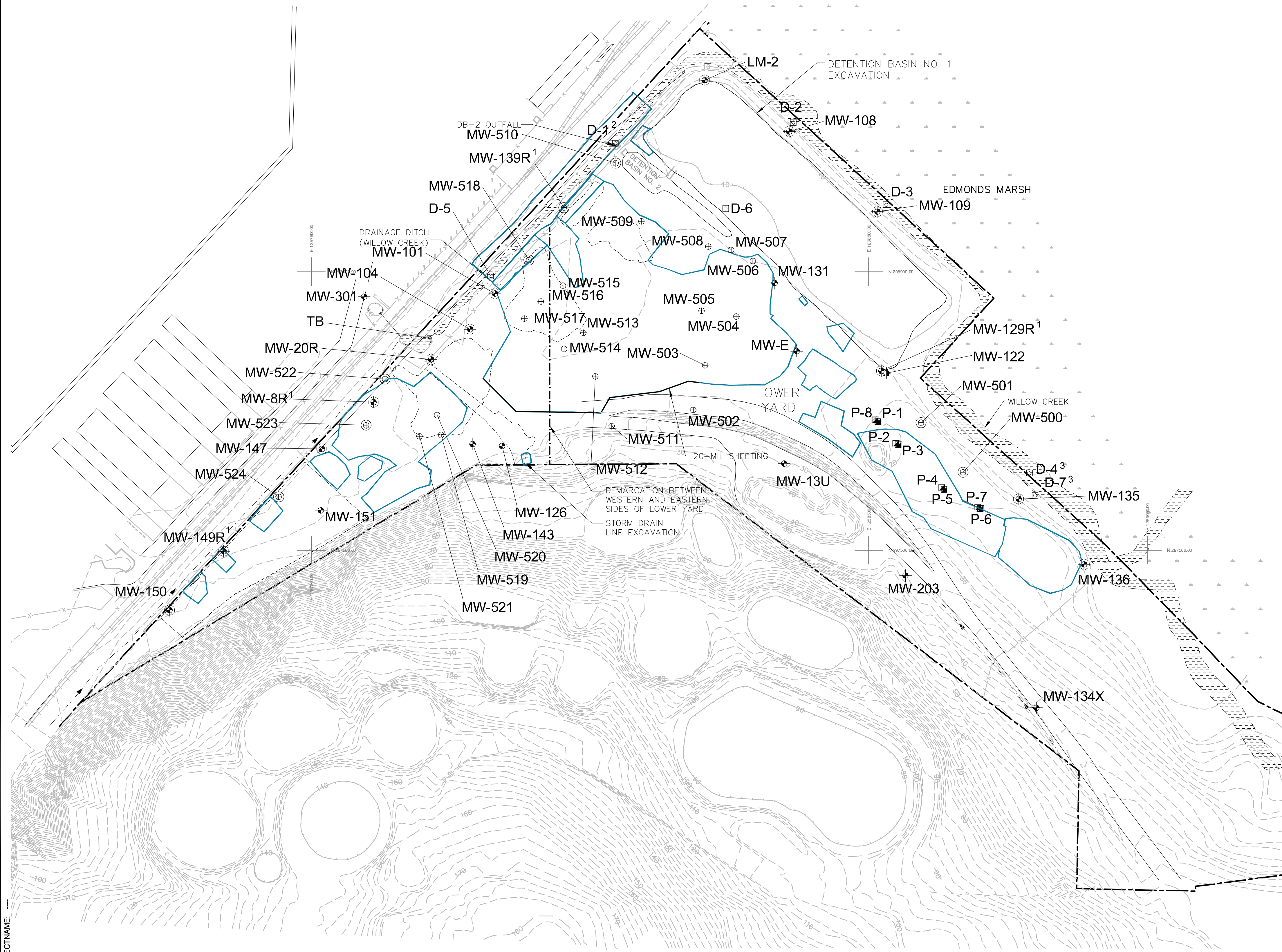

LEGEND:

MW-203 — MONITORING WELL LOCATION AND DESIGNATION

MW-122 — DEEP MONITORING WELL LOCATION AND DESIGNATION

MW-109 — EXISTING SURFACE WATER COMPLIANCE MONITORING WELL LOCATION AND DESIGNATION

MW-510 — SURFACE WATER COMPLIANCE MONITORING WELL LOCATION INSTALLED OCTOBER 2008

MW-521 — MONITORING WELL LOCATION INSTALLED OCTOBER 2008

PIEZOMETER

STAFF GAUGE

2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE

LOWER YARD PROPERTY BOUNDARY

2007/2008 EXCAVATION BOUNDARIES

NOTES:

1. MONITORING WELLS MW-129R, MW-139R, MW-8R, AND MW-149R WERE ABANDONED DURING INTERIM ACTION AND REPLACED IN OCTOBER 2008.
2. STAFF GAUGE D-1 RE-ESTABLISHED PRIOR TO JUNE 2009 SAMPLING EVENT.
3. STAFF GAUGE D-4 WAS ESTABLISHED PRIOR TO JUNE 2009 SAMPLING EVENT TO REPLACE STAFF GAUGE D-7 WHICH IS NOT WITHIN THE WILLOW CREEK CHANNEL.
4. STAFF GAUGES WERE RESURVEYED BY OTAK INCORPORATED JUNE 1, 2009. STAFF GAUGES WERE SURVEYED FROM TOP OF GAUGE AND WATER LEVELS ARE NOW MEASURED FROM TOP DOWN TO WATER.
5. 20-MIL SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 10 FT BGS.

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SITE LAYOUT MAP

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FIGURE
2

CITY: (TAMPA, FL) SYRACUSE, NY DIV/GROUP: ENVCAD DB: (J. RICHARDS) K. DAVIS, P. LISTER PM: R. ANDRESEN TM: S. ZORN TR: D. RASAR LYR: ON=*;OFF=*REF* PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 6/1/2011 11:42 AM BY: LISTER, PAUL
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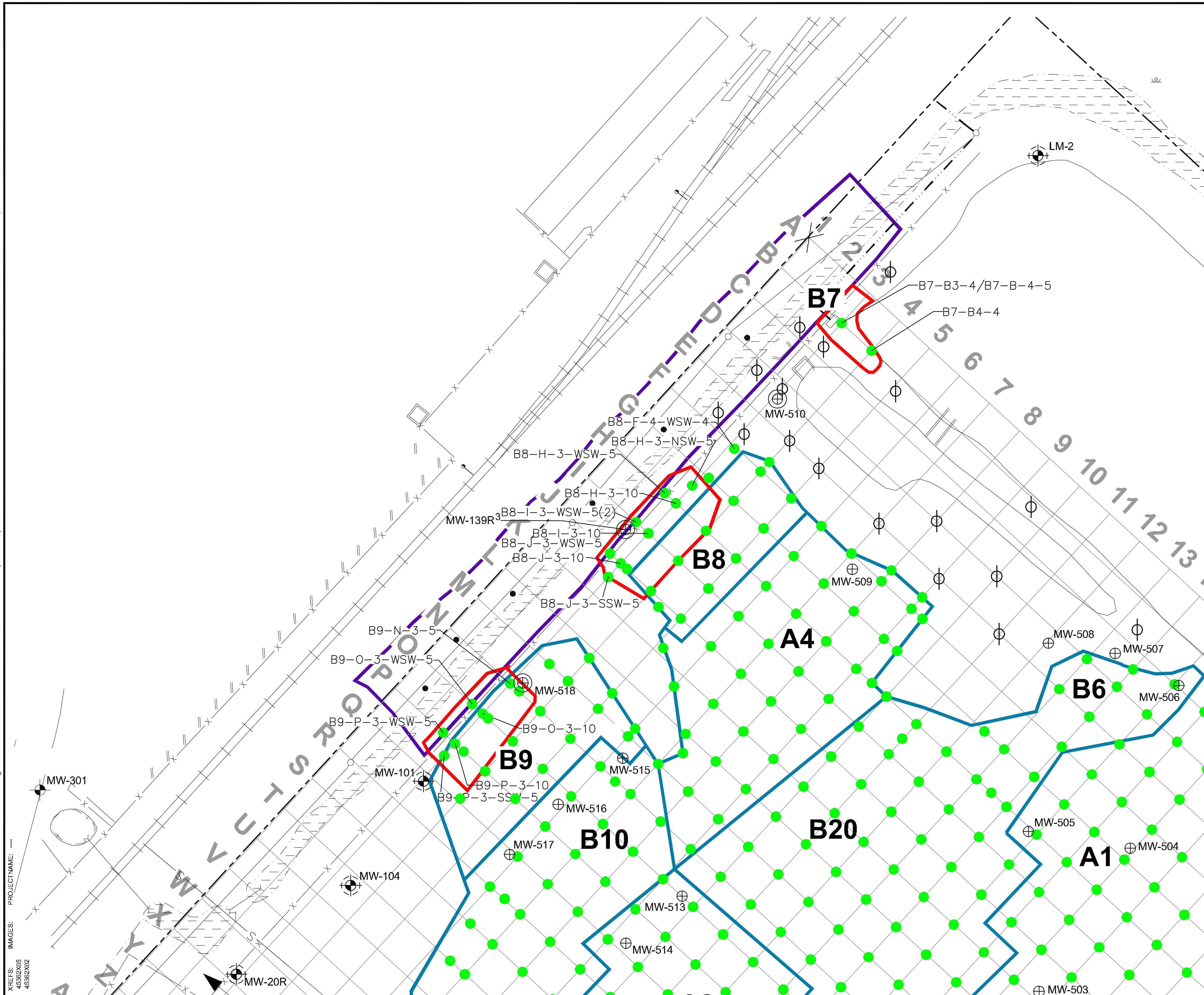

LEGEND:

- LOWER YARD SITE BOUNDARY
- DRAINAGE DITCH
- PHASE I EXCAVATION AREAS
- PHASE II EXCAVATION AREA
- PHASE II SEDIMENT REMOVAL AREA
- CONFIRMATION SOIL SAMPLES WITH ANALYTE CONCENTRATIONS LESS THAN SOIL REMEDIATION LEVELS
- PROPOSED SOIL BORING LOCATION
- EXISTING MONITORING WELL LOCATION
- LM-2 EXISTING SURFACE WATER COMPLIANCE MONITORING WELL LOCATION
- MW-510 SURFACE WATER COMPLIANCE MONITORING WELL LOCATION INSTALLED OCTOBER 2008
- MW-509 MONITORING WELL LOCATION INSTALLED OCTOBER 2008

NOTES:

1. BASE MAP SUPPLIED BY SLR INTERNATIONAL CORP.,APRIL 2007, AT A SCALE OF 1"=150'.
2. NO SAMPLING REQUIRED IN THE SEDIMENT REMOVAL AREA AS DEFINED IN THE INTERIM ACTION REPORT.
3. MONITORING WELL MW-129R WAS ABANDONED DURING INTERIM ACTION AND REPLACED IN OCTOBER 2008.

0 30' 60'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
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EDMONDS, WASHINGTON

PROPOSED SOIL BORING LOCATIONS

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FIGURE
3

CITY: SYRACUSE, NY GROUP: ENVCAD DB: K. DAVIS, P. LISTER PIC: J. VOGELEY PM: R. ANDRESEN TR: D. RASAR LYR: ON=*;OFF=REF, (FRZ) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 6/1/2011 12:17 PM BY: LISTER, PAUL
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Standard Operating Procedure for LNAPL Baildown Test

Rev. # 2

Rev. Date: January 14, 2010

Approval Signatures

Prepared by: ______________________ Date: January 14, 2010
Jonathon J. Smith

Reviewed by: ______________________ Date: January 14, 2010
Brad W. Koons, P.E.

I. Scope and Application

The objective of this Standard Operating Procedure (SOP) is to establish uniform procedures for conducting rising-head light non-aqueous-phase liquid (LNAPL) baildown tests to evaluate LNAPL conductivity (K_n) in the subsurface at a specific well location. The data generated from the LNAPL baildown test can be used, along with other site data, to evaluate LNAPL mobility and recoverability at a site. This SOP describes the equipment, field procedures, materials and documentation procedures necessary to determine LNAPL conductivity. The details within this SOP should be used in conjunction with project work plans.

This SOP applies to task orders and projects associated with ARCADIS. This SOP may be modified, as required, depending on site-specific conditions, equipment limitations or limitations imposed by the procedure. The ultimate procedure employed will be documented in the appropriate project work plans or reports. If changes to the testing procedures are required due to unanticipated field conditions, the changes will be discussed with the project manager as soon as practicable and documented in the project report.

II. Personnel Qualifications

Only qualified ARCADIS-related personnel will conduct LNAPL baildown tests. ARCADIS field sampling personnel will have sufficient “hands-on” experience necessary to successfully complete the LNAPL baildown test field work. Training requirements for conducting LNAPL baildown tests include reviewing this SOP and other applicable SOPs and/or guidance documents, instrument calibration training, and health and safety training.

ARCADIS field sampling personnel will have completed current company-required health and safety training (e.g., 40-hour Hazardous Waste Operations training, site-specific training, first aid and cardiopulmonary resuscitation (CPR) training), as needed.

III. Equipment List

Equipment and materials used for conducting the LNAPL baildown tests may include, but are not limited to, the following:

- appropriate personal protective equipment (PPE), as specified in the site Health and Safety Plan (HASP)
- equipment decontamination supplies
- photoionization detector (PID) (see ARCADIS SOP: Photoionization Detector Air Monitoring and Field Screening)
- plastic sheeting
- oil absorbent pads
- stopwatch
- polypropylene rope
- clean disposable bailers
- oil-specific skimmer pump
- vacuum truck
- plastic bucket with lid
- plastic beakers or graduated cylinders (appropriately sized for anticipated NAPL/water recovery volume)
- Calculator
- appropriate field logs/forms
- oil-water interface probe (see ARCADIS SOP: Water Level Measurement)
- data logger and transducer
- white masking tape

- measuring tape with gradation in hundredths of a foot
- indelible ink pen
- monitoring well keys
- bolt cutters
- monitoring well locks
- field log book or PDA or field (computer) notebook

IV. Cautions and Procedure Considerations

Wells containing LNAPL for baildown testing should be selected based on project-specific objectives and a review of historical site data. It is good practice to select several baildown test wells to bracket the range of observed historical apparent LNAPL thickness measurements and LNAPL mobility/recoverability conditions across a given area. As a rule of thumb, apparent LNAPL thicknesses in wells used for baildown tests should be greater than or equal to the borehole diameter (Lundy and Parcher, 2007). Additional guidelines for selecting appropriate wells for LNAPL baildown testing include:

- Select wells located near the interior and exterior portions of the LNAPL plume(s)
- Select wells located in a variety of geologic materials, as feasible
- Consider the position of wells relative to groundwater and LNAPL flow direction
- Consider the potential of wells to exhibit different equilibrated apparent LNAPL thicknesses
- Select wells which contain different types of LNAPL, if present

In addition, understanding the areas affected by recent remediation efforts should be considered because these areas may not be representative of static subsurface conditions. Also, ARCADIS field sampling personnel must be aware of historical fluid levels as they compare to the conditions at the time of testing (i.e., the smear zone).

If higher LNAPL recovery rates are expected, larger diameter wells (4- to 6-inch-diameter casings) are generally preferred. The increased area of the wellbore seepage face for larger diameter wells will provide information that is applicable to a larger, more representative volume of aquifer material. However, if the expected recovery rate is low, smaller diameter wells are often preferred because the volume of the borehole is smaller relative to the formation recovery capacity. Further discussion on accounting for the well filter pack is presented in *A Protocol for Performing Field Tasks and Follow-up Analytical Evaluation for LNAPL Transmissivity using Well Baildown Procedures* (Beckett and Lyverse, 2002).

ARCADIS project personnel must confirm that the test wells have been properly developed. This cannot be overemphasized, as incomplete well development results in underestimates of LNAPL transmissivity (T_n) and LNAPL conductivity (K_n). See the ARCADIS SOP titled *Monitoring Well Development* for additional details.

ARCADIS field sampling personnel must verify that the air/LNAPL and LNAPL/groundwater interfaces occur within the screen interval. At a minimum, the piezometric head elevation in the well should occur below the top of the screen.

ARCADIS field sampling personnel will choose the most appropriate technique to evacuate the LNAPL from the well. These techniques include:

- **Manual bailer** — A 1¾-inch-diameter bailer will be used for 2-inch-diameter wells. For 4-inch-diameter wells, a 3-inch-diameter bailer will be used for LNAPL recovery. ARCADIS highly recommends using product recovery cups, which attach to the bottom of the bailer and maximize the surface area for LNAPL recovery (For example, the Superbailer™, manufactured by EON Products, Inc. has this feature built-in). This will allow for more complete LNAPL removal and more accurate recovery measurements.

- **Pumping** — LNAPL removal can be accomplished by using an oil-specific skimmer pump that operates at a pumping rate which exceeds the LNAPL recharge capacity. For shallow wells (< 25 feet below ground surface), a peristaltic pump may also be a useful, effective and appropriate mode of LNAPL removal.

- **Vacuum Truck** — If large LNAPL volumes are to be removed or extremely rapid recovery rates are anticipated, LNAPL removal can be accomplished using a vacuum truck. The vacuum extraction line is to be outfitted with a small-diameter stinger attachment that will be extended down the well and an in-line site glass to observe extracted fluid color for determination of whether LNAPL or groundwater is being extracted. Begin pumping at the LNAPL/air interface and slowly move the stinger tube downward to extract LNAPL. When groundwater recovery is observed indicating that the LNAPL has been evacuated withdraw the stinger tube and begin fluid level measurements.

Follow the sequential steps below for each baildown test well. Data collection is generally manual using an interface probe, although a data logger can also be used as long as it can sense either the fluid interfaces or the head change only with respect to LNAPL. Before performing an LNAPL baildown test, allow monitoring well water and LNAPL levels to equilibrate with atmospheric pressure. Gauge fluid levels periodically for 5 to 10 minutes to monitor changes in head. Monitoring wells without vents (flush mounts) may require more time to equilibrate with atmospheric pressure following well cap removal.

ARCADIS recommends taking LNAPL measurements initially in one-minute intervals and then adjusting the frequency of measurements thereafter, based on site-specific conditions. The rate of LNAPL recovery will usually slow over time unless the zone of interest is highly conductive. Once the rate of recovery is slow enough, a new baildown test can be initiated at another location, returning to take periodic measurements at the initial test well. Continue this process as long as it is viable based on soil characteristics, field logistics, well locations and data collection needs. Real-time examination of the data curves is the best indicator of data sufficiency. A plot of the change in LNAPL thickness over time may exhibit up to three theoretical segments:

1) initial steep segment that could reflect filter pack drainage

2) main production segment where the formation LNAPL gradient to the wells controls recovery

3) third segment where the diminishing formation LNAPL gradient produces a flatter recovery curve

Repeatedly introducing the oil-water interface indicator may alter the fluid-level measurements. Avoid splashing the probe into the water table or lowering the probe too far beyond the LNAPL-water interface depth. To avoid introducing surface soil or other material into the monitoring well, stage downhole equipment on a clean and dry working surface.

Two field personnel are recommended to adequately perform this test, one person to collect the data and one person to record the data.

V. Health and Safety Considerations

Overall, the Loss Prevention System™ (LPS) tools and the site-specific HASP will be used to guide the performance of LNAPL baildown tests in a safe manner without incident. A Job Safety Analysis (JSA) will be prepared for LNAPL baildown tests. The following specific health and safety issues must be considered when conducting LNAPL baildown tests:

- Monitoring for volatile organic compounds (VOCs) in the monitoring well head space must be conducted with a PID and recorded in the field logbook prior to initiating the LNAPL baildown test. PID readings will be compared to action levels established in the site HASP for appropriate action.

- Appropriate PPE must be worn to avoid contact with LNAPL during the baildown test.

- LNAPL removed from the test well must be managed with caution to avoid igniting the LNAPL material. LNAPL characteristics must be reviewed in the JSA, which will be prepared and reviewed by the project team prior to implementing the baildown test.

- LNAPL generated during the baildown test must be properly managed in accordance with facility and applicable regulatory requirements.

- Well covers must be carefully removed to avoid potential contact with insects or animals nesting in the well casings.

VI. Procedure

Specific procedures for conducting LNAPL baildown tests are presented below:

1. Identify site, well number, date and time on the LNAPL Baildown Test Log and field logbook or PDA, along with other appropriate LNAPL baildown testing information. An example LNAPL Baildown Test Log is provided in Attachment 1 to this SOP.

2. Place clean plastic sheeting and several oil absorbent pads on the ground next to the well.

3. Unlock and open the monitoring well cover while standing upwind from the well.

4. Measure the concentration of detectible organics present in the worker breathing zone immediately after opening the well using a PID. If the PID reading(s) exceed the thresholds provided in the HASP, take appropriate actions per the HASP. After monitoring the worker breathing zone, proceed to

monitor the well head space with the PID and record the PID reading in the field logbook.

5. Prepare a test log to record LNAPL recovery data. Initially, data should be collected very frequently. As time progresses and the LNAPL recovery rate slows, less frequent measurements will be required. In most cases, initial measurement increments of 1 minute are sufficient, with subsequent measurements farther apart as appropriate, based on observed rate of recovery during the first few readings. If LNAPL recovery rates are high, data should be collected more frequently. For lower LNAPL recovery rates, time intervals between measurements can be increased.

6. It is important to monitor rapid LNAPL recovery at a higher frequency, again as indicated by the observed recovery data.

7. Secure one end of the rope to the bailer and the other end to the well casing using a bowline knot.

8. Before beginning the baildown testing, measure and record static fluid levels using the oil/ water interface probe (i.e., depth to LNAPL and depth to groundwater) and document the well construction details. Using the conversion chart at the bottom of the test log, the measured LNAPL thickness and the well diameter, calculate and record the initial LNAPL volume in the well. Gauge fluid levels periodically for 5 to 10 minutes to monitor changes in head. Do not begin the test until the well has equilibrated. Ideally, one person will be responsible for lowering the bailer into the well and recording time intervals in the log, and another person will be responsible for lowering the water-level probe into the well and measuring and communicating water-level depths to the person recording information in the log.

9. To begin baildown testing, slowly lower the bailer or equivalent into the well until it is just below the LNAPL-water interface.

10. Set stopwatch. Wait to start the stopwatch until immediately after LNAPL removal is finished.

11. Evacuate LNAPL from the well by gently bailing, pumping, or vacuum recovery as described in Section IV above <u>while minimizing water production. One of the assumptions employed in the analysis of the baildown test data is that the LNAPL is removed from the well instantaneously. Thus, it is important to avoid spending excessive amounts of time (more than 5 minutes) removing LNAPL from the well.</u>

12. Record the time at which LNAPL removal is complete (or removed to the maximum practical extent) as the test start time. Begin measuring the elapsed time, starting with this point. Monitor depth to LNAPL and depth to water at the appropriate intervals, as discussed above (5). Measure fluid levels to the nearest hundredth of a foot with the oil-water interface probe and record, along with the corresponding time reading in minutes and seconds.

13. Transfer the LNAPL and groundwater evacuated from the well into an appropriately sized beaker or graduated cylinder. Record the volumes of LNAPL and groundwater on the Baildown Test Log (Attachment 1). If an LNAPL/water emulsion was formed during fluid recovery, allow time for LNAPL/water separation and make note of the observed emulsification.

14. Two to eight hours of data collection is usually sufficient. However, faster LNAPL recovery need not be monitored for extended periods, and slow recovering wells may benefit from follow-up readings the next day.

15. Place all LNAPL and groundwater collected during the test into an appropriate container for proper waste management.

16. Decontaminate the oil-water level indicator with a non-phosphate detergent and water scrub, a tap water rinse, a reagent grade methanol rinse, a second tap water rinse, a second methanol rinse, a third tap water rinse, and a triple rinse with distilled water (see SOP titled *Field Equipment Decontamination*).

17. Secure the monitoring well prior to leaving by replacing the well cap and/or cover and locking it.

VII. Waste Management

Rinse water, PPE and other waste materials generated during equipment decontamination must be placed in appropriate containers and labeled. Containerized waste will be disposed of in a manner consistent with appropriate waste management procedures for investigation-derived waste.

VIII. Data Recording and Management

ARCADIS field sampling personnel will record data using the LNAPL Baildown Test Log (Attachment 1). All information relevant to the test data beyond the items identified in the Baildown Test Log will be recorded using the field logbook, PDA or field computer. Field equipment decontamination activities and waste management activities will be recorded in the field logbook. Records generated as a result of implementing this SOP will be controlled and maintained in the project record files in accordance with client-specific requirements.

IX. Quality Assurance/Quality Control

ARCADIS project personnel will review the data set collected during the LNAPL baildown test in the field to determine whether or not the data are reasonable given site-specific conditions. For example, if the data indicates that LNAPL recovery is very rapid in a very low-permeability soil type, this may indicate that there are problems with the data set. If the data are questionable, the field equipment must be checked to confirm it is working properly and the test will be repeated, if possible. Depending on data quality objectives, a duplicate LNAPL baildown test may be conducted as a quality control check 48 hours after the initial test, assuming water levels and apparent LNAPL thicknesses have returned to static conditions.

Any issues that may affect the data must be recorded in the field log book so that analysts can consider those issues when processing the data.

X. References

Beckett, G.D. and Lyverse, M.A. 2002. *A Protocol for Performing Field Tasks and Follow-up Analytical Evaluation for LNAPL Transmissivity using Well Baildown Procedures, August 2002.*

Lundy, D. and Parcher, M. 2007. *Assessment of LNAPL Volume, Mobility and Recoverability for Recovery Systems: Design and Risk-Based Corrective Action. National Ground Water Association Short Course, November 2007.*

ARCADIS SOPs Referenced Herein:

Field Equipment Decontamination, Revision No.1, April, 2009.

Monitoring Well Development, Revision No.2, March, 2008.

Photoionization Detector Air Monitoring and Field Screening, Revision No. 0, July, 2003.

Water Level Measurement, Revision No. 1, March, 2004.

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Attachment 1: LNAPL BAILDOWN TEST LOG

LNAPL Baildown Test Standard Operating Procedure

Site Name		Test Well ID	
Date and Time In		Date and Time Out	
Personnel		Weather	

Well Construction Details

Top of Casing Elevation (ft amsl)		Screen Slot Size (in)	
Total Well Depth (ft)		Filter Pack Type	
Depth to Top of Screen (ft)		Depth to Bottom of Screen (ft)	
Well Casing Diameter (in)		Borehole Diameter (in)	

Initial Test Conditions

Static Depth to LNAPL (ft)		Test Date	
Static Depth to Water (ft)		Start Time	
LNAPL Thickness (ft)		Initial LNAPL Volume in Well (gal)	

LNAPL Removal Information

LNAPL Removal Method/Equipment		Time LNAPL Removal Begins	
Volume of LNAPL Removed (gal)		Time LNAPL Removal is Completed	
Volume of Groundwater Removed (gal)			

Baildown Test Data

Elapsed Time (min)	Depth to LNAPL (ft)	Depth to Water (ft)	Observations

(Modified after Beckett and Lyverse, 2002)

Well Casing Volumes	1-¼" = 0.06	2" = 0.16	3" = 0.37	4" = 0.65
(Gal./Ft.)	1-½" = 0.09	2-½" = 0.26	3-½" = 0.50	6" = 1.47