LaBella
Powered by partnership.

July 9, 2024

Ms. Caroline Jalanti
New York State Department of Environmental Conservation
Division of Environmental Remediation, Remedial Bureau C
625 Broadway, 12th Floor, Albany, NY 12233-7014

Re: Pre-Design Investigation Work Plan
Warburton Dry Cleaners
305-321 Warburton Ave, 32 Point St, 247-262A Woodworth Ave
Yonkers, New York 10705, Westchester County
BCP Site No. C360227

Dear Ms. Jalanti:

LaBella Associates (LaBella) has prepared this Pre-Design Investigation (PDI) Work Plan for the Warburton Dry Cleaners Site (BCP Site No. C360227) located at 305-321 Warburton Ave, 32 Point St, and 247-262A Woodworth Ave in the City of Yonkers, New York, to summarize the means and methods of the lead delineation investigation activities as well as additional investigation activities to support the design of a groundwater treatment system.

The scope of work for the PDI included the following tasks:

- Delineation of the extent of lead across the Site in High Concentration Lead Areas (HCLAs)
- Groundwater treatment system design investigation, including groundwater monitoring and hydraulic conductivity testing methods.

The means and methods for the PDI are detailed in the following sections. The PDI – HCLA Report was submitted on June 5, 2024 summarizing findings of the lead delineation. The PDI – PRB Design Report summarizing the groundwater treatment system design investigation will be submitted in the August 2024 reporting period.

PRE-DESIGN INVESTIGATION – LEAD DELINEATION

Several borings from the Remedial Investigation (RI) exhibited high concentrations of total lead. Preliminary lead characterization performed in the RI indicated that hazardous lead was identified in the following areas of the Site (**Figure 1A-1C**):

- The vicinity of SB-26 and a suspected former coal burning furnace (Block 2115: Lots 34-37) to a depth of 2 to 6 ft bgs.
- The vicinity of SB-09 and SB-44 (Block 2116: Lots 21-22) to a depth of 2 to 8 ft bgs.
- The vicinity of SB-38 (Block 2116, Lot 28) to a depth of 2 to 8 ft bgs.

The PDI was designed to collect adequate data for approval from soil disposal facilities for both hazardous waste levels of lead and for non-hazardous and 'clean' soils. This work also helped further define the horizontal and vertical extent of soil in the HCLAs containing lead at concentrations that exceed the restricted residential soil cleanup objective of 400 mg/kg in order to refine the remedial extent of excavation required to achieve Track 2 cleanup objectives.

In addition, all samples collected during the RI and PDI that contained over 100 mg/kg of total lead were subsequently submitted for Toxicity Characteristic Leaching Procedure (TCLP) analysis. Samples that contained 5 mg/L based on TCLP analysis were considered characteristic hazardous. Based on disposal facility requirements, if a sample exceeds 5 mg/L for TCLP Lead, additional HCLA borings will be off-set 8 to 10 feet in four cardinal directions (i.e. N, S, E, W) from the original boring. Each off-set boring will be advanced to depths necessary to fully characterize the soil for both the remedial excavation limits and the development excavation limits.

Soil Boring Protocol

Soil borings will be advanced utilizing a Geoprobe® direct-push drill rig. Soil samples will be collected from each boring, starting from the two-foot interval immediately below the surface (0 to 2 ft bgs) and every two feet thereafter until 8 ft bgs initially. As needed boring locations will be extended deeper based on detections of total lead over 100 mg/kg and/or TCLP lead above 5 mg/L (i.e., borings will extend until results indicate total lead less than 400 mg/kg and TCLP lead less than 5 mg/L). In addition, disposal facilities may require additional delineation for detections of TCLP Lead over 4 mg/L, even though this material would still not be considered characteristic hazardous.

Each soil core will be documented with soil types, changes in lithology, and wastes (if any) encountered. LaBella utilized a PID to screen the soils from the soil cores for volatile organic vapors. A soil boring log was developed for each boring.

Soil Sampling Protocol

Soil samples will be collected in accordance with the soil sample summary table below to evaluate soil quality. Soil samples will be analyzed for Total Lead by EPA Method 6010D and TCLP Lead by EPA Method 6010D. Initially, samples below 4 ft bgs may be placed on hold and run at a later date if an exceedance is detected in the interval from 2 to 4 ft bgs. Vertical sampling will continue until the pre-determined protocols above are confirmed with data. Samples will be transferred to laboratory-supplied glassware, packed in a cooler with ice and shipped under proper chain-of-custody protocols to a NYSDOH ELAP certified laboratory for analysis following NYSDEC ASP – Category B Deliverables.

Requirements for sample analyses are described below. All samples will be submitted to Alpha Analytical Laboratories in Westborough, Massachusetts, a NYSDOH ELAP-certified laboratory. Analytical methods, preservation, container requirements, and holding times are summarized below. Analysis conformed to NYSDEC ASP Category B and data deliverables will be submitted to the NYSDEC.

Sample Matrix	Sample Type	Parameters	EPA Method	Sample Preservation	Holding Time	Sample Container
Soil	Grab	Total Lead	6010D	Cool to 4°C	180 days	Glass 60mL/2oz unpreserved
Soil	Grab	TCLP Lead	6010D	Cool to 4°C	180 days	Glass 250 mL/8oz unpreserved

Sampling will follow the procedures indicated in the QAPP (Section 8.0 of the April 2023 Remedial Investigation Work Plan). Each sample will be identified with a set of information relating to individual sample characteristics. Required information consist of Sample Designation, Depth, Date, Time, and Matrix. Sample Designation for the 'step-out' or 'off-set' HCLA borings will be based upon the direction the boring was off-set from the boring location which contained exceedances of lead (i.e. SB-44 S, SB-44 N, SB-44 W, SB-44 E).

The Community Air Monitoring Plan (CAMP) will be implemented and executed in accordance with 29 Code of Federal Regulations (CFR) 1910.120(h) and the NYSDOH Generic CAMP. Upwind and downwind CAMP will be conducted during all ground intrusive activities.

Please note that the HCLA soil borings were performed during the PDI from January 2024 through May 2024. Findings from the lead delineation were reported in a PDI – HCLA Report dated June 5, 2024, which reflected a significant increase in the vertical and horizontal extent of the HCLAs above that which was reported in the Remedial Investigation Report. Based upon discussion with the NYSDEC, 20% of the analytical data, at a minimum, will be provided to a third-party data validator for data validation, and Data Usability Summary Reports will be provided to the NYSDEC upon completion. Electronic data deliverables will also be submitted to EQuIS upon receipt.

PRE-DESIGN INVESTIGATION – GROUNDWATER TREATMENT DESIGN

The groundwater investigation during the RI indicated elevated levels of VOCs, specifically PCE and TCE, SVOCs, metals, and PFAS, specifically PFOS and PFOA, in exceedance of applicable AWQS across the Site (Figure 2). Highly elevated levels of PCEs were detected in the upgradient well MW-2 on the northeast corner of the site, closest to the off-Site former dry cleaners that was located to the east. PCE in groundwater appears to be elevated at the wells closest to MW-2. PCE was detected at the lowest concentration at well MW-3, which is the furthest downgradient well. TCE was detected in exceedance of AWQS in one monitoring well, MW-4. SVOCs were detected at levels in exceedance of the AWQS at wells MW-1, MW-3, MW-4, MW-5, and MW-6. Metals were detected in exceedance of the AWQS at all of the wells on-Site. PFOA and PFOS were detected in exceedance of the AWQS at all of the wells on-Site.

A Permeable Reactive Barrier (PRB) was selected as the groundwater treatment remedy for the Site to address chlorinated-VOCs (PCE, TCE and breakdown compounds). The proposed PRB is located on the eastern boundary of the Site along Warburton Ave (Figure 1). The PRB design will be based on the results of groundwater sampling and slug test tests to determine hydraulic conductivity/groundwater velocity and evaluate groundwater chemistry to select the appropriate chemical treatment.

The investigation will include conducting slug testing to determine the hydraulic conductivity of the aquifer and groundwater sampling of select wells to assess contaminant concentrations vertically and water quality parameters to assess existing conditions (e.g., anaerobic vs. aerobic, reductive state, etc.). The hydraulic conductivity will be used to determine the rate of groundwater flow and the residence time impacted groundwater would have as it flows across the site.

Passive Diffusion Bag Sampling

Passive diffusion bags (PDBs) will be deployed in three (3) wells (MW-2, MW-4, and MW-6) that are closest in proximity to the planned PRB. The PDBs will be deployed at the following depths in each well, at the top, middle, and bottom of the water column. Depths will be confirmed based on the depth-to-water measurements at the time the PDB is deployed and the well screen for each well.

Monitoring Well	Well Screen Depth (FT BGS)	Depth of PDB (FT BGS)
MW-2	56 - 76	60
		66
		73.5
MW-4	56 - 76	59
		66.5
		73.5
MW-6	56 - 76	65
		70
		73.5

The objective of the PDB sampling is to assess the vertical profile of contamination and evaluate any variations in PCE concentration with depth. This information will be utilized to determine if placement of additional PRB treatment chemical may be necessary in different vertical zones. The PDBs will be deployed and sampled in accordance with the EON Standard Operating Procedure for Groundwater Sampling Using Passive Diffusion Samplers (Attachment 1). The PDBs will be left in the wells for a minimum of two weeks to equilibrate and removed and sampled for Volatile Organic Compounds (VOCs) via EPA Method 8260.

Groundwater Sampling

All of the monitoring wells on-site (MW-1, MW-1D, MW-2, MW-3, MW-4, MW-5, and MW-6) will be sampled for baseline conditions prior to the installation of the PRB. The wells will be sampled via low-flow sampling techniques consistent with the procedures utilized during the Remedial Investigation. Purge water will be containerized and run through a carbon filter and discharged to the ground surface.

During sampling, the following parameters will be measured and recorded at three (3) to five (5) minute intervals:

- Water level drawdown (<0.3')
- Temperature (+/- 3%)
- pH (+/- 0.1 unit)
- Dissolved oxygen (+/- 10%)
- Specific conductance (+/- 3%)
- Oxidation reduction potential (+/- 10 millivolts)
- Turbidity (+/- 10%, <50 NTU for metals)

Samples will be collected when the parameters have stabilized within the specified range for three (3) consecutive intervals. The samples will be collected and transported to an ELAP-certified laboratory under standard chain of custody procedures for analysis of:

- Alkalinity, EPA Method 031.2
- Chloride, EPA Method 0300
- Hardness, EPA Method 130.1
- nitrate/nitrite, EPA Method 353.2
- sulfate/sulfide, EPA Method 300/376.1
- Ferrous iron, EPA Method 3010
- Total Organic Carbon (TOC), EPA Method 9060

Additionally, samples will be collected from the wells without PDBs deployed (MW-1, MW-1D, MW-3, and MW-5) for TCL VOCs by USEPA Method 8260.

Hydraulic Conductivity Testing

LaBella will conduct hydraulic conductivity testing on three (3) wells (MW-2, MW-4 and MW-6) that are closest in proximity to the planned PRB. The methods for conducting slug testing are as follows:

- Measure and record static water level of the well being tested prior to initiating the test.
- Place a pressure transducer into the wells listed above, one well at a time, to record water level measurements over time.
- Drop a slug into the well to quickly displace a volume of water. The slug will consist of a solid PVC cylinder capped at each end with a known mass and volume.
- Periodically confirm pressure transducer measurements using static water level meter,
- Remove the slug (if applicable) and pressure transducer from the well once the well has returned to the initial static water level.
- Repeat the test using the same procedures.
- Calculate hydraulic conductivity for each well tested using the Hvorslev Method.

Additional details on slug testing are included in the attached USEPA Standard Operating Procedures: Slug Tests dated April 29, 2020, included as Attachment 2.

Please note that groundwater sampling was performed in June 2024 after the PDBs were deployed and sampled for VOCs. The groundwater treatment design investigation will be reported on in a PDI – PRB Design Report in August 2024. One round of conductivity testing was performed in June 2024, and additional conductivity testing will be performed in July 2024.

SCHEDULE

The schedule of field work and deliverables for the work performed as part of the PDI are noted below.

Field Work:

- HCLA borings and sampling performed from January 2024 through May 2024
- PDBs were deployed from May 21 through May 28, 2024
- Groundwater sampling (including PDBs) performed on June 10 and 11, 2024
- Conductivity Testing performed on June 20, June 21
- Additional conductivity testing will be performed on July 19, 2024

Deliverables:

- PDI – HCLA Report was submitted on June 5, 2024
- PDI Report – PRB Design Report will be submitted in mid-August 2024

If you have any questions, please contact me at (917) 280-6364.

Respectfully submitted,

LaBella Associates, D.P.C.

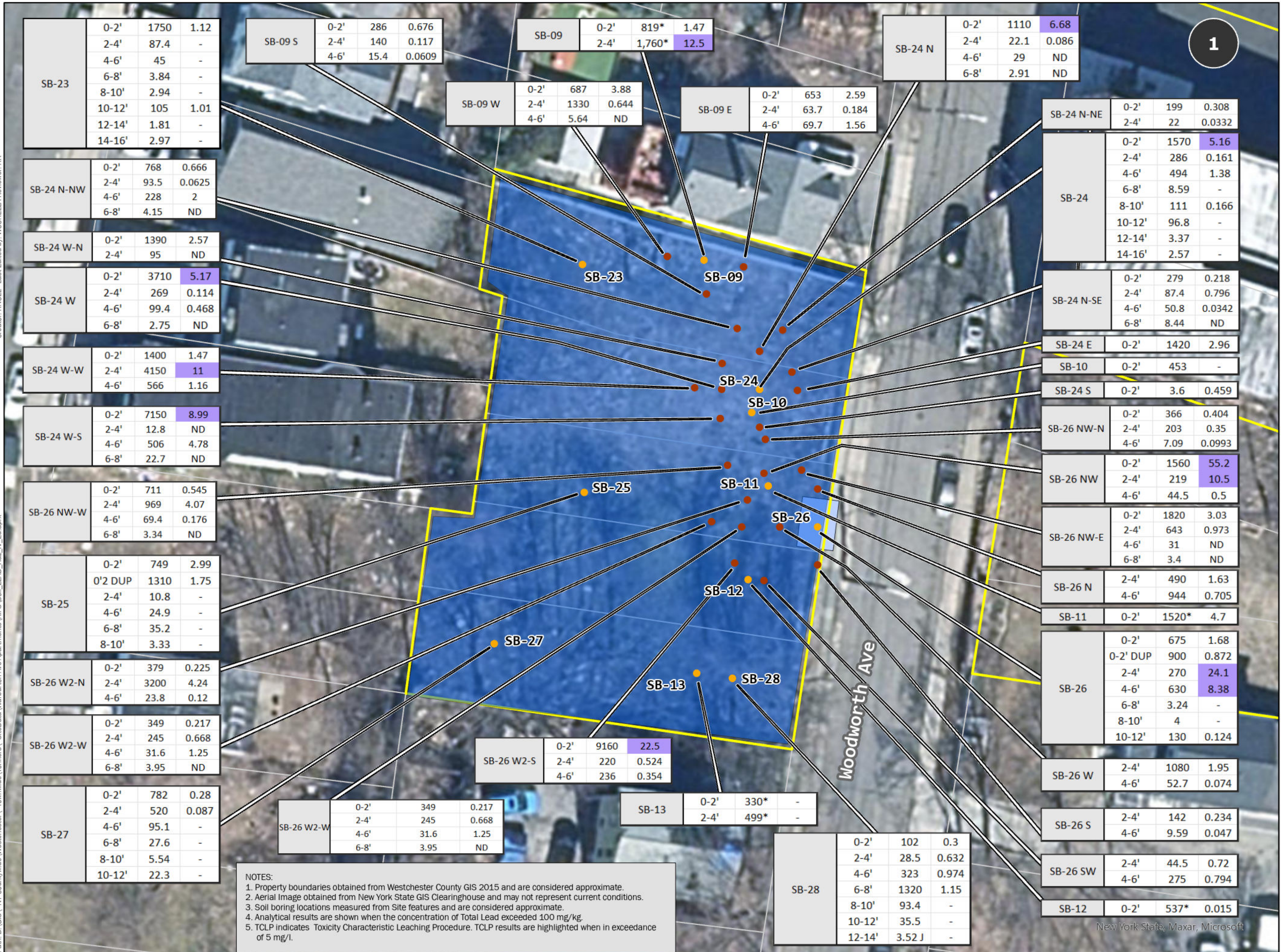
Richard T. Kampf, PG, LEP
NYC Regional Manager

Attachments

Figure 1A-C – Remedial Investigation - Preliminary HCLA Results
Figure 2 – Remedial Investigation – Groundwater Exceedances
Figure 3 – Proposed Permeable Reactive Barrier

Attachment 1 – EON Standard Operating Procedures: Groundwater Sampling Using Passive Diffusion Samplers
Attachment 2 – USEPA Standard Operating Procedures: Slug Tests

FIGURES



Sample ID	Sample Interval	Total Lead (mg/kg)	TCLP Lead (mg/L)
SB-23	0-2'	1750	1.12
	2-4'	87.4	-
	4-6'	45	-
	6-8'	3.84	-
	8-10'	2.94	-
	10-12'	105	1.01
	12-14'	1.81	-
	14-16'	2.97	-
SB-24 N-NW	0-2'	768	0.666
	2-4'	93.5	0.0625
	4-6'	228	2
	6-8'	4.15	ND
SB-24 W-N	0-2'	1390	2.57
	2-4'	95	ND
SB-24 W	0-2'	3710	5.17
	2-4'	269	0.114
	4-6'	99.4	0.468
	6-8'	2.75	ND
SB-24 W-W	0-2'	1400	1.47
	2-4'	4150	11
	4-6'	566	1.16
SB-24 W-S	0-2'	7150	8.99
	2-4'	12.8	ND
	4-6'	506	4.78
	6-8'	22.7	ND
SB-26 NW-W	0-2'	711	0.545
	2-4'	969	4.07
	4-6'	69.4	0.176
	6-8'	3.34	ND
SB-25	0-2'	749	2.99
	0'2 DUP	1310	1.75
	2-4'	10.8	-
	4-6'	24.9	-
	6-8'	35.2	-
	8-10'	3.33	-
SB-26 W2-N	0-2'	379	0.225
	2-4'	3200	4.24
	4-6'	23.8	0.12
SB-26 W2-W	0-2'	349	0.217
	2-4'	245	0.668
	4-6'	31.6	1.25
	6-8'	3.95	ND
SB-27	0-2'	782	0.28
	2-4'	520	0.087
	4-6'	95.1	-
	6-8'	27.6	-
	8-10'	5.54	-
	10-12'	22.3	-
SB-09 S	0-2'	286	0.676
	2-4'	140	0.117
	4-6'	15.4	0.0609
SB-09	0-2'	819*	1.47
	2-4'	1,760*	12.5
SB-09 W	0-2'	687	3.88
	2-4'	1330	0.644
	4-6'	5.64	ND
SB-09 E	0-2'	653	2.59
	2-4'	63.7	0.184
	4-6'	69.7	1.56
SB-24 N	0-2'	1110	6.68
	2-4'	22.1	0.086
	4-6'	29	ND
	6-8'	2.91	ND
SB-24 N-NE	0-2'	199	0.308
	2-4'	22	0.0332
SB-24	0-2'	1570	5.16
	2-4'	286	0.161
	4-6'	494	1.38
	6-8'	8.59	-
	8-10'	111	0.166
	10-12'	96.8	-
	12-14'	3.37	-
	14-16'	2.57	-
SB-24 N-SE	0-2'	279	0.218
	2-4'	87.4	0.796
	4-6'	50.8	0.0342
	6-8'	8.44	ND
SB-24 E	0-2'	1420	2.96
SB-10	0-2'	453	-
SB-24 S	0-2'	3.6	0.459
SB-26 NW-N	0-2'	366	0.404
	2-4'	203	0.35
	4-6'	7.09	0.0993
SB-26 NW	0-2'	1560	55.2
	2-4'	219	10.5
	4-6'	44.5	0.5
SB-26 NW-E	0-2'	1820	3.03
	2-4'	643	0.973
	4-6'	31	ND
	6-8'	3.4	ND
SB-26 N	2-4'	490	1.63
	4-6'	944	0.705
SB-11	0-2'	1520*	4.7
SB-26	0-2'	675	1.68
	0-2' DUP	900	0.872
	2-4'	270	24.1
	4-6'	630	8.38
	6-8'	3.24	-
	8-10'	4	-
	10-12'	130	0.124
SB-26 W	2-4'	1080	1.95
	4-6'	52.7	0.074
SB-26 S	2-4'	142	0.234
	4-6'	9.59	0.047
SB-26 SW	2-4'	44.5	0.72
	4-6'	275	0.794
SB-12	0-2'	537*	0.015
SB-26 W2-S	0-2'	9160	22.5
	2-4'	220	0.524
	4-6'	236	0.354
SB-26 W2-W	0-2'	349	0.217
	2-4'	245	0.668
	4-6'	31.6	1.25
	6-8'	3.95	ND
SB-13	0-2'	330*	-
	2-4'	499*	-
SB-28	0-2'	102	0.3
	2-4'	28.5	0.632
	4-6'	323	0.974
	6-8'	1320	1.15
	8-10'	93.4	-
	10-12'	35.5	-
	12-14'	3.52 J	-

NOTES:
1. Property boundaries obtained from Westchester County GIS 2015 and are considered approximate.
2. Aerial Image obtained from New York State GIS Clearinghouse and may not represent current conditions.
3. Soil boring locations measured from Site features and are considered approximate.
4. Analytical results are shown when the concentration of Total Lead exceeded 100 mg/kg.
5. TCLP indicates Toxicity Characteristic Leaching Procedure. TCLP results are highlighted when in exceedance of 5 mg/l.

Creator: RNOLL Last Edited by: WCORELLA Reviewer: RK

Path: B:\GIS\~NY Countywide\Westchester\~Townwide\Yonkers\~SiteData\Warburton Ave Apartments\RIFS\Soil_LEAD_Haz_IV_Ed.aprx

LaBella
Powered by partnership

Warburton Avenue Apartments, LLC

Warburton Dry Cleaners Site
City of Yonkers,
Westchester County, NY

Remedial Investigation

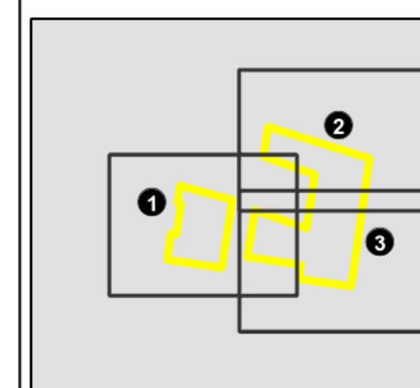
N

0 10 20 Feet
1 inch equals 24 feet

- Soil Boring Location
- High-Concentration Lead Area Delineation Boring Location
- AOC: Metallic Anomaly (Suspect Historic Furnace)
- Site Boundary

Callout Legend:

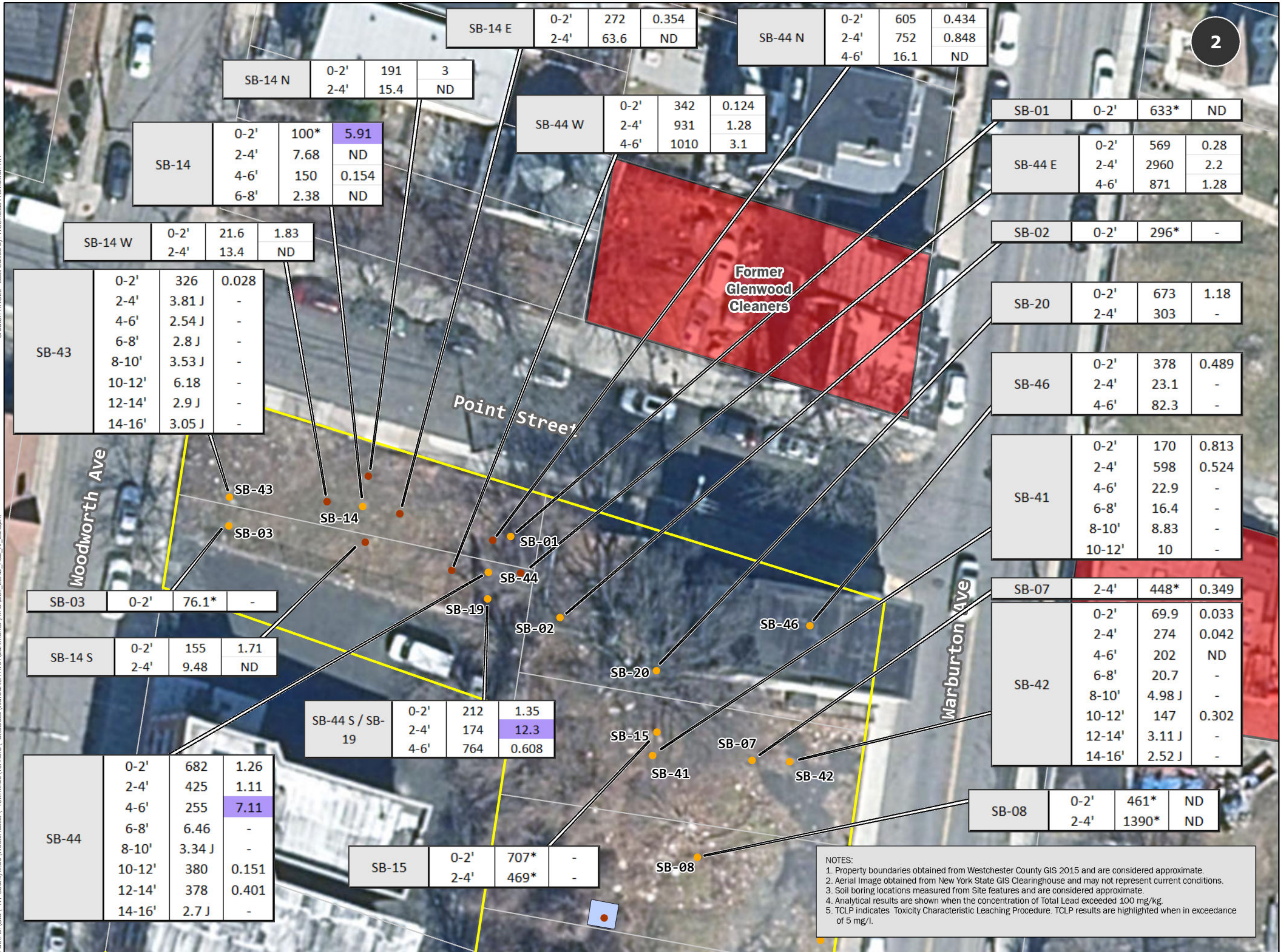
Sample ID	Sample Interval	Total Lead (mg/kg)	TCLP Lead (mg/L)



Soil Sampling Results/ Lead Characterization

FIGURE 1A

LaBella Project No: 2221378
Date: January 2024



Sample ID	Sample Interval	Total Lead (mg/kg)	TCLP Lead (mg/L)
SB-14 E	0-2'	272	0.354
	2-4'	63.6	ND
SB-44 N	0-2'	605	0.434
	2-4'	752	0.848
	4-6'	16.1	ND
SB-14 N	0-2'	191	3
	2-4'	15.4	ND
SB-44 W	0-2'	342	0.124
	2-4'	931	1.28
	4-6'	1010	3.1
SB-14	0-2'	100*	5.91
	2-4'	7.68	ND
	4-6'	150	0.154
	6-8'	2.38	ND
SB-14 W	0-2'	21.6	1.83
	2-4'	13.4	ND
SB-43	0-2'	326	0.028
	2-4'	3.81 J	-
	4-6'	2.54 J	-
	6-8'	2.8 J	-
	8-10'	3.53 J	-
	10-12'	6.18	-
	12-14'	2.9 J	-
	14-16'	3.05 J	-
SB-03	0-2'	76.1*	-
SB-14 S	0-2'	155	1.71
	2-4'	9.48	ND
SB-44 S / SB-19	0-2'	212	1.35
	2-4'	174	12.3
	4-6'	764	0.608
SB-44	0-2'	682	1.26
	2-4'	425	1.11
	4-6'	255	7.11
	6-8'	6.46	-
	8-10'	3.34 J	-
	10-12'	380	0.151
	12-14'	378	0.401
	14-16'	2.7 J	-
SB-15	0-2'	707*	-
	2-4'	469*	-
SB-01	0-2'	633*	ND
SB-44 E	0-2'	569	0.28
	2-4'	2960	2.2
	4-6'	871	1.28
SB-02	0-2'	296*	-
SB-20	0-2'	673	1.18
	2-4'	303	-
SB-46	0-2'	378	0.489
	2-4'	23.1	-
	4-6'	82.3	-
SB-41	0-2'	170	0.813
	2-4'	598	0.524
	4-6'	22.9	-
	6-8'	16.4	-
	8-10'	8.83	-
	10-12'	10	-
SB-07	2-4'	448*	0.349
SB-42	0-2'	69.9	0.033
	2-4'	274	0.042
	4-6'	202	ND
	6-8'	20.7	-
	8-10'	4.98 J	-
	10-12'	147	0.302
	12-14'	3.11 J	-
	14-16'	2.52 J	-
SB-08	0-2'	461*	ND
	2-4'	1390*	ND

NOTES:
1. Property boundaries obtained from Westchester County GIS 2015 and are considered approximate.
2. Aerial Image obtained from New York State GIS Clearinghouse and may not represent current conditions.
3. Soil boring locations measured from Site features and are considered approximate.
4. Analytical results are shown when the concentration of Total Lead exceeded 100 mg/kg.
5. TCLP indicates Toxicity Characteristic Leaching Procedure. TCLP results are highlighted when in exceedance of 5 mg/l.

Creator: RNOLL Last Edited by: WCORELLA Reviewer: RK

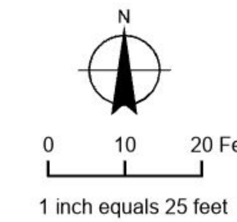
Path: B:\GIS\~NY Countywide\Westchester\~Townwide\Yonkers\~SiteData\Warburton Ave Apartments\RIFS\Soil_LEAD_Haz_IV_Ed.aprx

LaBella
Powered by partnership

Warburton Avenue Apartments, LLC

Warburton Dry Cleaners Site
City of Yonkers,
Westchester County, NY

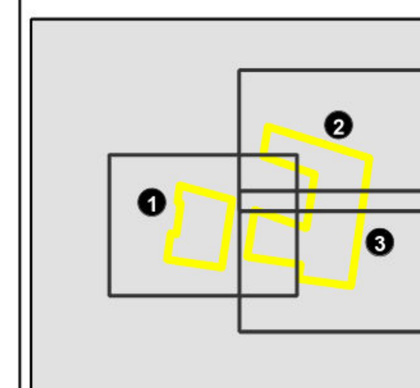
Remedial Investigation



- Soil Boring Location
- High-Concentration Lead Area Delineation Boring Location
- Site Boundary

Callout Legend:

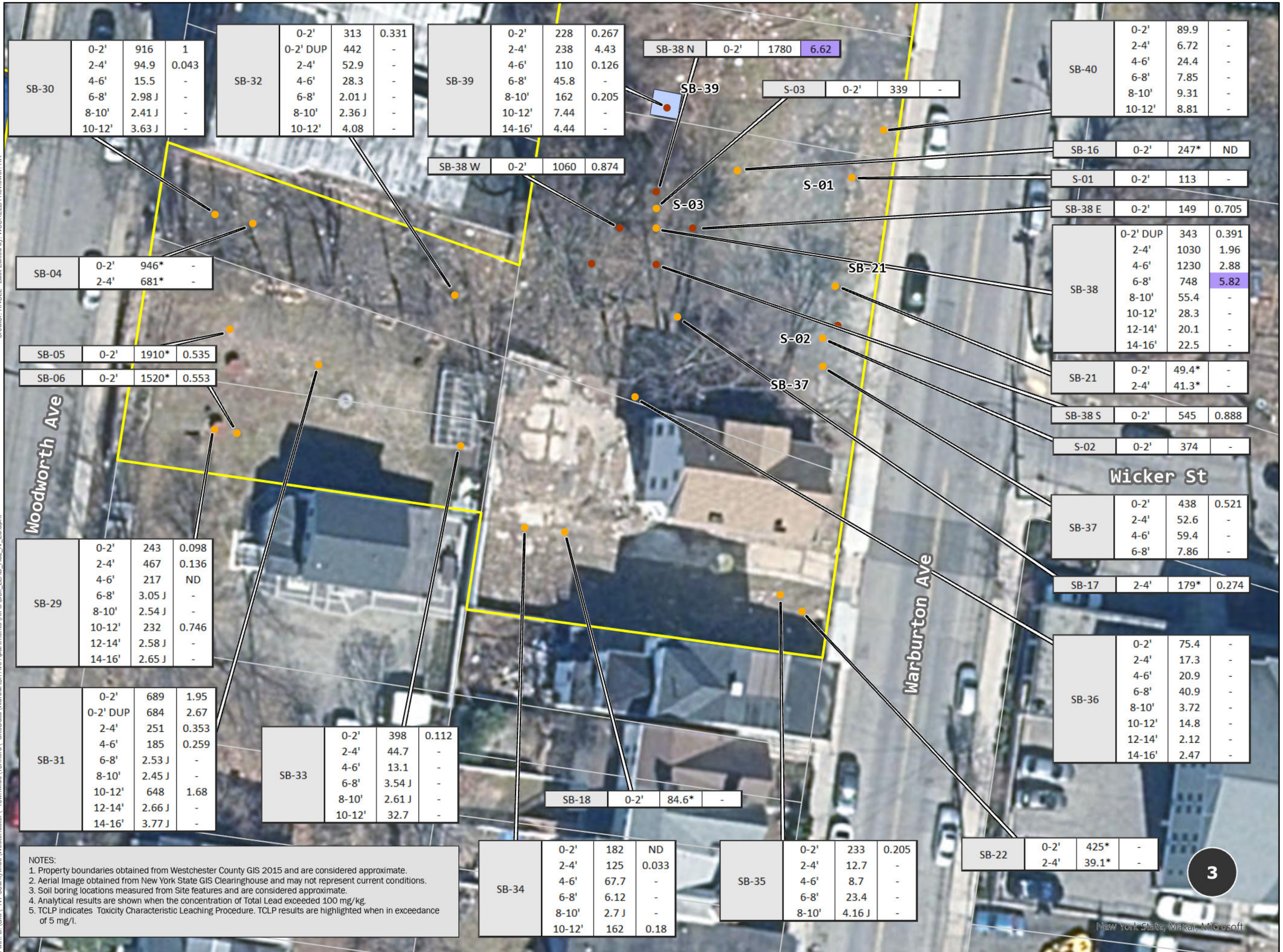
Sample ID	Sample Interval	Total Lead (mg/kg)	TCLP Lead (mg/L)



Soil Sampling Results/ Lead Characterization

FIGURE 1B

LaBella Project No: 2221378
Date: January 2024



SB-30	0-2'	916	1
	2-4'	94.9	0.043
	4-6'	15.5	-
	6-8'	2.98 J	-
	8-10'	2.41 J	-
	10-12'	3.63 J	-

SB-32	0-2'	313	0.331
	0-2' DUP	442	-
	2-4'	52.9	-
	4-6'	28.3	-
	6-8'	2.01 J	-
	8-10'	2.36 J	-
	10-12'	4.08	-

SB-39	0-2'	228	0.267
	2-4'	238	4.43
	4-6'	110	0.126
	6-8'	45.8	-
	8-10'	162	0.205
	10-12'	7.44	-
	14-16'	4.44	-

SB-38 N	0-2'	1780	6.62
S-03	0-2'	339	-
SB-38 W	0-2'	1060	0.874

SB-40	0-2'	89.9	-
	2-4'	6.72	-
	4-6'	24.4	-
	6-8'	7.85	-
	8-10'	9.31	-
	10-12'	8.81	-

SB-16	0-2'	247*	ND
S-01	0-2'	113	-
SB-38 E	0-2'	149	0.705

SB-38	0-2' DUP	343	0.391
	2-4'	1030	1.96
	4-6'	1230	2.88
	6-8'	748	5.82
	8-10'	55.4	-
	10-12'	28.3	-
	12-14'	20.1	-
	14-16'	22.5	-

SB-21	0-2'	49.4*	-
	2-4'	41.3*	-

SB-38 S	0-2'	545	0.888
S-02	0-2'	374	-

SB-04	0-2'	946*	-
	2-4'	681*	-

SB-05	0-2'	1910*	0.535
SB-06	0-2'	1520*	0.553

SB-37	0-2'	438	0.521
	2-4'	52.6	-
	4-6'	59.4	-
	6-8'	7.86	-

SB-17	2-4'	179*	0.274

SB-29	0-2'	243	0.098
	2-4'	467	0.136
	4-6'	217	ND
	6-8'	3.05 J	-
	8-10'	2.54 J	-
	10-12'	232	0.746
	12-14'	2.58 J	-
	14-16'	2.65 J	-

SB-36	0-2'	75.4	-
	2-4'	17.3	-
	4-6'	20.9	-
	6-8'	40.9	-
	8-10'	3.72	-
	10-12'	14.8	-
	12-14'	2.12	-
	14-16'	2.47	-

SB-31	0-2'	689	1.95
	0-2' DUP	684	2.67
	2-4'	251	0.353
	4-6'	185	0.259
	6-8'	2.53 J	-
	8-10'	2.45 J	-
	10-12'	648	1.68
	12-14'	2.66 J	-
	14-16'	3.77 J	-

SB-33	0-2'	398	0.112
	2-4'	44.7	-
	4-6'	13.1	-
	6-8'	3.54 J	-
	8-10'	2.61 J	-
	10-12'	32.7	-

SB-18	0-2'	84.6*	-

SB-34	0-2'	182	ND
	2-4'	125	0.033
	4-6'	67.7	-
	6-8'	6.12	-
	8-10'	2.7 J	-
	10-12'	162	0.18

SB-35	0-2'	233	0.205
	2-4'	12.7	-
	4-6'	8.7	-
	6-8'	23.4	-
	8-10'	4.16 J	-

SB-22	0-2'	425*	-
	2-4'	39.1*	-

NOTES:
1. Property boundaries obtained from Westchester County GIS 2015 and are considered approximate.
2. Aerial Image obtained from New York State GIS Clearinghouse and may not represent current conditions.
3. Soil boring locations measured from Site features and are considered approximate.
4. Analytical results are shown when the concentration of Total Lead exceeded 100 mg/kg.
5. TCLP indicates Toxicity Characteristic Leaching Procedure. TCLP results are highlighted when in exceedance of 5 mg/l.

LaBella Powered by partnership

Warburton Avenue Apartments, LLC

Warburton Dry Cleaners Site
City of Yonkers,
Westchester County, NY

Remedial Investigation

N

0 10 20 Feet

1 inch equals 25 feet

- Soil Boring Location
- High-Concentration Lead Area Delineation Boring Location
- Site Boundary

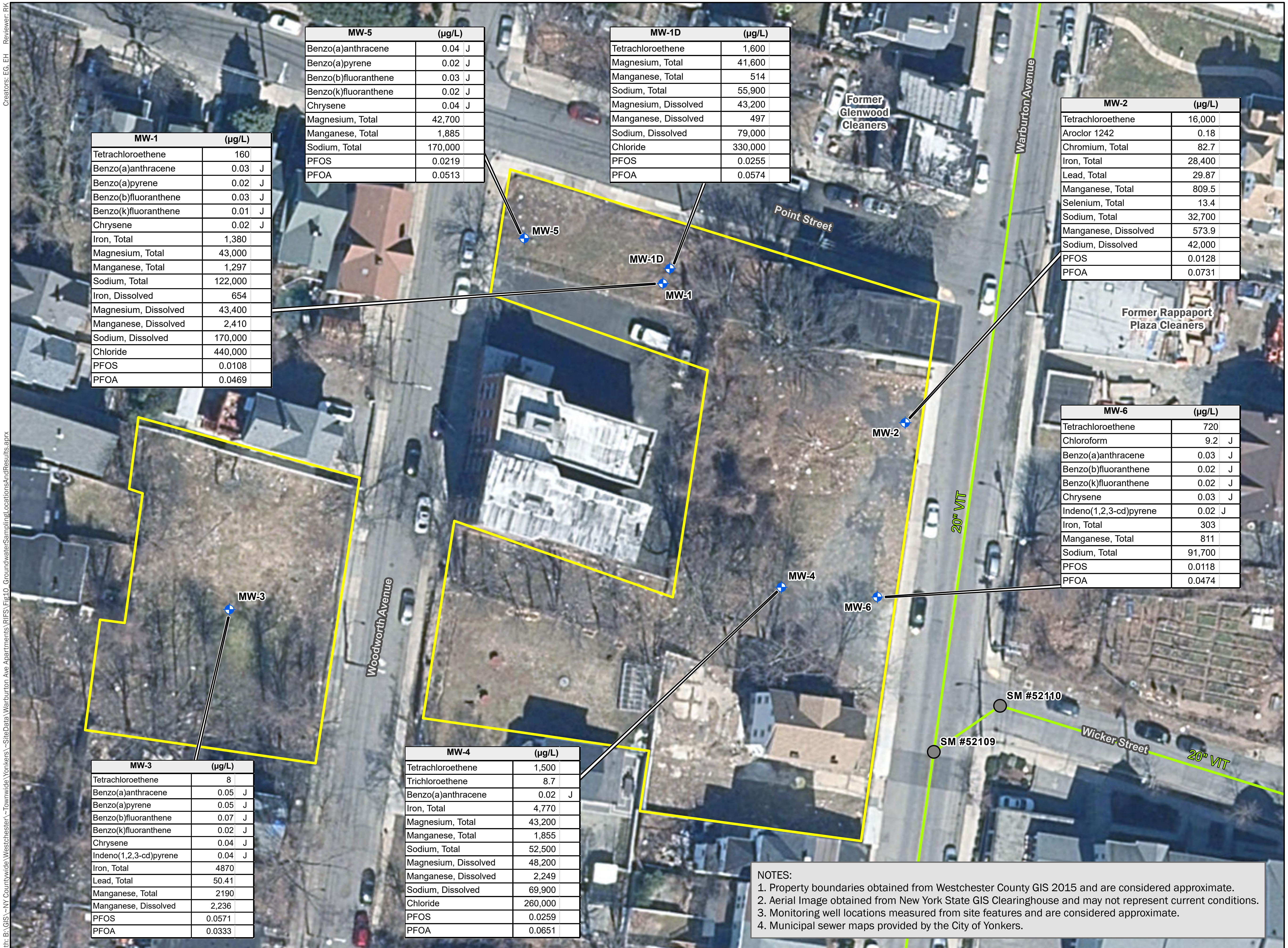
Callout Legend:

Sample ID	Sample Interval	Total Lead (mg/kg)	TCLP Lead (mg/L)

Soil Sampling Results/
Lead Characterization

FIGURE 1C

LaBella Project No: 2221378
Date: January 2024



MW-5	(µg/L)	
Benzo(a)anthracene	0.04	J
Benzo(a)pyrene	0.02	J
Benzo(b)fluoranthene	0.03	J
Benzo(k)fluoranthene	0.02	J
Chrysene	0.04	J
Magnesium, Total	42,700	
Manganese, Total	1,885	
Sodium, Total	170,000	
PFOS	0.0219	
PFOA	0.0513	

MW-1D	(µg/L)	
Tetrachloroethene	1,600	
Magnesium, Total	41,600	
Manganese, Total	514	
Sodium, Total	55,900	
Magnesium, Dissolved	43,200	
Manganese, Dissolved	497	
Sodium, Dissolved	79,000	
Chloride	330,000	
PFOS	0.0255	
PFOA	0.0574	

MW-1	(µg/L)	
Tetrachloroethene	160	
Benzo(a)anthracene	0.03	J
Benzo(a)pyrene	0.02	J
Benzo(b)fluoranthene	0.03	J
Benzo(k)fluoranthene	0.01	J
Chrysene	0.02	J
Iron, Total	1,380	
Magnesium, Total	43,000	
Manganese, Total	1,297	
Sodium, Total	122,000	
Iron, Dissolved	654	
Magnesium, Dissolved	43,400	
Manganese, Dissolved	2,410	
Sodium, Dissolved	170,000	
Chloride	440,000	
PFOS	0.0108	
PFOA	0.0469	

MW-2	(µg/L)	
Tetrachloroethene	16,000	
Aroclor 1242	0.18	
Chromium, Total	82.7	
Iron, Total	28,400	
Lead, Total	29.87	
Manganese, Total	809.5	
Selenium, Total	13.4	
Sodium, Total	32,700	
Manganese, Dissolved	573.9	
Sodium, Dissolved	42,000	
PFOS	0.0128	
PFOA	0.0731	

MW-6	(µg/L)	
Tetrachloroethene	720	
Chloroform	9.2	J
Benzo(a)anthracene	0.03	J
Benzo(b)fluoranthene	0.02	J
Benzo(k)fluoranthene	0.02	J
Chrysene	0.03	J
Indeno(1,2,3-cd)pyrene	0.02	J
Iron, Total	303	
Manganese, Total	811	
Sodium, Total	91,700	
PFOS	0.0118	
PFOA	0.0474	

MW-3	(µg/L)	
Tetrachloroethene	8	
Benzo(a)anthracene	0.05	J
Benzo(a)pyrene	0.05	J
Benzo(b)fluoranthene	0.07	J
Benzo(k)fluoranthene	0.02	J
Chrysene	0.04	J
Indeno(1,2,3-cd)pyrene	0.04	J
Iron, Total	4870	
Lead, Total	50.41	
Manganese, Total	2190	
Manganese, Dissolved	2,236	
PFOS	0.0571	
PFOA	0.0333	

MW-4	(µg/L)	
Tetrachloroethene	1,500	
Trichloroethene	8.7	
Benzo(a)anthracene	0.02	J
Iron, Total	4,770	
Magnesium, Total	43,200	
Manganese, Total	1,855	
Sodium, Total	52,500	
Magnesium, Dissolved	48,200	
Manganese, Dissolved	2,249	
Sodium, Dissolved	69,900	
Chloride	260,000	
PFOS	0.0259	
PFOA	0.0651	

NOTES:
1. Property boundaries obtained from Westchester County GIS 2015 and are considered approximate.
2. Aerial Image obtained from New York State GIS Clearinghouse and may not represent current conditions.
3. Monitoring well locations measured from site features and are considered approximate.
4. Municipal sewer maps provided by the City of Yonkers.

LaBella
Powered by partnership.

Warburton Avenue Apartments, LLC

Warburton Dry Cleaners Site
City of Yonkers,
Westchester County, NY

Remedial Investigation Report

N
0 20 40 Feet
1 inch equals 40 feet

- Approximate Location of Monitoring Well
- Site Boundary
- Approximate Location of Sewer Line
- Sewer Manhole

List of Terms:	
PFOS	Perfluorooctanesulfonic Acid
PFOA	Perfluorooctanoic Acid

Groundwater Sampling Locations with AWQS Exceedances

FIGURE 2

LaBella Project No: 2221378
Date: April 2024

NOTES:
1. Property boundaries obtained from Westchester County GIS 2015 and are considered approximate.
2. Aerial Image obtained from New York State GIS Clearinghouse and may not represent current conditions.
3. Monitoring well locations measured from site features and are considered approximate.
4. Municipal sewer maps provided by the City of Yonkers.
5. Estimated area of direct influence of each injection point is shown to scale (i.e., 10'-radius circle)

Creators: EG, EH Reviewer: RK

Path: B:\GIS\~NY Countywide\Westchester\~Townwide\Yonkers\~SiteData\Warburton Ave Apartments\RIFS\Fig10_GroundwaterSamplingLocationsAndResults.aprx

LaBella
Powered by partnership.

Warburton Avenue Apartments, LLC

Warburton Dry Cleaners Site
City of Yonkers, Westchester County, NY

Remedial Action Work Plan

N

0 25 50 Feet

1 inch equals 40 feet

- Approximate Location of Monitoring Well
- Proposed Monitoring Well
- Proposed PRB Injection Points
- Sewer Manhole
- Site Boundary
- Approximate Location of Sewer Line
- Topographic Elevation Contour Line
- Proposed Building Footprint
- Proposed Cellar Footprint (approximately 13 ft bgs)
- Proposed Sub Cellar Footprint (approximately 22 ft bgs)
- SubjectPropEast
- StreetSegment
- (FOR LABELS ONLY) AOC-3: Former Dry Cleaner

Proposed Permeable Reactive Barrier Injection Plan

FIGURE 3

LaBella Project No: 2221378
Date: April 2024

ATTACHMENT 1

EON Standard Operating Procedures:
Groundwater Sampling Using Passive Diffusion Samplers

Standard Operating Procedures
for
GROUNDWATER SAMPLING USING PASSIVE DIFFUSION SAMPLERS

I. Purpose

This Standard Operating Procedure (SOP) is written to enable the field project team to perform groundwater sampling using a Passive Diffusion Samplers as supplied by EON Products, Inc. This SOP is to be used in conjunction with ASTM Method D 4448-01, Standard Guide for Sampling Ground-Water Monitoring Wells.

II. General Materials Requirements

- Site-Specific Health and Safety Plan (SSHSP);
- Job Hazard Assessment;
- Personal protective equipment (PPE) in accordance with SSHSP;
- Air monitoring equipment, if required in the SSHSP;
- Site Access: agreements, photo identification, property owner contacts, keys, tools, etc.
- Site Documentation: Site map with sampling locations, list of wells to be sampled, field
- Logbook, Monitoring Well Sampling Forms, Well Construction Diagrams, etc.;
- Water level indicator and other instrumentation as required to meet site Data Quality Objectives (DQOs)
- Decontamination supplies;
- Laboratory-supplied containers with proper preservation;
- Chain-of-Custody forms; and,
- Coolers/shipping containers, ice and packing media.
- Deionized water travel blanks provided in sampler membrane materials when pre-filled samplers are used.

III. Diffusion Sampler Function

Diffusion sampling is based on the underlying principle that there is constant, mostly horizontal flow from the aquifer through the saturated screened interval and that this flow, along with molecular diffusion, causes water within the saturated well screen to have the equivalent contaminants and concentrations as the surrounding aquifer.

The diffusion sampling device consists of one or more semipermeable membranes formed into a tubular shape, sealed at the bottom and filled with laboratory-grade deionized (DI) water. The top is typically manufactured with a nozzle for filling the sampler with the DI water however, some diffusion samplers are “prefilled” with DI water by the manufacturer and sealed at both ends. The sampler is then suspended in the saturated screen zone of the monitor well using a suspension tether assembly and left in place for chemical equilibration to occur.

When the sampler is installed, a concentration gradient will exist between the contaminants outside the sampler and the DI water inside. Because the membrane is semipermeable, certain molecules pass through the membrane without restriction, so that during the residence time, the concentration gradient causes molecules to flow in or out of the sampler until chemical equilibrium is reached. When sufficient time has elapsed for equilibration, the device is then removed from the well, and the water within the sampler is transferred to the appropriate laboratory container and analyzed by standard laboratory methods. The user should consult with the manufacturer to select the appropriate sampler with membranes suitable for the compounds being sampled.

IV. Diffusion Sampler Installed Depth

One or more passive diffusion samplers are suspended at predetermined depths in the saturated screen to intercept groundwater flow and produce a representative sample of the contaminants and their concentrations at that depth. If it is known that the aquifer adjacent to the saturated screen is somewhat homogeneous and the contaminants are not stratified, then a single sampler can be used to represent the entire saturated screen length. In the absence of those conditions or other knowledge about the well and contaminants, a single sampler should not be used to represent a vertical interval of more than about five feet. Wells having longer saturated screens or unknown stratification may be profiled using several samplers at intervals across the screen length for sampling specific intervals or to determine future placement of one or more samplers. Diffusion sampler depth setting is typically referred to by the mid-point of the sampler.

V. Diffusion Samplers Filled with Deionized Water

Passive diffusion samplers are available pre-filled with laboratory-grade deionized water from the supplier or may be ordered empty for filling by the user. Some laboratories provide laboratory-grade water for the user to fill empty samplers before deployment and some laboratories may provide PDBs pre-filled with laboratory-grade water. If samplers are purchased empty, consult the manufacturer's filling instructions.

A Fill Water Travel blank, constructed from the sampler membrane materials and the same lot of DI water used to fill the samplers, should be ordered or produced and accompany the samplers from the point of filling to the project site. A spare sampler may also be used to contain a travel blank. Because diffusion samplers will come to equilibration with the surrounding groundwater, low concentrations of diffusible compounds that may be in the sampler or fill water prior to installation will equilibrate with the surrounding groundwater. There are several compounds, including acetone, MTBE and butanone compounds, that may not equilibrate when using a single membrane polyethylene diffusion sampler for VOCs. In these cases, and for general data quality reporting, a certificate of analysis of the lot of water used to fill the samplers and a fill/travel blank representing any compounds that enter the sampler during transportation and storage and are in the sampler at the time of deployment. Travel blanks should be sampled at the project site during the deployment process. Typically, one sampler per site per round of deployment is used.

VI. Diffusion Sampler Residence Time Requirements

The required sampler residence time requirement is made up of two components; the well must first stabilize and return to its natural flow conditions after being disrupted by the installation of the sampler, followed by the sampler contents coming into chemical equilibrium with the surrounding groundwater. It is generally accepted that two weeks is the minimum residence time to cover installation and equilibration when sampling for VOCs and 3 weeks when sampling for metals, inorganics and other compounds. There has not been shown a maximum residence time, as the diffusion process maintains a dynamic equilibrium, keeping the sampler at the same concentrations as the surrounding groundwater even as changes in the aquifer occur.

For cost savings and logistics, samplers can be installed during one event and left in place until the next sampling event and then removed, sampled and replaced for the next event.

Samplers have been used successfully in this manner with sampling intervals longer that one year. Because the diffusion process requires some time and occurs at differing rates for each compound, the acquired sample will represent the chemistry of the past few days in residence, to about one week prior to removal of the sampler from the well.

VII. Diffusion Sampler Installation Assemblies

Dedicated sampler suspension tether assemblies can be made to order by the PDB supplier such as EON Products in Atlanta, Georgia (800-474-2490), are re-usable and remove the time and effort required to measure and construct these cleanly in the field. Because the assemblies are a one-time investment, with only the disposable samplers requiring replacement, it is recommended that dedicated PDB assemblies (tethers, reels, and weights) be purchased ready-made from the supplier.

A. To ensure that project deadlines are met, contact the sampler and tether-assemblies supplier as far in advance as possible, preferably at least two weeks before the planned PDB deployment date. If this is the first use of diffusion samplers in any well, deploy the samplers in the wells at least two to three weeks (depending on sampler type and contaminants of interest) before the planned sampling date.

B. To order pre-made PDB assemblies, provide the supplier with the following information:
   a. Well identification (ID)
   b. Well diameter
   c. Total depth of well at the time of installment (feet below Top of casing (ft bTOC)
   d. Screened interval (ft bTOC)
   e. Number of samplers per well and desired sampling depths of each
   f. Ship-to address and purchase order number (project number)

C. Each standard dedicated diffusion sampling assembly, as provided by the supplier, should include the following:
   a. diffusion sampler bag (disposable)

i. select prefilled with Lab grade DI water by manufacturer, or
ii. unfilled for filling by the lab or
iii. for filling by the sampling team

b. stainless steel weights with split ring connectors
c. tether made of braided polypropylene rope on a plastic reel
d. embedded stainless steel connection rings at sampler depths-2 per sampler.
e. aluminum tag with well ID inscribed
f. snap connectors
g. cable ties
h. well caps (optional: prepared with rings from which to suspend tethers in the well)
i. discharge tubes (disposable)
j. deionized water (for unfilled samplers)
k. deionized water travel-blank (for prefilled samplers, minimum one per shipment)
l. Deionized water certificate of analysis for water used to fill the samplers.

VIII. Filling and Transporting Passive Diffusion Samplers

A. All sampler bags should be filled at a single time to save time and minimize the potential for contamination, before mobilizing to the various wells for deployment

B. Wear disposable, powder-free latex or nitrile gloves.

C. If the samplers are not pre-filled, fill the sampler with laboratory-grade deionized water and follow the manufacturer's instructions for filling the samplers so that the sample bag is expanded to its maximum capacity. Remove visible air pockets. Air (headspace) is of little concern provided sample volume is adequate.

D. Filled sample bags should be placed in a clean poly bag and the poly bags placed in a clean cooler with a tight-fitting lid, for transportation to and on the site to reduce potential contamination.

E. From the point the samplers are filled with DI Water, the travel blank should travel with the samplers at all times. The project manager should decide at which location on-site the blank should be

IX. Installing Suspension Tethers and Diffusion Samplers

If the suspension tether has already been installed and is in use in the well, go to the section **X. Retrieving and Sampling Diffusion Samplers** for information on removing installed samplers before installing new samplers. If the suspension tether is new and hasn't been previously installed, follow the manufacturer's directions to;

a. Unpackage the spooled tether. The weights should be attached to the ring on the leading end of the rope. If not, find the correct weight and attach.
b. Find the Well ID Tag located on the spooled tether. Match the ID tag to the well ID.
c. Place the weighted leading end of the suspension tether into the well and slowly lower until a small diameter (~.50-in) stainless steel ring is located on the tether. A second ring should be located further up the rope at a distance slightly more than the length of the sampler.

F. Use a Zip-Tie to attach the bottom ring or loop on the sampler to the lower of the two rings embedded in the tether. Use a Zip Tie to attach the loop near the top of the sampler to the upper stainless-steel ring on the tether. Repeat the sampler attachment process for each set of rings on the tether if more than one sampler is used in the well. Optionally trim the excess zip-tie. Do NOT hold the sampler over the well before attaching zip-ties to prevent accidental loss down the well)

G. Once all the samplers are securely attached to the tether rings continue to lower the tether into the well until the black snap connector is located on the tether. It is usually clipped to the spool.

H. Hold the tether or otherwise secure it so that it cannot slip free down the well and move the snap connector from the spool to the ring on the underside of the well cap.

I. If there is extra tether rope past the snap connector, place the rope in the well so it hangs alongside the tether. The excess can be zip-tied to the tether if preferred. The extra length allows for field lowering the assembly if the well depth or sampler location is deeper than reported. When the well cap is installed the stainless-steel weight will typically be resting on the well bottom and the sampler will be in the desired position within the screened interval.

J. More than one sample bag may be deployed in-line along a single tether assembly to allow samples to be collected from discrete depths within the screened interval. In wells larger than two inches, samplers may be placed side by side to obtain more volume if duplicates are needed and the volume of the selected sampler is not adequate. A heavier weight will be needed to hold multiple sample bags in place.

K. If the well has become silted such that the actual total depth is less than the total depth when the well was installed, the portion of the pre-made tether between the weight and the sample bag can be shortened by creating several small loops and securing them with a cable tie. DO NOT cut the tether to shorten it, because the full length will be needed if the well is redeveloped and restored to its original depth.

L. Record the water level and the date, time, and depth of sampler installations in the field notebook. Note any occurrences during deployment.

X. Retrieving and Sampling Diffusion Samplers

A. To avoid loss of analytes, do not retrieve the PDB unless you are ready to sample it immediately. Samples should be decanted into laboratory containers immediately upon retrieval.

B. Remove the sample bag from the well by reeling the tether onto the dedicated reel. Secure the rope and/or reel so that the weighted tether and samplers do not spool back down the well. This can be done by tying off the rope to the casing or hanging some types of spools on the top of the casing or using a tripod assembly over the well. Small leaks do not interfere with the results provided there is adequate sample volume. Users should make efforts to protect themselves from contact with contaminated samples and spray.

C. Remove the sampler from the tether by carefully using a small snipping tool to cut the zip-ties that hold the sampler to the rings on the tether. Be careful to not let anything touch the area of the sample bag where you intend to insert the discharge tube.

D. Open one end of the plastic wrapper containing the discharge tube and, leaving this wrapper on the tube, puncture the upper part of the sample bag (similar to using a "juice-box), It may help to hold the sampler at the upper white nozzle area to reduce squeezing.

E. Remove the plastic wrapper from the discharge tube and let the straw purge for a second or two and then fill the laboratory-supplied containers in the usual manner, manipulating the sample bag to start and stop flow as needed.

F. If VOCs and other compounds are collected from the same sampler, fill the VOC containers first.

G. Collect field duplicates as needed by filling a second set of laboratory-supplied containers immediately after collecting the first set.

H. Prepare and ship all samples as usual to meet standard lab requirements.

I. Dispose of the remaining water in the PDB as directed by the project manager.

J. At the project manager's discretion, new sample bags for the next sampling event may be deployed at this time to avoid an additional mobilization.

XI. Decontamination and Disposal

A. If new sample bags are not deployed during the sampling event the dedicated suspension tether assemblies may be left in the well or, if the project manager does not want to leave the dedicated tether assemblies in the well, reel the entire assembly onto the dedicated reel (having marked the reel with the well ID using an engraver or marker) and secure the tether with cable ties. At the project manager's discretion, segregate secured assemblies in plastic bags by level of contamination. It may be desirable to rinse the tethers with DI water however the use of cleaning agents is discouraged because of the potential for carry-over into the well upon the next installation. ONLY a tether in the well originally designated for that specific tether.

B. Dispose of the spent PDB in the same manner as other disposable items such as latex gloves, tubing, etc., or as directed by the project manager.

XII. Other Considerations

A. Select the sampler type for sampling the contaminants of concern (CoCs). Single membrane passive diffusion bag samplers are only viable for VOCs. Multi-membrane samplers will provide reliable samplers for virtually any CoC however, verify specific CoCs with the manufacturer.

B. Select the sampler size to fit the well diameter, saturated screen and sample volume requirements. If adequate sample volume may be difficult to acquire, ask the laboratory for the Minimum Volume Requirements to meet the site Data Quality Objectives. In most cases the laboratory will be able to perform the analyses with significantly reduced sample volume.

C. If there is any question regarding the integrity of the sample when collected, a new PDB should be deployed at that time so that a new sample could be provided to the laboratory two or three weeks later if the laboratory data are questionable.

VII. **References**

EON Products, Inc.

Phone: (800) 474-2490

Web: www.eonpro.comEmail:

Email: Info@eoonpro.com

- Equilibrator™ Diffusion Sampler Instructions
- Discharging a Sample from the Equilibrator™ Passive Diffusion Sampler

United States Geologic Survey (USGS)

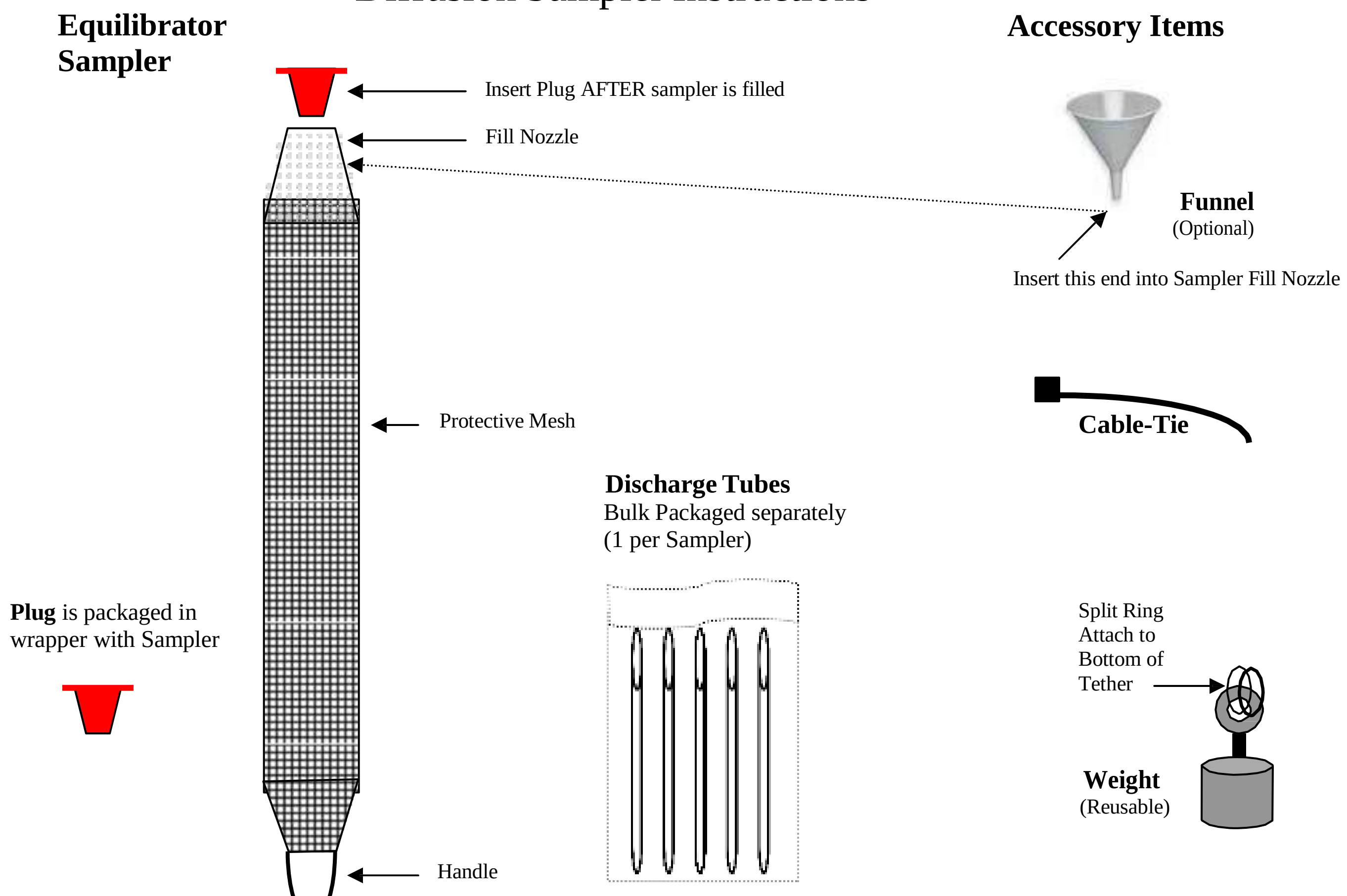
- User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells. (2001)

Interstate Technology Regulatory Council (ITRC)
Passive Sampling team

- **Tech-Reg Document**
  Technical and Regulatory Guidance Document for Using Polyethylene Diffusion Bag Samplers to Monitor Volatile Organic Compounds in Groundwater (2002)

- **Technology Overview**
  Technology Overview of Passive Sampler Technologies (2006)

EQUILIBRATOR ™
Diffusion Sampler Instructions



BASIC USE INSTRUCTIONS* (Fig 1)

1. **Fill the Sampler with deionized water** until the entire assembly is completely full of water. To use the funnel, insert the tip into the Sampler and pour deionized water into the tube. Fill the Sampler until water rises and stands at least two inches up the funnel to expand the Sampler to its maximum capacity. ***Gently squeeze and add more water to expand the membrane and remove air pockets. Repeat as needed until completely full.*** *Disclosure Statement – When filling the Sampler, we recommend that you hold the Sampler firmly at the top as close to nozzle tip as possible to prevent unnecessary stress on inside poly bag which could cause a leak to develop.*

2. **Insert the Plug firmly into the Sampler,** until the rim of the plug is as close to the nozzle as possible.

3. Attach a Weight to the bottom of the Tether or Hanger.

4. **Attach the Equilibrator(s) to the Tether line.** If installing on a factory prepared tether, locate the small (1/2" diameter) stainless steel rings that are attached to the Tether line. The rings will be separated by approximately 2/3 the length of the sampler. Use a Cable-Tie through the lower of two adjacent rings and through handle. Use a second Cable-Tie through upper of two adjacent rings and through a section of mesh below the fill nozzle in the softer part of the filled sampler. Tighten the Cable-Ties and snip off excess. Continue with each Sampler. If the factory did not prepare the Tether, then securely attach the Sampler(s) to the tether using cable ties at the intended location(s).

5. **Lower the Tether with Sampler(s) attached into the well.** Locate Sampler(s) below the water surface, in the screen flow zone of the well. Attach the top of the suspension cord to a well cap or other secure location at the top of the well. Leave Sampler in place for a time suitable for equilibration, a minimum of 2 weeks required.

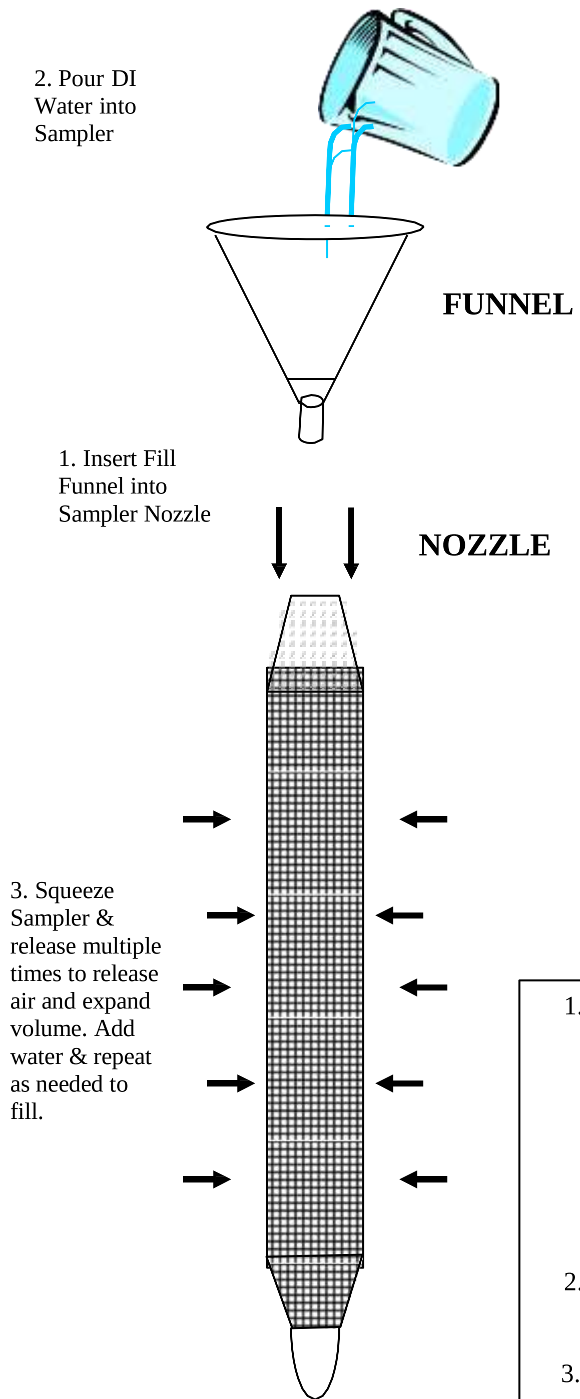
6. **Upon retrieval: Discharge sample immediately** to avoid loss of volatile compounds. Select a point on the Sampler near the handle/bottom of sampler. Press one end of the Discharge Tube firmly into the clear polyethylene membrane at a downward angle until it pierces the membrane. ***Discharge small amount to waste to purge discharge tube.***

***Contact EON for detailed installation information and for factory prepared Tethers.**

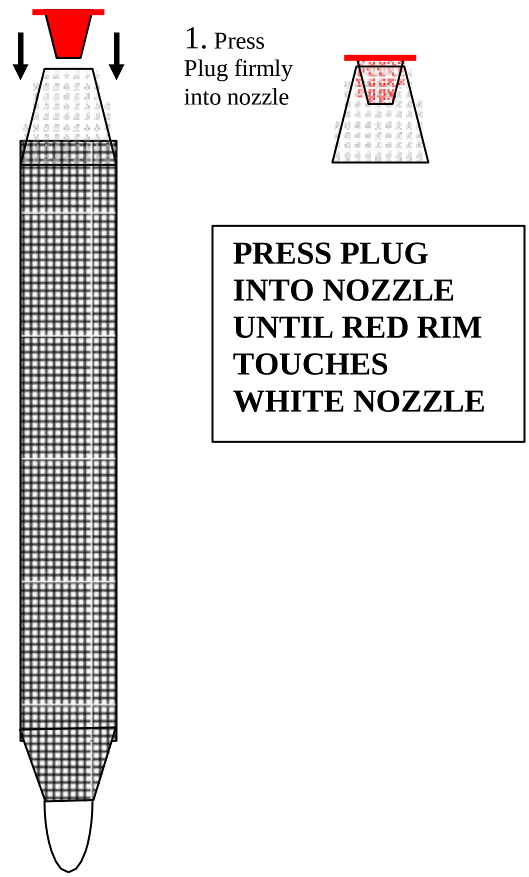
800-474-2490

EQUILIBRATOR ™
Diffusion Sampler Instructions

STEP 1



STEP 2

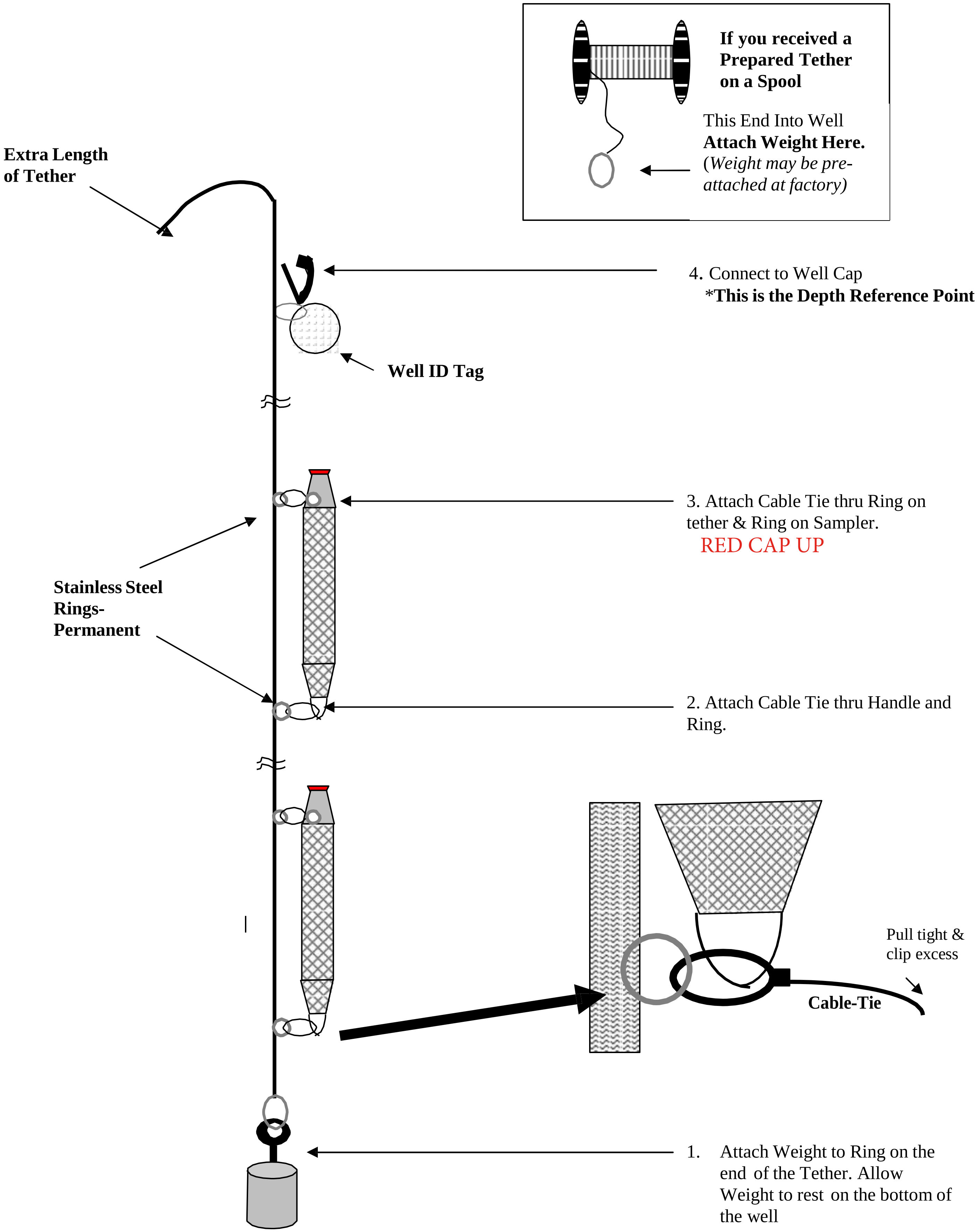


1. Fill the Sampler with deionized water until the entire assembly is completely full of water. To use the Funnel, insert the short nozzle into the Sampler and pour deionized water into the tube. Fill the Sampler until water rises and stands at least two inches up the funnel to expand the Sampler to its maximum capacity. **Squeeze the Sampler several times and add more water. Repeat as needed to expand the membrane and remove air pockets.** Fill to top of nozzle, leaving a meniscus.

2. Insert the Plug firmly into the Sampler, **until the rim touches the nozzle.**

3. Fill at least two VOA Vials with the DI water used to fill the samplers to use as a **water blank**. (See *Using a Field/Trip Blank*)

EQUILIBRATOR ™
Diffusion Sampler Instructions



EQUILIBRATOR™
Diffusion Sampler Instructions

Using a Field/Trip Blank (Prefilled at EON or filled by you)

1. Fill Blank with the **same water** as your samplers at the **same time and place** that you fill them**.** When EON sends you prefilled samplers and a blank, they have been filled and shipped together. *This will serve as a control for the water in the samplers that you will deploy.*

2. Store and **transport Blanks with the other samplers** prior to installing the samplers. *This increases the control by ensuring that all bags are exposed to the same environmental conditions before deployment.*

3. Once you have arrived at the sampling site, use a discharge straw (See Figure 1) to fill 2 or more VOAs with the water from the Blank **at the site, immediately before deploying the bags.** *This gives you the closest possible representation of the composition of the water in the samplers when they are deployed into the well.*

4. **Send the VOAs to the lab as soon as possible for the same analysis the sampler will undergo when it is recovered**

Why Use a Blank?

Water is called the "Universal Solvent" because virtually anything with which the water comes into contact will dissolve into the water over time. Even the most "pure" deionized water will contain traces of compounds that dissolve from casual contact, even through the air, during manufacturing, transport, and handling.

Passive Diffusion Samplers allow some molecules to readily diffuse and not others. If the water in the sampler has molecules that do not readily diffuse out when the sampler is deployed, those molecules will show up in the lab results if they are on the list of compounds routinely reported. Compounds that readily diffuse will equilibrate to the actual groundwater concentrations.

EON offers a water "Trip Blank" that is filled from the same water lot and is exposed to the same environment as the samplers travelling with it. **(See "Using a Field/ Trip Blank" Above)**

By comparing the lab results from the Blank (#4 above) with those from the Samplers, you can account for any VOCs (acetone, for example) reported by the lab that are not in the well. This will ensure the most accurate representation of the water composition inside the well. To insure the quality of our water, we send it to an independent lab before filling each bag. It's smart and easy to use our blank!

***Contact EON for detailed installation information.**

800-474-2490

Discharging a Sample from the Equilibrator™ Passive Diffusion Sampler

EON recommends using 1 sampler with clean water to practice the discharge straw process before sampling in the field

1. Set up the sample bottles in a convenient location for filling.
2. Recover the PDB from the well installation.
3. Locate the polypropylene "Juice Box Straw" provided with the PDB shipment.
4. Grasp the Equilibrator™ firmly but don't squeeze.
5. Press the pointed end of the straw between the black mesh and into the clear membrane. Work the straw tip to puncture the membrane. (Just like a Juice-Box!)
6. Allow the sample to flow through the straw for 1-2 seconds before filling the first bottle.
7. Maneuver the bag and the straw to control the velocity and flow of water into a sample bottle.
8. Do not allow the sample to touch anything other than the sample bottle.
9. Use 1 new straw per PDB to avoid cross contamination.
10. Sample PDBs immediately upon removal from the well.

Hints:

- Immediately after inserting the straw, point it upward along the PDB to reduce the flow.
- Tilting the bag slightly toward horizontal, away from the straw will help control the flow.
- As the sampler empties slight squeezing can help empty the contents.

P.O. Box 443, Snellville, Georgia 30078-0443
800-474-2490 770-978-9971 Fax: 770-978-8661
www.eonpro.com

EQUILIBRATOR™
Diffusion Sampler Instructions

Using a Field/Trip Blank (Prefilled at EON or filled by you)

1. Fill Blank with the **same water** as your samplers at the **same time and place** that you fill them**.** When EON sends you prefilled samplers and a blank, they have been filled and shipped together. *This will serve as a control for the water in the samplers that you will deploy.*

2. Store and **transport Blanks with the other samplers** prior to installing the samplers. *This increases the control by ensuring that all bags are exposed to the same environmental conditions before deployment.*

3. Once you have arrived at the sampling site, use a discharge straw (See Figure 1) to fill 2 or more VOAs with the water from the Blank **at the site, immediately before deploying the bags.** *This gives you the closest possible representation of the composition of the water in the samplers when they are deployed into the well.*

4. **Send the VOAs to the lab as soon as possible for the same analysis the sampler will undergo when it is recovered**

Why Use a Blank?

Water is called the "Universal Solvent" because virtually anything with which the water comes into contact will dissolve into the water over time. Even the most "pure" deionized water will contain traces of compounds that dissolve from casual contact, even through the air, during manufacturing, transport, and handling.

Passive Diffusion Samplers allow some molecules to readily diffuse and not others. If the water in the sampler has molecules that do not readily diffuse out when the sampler is deployed, those molecules will show up in the lab results if they are on the list of compounds routinely reported. Compounds that readily diffuse will equilibrate to the actual groundwater concentrations.

EON offers a water "Trip Blank" that is filled from the same water lot and is exposed to the same environment as the samplers travelling with it. **(See "Using a Field/ Trip Blank" Above)**

By comparing the lab results from the Blank (#4 above) with those from the Samplers, you can account for any VOCs (acetone, for example) reported by the lab that are not in the well. This will ensure the most accurate representation of the water composition inside the well. To insure the quality of our water, we send it to an independent lab before filling each bag. It's smart and easy to use our blank!

***Contact EON for detailed installation information.**

800-474-2490

ATTACHMENT 2

USEPA Standard Operating Procedures:
Slug Tests

SLUG TESTS

CONTENTS

The policies and procedures established in this document are intended solely for the guidance of OLEM employees of the U.S. Environmental Protection Agency (EPA). They are not intended and cannot be relied upon to create any rights, substantive or procedural, enforceable by any party in litigation with the United States. EPA reserves the right to act at variance with these policies and procedures, and to change them at any time without public notice. EPA strongly encourages all readers to verify the validity of the information contained in this document by consulting the most recent Code of Federal Regulations (CFR) and updated guidance documents.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

1.0 SCOPE AND APPLICATION

Slug tests are a quick and reliable method to estimate the hydraulic parameters: transmissivity (T) and, for select cases, storativity (S) in the vicinity of a well location. From the T, hydraulic conductivity (k) can be estimated. A slug test assesses only the impact of groundwater flow in the vicinity of the well. If hydraulic parameters are required over a larger scale, a constant head test or multi-well pumping test is recommended.

Hydraulic parameters that are estimated from a slug test assume horizontal flow within the saturated zone of the saturated-screened interval. Slug tests are ideal for determining the hydraulic parameters for wells ranging from 2- to 6-inch diameter in low to medium permeability formations (e.g., can be pumped or bailed dry), and for determining the spatial variations in hydraulic parameters across a monitoring well field (i.e., aquifer heterogeneities). Slug tests can be completed relatively quickly and easily, and produce reliable and reproducible results. Data analysis of slug tests is not discussed in detail in this document.

A Quality Assurance Project Plan (QAPP) in Uniform Federal Policy (UFP) format describing the data objectives must be prepared prior to deploying for a sampling event. The testers need to ensure that the methods are adequate to satisfy the data quality objectives listed in the QAPP for the site. The procedures in this SOP may be changed if site conditions and or equipment limitations dictate. In all instances, deviations from the SOP must be documented on a Field Change Form and attached to the QAPP and documented in the final deliverable.

For high permeability formations and large diameter municipal wells, it is recommended that a controlled pumping test is done to determine aquifer hydraulic parameters as detailed in in ERT SOP, *Controlled Pumping Test*.

2.0 METHOD SUMMARY

A slug test involves the measurement of groundwater head or pressure over time as it re-equilibrates (stabilizes) following the controlled, instantaneous disturbance of water level (head) within a well. The head change is typically brought about by the insertion or removal of a solid cylinder (slug) into the well or less frequently by the addition/removal of a volume of water. Slug test recovery data is typically collected electronically using an integrated pressure transducer/data logger, however, data may also be collected manually using a water level indicator and a logbook or field sheet. With the removal/addition of water and manual data collection methods, accuracy and ease of conducting the test are sacrificed. Hence, this SOP focuses primarily on the solid slug and electronic data collection method.

Benefits of using a slug test to estimate hydraulic parameters include:

- Measurements are made in-situ, thereby avoiding errors that may occur in a laboratory by testing disturbed soil,
- Tests can be performed quickly at a relatively low cost, and
- If done using a solid slug, the need to treat contaminated water is avoided.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

This section is not applicable to this SOP.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

This SOP defines a single slug test as paired slug-in/slug-out tests. Where practical, at least two slug tests per well are recommended for precision. The technical limitations of slug tests are:

- Only the hydraulic parameters of the aquifer next to the screened interval are estimated, which are likely not representative of the larger scale hydraulic parameters of the water-bearing zone.
- Slug tests are very sensitive to well construction (e.g. primarily sand pack diameter and to a lesser extent screen slot size) and near-well conditions (e.g. primarily inadequate well development or wellbore skin due to drilling). Well development may be the most important factor in the success of a slug test program. Slug tests should be performed only on developed wells. An old well may need to be redeveloped prior to slug testing. Refer to ERT SOP, *Well Development*. A slug test is sensitive to well development because the remobilization of fine particles (silt or clay) trapped in the well will lower the T-value over successive tests. Fine particles that have settled to the well bottom can be mobilized during consecutive slug tests. This can be recognized by overlying displacement curves from the slug-in/slug-out tests (Figure 1), and after data analysis - if the difference in T-values from the first to last test is greater than two-orders of magnitude (Butler, 1997). It is important that a slug test measure the properties of the aquifer and not the effects of the well construction or well development.

5.0 EQUIPMENT/APPARATUS

The following equipment is required to perform a slug test (Figure 3):

- Water-proof ink pen and field logbook;
- Well construction diagram(s);
- Decontamination supplies;
- Water level indicators incremented to hundredths of a foot;
- Varying diameter and length slugs;
- Rope, to secure to the slug to safely insert and remove it from the well;
- Weighted bailer if a solid slug is not used;
- Weighted tapes;
- Integrated water pressure transducers/data loggers;
- Portable computer and appropriate software to access the transducer and manipulate/download data;
- Semi-log graph paper for plotting manually logged data;
- Calculator;
- Submersible pumps and 55-gallon drums in the event well redevelopment is needed; and
- Two field technicians.

6.0 REAGENTS

All equipment must be decontaminated prior to use in a slug test; all down-well tools should be decontaminated upon test completion. Refer to ERT SOP, *Sampling Equipment Decontamination* and the site-specific QAPP for acceptable decontamination protocols.

7.0 PROCEDURES

It is recommended that a slug test is performed with a solid slug, and an integrated transducer/electronic data logger (displayed in Figure 3 and a schematic diagram in Figure 4). The insertion/removal of a slug is relatively instantaneous (Figure 4). A transducer/data logger allows for precision and accuracy of the collected data (Figure 5). It also allows early test data, when pressure head changes rapidly, to be collected geometrically at a high temporal resolution, which is impractical for manual data collection. In relatively high transmissivity zones with rapid head re-equilibration manual measurement may be precluded, and electronic data collection may be the only option (Figure 6). Automated data collection with good teamwork leads to proficiency and improved test results

7.1 Pre-Test Procedure: Selecting a Slug

Slugs should be easily lowered/withdrawn from a well and not impeded by downhole transducer cables and well tapes or well-casing joints. Slugs may be solid cylindrical inserts or fabricated PVC pipe filled with water or sand and capped at both ends. Solid cylindrical inserts have a balanced weight distribution and are preferred. Remember to ensure the cap and bottom plug are flush or account for the slightly wider measurement of slip caps and plugs.

To collect quality data, the United States Geologic Survey (USGS 1997) recommends a head displacement ranging from 0.3 to 3 feet. Slugs can be custom fabricated to any dimension to meet the needs of a particular well/site. However, solid inserts tend to be a standardized four- or five-feet long and are applicable in most scenarios.

It is prudent to have slugs of multiple diameters for a study: well construction and downhole equipment (e.g., transducer and water-level indicator cables, well-casing joints) may reduce available space within a well. For example, when slug testing a 2-inch-diameter well, it is advisable to have both a 1- and 1.5-inch-diameter slugs; and for 4-inch diameter wells, have both a 3- and 3.5-inch-diameter slugs. A 4-inch-diameter slug is about the largest, and will easily fit into larger diameter wells as well along with other downhole equipment.

Tables 1 and 2 can be used in tandem to optimize slug selection. Table 1 displays the displacement volume for different slug diameters (topline) and lengths (first column); and Table 2 lists the projected maximum head displacement for varying well diameters. The tables can be used as follows**:** for a 2-inch-diameter well, a 1.5-inch-diameter, 5-foot-long slug is projected to produce a maximum volume displacement of 0.061 cubic feet (ft^3), highlighted in **yellow** in Table 1; this translates into a 2.5 to 3.0 feet head displacement (Table 2).

TABLE 1
Slug Diameter (inches)

Length (ft)	1	1.5	2.0	2.5	3.0	3.5	4.0
2	0.011	0.025	0.044	0.068	0.098	0.134	0.175
3	0.016	0.037	0.065	0.102	0.147	0.200	0.262
4	0.022	0.049	0.087	0.136	0.196	0.267	0.349
5	0.027	0.061	0.109	0.170	0.245	0.334	0.436
6	0.033	0.074	0.131	0.205	0.295	0.401	0.524

For a 4-inch diameter well: a 3.5-inch-diameter, 4-foot-long slug is projected to produce a maximum volume displacement of 0.267 ft^3 (highlighted in **green** in Table 1) which translates into a maximum head displacement of approximately 3.0-foot (Table 2).

TABLE 2
Slug Displacement Volume in Cubic Feet Based on Slug Diameter and Length

Well Ø (inches)	0.3-ft change	0.5-ft change	1.0-ft change	1.5-ft change	2.0-ft change	2.5-ft change	3.0-ft change
2	0.007	0.011	0.022	0.033	0.044	0.054	0.065
4	0.026	0.044	0.087	0.131	0.175	0.219	0.267
6	0.059	0.098	0.196	0.295	0.395	0.497	0.589

Ø = diameter

7.2 Planning

1. Identify the wells to be tested, the testing method, the slug dimensions (refer to Tables 1 and 2), and all required equipment.

2. Develop a check list of all equipment needed.

3. Obtain and review well construction and development data. Review well development data consistent with ERT SOP, *Monitoring Well Development.* Old wells may need to be redeveloped.

4. Assemble and verify required equipment is functional.

5. Assemble and recheck required equipment. Verify that equipment is clean and in working order. In particular, check and calibrate transducers consistent with ERT SOP, *Submersible Pressure Transducer,* and verify that appropriate software is loaded on the field computer.

6. Determine the order in which wells will be slug tested.

7. Prepare a test schedule and coordinate with staff, clients, and regulatory agency, if appropriate.

7.3 Field Preparation

Review the site QAPP and well construction records: borehole and well radii, screen intervals, filter pack, borehole logs; and time since the wells were installed/developed.

1. Perform a general site survey prior to site entry consistent with the site-specific Health and Safety Plan (HASP).

2. Locate and mark all monitoring wells to be tested.

3. Recheck and ensure the proper operation of all field equipment. If a transducer is used, please refer to ERT SOP, *Submersible Pressure Transducer*.

4. For backup, assemble a sufficient number of field data forms to manually log the tests, if

needed.

5. Redevelop wells identified for redevelopment consistent with ERT SOP, *Monitoring Well Development.* When in doubt, always redevelop a test well.

6. Background water level data should be taken at each well being tested to verify static conditions. A 24-hour period of background monitoring is recommended for the typical case with transducers/data loggers. For manual logging, several equi-spaced manual background water levels should be taken. Hydrologic events that may cause non-static groundwater conditions include nearby pumping, tides, river level fluctuations, recent rainfall recharge, surface mass loading (e.g. passing cargo train), etc.

7.4 Slug-In Test

It is recommended that two technicians perform a slug test: one responsible for slug testing (the slug tester), and the other for data collection (the data collector). Each slug test consists of both falling-head (slug in) and rising-head (slug out) runs (Figure 4, Appendix A). Prior to performing the slug test the following must be completed:

- Record static water level (head) and total well depth in accordance with ERT SOP, *Manual Fluid Level Measurements*.

- Collect data using a pressure transducer with electronic data logging capability. Refer to ERT SOP, *Submersible Pressure Transducer* for guidance on programming data loggers for a test. Typically, an integrated transducer/data logger is used and is installed 1 to 2 feet above the well bottom (Figure 4).

  It is important to place the transducer above any sediment that may have collected in the well trap. Sediment may damage the transducer and adversely impact data.

- Note serial number or other identification number of the transducer in the notes and field data collection sheet. This will allow for tracking of possible corrupted data if a transducer is determined not to be functioning properly.

- Using a field-portable computer (e.g., In-Situ's Rugged Reader), program the transducer/data logger for the manual start data logging option with a logarithmic time scale data collection; refer to ERT SOP, *Submersible Pressure Transducer* for guidance.

When performing a slug test with a solid slug, the following should be done:

1. Attach a sturdy rope to the slug long enough to totally submerge the slug (Figures 3 and 4).

2. Lower the slug into the well about 1-foot or so above the water surface. Following an agreed on approach for initiating the test, the data collector may issue the following command, "1, 2, 3 slug in." At the command of "3", the data collector initiates data collection using the manual start data logging option, and at the command of "slug in", the slug is rapidly lowered by the slug tester (not dropped) below the groundwater surface. The data collection is started incrementally before slug entry to capture the ambient water

level. In the rare event a transducer/data logger is not available, water levels will be logged manually upon insertion of the slug.

3. The slug should be totally submerged, if the water column is greater than the length of the slug. However, care should be exercised to ensure that the slug does not come in contact the transducer. The shock of the slug impacting the transducer may create noise in the data, or, worse yet, damage the transducer. In the event the water column is less than the slug length, part of the slug will protrude above the water surface; this may preclude manual water-level measurements, and a transducer/data logger is the only option. An example of a raw and processed slug-in run is shown in Figure 6.

4. Review the head displacement data to determine when the test is complete (e.g. the water level is stable). End data collection when the test is complete and set up the portable-computer-transducer-data-logger assembly for the slug-out test.

5. To ensure the test precision, repeat the slug-in test at least once

7.5 Slug-Out Test

1. Reprogram the transducer/data logger for the slug-out (rising head) test. Set up the test to collect rising head measurements also on a logarithmic time scale using the manual start data logging option. At the command of “1, 2, 3 slug out” by data collector, the data collector initiates data collection at “3”; and at “slug out,” the slug tester rapidly removes the slug from the water column.

2. Review the head displacement data to determine when the test is complete (e.g. the water level is stable). End data collection when the test is complete and set up for another test, if needed.

3. To ensure the test precision, repeat the slug-out test at least once and compare the data.

4. Automated data collection and good teamwork leads to proficiency and improved test results.

7.6 Post-Test Operation

1. Review and graph data in the field for completeness/precision.

2. Decontaminate or dispose of equipment per ERT SOP, *Sampling Equipment Decontamination*.

3. In the field, regularly download data from the data logger to a portable computer at the end of each field day at the maximum. Back in the office, store all electronic data at a secure location (e.g., on a server under the work assignment specific folder). Compress large data sets (e.g. into *.zip files) for sharing.

4. Replace testing equipment in storage containers.

5. Check equipment and supplies. Repair or replace all broken or damaged equipment.

6. Review field forms for completeness.

7.7 Common Mistakes

The common mistakes associated with slug tests include:

- Not having essential equipment or using malfunctioning equipment at a remote site.
- Dropping or losing a slug (or bailer) in the well: this can be avoided by securing the slug to a sturdy rope and attaching the rope to the outer well casing or some other rigid structure.
- Not reviewing construction details in advance to identify access issues for the down-well test equipment.
- Not having slugs of varying diameters in the field where a slug of larger diameter slug may be needed to create a significant head displacement in a test well (> 0.3-foot), especially in higher transmissivity formations, or where a smaller diameter slug may be needed due to downhole equipment obstruction. It is recommended to have slugs with varying dimensions in the field.
- Dropping the slug on top of the transducer may cause disturbance in the data or damage the transducer.
- Slug testing a new or an old well that needs to be developed/redeveloped.
- Not repeating the slug tests to establish test precision.
- Different data collectors using more than one datum point at the wellhead so that manual water-level measurements have inherent error producing noisy data.
- Slug tester/data collector are unfamiliar with test equipment in advance of field deployment.
- Placing the transducer in sediment collected in the well bottom could impact data quality and accuracy, but may damage the transducer.

7.8 Documentation of Slug Test Data

Well construction details (e.g. screen/casing diameter, depth to top of well screen, screen length, radius of casing, and radius of screen), aquifer conditions (e.g. confined/unconfined, thickness, and static water level), and test data (e.g. transducer depth, slug dimensions, and hydraulic head versus time) will need to be recorded and tabulated for each well to facilitate the slug test data analysis. All data should be collected using consistent units. The method of data analysis should be determined or anticipated prior to mobilizing to the field to ensure all applicable parameters and dimensions are measured and recorded during the test.

8.0 CALCULATIONS

8.1 Data Analysis

Computer software containing analytical solutions (e.g., Hvorslev (1951), Cooper et al (1967), Bouwer and Rice (1976), etc.) can be used for interpreting slug test data. The selected method(s) should be consistent with the groundwater conceptual site model (CSM). The CSM is based on site conditions such as: is the aquifer confined or unconfined, is the well partially or fully penetrating, heterogeneity, etc. Computed values depend on the choice of conceptual model used to analyze data; the selection of an appropriate model is the single most important step in data analysis. A good reference for selecting the correct analysis is the American Society for Testing and Materials (ASTM) D4043-96 (2010).

9.0 QUALITY ASSURANCE/QUALITY CONTROL

Specific QA/QC activities that apply to the implementation of these procedures will be listed in the QAPP prepared for the applicable sampling event. The following general QA procedures will also apply:

1. All data must be documented on approved field data sheets, in a site logbook, and/or recorded electronically.

2. All instrumentation must be operated in accordance with operation instructions as supplied by the manufacturer, unless otherwise specified in the QAPP. Equipment checkout must be performed prior to operation and must be documented.

3. A training record indicating the level of competency for each field employee will be documented and maintained on file.

10.0 DATA VALIDATION

Data validation (completeness checks) must be conducted to ensure that all data inputs are present for ensuring the availability of sufficient information. These data are essential to providing an accurate and complete final deliverable. The Contractor Task Leader (TL) is responsible for completing the UFP-QAPP verification checklist for each project. The data generated will be reviewed and processed by the TL or hydrogeologist prior to distribution.

11.0 HEALTH AND SAFETY

Follow United States Environmental Protection Agency (U.S. EPA), Occupational Safety and Health (OSHA), and corporate health and safety practices when working with potentially hazardous materials or field hazards. All Contractor field activities require a site-specific HASP.

12.0 REFERENCES

American Society for Testing and Materials (ASTM), 2005. Method D5912-96: (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug).

American Society for Testing and Materials (ASTM), 2005. Method D5881-95: (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug).

American Society for Testing and Materials (ASTM), 2008. Method D4044-96: (Field Procedure) for Instantaneous Changes in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers.

American Society for Testing and Materials (ASTM), 2010. Method D4043-96: Standard Guide for the Selection of Aquifer-Test Methods in Determining the Hydraulic Properties by Well Techniques.

American Society for Testing and Materials (ASTM), 2010. Method D4104-96: (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests).

American Society for Testing and Materials (ASTM), 2013. Method D5785-95: (Analytical Procedure) for Determining Transmissivity of Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Tests).

Bouwer H. and Rice, R.C., 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells, Water Resources Research, V. 12, No. 3, pp. 423-428.

Butler, J.J., 1997. The Design, Performance, and Analysis of Slug Tests, Lewis Publishers, New York.

Bureau of Reclamation, 1985. Ground Water Manual. U.S. Department of the Interior.

Cooper, H.H., Bredehoeft, J.D., and Papadopulos, I.S., 1967, Response of a Finite Diameter Well to an Instantaneous Charge of Water, Water Resources Research, V. 3, No. 1, pp 263-269.

Dawson, K. and J. D. Istok, 1991. Aquifer Testing, Design, and Analysis of Pumping and Slug Tests. Lewis Publishers, Inc.

Driscoll, F. G. (editor), 1986. Groundwater and Wells. 2nd edition. Johnson Screens, St. Paul, Minnesota.

Ferris, J. G., D. B. Knowles, R. H. Brown, and R. W. Stallman, 1962. Theory of Aquifer Tests. U.S. Geological Survey, Water-Supply Paper 1536E.

Hvorslev, M.J. 1951, Time Lag and Soil Permeability in Ground-Water Observations, Waterways Experiment Station, Corps of Engineers, US Army Bulletin, No. 36, p50.

Lohman, S. W., 1972. Groundwater Hydraulics. U.S. Geological Survey Professional Paper 708.

Ohio EPA, 2006. Pumping and Slug Tests, Chapter 4, *Technical Guidance Manual for Ground Water Investigations*. Division of Drinking and Ground Waters. State of Ohio Environmental Protection Agency. December 2006.

Todd, D. K., 1980. Groundwater Hydrology. 2nd edition. John Wiley & Sons, Inc.

Unites States Geological Survey (USGS). 1997. GWPD17 – Conducting an Instantaneous Change in Head (Slug) Test with a Mechanical Slug and Submersible Transducer, Ver 2010.1.

13.0 APPENDICES

A – Figures
B – Slug Test Data Sheet

APPENDIX A
Figures
SOP: ERT-PROC-2046-20
April 2020

FIGURE 1

Three consecutive slug tests show a decreases of transmissivities or evidence of a low-transmissivity, well skin effect (Butler, 1997)

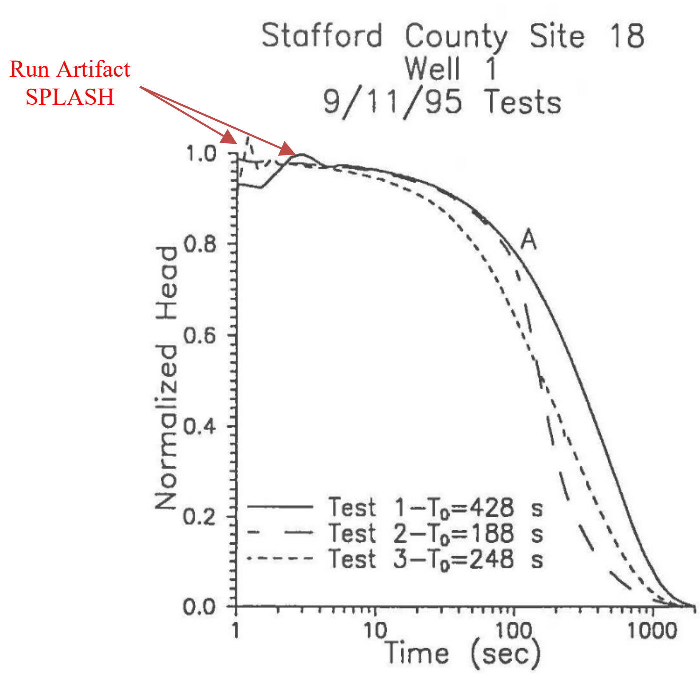


FIGURE Normalized head ($H(t)/H_0$, where $H(t)$ is measured deviation from static and H_0 is magnitude of the initial displacement) vs. log time plot of a series of slug tests performed in well 1 at monitoring site 18 in Stafford County, Kansas (T_0 and A defined in text).

FIGURE 2

Deflection of the displacement curve at point "A" suggests the early recovery represents the well efficiency or high-transmissivity well skin effect and later recovery indicative of the formation transmissivity (Butler, 1997)

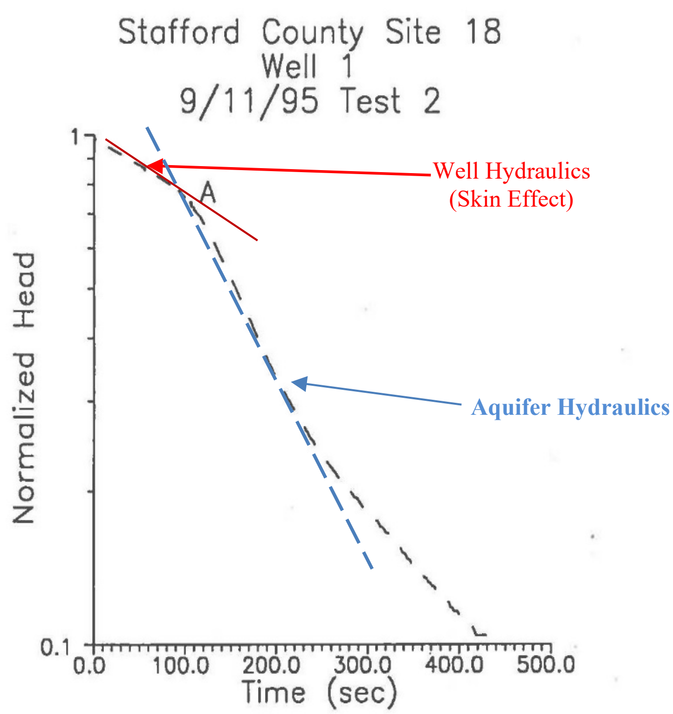


FIGURE Logarithm of normalized head ($H(t)/H_0$) vs. time plot of a slug test performed in well 1 at monitoring site 18 in Stafford County, Kansas (A defined in text).

FIGURE 3. Slug Test Equipment

FIGURE 4. Falling Head and Rising Head Slug Test Diagram

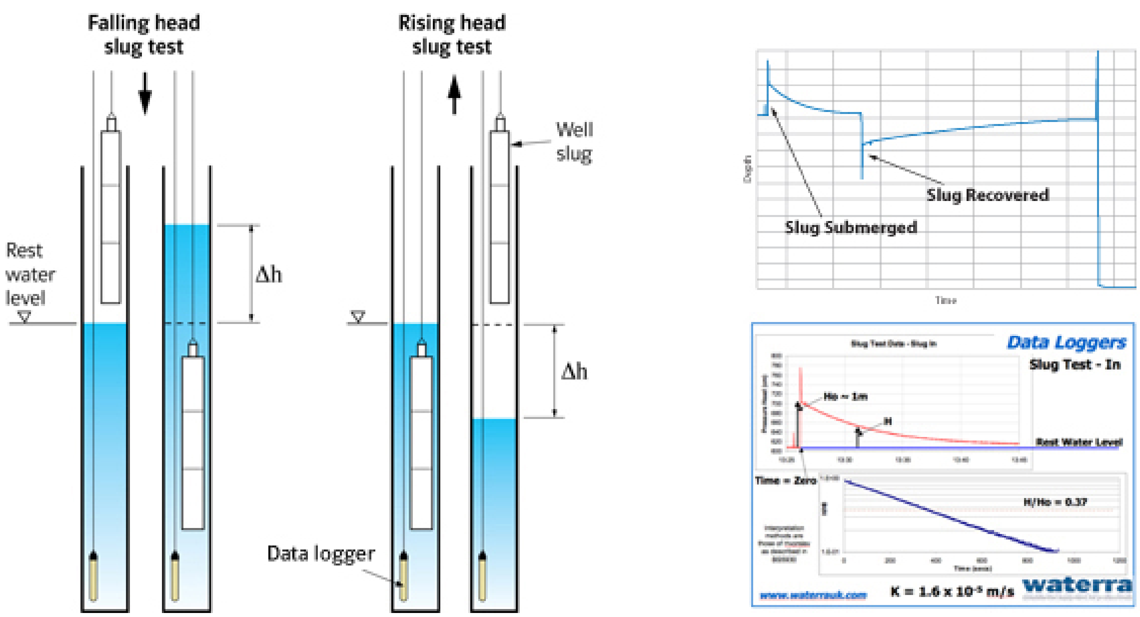
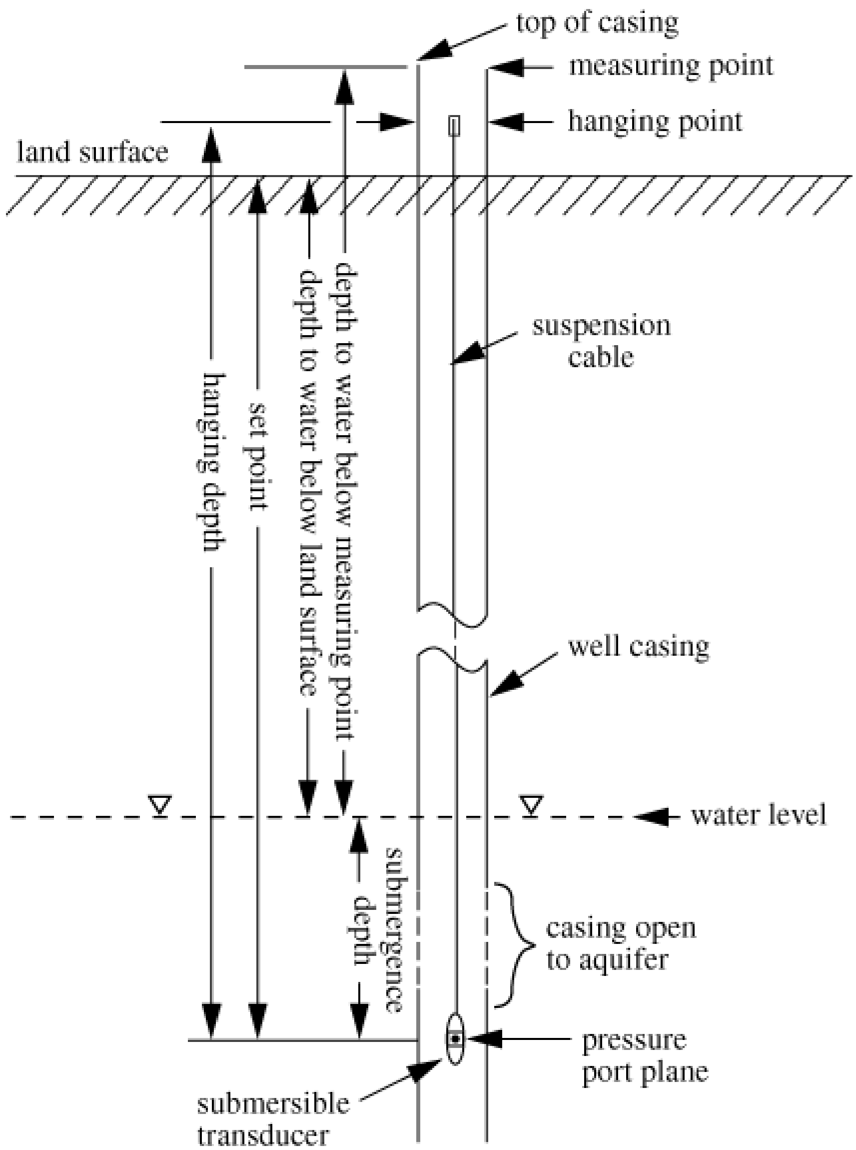
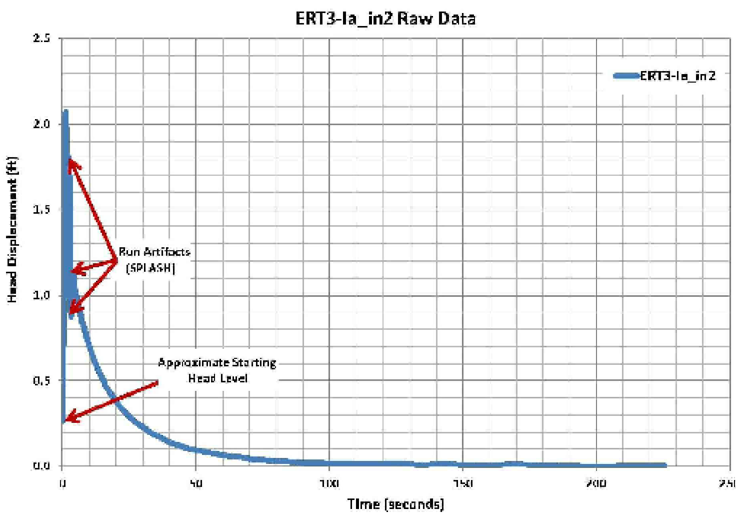


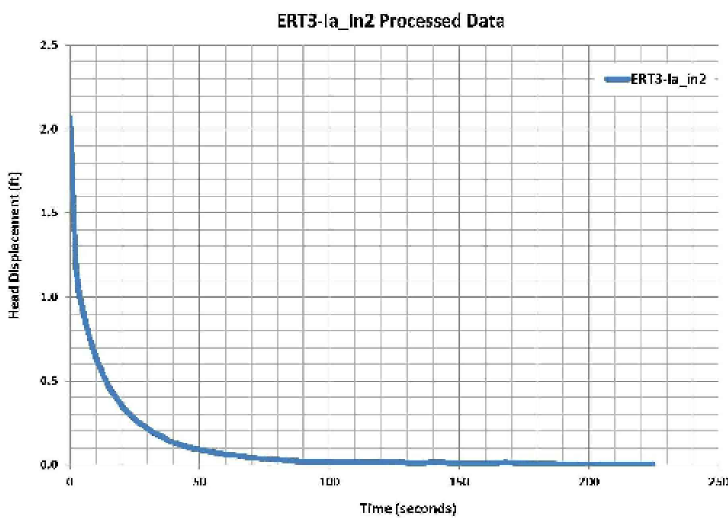
FIGURE 5. Installation of a Submersible Pressure Transducer Diagram



(Taken from USGS, Techniques of Water Resources Investigations 8-A3)

FIGURE 6. Example of Raw and Processed Data from a Slug-In Run





APPENDIX B
Slug Test Data Sheet
SOP: ERT-PROC-2046-20
April 2020

PAGE 1 OF 1

SLUG TEST DATA SHEET

SITE ID: ___________________________

TOTAL DEPTH OF WELL (FT): __________
DEPTH TO WATER ____________________
HEIGHT OF WATER COLUMN: _________

WELL ID: __________________________

LOGGER: ____________________

TEST START

DATE: ______________
TIME: ______________
STATIC WATER LEVEL (FT): ______

TEST END

DATE: ________________
TIME: ________________
STATIC WATER LEVEL (SWL-FT): ______

MEASUREMENT METHODS _________________________________
COMMENTS ____
____

ELAPSED TIME (min)	DEPTH TO WATER (DTW_t ft)	DISPLACEMENT[1] (SWL-DTW_t ft)	COMMENTS

min = minutes, ft = feet, SWL = Static Water Level, DTW_t = Depth to Water at Time at *t*,

1. Displacement is defined as SWL - DTW_t, with maximum displacement between 1 to 3 feet.