PACIFIC groundwater GROUP

SUNNYSIDE MUNICIPAL AIRPORT
PESTICIDE SPRAY SHED
REMEDIAL INVESTIGATION WORK PLAN
SUNNYSIDE, WASHINGTON

December 17, 2013

SUNNYSIDE MUNICIPAL AIRPORT
PESTICIDE SPRAY SHED
REMEDIAL INVESTIGATION WORK PLAN
SUNNYSIDE, WASHINGTON

Prepared for:

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Sunnyside RIWP

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SIGNATURE

This report, and Pacific Groundwater Group's work contributing to this report, were reviewed by the undersigned and approved for release.

2664

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1.0 INTRODUCTION

The Sunnyside Municipal Airport serves the City of Sunnyside and surrounding agricultural areas and is located on the eastern edge of the city (Figure 1). The Sunnyside Municipal Airport is owned by the City of Sunnyside. Portions of the airport have been used for crop duster operations including tank filling and aircraft spray down since the 1940s. Ecology confirmed the presence of pesticide-impacted soil in 2010 near a former pesticide storage shed.

The primary objective of the Remedial Investigation Work Plan (RI Work Plan) is to identify work to be completed in support of a Remedial Investigation report (RI). The RI will include the site conceptual model, description of the nature and extent of contamination, fate and transport analysis, and proposed cleanup levels. The RI will provide the basis for an Interim Action or Feasibility Study to be conducted under an amendment to the Agreed Order.

The proposed field sampling and analysis will include a preliminary geophysical investigation of the extent of buried debris and two phases of soil and groundwater sampling. Phase I will collect soil samples across the site in a coarse grid, and groundwater samples at three locations to investigate the nature and extent of pesticide impacts. Phase II will fill data gaps identified in the Phase I results.

Pacific Groundwater Group has produced this RI Work Plan under contract to The City of Sunnyside. PGG's work was performed, and this report prepared, using generally accepted hydrogeologic and environmental practices at this time and in this vicinity, for exclusive application to Sunnyside Municipal Airport Pesticide Shed site and for the exclusive use by the City of Sunnyside. This is in lieu of other warranties, express or implied.

The City presents this draft RI Work Plan in accordance with Agreed Order DE 9746.

1.1 GENERAL FACILITY INFORMATION

Site Name: Sunnyside Municipal Airport Pesticide Spray Shed
Site Address: 3318 Edison Road, Sunnyside, WA 98944
Parcel Number: 23102924003
Facility/Site ID: 20367
Cleanup Site ID: 11423
Agreed Order Number: DE 9746 (effective March 13, 2013)

1.2 SITE HISTORY

The Sunnyside Municipal Airport has been active since at least the 1940s. The airport was originally a dirt strip with later paving of the runway and taxiways.

Ecology began a preliminary site investigation after a citizen report of pesticide releases related to a now-removed pesticide storage shed (Ecology, 2008; 2010). Ecology phone interviews in 2010 indicated several locations of historic use:

- Aircraft wash down area.
- Storage shed located mid-field, near the plane wash-down area; this shed was reportedly removed in the early 1990s.

- Possible runoff to the south from wash down area.

Ecology collected soil samples soil in October 2010 that confirmed the presence of pesticides in soil (Table 1). Soil samples were analyzed for herbicides (Method 8151A), organochlorine pesticides (Method 8081A), and petroleum hydrocarbon identification. Soil samples at all four locations (5 samples) exceeded screening levels (Ecology, 2010) (Figure 2). Motor oil and diesel-range petroleum hydrocarbons were detected in one sample, with concentrations below MTCA Method B standard table value cleanup levels. The petroleum detections likely reflect incidental spills from vehicle parking. Ecology added the site to the confirmed and suspected contaminated sites list (CSCSL) upon receipt of the laboratory data. Ecology has not issued a formal site hazard assessment and site ranking.

It is likely that the pesticide releases to soil occurred in the 1980s or earlier. All of the pesticide and herbicide compounds exceeding MTCA Method B cleanup levels have been banned by the EPA for more than 20 years:

- Toxaphene was banned in 1990 (EPA, 2013A)
- DDT was banned in 1972 (EPA, 1972)
- DDE is a breakdown product of DDT
- Dieldrin was banned in 1987 (EPA, 2013B)

Buried metal debris was encountered during foundation excavation for a new building constructed at the site in 2010. The buried debris was encountered at between 5 and 7 feet below ground surface at the southwest corner of the building. The metal debris reportedly included metal cans with markings indicating that they held pesticides including DDT. The age of the metal debris is not known.

The site is currently used for civilian aviation including support for crop dusting operations and operation of other small aircraft. The site is level and is not paved beyond the edges of the asphalt taxiway.

1.3 DISTRIBUTION LIST

The following individuals will receive copies of the RI Work Plan after review and approval by Ecology.

- Jennifer Lind, Site Manager, Department of Ecology (509) 454-7839
- Shane Fisher, Designated Representative, City of Sunnyside (509) 837-5399
- Glen Wallace, Project Manager, Pacific Groundwater Group, (206) 329-0141

1.4 QUALITY ASSURANCE PROJECT PLAN

The Quality Assurance Project Plan is located in Appendix A.

1.5 PUBLIC PARTICIPATION PLAN

Ecology will maintain the responsibility for public participation at the Site, and the site does not have a formal Public Participation Plan (PPP). Public participation requirements are described in the Agreed Order (DE 9746).

1.6 GEOLOGIC SETTING

The Sunnyside Municipal Airport is located on Quaternary sedimentary deposits including both fluvial deposits and Missoula Flood deposits (Schuster, 2005). These sediments overlie a broad structural basin formed by folded Columbia River Basalts and interbeds of the sedimentary Ellensburg Formation. Nearby well logs indicate that the surficial unit is composed of approximately 35 feet (ranging in thickness from 20 to 68 ft) of clay and sand, which generally overlies either a deeper sand-gravel or bedrock aquifer.

1.6.1 Groundwater

Shallow groundwater regionally flows to the southwest (USGS, 2009). Depth to groundwater has not been measured at the site, but is expected to be between 5- and 18-feet below ground surface based on the depth of nearby irrigation drains and water levels in nearby domestic wells. The water level is expected to vary seasonally with changes in irrigation pumping and infiltration. Deeper wells in the vicinity are flowing-artesian.

2.0 CONSTITUENTS OF POTENTIAL CONCERN

Constituents of Potential Concern (COPCs) at the site include pesticides and herbicides. Organochlorine pesticides and herbicides were detected in soil above MTCA Method B direct standard formula values (Ecology, 2010) (Table 1); organophosphorous pesticides have likely been used at the site. Diesel and/or naphthalene may have been used as carrier application fluid. Table 2 lists COPCs in the three classes of pesticides and herbicides, and petroleum compounds:

- Organophosphorous Pesticides
- Organochlorine Pesticides
- Herbicides
- Diesel-range hydrocarbons (TPH-Dx), naphthalene, benzene, toluene, ethylbenzene, xylenes (BTEX)

BTEX compounds were not independently used as pesticide/herbicide carrier fluids, but are included as indicators of petroleum mixtures.

3.0 PRELIMINARY SITE CONCEPTUAL MODEL

The preliminary site conceptual model is based on available data including telephone interviews conducted by Ecology staff, samples collected by Ecology in 2010, regional hydrogeology, and physical characteristics of pesticides and herbicides in soil and groundwater. The source areas for the pesticide and herbicide contamination are likely the aircraft wash down area and an adjacent storage shed (also referred to as the spray shed) which is reported to have been used for pesticide storage and handling in support of spray operations. Releases likely occurred during handling near the shed, as residue washed off of planes, with subsequent redistribution at the surface through surface runoff or tracking. Significant vertical migration through leaching is likely restricted to primary release areas where use was associated with standing water and subsequent infiltration. Diesel and naphthalene have commonly been used as carrier fluid for pesticides and herbicides; if this practice was adopted at this site, then petroleum impacts may also be present in pesticide and herbicide preparation and storage areas.

Buried debris including metal cans was discovered at approximately 5- to 7-feet bgs during excavation for a building foundation in 2010 (Figure 3). The metal cans reportedly had markings indicating that they had contained pesticides, and the debris is therefore assumed to be impacted with pesticide residue. Given the depth of the debris, it is most likely to have been placed in an excavation, and is therefore expected to occur within limited areas. The extent and distribution of the debris is not known and debris may be present in one or multiple locations.

Groundwater impacts are expected to be minimal because the majority of the contaminant mass is likely to be sorbed to soils in the vadose zone. Organochlorine pesticides such as DDT and toxaphene have strong sorption coefficients and low solubility in water (Flury, 1996). Shallow groundwater contamination beneath the site is possible due to leaching, though not expected to be substantial since most pesticides and herbicides sorb strongly to soils and have low solubilities.

3.1 POTENTIAL RECEPTORS

The site conceptual model suggests several potential receptor pathways that should be considered in evaluating impacts to human health and the environment. Potential receptor pathways include:

- Soil direct contact
- Soil ingestion
- Soil leaching to groundwater
- Groundwater direct contact
- Groundwater consumption

Groundwater consumption is unlikely to be a complete receptor pathway due to the hydrophobic characteristics of COPCs, and travel distance to the nearest potential receptors.

Receptor pathways will be evaluated in the Remedial Investigation report.

3.1.1 Terrestrial Ecological Evaluation

Terrestrial ecological evaluations (TEE) are conducted to determine if contamination at a site presents risk to plants or animals that may inhabit or occupy the site. The TEE follows a tiered approach in which a simplified screening is used to determine 1) no risk and the TEE is complete or 2) to a site-specific evaluation is necessary in which terrestrial receptors are considered in the calculation of cleanup levels.

A simple TEE for the site indicates that the site does not have a substantial potential for adverse effects to terrestrial receptors by meeting the criteria in WAC173-340-7492(2)(a)(ii). The simple TEE uses scoring criteria outlined in WAC 173-340 Table 749-1, in which the area of undeveloped land is compared to potential terrestrial impact indicators. If the score allocated to the undeveloped area is less than the score allocated to the impact indicators, then the TEE is complete. Criteria entered in Table 749-1 and input rationale is listed below:

Undeveloped Area Criteria:

1. There are approximately 1.8 contiguous undeveloped acres at and west of the site[1]. Surrounding areas are either paved, cultivated (plowed), covered by buildings, or covered by gravel roads (Figure 2). This area corresponds to a score of 8.

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[1] According to WAC 173-340-7491(1)(c)(iii): *""undeveloped land" shall mean land that is not covered by buildings, roads, paved areas or other barriers that would prevent wildlife from feeding on plants, earth-worms, insects*

Potential Impact Criteria:

2. The site is a commercial property with a score of 3.
3. The undeveloped area is mowed grass and weeds, and has a “Low” habitat quality with a corresponding score of 3.
4. The area is disturbed, and unlikely to attract wildlife, resulting in a score of 2; birds are actively discouraged at airports.
5. Pesticides listed in Table 749-1 are present at the site, with a corresponding score of 1.

The undeveloped area criteria score (8) is less than the sum of indicator criteria 2 through 5 (9) completing the requirements of the TEE. The score comparison indicates that the site does not have a substantial potential for adverse effects to terrestrial receptors.

4.0 SOIL AND GROUNDWATER REGULATORY LEVELS

Soil and groundwater screening levels are developed based on a review of applicable, relevant and appropriate requirements (ARARs), and summarized in Tables 3 and 4. Current soil and groundwater ARARs were downloaded from the Washington Department of Ecology Cleanup Levels and Risk Calculations (CLARC) online database in April 2013.

4.1 GROUNDWATER SCREENING LEVELS

The groundwater screening levels are based on a review of applicable state and federal surface water and groundwater criteria, with the most stringent values selected as site screening levels (Table 3). PQLs are adopted as conservative screening levels for δ-BHC, dichloroprop, and diazinon. Practical quantitation limits (PQLs) are used as groundwater screening levels for constituents without applicable ARAR values. Those constituents without ARAR values also do not have adequate toxicological data in the EPA integrated risk information system (IRIS) database to calculate soil and groundwater screening levels following MTCA Method B equations (720-1, 720-2, 740-1, 740-2)(MTCA, 2007).

4.2 SOIL SCREENING LEVELS

Soil screening levels applied to the Sunnyside Municipal Airport Pesticide Spray Shed site are the more stringent of MTCA standard formula values based on direct contact, or the soil concentration protective of the soil leaching to groundwater pathway (Table 4). PQLs are adopted as conservative screening levels for δ-BHC, dichloroprop, and diazinon, which have neither published ARAR values nor adequate toxicological data to calculate a value using the Method B procedures.

Soil protective of groundwater values are calculated using Equation 747-1 from WAC 173-340-747 to be protective of the groundwater screening levels listed in Table 3. Default values are used for fraction organic carbon, air- and water-filled porosity, and soil bulk density. Octanol-water coefficients (Koc) and Henrys Law constants (Hcc) are taken from the Ecology Clarc online database where available; literature values are used where Clarc values are not available.

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or other food in or on the soil. "Contiguous" undeveloped land means an area of undeveloped land that is not divided into smaller areas by highways, extensive paving or similar structures that are likely to reduce the potential use of the overall area by wildlife.”

5.0 FIELD SAMPLING PLAN

Sampling and analysis will include a preliminary geophysical investigation of the extent of buried debris and two phases of soil and groundwater sampling. Phase I will collect soil samples across the site in a coarse grid, and groundwater samples at three locations to investigate the nature and extent of pesticide impacts. Phase II will fill data gaps identified in the Phase I results. Sampling and quality assurance protocols are included in Appendix A. Appendix B is the Health and Safety Plan for the sampling activities.

5.1 PRELIMINARY DEBRIS MAPPING

The extent of buried debris will be mapped using a magnetometer within the area shown on Figure 3. Debris is expected to occur in clusters based on a conceptual model of the debris having been placed in excavations. The objective of the debris mapping will be to outline the extent, to facilitate estimation of the quantity of debris, and to determine locations for soil and groundwater sampling to assess potential impacts from the debris. Phase I sampling locations may be revised based on the mapped extent of debris.

The debris will be mapped using portable electromagnetic instruments similar to a Geonics EM-31 MK2 and/or EM-61 MK2. These devices are similar to metal detectors, but designed to detect metal objects at depths up to 10 ft, and are commonly used to locate buried ordinance and other buried metal materials. The magnetometers will be run on transects spaced 10-feet apart across the area shown in Figure 3. Anomalies will be plotted on a field map.

The metal building adjacent to the known buried debris and overhead power lines to the south may cause interference with the magnetometer readings. Areas beneath existing structures will not be accessible for magnetometer readings.

5.2 PHASE I SOIL AND GROUNDWATER SAMPLING

Phase I soil and groundwater sampling will be at locations with expected contamination based on site history. A direct-push drill rig will be used to collect samples following procedures outlined in Appendix A. Soil and groundwater samples will be analyzed for the standard laboratory analyte lists for constituents listed in Table 2; a subset of soil samples will be analyzed for petroleum compounds. All samples will be collected into laboratory provided containers and placed on ice in clean coolers.

5.2.1 Soil Sampling

Soil samples will be sampled from discrete depth intervals at 17 locations shown in Figure 3. Samples will be collected from the following depth intervals:

- Between 6- and 18-inches below ground surface
- Between 30- and 42-inches below ground surface
- At base of buried metal debris, where present

Sample depth intervals and locations may be modified based on field conditions and observations, or based on results of the preliminary debris mapping. Boring will be advanced to at least the target sampling intervals with total depths rounded up to the direct push drill rod length (typically increments of 4- or 5-feet). Boring logs will be completed for each soil exploration location.

Petroleum compounds will be analyzed in the 5 soil samples from the 6- to 18-inch interval located between the former spray shed and the building immediately to the west. Soil samples with petroleum odors or staining in soil cores will also be analyzed for petroleum compounds.

Samples will be analyzed in a tiered approach to provide adequate spatial coverage while minimizing analytical costs. Exceedance of cleanup levels in a shallow sample (6-18 inches) will trigger analysis of the paired deeper sample (30-42 inches) for the analytical method with the exceedance provided both the shallow and deep samples can be analyzed within holding times. If the tiered approach cannot be completed within applicable holding times, then both samples will be analyzed.

5.2.2 Groundwater Sampling

Three groundwater samples will be collected at the water table in historic use areas (Figure 3). Groundwater sample locations target areas that were most likely to have had COCs reach the water table based on historic use, including the location of buried debris. Groundwater is assumed to flow to the southwest, however local variations in groundwater flow may occur at and near the site (ie, local flow direction to the west or south). Therefore, groundwater samples are located as close as possible to potential release areas such that they will remain downgradient or within a potential hotspot within the expected range of possible groundwater flow directions.

Samples will be collected from a temporary direct-push well with either a standard 4-foot stainless steel telescoping screen, or with a temporary 10-slot PVC pipe set in the borehole if direct-push screens produce excessive turbidity or prohibitively slow flow rates. The temporary well will be purged using a peristaltic pump, with special attention to minimizing turbidity. All boreholes will be backfilled with bentonite chips or granules after sampling is completed.

Inclusion of sediment in groundwater samples (artifactual turbidity) due to disturbance of the soil during drilling and sampling could bias samples high due to hydrophobic constituents sorbed to soil particles. The potential inclusion of sorbed contaminants on soil particles bias analytical results high because contaminant mass sorbed to soil particles would not be mobile in groundwater flow. Therefore, samples will be lab-centrifuged prior to extraction if field observations indicate excessive turbidity; turbidity exceeding 10 nephelometric turbidity units (NTU) will trigger centrifuging. Centrifuging is preferred to filtering because hydrophobic compounds could sorb to filter media and bias results low.

5.3 PHASE II SOIL AND GROUNDWATER SAMPLING

Phase II sampling will fill data gaps identified following review of the Phase I sampling results. Phase II samples will be analyzed for constituents that exceeded the site screening levels or indicator constituents instead of the full analyte list in Table 2 where adequate information on nature and extent can be obtained from the reduced analyte list (Section 5.5).

Phase II sampling locations and analytes (see Section 5.4) will be proposed to Ecology via email as tables and figures for review. Ecology is requested to provide review of sampling locations within 7 calendar days of submittal because Phase II sampling must be approved by Ecology and meet the schedule outlined in the Section 6.

5.4 GROUNDWATER SAMPLING CONTINGENCY

Because of the hydrophobic characteristics of the COCs at the site, groundwater is not anticipated to exceed cleanup levels. However, if groundwater samples collected during Phase I exceed screening levels, monitoring wells will be installed during Phase II at locations identified from Phase I results.

5.5 INDICATOR HAZARDOUS SUBSTANCES

If appropriate, based on a review of data during Phase I and II sampling, the analyte list will be reduced to include only indicator hazardous substances (IHS). MTCA allows a reduced analyte list of IHS to be used for the purposes of defining site cleanup requirements when other substances only contribute a small percentage to the overall threat to human health and the environment (WAC 173-340-703). The use of IHS will be reviewed during analysis of Phase I samples and proposed for implementation if technically supported. Transition to use of IHS will be implemented if approved in writing by Ecology.

Preliminary data indicate that contamination at the site may be suitable for adoption of an IHS approach. Sampling results indicate that organochlorine pesticide constituents toxaphene, DDT, DDE, dieldrin, and possibly endosulfan compounds are detected at higher concentrations than most analyzed constituents, and also constitute the largest percentage of the overall threat to human health and the environment (Table 1). Other constituents are detected close to reporting limits and are below screening levels.

6.0 SCHEDULE

Sampling will begin within 30 days of Ecology approval of the RI Work Plan and be completed within 60 days. A draft Remedial Investigation report will be submitted within 60 days of receipt of final analytical data.

7.0 REFERENCES

Ecology, 2008. *Environmental Report Tracking System Initial Report*. ERTS # 609136.

Ecology, 2010. *Department Decision Recommendation Sunnyside Municipal Airport Pesticide Spray Shed*. ERTS # 609136, F/S # 20367. September 28, 2010.

EPA, 1972. *DDT Ban Takes Effect*. EPA press release visited on 5/3/13 at http://www.epa.gov/history/topics/ddt/01.html

EPA, 2013A. *Basic Information about Toxaphene in Drinking Water*. Visited on 5/3/13 at http://water.epa.gov/drink/contaminants/basicinformation/toxaphene.cfm

EPA, 2013B. *Aldrin/Dieldrin,Persistent Bioaccumulative and Toxic (PBT) Chemical Program*. Visited on 5/3/13 at http://www.epa.gov/pbt/pubs/aldrin.htm

Flury, M., 1996. Experimental Evidence of Transport of Pesticides through Field Soils- A Review. Journal of Environmental Quality. Vol. 25, no. 1. January 1996.

Schuster, E., 2005. *Geologic Map of Washington State*. Department of Natural Resources Geologic Map Series.

USGS, 2009. Hydrogeologic Framework of the Yakima River Basin Aquifer System, Washington. Scientific Investigations Report 2009–5152.

Model Toxics Control Act (MTCA), 2007. Chapter 70.105D RCW; MTCA Cleanup Regulation in Chapter 173-340 WAC.

Table 1. Ecology Soil Sampling Results

Sunnyside Airport Pesticide Shed, Sunnyside, Washington

Constituent	Unit	180610SMA-S001-06	180610SMA-S001-12	180610SMA-S002-12	180610SMA-S003-16	180610SMA-S004-12	*Soil Screening Level*
Organochlorine Pesticides (Method 8081A)							
4,4'-DDD	ug/Kg	**160**	**180**	**0.4 J p**	**63**	**200**	335
4,4'-DDE	ug/Kg	**130**	**930**	**4.1 p**	**680**	**3400**	446
4,4'-DDT	ug/Kg	**4700**	**4700**	**13**	**1600**	**4300**	2941
Aldrin	ug/Kg	1.1 U	1 U	1.1 U	1.1 U	1.1 U	2.5
α-BHC	ug/Kg	1.1 U	1 U	1.1 U	1.1 U	1.1 U	0.5
cis-Chlordane	ug/Kg	1.1 U	1 U	1.1 U	1.1 U	1.1 U	2857
β-BHC	ug/Kg	1.1 U	1 U	1.1 U	1.1 U	1.1 U	2.3
δ-BHC	ug/Kg	1.1 U	1 U	1.1 U	1.1 U	1.1 U	1.0
Dieldrin	ug/Kg	**30**	**180**	**8.1**	2.1 U	2.2 U	2.8
Endosulfan I	ug/Kg	**5.2 p**	**15 p**	1.1 U	1.1 U	1.1 U	304683
Endosulfan II	ug/Kg	**48 P**	**150 P**	**2.7 P**	**94 P**	**100 P**	304683
Endosulfan sulfate	ug/Kg	2.1 U	2.1 U	2.2 U	2.1 U	2.2 U	480000
Endrin	ug/Kg	2.1 U	2.1 U	**2.4**	2.1 U	2.2 U	440
Endrin aldehyde	ug/Kg	2.1 U	2.1 U	2.2 U	2.1 U	2.2 U	24000
Endrin ketone	ug/Kg	2.1 U	2.1 U	**0.63 J p**	**82 P**	2.2 U	8560
γ-BHC (Lindane)	ug/Kg	**2.3**	**6.1**	**2.7**	1.1 U	1.1 U	6.2
trans-Chlordane	ug/Kg	1.1 U	1 U	**1.5 p**	1.1 U	1.1 U	2857
Heptachlor	ug/Kg	1.1 U	1 U	1.1 U	1.1 U	1.1 U	3.8
Heptachlor epoxide	ug/Kg	**5.3 p**	**18 p**	1.1 U	**7.9 p**	**12 p**	8.0
Methoxychlor	ug/Kg	^	10 U	^	11 U^	^	64160
Toxaphene	ug/Kg	**2900**	**13000**	**77 J p**	**7300**	**11000**	153
Herbicides (Method 8151A)							
2,4,5-T	ug/Kg	7.2 U	7.1 U	7.3 U	7.2 U	7.2 U	1.0
2,4-D (Dichlorophenoxyacetic a	ug/Kg	**7 J**	**14**	7.3 U	7.2 U	**31**	860
2,4-DB (Dichlorophenoxy, 2,4-	ug/Kg	7.2 U	7.1 U	7.3 U	7.2 U	7.2 U	16179
Dalapon	ug/Kg	27 U	27 U	27 U	27 U	27 U	959
Dicamba	ug/Kg	18 U	18 U	18 U	18 U	18 U	3258
Dichloroprop	ug/Kg	7.2 U	7.1 U	7.3 U	7.2 U	7.2 U	1.0
Dinoseb	ug/Kg	18 U	18 U	**10 J**	18 U	18 U	688
MCPA	ug/Kg	7.2 U	7.1 U	7.3 U	7.2 U	7.2 U	424
MCPP (Mecoprop)	ug/Kg	7.2 U	7.1 U	7.3 U	7.2 U	7.2 U	498
Pentachlorophenol	ug/Kg	**13 J**	**6.5 J**	18 U	18 U	18 U	3.5
2,4,5-TP (Silvex)	ug/Kg	7.2 U	7.1 U	7.3 U	7.2 U	7.2 U	4979
Petroleum Compounds							
#2 Diesel (>C12-C24)	mg/Kg	53 U	52 U	53 U	52 U	**94 Y**	
Gasoline	mg/Kg	21 U	21 U	21 U	21 U	21 U	
Motor Oil	mg/Kg	110 U	100 U	110 U	100 U	**710**	
Soil Parameters							
Percent Moisture	%	8	7.6	10	8.8	9.3	
Percent Solids	%	92	92	90	91	91	

Notes:
U: Non-detect at reporting limit shown
^: Instrument related QC exceeds the control limits, no result reported.
J: Result is less than reporting limit, but greater than MDL; result is approximate.
p: The %RPD between the primary and confirmation column/detector is >40%. The lower value has been reported.
P: The %RPD between the primary and confirmation column/detector is >40%. The higher value has been reported
Y: The chromatographic response resembles a typical fuel pattern.
0.2 Bold indicates compound detected above reporting limit; shading indicates exceedance of screening level (see Table 4)
Samples collected June 18, 2010 by Jason Shira, Washington Department of Ecology.
ug/kg: micrograms per kilogram
mg/kg: milligrams per kilogram

Table 2. Soil and Groundwater Constituents

Sunnyside Airport Pesticide Shed, Sunnyside, Washington

Constituent	CAS Registry No	Analytical Method
Organochlorine Pesticides		
Aldrin	309-00-2	EPA 8081B
α-BHC	319-84-6	EPA 8081B
β-BHC	319-85-7	EPA 8081B
γ-BHC (Lindane)	58-89-9	EPA 8081B
δ-BHC	319-86-8	EPA 8081B
cis-Chlordane	5103-71-9	EPA 8081B
trans-Chlordane	5103-74-2	EPA 8081B
4,4'-DDD	72-54-8	EPA 8081B
4,4'-DDE	72-55-9	EPA 8081B
4,4'-DDT	50-29-3	EPA 8081B
Dieldrin	60-57-1	EPA 8081B
Endosulfan I	959-98-8	EPA 8081B
Endosulfan II	33213-65-9	EPA 8081B
Endosulfan sulfate	1031-07-8	EPA 8081B
Endrin	72-20-8	EPA 8081B
Endrin aldehyde	7421-93-4	EPA 8081B
Endrin ketone	53494-70-5	EPA 8081B
Heptachlor	76-44-8	EPA 8081B
Heptachlor epoxide	1024-57-3	EPA 8081B
Hexachlorobenzene	118-74-1	EPA 8081B
Methoxychlor	72-43-5	EPA 8081B
Toxaphene	8001-35-2	EPA 8081B
Hexachlorobutadiene	87-68-3	EPA 8081B
Herbicides		
2,4-D	94-75-7	EPA 8151A
2,4-DB	94-82-6	EPA 8151A
2,4,5-TP (Silvex)	93-72-1	EPA 8151A
2,4,5-T	93-76-5	EPA 8151A
Dalapon	75-99-0	EPA 8151A
Dicamba	1918-00-9	EPA 8151A
Dichloroprop	120-36-5	EPA 8151A
Dinoseb	88-85-7	EPA 8151A
MCPA	94-74-6	EPA 8151A
MCPP (Mecoprop)	93-65-2	EPA 8151A
Pentachlorophenol	87-86-5	EPA 8151A
Organophosphorus Pesticides		
Chlorpyrifos	2921-88-2	EPA 8270D-SIM
Diazinon	333-41-5	EPA 8270D-SIM
Dimethoate	60-51-5	EPA 8270D-SIM
Disulfoton	298-04-4	EPA 8270D-SIM
Malathion	121-75-5	EPA 8270D-SIM
Parathion, ethyl	56-38-2	EPA 8270D-SIM
Parathion, methyl	298-00-0	EPA 8270D-SIM
Phorate	298-02-2	EPA 8270D-SIM
Sulfotepp	3689-24-5	EPA 8270D-SIM
Petroleum Compounds		
TPH-Dx		NWTPH-Dx
Naphthalene	91-20-3	EPA 8260
Groundwater Field Parameters		
pH, Field		Field Meter
Specific Conductance, Field		Field Meter
Oxidation-Reduction Potential		Field Meter
Temperature		Field Meter
Turbidity		Field Meter

Table 3. Groundwater Screening Levels

Sunnyside Airport Pesticide Shed, Sunnyside, Washington

Constituent	CAS Registry No	Groundwater Screening Level (ug/L)[2]	Practial Quantitation Limit (PQL) (ug/L)	Groundwater - Federal and MTCA Cleanup Values						Screening Level Basis
				ARAR - Federal Maximum Contaminant Level Goal (MCLG) (ug/L)	ARAR - Federal Primary Maximum Contaminant Level (MCL) (ug/L)	ARAR - State Primary Maximum Contaminant Level (MCL) (ug/L)	Method A, Table Value (µg/L)	Method B, Carcinogen, Standard Formula Value (µg/L)	Method B, Non-carcinogen, Standard Formula Value (µg/L)	
Organochlorine Pesticides										
Aldrin	309-00-2	0.003	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	0.003	0.24	ARAR
α-BHC	319-84-6	0.014	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	0.014	Not Researched	ARAR
β-BHC	319-85-7	0.049	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	0.049	Not Researched	ARAR
γ-BHC (Lindane)	58-89-9	0.2	0.005	0.2	0.2	0.2	0.2	Researched-ND	4.8	ARAR
δ-BHC	319-86-8	0.005	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	Not Researched	PQL
Chlordane	57-74-9	0.25		0	0.002	0.002	Researched-ND	0.25	8	ARAR
cis-Chlordane	5103-71-9	0.25	0.005	2	2	2	Researched-ND	0.25	8	ARAR
trans-Chlordane	5103-74-2	0.25	0.005	2	2	2	Researched-ND	0.25	8	ARAR
4,4'-DDD	72-54-8	0.365	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	0.36	Not Researched	ARAR
4,4'-DDE	72-55-9	0.257	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	0.26	Not Researched	ARAR
4,4'-DDT	50-29-3	0.257	0.005	Not Researched	Not Researched	Not Researched	0.3	0.26	8	ARAR
Dieldrin	60-57-1	0.005	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	0.01	0.8	ARAR
Endosulfan	115-29-7			Not Researched	Not Researched	Not Researched	Researched-No Data	Not Researched	96	
Endosulfan I[1]	959-98-8	96	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	96	ARAR
Endosulfan II[1]	33213-65-9	96	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	96	ARAR
Endosulfan sulfate[1]	1031-07-8	96	0.005	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	96	ARAR
Endrin[1]	72-20-8	2	0.005	2	2	2	Researched-ND	Not Researched	4.8	ARAR
Endrin aldehyde[1]	7421-93-4	2	0.005	2	2	2	Researched-ND	Not Researched	4.8	ARAR
Endrin ketone[1]	53494-70-5	2	0.02	2	2	2	Researched-ND	Not Researched	4.8	ARAR
Heptachlor	76-44-8	0.019	0.005	0	0.4	0.4	Researched-ND	0.02	8	ARAR
Heptachlor epoxide	1024-57-3	0.005	0.005	0	0.2	0.2	Researched-ND	0.00	0.104	ARAR
Hexachlorobenzene	118-74-1	0.055	0.005	0	1	1	Researched-ND	0.05	12.8	ARAR
Methoxychlor	72-43-5	40	0.01	40	40	40	Researched-ND	Not Researched	80	ARAR
Toxaphene	8001-35-2	0.080	0.05	0	3	3	Researched-ND	0.08	Not Researched	ARAR
Hexachlorobutadiene	87-68-3	0.56	0.01	Not Researched	Not Researched	Not Researched	Researched-ND	0.56	8	ARAR
Herbicides										
2,4-D (Dichlorophenoxyacetic acid,	94-75-7	70	0.024	70	70	70	Researched-ND	Not Researched	160	ARAR
2,4-DB (Dichlorophenoxy, 2,4- buty	94-82-6	128	0.047	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	128	ARAR
2,4,5-TP (Silvex)	93-72-1	50	0.024	50	50	50	Researched-ND	Researched-ND	Researched-ND	ARAR
2,4,5-T	93-76-5	0.02	0.024	Not Researched	Not Researched	Not Researched	Researched-ND	Researched-ND	Researched-ND	PQL
Dalapon	75-99-0	200	0.23	200	200	200	Researched-ND	Not Researched	240	ARAR
Dicamba	1918-00-9	480	0.024	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	480	ARAR
Dichloroprop	120-36-5	0.024	0.024	--	--	--	--	--	--	PQL
Dinoseb	88-85-7	7	0.024	7	7	7	Researched-ND	Researched-ND	Researched-ND	ARAR
MCPA	94-74-6	8	4.7	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	8	ARAR
MCPP (Mecoprop)	93-65-2	16	4.7	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	16	ARAR
Pentachlorophenol	87-86-5	0.219	0.0095	0	1	1	Researched-ND	0.219	80	ARAR
Organophosphorus Pesticides										
Chlorpyrifos	2921-88-2	48	0.2	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	48	ARAR
Diazinon	333-41-5	0.2	0.2	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	Researched-ND	PQL
Dimethoate	60-51-5	3.2	0.5	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	3.2	ARAR
Disulfoton	298-04-4	0.64	0.2	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	0.64	ARAR
Malathion	121-75-5	320	0.2	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	320	ARAR
Parathion, ethyl	56-38-2	96	0.2	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	96	ARAR
Parathion, methyl	298-00-0	4	0.2	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	4	ARAR
Phorate	298-02-2	3.2	0.2	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	3.2	ARAR
Sulfotepp	3689-24-5	8	0.2	Not Researched	Not Researched	Not Researched	Researched-ND	Not Researched	8	ARAR
Petroleum Compounds										
TPH-Dx	--	500	100	Not Researched	Not Researched	Not Researched	500	Not Researched	2000	ARAR
Benzene	71-43-2	0.8	0.2	--	10	10	5	0.8	32	ARAR
Toluene	108-88-3	640	1	1000	1000	1000	1000	Not Researched	640	ARAR
Ethylbenzene	100-41-4	6	0.2	700	700	700	700	Not Researched	6	ARAR
Xylenes	1330-20-7	9	0.4	10000	10000	10000	1000	Not Researched	9	ARAR
Naphthalene	91-20-3	160	1	Not Researched	Not Researched	Not Researched	160	Not Researched	160	ARAR

ARAR: Applicable or Relevant and Appropriate Requirement; includes both federal and state standard formula values when referenced in Screening Level Basis column.

Researched-ND means research has been conducted and no data exists in the database for this parameter.

Not Researched means research has not been conducted and no value exists in the database for this parameter.

[2] For certain Organochlorine Pesticide constituents, the most stringent cleanup level established is the ARAR MCLG (0 ug/L); these constituents will use the MTCA Method B table value.

[1] Groundwater and Soil screening levels established for parent chemical Endosulfan CAS No 115-29-7; which is related to Endosulfan I (alpha) CAS No 959-98-8, Endosulfan II (beta) CAS No 33213-65-9, and Endosulfan sulfate CAS No 1031-07-8. Screening levels established for Endrin CAS No 72-20-8, which is related to degradation products Endrin aldehyde CAS No 7421-93-4 and Endrin ketone CAS No 53494-70-5.

Most stringent cleanup level selected; MTCA Method C levels not considered because the site is not an industrial property

Screening Level Basis Includes:

ARAR values are the most stringent of applicable standard table values.

PQL is the practical quantitation limit and is used as the Screening Level basis where ARAR and toxicology values are not available.

Reported PQLs are the standard laboratory PQL for pesticide and herbicide analyses conducted by OnSite Environmental, Redmond, Washington.

Table 4. Soil Screening Levels

Sunnyside Airport Pesticide Shed, Sunnyside, Washington

Constituent	CAS Registry No	Soil Screening Level [2]		Practical Quantitation Limit (PQL) (ug/kg)	Soil - MTCA Standard Formula Values				Soil Protective of Groundwater Calculations [3]						
		(ug/kg)	(mg/kg)		Method A, Unrestricted Land Use, Table Value (mg/kg)	Method A, Industrial Land Use, Table Value (mg/kg)	Method B, Carcinogen, Standard Formula Value, Direct Contact (ingestion only), unrestricted land use (mg/kg)	Method B, Non-carcinogen, Standard Formula Value, Direct Contact (ingestion only), unrestricted land use (mg/kg)	Groundwater SL (ug/L) (see Table 3)	Henry Law Coefficient (unitless)	log Koc (log L/kg) [4]	Koc (L/kg)	Distribution Coefficient (L/kg)	Soil Protective of Groundwater (mg/kg)	Soil Protective of Groundwater (ug/kg)
Organochlorine Pesticides															
Aldrin	309-00-2	3	0.0025	5	Researched-No Data	Researched-No Data	0.058823529	2.4	0.00	0.00697		48685	48.69	0.0025	2.5
α-BHC	319-84-6	0.545	0.00055	5	Researched-No Data	Researched-No Data	0.158730159	Not Researched	0.01	0.00044		1762	1.76	0.0005	0.5
β-BHC	319-85-7	2.3	0.0023	5	Researched-No Data	Researched-No Data	0.56	Not Researched	0.05	0.00003		2139	2.14	0.0023	2.3
γ-BHC (Lindane)	58-89-9	6.2	0.0062	5	0.01	0.01	Researched-No Data	24	0.20	0.00057		1352	1.35	0.0062	6.2
δ-BHC	319-86-8	1.0	0.00	5	Researched-No Data	Researched-No Data	Not Researched	Not Researched	0.01	0.00018	4.00	10000	10.00	0.0010	1.0
cis-Chlordane	5103-71-9	2857	2.86	10	Researched-No Data	Researched-No Data	2.86	40	0.25	0.00411	6.97	9332543	9332.54	46.66	46664
trans-Chlordane	5103-74-2	2857	2.86	10	Researched-No Data	Researched-No Data	2.86	40	0.25	0.00411	6.97	9249516	9249.52	46.25	46249
4,4'-DDD	72-54-8	335	0.34	10	Researched-No Data	Researched-No Data	4.17	Not Researched	0.36	0.00016		45800	45.80	0.34	335
4,4'-DDE	72-55-9	446	0.45	10	Researched-No Data	Researched-No Data	2.94	Not Researched	0.26	0.00086		86405	86.41	0.45	446
4,4'-DDT	50-29-3	2941	2.94	10	3	4	2.94	40	0.26	0.000332		677934	677.93	3.49	3490
Dieldrin	60-57-1	2.8	0.003	10	Researched-No Data	Researched-No Data	0.06	4	0.01	0.00062		25546	25.55	0.00	3
Endosulfan	115-29-7	4301	4.30	10	Researched-No Data	Researched-No Data	Not Researched	480	96.00	0.00046		2040	2.04	4.30	4301
Endosulfan I [1]	959-98-8	304683	305	5	Researched-No Data	Researched-No Data	Not Researched	480	96.00	0.00004	5.20	158489	158.49	304.68	304683
Endosulfan II [1]	33213-65-9	304683	305	10	Researched-No Data	Researched-No Data	Not Researched	480	96.00	0.00004	5.20	158489	158.49	304.68	304683
Endosulfan sulfate [1]	1031-07-8	480000	480	10	Researched-No Data	Researched-No Data	Not Researched	480	96.00	0.00004	6.01	1023293	1023.29	1965.11	1965107
Endrin [1]	72-20-8	440	0.44	10	Researched-No Data	Researched-No Data	Not Researched	24	2.00	0.00031		10811	10.81	0.44	440
Endrin aldehyde [1]	7421-93-4	24000	24.00	10	Researched-No Data	Researched-No Data	Not Researched	24	2.00	0.01800	6.44	2754229	2754.23	110.18	110177
Endrin ketone [1]	53494-70-5	8560	8.56	10	Researched-No Data	Researched-No Data	Not Researched	24	2.00	0.00004	5.33	213796	213.80	8.56	8560
Heptachlor	76-44-8	3.8	0.00	5	Researched-No Data	Researched-No Data	0.22	40	0.02	0.0447000		9528	9.53	0.00	4
Heptachlor epoxide	1024-57-3	8.0	0.01	5	Researched-No Data	Researched-No Data	0.11	1.04	0.00	0.0003900		83200	83.20	0.01	8
Hexachlorobenzene	118-74-1	88	0.09	5	Researched-No Data	Researched-No Data	0.625	64	0.05	0.0541000		80000	80.00	0.09	88
Methoxychlor	72-43-5	64160	64.16	10	Researched-No Data	Researched-No Data	Not Researched	400	40.00	0.0006480		80000	80.00	64.16	64160
Toxaphene	8001-35-2	153	0.15	50	Researched-No Data	Researched-No Data	0.91	Not Researched	0.08	0.0002460		95816	95.82	0.15	153
Hexachlorobutadiene	87-68-3	604	0.60	10	Researched-No Data	Researched-No Data	12.82	80	0.56	0.3340000		53700	53.70	0.60	604
Herbicides															
2,4-D (Dichlorophenoxyacetic a	94-75-7	860	0.86	9.4	Researched-No Data	Researched-No Data	Not Researched	800	70.00	0.00000001	2.62	414	0.41	0.86	860
2,4-DB (Dichlorophenoxy, 2,4-	94-82-6	16179	16.18	9.5	Researched-No Data	Researched-No Data	Not Researched	640	128.00	0.00000003	3.79	6120	6.12	16.18	16179
2,4,5-TP (Silvex)	93-72-1	4979	4.98	9.5	Researched-No Data	Researched-No Data	Not Researched	640	50.00	0.0000005	3.68	4779	4.78	4.98	4979
2,4,5-T	93-76-5	1.0	0.001	9.5	Researched-No Data	Researched-No Data	Not Researched	800	0.02	0.0000004	3.26	1827	1.83	0.00	1
Dalapon	75-99-0	959	0.96	230	Researched-No Data	Researched-No Data	Not Researched	2400	200.00	0.0000146	1.60	40	0.04	0.96	959
Dicamba	1918-00-9	3258	3.26	9.4	Researched-No Data	Researched-No Data	Not Researched	2400	480.00	0.0000003	2.14	139	0.14	3.26	3258
Dichloroprop	120-36-5	1.0	0.001	71	--	--	--	--	0.02	0.0000009	3.26	1834	1.83	0.00	1
Dinoseb	88-85-7	688	0.69	9.5	Researched-No Data	Researched-No Data	Not Researched	80	7.00	0.0207850	3.67	4710	4.71	0.69	688
MCPA	94-74-6	424	0.42	940	Researched-No Data	Researched-No Data	Not Researched	40	8.00	0.0000001	3.39	2449	2.45	0.42	424
MCPP (Mecoprop)	93-65-2	498	0.50	940	Researched-No Data	Researched-No Data	Not Researched	80	16.00	0.0000010	3.13	1357	1.36	0.50	498
Pentachlorophenol	87-86-5	3.5	0.0035	0.95	Researched-No Data	Researched-No Data	2.5	400	0.22	0.0000010		592	0.59	0.00	3
Organophosphorus Pesticides															
Chlorpyrifos	2921-88-2	43891	43.89	20	Researched-No Data	Researched-No Data	Not Researched	240	48.00	0.0001729	4.66	45520	45.52	43.89	43891
Diazinon	333-41-5	30	0.03	20	Researched-No Data	Researched-No Data	Not Researched	Researched-No Data	0.20	0.0000047	3.86	7306	7.31	0.03	30
Dimethoate	60-51-5	13	0.013	20	Researched-No Data	Researched-No Data	Not Researched	16	3.20	0.000000003	0.28	2	0.00	0.01	13
Disulfoton	298-04-4	95	0.095	20	Researched-No Data	Researched-No Data	Not Researched	3.2	0.64	0.0002577	3.86	7208	7.21	0.09	95
Malathion	121-75-5	2522	2.52	20	Researched-No Data	Researched-No Data	Not Researched	1600	320.00	0.0000010	2.29	194	0.19	2.52	2522
Parathion, ethyl	56-38-2	10716	10.72	20	Researched-No Data	Researched-No Data	Not Researched	480	96.00	0.0000237	3.73	5381	5.38	10.72	10716
Parathion, methyl	298-00-0	447	0.45	20	Researched-No Data	Researched-No Data	Not Researched	20	4.00	0.0000237	3.73	5381	5.38	0.45	447
Phorate	298-02-2	162	0.16	20	Researched-No Data	Researched-No Data	Not Researched	16	3.20	0.0004988	3.37	2326	2.33	0.16	162
Sulfotepp	3689-24-5	1561	1.56	20	Researched-No Data	Researched-No Data	Not Researched	40	8.00	0.0001746	3.98	9559	9.56	1.56	1561
Petroleum Compounds															
TPH-Dx	--	2000000	2000	50	2000	2000	Not Researched	Not Researched	500				--	--	--
Benzene	71-43-2	5	0.0045	1.5	0.03	0.03	18.2	320	0.80	0.2280000		62	0.06	0.0045	4.5
Toluene	108-88-3	4654	4.65	7.5	7	7	Not Researched	6400	640	0.2720000		140	0.14	4.65	4654
Ethylbenzene	100-41-4	52	0.05	1.5	6	6	Not Researched	8000	6.0	0.3230000		204	0.20	0.052	52
Xylenes	1330-20-7	82	0.08	3	9	9	Not Researched	16000	9.0	0.2790000		233	0.23	0.082	82
Naphthalene	91-20-3	4457	4.46	1.5	5	5	Not Researched	1600	160	0.0198000		1191	1.19	4.46	4457

Not Researched means research has not been conducted and no value exists in the Clarc database for this parameter

[1] Groundwater and Soil screening levels established for parent chemical Endosulfan CAS No 115-29-7; which is related to Endosulfan I (alpha) CAS No 959-98-8, Endosulfan II (beta) CAS No 33213-65-9, and Endosulfan sulfate CAS No 1031-07-8. Screening levels established for Endrin CAS No 72-20-8, which is related to degradation products Endrin aldehyde CAS No 7421-93-4 and Endrin ketone CAS No 53494-70-5.

[2] Soil screening level based on the most stringent value from comparison of: standard table values based on direct contact; and soil protective of leaching to groundwater pathway calculated value.

[3] Soil concentrations protective of the soil leaching to groundwater pathway calculated using WAC 173-340 Equation 747-1 and default input values for: fraction organic carbon (0.001); dilution factor (20); air filled porosity (0.13); water filled porosity (0.3); dry soil bulk density (1.5 g/cc). Distribution coefficient (Kd) calculated from octanol-water partition coefficients (Koc) obtained from Clarc or literature sources (see note 2). Henrys law values obtained from Clarc or literature sources (see note 2)

[4] Values from literature reported Koc with units of log mg/L; values not available from Clarc database; corresponding Henrys Law coefficients also from literature; values downloaded from: http://www.gsi-net.com/en/publications/gsi-chemical-database/. Note: same Koc and Hcc values used for methyl- and ethyl-parathion.

Reported PQLs are the standard laboratory PQL for pesticide and herbicide analyses conducted by OnSite Environmental, Redmond, Washington.

Table 5. Summary of Analytical Methods and Hold Times

Sunnyside Airport Pesticide Shed, Sunnyside, Washington

Constituent Group	Analytical Method	Hold Time Soil	Hold Time Groundwater	Container Soil	Container Groundwater
Organochlorine Pesticides	Method 8081B	7 days	14 days	8oz WMG	2-500mL AG
Herbicides	Method 8151A	7 days	14 days	8oz WMG	2-500mL AG
Organophosphate Pesticides	Method 8270D-SIM	7 days	14 days	8oz WMG	2-500mL AG
Diesel-range Hydrocarbons	NWTPH-Dx	14 days	7 days	8oz WMG	2-500mL AG
Volatile Organic Compounds	Method 8260	14 days	14 days	2-40mL VOA	2-40mL VOA

AG: amber glass bottle
WMG: wide mouth glass jar
VOA: vial with teflon lid

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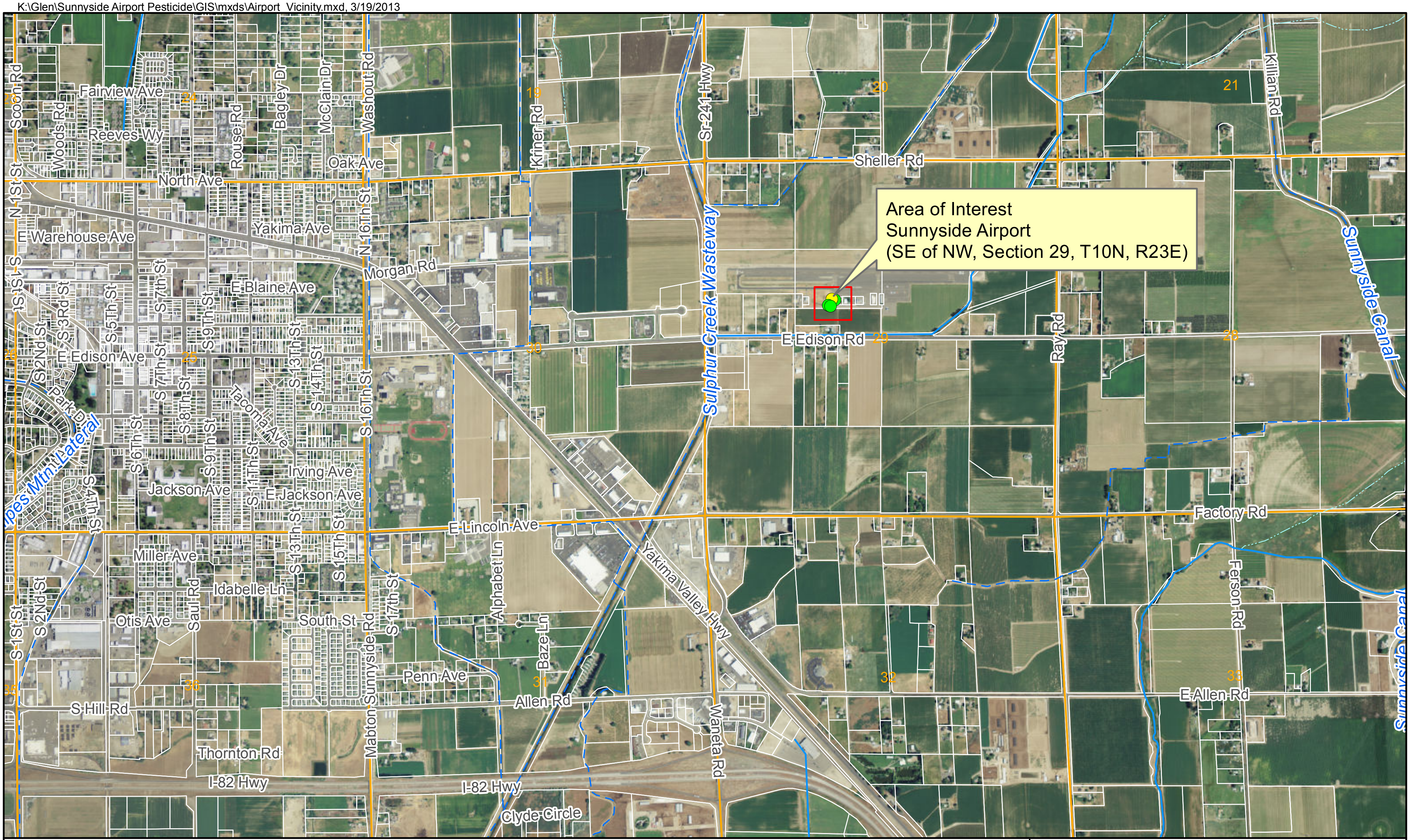
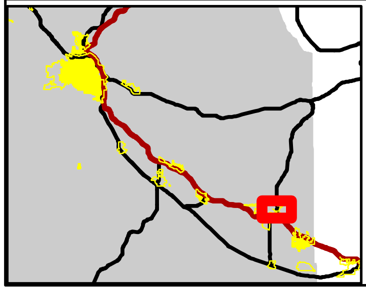


Area of Interest
Sunnyside Airport
(SE of NW, Section 29, T10N, R23E)



Sample Locations

🟢 Sample Exceeds Screening Level

🟡 Sample Does Not Exceed Screening Level

0 Feet 2,000

N

Figure 1

Sunnyside Airport Vicinity

Sunnyside Municipal Airport
Environmental Investigation

PgG

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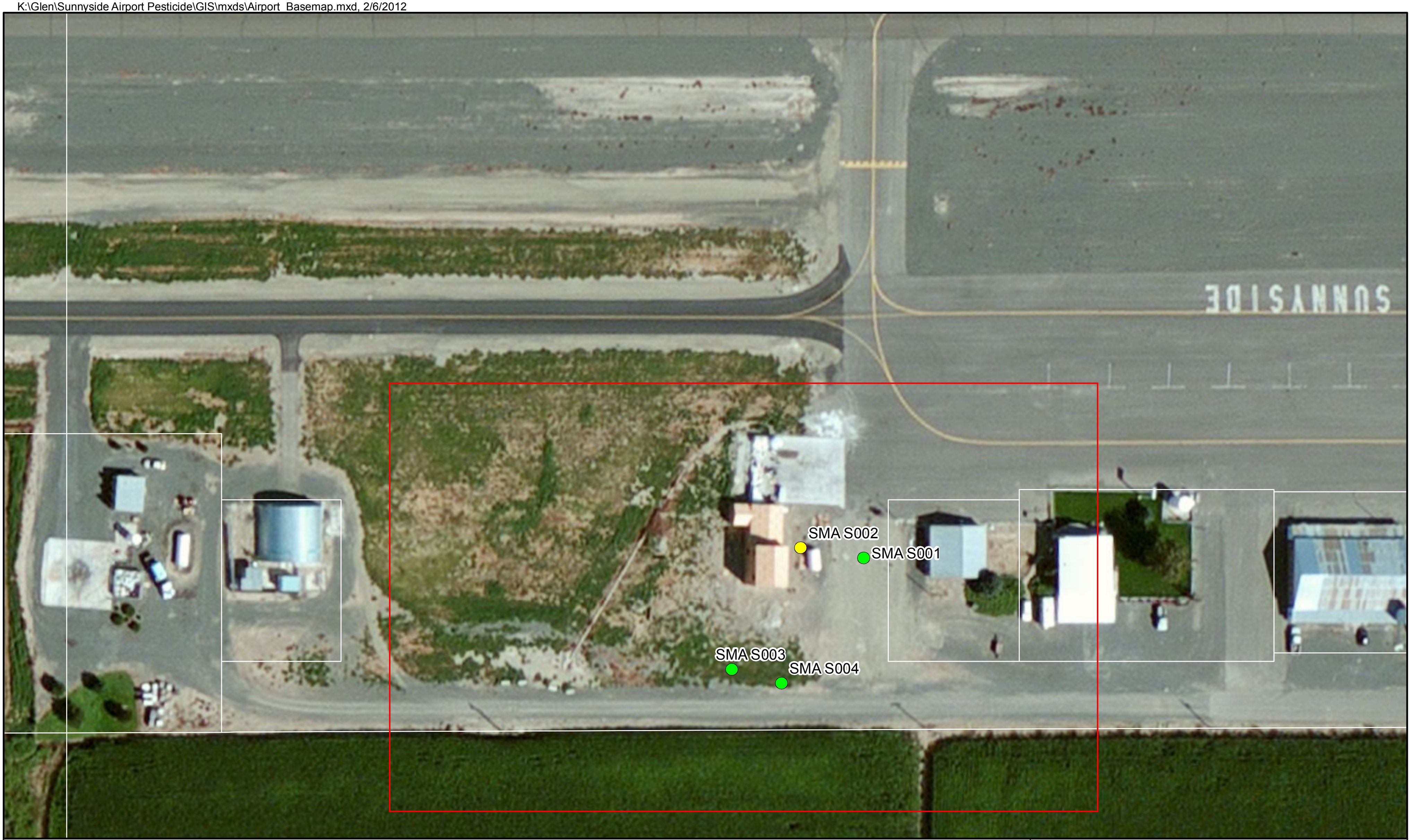

Sample Locations

● Sample Exceeds Screening Level

● Sample Does Not Exceed Screening Level

☐ Figure 3 extent

0 Feet 100

N

Aerial Photo from Bing Maps, Aug/Oct 2010

Figure 2

Ecology Sample Locations

Sunnyside Municipal Airport
Environmental Investigation

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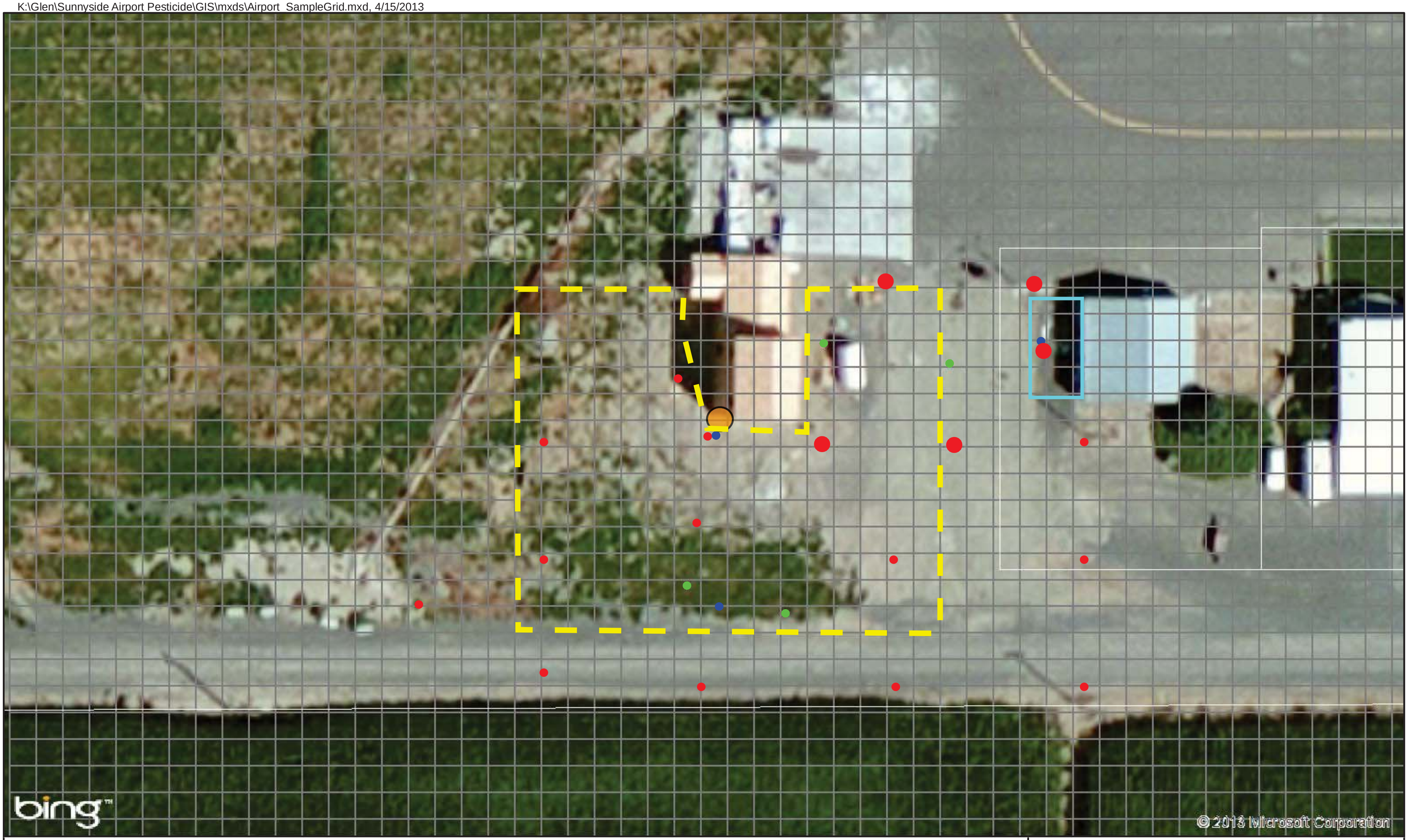

● Ecology Sample Locations

Airport Parcels

— 10-foot Sample Grid

● Proposed Phase I Groundwater Sample Locations

● Proposed Phase I Soil Sample Locations (● with Petroleum Compounds)

Approximate Extent of Former Pesticide Shed

● Approximate Location of Buried Metal Debris

Geophysical Survey Area

0 Feet 50

N

Aerial Photo from Bing Maps, Aug/Oct 2010

Figure 3

Investigation Locations

Sunnyside Municipal Airport
Environmental Investigation

PgG

APPENDIX A
QUALITY ASSURANCE PROJECT PLAN

SUNNYSIDE MUNICIPAL AIRPORT PESTICIDE SHED
QUALITY ASSURANCE PROJECT PLAN

October 20, 2013

SUNNYSIDE MUNICIPAL AIRPORT PESTICIDE SHED
QUALITY ASSURANCE PROJECT PLAN

Prepared for:

City of Sunnyside
818 E Edison Avenue
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Prepared by:

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October 20, 2013
JG1201

APPROVAL SIGNATURES

The following signatures acknowledge that these team members have read, fully understood, and are willing to adhere to this Quality Assurance Project Plan for the Sunnyside Municipal Airport Pesticide Shed.

Jennifer Lind Department of Ecology, CRO Project Coordinator, Ecology	Date
Shane Fisher City of Sunnyside Designated Representative	Date
Glen Wallace Pacific Groundwater Group Project Manger	Date

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APPENDICES

1.0 PROJECT MANAGEMENT

The following project management elements address the procedural aspects of the project, summarize the project team, and summarize the project.

1.1 DISTRIBUTION LIST

The following individuals will receive copies of the QAPP, once it has been reviewed and approved by the Washington Department of Ecology (Ecology).

- Jennifer Lind, Department of Ecology, CRO, Project Coordinator, 509-454-7839
- Shane Fisher, Designated Representative, City of Sunnyside, 509-837-5206
- Glen Wallace, Project Manager, Pacific Groundwater Group, 206-329-0141

1.2 PROJECT ORGANIZATION

The project team is formed by members of the Washington Department of Ecology (Ecology), City of Sunnyside, Pacific Groundwater Group (PGG), and subcontracting analytical laboratories and drillers, as needed. The project organization is summarized below.

Ecology is the lead regulatory agency for this project. Jennifer Lind is the Project Coordinator for Ecology.

The soil source area is located on property owned by the City of Sunnyside. Shane Fisher will act as the representative for the City of Sunnyside. Mr. Fisher will make arrangements for access to Sunnyside Airport.

The prime consultant for this study is PGG who will be responsible for field activities, data collection, data management, and reporting to the Ecology and the City of Sunnyside. The key PGG staff who will be involved in the project are:

- Glen Wallace, LG; Project Manager
- Travis Klaas; Field Analysis Lead
- Glenn Mutti-Driscoll; Field and Analysis Support
- Wayne Rennick; GIS Specialist

PGG will subcontract analytical laboratories and drilling.

1.3 BACKGROUND & PROBLEM DEFINITION

Ecology confirmed the presence of pesticides in soil likely related to historic crop dusting operations. This QAPP relates to sampling that will be conducted to investigate the nature and extent of soil and/or groundwater contamination in support of completing a Remedial Investigation and Feasibility Study (RIFS).

1.4 TASK DESCRIPTION SUMMARY

Ecology and the City of Sunnyside entered into an Agreed Order (DE9746) effective March 13, 2013. The order requires submittal of a Remedial Investigation (RI) Work Plan. This Quality Assurance Project Plan (QAPP) is part of the RI Work Plan. The RI includes soil and groundwater sampling. These tasks will be summarized in the following section and further detail is provided in Section 2.

1.4.1 Contaminants of Concern

Based on site history and previous sampling, the contaminants of concern are (Table 1):

- 4-4’-DDT
- 4-4’-DDE
- Toxaphene
- Dieldrin
- Naphthalene
- Diesel-range hydrocarbons

1.4.2 Chemicals of Potential Concern

Chemicals of potential concern (COPC) at the site include chemicals which may not have been part of the primary release, or have either not been tested for or not been detected above cleanup levels in soil and groundwater. COPCs at the site include the following classes of chemicals (Table 1):

- Organophosphorous Pesticides
- Organochlorine Pesticides
- Herbicides
- Benzene, toluene, ethylbenzene, xylenes (BTEX)

1.4.3 Soil and Groundwater Investigation

A soil and groundwater investigation will be performed under the RI Work Plan to accomplish two goals:

1. To further assess the nature and extent of soil and groundwater contamination.
2. Develop and support an adequate site conceptual model to support remedial actions.

To accomplish these goals, a network of soil samples and grab groundwater samples will be collected and analyzed (Figure 1). The soil and groundwater investigation will be conducted as described in the Remedial Investigation Work Plan (RIWP) (concurrent document). Section 2.2 details drilling and sampling methods. This may include collection of additional soil samples to fill data gaps identified in the first round of sampling, and may include additional groundwater sampling if samples indicate impacts to groundwater above screening levels.

1.4.4 Health and Safety

A Health and Safety Plan for field work at the Sunnyside Airport site is presented in the RIWP. The objective of the Plan is to provide health and safety guidance to PGG field personnel. The Plan may not identify all possible hazardous materials or environmental hazards, eliminate all risks, or provide any guarantees regarding site safety for workers. The Plan is a framework to continually recognize, evaluate, and control the hazards present in the workplace.

1.5 ASSESSMENT CRITERIA

Groundwater data from the Sunnyside Airport site will be assessed using the screening levels established in the RI Work Plan. Table 1 includes soil and groundwater screening levels.

1.6 DATA QUALITY OBJECTIVES

Quality assurance objectives for measurement data are usually expressed in terms of accuracy and precision. The data will be evaluated using the parameters discussed below.

Definitions of these characteristics are as follows:

Accuracy, A sample spike is prepared by adding a known amount of a pure compound to the environmental sample (before extraction for extractables), and the compound is the same or similar (as in isotopically labeled compounds) as that being assayed for in the environmental sample. These spikes simulate the background and interferences found in the actual samples and calculated percent recovery of the spike is taken as a measure of the accuracy of the total analytical method. When there is no change in volume due to the spike, percent recovery is calculated as follows:

$$PR = \frac{(O - X)\times 100}{T}$$

Where:

PR = percent recovery

O = measured value of analyte concentration after addition of spike

X = measured value of analyte concentration in the sample before the spike is added

T = value of the spike

Tolerance limits for acceptable percent recovery established by the lab in accordance with CLP guidelines will be followed for this project. Sample spike recoveries that fall outside the tolerance limits must be assessed and the problem identified and corrected. The result for that analyte in the unspiked sample is suspect and may not be reported for regulatory compliance purposes.

Surrogate spikes are also a measure of accuracy. When surrogate recoveries are outside the control limits established in the SW-846 methods, the corrective action procedures specified in the methods must be followed by the laboratory.

Precision. Aliquots are made in the laboratory of the same sample and each aliquot is treated exactly the same throughout the analytical method. The percent difference between the values of the duplicates, as calculated below, is taken as a measure of the precision of the analytical method.

$$RPD = \frac{2\left(D_1 - D_2\right) \times 100}{\left(D_1 + D_2\right)}$$

Where:

RPD = relative percent difference

D_1 = first sample value

D_2 = second (duplicated) sample value

The tolerance limit for percent differences between laboratory duplicates will be ± 20 percent. If the precision values are outside this limit, the laboratory should recheck the calculations and/or identify the problem. Reanalysis may be required. The result for that analyte in the unspiked sample is suspect and will be flagged when reported; it may not be viable for regulatory compliance purposes.

The tolerance limit for relative percent differences between the field duplicates will be ± 35 percent (see discussion under "Field Quality Control" below). If the precision values are outside this limit, a replicate sample may be run to verify Laboratory precision. If precision limit exceedances are linked to field sampling, samplers should recheck field sampling procedures and identify the problem. Resampling and analysis may be required.

Representativeness. Representativeness is a qualitative term to evaluate how closely the measured results typify the environmental conditions. The sampling plan design, sampling techniques, and sample handling protocols are developed to ensure representative samples.

Comparability. Comparability is a qualitative term that expresses the confidence with which one data set can be compared with another. The use of standard techniques for sample collection and certified analytical laboratories for analyses should make the data comparable throughout the RI work as well as with pre-existing analytical data.

Completeness. Completeness is the percentage of valid measurements collected out of the planned number of measurements. Results will be considered valid if all the precision and accuracy targets are met. Internal laboratory QC checks, preventive maintenance, and corrective action, as described in other sections of this document, will be implemented to help meet the QA objectives established for these analyses.

1.6.1 Measurement Performance Criteria

The laboratory quality control samples are described in Section 2.5. The target tolerance limits established by the lab in accordance with USEPA Contract Laboratory Program National Functional Guidelines (CLP Guidelines) will be followed for this project. The limits are summarized below.

Laboratory Quality Control

Laboratory quality control samples for water will be method blanks, laboratory control samples (LCS), matrix spikes, and matrix duplicates.

The goal is to have no detectable contaminants in the method blank. If contamination is detected in the method blank sample, the nature of the interference and the effect on the analysis of each sample in the batch will be evaluated. The source of contamination will be investigated and measures taken to minimize or eliminate the problem. Affected samples are reprocessed or data is appropriately qualified following CLP Guidelines.

LCS results are calculated in percent recovery. Results are compared to established acceptance criteria. A LCS that is within the criteria effectively establishes that the analytical system is in control and validates system performance for the samples in the associated batch. If a LCS result is found to be outside the criteria, this indicates that the analytical system is “out of control.” Any affected samples associated with an out of control LCS are reprocessed and re-analyzed (if possible), or the results reported with appropriate data qualifying codes.

The results from matrix spike analyses are expressed as percent recovery (%R) and relative percent difference (RPD). Results are compared to the established acceptance criteria. If the results are outside the criteria, the cause is investigated and corrective actions are taken if necessary, or the matrix spike data is reported with appropriate qualifiers.

The results from matrix duplicates are primarily designed to assess the precision of analytical results in a given matrix and are expressed as relative percent difference (RPD). Results are compared to established acceptance criteria. If results are outside the criteria, the cause is investigated and corrective actions are taken if necessary, or the matrix duplicate data is reported with appropriate qualifiers. The acceptance criteria for matrix duplicate analysis vary between analytical methods and will follow the ARI standard laboratory procedures.

1.7 TRAINING AND CERTIFICATION

Geoprobe drilling will be performed by a Washington State licensed well driller. Laboratory services will be performed by labs accredited by the Washington State Department of Ecology.

1.8 DOCUMENTS AND RECORDS

PGG will be responsible for distributing all versions of the QAPP to the individuals referenced on the distribution list (Section 1.1).

In addition, PGG will distribute draft and final versions of the Remedial Investigation report to Jennifer Lind, Ecology, and Shane Fisher, City of Sunnyside. These individuals will be responsible for distributing the report throughout their organizations as necessary.

2.0 DATA GENERATION AND ACQUISITION

This remedial investigation at Sunnyside Airport involves collection of soil and groundwater samples for laboratory analysis.

2.1 SAMPLING PROCESS DESIGN

The Sunnyside Airport RI will include soil and groundwater sampling.

The objective of the soil sampling investigation is to evaluate the extent and magnitude of soil contamination present at the Sunnyside Airport site, while the groundwater sampling investigation objective is to assess the quality of groundwater at the airport.

2.2 SAMPLING METHODS

Sampling methods vary according to the sample matrix and the analyte. Sampling methods that will be used in this study are summarized below. This section also provides drilling methods for the geoprobe sampling locations.

2.2.1 Drilling

Before drilling, One-Call Utility Locators will mark underground utility locations.

PGG will subcontract with a Washington-licensed driller for completion of geoprobe borings. Borings will be accomplished using a pushprobe to advance a 3-inch sampler. Water samples will be collected as discussed below.

The probe will be decontaminated before each use. Drill cuttings and decontamination water will be drummed for appropriate disposal.

2.2.2 Geoprobe Soil Sampling

Soil sampling will be conducted with a geoprobe for the RIWP. The discussion below assumes that soil sampling will include sampling at multiple depths.

Boring locations may be adjusted in the field at the time of drilling based on information from utility locating services, driller concerns, and access. If boring locations are to be moved more than 20 feet from the locations shown in the RIWP (PGG, 2013), the City of Sunnyside will confer with Ecology regarding the change in location.

Soil samples will be collected from a 3-inch diameter geoprobe sampler. Samplers will wear clean gloves and use decontaminated stainless steel spoons to fill laboratory soil jars. Spoons will be decontaminated in the following three-step wash process: spoons will be scrubbed in a decontaminant detergent (such as Liquinox) and water wash, rinsed with tap water, and rinsed again using deionized/distilled water.

Soil sampling containers and holding times are shown in Table 2. All sample handling and custody will be maintained in a manner to collect representative samples and obtain accurate laboratory results. Section 2.3 details sampling and custody methods.

2.2.3 Groundwater Sampling

Field water quality instruments will be calibrated at the beginning (prior to sampling) of each day. Calibration data will be recorded in the field notes. Groundwater samples collected from geoprobe borings will be sampled with a temporary screen and peristaltic pump as follows:

- Lower the new, clean Teflon or Teflon lined tubing into the well until the tubing intake is in the middle of the screened interval, or slightly above the middle of the screened interval. Secure the tubing to the top of the well and leave approximately 5 feet of tubing outside the well. Attach a 1-foot length of silicon tubing that is appropriate for a peristaltic pump to the polyethylene tubing.
- Attach the silicon tubing to the peristaltic pump. Purge (remove with pump) water from the well into a calibrated 5-gallon pail or similar and monitor flow rate.
- Use the EPA Low-Flow Groundwater Sampling Procedures and EPA Direct Push Guidance (Appendix A). The goal of this sampling approach is to create minimal screen velocities during purging that will entrain fines, potentially biasing sample results. This goal may be difficult to achieve under some circumstances and may require adjustment based on site-specific conditions and personal experience. Low-flow sampling involves several steps and can be summarized as follows. First, purge groundwater at a low rate (~100-200 mL/min). Second, monitor the discharge water for temperature, pH, specific conductance, turbidity, and oxidation-reduction potential[1] at least three times during the purging period. Third, measure the purge volume using a calibrated bucket. Fourth, record purge water volume, time, and field parameter values in the field notes
- If, after measuring field parameters three times, the field parameters are "stable," (see explanation below) sampling may begin. If the field water quality parameters continue to increase or decrease, continue purging until readings are "stable," then sample. Stabilization of turbidity values is considered critical in order to minimize sample bias.
- Collect samples of water for laboratory analysis in a manner that minimizes volatilization of potential contaminants from the water into the air. Hands and clothing will be clean when handling sampling equipment and during sampling.
- Clean, disposable, latex, nitrile, or equivalent material gloves will be worn when filling bottles for analyses. Gloves will be changed when dirty and between samples. All water samples will be collected from the pump discharge lines directly into the appropriate sample containers.

"Stable" is defined as:

- Specific conductance, turbidity, oxidation-reduction potential, pH, and temperature that do not indicate a trend (continuously increasing or decreasing between readings).
- Specific conductance, turbidity, oxidation-reduction potential, and temperature that do not vary by more than 10 percent between readings.
- pH measurements that do not vary by more than 0.1 pH units between readings.

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[1] Field parameters are measured using either a YSI 555 multiparameter meter, or an Oakton pHCON10, Extech ORP, and an optical turbidimeter depending on equipment availability.

Collect samples in the following manner:

- Semi-Volatile Compounds (including herbicides and pesticides) – Completely fill the appropriate number of bottles to meet laboratory volume requirements and cap securely.

Record sample identification data on each sample container, in the field notes, and on the chain-of-custody. Sample identification will be the same as the well name/number..

2.3 SAMPLE HANDLING AND CUSTODY

Following collection, groundwater and soil samples will be handled in the manner described below. A summary of analytical holding times is presented in Table 2.

- Place sample jars/bottles in clean, insulated containers (ice chests) containing frozen gel, ice, or another compound to maintain temperature near, but not at, or below, freezing. Use sufficient cooling materials to maintain temperature near freezing during the entire time of transport to the lab.
- Maintain custody of samples from time of sampling to receipt at the laboratory. "Custody" means that samples remain: in direct possession of a person who is recorded on the Chain-of-Custody form, or locked in secure vehicles or offices.
- Complete the appropriate Chain-of-Custody forms and any other pertinent sampling/shipping documentation to accompany the samples.
- Samples will be transferred to the analytical laboratory, accompanied by Chain-of-Custody forms and any other pertinent shipping/sampling documentation. One set of Chain-of-Custody forms will be used per laboratory shipment. Sample container custody seals will be used for all shipped containers not delivered directly to the lab by Pacific Groundwater Group personnel. Seals will consist of breakable tape (such as paper masking tape) signed in ink by the person relinquishing the sample. The tape will be placed in such manner that the tape must be broken in order to open the sample container.

2.4 ANALYTICAL METHODS AND LABORATORIES

The analytical methods for soil and groundwater samples are summarized in Table 2.

2.5 LABORATORY QUALITY CONTROL

OnSite Environmental in Redmond, Washington will perform analyses of water quality for the project. OnSite is accredited in accordance with WAC 173-50, Accreditation of Environmental Laboratories.

EPA Contract Laboratory Program (CLP) QA/QC procedures or similar efforts will be used for the analyses. ARI will follow the ARI Quality Assurance Manual.

Preparation batches have a maximum of 20 field samples of the same matrix. QA/QC samples processed with each batch are:

- One method blank. The method blank is used to assess the preparation batch for possible contamination during the preparation and processing steps. It is processed along with and under the same conditions as the associated samples.

- One laboratory control sample (LCS). The LCS is used to evaluate the performance of the total analytical system, including all preparation and analysis steps.
- One matrix spike (MS), if suitable. Matrix specific QA/QC samples indicate the effect of the sample matrix on the precision and accuracy of the results generated using the selected method. The information from these controls is sample/matrix specific and is not normally used to determine the validity of the entire batch.
- One matrix duplicate (MD). Matrix duplicates are replicate aliquots of the same sample taken through the entire analytical procedure. The results from this analysis indicate the precision of the results for the specific sample using the selected method. One duplicate sample is analyzed with each preparation batch. If sufficient sample is provided, this will be either a matrix spike duplicate or a matrix duplicate. If not, a laboratory control sample duplicate will be analyzed.

Target acceptance criteria are discussed in Section 1.6.

2.6 DATA MANAGEMENT, VERIFICATION, VALIDATION, AND ASSESSMENT

The data generated from field and laboratory measurements will be managed, evaluated, and reported. The data are evaluated to verify that DQO criteria for Accuracy, Precision, Representativeness, Completeness, and Comparability are obtained. The data will be independently validated for all analytical data generated for this project. The data validation will be performed in accordance with EPA National Functional Guidelines for organics and inorganic analyses (EPA 1999 and 2004, respectively), and laboratory-defined QC limits, with regard to the following, as appropriate to the particular analysis: sample documentation/custody, holding times, reporting limits, blank spike, matrix spike, and surrogate percent recoveries, laboratory duplicates, comparability, and completeness. Pre-existing data will be evaluated for comparability to new data. Following verification and validation of the data, the data will be assessed for usability. If the DQOs have been met, the quality of the data should be useable. If the DQOs have not been met the data will be assessed determine if they are still useable to help fill data gaps listed in the RI Work Plan. Ultimately, the assessment of the meaningfulness of the data to fill data gaps, improve the site conceptual model, and inform future work will be carried out as part of the RI Work Plan and Reporting.

3.0 REFERENCES

PGG, 2013. Sunnyside Municipal Airport Pesticide Shed Draft Remedial Action Work Plan. Consultant’s report to City of Sunnyside.

U.S. Environmental Protection Agency Office of Emergency and Remedial Response. June 2001. USEPA Contract Laboratory Program National Functional Guidelines.

U.S. Environmental Protection Agency Office of Environmental Information. December 2002. Guidance for Quality Assurance Project Plans EPA QA/G-5.

U.S. Environmental Protection Agency, 2005. Groundwater Sampling and Monitoring with Direct Push Technologies. August 2005. EPA 540/R-04/005.

Table 1. Soil and Groundwater Screening Levels

Sunnyside Airport Pesticide Shed, Sunnyside, Washington

			Reporting Limits [1]		Site Screening Levels	
Constituent	**CAS Registry No**	**Analytical Method**	**Groundwater Reporting Limit (ug/L)**	**Soil Reporting Limit (ug/kg)**	**Groundwater (ug/L)[2]**	**Soil (ug/kg)**
Organochlorine Pesticides						
Aldrin	309-00-2	EPA 8081B	0.005	5	0.003	2.5
α-BHC	319-84-6	EPA 8081B	0.005	5	0.014	0.5
β-BHC	319-85-7	EPA 8081B	0.005	5	0.049	2.3
γ-BHC (Lindane)	58-89-9	EPA 8081B	0.005	5	0.2	6.2
δ-BHC	319-86-8	EPA 8081B	0.005	5	0.005	1.0
cis-Chlordane	5103-71-9	EPA 8081B	0.005	10	0.25	2857
trans-Chlordane	5103-74-2	EPA 8081B	0.005	10	0.25	2857
4,4'-DDD	72-54-8	EPA 8081B	0.005	10	0.36	335
4,4'-DDE	72-55-9	EPA 8081B	0.005	10	0.26	446
4,4'-DDT	50-29-3	EPA 8081B	0.005	10	0.26	2941
Dieldrin	60-57-1	EPA 8081B	0.005	10	0.01	2.8
Endosulfan I [3]	959-98-8	EPA 8081B	0.005	5	96	304683
Endosulfan II [3]	33213-65-9	EPA 8081B	0.005	10	96	304683
Endosulfan sulfate [3]	1031-07-8	EPA 8081B	0.005	10	96	480000
Endrin	72-20-8	EPA 8081B	0.005	10	2.0	440
Endrin aldehyde	7421-93-4	EPA 8081B	0.005	10	2.0	24000
Endrin ketone	53494-70-5	EPA 8081B	0.02	10	2.0	8560
Heptachlor	76-44-8	EPA 8081B	0.005	5	0.02	3.8
Heptachlor epoxide	1024-57-3	EPA 8081B	0.005	5	0.005	8.0
Hexachlorobenzene	118-74-1	EPA 8081B	0.005	5	0.05	88
Methoxychlor	72-43-5	EPA 8081B	0.05	10	40	64160
Toxaphene	8001-35-2	EPA 8081B	0.05	50	0.08	153
Hexachlorobutadiene	87-68-3	EPA 8081B	0.01	10	0.56	604
Herbicides						
2,4-D	94-75-7	EPA 8151A	0.024	9.4	70	860
2,4-DB	94-82-6	EPA 8151A	0.024	9.5	128	16179
2,4,5-TP (Silvex)	93-72-1	EPA 8151A	0.024	9.5	50	4979
2,4,5-T	93-76-5	EPA 8151A	0.024	9.5	0.024	1.0
Dalapon	75-99-0	EPA 8151A	0.23	230	200	959
Dicamba	1918-00-9	EPA 8151A	0.024	9.4	480	3258
Dichloroprop	120-36-5	EPA 8151A	0.024	71	0.024	1.0
Dinoseb	88-85-7	EPA 8151A	0.024	0.69	7.0	688
MCPA	94-74-6	EPA 8151A	4.7	940	8.0	424
MCPP (Mecoprop)	93-65-2	EPA 8151A	4.7	940	16.0	498
Pentachlorophenol	87-86-5	EPA 8151A	0.0095	0.95	0.219	3.5
Organophosphorus Pesticides						
Chlorpyrifos	2921-88-2	EPA 8270D-SIM	0.2	20	48	43891
Diazinon	333-41-5	EPA 8270D-SIM	0.2	20	0.2	30
Dimethoate	60-51-5	EPA 8270D-SIM	0.5	20	3.2	13
Disulfoton	298-04-4	EPA 8270D-SIM	0.2	20	0.64	95
Malathion	121-75-5	EPA 8270D-SIM	0.2	20	320	2522
Parathion, ethyl	56-38-2	EPA 8270D-SIM	0.2	20	96	10716
Parathion, methyl	298-00-0	EPA 8270D-SIM	0.2	20	4.0	447
Phorate	298-02-2	EPA 8270D-SIM	0.2	20	3.2	162
Sulfotepp	3689-24-5	EPA 8270D-SIM	0.2	20	8.0	1561
Petroleum Compounds						
TPH-Dx	--	NWTPH-Dx	100	50	500	2000000
Benzene	71-43-2	EPA 8260	0.2	1.5	0.80	5
Toluene	108-88-3	EPA 8260	1	7.5	640	4654
Ethylbenzene	100-41-4	EPA 8260	0.2	1.5	6.0	52
Xylenes	1330-20-7	EPA 8260	0.4	3	9.0	82
Naphthalene	91-20-3	EPA 8260	1	1.5	160	4457
Groundwater Field Parameters						
pH, Field		Field Meter				
Specific Conductance, Field		Field Meter				
Oxidation-Reduction Potential		Field Meter				
Temperature		Field Meter				
Turbidity		Field Meter				

[1] Matrix interferences may result in elevated reporting limits. Reporting limits are as expected for routine analytical conditions

[2] For certain Organochlorine Pesticides constituents, the most stringent cleanup level established is the ARAR MCLG (0 ug/L); these constituents will use the MTCA Method B Table Value.

[3] Groundwater and soil cleanup levels established for parent chemical Endosulfan CAS No 115-29-7; which is related to Endosulfan I (alpha) CAS No 959-98-8, Endosulfan II (beta) CAS No 33213-65-9, and Endosulfan sulfate CAS No 1031-07-8

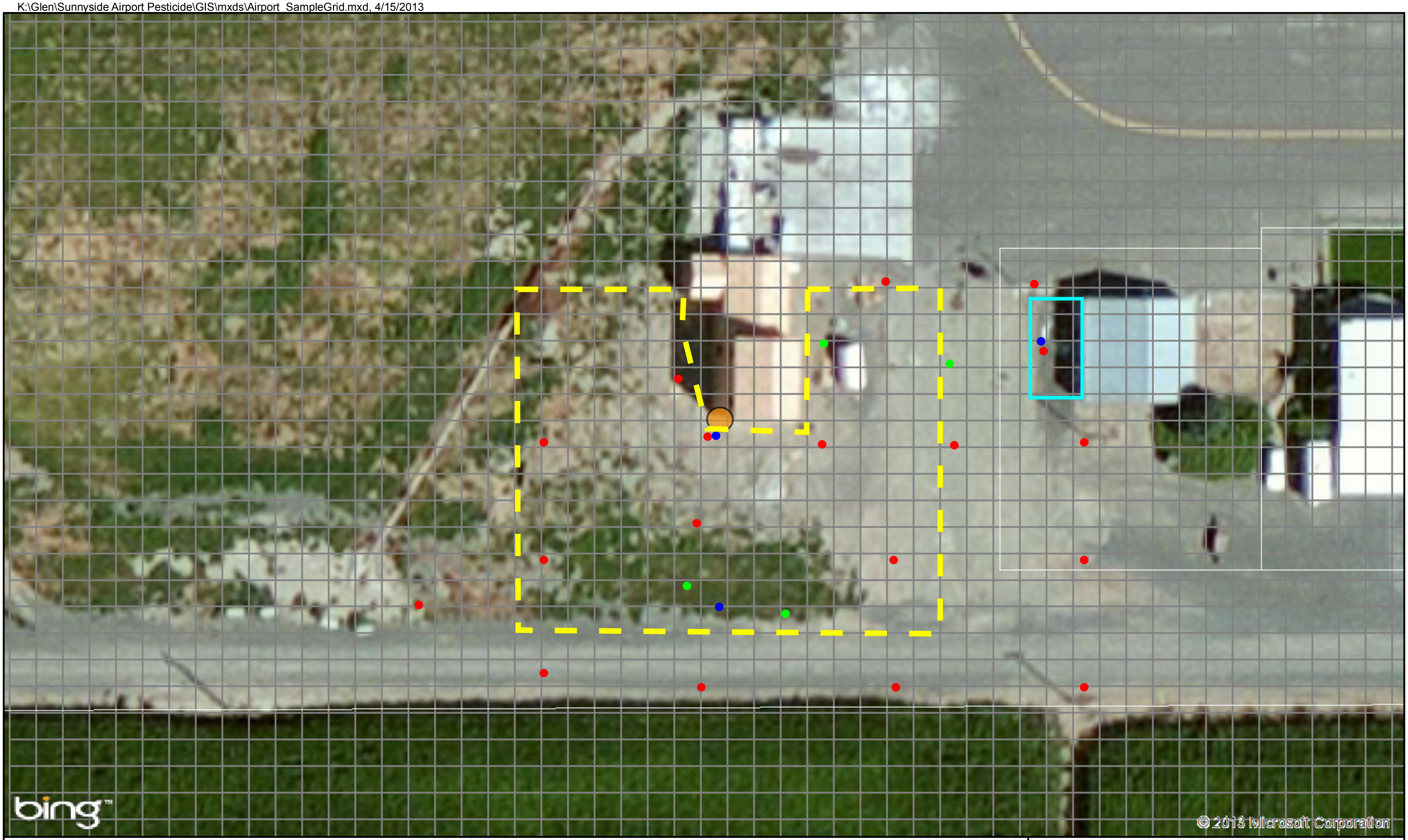
Table 2. Summary of Analytical Methods and Hold Times

Sunnyside Airport Pesticide Shed, Sunnyside, Washington

Constituent Group	Analytical Method	Hold Time Soil	Hold Time Groundwater	Container Soil	Container Groundwater
Organochlorine Pesticides	Method 8081B	7 days	14 days	8oz WMG	2-500mL AG
Herbicides	Method 8151A	7 days	14 days	8oz WMG	2-500mL AG
Organophosphate Pesticides	Method 8270D-SIM	7 days	14 days	8oz WMG	2-500mL AG
Diesel-range Hydrocarbons	NWTPH-Dx	14 days	7 days	8oz WMG	2-500mL AG
Volatile Organic Compounds	Method 8260	14 days	14 days	2-40mL VOA	2-40mL VOA

AG: amber glass bottle
WMG: wide mouth glass jar
VOA: vial with teflon lid

K:\Glen\Sunnyside Airport Pesticide\GIS\mxds\Airport_SampleGrid.mxd, 4/15/2013



● Ecology Sample Locations

Airport Parcels

— 10-foot Sample Grid

● Proposed Phase I Groundwater Sample Locations

● Proposed Phase I Soil Sample Locations

☐ Approximate Extent of Former Pesticide Shed

● Approximate Location of Buried Metal Debris

▭ Geophysical Survey Area

0 Feet 50

N

Aerial Photo from Bing Maps, Aug/Oct 2010

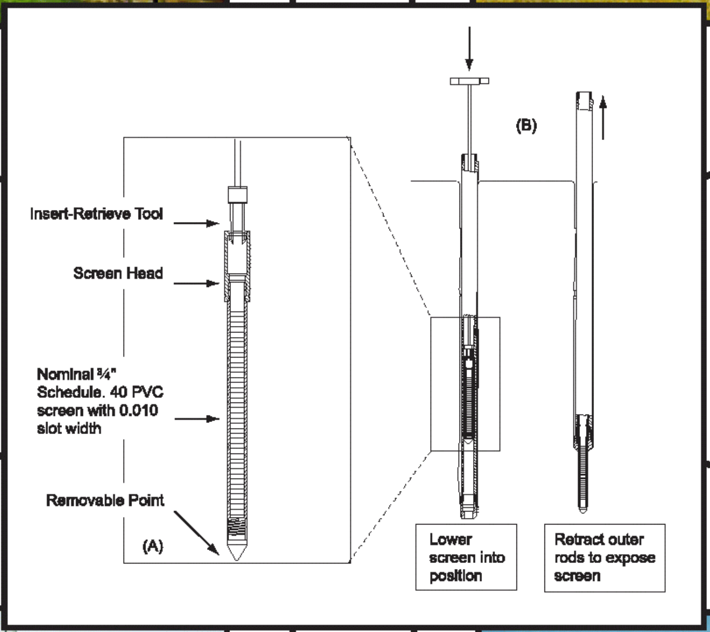
Figure 1
Investigation Locations

Sunnyside Municipal Airport
Environmental Investigation

PGG

APPENDIX A
EPA GUIDANCE DOCUMENTS

Groundwater Sampling and Monitoring with Direct Push Technologies



Solid Waste and
Emergency Response
(5204G)

OSWER No. 9200.1-51
EPA 540/R-04/005
August 2005
www.epa.gov

Groundwater Sampling and Monitoring with Direct Push Technologies

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Washington, DC 20460

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Abbreviations

ASTM	American Society for Testing and Materials
CPT	cone penetrometer testing
CSP	centrifugal submersible pump
DCE	dichloroethene
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DPT	direct push technology
DQO	data quality objectives
FID	flame ionization detector
GC	gas chromatograph
ID	inner diameter
LIF	laser-induced fluorescence
LNAPL	light non-aqueous phase liquid
MIP	membrane interface probe
OD	outer diameter
ORP	oxidation/reduction potential
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PE	polyethylene
PP	polypropylene
PTFE	polytetrafluoroethylene
PVC	polyvinyl chloride
QC	quality control
RCRA	Resource Conservation and Recovery Act
ROST	Rapid Optical Screening Tool
SC	specific conductivity
SVOC	semi-volatile organic compound
TCE	trichloroethene
EPA	United States Environmental Protection Agency
UV	ultraviolet
VOC	volatile organic compound

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Section 1: Introduction

Background

Direct push technology (DPT, also known as “direct drive,” “drive point,” or “push technology”) refers to a growing family of tools used for performing subsurface investigations by driving, pushing, and/or vibrating small-diameter hollow steel rods into the ground. By attaching sampling tools to the end of the steel rods they can be used to collect soil, soil-gas, and groundwater samples. DPT rods can also be equipped with probes that provide continuous in-situ measurements of subsurface properties (e.g., geotechnical characteristics and contaminant distribution). Interest in understanding how DPT groundwater collection methods compare with traditional monitoring well sampling methods has steadily increased since the mid-1980s when DPT first started being used for this purpose. Although environmental professionals recognize that DPT provide a cost-effective alternative to conventional approaches to subsurface sampling, some have been reluctant to use it for groundwater sampling because of uncertainty regarding the quality of samples that the technology can provide. This guidance is designed to encourage more widespread consideration of DPT by clarifying how DPT can be used to meet a variety of data quality requirements for a variety of site conditions.

Intended Audience

The primary audience for this guidance is EPA regional folks working on CERCLA, RCRA, and other related programs. It also may be useful for environmental professionals who oversee or undertake the collection of groundwater samples at contaminated sites and have a basic scientific understanding of groundwater sampling. Information is provided on the application and limitations of DPT for groundwater sampling activities. Although this document is not intended to provide substantial background information, Section 2 provides a general overview of DPT groundwater sampling and an extensive list of resources is cited within the text and listed in the reference section.

Scope and Limitations

This document focuses on groundwater sampling issues related to DPT, in particular those regarding the quality and usability of the groundwater data. Two general types of DPT groundwater sampling methods are discussed: “point-in-time” or “grab” sampling and sampling with direct push installed monitoring wells. In order to provide a concise and readable document, references are provided so that readers can access more detailed information where needed. Other uses of DPT, such as soil sampling, soil-gas sampling, and deployment of continuous logging equipment, generally are not controversial; therefore, they are not discussed at length. In addition, this guidance assumes a basic level of understanding of DPT equipment. Readers unfamiliar with DPT equipment should refer to:

- Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators (EPA, 1997). Chapter V of this guide, Direct Push Technologies, provides a good overview of the tools and their capabilities. It is available at: http://www.epa.gov/swerust1/pubs/sam.htm.

- The Field Analytical Technology Encyclopedia (FATE) contains a section on Direct Push Platforms. It is available at: http://fate.clu-in.org.

- ASTM direct push standards, Standard Guide for Installation of Direct Push Ground Water Monitoring Wells, D 6724-01; Standard Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers, D 6725-01; Standard Guide for Direct-Push Water Sampling for Geoenvironmental Investigations, D-6001; and Standard Guide for Direct Push Soil Sampling for Environmental Site Characterization, D-6282. They are available for purchase at: http://www.astm.org.

This guidance is not intended to replace the knowledge and advice of an experienced hydrogeologist. Site-specific situations may dictate that an expert familiar with site conditions and project goals be involved in the planning and implementation of any groundwater sampling event. Furthermore, Federal and State regulatory requirements can vary substantially among jurisdictions and the appropriate regulatory and State agencies must be consulted to ensure that legal requirements are met.

Advantages and Limitations of Direct Push Technologies

Direct push technologies are a valuable tool for environmental investigations because they can offer a number of advantages over conventional well installation and sampling methods and can provide many other types of data to a project team (e.g., in-situ detection of contaminants, real-time geotechnical data). Some of the typical advantages of using DPT over monitoring wells drilled and installed with conventional tools, such as hollow stem augers, include:

- Faster sampling capability that helps to provide more data, thereby improving site decision making and facilitates the use of a dynamic work plan strategy;
- In general, lower cost when greater data density is needed;
- Greater variety of equipment and methods resulting in greater flexibility in meeting project goals;
- Capability of collecting depth-discrete groundwater samples to locate contaminated layers;
- Better vertical profiling capability for generating three-dimensional profiles of a site that improve the conceptual site model; and
- Less investigation-derived waste generated, thereby saving additional time and money while minimizing the potential for exposure to hazardous substances.

However, DPT cannot completely replace the use of conventional monitoring wells. Rather, DPT provides environmental professionals with additional choices from which to select equipment and methods for collecting groundwater samples. Conventional methods still have a number of potential advantages over DPT, including:

- Fewer limitations for deployment in a variety of geologic and hydrogeologic settings. For example, conventional DPT may not be able to penetrate some caliches, bedrock, or unconsolidated layers with significant amounts of gravel or cobbles. DPT is not recommended where telescoped wells are needed to prevent contaminant migration below confining layers;
- Deeper limit of subsurface penetration than DP rigs in most geologic settings; and
- Easier collection of large sample volumes.

Consequently, DPT and conventional monitoring well technologies may both be useful for groundwater sampling. They can provide environmental professionals with a variety of options to collect data sufficient for decision making, even when high quality groundwater samples are needed.

How to Use This Guidance

This guidance is divided into four major sections designed to expose the reader to potential issues and solutions regarding groundwater sampling with DPT:

- *Section 2: Summary of Direct Push Technology Groundwater Sampling Methods*: provides an overview of the different types of equipment available with DPT to collect groundwater.
- *Section 3: Data Quality Objectives for Groundwater Sampling*: provides the reader with a summary of groundwater data quality issues that should be considered while planning a groundwater sample collection activity.
- *Section 4: Recommended Methods for Collecting Representative Groundwater Samples*: provides the reader with information on filter packs, well development, and low-flow sampling methods as they relate to DPT.
- *Section 5: Recommended Methods for Minimizing the Potential for Cross-Contamination*: provides the reader with information on drag-down, hydraulic conduits, decontaminating equipment, and decommissioning DPT boreholes.

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Section 2: Summary of Direct Push Technology Groundwater Sampling Methods

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DPT groundwater sampling equipment generally falls into one of two broad categories:

- **Point-in-time groundwater samplers:** These tools or devices, also referred to as "temporary samplers" or "grab samplers," are used to rapidly collect samples to define groundwater conditions during one sampling event. They are usually less than two inches outside diameter (OD) and are generally constructed of steel or stainless steel. Direct push methods (percussion or static weight) are used to advance point-in-time samplers below the static water level in unconsolidated formations. Generally, groundwater flows into the sampler from an exposed screen under ambient hydrostatic pressure. Groundwater may be collected from the sampler using bailers or pumps, or the sampler may be retracted to the surface to obtain the water sample. Once sampling is completed, these devices are removed and the boring should be abandoned in accordance with local regulations.

- **DPT-installed groundwater monitoring wells:** These monitoring wells are installed by direct push methods to permit short-term or long-term monitoring of groundwater and are usually two inches in diameter or less and constructed of PVC and/or stainless steel. Since monitoring wells are installed for periods of several months to several years, the annulus of the boring around the well casing is usually sealed to prevent migration of contaminants into the aquifer. Surface protection is required to prevent tampering with the well. A slotted or screened section permits groundwater to flow into the well under ambient hydrostatic pressure. Groundwater may be collected from monitoring wells using bailers, various pumps, or passive sampling devices.

Point-in-time sampling tools are typically used during site characterization to identify plume boundaries or hot spots. They cannot be used for long-term monitoring or trend analysis since the boreholes need to be decommissioned upon completion of sampling. In contrast, temporary and permanent monitoring wells are typically used to provide trend analysis of contaminant groundwater concentrations over an extended period of time. DPT can be used to install small-diameter (e.g., up to 2 inches outside diameter [OD]) monitoring wells.

Ideally, both DPT point-in-time and monitoring well groundwater sampling equipment should be used together to maximize their effectiveness. Point-in-time sampling techniques are generally better for identifying plume boundaries, hot spots, preferred pathways, or other monitoring points of interest. Once this information is collected, DPT monitoring wells, as well as conventional monitoring wells, can be optimally placed to provide project teams with the most useful monitoring data.

This section summarizes the various types of point-in-time sampling tools and DPT monitoring well installation techniques. Since DPT groundwater sampling methods are often used to their best advantage in combination with other specialized DPT measurement and logging tools, these associated tools are also discussed at the end of this section. This information is intended to provide the reader with an easily accessible summary of available

DPT tools. Other resources listed in the *Introduction* could also be used for a more comprehensive survey of available tools and their capabilities. Table 2.1 provides a list of some of the major DPT equipment available for groundwater investigations. It summarizes the capabilities of the equipment and helps the reader to sort through the variety of tools and how they may be useful for specific project goals. Because this section provides a basic overview of existing equipment, readers already familiar with the capabilities of DPT equipment may wish to proceed to Section 3 for information on how these tools can be used to collect groundwater samples to meet project objectives.

Point-in-Time Sampling

A variety of point-in-time groundwater sampling tools are available for site characterization, including:

- Sealed-screen sampling;
- Multi-level sampling (or vertical profiling); and
- Open-hole sampling.

With these techniques, the time needed to retrieve the sample will vary according to the hydraulic conductivity of the sampling zone. In general, sampling within coarse-grained sediments takes minutes while fine-grained sediments can take several hours or more. In situations where slow recharge inhibits the timely collection of groundwater samples, the sampler may be left in place to recharge while the DPT rig is moved to a new sampling location.

Sealed-Screen Samplers

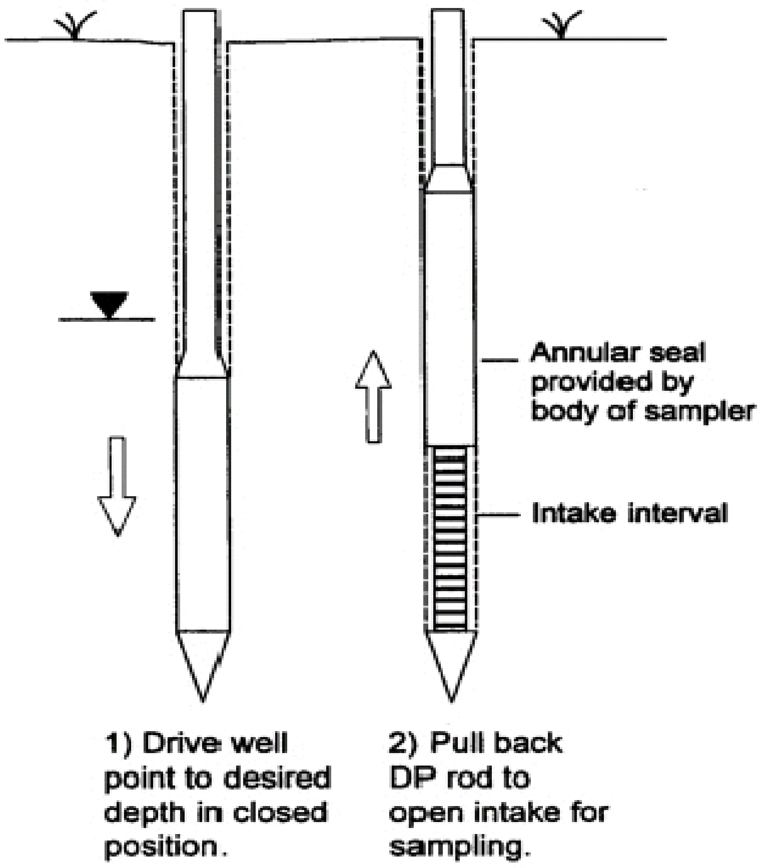
Sealed-screen samplers typically consist of a short (e.g., 6-inch to 3-foot) screen nested within a sealed, water-tight tool body (Figure 2.1). Because the screen is not exposed to the formation as the sampler is advanced into the subsurface, the screen does not become plugged or damaged. In addition, the potential for cross contamination is greatly reduced and a true depth-discrete sample that is representative of the target sampling zone can be collected. The sample volume collected with some sealed-screen samplers is limited by the volume of the sample chamber (e.g., 500 mL for the Hydropunch I™; 1.2 L for the Hydropunch II™; and 35 to 120 mL for each vial in the BAT™).

To collect the sample, the sealed-screen sampler is advanced to the target sampling depth and the protective outer rod is retracted, exposing the screen to groundwater. Groundwater flows through the screen under the hydraulic head conditions that exist at that depth and into the drive rods or sample chamber. O-ring seals placed between the drive tip and the tool body help ensure that the sampler is water tight as it is driven to the target sampling interval. The integrity of the seal can often be checked by lowering an electronic water level indicator into the sampler prior to retracting the protective outer rod.

Table 2.1
Comparison of Various Direct Push Technology Sampling and Data Collection Capabilities

	CAPABILITIES											
EQUIPMENT	Evaluate Strati-graphy	Measure Pore Pressure	Measure Soil Conduc-tivity	Detect Hydrocarbon	Detect VOC	Sample Soil	Sample Soil Gas	Sample Ground-water	Sample Pore Water	Evaluate Vadose Zone	Measure Water Level	Install Small Diameter Wells
Sealed-Screen Samplers												
BAT GMS								✓	✓			
BAT Enviroprobe							✓	✓				
Dual-Tube Samplers	✓					✓	✓	✓		✓	✓	✓
HydroPunch I and II™								✓				
PowerPunch™										✓	✓	✓
Screen Point 15								✓			✓	
SimulProbe®						✓	✓	✓				
Multi-Level Samplers												
Geoprobe	✓		✓		✓	✓	✓	✓		✓	✓	✓
Envirocore	✓					✓	✓	✓		✓	✓	✓
Vertek ConeSipper®	✓	✓	✓				✓	✓		✓	✓	
Waterloo Profiler							✓	✓		✓	✓	
Specialized Measurement and Logging Tools												
Cone Penetrometer	✓	✓	✓			✓	✓	✓		✓	✓	✓
Instrumented CPTs	✓	✓	✓	✓	✓	✓						

Figure 2-1
Sealed-Screen Sampler



Source: Cordry, 1995[1]

Sampling fine-grained formations may be difficult because of the long time it takes to fill the sampler with groundwater. Sample collection times in formations with low hydraulic conductivity may exceed several hours for some tools, compared to several minutes or tens of minutes in formations of high to moderate hydraulic conductivity (Zemo et al., 1994; Zemo et al., 1995). However, to avoid downtime, the samplers can be left in the borehole to recharge while the installing rig moves off the hole to another location to sample. To decrease sample collection time, samples can be collected from samplers with longer, 30- to 42-inch screens (e.g., Geoprobe® Screen Point 15) while the tool is downhole. A bailer or pump is needed to collect the sample from the target zone.

Sealed-screen samplers generally are limited to collecting one sample per advance of the sampler. However, depending upon the system used, multi-level sampling in a single borehole can be accomplished with sealed-screen samplers by retrieving the sampler and decontaminating it or replacing it with a clean sampler before reentering the hole to collect another sample.

Multi-Level Samplers

Multi-level samplers, most of which are exposed-screen samplers, are DPT equipment capable of collecting groundwater samples at multiple intervals as the sampling tool is advanced, without having to withdraw the tool for sample collection or decontamination. The terminal end of a typical multi-level sampling tool has a 6-inch- to 3-foot-long screen made up of fine-mesh, narrow slots, or small holes. The screen remains open to formation materials and water while the tool is advanced (Figure 2.2). This allows samples to be collected either continuously or periodically as the tool is advanced to vertically profile groundwater chemistry and aqueous-phase contaminant distribution.

Multi-level samplers can be used to measure water levels at discrete intervals within moderate- to high-yield formations to assist in defining vertical head distribution and gradient. Additionally, some of these tools can be used to conduct hydraulic tests at specific intervals to characterize the hydraulic conductivity in formation materials to identify possible preferential flow pathways and barriers to flow (Butler et al., 2000; and McCall et al., 2000).

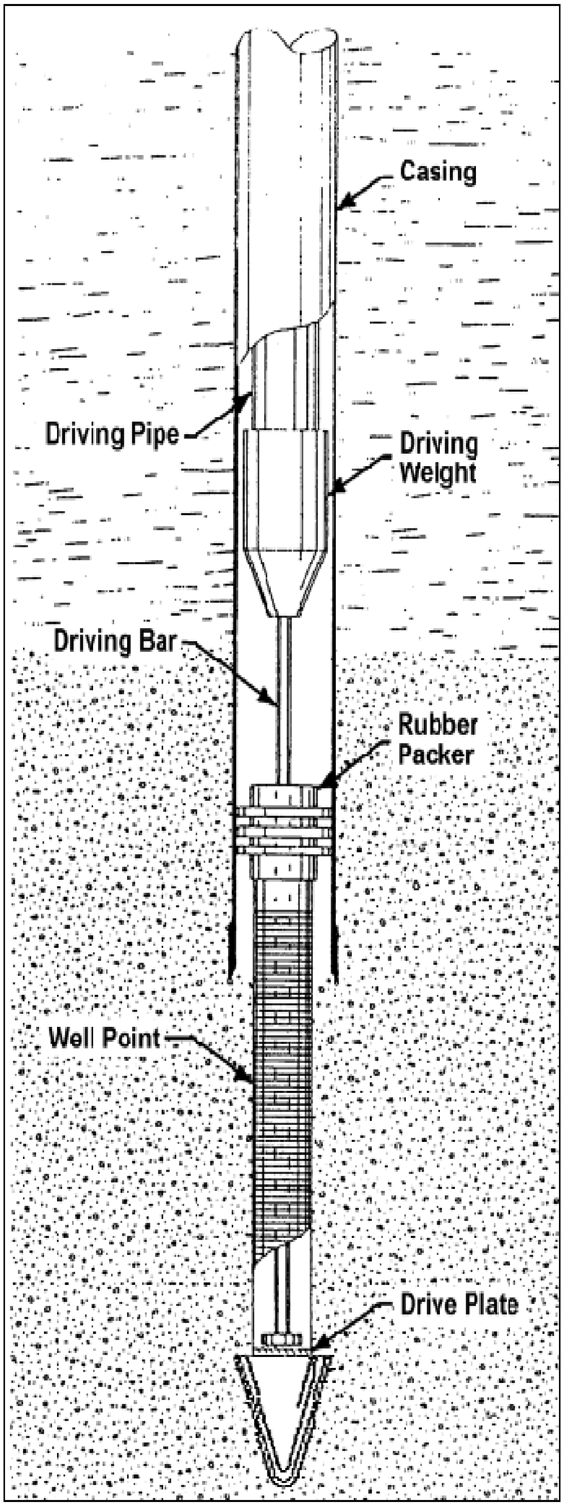
A drawback to multi-level sampling is the possible drag-down by the screen of contamination from zones above the desired sampling interval (Figure 2.3) (Pitkin et al., 1999). The Waterloo Profiler minimizes the potential for cross- contamination. It uses a 6-inch long, uniform diameter, stainless-steel sampling tool into which several inlets or sampling ports have been drilled and covered with fine-mesh screen. As the tool is advanced, distilled or deionized organic-free water is slowly pumped down tubing that runs inside the drive rod and leads to the sampling ports in the tool (Figure 2.4). The water keeps groundwater from entering the tool while it is advanced. A peristaltic pump is typically used for depths less than 25 feet; a double-valve pump can be used for sampling at greater depths.

After the first target interval is reached, the flow of the pump is reversed and the sampling tube is purged so water representative of the aquifer is obtained. After the sample is collected, the pump is reversed and distilled or deionized water is again pumped through the sampling ports. The tool is then advanced to the next target interval where the process is repeated (Figure 2.5).

Several field studies (Cherry, et al., 1992; Pitkin, et al., 1994; Pitkin, et al., 1999) have demonstrated that the Waterloo Profiler is capable of providing a very detailed view of contaminant plumes—particularly in complex stratified geological materials—without the effects of drag-down and the cross contamination of samples. However, because a peristaltic pump is typically used to collect samples when the sampling depth is less than 25 ft below ground surface (bgs), there may be a negative bias in samples collected for analysis of VOCs or dissolved gases. To avoid this potential bias, VOC samples should be collected in-line, ahead of the pump, and a sufficient volume of water should be pumped through the system to account for the initial filling of the containers when a negative head space was present.

Another multi-level sampler, the VERTEK ConeSipper®, attaches directly behind a standard cone penetrometer to collect groundwater as the cone penetrometer testing (CPT) is advanced. An inert gas flows to the ConeSipper® to control the rate of sample collection and to purge and decontaminate the device down hole. The ConeSipper® is equipped with two filters, which help minimize turbidity in the samples. The primary filter is a stainless steel screen whose openings can range in size from 51 to 254 µm. A secondary filter, which can be made from sintered stainless steel and comes with opening sizes ranging from 40 to 100 µm or regular

Figure 2.2
Exposed-Screen Sampler–Well Point Driven below the Base of a Borehole



Source: ASTM (2001e)

Figure 2.3
Schematic Illustration of Degrees of Drag Down Potentially Induced by Direct Push Sampling Devices

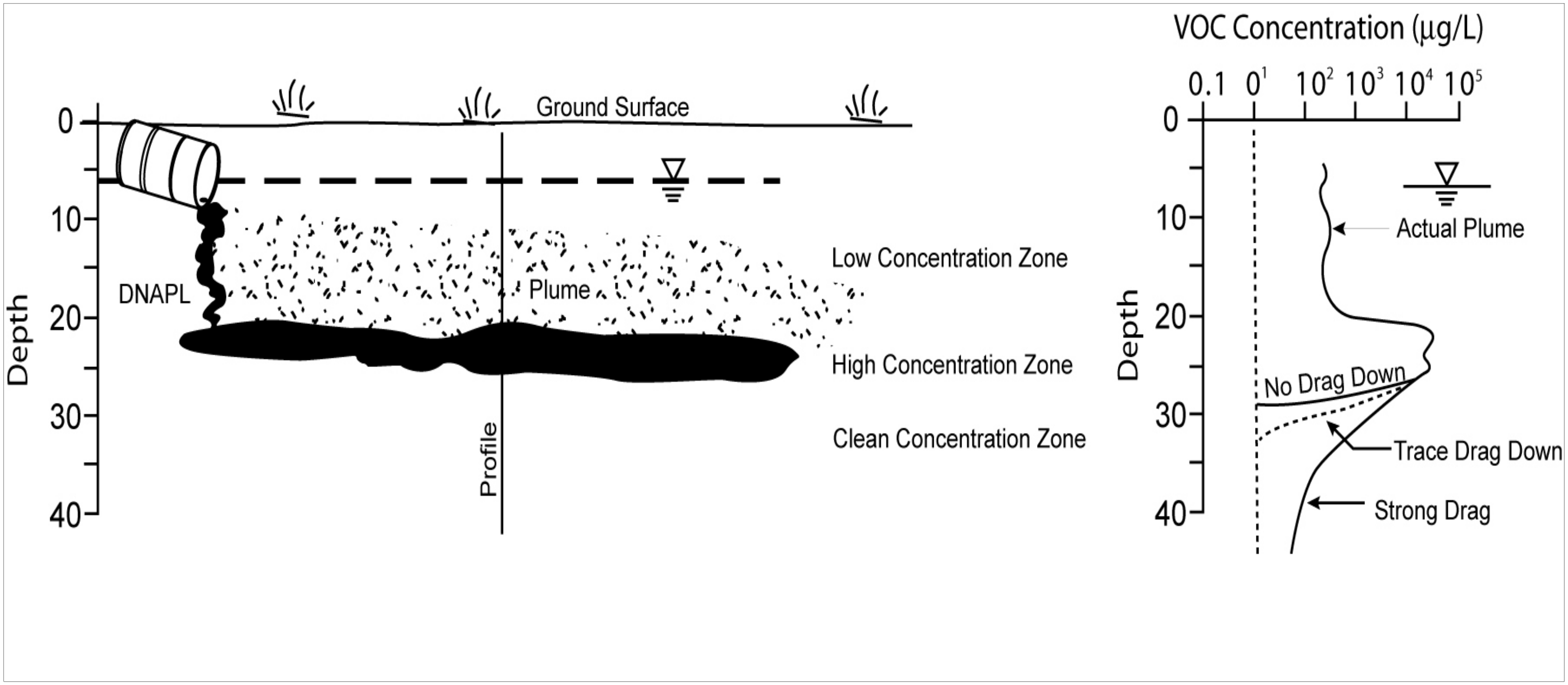
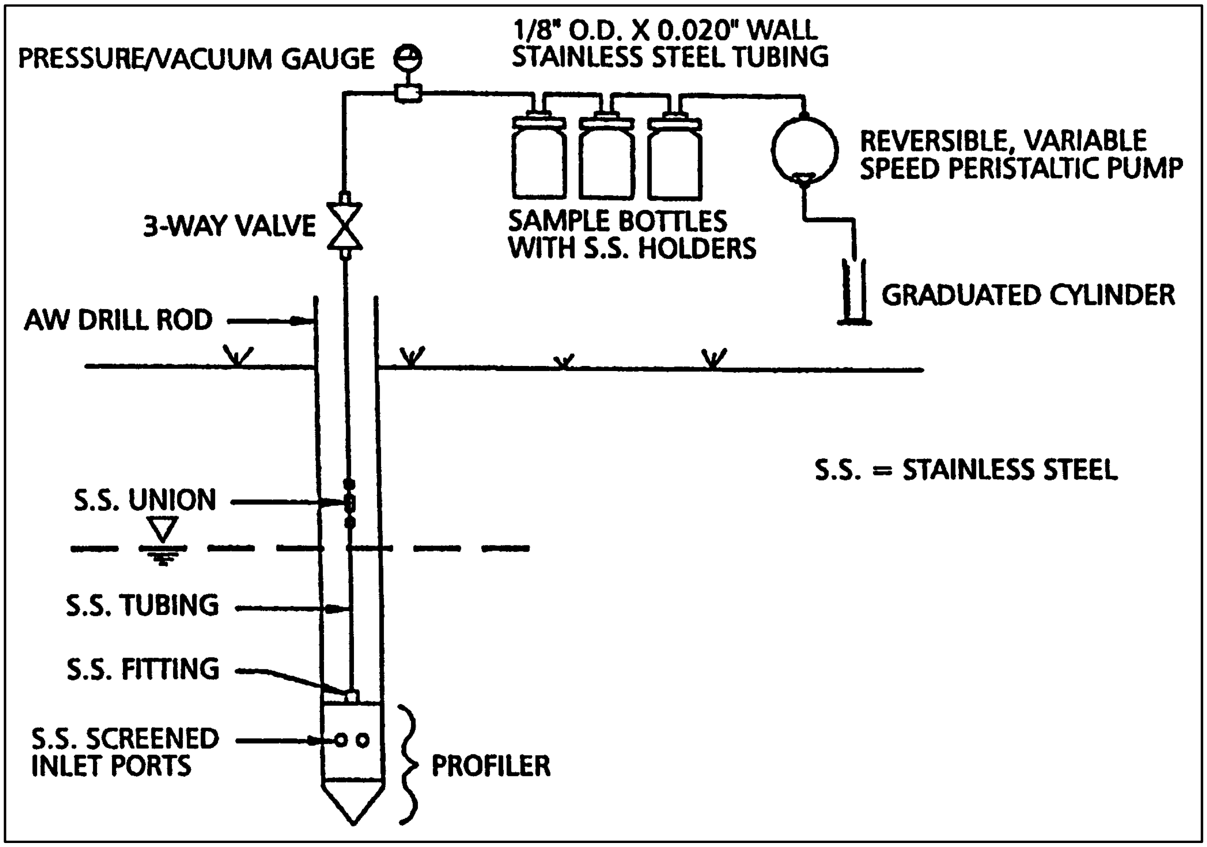


Figure 2.4
Operation of the Waterloo Profiler



Source: Pitkin et al. (1999)

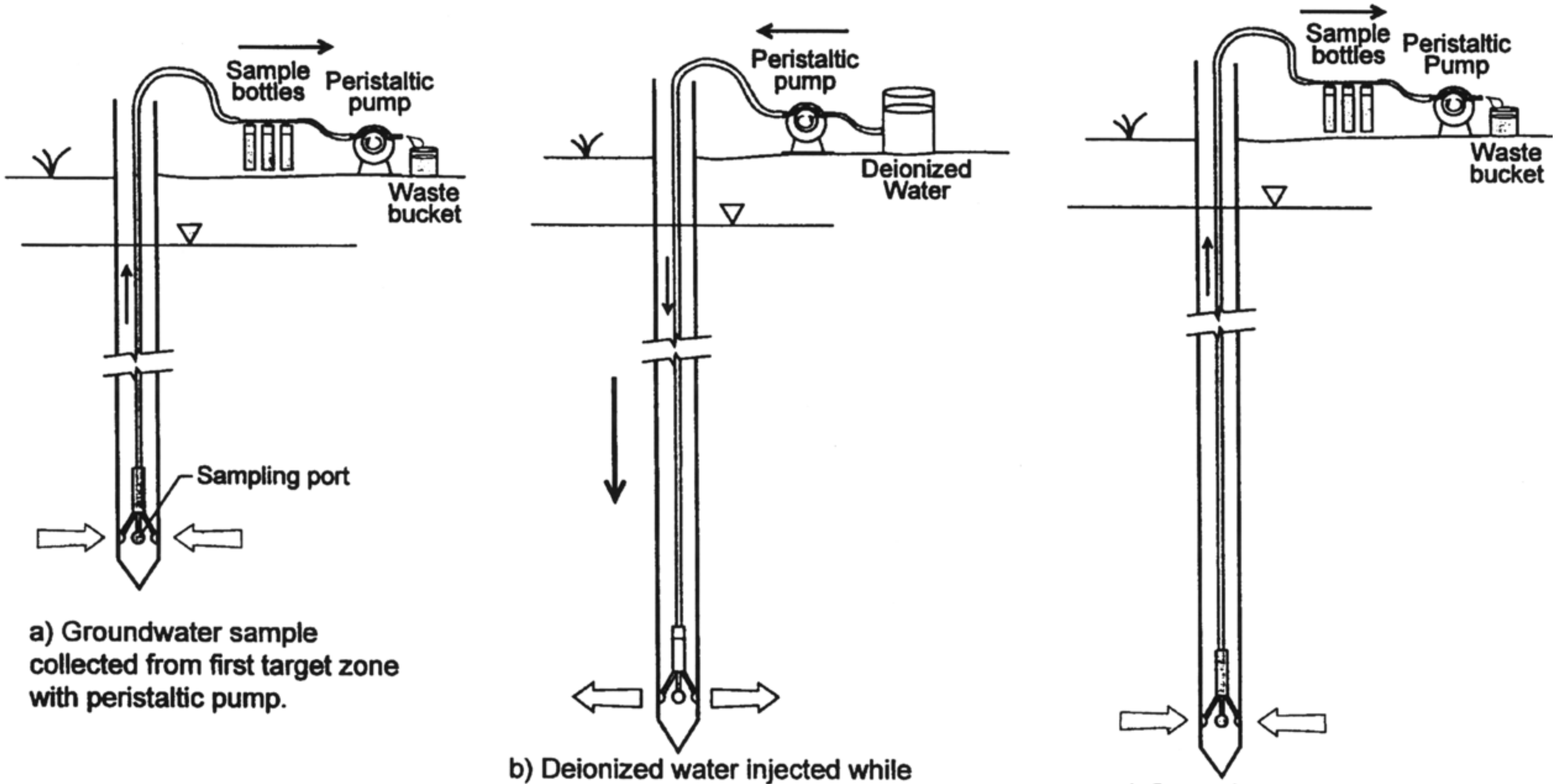
stainless steel with openings ranging in size from 38 to 74 µm, removes fines (Applied Research Associates, 2004).

Open-Hole Sampling Methods

Open-hole sampling is conducted by advancing drive rods with a drive point to the desired sampling depth. Upon reaching the sampling depth, the rods are withdrawn slightly which separates them from the drive tip and allow water to enter the rods. The water can be sampled by lowering a bailer into the rods or by pumping. The open-hole method is only feasible within formations that are fairly cohesive, otherwise the formation may flow upwards into the rods when they are withdrawn, preventing samples from being collected.

With single-rod systems, open-hole sampling can only be conducted at one depth within a borehole because the borehole cannot be flushed out between sampling intervals and cross-contamination may occur. Dual-tube systems, on the other hand, can be used to conduct multi-level sampling.

Figure 2.5
Collecting Samples From Discrete Depths (Profiling) Using the Waterloo Drive-Point Profiler



a) Groundwater sample collected from first target zone with peristaltic pump.

b) Deionized water injected while advancing tool to prevent sampling ports from becoming plugged.

c) Groundwater sample collected from second target zone with peristaltic pump.

Source: Precision Sampling, Inc.

Dual-tube samplers are typically advanced into the subsurface to collect continuous soil cores; however, groundwater samples can be collected at the end of each core run. Dual-tube samplers have an outer casing that is driven to the target soil coring depth. The outer casing holds the hole open and seals off the surrounding formation as an inner rod (with a sample liner for soil sampling) is lowered into the outer casing and both are driven into the undisturbed formation below. Once the soil core is retrieved, groundwater can be sampled by lowering a bailer or pump into the outer casing The borehole can continue to be advanced so that multiple groundwater samples can be retrieved from multiple depths in the same borehole. The water should be purged from the casing with subsequent advances of casing and inner rod so that groundwater from overlying intervals do not cross-contaminate the sample.

The amount of water that needs to be purged depends upon the type of sampling equipment that is used. For pumping systems, purging procedures similar to those designed for wells (low-flow purging) and described in Section 4, should be used. If bailers are used, then it is important that all the water contained in the outer casing be removed to ensure that the water the bailer is passing through comes from the interval of interest. The accepted procedure for traditionally completed wells when bailers are used is to remove at least three volumes of water and measure water quality indicators (e.g., pH, specific conductance) until they stabilize. The use of a bailer in this situation may preclude the collection of some parameters that may be sensitive to the iron in the outer casing (See Low-flow Purging Section 4.)

A dual-tube profiling system has been developed so that a simple screen can be inserted through the cutting shoe of a dual-tube soil sampling device (Figure 2.6). This system enables the operator to collect soil samples and then insert a screen at selected intervals, which they can then use for sampling or conducting slug tests to locate preferential migration pathways (Butler et al., 2000; McCall et al., 2000). This system also allows for bottom-up grouting to assure proper boring abandonment.

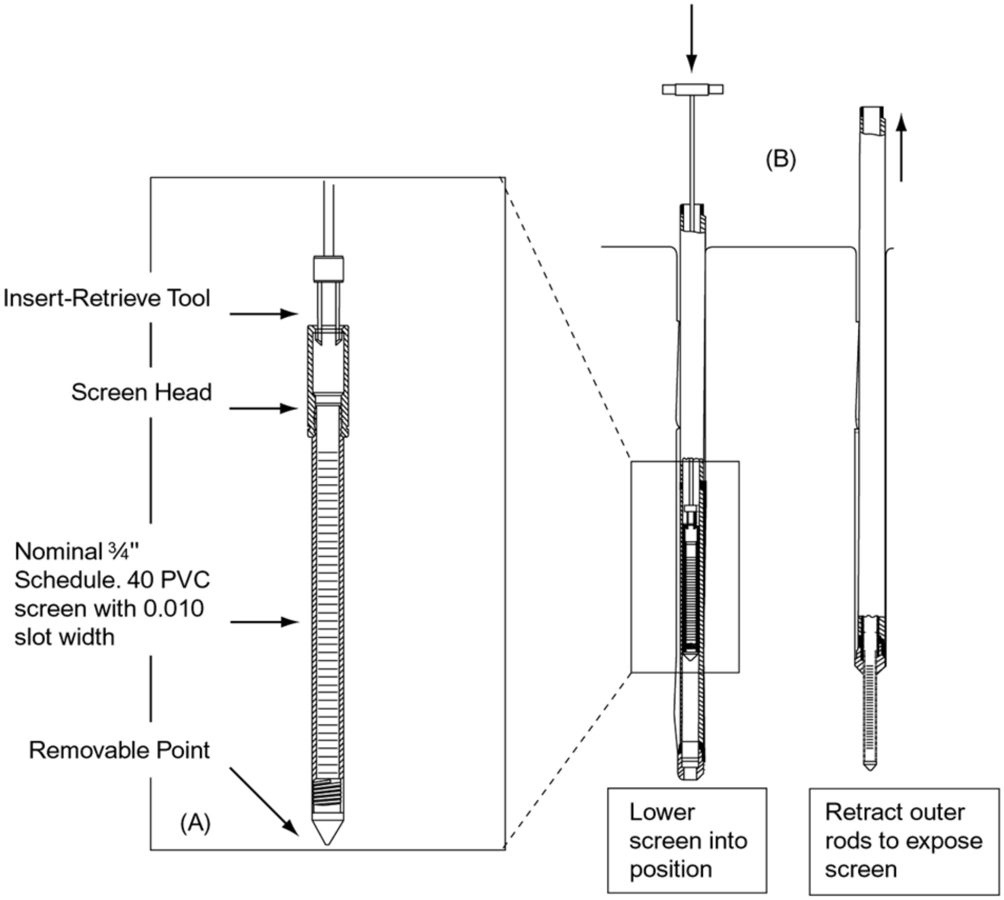
DPT Monitoring Well Installation

A variety of DPT methods are available for installing temporary or permanent monitoring wells. The two main installation methods used are exposed-screen and protected-screen wells. These methods are discussed in detail in ASTM D-6724 and D-6725 (ASTM, 2003a and 2003b) and are summarized here. As with conventional well installations, hydraulic connections should not be created between otherwise isolated water-bearing strata. In addition, precautions should be taken to minimize turbidity during the installation of filter packs and the development and sampling of wells (Section 4).

Exposed-Screen Well Installation Methods

With exposed-screen well installation methods, the well casing and screen are driven to the target depth using a single string of rods. Because the screen is exposed to formation materials while it is advanced, proper well development (as discussed in Section 4) is important to remove soil from screen slots. This method is not recommended for installing well screens within or beneath contaminated zones because drag-down of contaminants with the screen may cross-contaminate sampling zones and make acquisition of samples representative of the target zone impossible. Exposed-screen well installation methods should only be used in upgradient

Figure 2.6
Schematic of the Geoprobe® DT21 Profiler



A) Screen components for insertion through the dual-tube system for slug testing and sampling.

B) The profiling screen is lowered through the outer rods after the inner rods are removed. Once the screen is at the base of the outer rods, they are retracted as the screen is held in position for accurate placement.

Source: www.geoprobe.com

areas that are known to be uncontaminated. Also, some states prohibit allowing the formation to collapse around a well screen in the construction of a monitoring well**.** Therefore, state regulations should be consulted before selecting exposed-screen techniques.

In one type of exposed-screen installation, the PVC well screen and casing are assembled and placed around a shaft of a drive rod connected to a metal drive tip. The casing and screen, which rest on top of the drive tip, are advanced to the target depth by driving the rod to avoid placing pressure on the screen. The drive tip slightly enlarges the hole to reduce friction between the formation and the well screen and casing, and remains in the hole plugging the bottom of the screen. The filter pack surrounding the well screen commonly is derived from formation materials that are allowed to collapse around the screen. Rigorous well development improves the hydraulic connection between the screen and the formation and generally is necessary to remove formation fines and the effects of well installation, which may include borehole smearing or the compaction of formation materials. Due to the very small annulus (if any) that surrounds a well constructed using the exposed-screen method, it is not generally possible to introduce a filter pack or annular seal from the surface.

Exposed-screen methods also can be used to install well points—simple wells used for rapid collection of water level data, groundwater samples, and hydraulic test data in shallow unconfined aquifers. Well points are generally constructed of slotted steel pipe or continuous-wrap, wire-wound, steel screens with a tapered tip on the bottom. They can be driven into unconsolidated formations and used for either point-in-time sampling and decommissioned after the sample is collected, or left in place for the duration of the sampling program—possibly requiring the installation of a seal to prevent infiltration of water from the ground surface to the screened interval.

The optimum conditions for well point installations are shallow sandy materials. Predominantly fine-grained materials such as silt or clay can plug the screen slots as the well point is advanced. Because well points are driven directly into the ground with little or no annular space, the formation materials are allowed to collapse around the screen, and the well point needs to be developed to prepare it for sampling.

Protected-Screen Well Installation Methods

When installing a protected-screen well, the well casing and screen are either advanced within or lowered into a protective outer drive rod that has already been driven to the target depth. Once the well casing and screen are in place, the drive rod is removed. Alternatively, the casing, screen, and a retractable shield may be driven simultaneously to the target depth. Once in place, the screen is exposed and the entire unit remains in the ground. If there is sufficient clearance between the inside of the drive rod and the outside of the well casing and screen, a filter pack and annular seal may be installed by tremie from the surface as the drive casing is removed from the hole. Several filter packing and annular sealing approaches are available, depending on the equipment used for the installation (ASTM D5092 and D6725; ASTM, 2003b and 2003c). Regardless of the method of installation, the filter pack should be sized appropriately to retain most of the formation materials (refer to Driscoll, 1986 or ASTM D5092-02).

The most common protected-screen method for installing DPT wells is to advance an outer drive casing equipped with an expendable drive tip to the target depth. The well casing and screen are then assembled, lowered inside the drive casing, and anchored to the drive tip. The drive casing seals off the formations through which it has been advanced, protecting the well casing and screen from clogging and from passing through potentially contaminated intervals. The position and length of the screen should be selected to match the thickness of the monitoring zone, which can be determined by using additional information, such as CPT logs or continuous soil boring logs.

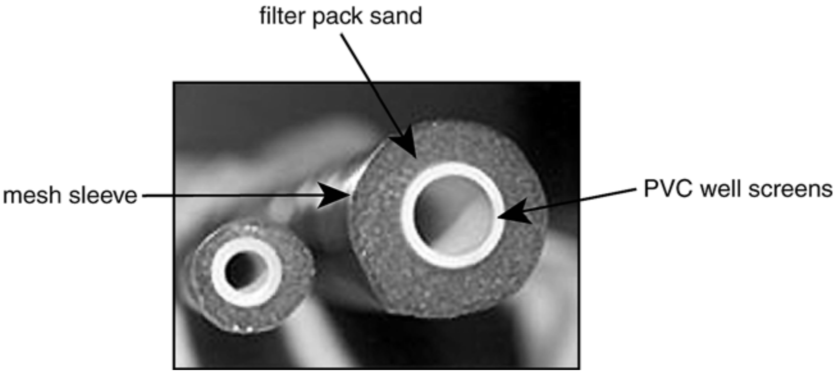
When DPT wells are installed in non-cohesive, coarse-grained formations, the formation can be allowed to collapse around the screen (if this technique is not prohibited by state well installation regulations) after it is placed at the target depth since turbidity problems are unlikely. When turbidity is likely to pose a problem for groundwater sample quality (see Section 3), a number of methods for installing filter packs are available. The filter pack can be poured or tremied into place as the drive casing is removed. Depending on the relative size of the drive casing and well, however, it may be difficult to introduce filter pack or annular seal materials downhole unless the hole is in a cohesive formation that will remain open as the drive casing is removed. Typical inside diameters of DPT wells range from 0.5-inch (schedule 80 PVC) to 2 inches (schedule 40 PVC), and the maximum inside diameter of drive casing is 3.5 inches. Table 2.2 provides a reference for understanding the relationship between inside diameters of DPT drive casing, the outside diameter of well casing and screen, and the annular space available for filter packs.

For the best control of filter pack placement and grain size, “sleeved” or “prepacked” well screens can be used (Figure 2.7). Pre-packed screens are generally composed of a rigid Type I PVC screen surrounded by a pre-sized filter pack. The filter pack is held in place by a stainless-steel wire mesh (for organic contaminants) or food-grade plastic mesh (for inorganic contaminants), such as polyethylene, that is anchored to the top and bottom of the screen. Sleeved screens consist of a stainless-steel wire mesh jacket filled with a pre-sized filter-pack material, which can be slipped over a PVC pipe base with slots of any size. Although sleeve thickness generally ranges from only 0.25 to 0.5 inch, it has been shown to provide an effective filter pack (Kram et al., 2000).

Table 2.2
Annular Space for Well Completion Based on Size of Well Casing and Screen

Inside Diameter of Well Casing and Screen (inches)	Outside Diameter of Well Casing and Screen (inches)	Annular Space with 1.5-inch Inside Diameter (1.8-inch OD) Drive Casing (inches)	Annular Space with 3-inch Inside Diameter (3.5-inch OD) Drive Casing (inches)
0.5	0.84	0.66	2.16
0.75	1.05	0.45	1.95
1	1.32	0.18	1.68
1.25	1.66	Not applicable	1.34

Figure 2.7
Photograph of Pre-Packed Well Screens



Courtesy Geoprobe® Systems, 1996.

Annular seals and grout should be placed above the filter pack to prevent infiltration of surface runoff and to maintain the hydraulic integrity of confining or semi-confining layers, where present. The sealing method used depends on the formation, the well installation method, and the regulatory requirements of state or local agencies. Most protected-screen installations tremie a high-solids (at least 20% solids) bentonite slurry or neat cement grout into place as the drive casing is removed from the hole. (Additional guidance on grout mixtures is available in ASTM D6725 (ASTM, 2003b).) A barrier of fine sand or granular or pelletized bentonite (where water is present) may be placed above the primary filter pack before grouting to protect it from grout infiltration, which could alter the water chemistry in the screened zone. Similar to the pre-packed and sleeved screens mentioned above, modular bentonite sleeves that attach to the well screens and are advanced with the well during installation are also available. As depicted in Figure 2.8, some manufacturers provide a foam seal that expands immediately when the casing is withdrawn to form a temporary seal above the screen[1]. A bentonite sleeve above the seal expands more slowly after the casing is withdrawn but forms a permanent seal once it hydrates.

To ensure a complete seal of the annular space from the top of the annular seal to the ground surface, the grout or slurry should be placed from the bottom up. By using a high pressure grout pump and nylon tremie tube (Figure 2.9) it is possible to perform bottom-up grouting in the small annular spaces of DPT equipment. Slurries of 20-30% bentonite or neat cement grout are most commonly used to meet state regulatory requirements.

A properly constructed DPT-installed monitoring well (Figure 2.10) can provide representative water quality samples and protect groundwater resources. A 1997 study (McCall et al., 1997) demonstrated that DPT wells installed in this manner beneath highly contaminated source zones consistently provided non-detect values. In addition, as with conventional wells, a properly constructed DPT well should have a flush-mount or above-ground well protection to prevent physical damage or tampering of the well. Small locking well plugs are also available for even 0.5-inch nominal PVC casing.

Specialized Measurement and Logging Tools

There are a number of specialized measurement and logging tools available that can be used with DPT equipment to optimize the number and location of groundwater samples. These tools can estimate geotechnical, geophysical, hydrogeologic, and analytical parameters in the subsurface. They are particularly useful when the subsurface is highly stratified or contains laterally discontinuous layers. In such situations, characterizing or monitoring a dissolved-phase plume may require identifying preferred groundwater flow pathways, such as zones of high hydraulic conductivity, for sampling. For example, if the presence of DNAPL is suspected, then possible locations where DNAPL has pooled should be targeted by mapping the surface and areal

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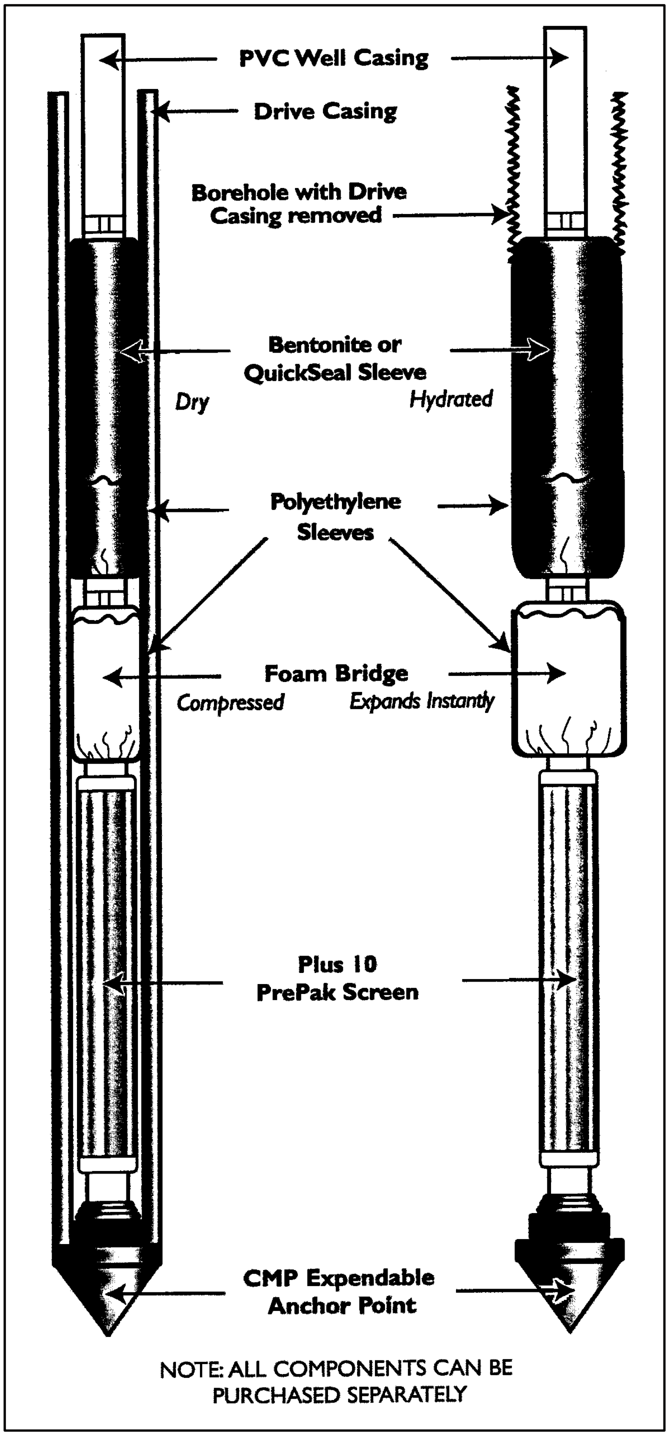
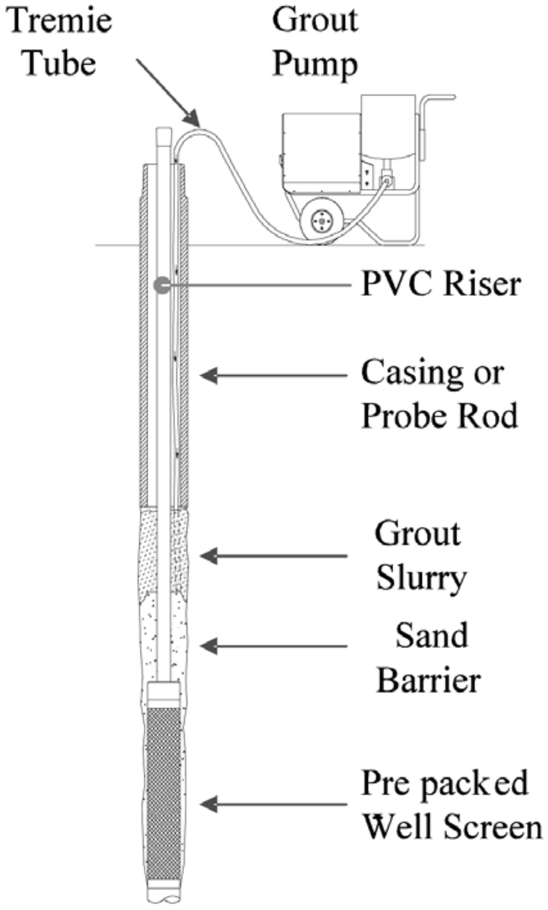
[1] The foam bridge is constructed of a polyethylene cover over polyurethane foam. In choosing to use this device, it should be kept in mind that polyethylene is permeable to many dissolved organic constituents and polyurethane foam will bind organic constituents that come in contact with it. Whether this will affect the quality of the sample is not known. However, purging the well should take care of any potential problems.

Figure 2.8
Small Diameter DPT Well Components



Source: GeoInsight Inc. product literature

Figure 2.9
Bottom-Up Method for Grouting Small Annular Spaces of DPT Wells



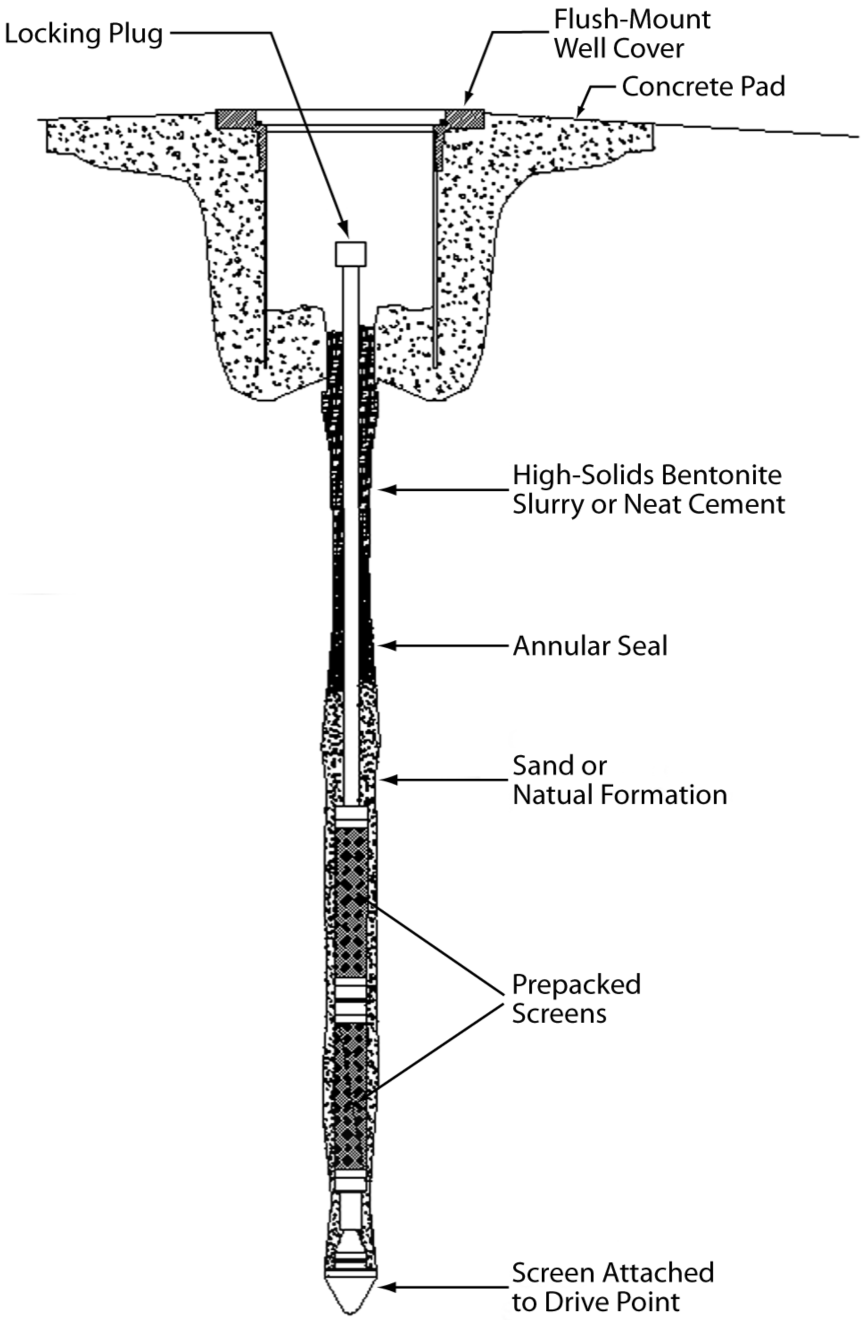
Adapted from Geoprobe®, 1996.

extent of an aquitard. The following section describes some of the specialized measurement and logging tools that are currently available. Since new tools are continually being developed, the list provided in this guide should not be considered complete and is directed at tools specifically concerned with groundwater quality.

Geotechnical

The most common type of DPT geotechnical measurements are conducted with a three-channel cone as part of a CPT rig. It simultaneously measures the tip resistance, sleeve resistance, and inclination of the cone. The ratio of sleeve resistance and tip resistance is used to interpret the soil behavior types encountered (Chiang et al., 1992). In general, sandy soils have high tip resistance and low sleeve resistance, whereas clayey soils have low tip resistance and higher sleeve resistance. The data are recorded in real time on a computer at the ground surface and compiled to generate logs that show soil behavior type and relative density with depth. Actual soil samples are needed to correlate CPT soil behavior data to site soil types.

Figure 2.10
Example of a Properly Constructed DPT Well Installation with Prepacked Well Screen



Adapted from Geoprobe®, 1996.

Geophysical

A number of geophysical measurements can be collected with probes or cones attached to direct push rods. The most common equipment is a conductivity probe that measures the bulk conductivity (or resistivity) of the adjacent soil as it is advanced. The differences in conductivity can be related to changes in stratigraphy. Although actual soil logs are important to correlate probe readings with actual site conditions, in general, finer-grained sediments (e.g., mineral clays) are more conductive than coarser sediments (e.g., sands, gravels). Conductivity probes are also affected by soil water content and ionic strength so they can be used to locate contaminant plumes that have a different salt content than naturally occurring water/soils. In addition, these instruments can sometimes be used for detecting DNAPL masses, which have low conductivities, when there is a sufficiently large conductivity difference between the DNAPL and the surrounding soil matrix. Although these probes will detect LNAPLs as well, there are generally simpler and more reliable ways of locating them than using conductivity probes. Electrical resistivity can also be measured with probes and cones to obtain similar information.

Hydrogeologic

CPT rigs can be equipped with piezocones that measure dynamic pore water pressure as the tool is advanced through the soil layers. The pore water pressure data can be used to determine the depth to the water table and the relative permeability of the layers. Advancement of the penetrometer can be paused at selected intervals to run dissipation tests to obtain estimates of hydraulic conductivity. The combined results of the CPT and piezocone tests can help identify potential preferential contaminant transport pathways in the subsurface. These pathways are especially useful for targeting groundwater sampling locations. Using point-in-time DPT sampling to identify which of these pathways are contaminated can further define optimum intervals for monitoring well screens.

Analytical

There are a number of probes that can be attached to DPT rigs to detect contaminants in the subsurface. These include induced fluorescence systems and volatilization and removal systems.

Induced Fluorescence Systems

Two widely available systems used with CPT rigs are the Site Characterization Analysis Penetrometer System, or SCAPS, and the Rapid Optical Screening Tool, or ROST™. Both use a CPT-deployed laser-induced fluorescence (LIF) probe to qualitatively identify the types and relative concentrations of petroleum hydrocarbons present. This is accomplished by transmitting ultraviolet (UV) light from a nitrogen laser through a sapphire window into the soil. The UV light causes polynuclear aromatic hydrocarbon (PAH) components to fluoresce, and the varying intensity of the fluorescence is indicative of the amounts of the PAHs present. The spectrum of the fluorescence describes the distribution of PAHs present in the hydrocarbon (or often contaminant mass), which can be used for rough fingerprinting of the type of hydrocarbon (Knowles, 1995).

Another induced fluorescence technology, sometimes referred to as a fuel fluorescence detector (FFD), is very similar to LIF except that it generally uses a mercury lamp as its light source, and the light is located in the probe at the sapphire window. This lamp provides a continuous source of light rather than the pulsed technique of the LIF. Although downhole detectors are available, fluorescence intensities from the soil are generally returned to the surface for measurement via fiber optic cable. It generally reads total fluorescence. Some vendors have filtering capabilities to limit wavelength reception to their detectors that allows some differentiation between contaminant types.

Volatilization and Removal Systems

There are two established systems for analysis of VOCs by volatilizing the contaminants in the subsurface and transporting them with a carrier gas to the surface for analysis. The membrane interface probe (MIP), used with percussion or hydraulic driven DPT rigs, heats the surrounding soil to promote diffusion of VOCs through a permeable membrane. Once VOCs enter the probe, they are transported to the surface to a detector (e.g., a photoionization detector or flame ionization detector) with a carrier gas. The probe is generally driven at a rate of one foot per minute to maintain operating temperatures. The presence or absence of VOCs and their relative distribution among sampling locations can be estimated. If more chemical specific information is needed, the MIP can be used in combination with a direct sampling ion trap mass spectrometer (DSITMS). Since this instrument does not have a separation column in front of it, it may not be able to differentiate between chemicals having the same major ion signature.

The SCAPS Hydrosparge™ can be used with either CPT or percussion rigs and is equipped with a module that is lowered into a sealed-screen sampler once the drive rods are retracted to expose the screen. The module uses helium gas at a calibrated flow rate to purge VOCs from the groundwater and transfer them via a Teflon tube directly into a detector at the surface for real time analysis. One sample per location can be analyzed. To collect additional samples at other depths, the sealed-screen sampler can be re-advanced at other locations adjacent to the sampled hole. Data from the hydrosparge is semi-quantitative because of uncertainty associated with sample volume measured.

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Section 3: Data Quality Objectives for Groundwater Sampling

Before selecting an approach to collecting environmental samples, EPA requires that EPA-funded projects use a systematic planning process to plan the collection of project data (EPA, 2000). To help planners select the best methods for obtaining data of the appropriate type, quality, and quantity for their intended use, EPA has developed a seven-step recommended data quality objective (DQO) process. DQOs are designed to provide qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that can be used as the basis for establishing the quality and quantity of data needed to support decisions. Because DQOs are intended to be project specific, they should be developed as part of the process for determining the goals for their activity. For some groundwater investigations, a DQO may be needed that describes the type of samples needed to characterize a groundwater plume; or a DQO may be needed to describe the type of samples required to establish that contamination is no longer a threat to drinking water. Although these DQOs may demand very different types of activities, the factors that should be evaluated for DPT groundwater sampling projects typically include:

- Determining the potential direction and degree of sampling bias;
- Evaluating whether the sample volume is sufficient for the selected analytical methods; and
- Minimizing the potential for contamination drag-down or creating a conduit for contaminant transport.

These factors are often issues for both DPT and conventional methods. Techniques exist for resolving problems for both methods, however, this section summarizes how they apply to DPT groundwater collection techniques.

Sample Bias

Sample bias generally is the systematic or persistent distortion of a measurement process that causes errors in one direction. In other words, sample measurements can be consistently different than the samples' true values. There are several potential sources of sample bias when sampling groundwater with any method, including DPT, but one of the most critical factors typically is the type of sampling equipment used to retrieve the sample (Nielsen and Yeates, 1985). Three of the most common sources of bias, due to sampling equipment and methods, include:

- Sample turbidity;
- Sample disturbance; and
- Sampling interval.

Sample turbidity can cause bias as a result of the adsorption of chemicals onto, or the release of chemicals from, the surface of particles in the sample. There also are several sources of bias that can result from sample disturbance. These sources are summarized in Table 3.1. Because sampling interval can have an impact on all analytes in a similar way, (i.e., errors do not necessarily result in one direction), it is not included in the table. The table helps to clarify what factors may have significant impacts on specific analytes and which would have little or no impact by indicating the direction of bias ("P" for positive bias and "N" for negative bias)

Table 3.1
Potential Impacts of Sources of Bias on Specific Analytes During Sampling

Analyte	Potential Source of Bias							
	Sample Disturbance						Turbidity	
	Pressure Decreases	**Temperature Increases**	**Exposure to Atmospheric Conditions**	**Adsorption onto Sampler Materials (Plastics & Metals)**	**Desorption from Sampler Materials**	**Agitation/ Aeration During Sample Collection**	**Adsorption onto Particles (a)**	**Releases from Particles (a)**
VOCs	N+++	N+++	N+++/P+++ (b)	N+	P+	N++	0	0
Dissolved Gases & ORP	N+++	N+++	N+++/P+++ (b)	N++ to N+++ (c)	P+	N++	0	0
Semi-Volatiles	N+	N++	N++	N+	P++	N+	N++	P++
Pesticides	N+	N+	N+	N+	0	N+	N++	P++
Trace Metals	N+	N+	N+++	N+ to N+++ (d)	P+	N+	N+++	P+++
Radionuclides	N+	N+	N+	N+	0	0	N+++	P++
Major Ions (Inorganic Anions & Cations)	0	0	N+	N+	0	0	N+	P+

Legend:

Bias Type:	Relative Degree of Impact:	
N = Negative	+	Weak
P = Positive	++	Moderate
0 = None	+++	Strong

(a) Adsorption to and release from particles is directly related to the level of turbidity and will also depend heavily on particle size and type. Adsorption is a greater factor when fine-grained, organic-rich particles are present.

(b) Depending on the analyte concentrations in the sample or the ambient atmosphere, concentrations in the sample may increase or decrease significantly.

(c) Reaction of the dissolved oxygen in groundwater with iron in the drive rods will significantly reduce measured dissolved oxygen and oxidation/reduction potential (ORP) due to oxidation of the zero valent iron under ambient conditions. Therefore, the sample must be isolated from steel drive rods to minimize this effect.

(d) Some trace metals can complex with hydrous iron oxides (rust) forming soluble ferrous iron. Therefore, the sample must be isolated from steel drive rods to minimize this effect.

and the degree of bias ("+" for weak, "++" for strong, and "+++" for very strong) when sampling for various analytes. For example, if investigators are interested in collecting groundwater samples for VOC analysis, they should be concerned about any changes in temperature or pressure of those samples because it would likely have a negative bias on results. However, if they were collecting the same samples for analysis of major, naturally occurring, inorganic anions and cations (e.g., Ca^{2+}, Na^{+}, K^{+}, SO_4^{2-}, CO_3^{2-}, NO^{3-}, Cl^{-}), they normally would not have to be concerned about pressure or temperature changes since they normally would not affect results.

The iron in steel drive rods of point-in-time samplers can have a significant affect on measured concentrations of analytes, such as dissolved oxygen, iron, and some trace metals as well as changing oxygen-reducing potentials. As discussed in Section 4, these affects can be minimized by placing the pump intake within the screened interval to be sampled and pumping at a low-flow rate to avoid drawdown of standing water in contact with the rods into the intake interval.

To minimize sampling bias, sampling equipment that meets project DQOs should be selected. For DPT, the primary difficulty in collecting groundwater samples typically is caused by the small inside diameter of many sampling points—generally 0.75-inch or less for the rods used with DPT sampling tools and 1 to 2 inches for DPT-installed wells. For DPT tools of these sizes, the available sampling devices are usually limited to less than 1-inch OD. For rods or well casing/screen with inside diameters less than 2 inches, sampling equipment usually is limited to bailers, inertial-lift pumps, suction-lift (e.g., peristaltic) pumps, gas-drive pumps, centrifugal pumps, and bladder pumps. For 2 inches and larger, additional devices available include gas-operated piston pumps and several designs of electric submersible pumps (e.g., gear-drive, helical rotor, or progressing cavity).

Bladder pumps (Pohlman et al., 1990; Unwin and Maltby, 1988; Parker, 1994; Barcelona et al., 1984), gear-drive electric submersible pumps (Imbrigiotta et al., 1988; Backhus et al., 1993), centrifugal pumps, and helical rotor pumps have consistently outperformed other pumps in their ability to deliver a representative sample for a wide variety of analytes under a wide range of field conditions. These devices are recommended for use in collecting samples for all classes of analytes. Each of the other devices has limitations that may affect the representativeness of samples for one or more classes of analytes (Nielsen and Yeates, 1985; Herzog et al., 1991; Parker, 1994; Pohlman et al., 1994; Pohlman and Hess, 1988; Pearsall and Eckhardt, 1897; Unwin and Maltby, 1988; Imbrigiotta et al., 1988; Pohlman et al., 1990). However, some of these devices may be appropriate for collecting samples for some sets of analytes.

A detailed discussion of the operational characteristics of sampling devices is provided in the Appendix. In addition, Table 3.2 provides a summary of some important operational characteristics related to DPT applications and the appropriateness of each device for sampling analyte classes. For example, the table shows that bailers are adequate for sampling narrow diameter wells when the analytes of concern are inorganic ions. If trace VOCs are being analyzed, bailers may not be as reliable for providing high quality samples as other methods. In addition, choosing a sampling tool is often related to the specific use the data acquired will be put. For example, bailers might be completely acceptable when sampling VOCs to locate a DNAPL source zone when the dissolved values in the water are very high and marginal losses are not important.

Table 3.2
Typical Operational Characteristics and Appropriateness of Groundwater Sampling Devices for Specific Analytes

Device	Approx. Minimum Well Diameter	Approx. Maximum Useful Depth to Groundwater	Approx. Minimum/ Maximum Sample Delivery Rate	Field Indicators				Inorganics			Organics		Radioactive		Biological
				SC	pH	ORP	DO	Major Ions	Trace Metals	Salts	VOCs	SVOCs	Radio- nuclides	Gamma α/β	Coliform
Bailer	½"	unlimited	highly variable	✓				✓		✓			✓		✓
Inertial-Lift Pump	½”	unlimited	highly variable	✓				✓		✓			✓		✓
Suction-Lift Pump (Peristaltic)	½"	25'	50 mL - 4 L/min	✓				✓		✓			✓		✓
Gas-Drive Pump*	½"	250'	50 mL - 20 L/min	✓	✓			✓	✓	✓		✓	✓	✓	✓
Bladder Pump	½"	300'	25 mL - 8 L/min	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Piston Pump	2"	1000'	100 mL - 8 L/min	✓	✓			✓	✓	✓		✓	✓	✓	✓
Electric Submersible Pumps:															
Gear-Drive	2"	300'	50 mL - 12 L/min	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Helical Rotor	2"	180'	100 mL - 6 L/min	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Centrifugal	1.75”	220'	100 mL - 34 L/min	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

✓ = Device compatible with analyte

* Presumes use of inert drive gas

<u>Abbreviations</u>

SC - specific conductivity
ORP - oxidation/reduction potential
DO - dissolved oxygen

VOCs - volatile organic compounds
SVOCs - semivolatile organic compounds

α - alpha
β - beta

Sample Turbidity

In groundwater sampling, turbidity generally refers to the presence of suspended particles in the sample. These particles may be entrained in the groundwater when the subsurface is disturbed, such as when a DPT sampling tool or well is advanced and installed. The disturbance may cause some compaction and disaggregation of granular material as well as the breakage of grain coatings and cementing agents. The largest particles (i.e., silts) typically will settle out quickly but much can remain suspended in the water column. Depending on their type and size, some particles are neutrally buoyant, remaining suspended once they have become suspended. Turbidity can also be generated during sampling activities due to the relatively high entrance velocity of groundwater into the well when water is withdrawn by sampling tools, such as high-speed submersible pumps, or sealed-screen samplers when the screen is opened to the formation.

Although turbidity can be present in samples from sand and gravel formations, it particularly can be a problem when sampling in fine-grained formations. High turbidity also can be associated with the DPT sampling tools that lack screens or filter packs to keep the fines from entering the sampling tool or well. Conventional wells can also produce samples with high turbidity, especially if the slot size of the screen or the grain size of the filter pack are incorrectly sized for the formation.

The term “artifactual turbidity” is sometimes used to distinguish particles stirred up during drilling and sampling, which would not be mobile under ambient groundwater flow conditions, from those particles that are mobile under ambient conditions—colloids. Colloids are typically clays, hydroxyls, and humic materials that are 1 to 1000 µm in diameter. Although colloidal transport may be considered important in formations made up of materials coarser than fine sand (Dragun, 1988; Mason, 1991), under most ambient conditions, colloids are immobile in the subsurface. Because most turbidity is artifactual in origin, for the purpose of this discussion it is just referred to as “turbidity”.

Sample turbidity can be important because it can be a common source of significant bias, both negative and positive, in groundwater samples, particularly when metals and semi-volatile organic compounds (SVOCs) are the analytes of concern (see Table 3.1). For example, some clay colloids can artificially increase the measured concentration of dissolved metals because metals are found in their structure (e.g., aluminum, magnesium, and iron) and as similarly sized impurities associated with them. The surficial negative charge of the colloids and impurities attracts and loosely typically binds the positively charged metal cations in groundwater. The risk of positive bias can be further increased when acid is used to preserve a sample because it will cause the metals to dissolve back into the sample. On the other hand, if the dissolved metals bind to the colloids, and the sample is then filtered to remove high turbidity levels, the concentration of dissolved metals in the groundwater may be significantly reduced and the sample normally would not be representative of actual conditions.

In a similar way, colloids can become a “source” or a “sink” for organic constituents. Although organic chemicals of concern generally do not occur naturally in clays, they can sorb to colloids and naturally occurring organic matter. The level of sorption that will occur depends on the individual chemical, whether it was in equilibrium with the suspended colloids before being collected, and the analytical preparation method used. If groundwater sampling creates or occurs under non-equilibrium conditions, then significant sorption may occur. In addition, if organic constituents in groundwater have bound to clays or humic acids in the subsurface, causing them to become immobile, the sampling process can disturb these immobile constituents and cause them to become dissolved in the groundwater sample.

One method of determining whether the level of turbidity will significantly impact the concentration of an organic constituent by causing it to become bound to colloids is to examine the logarithm of the *n*-octanol/water partition coefficient (log K_{ow}) because the log K_{ow} is a measure of a compound's tendency to remain dissolved in water. The higher the K_{ow} value, the more likely the chemical is to partition from the water onto suspended organic particles. Table 3.3 contains the log K_{ow} of a number of common organic chemicals.

This information can also be used as a quality control check on groundwater sample results. In general, the compounds with the higher log K_{ow} levels are SVOCs. If the groundwater concentrations for these chemicals approach or exceed their solubility, then the measured concentrations may have been artificially inflated by turbidity and other sampling data should be evaluated (e.g., nephelometric turbidity units [NTU], a measure of turbidity, dissolved oxygen). Alternatively, turbidity may not be a source of bias in a sample if the constituents of concern are organic compounds with low log K_{ow} values (e.g., < 2.5). In this situation, other issues, such as stability of groundwater indicator parameters during sampling, may be more important in evaluating groundwater sample quality. A paper by Paul and Puls (1997) helps to illustrate the significance of these numbers. In the study, which included analysis of both laboratory and field samples spiked with kaolinite and sodium montmorillonite clays, the researchers demonstrated that TCE, *cis*-DCE, and vinyl chloride concentrations were statistically unaffected by turbidity levels. This group of chemicals has low log K_{ow} values ($\leq$ 2.42). The report concluded that the presence of solids in the groundwater samples had little or no effect on the VOC concentrations evaluated in the study. Losses of VOC due to volatilization during the sampling process were thought to have a greater effect on concentrations. As a word of caution, however, matrix effects can affect the tendency of some compounds to sorb more than their low log K_{ow} values would indicate. This increased level of sorption generally occurs when the soil matrix contains a substantial amount of organic materials, which can range from humic and fulvic acids to organic debris (roots leaves) and peat. Site-specific factors, such as total organic carbon (TOC), should be considered when deciding to take measures to reduce turbidity in groundwater samples. High levels of TOC in groundwater samples can yield analytical results that indicate higher levels of dissolved VOCs than are actually present. These higher levels can drive a risk assessment, even though the VOCs are actually sorbed to particles and are immobile.

When turbidity is a concern for groundwater sampling, steps can be taken to minimize it, provided adequate quality control (QC) procedures, described in Section 4, are followed, such as installation of filter packs (also discussed in Section 2), developing the well, and using low-flow sampling. In addition, DPT methods that promote high turbidity levels, such as open-hole sampling or exposed-screen methods, should be avoided. A representative sample cannot be salvaged with filtering if inappropriate sampling techniques have already compromised the sample. If filtering is justified by a project's DQOs, proper filtering techniques should be used. For more information on filtering, readers should refer to *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers* (EPA, 2002).

Table 3.3
Log *n*-Octanol/Water Partition Coefficients (Log K_{ow}) of Common Organic Contaminants

Chemical	**Log K_{ow}[a]**	**Chemical**	**Log K_{ow}**
Acenaphthene	4.07	Ethylbenzene	3.13
Acetone	-0.24	Ethylene Glycol	-1.36
Aldrin	5.52	Fluoranthene	5.22
Anthracene	4.45	Fluorene	4.12
Arochlor 1221	2.8 estimated	Heptachlor	5.44
Arochlor 1242	5.58	Hexachlorobutadiene	4.78
Arochlor 1260	6.91	Indeno(1,2,3-cd)pyrene	7.7
Benzene	2.13	Lindane	3.7
Benzo(a)anthracene	5.61	Methoxychlor	4.3
Benzo(k)fluoranthene	6.85	Methyl Ethyl Ketone	0.29
Benzo(g,h,i)perylene	7.1	Methyl t-Butyl Ether	1.24
Benzo(a)pyrene	5.99	Naphthalene	3.59
Bis(2-ethylhexyl)phthalate	4.20, 5.11	Pentachlorophenol	5.01
Carbon Tetrachloride	2.83	Phenanthrene	4.468
Chlordane	6	Phenol	1.48
Chlorobenzene	2.84	Pyrene	5.18
Chloroform	1.97	Styrene	2.95
Chrysene	5.6	1,1,2,2-Tetrachloroethane	2.39
p, p-DDT	6.36	Tetrachloroethene (PCE)	3.4
Dibenz(a,h)anthracene	6.36	Toluene	2.73
Dibenzofuran	4.17	Toxaphene	3.3
1,1-Dichloroethane	1.79	1,1,1-Trichloroethane	2.49
1,2-Dichloroethane	1.48	1,1,2-Trichloroethane	2.07
cis-1,2-Dichloroethene	1.86	Trichloroethene	2.42
Dieldrin	5.16	Tetrahydrofuran1,4-Dioxane	-0.27
1,4-Dioxane	-0.27	Vinyl Chloride	0.6
Endrin	5.16	m-Xylene	3.2

[a] Log K_{ow} values taken from Howard et al., 1993a and 1993b and from Montgomery and Welkom, 1991.

Sample Disturbance

If groundwater samples are disturbed during the collection process (e.g., agitation, allowing sample temperature to increase, or creating a situation for sample materials to adsorb or desorb analytes) there is a risk of negative impacts on groundwater sample quality, beyond the issue of generating turbidity, because it may result in the:

- Volatilization of any VOCs that are present;
- Dissolution of dissolved gases; or
- Oxidation/reduction of metals.

Sampling methods should be carefully selected in order to minimize disturbance during sampling. As shown in Table 3.2, bladder pumps and to a lesser extent centrifugal pumps generally are the best equipment for all analytes when sampling rods or wells less than 2-inches in diameter and where high quality samples are needed. Research has shown that suction lift pumps (e.g., peristaltic pumps—see Appendix) cause a negative bias in VOC and dissolved gas measurements because of the negative pressure generated by the pumping action. When point-in-time sampling is conducted in situations where volatilization of VOCs is a concern, sealed-screen samplers, such as the BAT Enviroprobe™ or Hydropunch™, which maintain in-situ pressure conditions, should be considered.

Sampling Interval

The most appropriate sampling interval to use at a site should be determined because the location and length of a sampling interval can bias a sample. Short or long sampling screens can be used with both DPT and conventional monitoring wells; however, DPT point-in-time methods are generally more economical and better designed to target smaller sampling intervals than conventional wells. When selecting discrete sampling intervals (e.g., 6-inch interval), there is a risk of missing contaminants that may be migrating through sections of the aquifer that do not fall within the screened interval(s). When selecting long sampling intervals (e.g., 5 to 15 feet), there is a risk that a highly contaminated but discrete interval will be diluted by larger uncontaminated intervals.

To determine the most appropriate sampling interval, a number of sources of existing information should be evaluated and, if necessary, additional subsurface data collected. DPT equipment can provide many cost-effective and comprehensive methods for collecting subsurface data for this purpose, including continuous soil logs, detailed stratigraphic logs using specialized measurement and logging tools (e.g., cone penetrometer testing, membrane interface probe, induced fluorescence), multi-level discrete groundwater samples to create a vertical profile of contamination, and piezometric data over a wide area to determine groundwater flow direction (see U.S. EPA, 1997 for more details). Based on this information, as well as slug tests and/or aquifer tests to estimate hydraulic conductivity for specific stratigraphic zones, contaminant source locations can be estimated. At this point the appropriate sampling intervals can be selected, thereby minimizing the installation of extraneous and ineffective wells or the risk of missing or diluting important transport pathways.

Sample Volume

There are three sample volume issues that can be particularly relevant to collecting groundwater samples with DPT:

- Point-in-time methods can be extremely slow in fine-grained formations (e.g., several hours or more).
- Sample chamber volume of some sealed-screen, point-in-time samplers is quite small (e.g., less than one liter), which can make it difficult to collect the larger volumes needed for some types of analyses (e.g., SVOCs, PCBs/pesticides).
- Both DPT wells and point-in-time samplers often have a smaller diameter than their conventional well counterparts. The smaller volume of the DPT wells may require lower-flow purge rates to avoid significant drawdown during sampling.

Consequently, subsurface conditions and the required analytical suite should be considered when selecting a DPT method to sample groundwater. Depending on the site conditions and site DQOs, larger volume samplers or low-flow purge equipment capable of very low-flow rates (discussed in Section 4) may be needed, or a sampler can be left in place to recharge while other locations are sampled. If a sampler is left in place to recharge, sample quality can be compromised if the sample container is filled in increments collected over a period of time. This is a concern primarily when filling sample vials for volatile organic analysis, which need to be filled completely with one sampling effort. Otherwise, volatile compounds may partition into the headspace above the sample.

Sample Cross-Contamination

Any groundwater sampling method can cause cross-contamination that affects groundwater sample quality and/or long-term water quality in at least three ways:

- Causing contaminant drag-down;
- Creating hydraulic conduits; and
- Biasing samples from improperly decontaminated equipment.

In evaluating the potential for cross-contamination and developing a sampling plan, the site geology, the types of contaminants present, and the sampling methods and equipment used should be examined. For example, drilling a hole through an aquitard creates a potential conduit for contaminant migration. If DNAPLs are perched on top of the aquitard and precautions are not taken, they may migrate down the borehole and contaminate a previously uncontaminated aquifer.

Although cross-contamination can be a serious concern that may pose additional challenges when using DPT equipment, DPT methods also provide many strategies for minimizing or eliminating the risk of cross-contamination. Section 5 reviews these methods and additional resources that can provide specific details needed in the appropriate use of DPT equipment.

Selecting a DPT Groundwater Sampling Tool

DPT tools can be considered for a wide range of groundwater field applications, and they can meet project DQOs in a broad variety of cases. Sampling bias, sample volume, and cross-contamination are potential problems whether DPT or conventional monitoring wells are used. It is important to understand the limitations of equipment being used and how they relate to project needs. The first step in selecting equipment should be narrowing down the categories of appropriate tools. With DPT equipment, that can be done by deciding whether qualitative, semi-quantitative, or quantitative data are needed. Table 3.4 provides a summary of the applications of DPT tools, emphasizing the basic concept that the project objectives should be considered when selecting equipment and methods.

Table 3.4
Recommended DPT Groundwater Tools for Various Field Applications

General Field Application	Specialized Measurement and Logging Tools (a)	Point-in-Time Groundwater Sampler	DPT-Installed Monitoring Well
Presence of contamination (i.e., qualitative sampling goals)	✓	✓	
Approximation of contaminant zone/level (i.e., semi-quantitative sampling goals)	✓	✓	
Define specific contaminants and accurate concentrations (i.e., quantitative sampling goals)		✓	✓
Long-term monitoring			✓

(a) Includes induced fluorescence and volatilization and removal systems.

Section 4: Recommended Methods for Collecting Representative Groundwater Samples

Collecting groundwater samples that are representative of in-situ aquifer conditions generally is important in any groundwater investigation. One of the most important factors in meeting this goal, for many analytes, typically is to minimize turbidity. This is because particles from formation materials that are suspended in a sample, but are not normally suspended in groundwater, can provide a substrate for various analytes to adsorb or desorb. This process can create a positive or negative bias for analytical results. In addition, although the causes of turbidity and their solutions for both DPT and conventional groundwater sampling methods generally are similar, the relatively narrow rod diameters of DPT systems can create additional hurdles. This section focuses on the activities that can minimize turbidity, specifically for DPT systems.

As discussed in Section 3, turbidity can cause substantial bias, both negative and positive, when sampling metals and SVOCs, but typically is much less an issue when sampling VOCs. There are several precautions that can be taken to minimize turbidity in DPT groundwater samples. Important techniques to consider include:

- Installation of a filter pack;
- Well development; and
- Low-flow purging or passive sampling protocols.

Each of these techniques can be applied to monitoring wells installed with DPT, but not all are possible with point-in-time samplers. For example, filter packs normally cannot be installed when using point-in-time samplers. Furthermore, well development and low-flow/passive sampling protocols normally can only be used with those point-in-time samplers that provide access to the sample location from the surface (See Section 2). Usually, samplers that rely on a sealed sample chamber to retrieve groundwater cannot be developed, nor can low-flow or passive sampling protocols be followed. However, there are some samplers in this category that may work, such as one of the BAT™ system samplers, that sample water through a ceramic or polymer tip that acts as an in-situ filter to prevent turbidity. The decision to use a specific type of point-in-time sampler should be weighed against project DQOs.

Installation of a Filter Pack

As mentioned in Section 2, installing a filter pack in monitoring wells can be an important means of minimizing sample turbidity. However, its installation is not always possible or necessary, depending on project objectives. A common construction technique for DPT wells is to let the formation collapse around the screened interval, rather than installing a filter pack. In fact, this is the only option for exposed-screen well installations since there is no annular space between the drive rods and the borehole walls to accommodate a filter pack. Similarly, DPT point-in-time sampling techniques do not allow for the installation of filter packs due to the lack of annular space between the drive rods/sample tool and the formation. Wells installed using protected-screen methods, however, may have adequate annular space for a filter pack and should be selected where data quality objectives dictate. Please refer back to Section 2 for more information on filter pack installation techniques, including the use of pre-packed and sleeved well screens.

Well Development

Wells should be developed after completing the installation and allowing sufficient time for the annular seal to completely set (typically two weeks, but not less than 48 hours). The purpose of well development or development of a point-in-time sampler generally is to repair borehole damage caused by advancement and installation procedures, such as the smearing of fine-grained particles along the borehole walls and the generation of turbidity. Development generally is designed to remove these particles to improve the hydraulic connection between the well and formation so that groundwater can enter more freely. Development also is designed to remove the groundwater impacted by well installation so that groundwater representative of ambient conditions can be sampled.

Like conventionally installed wells, DPT-installed monitoring wells should be developed. This process typically involves block surging and pumping or bailing groundwater until certain water quality parameters (e.g., pH, specific conductance, dissolved oxygen, redox potential, and temperature) have stabilized and turbidity has been removed or decreased as much as possible. Wells are surged by raising and lowering a surge block (any tool that is slightly smaller than the inside diameter of the well casing) within the screened interval to mechanically backwash the well screen. These activities help to dislodge particles smeared within the borehole and the particles clogging the screen so they can be removed. In-line turbidimeters can be used during development or purging procedures to judge turbidity levels and their potential impact on sample quality.

Due to the way some point-in-time samplers are constructed and used, they may not accommodate a pump or bailer for development. Those samplers that can accommodate a pump or bailer can be developed similar to the method described above for wells, although due to the generally smaller diameters of point-in-time samplers, smaller diameter surge blocks, pumps, and bailers usually will be needed. In general, if DQOs recommend development for groundwater samples to meet quality standards, then many point-in-time samplers may not be appropriate for the situation.

Low-Flow Purging and Sampling

Low-flow purging, also referred to as low-stress purging, low-impact purging, and minimal drawdown purging, is a method of preparing a well for sampling which, unlike traditional purging methods, does not require the removal of large volumes of water from the well. The term “low-flow” refers to the velocity at which groundwater moves through the pore spaces of the formation adjacent to the screen during pumping. It does not necessarily reflect the flow rate of the water discharged by the pump at the ground surface. The focus of low-flow purging and sampling is on collecting high-quality samples by minimizing the impact of pumping on well hydraulics and aquifer chemistry. Because the flow rate used for purging is, in many cases, the same as or only slightly higher than the flow rate used for sampling, the process is a continuum and is referred to as "low-flow purging and sampling." Although minimizing the disturbance of sampling on the aquifer is important for all types of groundwater sampling devices, it can be particularly important for DPT point-in-time samplers and exposed screen wells because installation of a filter pack generally is not feasible with these tools.

Low-flow purging and sampling generally are appropriate for collecting groundwater samples in a wide variety of situations. It can be used to sample all categories of aqueous phase contaminants and naturally occurring analytes, including VOCs, SVOCs, trace metals and other inorganics, pesticides, PCBs, radionuclides, and microbiological constituents and often is particularly appropriate for situations where colloidal transport is an issue (i.e., radionuclides, metals, and hydrophobic compounds). However, low-flow methods generally are not applicable to the collection of NAPLs because they do not respond to the effects of pumping in the same manner as groundwater.

Theoretical and Research Basis for Low-Flow Purging and Sampling

Groundwater sampling research has demonstrated that water standing in a well casing for a protracted time is not representative of ambient groundwater quality (Gillham et al., 1985; Miller, 1982; Marsh and Lloyd, 1980; Barcelona and Helfrich, 1996). Hence, this water should not be collected as part of the sample for analysis. In addition, the water within the screened interval of nearly all wells generally is representative, provided that the well has been designed, installed, developed, and maintained properly and the aquifer has a sufficient flow rate to ensure the water in the screened interval is being replaced.

Based on these findings, recommended low-flow sampling protocols have been developed so that groundwater can be collected from the screened interval without significant mixing with the water standing in the casing. Research has shown that this method does indeed provide high quality, representative groundwater samples (Backhus et al., 1993; Bangsund et al., 1994; Barcelona et al., 1994; Karklins, 1996; Kearl et al., 1994; Kearl et al., 1992; McCarthy and Shevenell, 1998; Puls and Paul, 1995; Puls and Barcelona, 1996; Puls and Barcelona, 1989; Puls and Powell, 1992; Puls et al., 1992; Puls et al., 1991; Serlin and Kaplan, 1996; Shanklin et al., 1995).

Because they are sampled almost immediately, point-in-time DPT tools should not develop a stagnant water column that will affect most analytical results. However, a standing water column for even a short period of time can affect some inorganic analytes (e.g., iron, nitrogen, and hexavalent chromium) and sensitive geochemical parameters (e.g., dissolved oxygen, oxygen reducing potential, and pH) if the water is in contact with steel drive rods. The zero valent iron in the rods can quickly react with any dissolved oxygen in the groundwater causing alteration of the analytes and parameters and potentially complexing with metal analytes. As a result, water being collected should be isolated from contact with the drive rods when sampling for these analytes or parameters. Placing the pump intake within the screened interval and pumping at a low-flow rate to avoid drawdown of water in contact with the drive rods should help isolate the sample from the rods. Although there is little concern about the water column affecting organic analytes when sampling with point-in-time DPT samplers, when turbidity is a concern, low-flow sampling may help to lower turbidity to acceptable levels (McCall et al., 1997; EPA, 1996a).

Low-Flow Purging and Sampling Protocols

To conduct low-flow purging and sampling, a pump that can be operated at a low-flow rate normally is needed. For large wells (e.g., 2-inch diameter or greater), less than 500 mL/min is often needed; for small diameter DPT wells and point-in-time samplers~~;~~ flow rates as low as 100 mL/min may be needed. As a result of their design, bailers generally are inappropriate for low-flow purging and sampling. Inertial-lift pumps, or other well sampling devices that agitate the water column also generally cannot be used for low-flow purging and sampling

Before purging and sampling can begin, the hydraulic conductivity of the screened interval normally needs to be evaluated to ensure that low-stress pumping is maintained. To begin, the water level should be measured to determine when drawdown in the well stabilizes. As water is purged from the well, water quality indicator parameters (e.g., pH, temperature, specific conductance, dissolved oxygen, redox potential, and in some cases turbidity) generally need to be measured to determine when the readings stabilize and samples can be collected. The results can then be used to define well-specific, low-flow procedures.

Passive Sampling Protocols

In situations where a sampling point cannot yield sufficient water to support low-flow sampling, a passive sampling (also referred to as micropurging) approach generally is preferred (Powell and Puls, 1993; Puls and Barcelona, 1996). Passive sampling involves placing the pump intake within the screened interval and purging a minimal volume of groundwater from the well or sampler—a single volume of the pump chamber and discharge tubing, rather than the greater volumes purged by low-flow sampling or the multiple well volumes purged using other techniques. The goal of passive sampling generally is to obtain groundwater within the well screen or sampler screen, which is most representative of ambient groundwater quality, without disturbing the water column and introducing the stagnant water above. The sample should be collected immediately after purging the small volume of groundwater.

Passive sampling methods may be appropriate for use in a variety of situations and can be applied to most wells in which there is sufficient water to ensure that a pump intake is submerged throughout purging and sample collection. They are most often applied to wells and samplers installed in low-yield formations. In very low yield formations, however, the water in the screened interval may be of equivalent quality to that in the casing above and not representative of formation water. The application of passive sampling methods, therefore, should be evaluated on a site-specific basis.

Passive sampling typically is easiest to apply when dedicated pumps are used. The flow rates used for passive sampling are lower than those used for low-flow purging and sampling—generally less than 100 mL/min. Because very low hydraulic conductivity formations do not yield sufficient water to satisfy the demands of a pump, even at these low-flow rates, drawdown may occur. Thus, to determine the volume of water available for sampling, the volume of water within the well screen above the pump intake should be calculated. Only this volume, which normally will be very small for most DPT wells, should be collected. Sampling should not continue once water from the top of the screen is drawn close to the pump because casing water should not be collected as part of the sample. Since indicator parameters are not typically analyzed, this method does not normally provide any evidence that the sample taken is representative of formation water. When non-dedicated equipment is used, there is a higher risk of mixing casing and screened interval water which can add to the uncertainty of the representativeness of the sample. Table 4.1 provides a comparison between low-flow and passive sampling methods.

Table 4.1
Comparison of Some Key Elements of Low-Flow and Passive Sampling

	Low-Flow Sampling	Passive Sampling
Hydraulic Conductivity	Sufficient to maintain steady water level during sampling	Too low to allow low-flow sampling
Analyte Applicability	All analytes except NAPLs	All analytes except NAPLs
Pump Discharge Rate	500 mL/min to100 mL/min depending on well/sampling point size and hydraulic conductivity.	<100 mL/min
Purge Volume	Continuous until parameters (e.g., specific conductance, turbidity, O_2, redox) stabilize	Greater than the volume of the pump and the submerged tubing

Section 5: Recommended Methods for Minimizing Potential for Cross-Contamination

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As mentioned in Section 3, the potential for cross-contamination should be considered when advancing any type of groundwater sampling tool or monitoring well into the subsurface because it can result in sample bias, incorrect decisions, or the spread of contaminants. Methods for avoiding cross-contamination should be discussed and accounted for in project planning with respect to:

- Avoiding drag-down;
- Avoiding the creation of hydraulic conduits;
- Decontaminating equipment; and,
- Decommissioning DPT wells and borings.

These issues typically apply to both DPT and conventional wells; however, because of the different methods of construction, the solutions often differ even though the results are often the same. This section provides guidance on how these issues can relate to DPT methods because the methods for conventional wells are well established.

Avoiding Drag-Down

Drag-down of contamination is commonly considered to be less of a problem with DPT methods than with conventional well drilling techniques, such as hollow stem augering, where contaminants have a better chance of sticking to the augers as they advance. As DPT rods are advanced, the action of pushing the drive rods through new soil generally wipes away old soil. In fact, researchers have demonstrated the lack of drag-down with DPT in a number of studies (Cherry, et al. 1992; Pitkin et al., 1994; McCall et al., 1997; Pitkin et al., 1999); however, as with conventional drilling techniques, it is unlikely that DNAPL or certain soils, such as sticky clays, would be completely wiped clean as the rods advance. In addition, certain DPT methods can result in drag-down if used in inappropriate situations. This is primarily a problem with advancing multi-level samplers in contaminated fine-grained soil, which can clog the screens, and with advancing exposed screen monitoring well installations, which can carry shallow contaminated soil and groundwater to the target sampling depth. Thus, exposed screen well installations should not be considered for use in contaminated areas.

Where drag-down is a concern, use of DPT equipment that will minimize drag-down potential, such as protected-screen point-in-time samplers, the Waterloo Profiler, or sealed-screen monitoring wells should be considered. In addition, the DPT sampler or well should be properly developed to remove the affected soil and groundwater.

Avoiding the Creation of Hydraulic Conduits

Creation of hydraulic conduits that allow the downward flow of groundwater and contaminants can be avoided by sealing off the borehole annulus—the space between the borehole wall and the rod string. This issue is of particular concern when the borehole hydraulically connects previously unconnected hydrogeologic units, or when DNAPLs with low viscosity are present that can migrate downward along the vertical conduit. In addition to using grout to seal the annulus, an important method of reducing downward migration along the rod string is to minimize the borehole annulus. Two important considerations include:

- Using a drive tip that is the same diameter or smaller than the drive rods; and
- Using rods and samplers with the same diameter.

The absence of an annulus, however, does not necessarily prohibit contaminant migration because there may not be an effective seal between the steel rods and the borehole wall. This issue is not unique to DPT methods and should also be considered when drilling boreholes using conventional techniques.

DPT techniques are not recommended for installing monitoring wells with screens set in an interval below a confining layer if there is a real danger of contaminating the lower layer. Instead, construction of a “telescoped” monitoring well using conventional drilling methods should be used. This type of well involves drilling into the top of the aquitard, placing a steel casing in the hole and grouting it into place by tremieing grout into the annulus. The hole is then advanced using a drill bit that fits inside the steel casing. Upon reaching the target depth, the well screen and casing are lowered into place and the well completion materials are installed as the casing is slowly retracted. Multiple casings can be telescoped inside the other if more than one aquitard is present. DPT cannot be used for telescoped well construction because the annulus is too narrow to allow for an adequate grout seal to be installed along the drive casing.

Decontaminating Equipment

As with all groundwater sampling equipment, DPT equipment should be decontaminated before sampling at a new location to avoid cross-contamination. In addition, disposable material should be discarded properly. Some sampling tools, by virtue of their design, may be difficult to disassemble for cleaning. In these cases, when replacing associated tubing, hose, or pipe is not feasible, it may be more practical to clean these tools by circulating cleaning solutions and rinses through the device in accordance with appropriate guidance (e.g., ASTM D5088, ASTM, 2001g; RCRA Ground-Water Monitoring Draft Technical Guidance, EPA, 1992). Where field decontamination is not practical or possible, it may be simpler to use dedicated sampling devices or take a number of portable sampling devices into the field and decontaminate them later at a more appropriate location. Following any cleaning procedure, equipment rinseate blanks should be collected to assess the effectiveness of the cleaning procedure.

Decommissioning DPT Wells and Borings

As with conventional soil borings or abandoned monitoring wells, DPT boreholes for point-in-time sampling and abandoned DPT monitoring wells should be decommissioned to avoid creating a conduit for contaminant migration, either from the surface or between subsurface geologic units. Several methods are available for decommissioning DPT holes, but the method chosen should be capable of backfilling the hole completely with grout or a bentonite slurry, from bottom to top and without gaps. The most appropriate method will depend on a number of factors, including the type and size of DPT equipment being used, site-specific subsurface conditions, and state and/or local regulations. The type of slurry selected may also depend on the remedial action anticipated at the site. For example, a silica flour grout mixture may be selected for sites that may be treated with in-situ thermal technology.

The methods available for decommissioning DPT boreholes include:

- Retraction grouting;
- Re entry grouting; and
- Surface pouring.

These methods are detailed in ASTM D6001 (ASTM, 2001e), EPA (1997), and Lutenegger and DeGroot (1995). Figure 5.1 illustrates the use of these methods, and the following paragraphs summarize the techniques and their applications.

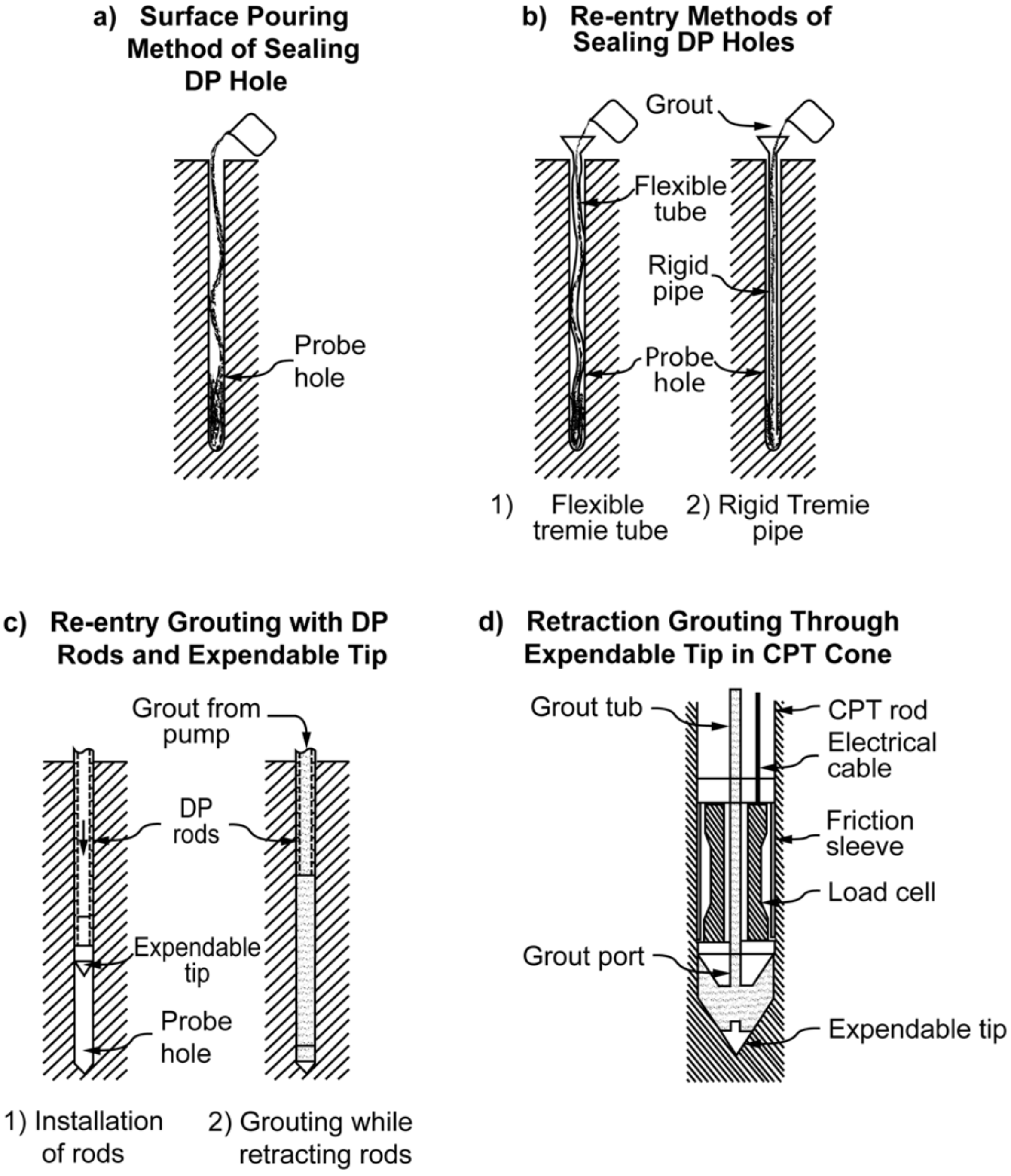
Retraction Grouting

Retraction grouting typically involves pumping a high-solids bentonite and water mixture or a neat cement grout through the rod and tool string and out the bottom of the sampling tool as the tool is withdrawn from the hole. To use this method, a port is needed at the end or sides of the tool or an expendable tip is necessary on the terminal end of the tool through which the grout can be pumped. Because the hole is grouted as the tool is withdrawn, this method ensures that the borehole is sealed throughout its length. Retraction grouting is generally considered to be the most reliable borehole sealing technique.

Re entry Grouting

Re entry grouting typically involves pumping grout through a tremie pipe (a rigid pipe, usually Schedule 40 or 80 Type I PVC) inserted into the borehole immediately following withdrawal of the rod string. Alternatively, the rod string may be reinstalled in the borehole, without the sampling tool, so that grout may be pumped through the open rods. The grout should be pumped continuously from the bottom of the hole to the top as the tremie pipe (or rod string) is withdrawn to avoid gaps and bridging (i.e., plugging the hole before grout reaches total depth) of the grout. Typically, re entry grouting is effective only if the hole remains open until tremie pipe or rods can be extended to the bottom of the borehole. If a portion of the borehole collapses, the tremie pipe or rods will not penetrate to the total depth of the hole. In this situation, it may be necessary to put an expendable tip on the end of the rod string, push the string to the total depth of the hole,

Figure 5.1
Sample Methods for Sealing Direct Push Technology Holes



Source: Adapted from Lutenegger & DeGroot, 1995 knock out the tip, and pump grout through the rods as they are withdrawn. Re entry grouting by this method may not provide a reliable seal if the DPT rods do not follow the original borehole, but the original borehole should provide the path of least resistance under most conditions.

By using a high pressure grout pump and nylon tremie tube it is possible to perform bottom-up grouting in the small annular spaces of DPT equipment. Slurries of 20-30% bentonite or neat cement grout are most commonly used to meet state regulatory requirements.

Surface Pouring

Surface pouring normally is the simplest method of borehole decommissioning; however, it may not be as effective as the other methods in most situations. It involves pouring either dry bentonite (granules, chips, or pellets), bentonite slurry, or neat cement grout from the surface down the open borehole after the rod string and tool are removed. Surface pouring may be effective if the borehole does not collapse after the rods are removed, and if the borehole is relatively shallow (less than about 10 or 15 feet). Where dry bentonite materials are proposed for use, it normally will only be effective if the bentonite is either hydrated from the surface immediately after installation or if it is installed beneath the water table. Maintaining a seal in the borehole requires that the soil moisture content be sufficient to keep the bentonite hydrated after installation. In deep holes, dry bentonite products can bridge, resulting in an incomplete seal. In situations where boreholes partially collapse, materials poured from the surface will not seal the borehole properly. This method can be improved by using a flexible tremie tube or a rigid tremie pipe to reenter the hole and fill it from the bottom up, however, if the hole collapses before the tremie can be installed, the tremie may not be effective either.

Section 6: Conclusions

Direct push technologies can be valuable tools for environmental investigations and facilitate the use of a dynamic work plan strategy. They have a number of potential advantages over conventional groundwater sampling methods and they can have the added benefit of being able to provide numerous other types of detailed subsurface data, such as geophysical, analytical, and hydrogeologic data. The diversity and capabilities of DPT equipment and methods are large enough that under many situations DPT can be used to provide the level of groundwater data quality needed for projects where the subsurface conditions and depth of investigation are amenable to pushing techniques. When techniques common to conventional well installation are followed, such as adequate well development, low-flow purging and sampling, proper decontamination of equipment, and preventing the creation of a hydraulic conduit, quality groundwater samples can be obtained.

DPT will not be appropriate for all situations. DPT methods typically are more limited in their depth of penetration and the types of materials they can penetrate than conventional drilling methods. Some methods may not be able to provide sufficient sample volume or sufficiently low turbidity. Use of DPT may be limited in lower yield formations. Conventional wells with larger diameters may be required to minimize the affect of lower yield formations. Lastly, DPT methods cannot always be used where confining layers are present and there is a danger of creating a vertical hydraulic conduit that could contaminate underlying layers. In these instances, telescoped wells may be needed to prevent downward migration of contaminants beneath a confining layer. As a result, DPT cannot completely replace the use of conventional monitoring wells. Rather, DPT provides additional choices to select equipment and methods for collecting environmental data.

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Appendix: Purging and Sampling Devices

A wide variety of purging and sampling equipment is available for use in DPT sampling points. Available devices can be classified into five general categories:

- Grab mechanisms (including bailers, thief samplers, and syringes);
- Suction-lift mechanisms (including surface centrifugal and peristaltic pumps);
- Centrifugal submersible pumps;
- Positive displacement mechanisms (including gas displacement pumps, bladder pumps, piston pumps, progressing cavity pumps and gear pumps); and
- Inertial-lift pumps.

Though frequently used in the groundwater industry for well development, the gas-lift method is generally considered unsuitable for purging and sampling because the extensive mixing of drive gas and water is likely to strip dissolved gasses from the groundwater and alter the concentration of other dissolved constituents (Gillham et al., 1983). This method is not discussed for this reason.

Grab Sampling Devices

Bailers, thief samplers (e.g., messenger samplers), and syringes are all examples of grab sampling devices. These devices are lowered into the sampling point on a cable, rope, string, chain, or tubing to the desired sampling depth and then retrieved for purge water discharge, sample transfer, or direct transport of the device to the laboratory for sample transfer and analysis.

The most commonly used grab samplers are bailers, which are available in both single check valve and dual check valve designs. The single check valve bailer is lowered to the sampling point, and water entering the bailer opens the check valve and fills the bailer. During retrieval, gravity and the weight of the water inside the bailer closes the check valve. There is some potential for the contents of the bailer to mix with the surrounding water column during retrieval. If mixing is not desirable, then a dual check valve bailer is advisable. Dual check valve bailers are intended to prevent mixing of the sample with the water column upon retrieval. Water passes through the dual check valve bailer as it is lowered. Upon retrieval, both check valves seat, retaining the aliquot of water inside the bailer. Groundwater investigators can minimize mixing by raising the bailer in a steady upward motion with no pausing or slight downward motion, which can occur if the retrieval is done manually.

The thief sampler, employs a mechanical, electrical, or pneumatic trigger to actuate plugs or valves at either end of an open tube to open and/or close the chamber after lowering it to the desired sampling depth, thus sampling from a discrete interval within the well.

The syringe sampler is divided into two chambers by a moveable piston or float. The upper chamber is attached to a flexible air line that extends to the ground surface. The lower chamber is the sample chamber. The device is lowered into the sampling point and activated by applying a suction to the upper chamber, thereby drawing the piston or float upward and allowing water to enter the lower chamber. In situations where the pressure exerted on the lower chamber by submergence is great enough to cause the piston or float to move upward prior to achieving the desired sampling depth, the upper chamber can be pressurized to prevent piston movement. The device is then activated by slowly releasing the pressure from the upper chamber, allowing water to fill the lower chamber.

Samples collected with grab samplers, especially various types of bailers, exhibit variable accuracy and precision in sample chemistry, often due to operator technique (Puls et al., 1992; Barcelona et al., 1984; Gillham et al., 1983; Pohlmann et al., 1991; Unwin and Maltby, 1988; Tai et al., 1991). Grab samplers can aerate and/or agitate a sample, causing sample oxidation, degassing, and stripping of VOCs from the sample. Care should be taken to avoid sample agitation during transfer of the sample from a grab sampler to the sample container. Pouring water from the top of a bailer either directly into the sample container or to a transfer vessel may agitate/aerate the sample and cause alteration of sample chemistry. These devices can also increase the turbidity of a sample through the surging action created in the well as the device moves through the water column. Grab samplers generally do not subject the sample to pressure changes, though some change may be imparted to a sample when using a syringe sampler activated with a suction. A potential for sample contamination exists due to exposure of the grab sampling device to the surface environment during repeated removal and reinsertion of the device during use. Also, the suspension cord or cable used with grab samplers could contribute contaminants to groundwater samples (Canova and Muthig, 1991).

Suction-Lift Pumps

Surface centrifugal pumps and peristaltic pumps are two common suction-lift pumps. These pumps are usually placed at or above ground level during purging and sampling. They draw water to the surface by applying suction to an intake line through the use of impellers or rotors typically driven by an electric motor. Surface centrifugal pumps use impellers that are typically constructed of brass or mild steel, plastic, or synthetic rubber. A peristaltic pump consists of a rotor with rollers that squeeze flexible tubing as they revolve within a stator housing. This action generates a reduced pressure at one end of the tubing and an increased pressure at the other end. Several types of elastomeric material can be used for the tubing, although silicone rubber is the most common.

Suction-lift pumps may be unacceptable for some groundwater sampling applications. Exertion of a reduced pressure on the sample can cause volatilization or may result in degassing, which can cause changes in the pH, redox potential, and other gas-sensitive parameters (Barcelona et al., 1983; Ho, 1983; Barker and Dickhout, 1988). Peristaltic pumps may be satisfactory for some analytes that are not affected by changes in the sample that can be caused by application of reduced pressure when used under low-flow rate and low lift conditions (Barcelona et al., 1983; Puls and Powell, 1992; Backhus et al., 1993).

Because surface centrifugal pumps can cause cavitation, they are not appropriate for collection of samples to be analyzed for dissolved gases, VOCs, or gas-sensitive parameters such as trace metals. Because the pumped water contacts the pump mechanism, artifacts from sample contact with these materials should be considered when evaluating these pumps for sampling. In addition, these pumps can mix air from small leaks in the suction circuit into a sample, which can cause sample bias. These pumps are typically difficult to adequately decontaminate between uses. To avoid the limitations posed by the effects of pumping or undesirable pump materials, an intermediate vessel could be used on the suction side of the pump circuit.

Peristaltic pumps do not usually cause cavitation but, as in all suction-lift pumps, the exertion of a reduced pressure on the sample can bias the sample. The flexible tubing required for use in a peristaltic pump mechanism may also cause sample bias.[2]

Centrifugal Submersible Pumps

A centrifugal submersible pump (CSP) consists of impellers housed within diffuser chambers that are attached to a sealed electric motor, which drives the impellers through a shaft and seal arrangement. Water enters the CSP by pressure of submergence, is pressurized by centrifugal force generated by the impellers, and discharged to the surface through tubing, hose, or pipe. A CSP is suspended in a well by its discharge line and/or a support line. Electric power is supplied to the motor through a braided or flat multiple-conductor insulated cable.

Flow rate and depth capability for all designs are wide ranging. For variable-speed CSPs, the discharge rate can be reduced by regulating the frequency of the electrical power supply and controlling the motor speed to reduce flow rate.

While there is no available peer-reviewed literature addressing the sampling effects of small-diameter variable-speed CSPs on dissolved gases or VOCs, one study found these pumps produced samples for some dissolved metals that were comparable to samples from bladder pumps (Pohlmann et al., 1994). With all CSPs, heat generated by the motor could increase sample temperature, which could result in loss of dissolved gases and VOCs from the sample.

CSPs are only available in diameters that will fit into sampling points 1.75 inches or larger in diameter. CSPs can be damaged when used in silty or sandy water, requiring repair or replacement of pump components and/or motor. If overheating occurs, there are three possible consequences. First, where the motor has internal water or oil in it for improved cooling characteristics, some of this liquid could be released into the sampling point, which could potentially contaminate the sampling point or samples. Because of this, motors that contain oil should not be used if the oil could interfere with the analytes of interest. Further, water used in motors should be of known chemistry. Second, when this type of motor eventually cools, it can draw in water from the sampling point, which could cause future cross-contamination problems. Proper decontamination of the pump should include changing internal cooling fluid if the pump is

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[2] For example, the plasticizers in flexible PVC can contaminate samples with phthalate esters. The use of silicone rubber tubing, which contains no plasticizers, can obviate this problem; however, the potential for sample bias due to sorption/desorption exists with both materials (Barcelona et al., 1985). These pumps can be used with the intermediate vessel system described above, so that the sample contacts only the intake tubing and vessel, avoiding contact with the pump mechanism tubing. Alternatively, using silicone rubber tubing at the pump head only can minimize this problem (Ho, 1983; Barker and Dickhout, 1988).

to be used in non-dedicated applications. As an alternative, dry sealed motors can be used to avoid these potential problems. Third, extensive or long-term overheating problems may result in motor failure, usually requiring replacement of the motor. CSPs should not be allowed to operate dry, or damage may occur to the pump seals and/or motor. Some CSP designs may be difficult to disassemble in the field for cleaning or repair. For these pumps, if used portably, cleaning is usually performed by flushing the pump and discharge line and washing the exterior surfaces in accordance with ASTM D5088 (ASTM, 2001h).

Gas-Drive Pumps

Gas-drive or gas-displacement pumps are distinguished from gas-lift pumps by the method of water transport. A gas displacement pump forces a discrete column of water to the surface via pressure-induced lift without the extensive mixing of drive gas and water produced by gas-lift devices. Hydrostatic pressure opens the inlet check valve and fills the pump chamber (fill cycle). The inlet check valve closes by gravity after the chamber is filled. Pressurized gas is applied to the chamber, displacing the water up the discharge line (discharge cycle). By releasing the pressure, the cycle can be repeated. A check valve in the discharge line maintains the water in the line above the pump. A pneumatic logic unit, or controller, is used to control the application and release of the drive gas pressure. The lift capability of a gas-displacement pump is directly related to the pressure of the drive gas used.

Although there is a limited interface in gas-displacement pumps between the drive gas and the water, the potential exists for loss of dissolved gases and VOCs across this interface (Barcelona et al., 1983; Gillham et al., 1983). This potential greatly increases if the pump is allowed to discharge completely, which would cause drive gas to be blown up the discharge line. Contamination of the sample may also result from impurities in the drive gas. Typical lifts for gas displacement pumps rarely exceed 250 feet using single-stage compressors; greater lifts can be achieved using two-stage compressors or compressed-gas cylinders. Gas-displacement pumps are available for sampling points as small as 1/2 inch in diameter.

Bladder Pumps

Bladder pumps, also known as gas-operated squeeze pumps or diaphragm pumps, consist of a flexible membrane (bladder) enclosed by a rigid housing. Water enters the bladder under hydrostatic pressure through a check valve at the pump bottom. The inlet check valve closes by gravity after the bladder is filled. Compressed gas is applied to the annular space between the outside of the bladder and pump housing, which squeezes the bladder. This action forces the water out of the bladder and up the discharge line to the surface. By releasing the gas pressure, this cycle can be repeated; a check valve in the discharge line prevents discharged water from re-entering the bladder. In some bladder pump designs, the water and air chambers are reversed, with water entering the annular space between the pump housing and bladder; the bladder is then inflated to displace the water. A pneumatic logic controller controls the application and release of drive gas pressure to the pump. The lift capability of bladder pumps is directly related to the pressure of the drive gas source.

Bladder pumps provide representative samples under a wide range of field conditions. There is no contact between the drive gas and the water in a bladder pump, eliminating the potential for stripping of dissolved gasses and VOCs and the potential for sample contamination by the drive gas. Pressure gradients applied to the sample can be controlled by reducing the drive gas pressure applied to the bladder, thus minimizing disturbance to the sample chemistry. Bladder pumps are recommended for sampling all parameters under a wide variety of field conditions (Parker, 1994; Kearl et al., 1992; Puls et al., 1992; Barcelona et al., 1983; Pohlmann et al., 1991; Unwin and Maltby, 1988; Tai et al., 1991; Pohlmann et al., 1994).

Bladder pump designs are available for use in sampling points as small as 1/2 inch in diameter. Bladder pump flow rates are controlled by adjusting the drive gas pressure or the discharge and refill cycle timing. Where maximum flow rates are too low for purging, secondary purging pumps or packers can be used in conjunction with bladder sampling pumps in order to reduce purge time requirements.

Dual-Acting Piston Pumps

Dual-acting piston pumps consist of a plunger or set of plungers (pistons) moving inside a stationary submerged barrel (cylinder). As the piston travels back and forth in the cylinder, it alternately draws water into the cylinder under suction, then displaces the water from the cylinder. In a dual-acting piston pump, water is simultaneously discharged and drawn in both directions of piston travel. A check valve in each discharge port or in the discharge line is used to prevent discharge water from re-entering the pump. The piston can be cycled manually, or through the use of a pneumatic or mechanical actuator.

Piston pumps can provide representative samples for some parameters (Barcelona et al., 1983; Knobel and Mann, 1993). Samples may be altered due to the suction produced during refill of the pump; this effect is reduced as the pump cycling rate is decreased. Likewise, reducing the pump cycling rate also reduces the pressure applied to the sample, minimizing the potential for sample alteration. If a flow restrictor or valve is used to reduce the discharge rate, the resultant pressure changes could alter sample chemistry (Barcelona et al., 1983; Gillham et al., 1983).

Currently available designs of dual-acting piston pumps will only fit in sampling points that are 2 inches in diameter or larger. The flow rate of a piston pump depends on the inside diameter of the pump cylinder and the stroke length and rate. The ability to control the minimum flow rate for sampling is dependent on the degree to which the stroke rate can be controlled.

Helical Rotor Pumps

Helical rotor pumps, also referred to as progressing cavity pumps, utilize a down-hole rotor and stator assembly driven by an electric motor to displace water through a discharge line to ground surface. Rotation of the helical rotor causes the cavity between the rotor and stator to progress upward, thereby pushing water in a continuous flow upward through the discharge line. In some progressing cavity pumps, the discharge rate can be varied by adjusting the speed of the pump motor between 50 and 500 rpm. The progressing cavity pump is typically suspended in a well by its discharge line or by a suspension cable. A two-conductor electric cable supplies power from a 12-volt DC power supply and control box to the pump motor.

The operating principle of progressing cavity pumps makes them suitable for collection of samples to be analyzed for VOCs (Imbrigiotta et al., 1988). There is some evidence these pumps may not be suitable for sampling trace metals and other inorganic analytes at higher flow rates due to increased turbidity (Barcelona et al., 1983); to control turbidity, a variable speed pump controller should be used to reduce flow rate. The pressure applied to a sample is directly related to the motor speed, and can be controlled in designs using variable-speed motor controls. Overheating of the motor may raise the temperature of the sample (Parker, 1994).

Progressing cavity pumps require sampling point diameters of at least 2 inches. The relatively low discharge rates attainable with most progressing cavity pumps makes them most useful in applications where purging does not require removal of large volumes of water from monitoring wells. With variable flow rate progressing cavity pumps, once purging is complete the discharge rate may be reduced before samples are collected.

Gear-Drive Pumps

Another type of positive displacement electric submersible pump is the gear-drive pump. In this type of pump, an electric motor drives a pair of PTFE gears. As these gears rotate, their advancing teeth draw water into the pump through the pump intake port and push it through the gears in a continuous flow up the discharge line. The discharge rate can be varied by using the pump controls to adjust the speed of the pump motor. As with many other submersible pumps, the gear-drive pump is usually suspended in a well by its discharge line. Electric power is supplied to the 24-volt DC motor through a cable from the power source and control box at ground surface.

Gear-drive pumps provide good recoveries of dissolved gases, VOCs, trace metals and other inorganics, and mobile colloids (Backhus et al., 1993; Imbrigiotta et al., 1988). However cavitation may occur if the pump is run at high rpm, which could affect dissolved gases or VOCs. The potential for cavitation can be reduced by controlling motor speed. The pressure applied by a gear-drive pump to a sample is directly related to the motor speed, and can be controlled by using the variable-speed motor controls. Gear-drive pumps are constructed of materials acceptable for sampling sensitive groundwater parameters; pump bodies are commonly constructed entirely of stainless steel materials while the gears are constructed of PTFE.

Gear-drive pumps require a sampling point diameter of at least 2 inches. Maximum discharge rates for gear-drive pumps range from more than 3 gallons per minute at lifts of less than 20 feet to 0.25 gallons per minute at lifts of 250 feet. Discharge rates are easily controlled by using the flow control, which adjusts the power supplied to run the pump motor; pump discharge can be adjusted to less than 50 ml/min.

Inertial Lift Pumps

Inertial lift pumps consist of a discharge line (either flexible tubing or rigid pipe) with a ball-check foot valve attached to the lower end of this line. In operation, the pump is lowered into a water column and cycled through reciprocating motion, either through manual action or through the use of a reciprocating mechanical arm mechanism driven by an electric motor or internal combustion engine, to achieve discharge of water. As the pump is moved upward, water that has entered the pump under hydrostatic pressure is lifted upward, held in the pump by the seated foot valve. When the upward motion of the pump is stopped, the inertia of the water column inside the pump carries it up and out of the discharge line. As the pump is pushed downward, the foot valve opens, allowing the pump to refill, and the cycle is repeated to pump water from the sampling point.

Inertial lift pumps can be constructed of any flexible tubing material or rigid discharge pipe that has sufficient strength to tolerate the pump cycling. Typically, these materials include rigid and flexible PVC, PE, PP, and PTFE. Tubing diameters of ¼ inch or ⅜ inch can be used to collect samples from sampling points as small as ½ inch in diameter.

If inertial-lift pumps are cycled rapidly prior to or during sample collection, some loss of VOCs and/or dissolved gasses could occur in the discharge stream. Inertial lift pumps do not cause pressure changes in the sample. However, the cycling action of an inertial lift pump in a sampling point can significantly increase sample turbidity and agitate and aerate the water column within the sampling point. This can result in alteration of concentrations of a wide variety of analytes (including dissolved gases, VOCs, and trace metals) and interference with analytical determinations in the laboratory.

The flow rate of an inertial lift pump is directly related to the cycling rate of the pump. Flexing of the tubing in the sampling point can cause the flow rate to drop. To achieve discharge rates suitable for sample collection, it is necessary to insert a short length of small-diameter flexible tubing into the discharge line to divert a portion of the discharge stream into sample containers.

STANDARD OPERATING PROCEDURE FOR LOW-STRESS (Low Flow) / MINIMAL DRAWDOWN GROUND-WATER SAMPLE COLLECTION

INTRODUCTION

The collection of “representative” water samples from wells is neither straightforward nor easily accomplished. Ground-water sample collection can be a source of variability through differences in sample personnel and their individual sampling procedures, the equipment used, and ambient temporal variability in subsurface and environmental conditions. Many site inspections and remedial investigations require the sampling at ground-water monitoring wells within a defined criterion of data confidence or data quality, which necessitates that the personnel collecting the samples are trained and aware of proper sample-collection procedures.

The purpose of this standard operating procedure (SOP) is to provide a method which minimize the amount of impact the purging process has on the ground water chemistry during sample collection and to minimize the volume of water that is being purged and disposed. This will take place by placing the pump intake within the screen interval and by keeping the drawdown at a minimal level (0.33 feet) (Puls and Barcelona, 1996) until the water quality parameters have stabilized and sample collection is complete. The flow rate at which the pump will be operating will be depended upon both hydraulic conductivity of the aquifer and the drawdown with the goal of minimizing the drawdown. The flow rate from the pump during purging and sampling will be at a rate that will not compromise the integrity of the analyte that is being sampled. This sampling procedure may or may not provide a discrete ground water sample at the location of the pump intake. The flow of ground-water to the pump intake will be dependent on the distribution of the hydraulic conductivity (K) of the aquifer within the screen interval. In order to minimize the drawdown in the monitoring well a low-flow rate must be utilized. Low-flow refers to the velocity with which water enters the pump intake from the surrounding formation in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface, which can be affected by flow regulators or restrictions (Puls and Barcelona, 1996). This SOP was developed by the Superfund/RCRA Ground Water Forum and draws from an USEPA's Ground Water Issue Paper, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedure, by Robert W. Puls and Michael J. Barcelona. Also, available USEPA Regional SOPs regarding Low-Stress(Low Flow)Purging and Sampling were used for this SOP.

SCOPE AND APPLICATION

This SOP should be used primarily at monitoring wells which have a screen or an open interval with a length of ten feet or less and can accept a sampling device which minimizes the disturbance to the aquifer or the water column in the well casing. The screen or open interval should have been optimally located to intercept an existing contaminant plume(s) or along flowpaths of potential contaminant releases. Knowledge of the contaminant distribution within the screen interval is highly recommended and is essential for the success of this sampling procedure. The ground-water samples which are collected using this procedure are acceptable for the analyses of ground-water contaminants which may be found at Superfund and RCRA contamination sites. The analytes may be volatile, semi-volatile organic compounds, pesticides, PCBs, metals and other inorganic compounds. The screened interval should be located within the contaminant plume(s) and the pump intake should be placed at or near the known source of the contamination within the screened interval. It is critical to place the pump intake in the exact location or depth for each sampling event. This argues for the use of dedicated, permanently installed sampling devices whenever possible. If this is not possible then the placement of the pump intake should be positioned with a calibrated sampling pump hose sounded with a weighted-tape or using a pre-measured hose. The pump intake should not be placed near the bottom of the screened interval to avoid disturbing any sediment that may have settled at the bottom of the well.

Water-quality indicator parameters and water levels must be measured during purging, prior to sample collection. Stabilization of the water quality parameters as well as monitoring water levels are a prerequisite to sample collection. The water-quality indicator parameters which are recommended include the following: specific electrical conductance, dissolved oxygen, turbidity, oxidation-reduction potential, pH, and temperature. The latter two parameters are useful data, but are generally insensitive as purging parameters. Oxidation-reduction potential may not always be appropriate stabilization parameter, and will depend on site-specific conditions. However, readings should be recorded because of its value as a double check for oxidation conditions, and for fate and transport issues. Also, when samples are collected for metals, semi-volatile organic compounds, and pesticides every effort must be made to reduce turbidity to 10 NTUs or less (not just the stabilization of turbidity) prior to the collection of the water sample. In addition to the measurement of the above parameters, depth to water must be measured during purging (U.S. Environmental Protection Agency, 1995).

Proper well construction, development and maintenance are essential for any ground-water sampling procedure. Prior to conducting the field work, information on the construction of the well and well development should be obtained and that information factored into the site specific sampling procedure. The attached Sampling Checklist is an example of the type of information that is useful.

Stabilization of the water-quality indicator parameters is the criterion for sample collection. But if stabilization is not occurring and the procedure has been strictly followed, then sample collection can take place once three (minimum) to six (maximum) casing volumes have been removed (Schuller et al., 1981 and U.S. Environmental Protection Agency., 1986; Wilde et al., 1998; Gibs and Imbrigiotta., 1990). The specific information on what took place during purging must be recorded in the field notebook or in the ground-water sampling log.

This SOP is not to be used where non-aqueous phase liquids (immiscible fluids) are present in the monitoring well.

EQUIPMENT

- Depth-to-water measuring device - An electronic water-level indicator or steel tape and chalk, with marked intervals of

0.01 foot. Interface probe for determination of liquid products (NAPL) presence, if needed.

- Steel tape and weight - Used for measuring total depth of well. Lead weight should not be used.
- Sampling pump - Submersible or bladder pumps with adjustable rate controls are preferred. Pumps are to be constructed of inert materials, such as stainless steel and teflon®. Pump types that are acceptable include gear and helical driven, centrifugal (low-flow type) and air-activated piston. Adjustable rate, peristaltic pump can be used when the depth to water is 20 feet or less.
- Tubing - Teflon® or Teflon® lined polyethylene tubing is preferred when sampling for organic compounds. Polyethylene tubing can be used when sampling inorganics.
- Power Source - If a combustion type (gasoline or diesel-driven) generator is used, it must be placed downwind of the sampling area.
- Flow measurement supplies - flow meter, graduated cylinder and a stop watch.
- Multi-Parameter meter with flow-through-cell - This can be one instrument or more contained in a flow-through cell. The water-quality indicator parameters which must be monitored are pH, ORP/EH, dissolved oxygen (DO), turbidity, specific conductance, and temperature. Turbidity readings must be collected before the flow cell because of the potential for sediment buildup which can bias the turbidity measurements. Calibration fluids for all instruments should be NIST-traceable and there should be enough for daily calibration through-out the sampling event. The inlet of the flow cell must be located near the bottom of the flow cell and the outlet near the top. The size of the flow cell should be kept to a minimum and a closed cell is preferred. The flow cell must not contain any air or gas bubbles when monitoring for the water-quality indicator parameters.
- Decontamination Supplies - Including a reliable and documented source of distilled water and any solvents (if used). Pressure sprayers, buckets or decontamination tubes for pumps, brushes and non-phosphate soap will also be needed.
- Sample bottles, sample preservation supplies, sample tags or labels and chain of custody forms.
- Approved Field Sampling and Quality Assurance Project Plan.
- Well construction data, field and water quality data from the previous sampling event.
- Well keys and map of well locations.

- Field notebook, ground-water sampling logs and calculator. A suggested field data sheet (ground-water sampling record or ground-water sampling log) are provided in the attachment.
- Filtration equipment, if needed. An in-line disposable filter is recommended.
- Polyethylene sheeting which will be placed on ground around the well head.
- Personal protective equipment specified in the site Health and Safety Plan.
- Air monitoring equipment as specified in the Site Health and Safety Plan.
- Tool box -All needed tools for all site equipment used.
- A 55-gallon drum or container to contain the purged water.

Materials of construction of the sampling equipment (bladders, pumps, tubing, and other equipment that comes in contact with the sample) should be limited to stainless steel, Teflon®, glass and other inert material. This will reduce the chance of the sampling materials to alter the ground-water where concentrations of the site contaminants are expected to be near the detection limits. The sample tubing diameter thickness should be maximized and the tubing length should be minimized so that the loss of contaminants into and through the tubing walls may be reduced and the rate of stabilization of ground-water parameters is maximized. The tendency of organics to sorb into and out of material makes the appropriate selection of sample tubing material critical for trace analyses (Pohlmann and Alduino, 1992; Parker and Ranney, 1998).

PURGING AND SAMPLING PROCEDURES

The following describes the purging and sampling procedures for the Low-Stress (Low Flow)/ Minimal Drawdown method for the collection of ground-water samples. These procedures also describe steps for dedicated and non-dedicated systems.

<u>Pre-Sampling Activities</u> (Non-dedicated and dedicated system)

1. Sampling locations must begin at the monitoring well with the least contamination, generally up-gradient or furthest from the site or suspected source. Then proceed systematically to the monitoring wells with the most contaminated ground water.

2. Check and record the condition of the monitoring well for damage or evidence of tampering. Lay out polyethylene sheeting around the well to minimize the likelihood of contamination of sampling/purging equipment from the soil. Place monitoring, purging and sampling equipment on the sheeting.

3. Unlock well head. Record location, time, date and appropriate information in a field logbook or on the ground-water sampling log (See attached ground-water sampling record and ground-water sampling log as examples).

4. Remove inner casing cap.

5. Monitor the headspace of the monitoring well at the rim of the casing for volatile organic compounds (VOC) with a Photo-ionization detector (PID) or Flame ionization detector (FID), and record in the logbook. If the existing monitoring well has a history of positive readings of the headspace, then the sampling must be conducted in accordance with the Health and Safety Plan.

6. Measure the depth to water (water level must be measured to nearest 0.01 feet) relative to a reference measuring point on the well casing with an electronic water level indicator or steel tape and record in logbook or ground-water sampling log. If no reference point is found, measure relative to the top of the inner casing, then mark that reference point and note that location in the field logbook. Record information on depth to ground water in the field logbook or ground water sampling log. Measure the depth to water a second time to confirm initial measurement; measurement should agree within 0.01 feet or re-measure.

7. Check the available well information or field information for the total depth of the monitoring well. Use the information from the depth of water in step six and the total depth of the monitoring well to calculate the volume of the water in the monitoring well or the volume of one casing. Record information in field logbook or ground-water sampling log.

Purging and Sampling Activities

8A. Non-dedicated system - Place the pump and support equipment at the wellhead and slowly lower the pump and tubing down into the monitoring well until the location of the pump intake is set at a pre-determined location within the screen interval. The placement of the pump intake should be positioned with a calibrated sampling pump hose, sounded with a weighted-tape, or using a pre-measured hose. Refer to the available monitoring well information to determine the depth and length of the screen interval. Measure the depth of the pump intake while lowering the pump into location. Record pump location in field logbook or groundwater sampling log.

8B. Dedicated system - Pump has already been installed, refer to the available monitoring well information and record the depth of the pump intake in the field logbook or ground-water sampling log.

9. Non-dedicated system and dedicated system - Measure the water level (water level must be measured to nearest 0.01 feet) and record information on the ground-water sampling log, leave water level indicator probe in the monitoring well.

10. Non-dedicated and dedicated system - Connect the discharge line from the pump to a flow-through cell. A “T” connection is needed prior to the flow cell to allow for the collection of water for the turbidity measurements. The discharge line from the flow-through cell must be directed to a container to contain the purge water during the purging and sampling of the monitoring well.

11. Non-dedicated and dedicated system - Start pumping the well at a low flow rate (0.2 to 0.5 liter per minute) and slowly increase the speed. Check water level. Maintain a steady flow rate while maintaining a drawdown of less than 0.33 feet (Puls and Barcelona, 1996). If drawdown is greater than 0.33 feet lower the flow rate. 0.33 feet is a goal to help guide with the flow rate adjustment. It should be noted that this goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience (Puls and Barcelona, 1996).

12. Non-dedicated and dedicated system - Measure the discharge rate of the pump with a graduated cylinder and a stop watch. Also, measure the water level and record both flow rate and water level on the groundwater sampling log. Continue purging, monitor and record water level and pump rate every three to five minutes during purging. Pumping rates should be kept at minimal flow to

ensure minimal drawdown in the monitoring well.

13. Non-dedicated and dedicated system - During the purging, a minimum of one tubing volume (including the volume of water in the pump and flow cell) must be purged prior to recording the water-quality indicator parameters. Then monitor and record the water-quality indicator parameters every three to five minutes. The water-quality indicator field parameters are turbidity, dissolved oxygen, specific electrical conductance, pH, redox-potential and temperature. Oxidation-reduction potential may not always be an appropriate stabilization parameter, and will depend on site-specific conditions. However, readings should be recorded because of its value as a double check for oxidizing conditions. Also, for the final dissolved oxygen measurement, if the readings are less than 1 milligram per liter, it should be collected and analyze with the spectrophotometric method (Wilde et al., 1998 Wilkin et al., 2001), colorimetric or Winkler titration (Wilkin et al., 2001). The stabilization criterion is based on three successive readings of the water quality field parameters; the following are the criteria which must be used:

Parameter	**Stabilization Criteria**	**Reference**
pH	± 0.1 pH units	Puls and Barcelona, 1996; Wilde et al.,
Specific electrical conductance (SEC)	± 3% FS/cm	Puls and Barcelona, 1996
oxidation-reduction potential (ORP)	± 10 millivolts	Puls and Barcelona 1996
turbidity	± 10 % NTUs (when turbidity is greater than 10 NTUs)	Puls and Barcelona, 1996 Wilde et al., 1998
dissolved oxygen	± 0.3 milligrams per liter	Wilde et al., 1998

Once the criteria have been successfully met indicating that the water quality indicator parameters have stabilized, then sample collection can take place.

14. If a stabilized drawdown in the well can't be maintained at 0.33 feet and the water level is approaching the top of the screened interval, reduce the flow rate or turn the pump off (for 15 minutes) and allow for recovery. It should be noted whether or not the pump has a check valve. A check valve is required if the pump is shut off. Under no circumstances should the well be

pumped dry. Begin pumping at a lower flow rate, if the water draws-down to the top of the screened interval again turn pump off and allow for recovery. If two tubing volumes (including the volume of water in the pump and flow cell) have been removed during purging then sampling can proceed next time the pump is turned on. This information should be noted in the field notebook or ground-water sampling log with a recommendation for a different purging and sampling procedure.

15. Non-dedicated and dedicated system - Maintain the same pumping rate or reduce slightly for sampling (0.2 to 0.5 liter per minute) in order to minimize disturbance of the water column. Samples should be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell. Disconnect the pump's tubing from the flow-through-cell so that the samples are collected from the pump's discharge tubing. For samples collected for dissolved gases or Volatile Organic Compounds (VOCs) analyses, the pump's tubing needs to be completely full of ground water to prevent the ground water from being aerated as the ground water flows through the tubing. The sequence of the samples is immaterial unless filtered (dissolved) samples are collected and they must be collected last (Puls and Barcelona, 1996). All sample containers should be filled with minimal turbulence by allowing the ground water to flow from the tubing gently down the inside of the container. When filling the VOC samples a meniscus must be formed over the mouth of the vial to eliminate the formation of air bubbles and head space prior to capping. In the event that the ground water is turbid,(greater then 10 NTUs), a filtered metal (dissolved) sample also should be collected.

If filtered metal sample is to be collected, then an in-line filter is fitted at the end of the discharge tubing and the sample is collected after the filter. The in-line filter must be pre-rinsed following manufacturer's recommendations and if there are no recommendations for rinsing, a minimum of 0.5 to 1 liter of ground water from the monitoring well must pass through the filter prior to sampling.

16A. Non-dedicated system - Remove the pump from the monitoring well. Decontaminate the pump and dispose of the tubing if it is non-dedicated.

16B Dedicated system - Disconnect the tubing that extends from the plate at the wellhead (or cap) and discard after use.

17. Non-dedicated system - Before locking the monitoring well, measure and record the well depth (to 0.1 feet).
Measure the total depth a second time to confirm initial measurement; measurement should agree within 0.01 feet or re-measure.

18. Non-dedicated and dedicated system - Close and lock the well.

DECONTAMINATION PROCEDURES

<u>Decontamination procedures for the water level meter and the water quality field parameter sensors</u>.
The electronic water level indicator probe/steel tape and the water-quality field parameter sensors will be decontaminated by the following procedures:
1. The water level meter will be hand washed with phosphate free detergent and a scrubber, then thoroughly rinsed with distilled water.

2. Water quality field parameter sensors and flow-through cell will be rinsed with distilled water between sampling locations. No other decontamination procedures are necessary or recommended for these probes since they are sensitive. After the sampling event, the flow cell and sensors must be cleaned and maintained per the manufacturer’s requirements.

<u>Decontamination Procedure for the Sampling Pump</u>

Upon completion of the ground water sample collection the sampling pump must be properly decontaminated between monitoring wells. The pump and discharge line including support cable and electrical wires which were in contact with the ground water in the well casing must be decontaminated by the following procedure:

1. The outside of the pump, tubing, support cable and electrical wires must be pressured sprayed with soapy water, tap water and distilled water. Spray outside of tubing and pump until water is flowing off of tubing after each rinse. Use bristle brush to help remove visible dirt and contaminants.
2.Place the sampling pump in a bucket or in a short PVC casing (4-in. diameter) with one end capped. The pump placed in this device must be completely submerged in the water. A small amount of phosphate free detergent must be added to the potable water

(tap water).

3. Remove the pump from the bucket or 4-in. casing and scrub the outside of the pump housing and cable.
4. Place pump and discharge line back in the 4-in. casing or bucket, start pump and re-circulate this soapy water for 2 minutes (wash).
5. Re-direct discharge line to a 55-gallon drum, continue to add 5 gallons of potable water (tap water)or until soapy water is no longer visible.
6. Turn pump off and place pump into a second bucket or 4-in. Casing which contains tap water, continue to add 5-gallons of tap water (rinse).
7. Turn pump off and place pump into a third bucket or 4-in. casing which contains distilled/deionized water, continue to add three to five gallons of distilled/deionized water (final rinse).
8. If a hydrophobic contaminant is present (such as separate phase, high levels of PCB’s, etc.) An additional decon step, or steps, may be added. For example, an organic solvent, such as reagent-grade isopropanol alcool may be added as a first spraying/bucket prior to the soapy water rinse/bucket.

FIELD QUALITY CONTROL

Quality control (QC) samples must be collected to verify that sample collection and handling procedures were performed adequately and that they have not compromised the quality of the ground water samples. The appropriate EPA program guidance must be consulted in preparing the field QC sample requirements for the site-specific Quality Assurance Project Plan (QAPP).

There are five primary areas of concern for quality assurance (QA) in the collection of representative ground-water samples:

1. Obtaining a ground-water sample that is representative of the aquifer or zone of interest in the aquifer. Verification is based on the field log documenting that the field water-quality parameters stabilized during the purging of the well, prior to sample collection.
2. Ensuring that the purging and sampling devices are made of materials, and utilized in a manner, which will not interact with or alter the analyses.
3. Ensuring that results generated by these procedures are reproducible; therefore, the sampling scheme should incorporate co-located samples (duplicates).

4. Preventing cross-contamination. Sampling should proceed from least to most contaminated wells, if known. Field equipment blanks should be incorporated for all sampling and purging equipment, and decontamination of the equipment is therefore required.
5. Properly preserving, packaging, and shipping samples.

All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The chain of custody procedures for the QC samples will be identical to the field ground water samples. The following are quality control samples which must be collected during the sampling event:

	Sample Type	Frequency
●	Field duplicates	1 per 20 samples
●	Matrix spike	1 per 20 samples
●	Matrix spike duplicate	1 per 20 samples
●	Equipment blank	Per Regional requirements or policy
●	Trip blank (VOCs)	1 per sample cooler
●	Temperature blank	1 per sample cooler

HEALTH AND SAFETY CONSIDERATIONS

Depending on the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. The site Health and Safety Plan should be reviewed with specific emphasis placed on the protection program planned for the sampling tasks. Standard safe operating practices should be followed, such as minimizing contact with potential contaminants in both the liquid and vapor phase through the use of appropriate personal protective equipment.

Depending on the type of contaminants expected or determined in previous sampling efforts, the following safe work practices will be employed:

Particulate or metals contaminants

1. Avoid skin contact with, and incidental ingestion of, purge water.
2. Use protective gloves and splash protection.

Volatile organic contaminants

1. Avoid breathing constituents venting from well.
2. Pre-survey the well head space with an appropriate device as specified in the Site Health and Safety Plan.
3. If monitoring results indicate elevated organic constituents, sampling activities may be conducted in level C protection. At a minimum, skin protection will be afforded by disposable protective clothing, such as Tyvek®.

General, common practices should include avoiding skin contact with water from preserved sample bottles, as this water will have pH less than 2 or greater than 10. Also, when filling pre-acidified VOA bottles, hydrochloric acid fumes may be released and should not be inhaled.

POST-SAMPLING ACTIVITIES

Several activities need to be completed and documented once ground-water sampling has been completed. These activities include, but are not limited to:

1. Ensure that all field equipment has been decontaminated and returned to proper storage location. Once the individual field equipment has been decontaminated, tag it with date of cleaning, site name, and name of individual responsible.
2. All sample paperwork should be processed, including copies provided to the Regional Laboratory, Sample Management Office, or other appropriate sample handling and tracking facility.
3. All field data should be complied for site records.
4. All analytical data when processed by the analytical laboratory, should be verified against field sheets to ensure all data has been returned to sampler.

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SAMPLING CHECKLIST

Well Identification:________________________

Map of Site Included: Y or N
Wells Clearly Identified w/ Roads: Y or N
Well Construction Diagram Attached: Y or N

Well Construction:

Diameter of Borehole:________ Diameter of Casing:__________
Casing Material:____________ Screen Material:______________

Screen Length:______________ Total Depth:_______________

Approximate Depth to Water:______________
Maximum Well Development Pumping Rate:__________________
Date of Last Well Development:______________

Previous Sampling Information:

Was the Well Sampled Previously: Y or N
(If Sampled, Fill Out Table Below)

Table of Previous Sampling Information

Parameter	Previously Sampled	Number of Times Sampled	Maximum Concentration	Notes (include previous purge rates)

Ground-Water Sampling Log

Site Name: **Well #:** **Date:**

Well Depth(Ft-BTOC[1]): **Screen Interval**(Ft):

Well Dia.: **Casing Material:** **Sampling Device:**

Pump placement(Ft from TOC[2]):

Measuring Point: **Water level (static)**(Ft):

Water level (pumping)(Ft):   **Pump rate**(Liter/min):

Sampling Personnel:

Other info: (such as sample numbers, weather conditions and field notes)

Water Quality Indicator Parameters

Time	**Pumping rates (L/min)**	**Water level (ft)**	**DO (mg/l)**	**ORP (mv)**	**Turb. (NTU)**	**SEC[3] (FS/cm)**	**pH**	**Temp. (C°)**	**Volume pumped (L)**

Type of Sample collected:

1-casing volume was:

Total volume purged prior to sample collection:

<u>Stabilization Criteria</u>

DO	±	0.3 mg/l
Turb.	±	10%
SEC	±	3%
ORP	±	10 mv
pH	±	0.1 unit

[1] **BTOC-Below Top of Casing**
[2] **TOC-Top of Casing**
[3] **Specific electrical conductance**

APPENDIX B
SITE HEALTH AND SAFETY PLAN

Pacific Groundwater Group

HEALTH AND SAFETY PLAN
Sunnyside Municipal Airport Pesticide Shed, Sunnyside, Washington

Revised: 4/30/2013

Job No. JG1201

Name of Site: Sunnyside Municipal Airport Pesticide Shed

Address of Site:
3318 Edison Rd
Sunnyside, Washington 98944

Client: City of Sunnyside

Site Contact: Shane Fisher (509) 837-5399

Site Activities Planned: Soil and groundwater as described in RI Work Plan and Quality Assurance Project Plan (all plans PGG, 2013)

Activity	Location	Date
Collect subsurface groundwater samples using direct-push sampler and/or hand tools	Sunnyside Airport	Summer 2013
Install groundwater monitoring wells and sample groundwater from monitoring wells (if needed)	Sunnyside Airport	TBD

Estimation of Direct Exposure Hazard to Pacific Groundwater Group Personnel

High___ Medium_ (Heavy equipment)__ Low_X__ None___

Physical Description of the Facility (attach map):

The subject area is located south of the airstrip, adjacent to hangars. The study area has a level gravel surface. The aircraft parking area north of the subject area is asphalt paved. The vicinity surrounding airport including the area immediately south of study area is plowed agricultural land.

Operational Description of the Facility:

The Sunnyside Municipal Airport is an active airport used primarily for private aviation and agricultural aviation.

Site Status

Active ☒ Inactive ☐ Abandoned ☐ Unknown ☐

HAZARD ASSESSMENT

Chemical State: Liquid ☒ Solid ☒ Gas ☐ Unknown ☐ Other ☐

Chemical Characteristics:

Corrosive ☐ Flammable ☐ Toxic ☒ Volatile ☐ Inert ☒ Other ☐

List the Chemicals of Concern:

Chemical Name	**Physical/Chemical Characteristics**	**Regulatory Standards**	**Exposure Routes/Symptoms**
DDT	Colorless crystals or off-white powder with a slight, aromatic odor. [pesticide]	Current OSHA PEL: TWA 1 mg/m3 TWA [skin]	Exposure Routes: inhalation, skin absorption, ingestion, skin and/or eye contact Symptoms: irritation eyes, skin; paresthesia tongue, lips, face; tremor; anxiety, dizziness, confusion, malaise (vague feeling of discomfort), headache, lassitude (weakness, exhaustion); convulsions; paresis hands; vomiting; [potential occupational carcinogen]
Toxaphene	Amber, waxy solid with a mild, piney, chlorine- and camphor-like odor. [insecticide]	OSHA PEL: TWA 0.5 mg/m3 [skin]	Exposure Routes: inhalation, skin absorption, ingestion, skin and/or eye contact Symptoms: nausea, confusion, agitation, tremor, convulsions, unconsciousness; dry, red skin; [potential occupational carcinogen]
DDE *(not documented by NIOSH, assume similar to DDT)*	See DDT	See DDT	See DDT
Silica, crystalline (as respirable dust)	Noncombustible solid	OSHA PEL: TWA approximately 15 mg/m3 (varies with silica content of dust)	Exposure Routes: inhalation, skin and/or eye contact Symptoms: Cough, dyspnea (breathing difficulty), wheezing; decreased pulmonary function, progressive resp symptoms (silicosis); irritation eyes; [potential occupational carcinogen]
Dieldrin	Colorless to light-tan crystals with a mild, chemical odor. [insecticide]	OSHA PEL: TWA 0.25 mg/m3 [skin]	Exposure Routes: inhalation, skin absorption, ingestion, skin and/or eye contact Symptoms: headache, dizziness, nausea, vomiting, sweating; myloclonic limb jerks, clonic, tonic convulsions, coma, [potential occupational carcinogen]

Hazards of Concern:

Heat Stress ☒ Cold Stress ☐ Explosive/Flammable ☐ Oxygen Deficient _☐

Excessive Noise☒ Inorganic Chemicals ☐ Organic Chemicals ☒ Other ☐

Describe Potential Environmental Hazards:

Exposure to chemicals of concern.
Noise and physical hazards during drill rig operation.
Noise and physical hazards due to nearby aircraft operation.
Hot and cold conditions.
Blowing wind (dust).

Describe Potential Worker Hazards:

Site is active. Potential hazards include:

- Falling and tripping hazards
- Working adjacent to heavy equipment that can fall from drill rig or fly from swinging backhoe or drill cables
- Injury from non-ergonomic use of hand sampling tools
- Mobilization of pesticide/herbicide-impacted dust and soils.
- Strenuous physical activity during manual sampling

ACTIVITY CONSIDERATIONS

Will site representative be present? Yes ☒ <u>Consultant familiar with site will be present</u>

Exact location of chemicals: Known _☒ Assumed ☒ Unknown ☐

Identify nearest offsite population and describe: Residential ☒ Industrial ☒ Rural ☒ Urban ☐

Site is located at an airfield with agricultural lands in the vicinity. Rural residential areas are nearby.

SAFETY CONSIDERATIONS

If there is more than one level of hazard, or if there are multiple "sites" within a site, a separate page should be completed to show specific safety considerations for each location.

Site locations:

Sunnyside Airport
Sunnyside, Washington

Objective of Work at this Location: to collect soil and groundwater samples for analysis to investigate the extent of contamination.

Level of Protection Planned: C ☐ D ☒

Possible Modifications: Addition or removal of dust mask or dust-filtering respirator if substantial dust is present in sampling area. May also include use of disposable tyvek overalls as needed.

Monitoring Equipment:

PID ☐ 0_2 Meter ☐ Explosimeter ☐ H2S Meter ☐ Other Visual☒

Action Levels: Visible dust in breathing space.

Type of Personal Protective Equipment to be Used:

NOTE: ALL PERSONS ON SITE MUST WEAR HARD HATS, SAFETY GLASSES, AND STEEL-TOE BOOTS DURING DRILLING.

Head:	Hard hat
Foot:	steel-toed boots
Hand:	Chemical resistant gloves (during all sampling and sample handling)
Eye/Face:	Protective glasses during water sampling
Clothing:	Coveralls or appropriate work clothes
Respiratory:	Visible dust is generated
Additional Gear:	Noise protection when noise levels exceed 85 decibels.

Work Party:

Name of Personnel	Responsibility	Level of Protection
Glen Wallace	Sampler	Level C or D
Travis Klaas	Sampler	Level C or D
Glenn Mutti-Driscoll	Sampler	Level C or D
Jeff Parker	Sampler	Level C or D

Safe Entry Procedures: WEAR APPROPRIATE PPE

Criteria for Changing Protection:

Visual observation of dust.

Decontamination Procedures:

Disposable PPE will be removed at the end of each day and disposed of as nonhazardous waste unless grossly contaminated.

Work boots in contact with site soils should be brushed off while at the site.

Work Limitations (time of day, conditions, etc.):

WORK WILL BE LIMITED TO DAYLIGHT HOURS.

Locations of Nearest:

Phone: A cellular telephone will be used by field personnel.
Running Water Source: Airport facilities.
Public Road: Edison Avenue
Rest Room: Airport facilities.

EMERGENCY PLANNING

Name	**Contact Person**	**Phone Number**
Local Police:		911
Local Ambulance:		911
Local Fire Department:		911
Poison Control Center:		911
Local Hospital:	Sunnyside Community Hospital	Emergency Room **(509) 837-1500** Hospital Switchboard **(509) 837-1500**
Address:	1016 Tacoma Ave Sunnyside, WA 98944	
Ecology:	Jennifer Lind	(509) 649-4449
Project Manager:	Glen Wallace	(206) 329-0141

Provide Directions to Nearest Available Medical Facility (attach map):

1. Drive through airport to **Edison Road**.

2. Head west on **E Edison Rd** toward **Hanford Rd**, drive1.8 miles

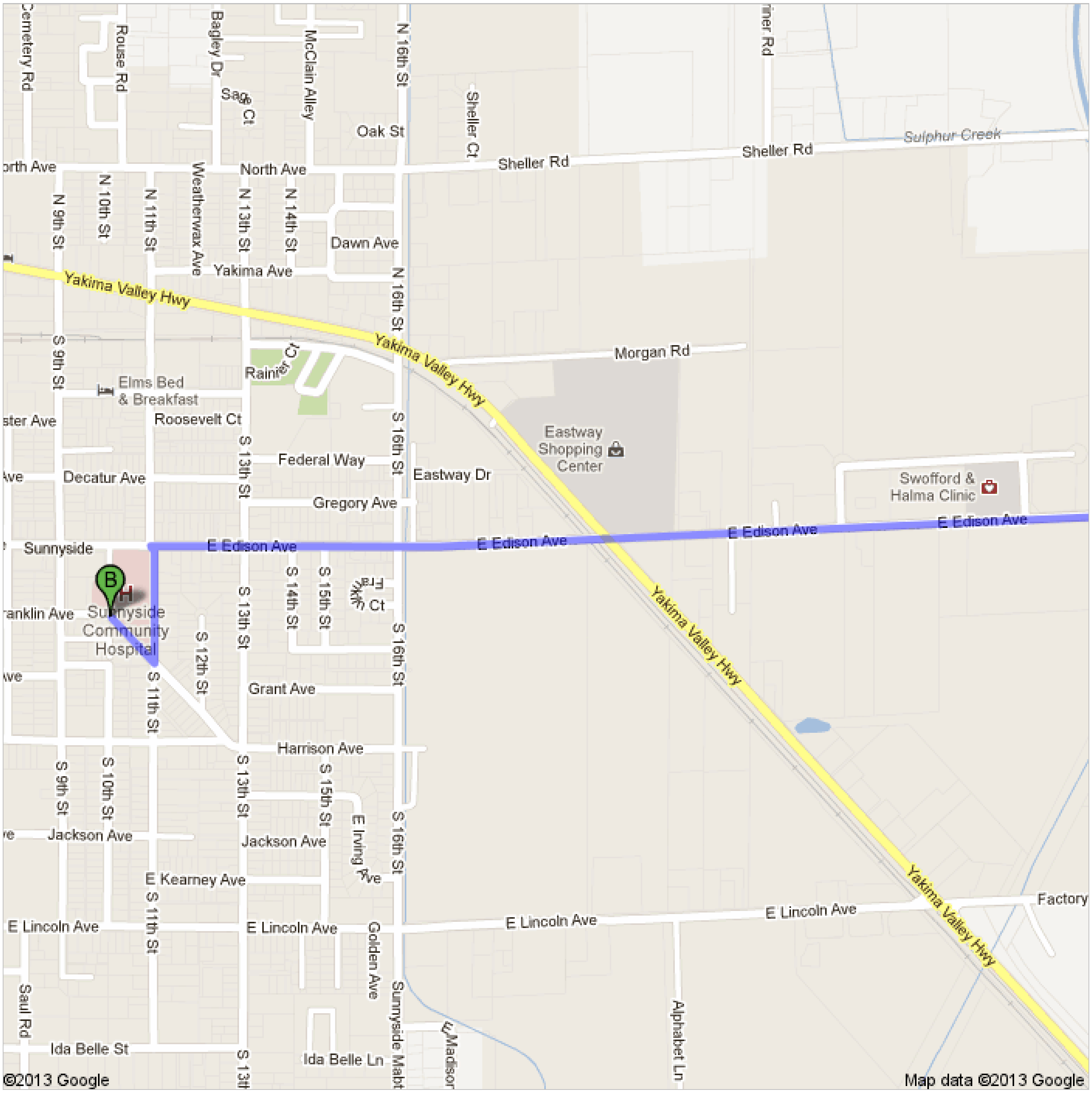
3. Turn left **onto S 11th St**, drive 0.2 mi

4. Sharp right onto Tacoma Ave **Sunnyside Community Hospital** will be on the right

Approvals	**Date**	**Signature**
Sampler:		
Sampler:		
Sampler:		
Site Safety Officer:		
Project Manager:		

cc: Project File

Directions to Sunnyside Community Hospital
1016 Tacoma Ave, Sunnyside, WA 98944
2.0 mi – about **7 mins**



A E Edison Rd

1.	Head **west** on **E Edison Rd** toward **Hanford Rd** About 6 mins	go 1.8 mi total 1.8 mi
↰ 2.	Turn left onto **S 11th St**	go 0.2 mi total 1.9 mi
↱ 3.	Sharp right onto **Tacoma Ave** Destination will be on the right	go 440 ft total 2.0 mi

B **Sunnyside Community Hospital**
1016 Tacoma Ave, Sunnyside, WA 98944

P 206.329.0141 | **F** 206.329.6968
2377 Eastlake Avenue East | Seattle, WA 98102

P 206.842.3202 | **F** 206.842.5041
8150 West Port Madison NE | Bainbridge, WA 98110

P 360.570.8244 | **F** 360.570.0064
1627 Linwood Avenue SW | Tumwater, WA 98512

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