Focused Site Investigation Work Plan for the L-Bar Site

Chewelah, Washington

Prepared for

Northwest Alloys, Inc.

April 2013

CH2MHILL®

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Acronyms/Abbreviations

bgs	below ground surface
DQO	data quality objective
EC	electrical conductance
Ecology	Washington State Department of Ecology
EM	electromagnetic
EP	east Perimeter
EPA	U.S. Environmental Protection Agency
FB	flux bar
FBR	flux bar residue
FTL	field team leader
GPS	global positioning system
H&SP	health and safety plan
IDW	investigation derived waste
mg/L	mg/L
MRP	Magnesite Residue Pile
MTCA	Model Toxics Control Act
MTCA	Model Toxics Control
PM	project manager
PPE	personal protective equipment
PPE	personal protective equipment
ppm	parts per million
PVC	polyvinyl chloride
QC	quality control
SP	south perimeter
SWBU	shallow water bearing unit
WAC	Washington Administrative Code

1 Introduction

This section provides background information (project understanding) which is the basis of the site investigation objectives and data needs.

1.1 Project Understanding

This document presents a Focused Site Investigation Work Plan (hereafter referred to as the work plan) to conduct a supplemental site investigation at the L-Bar site located in Chewelah, Washington (Figure 1). This work plan provides critical information needed to understand the project and associated data needs (project understanding); site investigation objectives; data quality objectives (DQOs); primary tasks; field investigation methods; quality control (QC); data management, and reporting.

In cooperation with Alcoa and at the approval of the Washington State Department of Ecology (Ecology), CH2M HILL recently completed a focused site investigation in spring 2012 at the L-Bar site to gain a better understanding of potential residual source materials hypothesized to be located in the southeastern corner of the Magnesite Residue Pile (MRP). The geophysical survey methods were described in the *Geophysical Investigation Work Plan for the L-Bar Site, Chewelah, Washington* (CH2M HILL 2012b). The geophysical survey was completed in June 2012 and the results were shared with the project team as summarized in the *Data Summary Report for the Supplemental Geophysical Survey Work Conducted at the L-Bar Site near Chewelah, Washington* (2012 Data Summary Report) (CH2M HILL, 2012a).

As described in the 2012 data summary report, an area of interest located just southwest of Well SA-10 atop the MRP, was identified and may potentially be representative of residual source materials (flux bar or flux bar residue [FB/FBR]). However, the 2012 data summary report identified supplemental data needs to complement and substantiate the results from the 2012 geophysical survey before potentially moving into a supplemental phase of source removal actions. The following data needs/activities were developed from the 2012 Data Summary Report as an outcome from the geophysical survey:

- Installation of two (temporary) piezometers to depths of less than 8 feet below ground surface (bgs) completed in the shallow water-bearing unit to better define the groundwater flow direction near the southeastern toe of the MRP (approximate location of piezometers shown on Figure 1).
- Testing of surface soils from grab samples using electrical conductance (EC) as a cost-effective indicator constituent to corroborate with the 2012 geophysical results in key areas located along the southeastern toe of the MRP (approximate sampling areas shown in Figure 1).
- Installation of temporary vapor sampling probes and collection of in situ vapor samples tested for ammonia as an indicator constituent that may be correlated to the presence of potential source materials (for example, FB/FBR). Vapor sampling probes will be installed to shallow depths (less than 10 feet below existing grade) in areas atop the MRP which showed an elevated response from the 2012 geophysical survey (approximate area for vapor probes shown in Figure 1).

The 2012 data summary report and associated data needs (recommendations itemized in previous text) were submitted to Ecology on October 23, 2012. Ecology replied on November 5, 2012 stating that they were in agreement with the geophysical data report findings and recommendations, and requested that Alcoa develop a work plan to proceed with the recommendations (listed above). This document constitutes the work plan requested by Ecology to guide this work planned to occur in late spring/or early summer 2013.

1.2 Site Investigation Objectives

The supplemental site investigation work will be conducted to determine if potential source areas of concern identified from the 2012 geophysical study can be further delineated and confirmed in a focused area of interest near the southeastern corner of the MRP (shown in Figure 1). The site work planned for spring 2013, along with the geophysical survey results obtained in 2012, will be used to facilitate management decisions regarding the need for potential supplemental source removal actions at the site.

The site investigation work as detailed in this work plan will be conducted in a manner supportive of and consistent with the selected remedy for the site, which consists of source removal, natural attenuation, and monitoring as established in the *L-Bar Cleanup Levels Development and Feasibility Study Report* (CH2M HILL, 1999). In addition, the objectives of the work planned herein are consistent with the requirements of the *Model Toxics Cleanup Program (MTCA) Agreed Order No. DE00TCPER-984* (June 12, 2000), and the *L-Bar Material Removal and Compliance Monitoring Work Plan* as required by the site's June 2000 Final Cleanup Action Plan (Ecology, 2000).

Results from the planned site investigation work scheduled for late spring 2013 as outlined in this work plan will be reported to Ecology, and the key findings and recommendations developed from the site investigation work will be the basis for establishing future management decisions (for example, if a need exists for supplemental source removal actions). If such future actions are deemed necessary, supplemental coordination, planning, and documentation as routed through Ecology's cleanup program (MTCA) will be necessary as a follow-on phase to the work activities described herein.

2 Site Investigation Work Plan

This section summarizes the project team, develops the data quality objectives, and identifies core elements of the site investigation work and health and safety.

2.1 Project Personnel

Execution of the work outlined in this work plan will involve all members of the planning team (identified from Step 1 of the DQOs per Appendix A). Specific responsibilities are outlined below:

- **CH2M HILL Project Manager (PM).** CH2M HILL's PM will coordinate with Alcoa and will be responsible for overall project delivery as outlined in the work plan within the established schedule and budget. CH2M HILL will be the technical lead in the development of the draft and final work plan, and all related elements of site work and reporting.
- **Alcoa.** Alcoa's Site Manager will coordinate with CH2M HILL to review the draft (and final) work plan prior to submittal to Ecology. Once the field work is complete, Alcoa's Site Manager and support staff will coordinate with CH2M HILL on completion of the final data summary report and potential follow-on recommendations.
- **Ecology's Site Manager.** Ecology's Site Manager will review the draft (and final) work plan and provide approval of activities in accordance with the selected remedy for the site under MTCA requirements. Ecology's Site Manager will also review the data summary report and provide feedback on future potential actions.
- **CH2M HILL Field Team Leader (FTL).** CH2M HILL's FTL and support staff will ensure that the field work is conducted in accordance with the work plan and the project-specific Health & Safety Plan (H&SP). CH2M HILL's PM will coordinate closely with the FTL to ensure the data are collected in accordance with the work plan.

2.2 Data Quality Objectives

The DQO process is the outcome from systematic planning conducted by project team members using a step-wise approach, which describes the goals and objectives of a project, and helps to guide the process on selecting the types and amounts of data that are needed in support of management decisions. Guidance on the systematic planning process is described in the U.S. Environmental Protection Agency's *Guidance on Systematic Planning Using the Data Quality Objective Process, EPA QA/G-4* (USEPA 2006). The Washington State Department of Ecology has adopted a similar process to help plan environmental studies as described in *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies, Publication No. 04-04-030* (Ecology, 2004). The systematic planning process is a management tool that develops new studies or environmental monitoring programs.

In accordance with the guidance, key elements of systematic planning include the following steps:

1. Statement of the problem
2. Goal of the study
3. Information Inputs (needed to support the goal of study)
4. Boundaries of the study area
5. Analytical approach
6. Performance criteria
7. Developing the plan for obtaining data

The DQO process listed above was used as a planning tool to develop the site investigation approach and sampling design for this work plan. Details of the DQO output are provided in Appendix A of this work plan.

2.3 Site Investigation Tasks

The site investigation work consists of three primary tasks:

- **Task 1—Develop Work Plan and Regulatory Coordination.** This task includes development of a detailed work plan for review and approval by Alcoa and Ecology. The work plan will guide the project team with pertinent details regarding the field installations, data collection, and reporting efforts.
- **Task 2—Fieldwork and Data Collection Activities.** This task includes field installations and data collection activities that are described in this work plan.
- **Task 3—Field Investigation Data Summary Report.** This task will document the as-built field installations and associated field monitoring results performed during the Task 2 field investigations.

This document constitutes the Task 1 work plan and will be used to guide the Task 2 field work and data collection activities (which were developed from the DQOs [Appendix A]). Section 3 describes the data management and reporting.

2.3.1 Field Installation and Preparation for Sampling

The following sections describe the details for Task 2 regarding installation of shallow piezometers, soil sampling, and vapor probes/sampling.

Table 1 summarizes the data needs and uses for each of the sampling activities. Table 2 summarizes the measurement performance objectives (for onsite measurements). Table 3 summarizes the data types, locations, and sampling frequency. Details regarding the field installation and related sampling are provided in the following sections.

2.3.1.1 Installation of Shallow Piezometers

Figure 2 shows the location of where the two piezometers will be installed to shallow depths (less than 8 feet bgs). Appendix B provides a construction plan which shows a typical piezometer configuration. A stainless steel hand auger that creates a 5-inch-diameter borehole will be used to advance and construct a 1-inch-diameter, Schedule-40 polyvinyl chloride (PVC) piezometer. Piezometers will be installed to approximately 2 feet below the zone of saturation (water table)—anticipated to be no greater than 2 or 3 feet bgs at each location (thus, total depth not expected to exceed 5 feet bgs in each location). The lowermost 2 feet of the PVC casing assembly will be perforated (either by a hand-drill or hack-saw) to constitute the piezometer screen adjacent to the zone of saturation. The annular space adjacent to the screen zone will be backfilled with 10x20 factory-packaged silica sand to a level of 1 foot above the top of the screen or perforated area. The remaining annular space will be backfilled with bentonite chips and hydrated to constitute the well seal. The shallow depth of these temporary piezometers (not to exceed 8 feet bgs) precludes the ability to fully satisfy the well construction standards of Chapter 173-160-400, *General Requirements for Resource Protection Wells*. This scenario is anticipated to require a variance and approval by Ecology to construct temporary piezometers in this manner.

Once the piezometers are installed they will be developed using a small-diameter bailer to agitate the screen zone and to purge water to enhance the hydraulic connection and to facilitate a representative groundwater level reading. Piezometer development activities will be completed upon visual confirmation that the groundwater is clear and the piezometer is hydraulically connected with the saturated zone based on groundwater recharge rates. It is anticipated that development will take approximately 30 minutes for each piezometer.

2.3.1.2 Establishing the Soil Sampling Grids

Soil sampling will be conducted in two focused areas along the southeast toe of the MRP, along with a selected background location in the west field (shown in Figure 2). A sampling grid will be established with grid spacing of approximately 20 feet in each of the two areas (delineated as east perimeter [EP] and south perimeter [SP]). This type of grid spacing is considered reasonable to yield a sufficient number of grab samples in each area to determine if these locations are (or are not) elevated above background levels. Appendix B provides a typical schematic of the soil sampling grid to be established at each of the two soil sampling areas.

2.3.1.3 Installation of Vapor Sampling Probes

Shallow vapor sampling probes will be installed in the suspected source areas of the MRP (as shown in Figure 2). At a minimum, at least five vapor probes will be installed in each of three areas atop the MRP in the areas shown/ approximated in Figure 2. Locations will target the approximate center of each of three locations, and four additional vapor sampling probes around the perimeter margin of each feature (thus, one at center, and another four around the perimeter for each of three locations). If there are surplus materials and sufficient time, supplemental vapor sampling points (in excess of the 15 planned) will be installed around the westernmost area as it represents the largest and most likely source area.

Appendix B provides a typical schematic of the vapor sampling probes. Similar to the temporary piezometers, the vapor probes will be installed with a stainless steel hand auger to facilitate installation of 1-inch-diameter PVC vapor probe. Installation depths are expected to be approximately 5 feet bgs at each location, but may require slight adjustment depending on ease or difficulty of auger advancement. The lower 2 feet of the PVC will be perforated (either by a hand drill or hack saw) to constitute the vapor sampling screen interval which will target approximately 5 feet bgs in the vadose zone of the existing MRP. The annular space adjacent to the screen zone will be backfilled with 10x20 factory-packaged silica sand to a level 1 foot above the top of the screen or perforated area. The remaining annualar space will be backfilled with bentonite chips and hydrated to constitute the surface seal to enhance representativeness of vapor sampling. The shallow depth of these vapor probes in the MRP (typically 5 feet bgs) is well above the depth to shallow groundwater, and, therefore, it is not deemed necessary to fully satisfy the well construction standards of Chapter 173-160-400 of the WAC, *General Requirements for Resource Protection Wells*.

Once the vapor probes are installed, each will be purged with an air pump connected to quarter-inch poly tubing set to the screen interval to withdraw any stagnant air entrained during probe installation. This exercise is considered similar to well development in that it is intending to enhance the representativeness of vapors for subsequent vapor sampling.

2.3.2 Data Collection Activities

The following sections describe the details for Task 2 regarding data collection for groundwater levels, soil sampling, and vapor sampling.

2.3.2.1 Measurement of Groundwater Levels and Calculation of Groundwater Elevations

Static groundwater levels will be obtained no earlier than 24 hours after installation to allow the saturated zone to fully recover after installation and development (described previously). Static groundwater levels will be measured with a hand-held electronic sounder from the top of PVC casing (fixed datum) and recorded to the nearest 0.01 foot. The top of PVC will be surveyed with an engineering rod and level using known reference point (such as the top of Well P-13 or Well SA-10); x-y location coordinates will be obtained with hand-held GPS unit, coupled with field measurements from adjacent nearby features. Static levels (converted to groundwater elevation) will be obtained from the two new piezometers, and existing nearby wells (P-12, P-13, SA-10, SA-11, SA-14, and P-09) to obtain a representative snap shot of groundwater elevation to construct a representative groundwater flow map.

At the conclusion of the project and in cooperation with Ecology, the temporary piezometers will be abandoned (decommissioned) in accordance with methods in Chapter 173-160-460 of the WAC, *Decommissioning Process for Resource Protection Wells*.

2.3.2.2 Soils Testing for Electrical Conductance

At each sampling location, a grab sample will be collected at ground surface (0 depth) and at approximately 6 inches bgs. Grab samples will be collected from each sampling location from either a stainless steel spoon or hand trowel. Grab samples will be prepared into a homogenized mixture of one-part sample and five- part deionized water. The soil-deionized sample mixture (sample) will then be transferred into a sampling beaker and a hand-held meter (YSI 63 or equivalent) will be used to measure the EC, and the values recorded in either micro Siemens per centimeter (low-range), or milli Siemens per centimeter (high-range) (final readings will be reported in consistent units). Each sampling location will be recorded as a unique sampling location with depth (such as

EC1-0, which would be unique sample “1” at zero depth; or EC1-6 which would be location 1 at 6 inches bgs). Coordinates for each grab sample location will be obtained from a hand-held GPS unit capable of sub-meter accuracy.

Between successive samples/depths, the sampling tools, sampling container(s), and EC meter will be cleaned with Alconox wash and rinsed with de-ionized water. The EC meter shall be calibrated in accordance with the manufacturer specifications at the start of each day of use and spot-checked with known standards routinely during the sampling effort (at least twice per day).

2.3.2.3 Vapor Sampling for Ammonia Concentrations

Appendix C provides sampling protocol and methods for using a Drager pump and collecting the vapor concentrations for ammonia using Drager tube (specific to ammonia). Vapor sampling will be performed at each vapor probe no sooner than 12 hours after installation and vapor purging (described above). An air pump will be connected to 0.25-inch poly tubing set to the screen depth and used to evacuate vapors into a sampling chamber (basically an enclosed container). Ammonia concentrations will be measured in the field using a Colorimetric indicator tube via Drager pump that withdraws the vapor sample from the sampling chamber. This method will yield ammonia concentrations in the range of 5 to 700 ppm with accuracy of 10 percent (+/-). Values less than 5 would be considered nondetect. Values at the higher end of the scale reading of 700 ppm would be considered “greater than 700 ppm.”

At the conclusion of the project and in cooperation with Ecology, the vapor probes will be abandoned (decommissioned) in accordance with methods per Chapter 173-160-460 of the WAC, *Decommissioning Process for Resource Protection Wells*.

2.4 Quality Control

QC methods and samples will be collected to ensure that the data are of known and appropriate quality to support the study objectives. Appendix A (Step 6.3 of the DQOs) develops the approach for QC methods and sampling.

2.5 Health and Safety

All personnel working onsite will follow site-specific health and safety procedures as required by Alcoa and as administered by CH2M HILL. CH2M HILL will prepare a project-specific Health and Safety Plan (H&SP). Known and potential site-specific hazards and personal protective equipment (PPE) requirements will be addressed in the H&SP. Subcontractors performing work on site (if needed) will be required to adhere to both the Alcoa and CH2M HILL H&SP, and implement their own health and safety procedures specific to the work conducted at the site.

Investigative derived waste (IDW) from this study is anticipated to be minimal (less than 3 cubic yards). Small quantities of IDW will be generated from piezometer installation (fill aggregate and native alluvial soil, and excess purge water during development), soil sampling (amended soil paste presumed to be fill aggregate in the sampling locations), and vapor probe installation (presumably MRP and potentially some FB or FBR source materials). All the soils and fill material generated during the investigation will be temporarily containerized and stored in a location atop the MRP until the field investigation results and sampling data have been reported to Ecology. Final disposition of these materials is anticipated to consist of spreading them atop the MRP provided that they do not consist of source materials. In the event that source materials are found/generated during the investigation they will be managed in accordance with the IDW protocol used during the Ecology-approved *L-Bar Material Removal and Compliance Monitoring Work Plan* (CH2M HILL, 2001). Disposable sampling materials and PPE will be discarded in a receptacle that is managed and transported to a permitted municipal solid waste facility.

3 Data Management and Reporting

This section describes the data management and reporting for the information collected under this work plan.

3.1 Data Management

The following sections describe the data recording, data reduction, and data storage.

3.1.1 Data Recording

Field observations and all field-measured data will be recorded on dedicated field forms (or field notebook) to create a permanent record of field activities. All hand-entered data will be reviewed by a second person to minimize data entry errors. A check for completeness of field records will ensure that all requirements for field activities have been fulfilled, complete records exist for each activity, and the procedures specified in this work plan have been implemented. Field documentation will ensure sample integrity and provide sufficient technical information to recreate each field event/sampling activity.

CH2M HILL's FTL will be responsible for keeping a daily log book and recording all field data. Field notes will include, at a minimum, the following information:

- Field team leader name
- Field team members' names
- Date(s) of data collection
- Working hours onsite
- Instrument(s) used
- Positioning method used (for example, GPS)
- Field-measured values
- Weather conditions
- Other relevant field notes and observations

Field data will be archived by the CH2M HILL PM at the conclusion of the field work. Pertinent field data will be compiled and summarized in support of the data summary report (described in Section 3.2).

3.1.2 Data Reduction

Data collected under the work plan will be reviewed by the FTL and discussed with the PM to determine if the measurement quality objectives and data needs have been satisfied. In general, the review will be accomplished by comparing the field notebook entries (field data) with the sampling methods/requirements outlined in this work plan (herein).

3.1.3 Data Storage and Archives

Data generated as part of the work plan will be handled and reviewed in accordance with the procedures outlined above. All collected data will be reviewed by (1) CH2M HILL's FTL during field work installations and/or sample collection with the methods and procedures described in Section 2 (as developed in Appendix A); and (2) by CH2M HILL's PM in accordance with the methods and data needs outlined in this work plan. The field data (or daily log books) will be retained by CH2M HILL and archived in the project files.

3.2 Reporting

Data collected under this work plan will be compiled by CH2M HILL in a manner consistent with the 'analytical approach' as described under Step 5 of the DQOs (per Appendix A). CH2M HILL will submit the draft data summary report and submit for Alcoa's review and approval. In cooperation with Alcoa, CH2M HILL will release and submit the final report to the project team, including copies to Ecology's Site Manager. Recommendations (alternative actions) that may be related to this work are considered outside the scope of the data report and will be presented separately and/or discussed with Ecology after the data report has been submitted.

4 References

CH2M HILL. 2012a. *Data Summary Report for the Supplemental Geophysical Survey Work Conducted at the L-Bar Site near Chewelah, Washington*. Prepared for Northwest Alloys, Inc. October.

CH2M HILL. 2012b. Focused Geophyscial Investigation Work Plan for the L-Bar Site, Chewelah, Washington. Prepared for Northwest Alloys, Inc. May 2012.

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U.S. Environmental Protection Agency. 2006. *Guidance on Systematic Planning Using the Data Quality Objective Process, EPA QA/G-4.*

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Washington State Department of Ecology. 2000. *L-Bar Site, Final Cleanup Action Plan*.

Tables

Table 1

Data Needs and Uses

L-Bar Site - Work Plan for Supplemental Site Investigation

Target Medium	Parameter/Units	Data Use	Data User	Comments
Groundwater Elevation	Groundwater Elevation (in Feet)	Develop updated groundwater flow map for SWBU in focused area of interest in southeast corner of MRP.	Hydrogeologist, remedial technologist, regulators, site manager.	Groundwater levels will be converted to groundwater elevations at the two new piezometer locations; the piezometers will be surveyed to determine their x-y location, and the top of casing elevation tied to existing site datum. The two new wells and the existing/nearby wells will be used to develop a groundwater flow map during seasonal high conditions.
Soil Samples	Electrical Conductance (EC) - microsemens per centimeter	Soils testing (EC) results will be used to confirm or refute the elevated response from the 2012 geophysical survey; if the EC results are substantially higher than background it may prompt further soils characterization in these areas from a laboratory test method.	Remedial technologist, regulators, site manager.	A background location (such as west field) will be tested for EC and used as a comparative threshold level to assess EC levels in the area(s) of interest.
Vapor Concentration	Ammonia Vapor Concentration measured in ppm; vapor concentration measured from vapor probes in the potential source areas of interest.	Ammonia concentrations will be used to assess the potential source areas atop the southeast corner of MRP that were identified from the 2012 geophysical survey.	Remedial technologist, regulators, site manager.	If relatively high vapor concentrations of ammonia are detected, this may support that source materials (such as Flux Bar) are still present atop the MRP and help with future management deicsions regarding source removals. If relatively low concentrations are detected, these would support that source material (in the form of Flux Bar) is not present, and these results would also guide management decisions.

Table 2

Measurement Performance Criteria (onsite field measurements)

L-Bar Site - Work Plan for Supplemental Site Investigation

Medium	Parameter	Method	Units	Accuracy	Detection Limits	Comments
Groundwater	Groundwater Elevation	Manual depth to water measurement from water-level meter; measured from known reference point (below top of PVC casing)	Feet (ft)	+/- 0.01 foot	Need a water-level indicator that is capable of measurement to at least 50 ft btc (to measure both shallow levels and also atop the MRP for depths of up to 30 ft btc)	Groundwater levels will be measured in the two new piezometers, and nearby existing monitoring wells to construct a groundwater flow map (P-12, P-13, SA-10, SA-11, SA-14, P-09).
Soil Samples	Electrical Conductance (EC)	Grab samples collected in grid-pattern and tested from a hand-held conductivity meter (YSI 63 or equivalent); prepare moist past via one-part sample & five parts deionized water.	Microsemens per centimeter (uS/cm)	+/- 0.5 percent	0 to 200 mS/cm	Samples will be collected at ground surface (0 depth) and 6-inches on a grid pattern of 20-ft spacing. Refer to Appendix B.
Vapor Concentration	Ammonia Vapor Concentration	Drager Pump and Ammonia Colormetric Tube; vapors will be withdrawn from vapor probes with a small-diameter tubing connected to an air pump.	PPM	+/- 10 percent of the measurement range from 5 to 700 ppm. See spec sheet in Appendix C.	5 to 700 ppm	Ammonia vapors will be measured from vapor probes installed atop the MRP in focused areas of interest.

Table 3

Sample Types, Locations, and Frequency

L-Bar Site - Work Plan for Supplemental Site Investigation

Sampling Medium	Matrix	Monitoring Location (sample ID)	Location[1]		Sampling Frequency	Comments
			Northing	Easting		
Groundwater (Piezometer)	Groundwater Level/Elevation	PZ-01-EP	N 48 15'13.20"	W 117 43'02.18"	Once	Piezometers & existing wells will be sampled same day in spring
		PZ-02-SP	N 48 15'14.95"	W 117 43'00.31"	Once	Piezometers & existing wells will be sampled same day in spring
Soil Samples	Electrical Conductance (EC)	Numerous[2]	TBD	TBD	Once	Soil samples collected as described in Section 2 & shown in Appendix B.
Vapor Probes/Vapor Sampling	Ammonia Vapor Concentration	VP-A-1	N 48 15'14.4243"	W 117 43'05.4435"	Once	Vapor probe 1 in Area A location atop MRP
		VP-A-2	N 48 15'14.6223"	W 117 43'05.4611"	Once	Vapor probe 2 in Area A location atop MRP
		VP-A-3	N 48 15'14.4668"	W 117 43'05.1895"	Once	Vapor probe 3 in Area A location atop MRP
		VP-A-4	N 48 15'14.2776"	W 117 43'05.4968"	Once	Vapor probe 4 in Area A location atop MRP
		VP-A-5	N 48 15'14.3526"	W 117 43'05.7141"	Once	Vapor probe 5 in Area A location atop MRP
		VP-B-1	N 48 15'14.5185"	W 117 43'04.1807"	Once	Vapor probe 1 in Area B location atop MRP
		VP-B-2	N 48 15'14.6179"	W 117 43'04.2042"	Once	Vapor probe 2 in Area B location atop MRP
		VP-B-3	N 48 15'14.5145"	W 117 43'04.0330"	Once	Vapor probe 3 in Area B location atop MRP
		VP-B-4	N 48 15'14.4092"	W 117 43'04.1577"	Once	Vapor probe 4 in Area B location atop MRP
		VP-B-5	N 48 15'14.4921"	W 117 43'04.3006"	Once	Vapor probe 5 in Area B location atop MRP
		VP-C-1	N 48 15'15.0763"	W 117 43'03.2595"	Once	Vapor probe 1 in Area C location atop MRP
		VP-C-2	N 48 15'15.1749"	W 117 43'03.2535"	Once	Vapor probe 2 in Area C location atop MRP
		VP-C-3	N 48 15'15.0514"	W 117 43'03.0687"	Once	Vapor probe 3 in Area C location atop MRP
		VP-C-4	N 48 15'14.9572"	W 117 43'03.2371"	Once	Vapor probe 4 in Area C location atop MRP
		VP-C-5	N 48 15'15.0803"	W 117 43'03.4071"	Once	Vapor probe 5 in Area C location atop MRP

Notes:

1. Coordinates are pre-investigation/installation and are provided to help field team locate the planned investigation/installation locations; as-built coordinates will be provided in the data report after installation.
2. Soil sample coordinates determined in-situ based on perimeter sampling areas and establishment of sampling grid as shown in Appendix B.

Figures

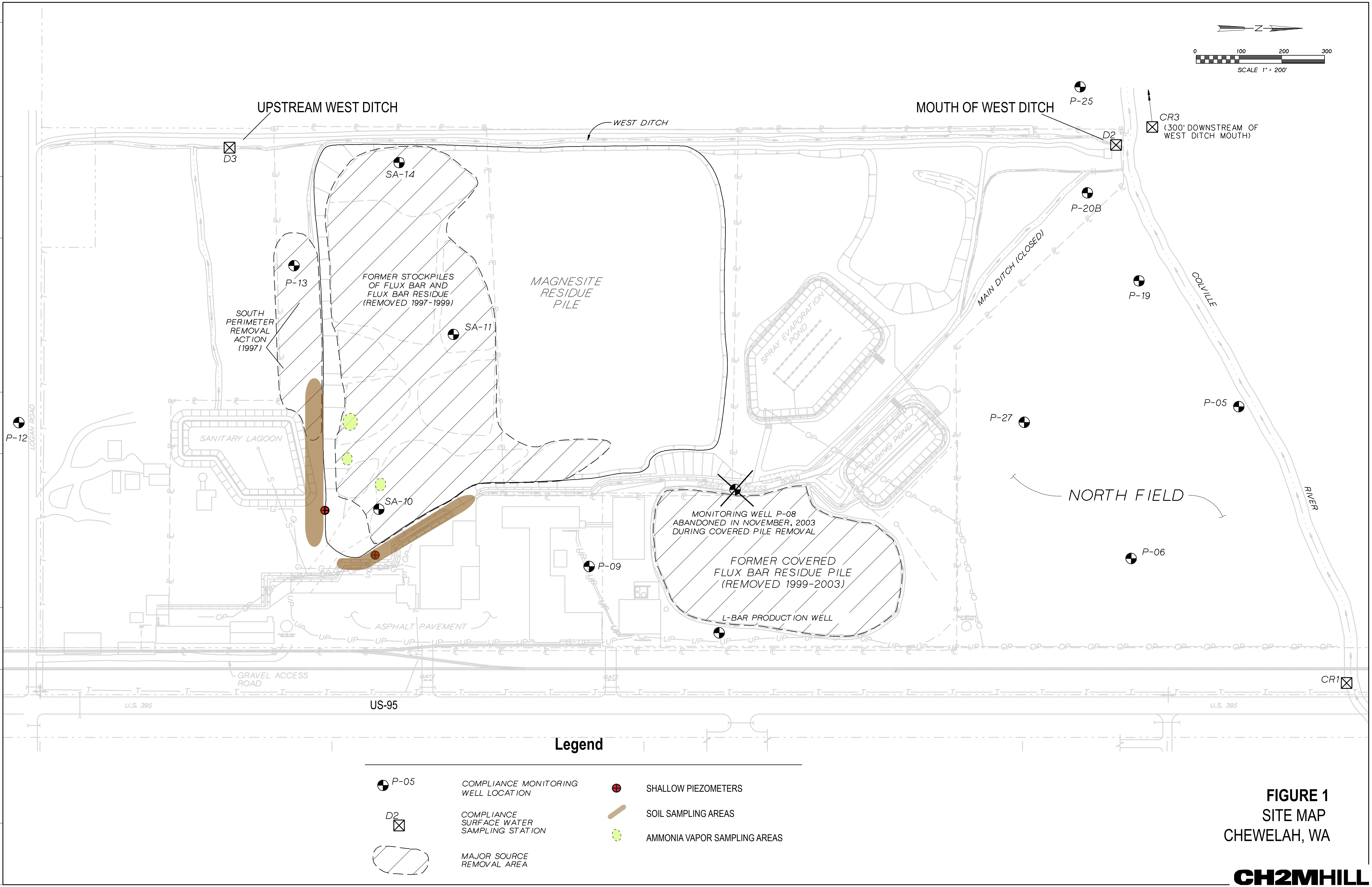
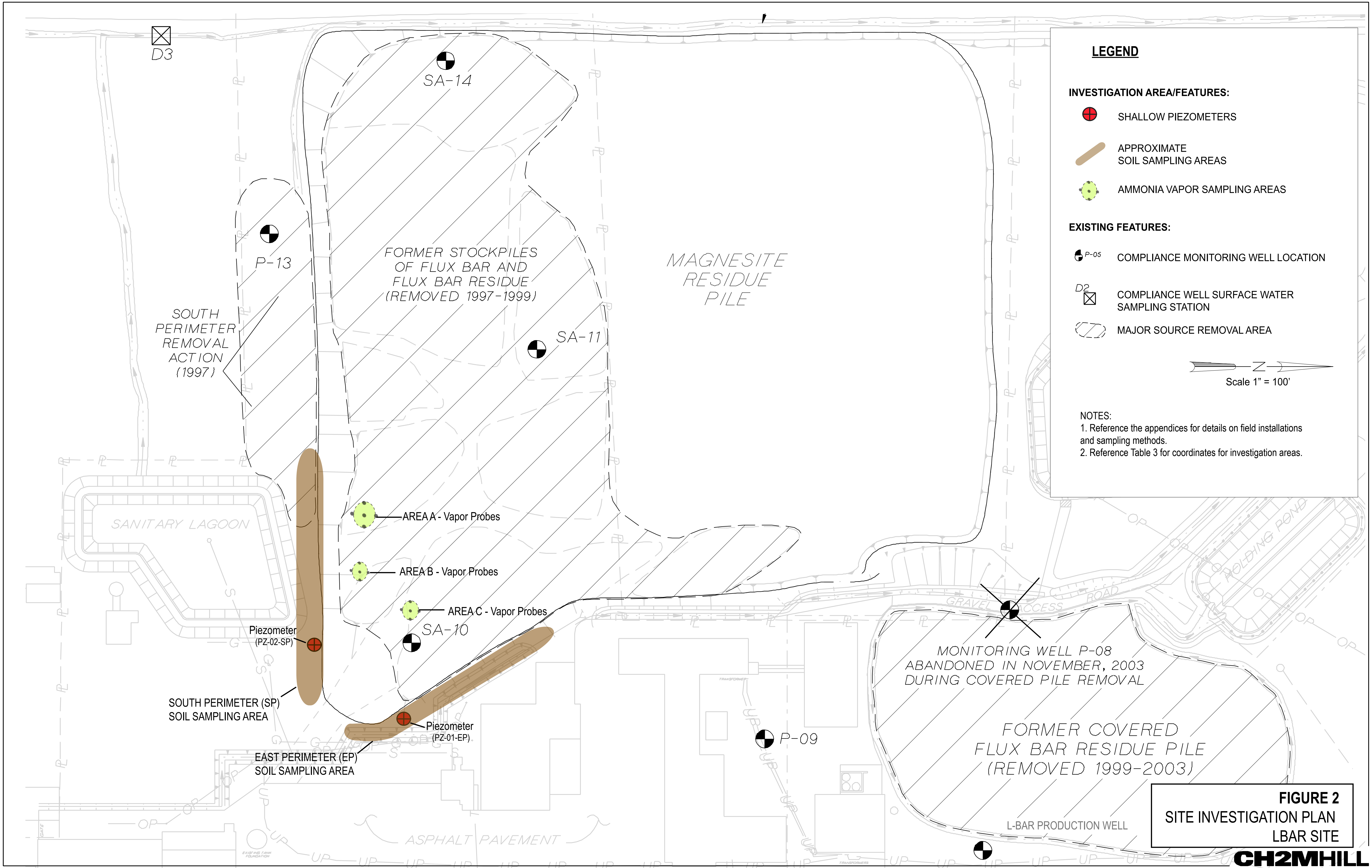


FIGURE 1
SITE MAP
CHEWELAH, WA

CH2MHILL

lb:E10M0001.dgn 1-25,28-41,43-45,47-62,64
lb:ANSI_BR.dgn 3-64

\bbh\proj\AlcoaInc\353079\CAD\Drawings\p10d054fAA_Gen.dgn 27-FEB-2007



NOTES:
1. Reference the appendices for details on field installations and sampling methods.
2. Reference Table 3 for coordinates for investigation areas.

FIGURE 2
SITE INVESTIGATION PLAN
LBAR SITE

CH2MHILL

Appendix A

Data Quality Objectives for Site Investigation at L-Bar

Appendix A

Data Quality Objectives for Site Investigation at L-Bar

Guidance on the systematic planning process is described in the U.S. Environmental Protection Agency's *Guidance on Systematic Planning Using the Data Quality Objective Process, EPA QA/G-4* (EPA, 2006). In accordance with the guidance, key elements of systematic planning include the following steps:

1 **Statement of the Problem**
  1.1 Background
  1.2 Description of the Problem
  1.3 Conceptual Site Model of the Potential Hazard
  1.4 Planning Team
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The following information is organized according to the steps listed above and provides detail regarding the data quality objectives (DQOs) to guide the site investigation work at the L-Bar site.

1 Statement of the Problem

Step 1 includes the background information; describes the problem; the conceptual site model of the environmental hazard; the planning team; and the available resources, constraints, and deadlines.

1.1 Background

The L-Bar site is located approximately 2 miles south of Chewelah, Washington, on the west side of US Highway 395 (shown in Figure 1). The site has extensive site history and is currently in the post-remediation monitoring phase (compliance monitoring) of groundwater remediation under the Model Toxics Control Act (MTCA) Agreed Order program as administered by the Washington State Department of Ecology (Ecology). Ecology's recent *Periodic Site Review for L-Bar Site* (Ecology, 2012) provides a thorough and current summary of site details such as the site history, regulatory background, nature and extent of contamination, interim-actions, remedial actions, environmental conditions in surface water and groundwater, and post-remediation monitoring. This information is not reiterated in the DQOs, but was considered as part of the technical planning process in support of conducting the 2012 geophysical survey and the follow-on investigation approach (herein).

Recent observations as described in the *L-Bar Site Compliance Monitoring Program Data Evaluation Report, 1996-2010* (CH2M HILL, 2011) identified a focused area of interest in the southeast corner of the Magnesite Residue Pile (MRP) because of the groundwater monitoring results from Well SA-10. One of the conclusions from this data report, in contrast to the characteristics of other compliance wells throughout the site, noted increasing concentrations in shallow groundwater at Well SA-10 for the primary contaminants of concern (chloride and ammonia). For example, chloride concentrations have increased from levels less than 2,000 milligrams per liter (mg/L) in 1999, to recent concentrations in excess of 10,000 mg/L in 2010. Similar increases for ammonia have been observed with concentrations below 400 mg/L in 1999, increasing to recent concentrations of approximately 1,000 mg/L in 2010. These increasing concentrations are in contrast to the characteristics observed in wells adjacent to SA-10 installed atop the MRP further to the west (Wells SA-11 and SA-14), which show a characteristic spike in the late 1990s coincident with source removal actions, and subsequent significant declines during the post-remedial action monitoring period (following source removal actions). However, the elevated concentrations and increasing trends at Well SA-10 led to the hypothesis that potential residual source materials within the MRP may be the cause. The significant increase in ammonia at SA-10 may suggest a flux bar residue source rather than residual flux bar leachate that was flushed out of the MRP, because ammonia in the unsaturated MRP is more likely to oxidize to nitrate.

1.2 Description of the Problem

A focused geophysical survey was conducted in June 2012 and the results were described in the *Data Summary Report for the Supplemental Geophysical Survey Work Conducted at the L-Bar Site near Chewelah, Washington* (hereafter referred to as the 2012 geophysical survey) (CH2M HILL, 2012a). The 2012 geophysical survey was completed in accordance with an Ecology-approved work plan and achieved the intended objectives to further characterize the site conditions in the focused area of interest near Well SA-10. It is believed that the 2012 geophysical survey results identified a candidate area(s) of interest just southwest of Well SA-10 atop the MRP, which most likely represents residual flux bar (FB) or flux bar residue (FBR) source material within the MRP that was not fully identified and/or removed during prior source removal actions. If this is the case, these residual source materials are likely causing the increasing concentration trends in shallow groundwater for indicator constituents at Well SA-10.

The following data needs have been identified to compliment the 2012 geophysical survey results, to fill data gaps, and to potentially move forward in the most cost-effective manner to properly identify and subsequently mitigate the increasing concentration levels at Well SA-10. The following list identifies the data gaps/uncertainty, along with the supplemental site investigation activities that will be conducted to address each of data gaps/uncertainty:

1. **Groundwater Flow Direction.** Given the limited number of groundwater monitoring points near Well SA-10, there is some uncertainty in the groundwater flow direction and/or hydraulic relationship between Well SA-10 and the nearby Main Ditch, which was closed in 2003 by backfilling with coarse-grained fill materials. To gain a better understanding of groundwater flow direction of the shallow water bearing unit (SWBU) in this area, two additional (temporary) piezometers will be installed near Well SA-10: one located to the east near the former Main Ditch, and another due south Well SA-10 just off of the MRP. Two new groundwater monitoring points, along with existing Well SA-10 and adjacent wells are believed to be sufficient to characterize the direction of groundwater flow in this area. Because the depth to groundwater in these areas is estimated at roughly 2 feet below ground surface (bgs), installation of two new piezometers with a hand-auger is considered to be a cost-effective option in support of this data gap.
2. **Soils Testing Along the Southeast Perimeter of MRP.** The 2012 geophysical survey results identified areas along the southeast toe of the MRP (east perimeter [EP] and south perimeter [SP] in the 2012 geophysical survey report) as “conductive soils and/or metallic-like response.” As described in the data report, the elevated EM31 conductivity response in these areas could be enhanced because of clay-rich soils and/or shallow groundwater. However, the source of the elevated EM31 in-phase response (metallic-like response) in the EP and SP areas is not readily known and cannot be determined from the geophysical data alone. To better understand what the near-surface soils/materials are in these areas, it is recommended that grab samples be tested using electrical conductance (EC) as a cost-effective indicator constituent. The general approach will be to establish a sampling grids to determine sampling locations within the SP and EP areas, and collect grab samples of near-surface soils/materials (either via shovel or hand trowel depths of 0 to 6 inches below existing grade), and perform in situ testing of EC on the samples after they have been prepared into an amended paste (for example, 10 grams of sample mixed with 50 milliliters of deionized water). EC results will be quantified in situ from a typical hand-held conductivity meter (for example. a YSI Model 63 which is routinely used for groundwater sampling). If the results from the EC field testing methods are significantly elevated, supplemental sampling and soils testing from a laboratory to quantify chloride and/or ammonia concentrations may be performed, if needed.
3. **Vapor Sampling atop the MRP.** Three areas atop the MRP just southeast of Well SA-10 were interpreted from the 2012 geophysical survey as locations in which former FB or FBR may be present within the MRP at relatively shallow depths (less than 10 feet bgs). In an attempt to further understand these potential source areas and/or whether these areas represent true FB or residual FBR, shallow vapor probes will be installed near the areas of interest to conduct in situ vapor sampling within the MRP. Vapor sampling will be conducted in a cost-effective manner by using ammonia as the indicator vapor. Vapor sampling probes will be installed to shallow depths of roughly 3 to 5 feet bgs in the MRP areas of interest (such as areas A, B, and C as identified from the 2012 geophysical survey). Vapor sampling will be conducted at each probe by exerting a vacuum (via small-diameter sampling tube) to withdraw the vapors, and quantifying the ammonia vapor concentrations by using a simple field-screening meter (for example, a Draeger pump with Colorimetric detection tubes). If significantly elevated ammonia vapors are identified, this may be supportive of the presence of FB or FBR materials, which could help to guide and optimize potential future removal actions.

These three activities are considered the data needs and equivalent to a “description of the problem” within the context of the DQO framework. These data needs guide the DQO process in subsequent steps.

1.3 Conceptual Site Model of the Potential Hazard

The approach for the focused 2012 geophysical survey work and the follow-on work in 2013 (herein) rely upon a basic understanding of several key site features which include the following:

- Characteristics of the MRP and source materials
- Source removal actions and source areas
- Groundwater flow direction (most notably near Well SA-10)

Details of these three items are summarized in the following text.

1.3.1 Magnesite Residue Pile and Source Materials

This section provides an important distinction between the MRP (existing stockpile) and the former source materials (which have since been removed, as described in the following text).

The MRP is an abovegrade stockpile that sits roughly 25 to 30 feet high atop the native alluvium fine-grained soils as part of the Colville River valley floodplain. The MRP covers nearly 17 acres of the southwest quadrant of the L-Bar property. The former property owner, Northwest Magnesite Company, originally processed and stockpiled vast quantities of magnesite ore at the site (which constitutes the present-day MRP, as illustrated in Figure 1). As described in the *L-Bar Site Feasibility Study Report* (CH2M HILL, 1999), the contaminants of primary concern related to the MRP materials include sulfate, and five trace metals (arsenic, boron, cadmium, copper, and selenium).

Magnesite ore processing was discontinued in 1967, and the facilities were later converted in the mid-1970s to recover magnesium from a magnesium processing byproduct commonly referred to as FB. FB was produced at the Northwest Alloys magnesium plant near Addy, Washington, and sold to the site owners. From 1986 to 1991, the site was owned and operated by L-Bar Products, Inc., a subsidiary of Reserve Oil and Minerals Corporation. L-Bar processed the FB blocks by crushing the raw flux bars and screening the crushed materials to recover metallic magnesium granules. The remaining nonmetallic crushed and screened material is called flux bar residue (FBR).

As described in the *L-Bar Site Feasibility Study Report* (CH2M HILL, 1999), the contaminants of primary concern related to FB/FBR include four inorganic constituents (chloride, ammonia, total dissolved solids [TDS]), and nitrate) and three metals (barium, manganese, and iron). Elevated levels of chloride, ammonia, and conductance in shallow groundwater are most notably correlated with the leaching of FB/FBR source materials. Approximately 50,000 tons of FB or FBR were stockpiled at the site from 1977 to 1983 and have since been removed. Materials stored on top of the MRP were predominantly weathered FB, whereas the materials located in the Covered Pile area (shown in Figure 1) were predominantly FBR.

In summary, the composition of the MRP materials were characterized during the remedial investigation effort and were demonstrated to not contribute elevated levels for the contaminants of primary concern that are associated with the leaching with FB/FBR materials (most notably chloride and ammoniaas the primary indicator constituents). Thus, current impacts observed at Well SA-10 for chloride and ammonia are not attributed to potential influence from the existing MRP materials; but rather, appear to be caused from residual FB/FBR that was not fully identified (nor removed) during the prior source removal actions (as described in the following text).

1.3.2 Source Removal Actions and Removal Areas

In cooperation with Ecology, the Selected Remedy for the site was source removal (of the FB/FBR materials) with natural attenuation and monitoring. Details of the feasibility study are detailed in *L-Bar Cleanup Levels Development and Feasibility Study Report* (CH2M HILL, 1999). Source removal activities were conducted from approximately 1997 to 2004, and the activities were guided by the Ecology-approved *L-Bar Material Removal and Compliance Monitoring Work Plan* (CH2M HILL, 2001).

The primary remedial actions/source removal activities included the following (areas shown in Figure 1):

- In 1997, removal of source materials consisting of FB and FBR in the area shown as the South Perimeter Removal Action.
- From 1997 to 1999, removal of source materials consisting of FB and FBR from atop the MRP.
- From 2000 to 2004, removal of the covered FBR pile (referred to as the Covered Pile) and materials stored in onsite plant buildings.
- In 2003, closure of the Main Ditch and removal of the high density polyethylene barrier wall along the western and northern perimeter of the Covered Pile.

Details of these and other remedial actions were documented in two previous reports: the *Interim Action Source Removal Summary Report – Magnesite Residue Pile, L-Bar Site* (CH2M HILL, 2001b), and the *Source Removal Summary Report – Covered Pile and Plant Buildings, L-Bar Site* (CH2M HILL, 2004). Noteworthy details of these former source removal actions in the vicinity of the MRP [per the aforementioned reports] are described in the 2012 geophysical survey report and are not reiterated herein.

1.3.3 Groundwater Flow Direction

The uppermost groundwater-bearing zone at the site has been characterized as the SWBU, which is a relatively thin unconfined water-bearing unit that is generally 1 to 3 feet thick and typically occurs at depths of 2 to 5 feet bgs. The SWBU consists of glaciolacustrine fine-grained sediments which have been characterized as very stiff to hard clayey silt with occasional lenses of silty sand and intermittent organic-rich layers. The SWBU is underlain by a clay aquiclude, which separates the uppermost SWBU from the deeper aquifers in the Colville River valley. In addition, an upward vertical hydraulic gradient from the deeper aquifer(s) to the upper SWBU also precludes any vertical migration from the SWBU.

Groundwater in the SWBU generally flows north-northwest toward the Colville River, which forms the northern property and hydraulic boundary of the site. Near the southern end of the MRP, the inferred groundwater elevation contours yield a radial pattern based on the groundwater levels from Wells P-12, P-13, P-09, and the three SA wells. There is a possible groundwater divide near the southern end of the MRP. It is hypothesized that the apparent radial pattern of the groundwater flow in this area is likely caused by recharge through the MRP and discharge to the nearby West Ditch and the Main Ditch. This hydraulic interpretation suggests groundwater flow is to the northeast in the vicinity of Well SA-10, and to the west near the southwest corner of the MRP. Because of limited observation points, however, some uncertainty exists in the localized groundwater flow direction of the SWBU in the immediate vicinity of Well SA-10.

The water-quality trends and the groundwater flow direction in relation to Well SA-10 was (and is) one of the fundamental factors considered as part of the supplemental geophysical survey approach. The fundamental hypothesis for the focused investigation was that source materials may remain in areas up or cross-gradient from Well SA-10 in the unsaturated portions of the MRP. This assumption on groundwater flow/transport, coupled with the understanding of where former source materials were identified (as described above), suggests a relatively focused (limited) area of interest with respect to where potential residual source materials may be present to cause the elevated concentrations and increasing trends observed at Well SA-10.

1.4 Planning Team

Members of the planning team include Alcoa (including staff from Northwest Alloys), Alcoa's consultants (CH2M HILL), and Ecology. In cooperation with Alcoa, CH2M HILL is the technical lead to develop the draft and final site investigation work plan (herein), which will be reviewed and approved by Ecology. Ecology's site manager ensures that the site cleanup and post-remedy monitoring are conducted in accordance with the selected remedy under MTCA requirements.

1.5 Available Resources, Constraints, and Deadlines

Alcoa is the responsible entity and allocates resources under the MTCA Agreed Order program to ensure the cleanup actions and post-remedy monitoring are fulfilled. CH2M HILL is under contractual agreement with Alcoa to conduct the work as outlined in this work plan, and under the regulatory oversight of Ecology's site manager.

Constraints that may potentially complicate the planned site work may arise because the L-Bar property is owned by a third party (not Alcoa), and it is assumed that an access agreement with the property owner will be needed to conduct the field installations and associated sampling as described in this work plan. Alcoa has the rights to conduct post-remedy monitoring as needed under the Compliance Monitoring Program (CH2M HILL 2012); however, a site access agreement (modification) is needed to support the supplemental site investigation work (and potential source removal actions). Although this issue is not expected to be problematic, it is a potential constraint of which the team should be aware.

The field work and associated data report in this work plan are planned for completion in 2013. As mentioned previously, Ecology has authorized Alcoa to proceed with this work and to develop a work plan (herein) in their November 5, 2012 letter. Ecology's approval of this work plan will establish the schedule for when this work may be conducted, and when the results are reported (as described in subsequent sections).

2 Goal of the Study

Step 2 develops the goal of the study. The goal of the study is developed and quantified from the primary questions (Step 2.1) and related alternative actions (Step 2.2). Alternative actions are expected as a result of site investigation results derived from execution of the data collection as described in this work plan.

2.1 Primary Study Questions

Primary study questions by medium have been developed based on a description of the problem in Section 1.2. They are as follows:

- **Study Question 1 (SQ1).** What is the groundwater flow direction in the immediate vicinity of Well SA-10 as enhanced/refined from supplemental groundwater levels (converted to groundwater elevations) obtained from the two new piezometers?
- **Study Question 2 (SQ2).** What is the EC of near-surface soils (0 to 6 inches bgs) in focused areas along the southeastern toe of the MRP?
- **Study Question 3 (SQ3).** What is the vapor concentration of ammonia at the new vapor sampling probes installed in key areas of interest in the southeastern corner of the MRP near Well SA-10?

Table 1 summarizes the data needs and data uses for each of these study questions. Figure 1 illustrates the data collection areas related to installation of temporary piezometers (SQ1), testing of EC in shallow soils (SQ2), and vapor sampling (SQ3).

2.2 Potential Alternative Actions

Potential alternative actions for each of the study questions are described in the following text.

2.2.1 SQ1—Groundwater Flow Direction

No formal alternative actions are expected from the supplemental groundwater level/elevation data. Groundwater elevations from the two new piezometers will be used to refine the understanding of groundwater flow direction in the vicinity of Well SA-10. Groundwater elevation data alone, however, are not anticipated to drive substantive management decisions regarding the need for supplemental source removal actions.

2.2.2 SQ2—Soils Testing along the SE Toe of MRP

If the EC of these areas is relatively low, then this would suggest that the 2012 geophysical results were indeed anomalous and these conditions would not warrant/suggest that further investigation or source removal actions are needed in these areas. If the EC of these areas is relatively high, this may confirm/substantiate that the 2012 geophysical results were valid in these areas and prompt more rigorous investigation (or soils testing from laboratory methods) in these areas to determine if they could represent source materials (though not expected given the site history).

Note that the relative EC levels will rely upon testing of soils in the west field (or some onsite area inferred to be unimpacted from FB/FBR source materials) and consider these materials as near neutral or background. For example, if the EC values obtained at the toe areas are found significantly above background levels, then these conditions would be considered relatively high. No set threshold level exists for the absolute characterization of EC values. The field-measured values in the area of interest will have to be qualitatively compared using best professional judgment to the background levels.

2.2.3 SQ3—Ammonia Vapors atop the MRP Near Well SA-10

If the ammonia vapors are relatively high, then this would suggest or support the presence of source material within the MRP (for example, FB), and be supportive of management decisions to proceed with supplemental source removal actions (as delineated/refined from the 2012 geophysical survey and the configuration of the vapor sampling probes). If the ammonia vapors are relatively low (or nondetect), then this would suggest source materials (for example, FB) are not present in these areas, and help to exclude these as candidate locations for further investigation/or source removal actions.

Note that ammonia vapors can be detected from odors encountered during routine groundwater sampling (via the excess purge water during routine sampling atop the MRP at Wells SA-10, -11, and -14). As such, it is anticipated that screening-level vapor sampling from Draeger Colorimetric tubes is a reasonable approach with accuracy of ±10 percent in the range of 5 to 700 parts per million (ppm).

Similar to the approach for EC, the field testing methods and testing of ammonia vapor concentration from screening-level methods is expected to provide a relative response of vapor concentration to assess whether source materials are, or are not believed to be present in the areas identified from the 2012 geophysical survey. As such, interpretation of the vapor concentration data will rely upon best professional judgment and consider the existing CSM to help with management decisions regarding the need for additional data and/or supplemental source removal actions in these areas.

3 Information Inputs

Step 3 summarizes the types/sources of information, basis of the performance criteria, and the field methods.

3.1 Types and Sources of Information

Table 1 provides a summary of the data needs/uses to answer the primary study questions for the respective data collection types. Figure 1 illustrates the locations of where these data will be obtained.

3.2 Measurement Performance Objectives

Table 2 summarizes the measurement performance objectives for the respective data collection types.

3.3 Field Installations and Sampling Methods

Data collection and sampling will be performed in situ (in the field) for each of the three primary data collection activities as described in the following text.

3.3.1 SQ1—Groundwater Flow Direction (Piezometer Installation and Measurement of Groundwater Levels)

Figure 2 shows the location of the two piezometers, which will be installed to shallow depths (less than 8 feet bgs). Appendix B provides a construction plan that shows a typical piezometer configuration. A stainless steel hand auger that creates a 5-inch-diameter borehole will be used to advance and construct a 1-inch-diameter, Schedule 40 polyvinyl chloride (PVC) piezometer. Piezometers will be installed to approximately 2 feet below the zone of saturation (water table)—anticipated to be no greater than 2 or 3 feet bgs at each location (thus, total depth not expected to exceed 5 feet bgs in each location). The lowermost 2 feet of the PVC casing assembly will be perforated (either by a hand drill or hack saw) to constitute the piezometer screen adjacent to the zone of saturation. The annular space adjacent to the screen zone will be backfilled with 10x20 factory-packaged silica sand to a level of 1 foot above the top of the screen. The remaining annular space will be backfilled with bentonite chips and hydrated to constitute the well seal. The shallow depth of these temporary piezometers (not to exceed 8 feet bgs) precludes the ability to fully satisfy the well construction standards of Chapter 173-160-400 of the WAC, *General Requirements for Resource Protection Wells*. This scenario is anticipated to require a variance and approval by Ecology to construct temporary piezometers in this manner.

Once the piezometers are installed they will be developed using a small-diameter bailer to agitate the screen zone and purge water to enhance the hydraulic connection and to facilitate a representative groundwater level reading.

Static groundwater levels will be obtained no earlier than 24 hours after installation to allow the saturated zone to fully recover after installation and development (described above). Static groundwater levels will be measured with a hand-held electronic sounder from the top of PVC casing (fixed datum) and recorded to the nearest 0.01 foot. The top of PVC will be surveyed with an engineering rod and level using known reference point (such as the top of Well P-13 or Well SA-10); x-y location coordinates will be obtained with hand-held GPS unit, coupled with field measurements from adjacent nearby features. Static levels (converted to groundwater elevation) will be obtained from the two new piezometers, and existing nearby wells (P-12, P-13, SA-10, SA-11, SA-14, and P-09) to obtain a representative snapshot of groundwater elevation to construct a representative groundwater flow map.

At the conclusion of the project and in cooperation with Ecology, the temporary piezometers will be abandoned (decommissioned) in accordance with methods in Chapter 173-160-460 of the WAC (*Decomissioning Process for Resource Protection Wells*).

3.3.2 SQ2—Soil Sampling and Electrical Conductance Measurements

Soil sampling will be conducted in two focused areas along the southeast toe of the MRP, along with a selected background location in the west field (shown in Figure 2). A sampling grid will be established with grid spacing of approximately 20 feet in each of the two areas (delineated as EP and SP). This type of grid spacing is considered reasonable to yield a sufficient number of grab samples in each area to determine if these locations are (or are not) elevated above background levels. Appendix B provides a typical schematic of the soil sampling grid to be established at each of the two sampling areas.

At each sampling location, a grab sample will be collected at ground surface (0 depth) and at approximately 6 inches bgs. Grab samples will be collected from each sampling location from either a stainless steel spoon or hand trowel. Grab samples will be prepared into a homogenized mixture of one part sample and an equal part deionized water to create a moist paste. The sample (paste) will then be transferred into a sampling beaker. A hand-held meter (YSI 63 or equivalent) will be used to measure the EC, and the values recorded in either micro Siemens per second (low-range), or milli Siemens per second (high-range) (final readings will be reported in consistent units). Each sampling location will be recorded as a unique sampling location with depth (such as EC1-0, which would be unique sample “1” at zero depth; or EC1-6 which would be location 1 at 6 inches bgs). Coordinates for each grab sample location will be obtained from a hand-held GPS unit capable of sub-meter accuracy.

Between successive samples/depths, the sampling tools, sampling container(s), and EC meter will be cleaned with Alconox wash and rinsed with de-ionized water. The EC meter shall be calibrated in accordance with the manufacturer specifications at the start of each day of use and spot-checked with known standards routinely during the sampling effort (at least twice per day).

3.3.3 SQ3—Installation of Vapor Probes and Vapor Sampling

Figure 2 shows the location of the shallow vapor sampling probes, which will be installed in the suspected source areas of the MRP. At a minimum, five vapor probes will be installed in each of three areas atop the MRP in the areas shown/approximated. Locations will target the approximate center of each of three locations, and four additional vapor sampling probes around the perimeter margin of each feature (thus, one at center, and another four around the perimeter for each of three locations). If surplus materials and sufficient time are available, supplemental vapor sampling points (in excess of the 15 planned) will be installed around the westernmost area as it represents the largest and most likely source area.

Appendix B provides a typical schematic of the vapor sampling probes. Similar to the temporary piezometers, the vapor probes will be installed with a stainless steel hand auger to facilitate installation of 1-inch-diameter PVC vapor probe. Installation depths are expected to be approximately 5 feet bgs at each location (but may require slight adjustment depending on ease or difficulty of auger advancement). The lower 2 feet of the PVC will be perforated (either by a hand-drill or hack-saw) to constitute the vapor sampling screen interval which will target approximately 5 feet bgs in the vadose zone of the existing MRP. The annular space adjacent to the screen zone will be backfilled with 10x20 factory-packaged silica sand to a level 1 foot above the top of the screen. The remaining annular space will be back-filled with bentonite chips and hydrated to constitute the surface seal to enhance representativeness of vapor sampling. The shallow depth of these vapor probes in the MRP (typically 5 feet bgs) is well above the depth to shallow groundwater, and thus, it is not deemed necessary to fully satisfy the well construction standards of Chapter 173-160-400 of the WAC, *General Requirements for Resource Protection Wells*.

Once the vapor probes are installed, each will be purged with an air pump connected to 0.25-inch poly tubing set to the screen interval (to withdraw any stagnant air entrained during probe installation). This exercise is considered similar to well development in that it is intending to enhance the representativeness of vapors for subsequent vapor sampling. After each probe has been purged, an end cap will be installed to seal the probe until sampling is performed.

Appendix C provides sampling protocol and methods for using the Draeger Pump and collecting the vapor concentrations for ammonia. Vapor sampling will be performed at each vapor probe no sooner than 12 hours after installation and vapor purging (described above). An air pump will be connected to 0.25-inch poly tubing set to the screen depth and used to evacuate vapors into a sampling chamber (basically an enclosed container). Ammonia concentrations will be measured in the field using a Colorimetric indicator tube via Draeger pump that withdraws the vapor sample from the sampling chamber. This method will yield ammonia concentrations (in the range of 5 to 700 ppm with accuracy of 10 percent (+/-). Values less than 5 would be considered nondetect. Values at the higher end of the scale reading 700 ppm would be considered “greater-than 700 ppm.”

At the conclusion of the project and in cooperation with Ecology, the vapor probes will be abandoned (decommissioned) in accordance with methods per Chapter 173-160-460 of the WAC, *Decommissioning Process for Resource Protection Wells*.

4 Boundaries of the Study Area

Step 4 defines the target population (that is, monitoring media), spatial and temporal boundaries, and the scale of inference.

4.1 Target Population

The target population refers to the monitoring media (or commonly called out as the "matrix" in the data needs tables). The target population is linked to the data needs per the study questions in Step 2.1 of the DQO planning process. Thus, the target population in focused areas near southeast corner of MRP includes (1) shallow groundwater (groundwater levels converted to groundwater elevations), (2) surface and shallow soil samples (tested for EC), and (3) vapor concentrations (tested for ammonia).

4.2 Spatial and Temporal Boundaries

The spatial and temporal boundaries of the study area are defined in this section.

4.2.1 Spatial Boundaries

Figure 1 illustrates the spatial boundaries for the study area. Figures 1 and 2 illustrate the target population to answer the primary study questions.

Table 3 summarize the (anticipated) monitoring locations and sampling IDs in support of the data needs and the related study questions (SQ1, SQ2, and SQ3). The actual (as-built) monitoring locations will be established and finalized after the field installations and sampling are performed; the location coordinates will be presented in the data report.

4.2.2 Temporal Boundaries

The field work and sampling as outlined in the work plan are expected to be completed in late spring 2013, and the results reported to the project team within 6 weeks of completing the field work (targeting early summer 2013).

The duration of field work and related sampling in support of the study questions is expected to require five (5) full working days (at least one week). Once the work plan is finalized and approved by Ecology, the field work will be planned and executed accordingly.

4.3 Scale of Inference

The scale of inference as defined in the DQO guidance (EPA, 2006) is the smallest unit of geographic area, volume, or time over which the data will be collected, analyzed, aggregated, and interpreted to produce an estimate to support a management decision.

As noted above, the field work and sampling are planned to occur over a full week (5 working days) in late spring 2013. Once completed, the data will be analyzed, compiled, and reported to the project team in early summer 2013. The totality of the CSM, the 2012 geophysical survey, and the supplemental site investigation (herein) will be used to support future management decisions regarding the need for supplemental source removal actions.

5 Analytical Approach

Step 5 develops the analytical approach that describes how the team analyzes the results to support management decisions. The analytical approach relies upon the population parameter, action levels, analytical methods (for example, calculations or how data are pooled, if needed), and the decision rules.

5.1 Population Parameter

The population parameter is the measured/sampled variable (or calculated metric) that is the basis in which to support inferences about the target population and guide management decisions.

The following table summarizes the study questions/data needs and population parameter

Study Question/Data Needs:	Population Parameter:
SQ1—Groundwater Levels.	**Groundwater elevation (feet).** Field-measured groundwater levels, measured in feet below top of casing, will be converted to groundwater elevation. Two new piezometers installed along southeast toe of MRP. Locations will be surveyed after installation.
SQ2—Soils Testing (EC).	**EC in micro Siemen per centimeter (µS/cm).** Field-measured concentrations obtained via soil-paste mixture from hand-held conductivity probe. Samples obtained from 0 and 6-inch depths via sampling grids in the EP and SP areas. Locations will be surveyed after sampling.
SQ3—Vapor Concentration (ammonia).	**Ammonia vapor concentration (ppm).** Vapors measured from hand-held Draeger pump using Colorimetric tubes to yield ammonia concentrations in the range of 5 to 700 ppm. Well points installed for vapor sampling in focused areas atop MRP to southeast of well SA-10. Locations will be surveyed after installation.

5.2 Action Levels

Formalized action levels (for example, absolute cleanup threshold levels) are not applicable for this study.

The data obtained from this study will be used in a qualitative manner to support management decisions regarding the presence and/or location of suspect source materials within the MRP.

5.3 Analytical Approach

Data obtained for this study as described in the work plan will be field-measured data and are not derived from analytical testing methods. The following information describes how the data will be evaluated and reported within the context of the study objectives.

SQ1—Groundwater Levels/Elevations. Groundwater levels from the two new piezometers, along with measurements from nearby wells (P-12, P-13, SA-10, SA-11, SA-14, and P-09) will be used to construct a groundwater flow map in the area of interest. A snap-shot of groundwater levels obtained from these locations during spring 2013 will be considered representative of seasonal high elevations.

SQ2—Soils EC Testing. EC results will be tabulated in spreadsheet form. EC results from the sampling grids in the EP and SP areas will be compared to the background levels. Sampling locations (grids) will be plotted on a site map to illustrate the sampling sites; areas above background (if necessary) will be annotated/highlighted in the tables and shown on the site map.

SQ3—Vapor Sampling for Ammonia atop MRP. Vapor concentrations for ammonia will be tabulated for each sampling point (vapor probe) and reported in ppm. Sampling locations (vapor probes) will be plotted on a site map to illustrate the spatial location of sampling results. Results will be evaluated in a relative sense to determine which locations are most elevated.

5.4 Decision Rules and Alternative Outcomes

Decision rules and alternative outcomes are the same as those described in Step 2.2 (see Section 2.2).

6 Performance Criteria

Step 6 develops the performance criteria, which are quantified by the measurement performance objectives, sampling and analysis methods, and quality control.

6.1 Measurement Performance Objectives

The measurement performance objectives need to be compatible with and support the study objectives and data needs as established in Step 2.

Table 2 summarize the measurement performance objectives for the respective data collection types.

6.2 Sampling and Analysis Methods

Field and analytical test methods need to be selected to generate data of appropriate and known quality in alignment with the study objectives and data needs as summarized in Step 2.

Table 2 summarize the sampling methods for the respective data collection types. Table 3 summarized the (anticipated) sampling locations; the actual (as built) locations will be reported following the field investigation.

Appendix B provides a construction plan which shows the piezometer design, soil sampling grids, and vapor probe detail. Appendix C provides details on sampling with the Draeger pump using ammonia Colorimetric tubes to quantify vapor concentration.

6.3 Quality Control

Quality control (QC) methods and samples will be collected to ensure that the data are of known and appropriate quality to support the study objectives.

6.3.1 SQ1—Groundwater Levels/Elevations

After the two new piezometers are installed, the reference point for the two new piezometers will be established at the north-facing rim of the PVC, and tied to existing plant coordinates using an engineering level and rod that is graduated in hundredths of a foot. The final datum will be triple-checked with both field representatives, and compared to existing datum for accuracy (for example, the top of PVC at Well P-13). A hand-held GPS unit with sub-meter accuracy will be used to develop x-y coordinates and converted to NAD83 to support in development of the updated site map (showing x-y location of the two new wells).

Groundwater levels will be measured to the nearest hundredth of a foot using a hand-held water-level meter with acoustic sounding device (indicator). At each location, the final reading will be triple-checked with both field representatives and recorded immediately into the field notebook. Groundwater elevations will be calculated by subtracting the field-measured depth to water (in feet below top of casing) from the surveyed datum (top of PVC rim measured to nearest 0.01 foot).

6.3.2 SQ2—Soils EC Testing

The EC field meter will be calibrated according to the manufacturer's specifications prior to each day of use. In addition, spot-checks with known calibration standards will be performed routinely during each day of use to ensure representative readings and proper function.

Replicate split samples will also be prepared and tested at a frequency 10 percent (i.e., minimum of one in ten samples). A replicate (split) sample will be prepared following preparation and homogenization of the parent sample; a 50/50 split of the homogenized parent sample will be performed to constitute the split samples and each individual (split) will be tested for EC using the same method. The EC readings between the split samples will be compared using the following formula to quantify the precision (difference):

Relative Percent Difference (RPD) = $[(C_1 – C_2) \times 100] / [(C_1 + C_2) / 2]$

Where C_1 and C_2 are observed values; C_1 larger than C_2.

6.3.3 SQ3—Vapor Sampling for Ammonia atop MRP

A Draeger pump and Colorimetric tubes for ammonia will be used to measure vapor concentrations at each vapor probe. The Draeger tubes will be obtained from the manufacturer and used in new condition for each vapor probe in accordance with the methods prescribed by the manufacturer (per Appendix C). Vapor sampling will be conducted in the same manner at each location; vapor concentrations will be measured by inserting the Draeger tube into the sampling container (box of known volume) while using an air pump to withdraw vapor from the probe's screen interval through a quarter-inch poly-tubing and into the sampling container.

Replicate (or duplicate) sampling will be conducted at a frequency of 20 percent (minimum of one in five sample locations). Replicate vapor concentrations will be obtained by recording the initial (parent) concentration from the initial Draeger tube sample; then repeating the same sampling method and using a new Draeger tube to obtain a second (replicate or duplicate) vapor concentration from the same vapor probe. This QC process is not truly a replicate or a field duplicate sample, but considered a reasonable assessment of vapor sampling method and precision. The vapor concentration values will be compared using the following formula to quantify the precision (difference):

Relative Percent Difference (RPD) = $[(C_1 – C_2) \times 100] / [(C_1 + C_2) / 2]$

Where C_1 and C_2 are observed values; C_1 larger than C_2.

7 Develop the Plan for Obtaining Data

Step 7 describes the key assumptions, monitoring design, and adaptive management.

7.1 Key Assumptions for the Selected Monitoring Design

The following items describe the key assumptions for the selected monitoring design:

- The 2012 geophysical survey and related recommendations are the primary basis of the study questions and data needs. Details regarding the methods used to collect data in support of the study questions are developed from the DQO process (herein).
- Key information provided in the 2012 geophysical survey was used as the technical basis to develop the study approach, but is not fully reiterated herein. It is assumed that all members of the planning team are familiar with the body of existing information for the site and key information provided in the 2012 geophysical survey.
- The CSM of the potential hazard is summarized from previous documentation as outlined in Step 1 of the DQOs. The CSM helped to formulate a reasonable understanding of site conditions in support of developing the study approach (as summarized in Step 1.2 of the DQOs).

7.2 Site Investigation Design

The monitoring design with respect to data types, methods, and locations, are established in previous steps of the DQOs (and summarized below).

Table 1 summarizes the data needs/study questions respective of groundwater levels, soil sampling, and vapor sampling.

Table 2 summarizes the measurement performance objectives.

Table 3 summarize the sample types, locations, and frequency. The actual (as-built) sampling locations will be developed following completion of the planned field work.

Figures 1 and 2 illustrate the overall field investigation plan for the three data collection types. Appendix B provides a construction plan for the data collection types. Appendix C provides detail in support of vapor sampling.

The totality of information in the DQOs text (Steps 1 through 7), tables, and figure summarize the outcome of the DQO process that is the basic framework for the work plan.

7.3 Adaptive Management

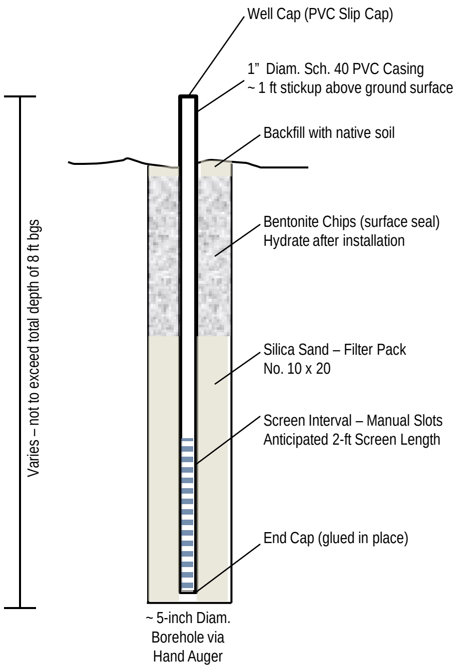
The term "adaptive management" in the context of environmental studies refers to a systematic strategy for continually learning from the available site information to most cost effectively administer future site activities and management decisions. Assessment of the environmental conditions against the study questions and potential alternative actions provides a technical basis for continual adaptive management. It is expected that the site data obtained from this field investigation program will be reviewed with Ecology's site manager to determine if subsequent data needs and/or source removal actions are needed.

Works Cited

Refer to Section 4 of the work plan.

Appendix B
Construction Detail and Sampling Plan

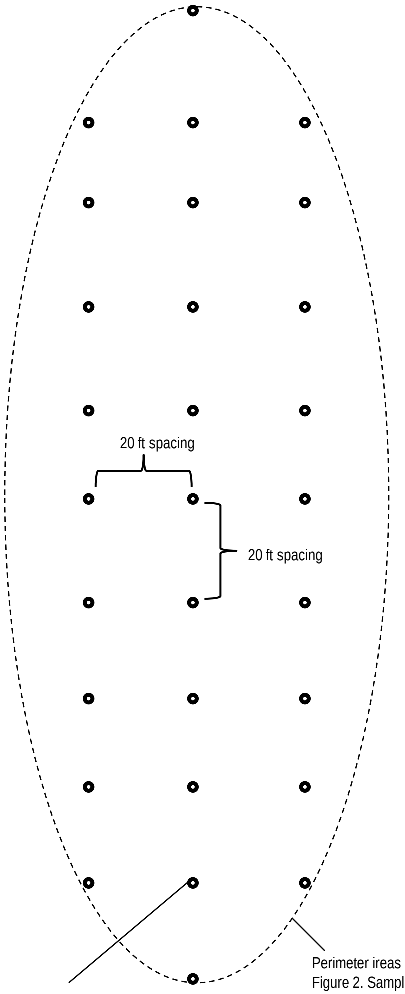
Typical Piezometer Design



Note:

1. Refer to Figure 2 for the two (2) locations planned for piezometer installation.

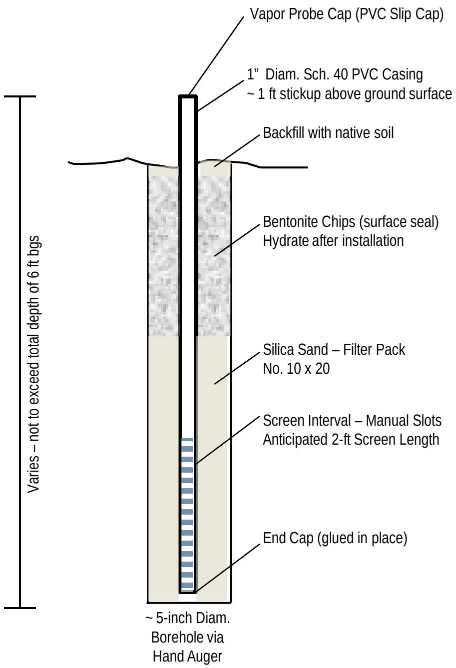
Typical Soil Sampling Grid Design



Represents soil sampling location; samples collected at ground surface (0 depth) and at 6 inches bgs at each location.

Perimeter ireas shown on Figure 2. Sampling grid developed from within perimeter boundaries on 20 ft spacing.

Typical Vapor Sampling Probe Design



Notes:

1. Refer to Figure 2 for vapor probe locations; a total of fifteen (15) shallow vapor probes are planned, five (5) at each of three areas of interest.
2. Refer to Appendix C for details on Drager Pump and Ammonia Tube specifications.

Appendix B. Construction and Sampling Plan

Appendix C

Manufacturer Information for using Drager Pump and Ammonia Colorimetric Tubes

Selected information from Drager (manufacturer) on ammonia vapor sampling methods.

Dräger-Tubes & CMS-Handbook

15th edition

Soil, Water, and Air Investigations as well as
Technical Gas Analysis

Dräger. Technology for Life®

Table of Contents

1. General

1.1 Introduction to Gas Measuring

Natural, ambient air is chemically a gas mixture that consists of 78 % nitrogen, 21 % oxygen 0.03% carbon dioxide as well as argon, helium and other rare gases in trace concentrations. In addition there is water vapor, e. g. humidity. If the concentrations of the components change, or a foreign gas is added, we no longer have natural air. When these changes occur, the potential for adverse health effects exist.

The spectrum of other so-called air components can be extremely broad. It can range from the pleasant fragrance of a good perfume to the over powering stench of hydrogen sulfide. Likewise, the hazard of each “air pollutant” varies considerably. The type of substance, its concentration and duration of occurrence, as well as probable synergistic effects with certain gas compounds must all be considered. In addition, there are many air pollutants which cannot be perceived by human senses because they are colorless and odorless (e. g. carbon monoxide).

If the composition of the natural air changes in any way, it should be tested, to determine the substance which caused this change. Even substances with distinctive odors cannot be reliably assessed with the aid of the olfactory nerve in the nose. The olfactory nerve can become desensitized after a certain period of time or repeated exposure, making it impossible to smell even immediately dangerous concentrations. After a few hours we do not even perceive the pleasant fragrance of our own perfume and high concentrations of hydrogen sulfide escape from the sense of smell even after a very short while.

Subjectively, one persons sense of smell may be more sensitive to certain air pollutants than others. In many cases substances are noticed in very low concentrations which, even after a long-term exposure do not necessarily cause adverse health effects. In general the sense of smell is sufficient in determining the presence of air pollutants, but the need exists for an objective gas analysis method. Gas measurement serves as a technical aid and an assessment of the concentration is only possible with a gas measurement device. To determine the hazard potential of a gas it is necessary to measure its concentration and to consider the duration of exposure and other parameters such as the type of work being performed.

If only the concentration of an air pollutant is known it is difficult to evaluate the degree of the hazard. For Example, there is a degree of uncertainty regarding the health effects of cigarette smoking. The synergistic effect of the more than 800 single substances in cigarette smoke and the physiological condition of the smoker are all factors in determining the toxicological influence to the individual.

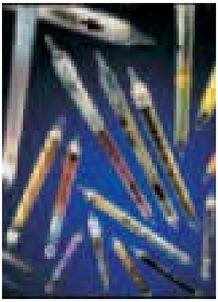
An important prerequisite to determining the potential of any gaseous air pollutants is the determination of the concentration with a suitable gas measurement device. The kind of device to be used depends on which gases have to be measured and how often. Much to the dismay of both the user and the manufacturer, there is no universal instrument which measures all gases or vapors. The variety of substances is too wide for a single technique to measure all possible air pollutants. The more chemically complex a substance is, the more complex the gas measurement technique.

It may be that more than one measurement device or measurement method may be employed, each based on different operational principles. The instrumentation industry offers various devices for this purpose which can be used, individually or in combination on the measurement task:
- flame ionization detectors
- photo ionization detectors
- gas chromatographs
- infrared spectrometers
- UV-VIS photometers
- warning devices for explosion hazards
- Dräger-Tubes
- Dräger Chip-Measurement-System
- laboratory analysis in conjunction with sampling tubes or gas wash bottles (impinger)
- mass spectrometers
- substance selective instruments with e. g. electrochemical sensors

The choice of which monitor or measurement method to use depends upon the objective. The user must evaluate the situation and determine which substances to measure, how often, etc. Each of the above mentioned devices and methods have advantages and limitations. There is no universal monitor for all possible scenarios. For the selection of a suitable measuring device and to support the user in solving measurement problems, Dräger Safety AG & Co. KGaA offers competent know-how and technical assistance. The customer / employer should carefully train the user / employee on the use of their measurement device. Any use of the measurement device without receiving prior comprehensive training can be permitted by the customer / employer to the user / employees, at the customer / employees own risk.

Dräger X-am 5000

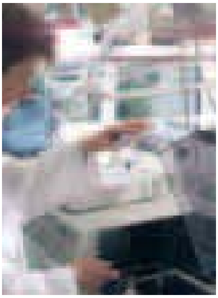
Photo and flame ionization detectors are distinguished by short response periods but they do not offer substance selectivity. Gas chromatographs, infrared and UV-VIS photometers are very versatile but on the other hand they are comparatively expensive and require a specialist to calibrate the devices and interpret the readings correctly. Warning devices for explosion hazards like the Dräger X-am 5000 are equipped with catalytical sensors to determine explosion levels of combustible gases and vapors. They are not designed to measure lower concentrations and thus are not suitable for this task.


1-394-90

Dräger-Tubes

Dräger-Tubes with direct reading colorimetric indication have many applications. Approximately 500 different substances can be measured with Dräger-Tubes.
Limited selectivity and the fact that Dräger-Tubes are usually capable of only being used a once may present a disadvantage. If repeated measurements of the same substance are to be performed daily, a measurement device like the Dräger Pac 7000 CO with its electrochemical sensor for the measurement of carbon monoxide is more economic than Dräger-Tubes.

When complex mixtures (e. g. solvent mixtures), are present, usually only a laboratory analysis will suffice. The prerequisite is that the contaminated air is trapped in a sorbent sampling tube like silica gel or activated charcoal.


ST-967-2004

Laboratory Analysis in the Dräger Analysis Service

After collecting the sample, analysis is performed in the laboratory with gas chromatographic methods, or sometimes by the combination of gas chromatography / mass spectroscopy. Laboratory procedures of this kind offer particularly high selectivity, but the analysis devices are very expensive, requiring high maintenance costs and operation by specialists.
Regardless of the gas measurement device or what analysis procedure is used, it is essential that the contaminant of interest be identifiable and measurable. Apart from a few exceptions in process monitoring, it is very unlikely that concentrations of other substances can be determined by subtracting the concentration of the gas which can be identified. For example, if the oxygen concentration is below the 17 or 19.5 Vol. % limit, it cannot be said which substance has displaced the oxygen without further investigation. In the case of very high carbon dioxide concentrations there is the danger of suffocation; likewise if there is a leak in a gas pipeline the presence of methane poses an explosion hazard. Other

contaminants present in the ppm range would not influence the oxygen measurement enough to alert anyone to a potential hazard. Since many of the occupational exposure limits are in the range of 1 ppm, the measurement by difference technique is typically inadequate.

Before each measurement an assessment of the situation should be made as to what contaminants are in question, at what locations, at what times, and so forth, according to established safety procedures. Monitoring according to established safety guidelines will help ensure safety in the workplace and effective use of monitoring equipment.

1.2 Concentration, Specifications, and Conversions

Concentrations are given as the content of a substance in a reference substance. For the measurement of contaminants in air, a concentration is used for the amount of the substance compared to the air. An appropriate engineering unit is chosen, to give simple, handy figures for indicating a concentration.

High concentrations are generally given in volume percent (Vol.-%), i.e. 1 part of a substance in 100 parts of air. Air consists of 21 Vol.-% oxygen. (i.e. 100 parts of air contain 21 parts of oxygen).

In smaller concentrations the engineering unit ppm = parts per million (mL/m^3) is used. The concentration ppm means 1 part of a substance in 1 million parts of air, ppb refers to 1 part of a substance in 1 billion parts of air.

The conversion of very small concentration units to Vol.-% is as follows:

$$1\ \text{Vol.-\%} = 10{,}000\ \text{ppm} = 10{,}000{,}000\ \text{ppb}$$

In addition to gaseous components the air also contains solid particles or liquid droplets, called aerosols. Since an indication in volume percent is not very useful due to the small size of the droplets or particles, the concentration of the aerosols is given in mg/m^3.

		Vol.-%	ppm	ppb
Vol.-% =	10 L/m^3 1 cL/L	1	10^4	10^7
ppm =	mL/m^3 µL/L	10^{-4}	1	10^3
ppb =	$\mu L/m^3$ nL/L	10^{-7}	10^{-3}	1

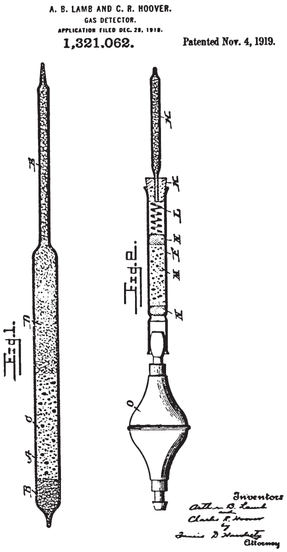
		g/L	mg/L	mg/m^3
g/L =	10 L/m^3 1 cL/L	1	10^3	10^6
mg/L =	mL/m^3 µL/L	10^{-3}	1	10^3
ppb =	$\mu L/m^3$ nL/L	10^{-6}	10^{-3}	1

2. Dräger-Tubes and Applications

2.1 Dräger-Tube Measurement

Today, detector tubes are one of the classical measurement techniques of gas analysis. The first detector tube patent appeared in America in 1919. Two Americans, A. B. Lamb and C. R. Hoover, impregnated pumice with a mixture of iodine pentoxide and sulfuric acid. This preparation, which they put in a vial, became the first chemical sensor for measuring or rather detecting carbon monoxide. Before this early detector tube, canaries were used as “sensors” in coal mining.

This first detector tube was only used for qualitative detection of the presence of carbon monoxide, quantitative measurement was not yet possible. Today the Dräger-Tubes provide quantitative results with a high degree of accuracy and selectivity. Since the development of the first Dräger-Tube, more than 70 years ago, Dräger has expanded the product line and Dräger-Tubes belong to the traditional products of Dräger.



Patent drawing by Lamb and Hoover

In comparison with the first detector tube patent, the basic shape and structure of a tube may appear not to have changed; however, closer inspection reveals the contents have changed dramatically. What is a Dräger-Tube? Simplistically, it is a vial which contains a chemical preparation that reacts with the measured substance by changing color. To achieve the normal shelf life of 2 years the tube tips are fused at both ends. Thus, the vial provides an inert package for the reagent system. Most of the Dräger-Tubes are scale tubes and it should be emphasized that the length-of-stain discoloration is an indication of the concentration of the measured substance.


1-282-50

Gas Sampling Pump 1950

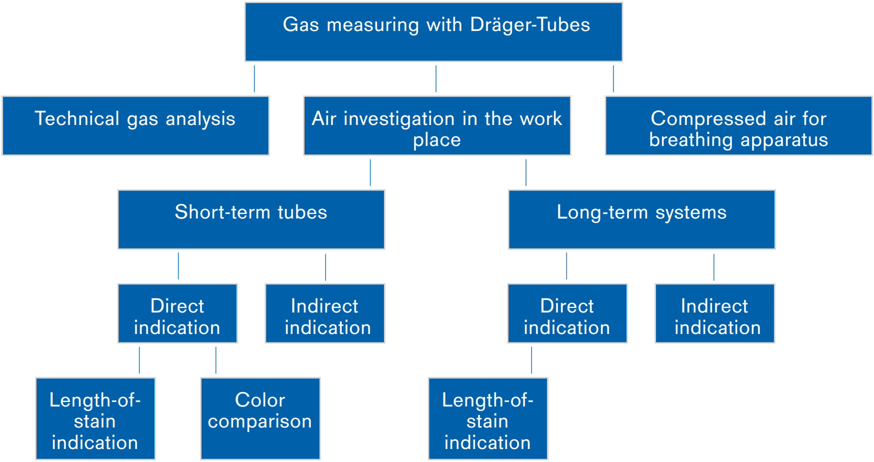
The printed scale allows a direct reading of the concentration. Thus, calibration by the user is not necessary. Of course the length-of-stain discoloration does not correspond to the concentration as a direct measure but is, strictly speaking, a measure of the mass reaction of the air contaminant with the Dräger-Tube preparation. Since the information that 25 mg of nitrogen dioxide has reacted is not practical information for the workplace, the calibration scale is prepared in the engineering units ppm or volume percent.

For many years, only a few gases could be measured with detector tubes. The main area of application was and still is the measurement of air contaminants in the workplace, in the concentration range of the occupational exposure limits. Decreasing occupational exposure limits have made it necessary to develop more sensitive Dräger-Tubes. In addition, efforts to better understand the exposure profile in the workplace have resulted in special Dräger-Tubes for long-term measurement which determine time weighted averages over given time periods.

ST-139-2001

Dräger-Tube
Nitrogen Dioxide 0.5/c

Dräger-Tubes can be schematically classified utilizing the following criteria:



Distinction is made according to the fundamentally different areas of application:

- **Air investigation in the workplace**
  Measurements in the range of the occupational exposure limits.
- **Technical gas analysis**
  Dräger-Tube measurements in the area of emission concentrations.
- **Compressed air for breathing apparatus and compressed gases**
  Specially calibrated Dräger-Tubes used with the Dräger Aerotest to determine the quality of compressed breathing air. The typical contaminants are CO, CO_2, water and oil.

Short-term tubes are designed for on-the-spot measurements at a particular location over a relatively short time period. Short-term tube measurements may last from 10 seconds to 15 minutes or so depending on the particular Dräger-Tube and sampling pump. Some applications for short-term tubes are the evaluation of concentration fluctuations in the workplace, the measurement of contaminants in the workers' breathing zone, the investigation of confined spaces (e. g. grain silos, chemical tanks, sewers) prior to entry and to check for gas leaks in process pipelines.

The Dräger short-term tubes and gas detector pumps are designed and calibrated as a unit. The use of other types of pumps with Dräger short-term tubes is not recommended. Although the volume may be the same, the difference in the flow characteristics of the pump and tube can result in considerable measurement errors.

Suitable pumps for Dräger short-term tubes are:
- **Gas detector pump Dräger accuro**
- **Automatic pump Dräger accuro 2000 with the gas detector pump accuro**
- **Dräger Quantimeter 1000**

For long-term measurements Dräger-Diffusion-Tubes with direct indication and sampling tubes and systems are available. Long-term measurements with diffusion tubes provide integrated measurements that represent the average concentration during the sampling period. Normally the measurements are performed between one and eight hours. These tubes can be used economically as personal monitors or area monitors to determine the weight average concentration. In contrast to short-term tubes, no pump is necessary for sampling with these measurement devices. The contaminant molecules automatically move into the tube or onto the badge, according to Fick's First Law of Diffusion.

The driving force for this movement of the contaminant molecules is the concentration differential between the ambient air and the inside of the tube. Since the diffusion tubes do not require a pump, they are particularly effective as personal gas monitors.

When complex substances or components that are chemically very similar, like methanol, ethanol, and propanol are present, direct reading Dräger-Tubes approach their limits of use. A colorimetric reaction system based on a chromate indicator cannot distinguish between the three alcohol types and indicates the sum of the concentration. In this example, the alcohols are indicated with almost the same sensitivity. Solvents usually consist of three to five different components, all chemically very similar. The use of a single Dräger-Tube in this case would not yield reliable results without any previous knowledge because of possible and probable cross sensitivities. In cases such as these, a sample should first be collected using a sampling tube which is then sent to a laboratory for analysis. The analysis will be conducted using gas chromatography or a photometric analysis technique.

Direct reading diffusion
tube with holder

Dräger sampling tubes contain coconut shell charcoal, different types of silica gel, or molecular sieve. The sampling tubes do not produce a color change and therefore can be described as indirect indicators. The sampling of isocyanates is accomplished using a specially prepared Dräger sampler which is analyzed after sampling via HPLC procedures.

After the analysis with sorbent sampling tubes it is often possible for subsequent measurements to be performed economically with direct reading short-term or long-term tubes targeted for particular components of a mixture.

Dräger diffusion sampler ORSA

In order to choose the best Dräger-Tube for the particular application, an assessment of the measurement with regard to the ambient conditions and the possible limits of use is very important. This assessment ensures that the advantage of the Dräger-Tube method does not turn into a disadvantage due to unforeseen cross sensitivities.

In any case, although the Dräger-Tube is an easily operated gas measurement method, it belongs in the hands of specialists. People trained in the field of industrial hygiene should be capable of determining the time and place to monitor, to recognise possible cross sensitivities, and to interpret measurement results correctly.

For all gas analysis tasks Dräger provides competent and extensive service beyond the initial sale of its products. This service includes:

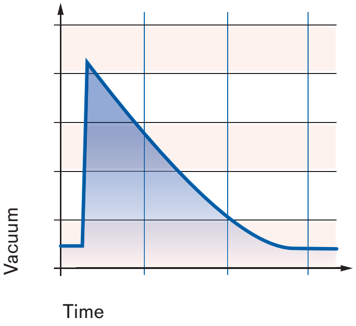
- free consultation for specific questions on measurements with Dräger-Tubes,
- 1)analysis of loaded samplers in the laboratory of the Dräger analysis service
- 1)measurement and sampling on site with analysis in the laboratory of the Dräger analysis service according to official regulations,
- Internet information system VOICE: www.draeger.com/voice
- Seminars about special subjects

1)This service is based in Germany.

The limits of the gas detection method must be considered when attempting to conduct an analytical determination. It is important with regard to the selectivity to know about potential cross sensitivities. Considering the exhaustive list of potential chemical substances, it is not possible to list all potential interferences. When questions about Dräger-Tubes arise, they should be directed to the local Dräger subsidiary or distributor.

2.3 Dräger-Tube Measurement System

The Dräger-Tube measurement system consists of a Dräger-Tube and a Dräger gas detector pump. Each Dräger-Tube contains a very sensitive reagent system that produces accurate readings when the technical characteristic of the gas detector pump precisely match the reaction kinetics of the reagent system in the tube. Therefore, a gas detector pump delivering the correct volume must also pull the sample through the Dräger-Tube at the proper rate. In effect, the pump and tube form a sampling unit. To interchange the pumps and tubes of various manufacturers can lead to erroneous results. These requirements are referenced in international as well as national detector tube standards or norms which require or recommend that detector tubes be used with a matching gas detector pump from the same manufacturer.



Suction characteristic of a
Dräger bellows pump

Dräger short-term gas detector pumps

The following gas detector pump can be used suitably for the measuring of momentary concentrations, e. g. concentration peaks, spot measurements and worst case measurement:.

- Gas Detector Pump Dräger accuro
- Automatic Pump Dräger accuro 2000 with Gas Detector Pump Dräger accuro
- Dräger Quantimeter 1000

The air sample is sucked strokewise through the Dräger-Tubes with these gas detector pumps. Basically all gas detector pumps are to be used according to the appropriate instructions for use.

Technical Data	Gas Detector Pump Dräger accuro
Application	For short-term measurements with a small number of strokes
Design	Bellows pump worked by hand, single-handed operation
Number of Strokes	1 to 50 and higher
Stroke volume	100 mL (±5%)
Size (H x W x D)	85 x 170 x 45 mm
Weight	approx. 250 g
Kind of protection	(not required)
Battery	(not required)

Gas Detector Pump
Dräger accuro

For the Gas Detector Dräger accuro the pump body (bellows) is pressed together completely. The pump can be easily operated with one hand and supply 100 mL with one stroke, during which the air contained in the pump chamber escapes through the exhaust valve. The suction process runs automatically after the bellows are set free. The exhaust valve is closed during the opening phase of the bellows so that the gas sample flows into the pump chamber through the Dräger-Tube connected in series. After the complete opening of the pump body into its original position the suction process is finished. The end of stroke is visible by an end of stroke indication. An internal scissor mechanism in the Dräger accuro provides complete even compression of the bellows and an automatic stroke counter which is integrated in the pump head records the number of strokes.

The gas detector pumps are independent of external energy sources. Therefore there are no usage restrictions in areas of explosion hazard.

For the Automatic Pump Dräger accuro 2000 the Gas Detector Pump Dräger accuro is the principal item of the measuring device. The Gas Detector Pump Dräger accuro can be automatically compressed in the Automatic Pump Dräger accuro 2000 after the number of strokes necessary for the measurement has been preselected. The measuring process is finished when the programmed number of strokes has been performed. Since the Dräger accuro 2000 does not comply with the explosion hazard regulations, measurements in areas with explosion hazards can only be performed manually with the gas detector pump Dräger accuro.

Pump System Dräger
accuro 2000

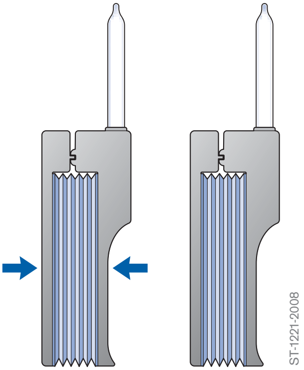
The Dräger Quantimeter 1000 is a microprocessor controlled automatic gas detector pump. The number of strokes can be preselected from n = 1 to n = 199 corresponding to an air volume from 0.1 to 19.9 litres. Continuous operation is also possible. It features two LC displays indicating the preselected number and the actual number of strokes. The apparatus is operated with a rechargeable battery which can be exchanged.

Dräger Quantimeter 1000

Technical Data	Automatic Pump Dräger accuro 2000	Dräger Quantimeter 1000
Application	For short-term measurements with higher number of strokes or in continuous operation	For short-term measurements with higher number of strokes or in continuous operation
Design	Electrically operated, automatic pump for the operation of the Gas Detection Dräger Pump accuro	Electrically operated, micropro cessor controlled bellows pump in compact contruction
Number of strokes	1 - 199 pre-selectable or contiuous operation	1 - 199 pre-selectable or contiuous operation
Stroke volume	100 mL (±5%)	100 mL (±5%)
Size (H x W x D)	270 x 190 x 100 mm	180 x 165 x 62 mm
Weight	approx. 2.4 Kg	approx. 1.8 Kg
Battery	Nominal voltage 6 V / 1 Ah	Nominal voltage 6 V / 1 Ah

Functional capability of gas detector pumps

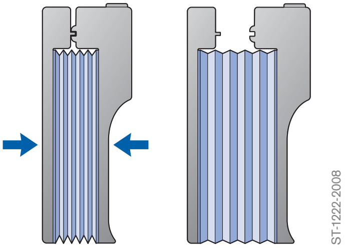
To help ensure precise measurement results, it is particularly important to confirm that the pump is operating properly. Short-term pumps should be checked before each measurement for leaks and suction capacity according to the operating manual. In addition, after a measurement short-term pumps should be flushed with clean air by performing several strokes without a Dräger-Tube in the pump. This purges the pump of reaction products which enter the bellows due to the reaction in the tube.



Insert an unopened Dräger-Tube and squeeze the pump completely.

After releasing the position of the pump body should not change within one minute.

Quick test to check bellows pump for leaks



Squeeze the pump completely.

After releasing, the pump must open instantly.

Quick test to evaluate the suction capacity of the bellows pump

2.4 Dräger-Tubes for Short-Term-Measurements

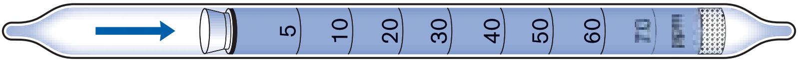
Short-term tubes are intended for the measurement of momentary concentrations. The duration of a short-term measurement is usually in the range of 10 seconds to 15 minutes The measured value shows the actual concentration during the time period covered by the test.

The design of the short-term tube depends on the measurement task, particularly on the substance to be measured and the concentration range to be determined. There are several types of Dräger short-term tubes:

- tubes with a single indication layer,
- tubes with one or more pre-layers plus an indication layer,
- combination of two tubes,
- tubes with connecting hoses,
- tubes with a built in reagent ampoule,
- tubes for simultaneous measurement

Short-term tubes with a single indication layer

The whole filling layer in these tubes serves as the indication layer.



ST-1223-2008

Dräger-Tube with a single indication layer

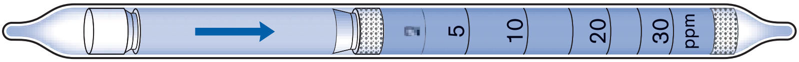
Examples include: Acetone 100/b,
Ammonia 5/a.

Short-term tubes with one or more pre-layers

In addition to the indication layer they have one or more pre-layers. These pre-layers are designed to:

adsorb moisture or
trap interfering substances or
convert substances into measurable substances

Examples include: Alcohol 100/a,
Hydrocyanic Acid 2/a.



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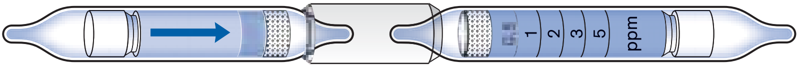
Dräger-Tube with one prelayer

Combination of two Dräger-Tubes

Two Dräger-Tubes, a pretube and an indication tube, are connected with shrink wrap tubing. Prior to the measurement, both inner tips and outer tips must be opened to allow air to be drawn through both tubes. The preparation in the pre-tube serves a purpose similar to the pre-layer of a single tube.

Examples include: Halogenated Hydrocarbons 100/a,
Formaldehyde 0.2/a

Short-term tubes with connecting tubes



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Combination of two Dräger-Tubes

These tubes consist of one indication tube and an additional tube. After breaking off the tube tips both tubes are connected with a short piece of rubber tubing supplied with the tubes. The additional tube must be connected in front of or behind the indication tube according to the instructions for use. If connected behind the indication tube, it functions as an adsorption layer for reaction products which result from the reaction in the indication tube. If it is connected in front of the indication tube, it functions similarly to the pre-layer in a standard Dräger-Tube.

Examples include: Oxygen 5%/B,
Benzene 2/a

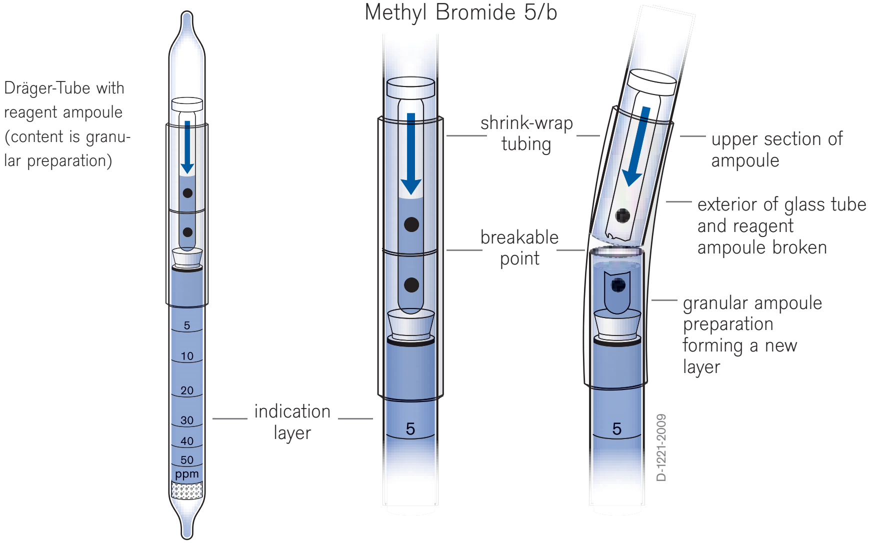
ST-1226-2008

Dräger-Tube with pre-tube

Short-term tubes with a built-in ampoule

Due to chemical incompatibility some reagents must be kept separate until just before the actual measurement. These tubes feature a built-in reagent ampoule in addition to the indication layer. The compound in the ampoule can be vaporous, liquid, or solid (i. e. granular).

Examples include: Oil Mist 1/a, Methyl Bromide 5/b



Dräger-Tube with built-in reagent ampoule

Dräger-Tubes for simultaneous measurement

A set of five specially calibrated tubes are provided in a rubber fixture. Each tube has one or two calibration marks for semiquantitative evaluation. The tips of all five tubes are broken and the set is connected to a five tube adapter which is connected to the gas detector pump (e. g. Dräger accuro) and the air sample is drawn through all five tubes simultaneously. Since the test sets are designed as a system, the use of other tubes is not recommended and will lead to erroneous results.

Test Set I for simultaneous measurement of inorganic combustion gases.

Examples include: Dräger Simultaneous Test Set I and II measurement of inorganic combustion gases. Dräger Simultaneous Test Set III measurement of organic vapors.

2.5 Evaluation of Dräger-Tubes

The evaluation of the indication on the Dräger-Tube is another important factor to be taken into consideration. The following are guidelines for interpreting the indication:

- **continuously observe the tube during the measurement**
- **evaluate the indication immediately following the measurement according to the instructions for use**
- **use sufficient lighting**
- **light background**
- **compare with an unused tube**

Observing the tube during the measurement is particularly important to make sure that a complete discoloration of the tube has not happened without being realised. This complete discoloration can sometimes occur abruptly with high concentrations even during the course of the first stroke.

A sufficient lighting source is necessary. However, direct sunlight should be avoided because the UV-radiation of the sun may cause a change in the discoloration. Since such a change can sometimes occur even after a longer period of time.

The reading of the tube must be done immediately following the measurement.

Also, keeping the used tube as proof is not useful in most cases, because even tubes which have been sealed with rubber caps will show a change in the indication over time.

A light background (white paper) is very helpful, in improving the readability of the discoloration. When there is no source of ambient lighting the reflector of a switched-on flashlight will suffice.

The comparison of a used tube with an unused one is yet another way to more accurately evaluate the discoloration.

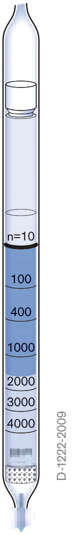
In all cases the entire length of the discoloration must be read. This means the sum of all colors (e. g. carbon monoxide tubes produce light brownish green discolorations).

It must also be pointed out that an individual's perception of a particular color or intensity of a color is somewhat subjective. It is possible, for example, that one person calls a color light brown whereas another person calls the same color brown. These deviations in the individual perception of color or sense of color should not be overemphasised unless color blindness is an issue.

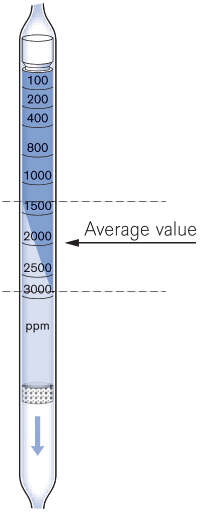
When reading the concentration on a scaled tube, three different situations can be encountered:

- the color indication ends at a right angle to the tube's longitudinal axis
- the color indication is oblique to the tube's longitudinal axis
- the end of the color indicatlon becomes very diffuse

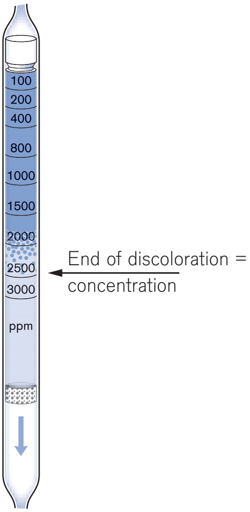
When the color indication is at a right angel to the tube's longitudinal axis. the concentration can be read directly against the scale (see example 1). If the color indication is oblique (i. e. runs in a slanting direction to the tube’s longitudinal axis), then a long and a short discoloration can be observed. In this case the average reading indicates the concentration (see example 2). If the color indication become progressively diffuse, the end of the discoloration may be difficult to evaluate. In this case the final edge of the discoloration has to be read at the point where a faint discoloration is just visible (see example 3)



Example 1



Example 2



Example 3

The detection limits determined by the VDI-Richtlinie 2449 page 1 as absolute units are:

formaldehyde		10 ng
glutardialdehyde		30 ng
toluene diisocyanate	(TDI)	1 ng
diphenylmethane-4,4'-diisocyanate	(MDI)	4 ng
hexamethylene diisocyanate	(HDI)	1 ng

and related to a sampling volume for 20 L:

formaldehyde		0.40 ppb
glutardialdehyde		0.36 ppb
toluene diisocyanate	(TDI)	0.007 ppb
diphenylmethane-4,4'-diisocyanate	(MDI)	0.019 ppb
hexamethylene diisocyanate	(HDI)	0.007 ppb

These methods allows the measurement far below the occupational exposure limits.

2.18 Quality Control for Dräger-Tubes

Dräger-Tubes are normally used for the quantitative determination of contaminants in the air. The need to measure these contaminants may happen on a moments notice. A major advantage of the Dräger-Tube method is its constant state of readiness to provide answers during emergencies or routine monitoring. The extensive quality control program in operation at Dräger Safety AG & Co. KGaA provides the customer of a quality product that can be relied upon time and time again.

Dräger-Tube quality control warehouse

The development, production, and testing of Dräger-Tubes is done within the context of the Dräger quality system, an established company standard. This standard contains as a basic document, the Dräger quality handbook and other detailed quality standards as

performance regulations. The quality control system meets international standards. The fact that the Dräger quality system conforms to the requirements of DIN ISO 9001 was confirmed by an independent institute.
Starting with the basic design idea, through all the detailed development stages, to serial production and eventually full production, Dräger builds quality into its Dräger-Tubes.

To verify the performance of Dräger-Tubes, Dräger takes several packages of each production batch and stores them for routine quality tests at regular intervals.

Detector tube standards were established in various countries to ensure the user that the tubes are indicating properly. In the USA for instance, Dräger-Tubes and Dräger gas detector pumps are tested according to NIOSH Method/TCA/A-012, "Certification Requirements for Gas Detector Tube Units" for the Safety Equipment Institute Certification Program. Each manufacturer's detector tubes and gas detector pump(s) are tested as a unit by an independent, third party laboratory accredited by the American Industrial Hygiene Association (AIHA).

4.2 Dräger-Tubes for Short-Term Measurements

Dräger-Tubes	Order Code	Standard Range of Measurement [20 °C, 1013 hPa]	Measurement Time [min]	Page
Acetaldehyde 100/a	67 26 665	100 to 1000 ppm	5	96
Acetic Acid 5/a	67 22 101	5 to 80 ppm	30 s	97
Acetone 40/a	81 03 381	40 to 800 ppm	1	98
Acetone 100/b	CH 22 901	100 to 12000 ppm	4	99
Acid Test	81 01 121	qualitative	3 s	100
Acrylonitrile 0.5/a (5)	67 28 591	1 to 20 ppm	2	101
		0.5 to 10 ppm	4	
Acrylonitrile 5/b	CH 26 901	5 to 30 ppm	30 s	102
Activation tube for use in conjunction with Formaldehyde 0.2/a tube	81 01 141			
Alcohol 25/a	81 01 631		5	103
Methanol		25 to 5000 ppm		
i-Propanol		50 to 4000 ppm		
n-Butanol		100 to 5000 ppm		
Ethanol		25 to 2000 ppm		
Alcohol 100/a	CH 29 701	100 to 3000 ppm	1.5	104
Amine Test	81 01 061	qualitative	5 s	105
Ammonia 0.25/a	81 01 711	0.25 to 3 ppm	1	106
Ammonia 2/a	67 33 231	2 to 30 ppm	1	107
Ammonia 5/a	CH 20 501	5 to 70 ppm	1	108
		50 to 700 ppm	6 s	
Ammonia 5/b	81 01 941	5 to 100 ppm	10 s	109
Ammonia 0.5%/a	CH 31 901	0.5 to 10 Vol%	20 s	110
Aniline 0.5/a	67 33 171	0.5 to 10 ppm	4	111
Aniline 5/a	CH 20 401	1 to 20 ppm	3	112
Arsine 0.05/a	CH 25 001	0.05 to 3 ppm	6	113
Benzene 0.5/a	67 28 561	0.5 to 10 ppm	15	114
Benzene 0.5/c (5)	81 01 841	0.5 to 10 ppm	20	115
Benzene 2/a (5)	81 01 231	2 to 60 ppm	8	116
Benzene 5/a	67 18 801	5 to 40 ppm	3	117
Benzene 5/b	67 28 071	5 to 50 ppm	8	118

Ammonia 5/a

Order No. CH 20 501

Application Range

Standard Measuring Range:	5 to 70 ppm
Number of Strokes n:	10
Time for Measurement:	approx. 1 min
Standard Deviation:	± 10 to 15 %
Color Change:	yellow orange → blue

Ambient Operating Conditions

Temperature:	10 to 50 °C
Absolute Humidity:	< 20 mg H_2O / L

Reaction Principle

NH_3 + pH indicator → blue reaction product

Cross Sensitivity

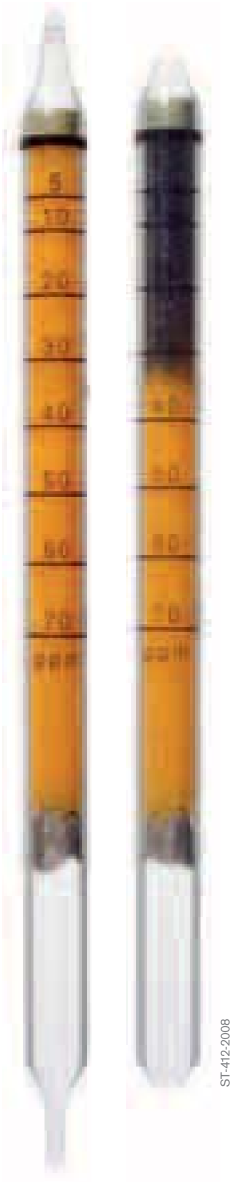
Other basic substances such as e.g. organic amines are indicated as well.

The indication is not affected by:

300 ppm nitrous fumes
2,000 ppm sulfur dioxide
2,000 ppm hydrogen sulfide

Extension of the Measuring Range

Using n= 1 stroke, multiply the reading by 10; the measuring range will be 50 to 700 ppm.



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