Work Plan/Sampling Analysis Plan for Data Gap Monitoring Well Installation

Well No. WUABFFMW01

Kirtland Airforce Base Bulk Fuels Facility, Albuquerque, New Mexico

Prepared for:

Albuquerque Bernalillo County Water Utility Authority
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ABBREVIATIONS AND ACRONYMS

AES	Advanced Environmental Solutions
amsl	above mean sea level
AST	above storage tank
ASTM	ASTM International
BFF	Bulk Fuels Facility
bgs	below ground surface
Cascade	Cascade Drilling
CFR	Code of Federal Regulations
CHSP	Corporate Health and Safety Plan
COC	constituent of concern
CPB	Construction Programs Bureau
CPR	cardiopulmonary resuscitation
CT	Chemical Transportation Incorporated
DMS	dual membrane sampler
EDB	ethylene dibromide
Eon	Eon Products, Inc
Eurofins TestAmerica	Eurofins
ft	feet *or* foot
FTL	field technical lead
GIS	global information system
gpm	gallons per minute
GR	gamma ray
GWM	groundwater monitoring
H&S	Health and Safety
HCl	Hydrogen Chloride
HEAL	Hall Environmental Analysis Laboratory
IDW	investigation derived waste
INTERA	INTERA Incorporated
KAFB	Kirtland Air Force Base
LNAPL	light non-aqueous phase liquid
NELAP	National Environmental Laboratory Accreditation Program
NIST	National Institute of Standards and Technology

NMDOT	New Mexico Department of Transportation
NMED	New Mexico Environmental Department
NTU	nephelometric turbidity unit
OD	outer diameter
OSE	Office of the State Engineer
OSHA	Occupational Safety and Health Administration
PDB	passive diffusive bag
PPE	personal protective equipment
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
ROW	right of way
Site	Kirtland Air Force Base Bulk Fuels Facility
SSHASP	Site-Specific Health and Safety Plan
SOP	Standard Operating Procedures
SSO	site safety officer
SVE	soil vapor extraction
SVM	soil vapor monitoring
SVOC	semi-volatile organic compound
SWS	Southwest Safety Services
USCS	Unified Soil Classification System
VOC	volatile organic compound
Water Authority	Albuquerque Bernalillo County Water Utility Authority
WQCC	Water Quality Control Commission
Work Plan/SAP	Work Plan and Sampling and Analysis Plan

1.0 INTRODUCTION

INTERA Incorporated (INTERA), under contract with the Albuquerque Bernalillo County Water Utility Authority (Water Authority), was tasked to drill, install, test, and sample a data gap groundwater monitoring well associated with the Kirtland Air Force Base (KAFB) Bulk Fuels Facility (BFF) (Site) located in Albuquerque, New Mexico (**Figure 1**). These efforts are being implemented by INTERA and their subcontractors, Cascade Drilling (Cascade), Eurofins TestAmerica (Eurofins), Hall Environmental Analytical Laboratory (HEAL), Jet West Geophysical Services, High Mesa Consulting Group, Advanced Environmental Solutions (AES), and Southwest Safety Services (SWS), to successfully complete project objectives as defined in the Proposal and Cost Estimate submitted by INTERA on August 13, 2021 (INTERA, 2021a).

Water Authority received New Mexico Capital Outlay funding to install, test, and sample a data gap groundwater monitoring well (WUABFFMW01) to address an outstanding data gap in the ethylene dibromide (EDB) groundwater contamination plume associated with the KAFB BFF project. The purpose of this well is to determine if EDB is present at depth in the northern extent of the plume, based on historical EDB concentrations measured in groundwater and the local geology, and to support Water Authority in its confidence in the safety of nearby water supply wells. WUABFFMW01 will be located near the northern boundary of the EDB plume within Indiana Street SE, just south of Kathryn Avenue SE, Albuquerque, New Mexico (800 Indiana Street SE) (**Figure 1**).

To guide the field, laboratory, and data reporting efforts associated with this project, INTERA has prepared this Work Plan and Sampling and Analysis Plan (Work Plan/SAP). The Work Plan portion of this document describes the drilling, construction and monitoring well completion activities, while the SAP portion of the document describes the groundwater sampling activities and slug testing.

1.1 Document Purpose and Scope

The objective of this Work Plan/SAP is to clearly document the types and objectives of field activities to be completed by INTERA and their subcontractors as part of this investigation. Health and safety requirements are presented in the Site-Specific Health and Safety Plan (SSHASP). Once this Work Plan/SAP has been reviewed and approved by Water Authority and the New Mexico Environmental Department (NMED), project field activities and data collection can commence. The NMED Construction Programs Bureau (CPB) will need to review and approve the well construction design specifications at the completion of drilling and prior to well construction activities.

2.0 BACKGROUND INFORMATION

The KAFB is located in Bernalillo County, New Mexico, in the southeast portion of the city of Albuquerque. INTERA submitted a technical memo to the Water Authority with a recommended data gap monitoring well location and drilling method for this project (INTERA, 2021) (**Appendix A**).

3.0 PROJECT DESCRIPTION AND MANAGEMENT

The objective of this project is to address the ongoing data gap at the Site by determining the vertical extent of EDB in the northernmost extent of the EDB plume. To achieve project objectives, INTERA has been contracted to design and advance one boring in the northernmost extent of the EDB plume. A monitoring well (WUABFFMW01) will be installed based on data collected in the field. In addition to drilling, aquifer data and groundwater samples will be collected.

Field activities and procedures related to all phases of the project are addressed in this document and include the following:

- Soil boring drilling.
- Geologic and geophysical logging.
- Monitoring well installation and development.
- Fluid level monitoring and sampling.
- Sampling, management, and disposal of investigation-derived waste (IDW) (soil and water generated during drilling activities).
- Slug testing.
- Site demobilization.

3.1 Project Organization

INTERA's quality assurance/quality control (QA/QC) system established for the project includes two levels of management control: the Oversight Level and the Technical/Field Level. The Oversight Level includes INTERA activities that support common or standardized functions associated with the project. The Field Level consists of investigation-specific field activities implemented by INTERA in support of project objectives.

Roles, responsibilities, and contact information for key investigation personnel who will be involved in project activities as described in this document are presented in **Table 1** and summarized in the subsections below. In some cases, more than one responsibility may be assigned to one person.

Table 1. Personnel Roles and Responsibilities

Name	Responsibility	Affiliation	Email Address	Contact Number
Diane Agnew	Project Manager	Water Authority	dagnew@abcwua.org	505-206-7148 (mobile)
Kelsey Bicknell	Senior Water Resource Scientist	Water Authority	kbicknell@abcwua.org	505-916-9160 (mobile)
Shelby Stimson	Water Resource Scientist	Water Authority	sstimson@abcwua.org	505-289-3009
Joseph Tracy, PG	Project Manager	INTERA	jtracy@intera.com	505-301-1134 (mobile)
Joe Galemore, PG	Senior Technical Advisor	INTERA	jgalemore@intera.com	505-239-6414 (mobile)
Robert Sengebush, PG	Task 4 Drilling/MW Installation Technical Lead	INTERA	rsengebush@intera.com	505-235-3271 (mobile)
Austin Hanson	Task 4 Drilling/MW Installation	INTERA	ahanson@intera.com	484-264-3095 (mobile)
Lynda Price	Task 4 Groundwater Sampling and Slug Testing Technical Lead	INTERA	lprice@intera.com	512-492-2072 (mobile)
Andrew Murphy	Task 4 Groundwater Sampling and Slug Testing	INTERA	amurphy@intera.com	901-412-7524 (mobile)
Lee Dalton	Task 4 Investigation Derived Waste Manager	INTERA	Ldalton@intera.com	505-730-7372 (mobile)

3.1.1 Oversight Level

The Project Oversight Team is comprised of select personnel from INTERA who specialize in particular aspects of Project and QA management. The Project Oversight Team oversees all applications associated with implementation of activities under the project.

Ms. Diane Agnew serves as the Water Authority Project Manager and is considered the principal decision-maker for the project. In addition to Ms. Agnew, Ms. Kelsey Bicknell and Ms. Shelby

Stimson will provide oversight for the Water Authority. Mr. Joseph Tracy serves as the INTERA Project Manager and is the primary of point of contact for the Water Authority. The INTERA Project Manager has primary responsibility for the supervision, coordination, and implementation of the Project's proposed technical scope of work. Specific responsibilities include maintaining communication between all project levels; coordinating, reviewing, and approving any task-specific deliverables or guidance, including the preparation of this Work Plan/SAP; review of Project QA; and any corrective action(s).

3.1.2 Technical/Field Level

The field activities that will be conducted to support project objectives include the following:

- Drill, construct, and develop one monitoring well (WUABFFMW01).
- Conduct a slug test on the newly installed well and up to five existing monitoring wells in the vicinity.
- Collect groundwater samples from the newly installed well during two groundwater monitoring events.

Mr. Rob Sengebush and Ms. Lynda Price of INTERA have been appointed to serve as the Technical Leads. Primary responsibility of this position is the supervision, coordination, and implementation of the project's drilling, testing, and sampling activities. Both technical leads will be responsible for the supervision, coordination, and implementation of the project's drilling, testing, and sampling activities, through verification that appropriate site-specific technical and QA/QC protocols are being implemented; and verification that all field staff are properly trained and educated on site-specific tasks to be completed.

3.1.2.1 Field Technical Leads

As needed, INTERA may select one or more Field Technical Leads (FTLs) during the course of the project. The FTL shall be present on-site and shall be responsible for the oversight and management of their assigned task(s) during field implementation. The primary responsibility of the FTL is practical field implementation of both technical and QA/QC requirements for the appointed activity as identified in this Work Plan/SAP, including but not limited to daily management and oversight of any assigned field samplers designated to assist in the assigned activity.

The FTL position is a flexible position; in many cases, the INTERA staff member assigned to be an FTL for the drilling or sampling duties may also be qualified to perform the daily field H&S duties (as the Site Safety Officer [SSO]).

FTLs report directly to the Technical Leads but may also respond to direct requests from other members of the Project Oversight Team. Upon request, an FTL will deliver directly any field or other documents to review for purposes of QA. As appropriate, FTLs shall execute their responsibilities in close coordination with other INTERA field team members or contractors that are actively executing activities in the field. Additional FTLs may be appointed as appropriate.

3.1.2.2 Field Samplers

As needed, INTERA may select one or more Field Samplers to aid in the execution of the well installation and sampling operations. Field Samplers are guided by and directly report to the appropriate FTLs. INTERA personnel currently identified to operate, as required, as Field Samplers for this Project include Mr. Andrew Murphy, Mr. Brian Archuleta, and Ms. Lynda Price of the INTERA Albuquerque Office. Additional Field Samplers may be appointed as appropriate.

3.1.3 Additional Contracted Partners and Vendors

In addition to INTERA technical support, further support for the successful completion of the activities as detailed in this Work Plan/SAP shall be provided by the following contractors:

- Cascade: drilling contractor selected to drill, install, and develop WUABFFMW01 (New Mexico Well Drilling License No. WD-1664) (night and weekend security services will be provided by IPS as a subcontractor to Cascade).
- Eurofins (ELAP Certificate No 2897, State of California) is the off-site analytical laboratory selected for ground water sample constituent of concern (COC) analysis.
- Hall Environmental Analytical Laboratory (HEAL) of Albuquerque, New Mexico will provide select analytical analysis of push-ahead groundwater samples and IDW samples.
- Jet West Geophysical Services: conduct the geophysical logging of WUABFFMW01.
- High Mesa Consulting Group: elevation survey of WUABFFMW01.
- AES: IDW storage, hauling, and disposal (NM Contractor’s License No. 83422).
- SWS: will provide traffic control and road closure signage per an approved traffic control plan (TCP) (NM Contractor’s License No. 82265).

3.1.4 General Health and Safety Training Requirements

INTERA personnel shall be trained to and comply with the INTERA Corporate Health and Safety Program (CHSP) (INTERA, 2019, as amended). All on-Site INTERA personnel shall comply with Occupational Safety and Health Administration (OSHA) standards. At least one assigned team member of the Field Team will maintain current certification in the American Red Cross “Multimedia First Aid,” and “Cardiopulmonary Resuscitation (CPR) Modular,” or equivalent.

3.2 Health and Safety Plan

A SSHASP has been prepared according to INTERA requirements and approved by the INTERA Health and Safety Manager. The INTERA-prepared SSHASP will be strictly followed during all Site activities. All field activities will be conducted using modified Level D PPE, including hard hat, safety glasses, and safety-toed boots. Nitrile gloves will be used to handle all soil and groundwater samples. A safety meeting will be conducted prior to the initiation of work, and chemical and physical hazards of the work will be reviewed and discussed. Safety tailgate meetings will be held each field day with the INTERA field staff and the drilling team. A copy of all SSHASP requirements and protocols are included in the SSHASP.

3.3 Documentation and Records

The following sections discuss the requirements for documenting field activities and for preparing laboratory data packages. This section also describes reports that will be generated as a result of this Project.

3.3.1 Field Documentation

Field personnel will use permanently bound field logbooks with sequentially numbered pages to record and document all field activities. The logbook will list the contract name and number, the project number, the site name, and the names of the subcontractors and the client. At a minimum, the following will be recorded in the field logbook:

- Names and affiliations of all on-site personnel or visitors.
- Weather conditions during the field activity.
- Summary of daily activities and significant events.
- Notes of conversations with coordinating officials.
- References to other field logbooks or field forms that contain specific information.
- Discussions of problems encountered and the resolution(s).
- Discussions of deviations from Project-governing documents.
- Descriptions of on-site photographs taken by INTERA personnel.

The field team will also use various field forms, as applicable, to record field activities. Applicable field forms for this project are provided in **Appendix B.**

- Any required field screening or monitoring activities shall also be recorded in the field logbook and/or appropriate field forms.

- Instrument calibration and standards' traceability documentation capable of providing a reproducible reference point shall be recorded in the field logbook and/or appropriate field forms.

- Documentation of proper sample handling, storage, and transport is also required and mainly controlled through the use of a standardized project sample chain-of-custody form.

- Chain-of-custody forms shall accompany the sample(s) at all times. Sample documentation and chain-of-custody procedures are further described in Section 5.4.

- Photographs of field operations will be taken by the on-site geologist to document key aspects of the well drilling and related tasks. A photo log, as well as a copy of all field notes and field forms will be included as attachments to the final report.

4.0 INVESTIGATION METHODS

The following sections discuss the details of how drilling, logging lithology, well construction, well development, and surveying the new monitoring well will be conducted. The procedures, methods, and techniques discussed in this Work Plan/SAP will be approved by the NMED before work commences.

4.1 Premobilization Activities

Before drilling can commence, agreement(s), permit(s), contract(s) need to be set up, approved, and in place. The project schedule may be impacted if there are delays in the permit approval. Specific documents and tasks are needed before mobilization can occur and include the following:

- WUABFFMW01 is located within Indiana Street. INTERA will apply for a barricade/excavation permit from the City of Albuquerque.
- INTERA will apply for a monitoring well permit from the OSE.
- INTERA will execute agreements with subcontractors for all supporting services.
- INTERA and Cascade will contact New Mexico 811 to mark utility locations.
- INTERA will schedule personnel resources to oversee and perform field activities. The drilling, lithologic logging, well construction, and well development activities will be under the direction of an INTERA registered Professional Geologist.
- INTERA will secure equipment, vehicle, Work Plan/SAP, SSHASP, field book, lithologic logging tools and tablet, camera, etc.
- INTERA will coordinate with SWS to provide a traffic control plan. Cascade will coordinate with SWS to provide traffic control.
- INTERA will secure a construction noise control permit from the City of Albuquerque. Cascade will provide and erect noise control abatement panels (sound barriers) prior to drilling activities.
- INTERA will coordinate drill cuttings (primarily sonic core) and water associated with well drilling and development disposal. Cascade and INTERA staff will be responsible for coordinating the waste management. Drilling produces clay, silt, sand, and gravel cuttings. The drilling and well development process produces either water used during drilling or groundwater once the water table is reached. Soils will be containerized in lined, steel roll-off bins and the full bins (solids) will be periodically transported off-site for disposal. The fluids will be stored temporarily on site in tanks (“totes” or equivalent) and periodically disposed of off-site by AES. The solids and the liquids will be analyzed for the presence of petroleum hydrocarbons by the disposal contractor as part of the

disposal process. Water Authority will sign disposal manifests prior to transport and disposal.

- INTERA will subcontract geophysical logging. Geophysical logging will be conducted by Jet West, of Farmington, New Mexico, a professional geophysical logging firm. The well's screened interval and other well construction details are selected based in part on the information provided by the geophysical log. The geophysical logging suite is described in more detail in Section 4.3.
- INTERA will subcontract wellhead survey (High Mesa Consulting Group) for location and elevation: The wellhead survey will be contracted through INTERA.
- Site Security: Site security will be the responsibility of Cascade.

4.1.1 Additional Drilling Plans and Requirements

Below are additional plans and requirements for the drilling task:

- Schedule will be Monday – Friday from 7:00 am to 5:00 pm; no drilling will be allowed at night or on the weekends without prior approval by the Water Authority and City of Albuquerque (noise permit condition).
- INTERA is responsible for site restoration to meet the requirements of the City of Albuquerque, including asphalt patching and City of Albuquerque inspections.
- No potable water is available on site; water necessary for drilling activities will need to be provided by Cascade in coordination with the Water Authority and INTERA.
- All material used for the construction of WUABFFMW01 will be new, straight, and free of corrosion or defects. All provided well casing and well screen material shall be individually wrapped and provided with O-rings between joints. Any dry cement or bentonite materials that show evidence of solidification will not be used.
- Cascade will be responsible for containing and cleaning up any hydraulic oil and/or other fluid leaks from their equipment.
- Cascade shall be responsible for the security of its own equipment. The City of Albuquerque, Water Authority, INTERA, or other parties will not be responsible for vandalized or stolen equipment or materials.
- Cascade must secure and remove all process generated trash from the Site daily.
- No Site work will be performed by Cascade or any subcontractor without direct oversight by INTERA.

4.2 Drilling Method

WUABFFMW01 will be drilled and installed using the sonic drilling technology, as recommended in INTERA's Technical Memorandum (INTERA, 2021b). The sonic drill rig is owned and will be operated by Cascade Drilling, contracted through INTERA. The drilling sequence of events and well specifications are presented below:

4.2.1 Drilling

Field Logistics

The drilling site is located on Indiana Street SE, immediately south of Kathryn Avenue SE (**Figure 1**). The space requirements for the drilling rig and supporting vehicles (drill site) are approximately 50 ft by 80 ft. The drilling rig and all support vehicles will be located on the drill site during field activities. Water for drilling will be obtained by Cascade from the nearest construction hydrant. Cascade will follow the necessary steps to secure permission, a temporary meter, and ultimately pay for any water needed during the well drilling and installation process.

Drilling Process Details

1. *Well Identification:* Data Gap Well WUABFFMW01
2. *Location:* See **Figure 1.** The drill site is located on a flat, asphalt-paved neighborhood street, near address 804 Indiana Street.
3. *Latitude, Longitude, Elevation:* Latitude: 35.065297 N, Longitude: -106.570909 W, elevation 5330 ft amsl.
4. *Access:* Access is via Indiana Street SE and Kathryn Avenue SE. The layout of the drilling and related equipment is provided in the Site Plan (**Figure 2**).
5. *Daylighting for underground utilities*: Cascade will call New Mexico One Call (811 notification) before drilling. The confirmation ticket number and renewals (if necessary) shall be provided to INTERA within 24 hours of receiving them and no later than 48 hours before breaking ground. The boring location will be "daylighted" or "potholed" using an air knife and soil vacuum service or equivalent, (obtained through Cascade) to check for the presence of buried underground utilities. The potholing will be a cross pattern, star pattern, or cylinder with the same diameter as the largest drilling bit to be used for the monitoring well boring. The well location may have to be shifted slightly in order to accommodate the location of subsurface utilities. The location of subsurface utilities is largely known in this area and potential shifting of the location is assumed to be minimal.

   Overhead power lines are present along the south side of Kathryn Avenue SE in the vicinity of WUABFFMW01 location and the drilling equipment must be kept at a safe distance from the lines at all times.

6. *Mobilization:* Mobilization to the Site will consist of moving the drill rig, casing, drill pipe, roll off bins and water tank onto the site. The Site will be enclosed with sound proofing and fencing, with traffic cones and signage that indicate the street is closed. The street closure will be under permit and will be approved and coordinated through the City of Albuquerque permit process. The drill rig will be positioned over bermed plastic sheeting to capture any fluid leaks or spills from the undercarriage of the drill rig or from leaking drill hydraulic systems. Leaks identified during operations will be repaired.

Boring Specifications

Diameter: The borehole diameter will reflect the outside diameter (OD) of the sonic casing and will be approximately 8 inches in diameter.

1. The anticipated total depth of WUABFFMW01 is presented in the INTERA Technical Memorandum (INTERA, 2021b) and has been approved by the Water Authority technical team. The expected total depth of the boring is 610 ft bgs and the expected total depth of the well is 605 ft bgs.

4.3 Lithologic Logging, Push-ahead Groundwater Sampling, and Geophysical Logging

Lithologic Logging

Sonic core samples will be collected continuously by Cascade and provided to the supervising geologist. The samples will be described by the geologist using the Unified Soil Classification System (USCS) in accordance with ASTM Standard D 2488–17e1 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM, 2018). The sample descriptions will be documented using an electronic data logging device and saved daily to the INTERA server and the data cloud. Representative samples will be placed in labeled “chip trays” with individual compartments for each sample interval. These sample trays will be delivered to the Water Authority upon completion of drilling operations. The Water Authority project manager will receive a copy/photo of the lithologic log at the end of each day of drilling (via email) to support the timely response and approval of the final well construction design.

Bulk Sampling for Grain-Size Analysis

Bulk samples may be collected from each 10-ft drilling interval for grain-size analysis and future reference. Each sample will consist of one 1-quart plastic bag labeled and archived for later delivery to the Water Authority, if requested.

Push-ahead Groundwater Sampling

Push-ahead groundwater sampling will be conducted during drilling at up to five depths. The purpose of this sampling is to obtain groundwater samples during the drilling process within the "data gap" interval. The samples will be analyzed within approximately 24 hours for the presence of EDB and the results used to inform the selection of the screened interval. The decisions for where to sample will be made by the INTERA and Water Authority technical team based on lithologic characteristics of the sonic core.

Geophysical Logging

The geophysical logging equipment suite will be run in the steel sonic casing and will consist of the following:

- Natural gamma ray log (GR)
- Caliper log
- Neutron log
- Omni-directional density log

Electric logs (i.e. dual induction) will not be possible due to the presence of the steel casing in the borehole.

The logging will take place immediately upon reaching the boring total depth, as determined by the supervising geologist, the INTERA technical team, and the Water Authority. Cascade will be available to assist the geophysical logging operation by making the area around the borehole accessible. The supervising geologist will oversee the logging operation to confirm that the logs provide the best possible data. The field copies of the geophysical logs will be available immediately after logging. The geophysical logging data, as well as the soil boring log, will be used to confirm the final well design and construction. INTERA will prepare an updated well construction design for submittal to the Water Authority for approval. Following Water Authority approval, the well design will be submitted to NMED for review and approval. Once approved by both the Water Authority and NMED, well construction will begin.

4.4 Well Construction

Monitoring Well WUABFFMW01 will be installed in according with INTERA SOP 7 (**Appendix C**) and industry standard methods (ASTM, 2016). WUABFFMW01 has been proposed to be completed as a single monitoring well with a screened interval between approximately 580 and 600 feet below ground surface (ft bgs) (**Figure 3**).

Well Specifications

1. *Depth:* Estimated Total Depth of boring: 610 ft bgs. Estimated Total depth of Well: 605 ft bgs. **Figure 3** is a schematic of the proposed well design.

1. *Well Casing:* Nominal 3-inch, flush threaded Schedule 80 polyvinyl chloride (PVC). A 5-ft section of casing will be attached below the bottom of the screen as a sump. A threaded stainless steel end cap without rivets, screws, or glued pieces will be attached to the bottom of the sump casing. The well will either be allowed to hang or be pulled taught using the rig during annular backfilling activities, to ensure the well hangs plumb. The well will be able to ultimately accommodate a dedicated pressure transducer and a Bennett groundwater sampling pump set at the bottom of the screen.
2. *Centralizers:* Stainless steel centralizers will be installed at the base of the well (on the 5-ft sump below the bottom of the screen) and on the blank casing approximately 5 ft above the top of the screen.
3. *Screen:* Estimated 20-ft by nominal 3-inch schedule 80 PVC, 0.020-inch slot. Screen length and anticipated screened interval may be changed based on the results of the push-ahead sampling and the geophysical logging. Anticipated screen interval is 20 feet, set between 580 ft and 600 ft bgs. This may change based on the final well design document to be developed at the conclusion of drilling activities.
4. *Sand Pack:* 10/20 silica sand (minimum siliceous material content 95%), will extend from the bottom of the well to a minimum of 3 ft above the top of the screen. Additional sand thickness may be requested by the Water Authority or INTERA technical advisors. Filter pack material grain size may be altered based on data collected during drilling.
5. *Casing Installation:* The well casing will be "hung" in the boring above the total depth of the well; the well must not be allowed to rest on the bottom of the boring, due to the potential to damage the well under the weight of casing and screen.
6. *Bentonite Seal:* ⅜-inch time-release coated bentonite pellets shall be placed by gravity fall from the surface for a minimum of 5 ft above top of the sand pack. The seal will be allowed to hydrate a minimum of 4 hours prior to placement of additional annular materials. The seal is expected to be within the saturated zone. However, if this seal is above the water table, the bentonite pellets will be hydrated by the addition of potable water in the well annulus via tremie pipe. If any water is added, the amount of water added will be recorded and subsequently removed during well development.
7. *Grout to Surface:* A cement-bentonite grout will be installed from the top of the bentonite seal to 2 ft bgs. To avoid damage to the well from heat of hydration, a minimum of 3 lifts with 8-hour curing time between lifts will be required. The grout will have a 96% cement and maximum 4% high solids bentonite powder ratio by dry weight. Grout mixtures shall have a maximum of 7.8 gallons of potable water per 94-pound sack of grout. Grout shall be placed by pumping through a tremie pipe.

7. Cascade shall bring two 55-gallon drums and a diverter, or an equivalent system, to capture displaced groundwater generated during the grouting activities.
8. *Surface completion:* The well surface completion shall be a traffic-rated flush-mounted vault. The vault shall have a minimum skirt length of 12 inches. Vault diameter shall be 12 inches. A minimum 2-ft square, 4-inch thick 3,000-psi concrete pad by will be installed around the well vault. The concrete pad shall slope away from the vault at a minimum of ¼-inch per foot.
9. Cascade shall provide a lockable J-plug cap for the well.

4.5 Monitoring Well Development

After installation, WUABFFMW01 will be developed in accordance with INTERA SOP 8 *Monitoring Well Development* (**Appendix C**). WUABFFMW01 will be developed using a separate "development rig" provided by Cascade and will take place within 2 to 3 days following well and grout installation and no sooner than 48 hours following final grout installation. Well development must include the following details:

- Initial development will consist of swabbing and bailing until little, or no sediment enters the well. Development and purge water will be contained in a temporary tank, tote, or drum. If the addition of water is necessary to facilitate surging and bailing, only clean potable water will be used.
- A bailer fitted with a toggle valve will be lowered into the well and used to gently surge the well screen interval to remove any sand, silt, and debris accumulated in the well bore.
- An Imhoff cone, provided by Cascade, will be used to collect water from the first bailer run to evaluate the amount of silt and sediment in the water. This process will be repeated after each cycle of surging development. The data gap groundwater monitoring well WUABFFMW01 will be bailed until the discharge water contains less than 2 milliliters of sediment per 1 liter of water, as measured in the Imhoff cone.
- A minimum of five casing volumes of water will be purged from the well to develop the filter pack. Additional water that was added during drilling and/or development activities must be purged in addition to the five casing volumes.
- Water quality will be monitored during well development. Temperature, pH, specific conductance, and turbidity will be recorded on a Well Development field form. A copy of the field form is provided in **Appendix B.** Photographic documentation will also be collected.

4.6 Waste Management, Handling, and Disposal

Anticipated wastes streams generated from drilling activities will include soil cuttings, displaced borehole water from grouting, well development water, and decontamination water. All drilling-derived wastes will be properly disposed of according to local, state, and federal regulations. All drilling-derived solid wastes will be containerized and stored in the drilling-derived waste roll-off container until it has been properly characterized via analytical testing. Solids shall be separated from fluids when practical. Cascade is responsible for double lining the roll off containers with 6-mil plastic liner, transporting waste to the storage container, and placing the materials in the container(s). No drilling derived waste shall be left on the ground or unsecured overnight.

Before arrival on-site, all down-hole equipment shall be decontaminated with heated pressure washer. Before leaving the Site, down hole equipment and the rig should be cleaned over a 6-mil plastic liner decontamination pad to capture the water and transferred to IDW fluid containers. More details about IDW handling and disposal are discussed in Section 5.7.

4.7 Well Record

Cascade shall keep a record of the borehole and well construction as the work progresses and provide a daily work ticket, including a record of well materials used, to the supervising geologist for review and approval. The record shall be included in the daily log presented to INTERA for billing purposes. After the installation of the well, Cascade shall prepare a formal Well Record using the OSE-required format. A draft of the Well Record shall be provided to the Water Authority and INTERA for comment prior to submittal within 15 days of completing the well. A final version (including Water Authority and INTERA requested revisions, as necessary) shall be submitted to the OSE within 20 days after completion of WUABFFMW01. A copy of the final Well Record shall be provided to the Water Authority and INTERA by Cascade.

4.8 Wellhead Survey

The wellhead survey will be performed by a New Mexico licensed surveyor (High Mesa Consulting Group). The survey will be conducted after well installation activities and will consist of surveying X and Y coordinates of the well location, as well as the latitude and longitude of the well, performed to 0.01-ft accuracy. Elevation of the ground surface, Z, and the measuring point on the wellhead will be surveyed with respect to mean sea level.

5.0 MONITORING AND SAMPLING

WUABFFMW01 will be allowed to recover for a minimum of 24 hours following development before gauging or sampling. WUABFFMW01 will be sampled using two sampling methods: (1) passive sampling using passive diffusion bag (PDB) samplers for volatile organic compounds (VOC) constituents and dual membrane passive diffusion samplers (DMS) for non-VOC constituents, and (2) a combination of low-flow sampling and purging three saturated well-casing volumes using a dedicated Bennett Pump. WUABFFMW01 will be monitored in accordance with the procedures for gauging and sampling described in the following sections and will be analyzed for the parameters summarized in **Table 2.**

WUABFFMW01 will be sampled during two sampling events, the first sample collected 2 weeks following the completion of well development and the second sampling event conducted approximately 30 to 90 days after the initial sampling event. If EDB is identified in the initial sample, the second sampling event will be conducted approximately 30 days after the initial sampling event. If EDB is not identified in the initial sample, the second sample will be collected within 90 days of the initial sampling event. The sections below describe the procedures that will be employed for groundwater gauging and sample collection. Liquid IDW will be generated from groundwater sampling and decontamination activities and will be managed, characterized, and disposed of per the procedures outlined in Section 5.6.

5.1 Premobilization Activities

Several tasks and/or logistics need to be completed before sampling begins. The activities include the following:

- Purchasing and setting up a dedicated sampling system for WUABFFMW01. This dedicated system includes a Bennett Pump, tubing bundle with sufficient length to sample the middle of the screen, dedicated transducer cable/data logger/connector, a dedicated generator, and a trailer on which to mount the equipment.
- Set up traffic control, if warranted.
- Purchase the PDBs and DMSs from Eon. More information is provided in Section 5.3.2.

5.2 Groundwater Gauging

Depth to groundwater and depth to LNAPL, if present, will be measured prior to sampling. LNAPL is not anticipated to be present in WUABFFMW01, but an electronic oil-water interface probe will be used to confirm LNAPL is not present at the water surface. Upon retraction, the well gauging tape should be thoroughly decontaminated in accordance with Section 5.6.2. Well gauging activities shall be conducted in accordance with INTERA SOPs. The gauging measurement, along with measurement date and time, will be recorded in the field logbook.

5.3 Groundwater Sampling Procedures

Two groundwater sampling methods will be used to collect samples from WUABFFMW01. The methods are described in the following sections.

5.3.1 Method 1: PDB and DMS

Before each sampling event, the PDBs and DMSs and accessories will need to be ordered from Eon (https://store.eonpro.com/store/c/71-Water-Sampling-Pumping.aspx) with enough time for Eon to (1) build the order based on the INTERA provided well specifications (total depth, screened interval, water level, well diameter, and the proposed analytical suite) and (2) ship the samplers.

Before the tethered line of PDB and DMS samplers are deployed downhole into the screened interval, the groundwater level will be gauged as discussed in Section 5.1. Once the samplers are deployed in the screened interval, they will be left downhole for a minimum of 3 weeks. The samplers will be deployed, retrieved, and samples will be collected following the Eon's PDB and DMS Sampler SOPs provided in **Appendix D**.

5.3.2 Method 2: Purging and Low-Flow Sampling using a Bennet Pump

WUABFFMW01 will be sampled using low-flow sampling methods in accordance with industry guidance (ASTM, 2002). Low-Flow sampling will occur after the PDB/DMS Method 1 sample collection. WUABFFMW01 will be purged using a dedicated Bennett Pump. The pump will be placed in the center of the well screen, the flow rate will be adjusted for minimal drawdown (<0.3 ft) using low-flow rates between 0.05 and 0.13 gallons per minute (gpm) (ASTM, 2002). During purging activities, groundwater quality parameters (specific conductivity, temperature, turbidity and pH) will be monitored for stabilization using a YSI Plus 1030 water quality meter or similar water quality meter and a separate turbidity meter. Stability is defined as measurements within 10 percent (%) of each other for specific conductivity and temperature, within 0.5 standard units for pH, and turbidity is either below 10 nephelometric turbidity units (NTUs) or measurements within 10% of each other. Purging will be considered complete when the monitoring well has been purged a minimum of 3 saturated well-casing volumes and the groundwater quality parameters have stabilized for 3 consecutive readings. This approach is being conducted to be consistent with NMED requirements of the KAFB BFF monitoring work and past Air Force sampling practices. Once achieved, a sample will be collected. All purge, water quality data and sample collection data and will be documented on the designated field form(s) (**Appendix B**). Final water quality stabilization values, sample collection time and total water purged will be documented in the field logbook. Purge water will be containerized in a 55-gallon drum(s).

5.4 Groundwater Sample Collection, Packing and Shipping

Groundwater samples will be collected by two sampling methods in the following order: (1) PDBs and DMSs and (2) a combination of low-flow sampling and purging three saturated well-casing volumes using a dedicated Bennett Pump. General adherence to INTERA's Monitoring Well Groundwater Sampling SOP (**Appendix C**) will also be followed.

Upon collection and labeling, samples shall be packed for delivery to Eurofins. For samples with short holding time requirements (**Table 2**), INTERA will deliver such samples to Eurofins via FedEx overnight delivery to avoid missing a short hold time (48 hours). Note that some analytical methods will require field filtering.

Until shipment or drop off at the laboratory, sample integrity will be maintained in the field by INTERA field personnel using appropriate sample handling procedures. Specifically, appropriate sample preservation techniques (e.g., chemical preservations, stored in coolers with ice) will be applied to collected samples, samples will be packaged to prevent breakage or cross-contamination, and samples will remain under the control (e.g., within sight, locked storage) of the Field Sampling Team until custody is relinquished to the overnight delivery service. If samples are held overnight, sufficient ice (if necessary) will be added to the cooler to maintain the required preservation temperature of 6°C and the coolers will be kept in a locked, secure location.

All samples being collected for laboratory analysis will require INTERA transfer from the Site to Eurofins. When transporting samples by vehicle, the following steps should be completed:

1. Select a sturdy cooler in good condition. Secure and tape the drain plug with duct tape both inside and outside.
2. Be sure the caps on all bottles are tight (will not leak); check to see that labels and chain-of-custody records are completed properly.
3. Place all bottles in separate and appropriately sized plastic zip-top bags and close the bags. Up to three VOC vials may be packed in one bag. Bottles may be wrapped in bubble wrap. It is preferable to place glass sample bottles and jars into the cooler vertically. Due to the strength properties of a glass container, there is much less chance for breakage when the container is packed vertically rather than horizontally.
4. Put ice and sample containers in a large garbage bag(s) and properly seal with tape (if shipping).
5. Place the completed chain-of-custody form into a plastic zip-top bag, tape the bag to the inner side of the cooler's lid, and then close the cooler.

Upon laboratory receipt, laboratory personnel will open the shipping container and sign the chain-of-custody form to document transfer of samples. A copy of the chain-of-custody form will be provided to INTERA by Eurofins via email. INTERA will provide all copies of chain-of-custody forms to the Water Authority upon receipt and as part of an attachment to the Final Report.

5.5 Analytical Requirements and Sample Quality Control

As identified in Section 3.1.3, Eurofins has been selected to provide the required fixed-laboratory analytical services needed for the Project. Groundwater samples will be collected, labeled, packaged, and submitted to Eurofins via overnight delivery for the following analyses:

- VOCs via United States Environmental Protection Agency (EPA) Method 8260.
- Semi volatile organic compounds (SVOCs) via EPA Method 8270.
- Metals via EPA Method 6010.
- Anions via EPA Method E300.0.
- EDB via EPA Method 8011.
- Alkalinity via EPA Method SM2320B.

Table 2 lists the laboratory preservation requirements and hold times for each method of analysis.

5.6 Instrument Testing, Inspection, and Maintenance

All equipment used during the remediation activities will be properly tested, inspected, maintained, and calibrated.

5.6.1 Instrument Calibration

Numerous instruments are commercially available for procurement of environmental data and often more than one instrument make/model/type is approved for a particular function. Although this Work Plan/SAP identifies (in **Section 5.3.1** above) certain makes and models of instruments anticipated for use during this project; the potential always exists that alternate instruments considered equivalent to those proposed may be selected. As such, setup and implementation of any instrument selected for this project should follow a basic format that applies consistency of use. Regardless of the brand of instrument used, all should be properly maintained, calibrated, and operated in accordance with the manufacturer's instructions. Calibration fluids for any instrument used should be National Institute of Standards and Technology (NIST)-traceable and there should be enough volume to conduct one or more daily calibrations throughout the sampling event (as required by the manufacturer's specifications).

5.6.1.1 Field Equipment

All utilized field instrumentation should be calibrated at least daily prior to its first use. Re-calibrations or field checks should also be performed throughout the field day to verify that the equipment is operating properly; the frequency for which these checks should be performed is typically stipulated in the accompanying manufacturer's instructions.

With every calibration, the results and methods should be recorded in the field logbook and/or on a calibration log sheet accompanying the instrument. At a minimum, the following information shall be recorded:

- Date and time of calibration.
- Type and identification number of equipment being calibrated.
- Reference standard(s) used for calibration.
- Name or initials of person performing the calibration.

The FTL (or qualified designee) is responsible for ensuring the proper quality checks of the field equipment are routinely performed and recorded.

5.6.2 Equipment Decontamination

Equipment decontamination should be completed within a designated work area. For this project, equipment anticipated to require decontamination will be drilling equipment and non-disposable sample equipment. All reusable equipment will be decontaminated before use and between discrete sampling events in accordance with the INTERA SOP provided in **Appendix C.** Equipment will be cleaned using Liquinox (or equivalent) soap and rinsed twice, final rinse will be with distilled or deionized water. Any material removed or generated in response to decontamination shall be managed as IDW as outlined below in **Section 5.7**.

5.7 Investigation-Derived Waste

IDW generated from this project will be managed as specified in this Work Plan/SAP. Waste volumes will be minimized to the extent practical. Based on the location of t WUABFFMW01, along with historical data at the BFF project site, the IDW from this project is anticipated to be nonhazardous.

5.7.1 Soil Investigation-Derived Waste

Soil will be 100% captured and contained at the drill site and/or lay down area. All necessary equipment will be provided to contain and transport soil IDW back to the storage area for characterization, temporary storage and/or disposal.

For profiling soil cuttings, each container will be characterized for disposal with a 5-point composite IDW sample. The soil samples will be analyzed for the suites outlined in **Table 2** to determine if they meet the waste acceptance criteria for a receiving landfill, either the City of Albuquerque Cerro Colorado Landfill in Albuquerque or the Waste Management Landfill Facility in Valencia County.

Once the analytical results are received and reviewed, the IDW will disposed of at the proper waste facility by AES under INTERA oversight. Analytical results for the IDW profiling sampling, waste management forms, and chain-of-custody documentation for sampling will be submitted to the Water Authority upon receipt. Waste manifests will also be provided to the Water Authority for signature.

5.7.2 Water Investigation-Derived Waste

All water generated during drilling, well development, decontamination or during sampling events will be 100% captured and contained. One sample of drilling and/or development water will be analyzed, as summarized in **Table 2** for waste profiling before disposal.

Purge water from sampling WUABFFMW01 will be containerized and held in a designated staging area as approved by Water Authority, pending receipt of analytical data to establish a nonhazardous waste profile. The liquid IDW sample will be analyzed for the parameters summarized in **Table 2.** Once analytical results have been received and reviewed, the liquid IDW will be disposed of in the proper waste facility or if warranted, disposed on an impervious surface to evaporate. Analytical results for the IDW profiling sampling, waste management forms, and chain-of-custody documentation for sampling will be submitted to the Water Authority upon receipt. A waste manifest for the liquid IDW waste stream will be provided to the Water Authority for signature.

Based on analytical results from KAFB BFF monitoring wells in the vicinity, the liquid IDW could have concentrations of EDB, iron and manganese above New Mexico Water Quality Control Commission (WQCC) groundwater protection standards. If the liquid IDW water does have elevated concentrations of EDB, iron and/or manganese, the water will need to be transported off-site for disposal. If the liquid IDW samples indicate that EDB, iron, and manganese are not present, the liquid IDW containers will be transported off-Site by AES for disposal at their facility in Belen, New Mexico.

6.0 SLUG TESTING

Pneumatic slug tests will be performed by pumping air into WUABFFMW01 until the desired increased pressure is reached and the water level stabilizes. Once stabilized, the pressure is “instantaneously” released and the water level allowed to re-equilibrate. The rapid release of pressure represents the removal of a “slug” of water. Aquifer parameters such as hydraulic conductivity, specific storage, and other aquifer characteristics may be estimated from the pressure recovery curve after the “slug” is removed. Multiple tests at varying pressures will be performed at WUABFFMW01 and other nearby KAFB BFF monitoring wells. The list of wells will be determined in coordination with KAFB. The Water Authority will provide the list of wells two weeks prior to mobilization for slug testing.

6.1 Premobilization Activities

Several tasks and/or logistics need to be completed before sampling begins. The activities include the following:

- A water level meter and data cables capable of ~600-ft depths.
- Set up traffic control, as warranted.
- Testing will take multiple days. Field equipment will be transported to and from the site each day.

6.2 Groundwater Gauging

Depth to groundwater will be measured prior to slug testing. LNAPL is not anticipated to be present in WUABFFMW01, but an electronic oil-water interface probe will be used to confirm this during well sampling. Well gauging activities shall be conducted in accordance with INTERA SOPs. All wells subject to slug testing will be gauged and recorded on a field form including measurement date and time.

6.3 Slug Testing Procedures

- INTERA will perform and analyze pneumatic slug tests on WUABFFMW01 and up to five nearby Air Force monitoring wells.

- The slug tests will be performed following ground water sampling (both Methods 1 and 2). Slug testing activities will be performed in accordance with ASTM standards. In general, the tests will be performed by pumping air into the well until the desired increased pressure is reached and water level stabilizes. Once stabilized, the pressure is “instantaneously” released, and the water level is allowed to re-equilibrate. The rapid release of pressure represents the removal of a “slug” of water. An estimate of hydraulic conductivity can be derived from the pressure recovery curve after the slug is removed. A pressure transducer and data logger will be used to collect the water-level recovery curve data. The Water Authority’s Level TROLL 700 data logger will be used for data logging.

- Multiple pneumatic tests will be performed at WUABFFMW01 with varying pressures.
- Slug test data will be analyzed using nSIGHTS software or equivalent industry standard aquifer test analysis methods. The analysis will consider typically ignored effects related to “in-well” hydrodynamic processes such as water level oscillations and skin effects using the nSIGHTS code (developed by INTERA for Sandia National Laboratories), which is one of the most advanced well testing analysis codes available. Multiple analytical curve-matching methods will be implemented for interpretation comparison. Results of the analysis will give estimates of hydraulic conductivity (K) values. Specific storage (S_s), and anisotropy ratios (K_y/K_h) for each well are typically reported but are not considered reliable when using data from a single-well test.
- Slug test results will be included in the Final Report and illustrated on Task 4 lithologic logging results.

7.0 FINAL REPORT

A final report that documents field activities, final construction design, slug testing results and analysis, and water quality data results will be prepared and submitted to Water Authority. In addition of a technical report, the AECOM (2015) A-A' cross-section will be updated to include the geologic data observed during the drilling of WUABFFMW01 as well as the EDB plume extent as defined by the results of WUABFFMW01 (INTERA, 2021b). The report will include all field documentation (e.g. field notes, photographs, lithologic logs, etc.), water quality data summary tables, and estimated aquifer parameters from the slug test analysis. Any deviations from the Work Plan/SAP will be clearly documented in the final report. Additionally, GIS files as well as source files associated with the tasks described in this Work Plan will be submitted to the Water Authority with the final report.

8.0 SCHEDULE

The drilling, well completion, development, and sampling schedules are described below.

- Drilling operations are scheduled to commence on January 24, 2022. The drilling, logging, well completion, and development are estimated to take approximately 20 working days (estimated completion by February 18, 2022).
- Low-flow groundwater sampling will take place 2 weeks after well completion and take approximately 2 days (estimated completion by March 8, 2022). This includes installation and removal of the portable sampling pump. Analytical results are expected on standard turnaround within 10 days of sampling (to March 18, 2022)
- The pneumatic slug testing will commence after groundwater sampling and should be completed within 5 days (estimated completion by March 15, 2022). This may or may not include testing of the additional wells.
- The passive diffusion sampling bags will be installed in the well upon completion of the slug testing.
- Slug test analysis is expected to be completed by March 23, 2022.
- An additional groundwater sampling event will be conducted 30 to 90 days after the initial sampling event Both Methods 1 and 2 (PDB and low-flow sampling) will be utilized during the second sampling event.
- A copy of the updated schedule is included as Table 3.

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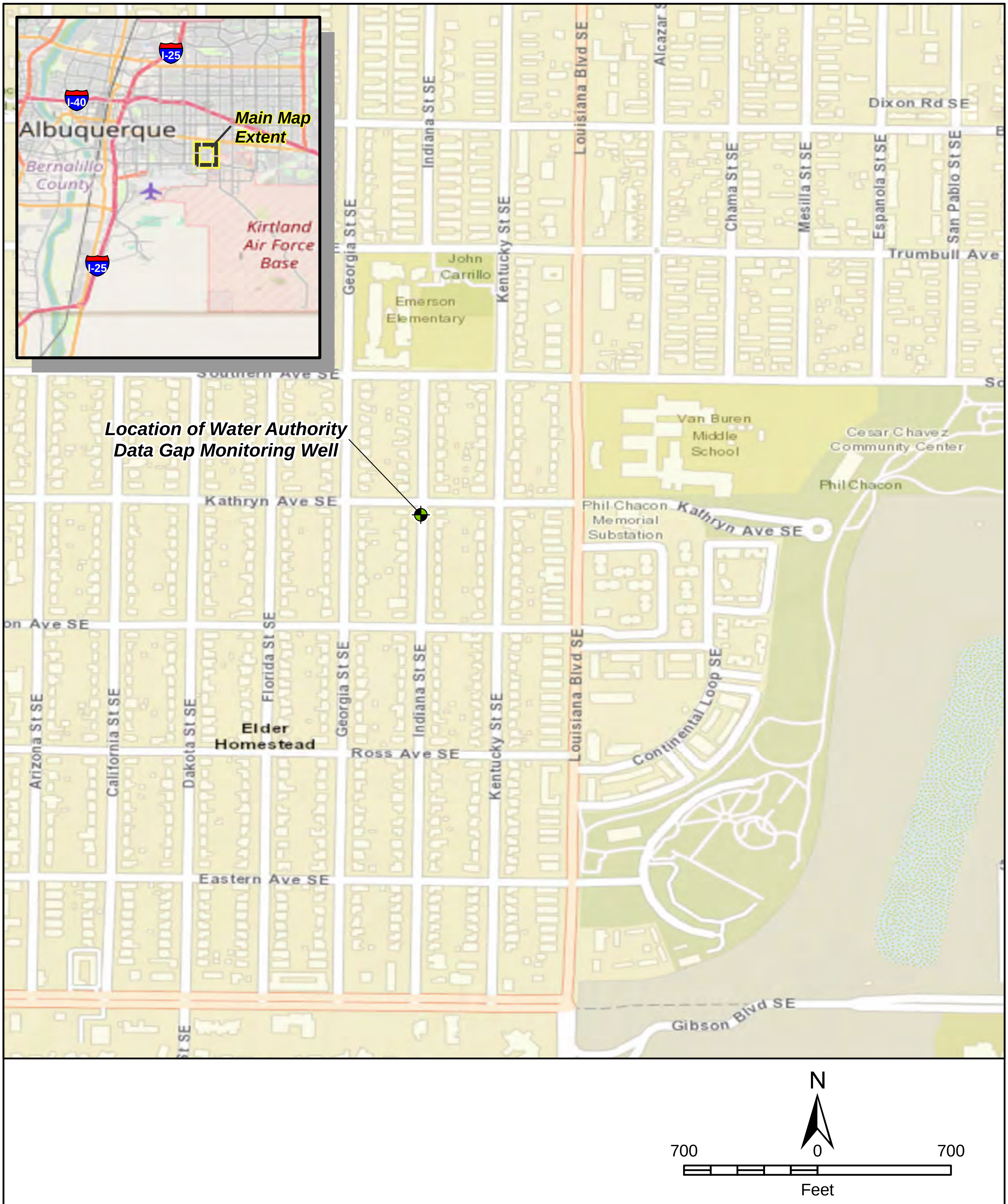
FIGURES

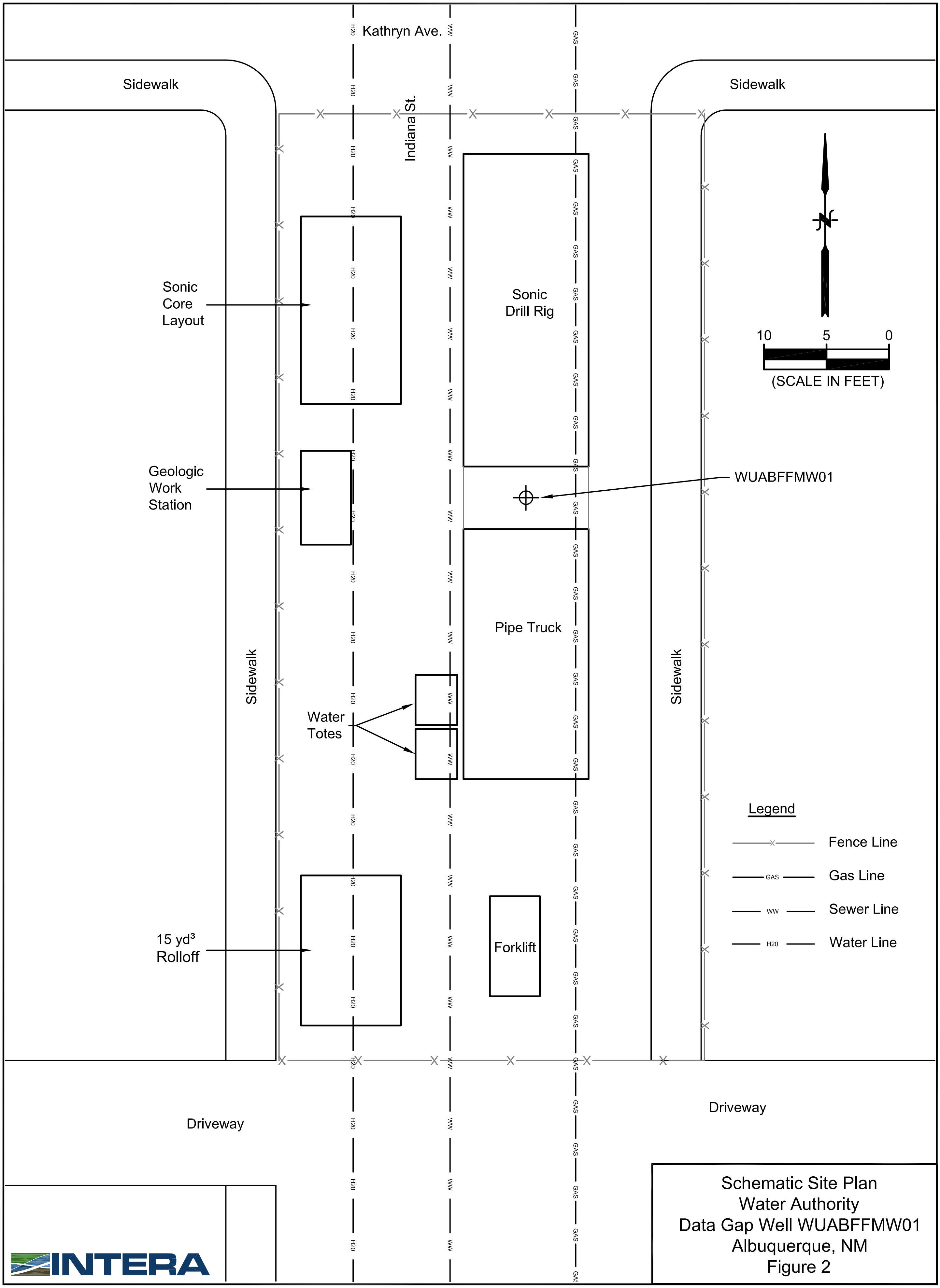


Location of Water Authority Data Gap Monitoring Well

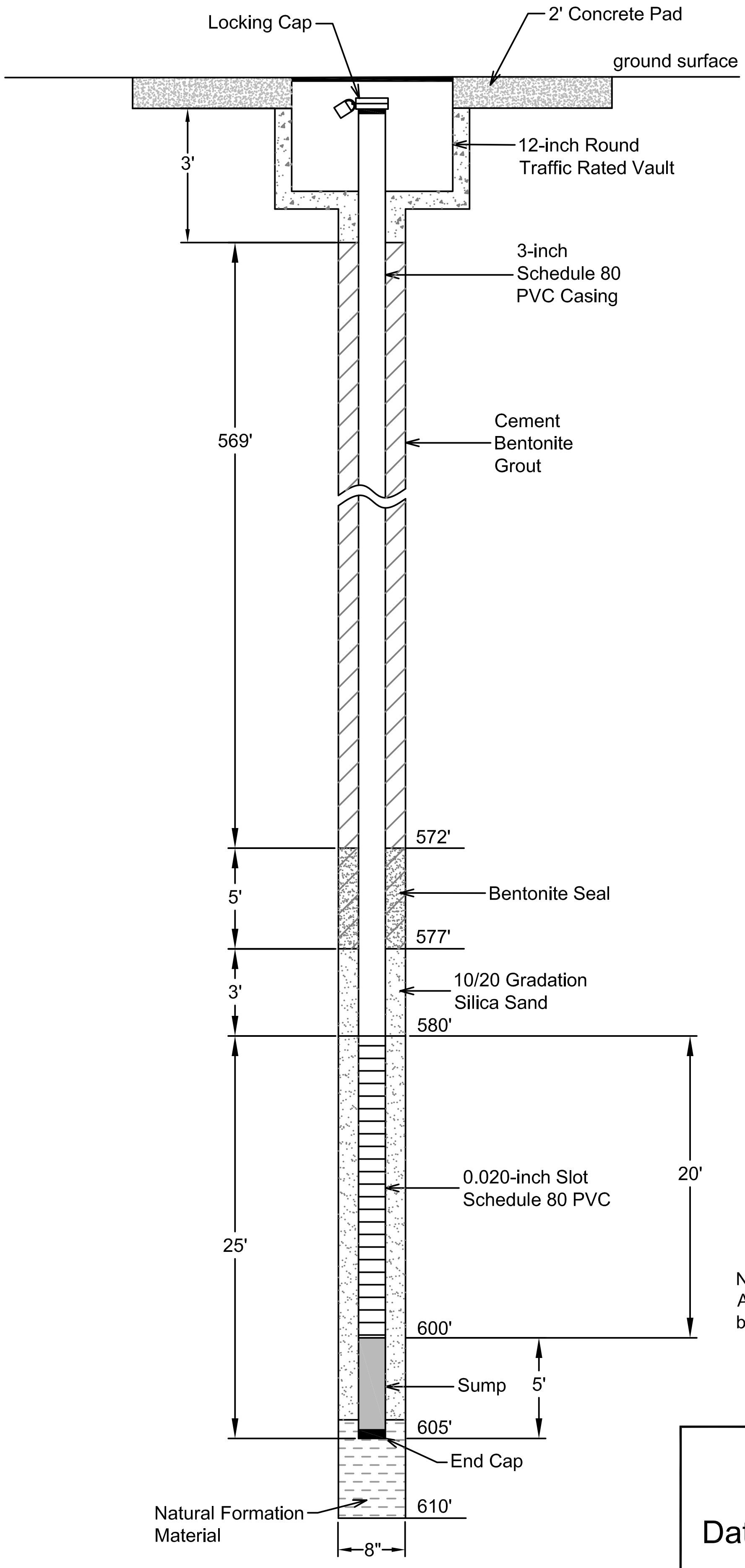
WUABFFMW01 Location
Water Authority Data Gap Well
Bernalillo County, New Mexico
Figure 1

INTERA

FILE: S:\ABQ\ABWUA.C009.KAFB\Data_Gap_Well\Graphics\GIS\Map_Docs\00_WADataGapWellLoc.mxd Date: 12/7/2021



Schematic Site Plan
Water Authority
Data Gap Well WUABFFMW01
Albuquerque, NM
Figure 2



NOTE:
Actual boring and well depth to be determined based on Lithologic and Geophysical logging

Well TD approx. = 605' bgs
Boring TD approx. = 610' bgs

INTERA

NOT TO SCALE

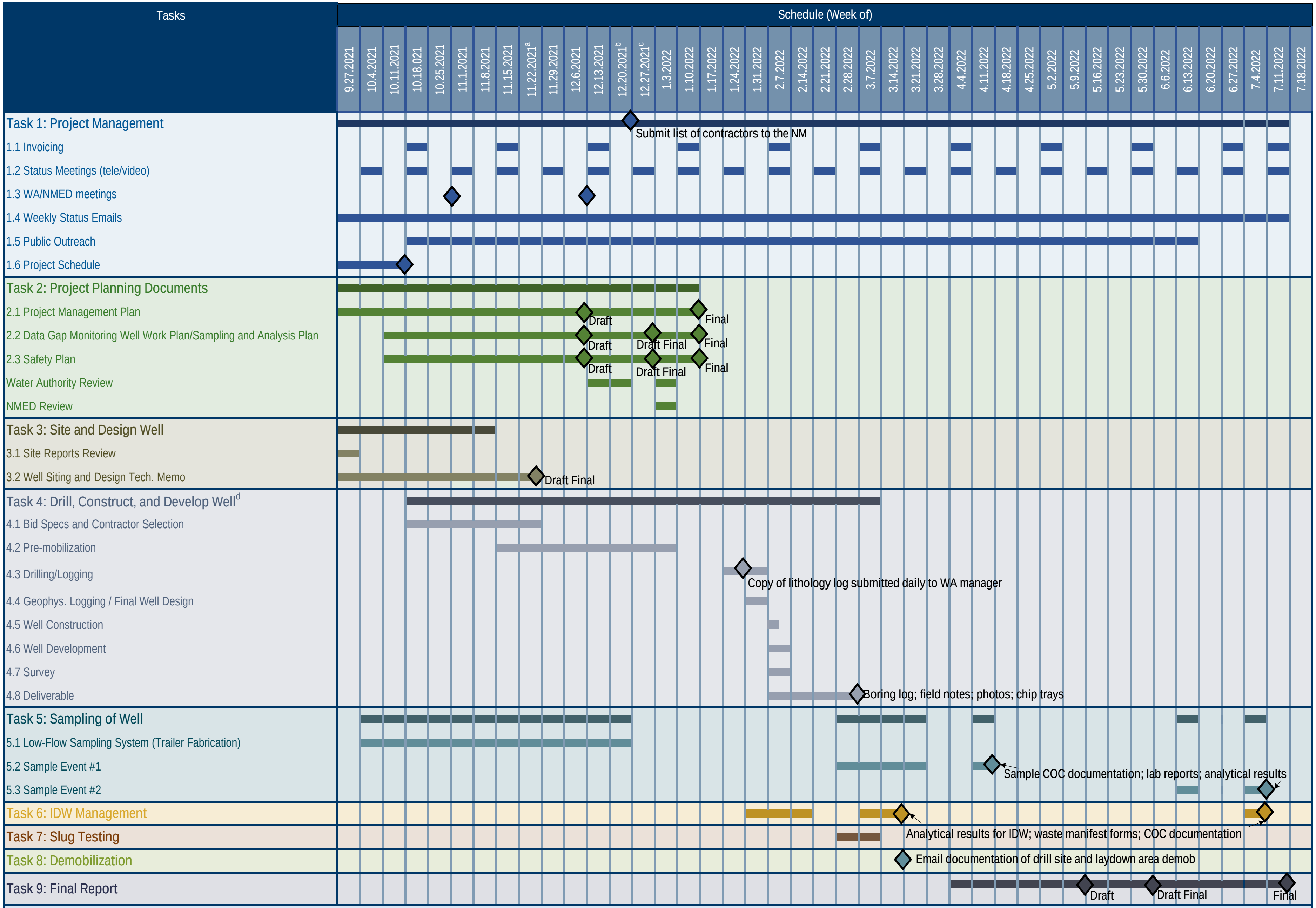
Schematic Well Diagram
Water Authority
Data Gap Well WUABFFMW01
Albuquerque, NM
Figure 3

TABLES

TABLE 2
Analytical Parameter, Matrix, Method, Sample Container, Preservation, and Holding Time Requirements
Work Plan and Sampling and Analysis Plan Data Gap Monitoring Well Installation

Target Analytes	Sample Purpose	Matrix	Analytical Method	Sample Volume/Container	Preservative	Holding Time
SVOCs	GWM & IDW	Water	EPA Method 8270	1- L Amber	None; Cool to 6°C	7 days
Anions (chloride, bromide, sulfate)	GWM	Water	EPA Method E300.0	1- 250mL glass or HDPE	None; Cool to 6°C	28 days
Anions (Nitrate/Nitrite nitrogen)	GWM	Water	EPA Method E353.2	2x 250mL glass or HDPE	Sulfuric Acid; Cool to 6°C; pH<2	**48 hours if filtered;** 28 days if not filtered
Alkalinity (Bicarbonate/Carbonate)	GWM	Water	EPA Method SM2320B	1- 250mL glass or HDPE	None; Cool to 6°C	14 days
VOCs	GWM & IDW	Water	EPA Method 8260	3-40 mL VOA	HCl; Cool to 6°C; pH<2	14 days
Ethylene Dibromide (EDB)	GWM & IDW	Water	EPA Method 8011	2- 40mL VOA	HCl; Cool to 6°C; pH<2	14 days
Total Metals (calcium, magnesium, potasium, sodium)(arsenic, lead)	GWM & IDW	Water	EPA Method 6010C/6020A	1x 250 HDPE	Nitric Acid; Cool to 6°C; pH<2	180 days
Dissolved Metals (iron, manganese)	GWM & IDW	Water	EPA Method 6010C			
Flashpoint	IDW	Water	EPA Method SW1010A	1- 250mL HDPE	None; Cool to 6°C	NA
pH	IDW	Water	EPA Method 9040C	1- 250mL HDPE	None; Cool to 6°C	Upon receipt
VOCs	IDW	Soil	SW5035A/8260C	3 x EnCore/ Terracore samplers; 1 x 4-oz; Glass	None; Cool ≤6°C	14 days
SVOCs	IDW	Soil	SW3546/8270D	1 x 8-oz glass	None; Cool ≤6°C	40 days
Ethylene dibromide	IDW	Soil	SW8011	1 x 8-oz glass	None; Cool ≤6°C	14 days
Metals	IDW	Soil	SW6010C	1 x 8-oz glass	None; Cool ≤6°C	180 days
Mercury	IDW	Soil	SW7471B	1 x 8-oz glass	None; Cool ≤6°C	28 days
Ignitability	IDW	Soil	SW1020A	1 x 8-oz glass	None; Cool ≤6°C	NA
pH	IDW	Soil	SW9045C	1 x 8-oz glass	None; Cool ≤6°C	NA
Cyanide, Total and/or Amenable	IDW	Soil	SW9012B	1 x 8-oz glass	None; Cool ≤6°C	28 days
Pesticides	IDW	Soil	SW3546/8081B	1 x 8-oz glass	None; Cool ≤6°C	40 days
Herbicides	IDW	Soil	SW3550C/8151A	1 x 8-oz glass	None; Cool ≤6°C	40 days
Toxicity characteristic leaching procedure	IDW	Soil	SW1311	8-oz glass per parameter/method	NA	NA

Table 3 - Revised Schedule



◆ Deliverable (labeled where not evident based on subtask title); WA = Water Authority, COC = chain-of-custody; [a] INTERA assumes that work will not occur on 11.25.2021 or 11.26.2021 due to the Thanksgiving Holiday; [b] INTERA assumes that work will not occur on 12.24.2021 due to the Christmas Eve Holiday; [c] INTERA assumes that work will not occur on 12.31.2021 due to the New Year's Eve Holiday; [d] This schedule assumes a Monday – Friday from 7:30 am to 5:00 pm work week during drilling activities; The proposed schedule could be impacted by weather, especially during the winter months.

APPENDIX A

INTERA Technical Memo dated November 19, 2021

INTERA Incorporated
2440 Louisiana Blvd. NE, Suite 700
Albuquerque, NM 87110 USA
505.246.1600

TECHNICAL MEMORANDUM

To: Ms. Diane Agnew, Albuquerque Bernalillo County Water Utility Authority

From: INTERA Incorporated

Date: November 19, 2021

Re: Proposed Monitoring Well Location and Screened Interval for the Water Authority Data Gap Well

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1.0 Introduction

This Technical Memorandum (Tech Memo) describes the data and processes used to identify candidate locations for the proposed Albuquerque Bernalillo County Water Utility Authority (Water Authority) Data Gap Well within the area of interest (AOI). The Data Gap Well is intended to provide groundwater quality data that will constrain the vertical distribution of ethylene dibromide (EDB) contamination in the distal (i.e., north) end of the Kirtland Airforce Base (KAFB) Bulk Fuel Facility's (BFF) groundwater plume. KAFB installed monitoring wells to delineate the extent of the >1-mile-long EDB plume emanating from the BFF source area. Having raised questions about the relatively poor vertical delineation of the EDB plume numerous times in the past, the Water Authority is concerned that the current BFF monitoring well network has not been sufficient to discern the limits of EDB in groundwater either laterally or vertically.

The potential for there to be a data gap was identified in the INTERA (2017) Technical Memorandum that provided review comments on the latest version of the Resource Conservation and Recovery Act (RCRA) Facilities Investigation (RFI) report. INTERA (2017) identified intervals within the aquifer where EDB could potentially escape detection in the existing well network, leading to EDB migration downgradient toward Water Authority groundwater supply wells (e.g., Ridgecrest 5) and KAFB supply well KAFB-003. The AOI (**Figure 1**), within which the Data Gap Well will be installed, was previously defined by the Water Authority in Request for Bid (RFB) P2022000002 (Water Authority, 2021) and was based on the Water Authority RFI Review. Based on the RFI review, published geologic literature, local monitoring well lithologic logs, screen interval data, and EDB analytical data, INTERA proposes a recommended location and completion depth for the Data Gap Well.

The following sections of this Tech Memo describe the background geology and hydrogeology, site-specific geology, hydrogeology, and historical EDB concentration distributions. Finally, this document presents a recommendation for the location and screened interval depth for the Data Gap Well.

2.0 Background Geology and Hydrogeology

The following geologic summary is primarily from the early works by Hawley and Hasse (1992); extensive studies by Connell et al. (2004); Connell (2006); Grauch and Connell (2013); and Powell and McKean, (2014); and most recently work of the United States Geological Survey (USGS) publication of Meyers and Friesz (2019). INTERA has found these publications to be the most detailed hydrogeologic works in the

Albuquerque Basin. Figure 2 from the Meyers and Friesz (2019) paper has been modified and included as **Figure 2** in this Tech Memo to provide geologic and hydrogeologic context.

The project site is in the Albuquerque Basin, and the subsurface sediments consist of unconsolidated sand, silt, clay, and occasional gravel zones in the Santa Fe Group of Oligocene to Pleistocene age. The Santa Fe Group has been divided into lower, middle, and upper lithostratigraphic units based on lithology and age. The upper Santa Fe group is of most significance to the Data Gap Well and consists of the Ceja and Sierra Ladrones Formations. The Ceja Formation (older) is interpreted to have been deposited by fluvial processes sourced from west of the basin. The Sierra Ladrones Formation (younger) consists of ancestral Rio Grande axial-fluvial sediments transported from the north and piedmont-slope deposits derived from mountains to the east. Hawley and Hasse (1992) identify the fluvial deposits as the major hydrostratigraphic units: “Coarse-grained channel deposits of the modern and ancestral Rio Grande (lithofacies I and II) are the major components of the upper Santa Fe (USF-w) and river alluvium (RA) hydrostratigraphic units.” These deposits form a preferential groundwater flow corridor, as described by Meyers and Friesz (2019), who also reference Powell and McKean (2014):

> “The axial-fluvial deposits form an important geologic feature that greatly influences groundwater flow. The axial-fluvial sediments, deposited by the ancestral Rio Grande, form a north-northeast to south-southwest trending corridor of deposits (between the western and eastern limits of axial-fluvial sediments) with relatively higher conductivities. Given the same hydraulic gradients and effective porosities, groundwater within this corridor of higher hydraulic conductivity will flow at a faster volumetric rate than groundwater outside the corridor where hydraulic conductivities are lower. The axial-fluvial sediments, then, form a preferred corridor of flow, within which groundwater near the EDB plume flowed toward the northeast towards a large area of groundwater-level drawdown (Powell and McKean, 2014).”

The axial-fluvial sediments of the Sierra Ladrones Formation interfinger with sediments of the Ceja Formation in the central part of the basin and with the piedmont-slope deposits on the eastern side of the basin. As the channel of the ancestral Rio Grande shifted from the eastern side of the basin towards its present-day position near the center of the basin, piedmont-slope sediments overtopped axial-fluvial sediments and prograded westward as the river retreated. Fault movements on the east side of the basin caused the ancestral Rio Grande to shift to the east side of the basin, resulting in a stacked sequence of braided river-channel sediments in the eastern Middle Rio Grande Basin (Connell, 2004; Grauch and Connell, 2013). The axial-fluvial sediments have been characterized as braided river deposits consisting of coarse channel fill and bar sediments interbedded with silts and clays deposited in overbank and incipient floodplain environments (Agnew et al., 2016).

The result of these processes is a layer of piedmont-slope deposits that are up to approximately 200 feet (ft) thick, underlain by a sequence of fluvial-axial sediments that can be over 1,500 ft thick (Connell, 2006, cross section C-C’, Plate 2). Based on a set of select wells chosen by INTERA that are within and proximal to the AOI for the Data Gap Well (**Figure 1**), the historical minimum and maximum depth to groundwater ranged from 433 to 493 ft below ground surface (bgs) (**Table 1**). This indicates that the wells within and proximal to the AOI are completed in the fluvial-axial sediments of the Sierra Ladrones Formation.

Within the Sierra Ladrones Formation are two lithologic units characterized by abundant silt and clay layers, named A1 (lower) and A2 (upper). These units represent periods of lower energy deposition within the basin, and lower hydraulic conductivities, as compared to higher energy deposition of the fluvial-axial sand and gravel deposits, which have higher relative hydraulic conductivities. The elevations of the top and base of these units have been mapped by the USGS, providing structural contours within the study area. Notably, these fine-grained units are absent east of the Eubank Fault (**Figure 2**). The top of the A2 unit is approximately 800 to 900 ft bgs in the study area. These two units are recognized as influencing groundwater flow in the basin, but monitoring wells within and proximal to the AOI are screened above these units.

Interbedded silt and clay deposits are present within the Sierra Ladrones Formation and at depths that are pertinent to the Data Gap Well; however, there is little likelihood that these fine-grained layers are laterally continuous. These fine-grained beds are within the braided axial-fluvial sediments of the ancestral Rio Grande. These types of deposits are well known in the geologic literature and are described by Selley (1982) as “shoestring” silts or clays and are derived from the small amount of silt and/or clay that gets deposited in abandoned channels of braided alluvium. The geometry of these types of deposits tends to be linear and not laterally continuous.

Faults that dip west have been mapped in the study area (**Figure 2**). These faults trend approximately north to south and are spaced approximately 1 mile apart from near the front of the Sandia Mountains to the west side of the basin near Rio Rancho, New Mexico. Many of the water supply wells that are northeast of the KAFB BFF EDB plume (e.g., RC-3, RC-4, and RC-5) are east of the Coronado-Alameda Fault (**Figure 2**), which has approximately 70 ft of displacement (Meyers et al., 2019). Although these faults are well documented in the geologic literature (e.g., Connell, 2006), their possible influence on groundwater flow in the study area is not well known.

In summary, the geologic and hydrogeologic framework of the site vicinity and at the relevant depths for the Data Gap Well consist of braided ancestral Rio Grande axial-fluvial sediments of the Sierra Ladrones Formation of the Santa Fe Group, consisting of unconsolidated sand, silt, clay, and gravel layers, with medium- to coarse-grained sand being the dominant sediment type.

3.0 Site-Specific Geology and Hydrogeology

For this Tech Memo, AECOM’s (2015) regional-scale and plume-scale cross sections, and other site-specific data were evaluated. A discussion of hydrogeologic data from these sources and their relevance for selecting the Data Gap Well location and screened interval completion depth is provided below. AECOM’s (2015) T1 cross section was especially useful for this evaluation since it is aligned along the EDB plume’s longitudinal axis, crosses the AOI, and was used in INTERA’s 2017 review of the RFI to illustrate the gap in delineation of the vertical extent of the EDB plume. Regarding this gap, the figure used to support INTERA’s RFI review findings is provided in this Tech Memo as **Figure 3**. **Figure 1** provides the line of section for this cross section**.** The wells in **Figure 3** are in line from southwest to northeast through the AOI, except for well 106232, which is northwest of the line of section approximately 500 ft and is projected onto the section.

To further aid in the evaluation of the site-specific geology and hydrogeology, INTERA tabulated a list of select wells within and near the AOI and compiled their lithologic logs and historical depth to water (DTW) measurements (**Table 1**). As shown by the highlighted wells on **Table 1**, five wells (106215, 106221, 106224, 106227, and 106230) were drilled by a combination of air rotary casing hammer (ARCH) method (to a depth of approximately 450 ft bgs, which is near the water table) and the roto-sonic method to total depth. A sixth well (106234), which is also highlighted on **Table 1,** was cored while being drilled by mud rotary methods. Other wells included in **Table 1** were drilled entirely by ARCH methods. The sonic- and core-drilled intervals delivered continuous sediment core samples, as compared with the drill cuttings produced and logged from the ARCH drilling method. The lithologic logs from the sonic and mud rotary core resulted in more detailed delineation of all sediment types, but especially the relatively thin fine-grained layers, which are more easily missed in ARCH samples. The bore logs for these select wells are included with this Tech Memo as **Attachment 1**.

Upon inspection of the lithology provided in the cross section presented in **Figure 3,** a gravelly unit (indicated as orange and red) was identified that generally correlates across the cross section in the interval identified by INTERA (2017) as being a EDB data gap. A review of the boring logs for wells on the **Figure 3** cross section and boring logs for nearby wells drilled to depths between 500 and 600 ft bgs support that correlation (**Figure 4**). This coarse-grained unit is likely one of the channel deposits within the ancestral Rio Grande braided deposits that are referenced above. As indicated on the **Figure 3** and **Figure 4** cross section, these units typically have relatively high hydraulic conductivity and transmit large volumes of groundwater and, consequently, are a target interval for the screen of the Data Gap Well.

Descriptions of this unit in the boring logs generated for wells drilled by the ARCH method depict this coarse-grained unit as a fairly homogenous unit of well graded and poorly graded sand with interbedded layers of up to 35% gravel (with no silt or clay logged below 183 ft bgs to total depth of 625 ft bgs). In contrast, the boring logs generated from cores produced by sonic methods show a more heterogeneous mixture that, in addition to the thick sequences of coarse-grained sediments, includes interbeds of finer-grained materials. For example, well 106227 is logged as having eight layers of clay or clayey sand between 484 and 570 ft, averaging about 1 ft thick. Descriptions of this interval for **Figure 3** wells (and their drilling method and screen interval) are as follows:

- KAFB-106037 (ARCH, screened from 507 – 522 ft bgs,): predominantly sand and gravel from 480 to 520 ft bgs.
- KAFB-106058 (ARCH, screened from 511.8 – 526.8 ft bgs): predominantly sand and gravel from 495 to 524 ft bgs.
- KAFB-106227 (ARCH and Sonic, screened from 548 – 563 ft bgs): gravel generally present from 495 to 568 ft bgs with interbeds of clay and clayey sand from 561 to 566, well graded sand with clay and gravel at 566; lean clay at 570; etc.
- KAFB-106226 (ARCH, screened from 480 – 495 ft bgs): above the target depth for the Data Gap Well.
- KAFB-106225 (ARCH, screened from 450 – 480 ft bgs): above the target depth for the Data Gap Well.

- KAFB-106234 (Mud rotary and core, screened from 439.7 – 539.7 ft bgs): predominantly sand and gravel from 490 to 556 ft bgs with silt/fine sand layers at 502.7, 520.1, and 525.6 and multiple intervals that were not recovered during the coring.
- KAFB-106206 (ARCH, screened from 593.5 – 608.2 ft bgs): predominantly sand and gravel from 520 to 570 ft bgs.
- KAFB-106232 (ARCH, screened from 503 – 518 ft bgs): predominately sand and gravel from 508 to 555 ft bgs.

Within the intervals cored for these six wells, confidence in the lithologic descriptions may be considered higher as compared to the ARCH-drilled lithologic logs. However, even in these wells, fine-grained layers are scarce and generally very thin. For example, in well 106227, a fine-grained unit is shown on the cross section (T1) from approximately 520 to 525 ft bgs, but the log in this interval shows a 1-ft-thick clay from 519 to 520 ft bgs. Although the cross section may overstate the thickness of this clay, the fact that it is identified in the sonic core lithologic log suggests that the sonic-drilled lithologic logs are the most reliable.

Although **Figure 3** shows fine-grained units correlated between some wells, many of these facies may be "shoestring" deposits (e.g., Selley, 1982) and may not be laterally continuous. During Q4 2020, groundwater elevations ranged from 4,873.94 to 4,871.29 ft above mean sea level (amsl) for monitoring wells located in and proximal to the AOI and screened in multiple zones of the aquifer (**Table 1**). The essentially identical water levels that exist in wells screened at different intervals (i.e., the shallow, middle, and deep screened intervals of a monitoring well cluster) suggest that fine-grained units within the aquifer do not create confined or semi-confined aquifer conditions.

The water table has been on a long-term rising trend as it has recovered from historical drawdown since implementation of the San Juan Chama Drinking Water Project around 2008. Fluctuations of tens of feet in response to regional groundwater pumping may occur, which may vary significantly from year to year as a function of conjunctive management of surface water and groundwater supplies. Locally, extraction wells have been operated since about December 2015 in an attempt to capture the EDB plume.

The Q4 2020 and historical maximum and minimum water levels for wells along the AECOM (2016) cross section have been projected onto **Figure 4**. A key monitoring well in the area, well 106206, had a DTW of 460.55 ft bgs when measured in Q4 2020 (EA, 2021), and the Data Gap Well is expected to have a similar DTW.

4.0 EDB Distribution

The BFF plume of detectable EDB is approximately 6,600 ft long, perhaps 2,000 ft or more in width, and tens of feet thick. The Air Force has previously estimated 40 ft in thickness, and historical maximum concentrations on **Figure 4** suggest at least that much vertical extent of contamination below the current water table. The plume delineation is uncertain due to spatial distribution of existing wells and dynamic water table conditions.

Since the RFI Review (INTERA, 2017), continued monitoring of existing wells and installation of additional data gap wells and sentinel wells have added to the knowledge base for the site; however, the horizontal and vertical extent of the distal EDB plume remain uncertain. **Figure 4** updates the AECOM (2016) cross section and was modified by INTERA (2017) to illustrate information gathered through early 2021 and the remaining uncertainty in the area of the proposed Data Gap Well. Maximum concentrations of EDB in monitoring wells in the AOI over the period of record are listed in **Table 1** and posted on **Figure 4** to indicate EDB detections over time. The most downgradient extraction well within the EDB plume, well 106234, reportedly began interim-measure extraction in December 2015 (EA, 2021). Since then, the regional gradient in the unconfined aquifer containing the EDB plume and the distribution of the EDB within the plume have likely been affected by the pumping from nearby extraction wells 106228, 106233, and 106234. As an example, for calendar year 2020, well 106234 reportedly pumped 170 gallons per minute (gpm), with 97.1% run time, and potentiometric surface maps clearly illustrate cones of depression nearby (EA, 2021). While the effect of the extraction wells is significant, it is limited in the downgradient direction, as discussed in Section 6. Therefore, there remains potential for EDB to have migrated downgradient from well 106234 at vertical intervals that are unmonitored by existing well screens.

Over much of the EDB plume area, the highest concentrations appear to correspond to the water table, but this may not be the case at the distal end of the plume. Contours indicating the approximate horizontal extent of EDB within the top 10 ft below the water table in Q4 2020 are shown on **Figure 5**. The outermost contour level of 0.01 micrograms per liter (µg/L) is on the order of typical detection limits; hence its precise location is uncertain, but it is intended to more fully delineate the area of historical EDB migration than contours showing only EDB above the Maximum Concentration Limit (MCL) of 0.05 µg/L, e.g., those in **Figure 2**.

The deepest EDB was detected at monitoring wells 106037 and 106058 for a number of years, with concentrations that were historically up to 19 and 17 times the MCL, respectively. A single detection of EDB of 0.041 µg/L occurred in 2017 in the deeper, downgradient well, 106227, but has not been repeated since then. Another deep well further downgradient, well 106206, has consistently had non-detections for EDB, as have the deep sentinel wells at more distant locations. As noted in the RFI Review (INTERA, 2017), the wells with the deepest screened intervals may be isolated from EDB migration by silt-dominated intervals as shown in **Figure 3** and **Figure 4**, provided that the deep, silt-dominated intervals are in fact continuous.

Historical maximum EDB concentrations at clustered wells in the downgradient end of the plume appear to have been highest in wells screened at intermediate depths (**Figure 4**). For example, EDB has never been detected at shallow well 106204 (screened 462.5 to 492.5 ft bgs) nor at deep well 106206 (screened 593.5 to 608.2 ft bgs), whereas intermediate well 106205 (screened 492.5 to 507.5 ft bgs) has had multiple detections, reaching a peak of 0.043 µg/L (87% of the MCL) in January 2018. This suggests the horizontal extent of EDB has been greater (migrated further downgradient) at intermediate depths than at the water table, e.g., beyond the contours shown in **Figure 6**. Recent concentrations in well 106205 have oscillated above and below detection limits – the last available result was a detection of 0.014 µg/L in January 2021. Similarly, the maximum EDB concentration at intermediate well 106226 (screened 480 to 495 ft bgs) was 1.34 µg/L (27 times the MCL) in Q4 2015, when concentrations were an order of magnitude lower in shallow well 106225 (screened 450 to 480 ft bgs) and non-detectable in deep well 106227 (screened 555 to 570 ft bgs). The maximum EDB concentration at well 106226 was also higher than historical maximum concentrations in well 106225 and 106227, as shown in **Table 1**. There is not an intrinsic property of dilute EDB plumes that would cause them to dive, but it is possible there may downward migration due to hydrostratigraphic effects and tortuosity caused by fine-grained lenses or layers.

Finally, the gap remains in vertical coverage between the screens of the intermediate wells and deep wells discussed above, so INTERA cannot rule out the possibility of a pathway to locations downgradient from well 106234 at depths between roughly 510 and 590 ft bgs (**Figure 3** and **Figure 4**), as discussed further in the following section.

5.0 Vertical EDB Data Gap Summary and Interpretations

The RFI Review cross section (**Figure 3**) depicts the EDB plume traveling north through the screened zones in wells 106037 and 106058 at a depth of approximately 507 to 526 ft bgs (green arrows). If the EDB plume continues north past these wells within this interval, it is not detected in well 106227 because that depth is not screened in well 106227. The next well in line at this depth is the extraction well, 106234. EDB has been detected in this well with concentrations gradually decreasing since the initial measurement of 0.112 µg/L in January 2016. Note that the EDB concentrations identified in well 106234 are likely diluted due to extraction across the 100-ft-long screened interval.

As described above, a significant proportion of gravel is logged in well 106234 from 502 to 556 ft bgs, making this interval a zone of high transmissivity. A gravel zone is also identified in well 106206 from 518 to 555 ft bgs, with up to 35% gravel at 555 ft bgs and lower gravel percentages below that depth. This suggests that the 555 ft depth in these wells may be the base of a braided river-channel deposit. Such a channel might be the locus of preferential EDB flow and transport.

In summary, an EDB data gap exists within the current monitoring well network due to the absence of a well or wells screened in the interval of approximately 518 to 555 ft bgs. This is most visually recognizable between wells 106206 and 106205, where the screened intervals are 593 to 608 ft bgs and 492.5 to 507.5 ft bgs, respectively, leaving a nearly 90-ft interval (data gap) that remains untested (**Figure 4**). This interval overlaps with the gravel layer in the wells described above from 518 to 555 ft bgs (37 ft) and possibly correlating with the gravel zones logged to the south in well 106234.

These lithostratigraphic relationships along with maximum historical EDB concentrations are shown on the revised cross section, **Figure 4** of this Tech Memo.

6.0 Extraction Well KAFB-106234 Capture Zone

Extraction well 106234 was designed to capture EDB in groundwater at the distal end of the BFF plume from the upper approximately 80 ft of the aquifer. Well 106234 is screened from approximately 440 ft to 540 ft bgs; the depth to the water table at this location was approximately measured at 453.5 ft bgs in late 2020 (EA, 2021). Assuming a pumping rate of 150 gpm, a horizontal hydraulic conductivity (Kh) of 150 ft/day, a Kz to Kh ratio of 0.01, effective porosity of 0.2, and a regional hydraulic gradient of 0.0005 in a direction 11 degrees east of north, extraction well 106234's 6-year capture zone is predicted to extend approximately 600 ft from the extraction well in a direction downgradient to ambient groundwater flow and 900 ft in a direction transverse to ambient groundwater flow. This area is illustrated on **Figure 6** and is considered conservative since groundwater pumping rates from well 106234 are likely less than what was used in the prediction. Groundwater containing EDB that currently exists (and historically existed) beyond this area and below the bottom of the extraction well screen will continue to flow towards the Ridgecrest Well Field and go undetected if within the unmonitored vertical zone identified above. This area beyond the capture zone of well 106234 presents the greatest risk to the Ridgecrest Well Field and should be considered for the location of the Water Authority's Data Gap Well.

7.0 Recommendation for Data Gap Well Location and Screened Interval Depth

The analysis of regional and plume-scale hydrogeologic conditions, the extent and distribution of EDB in the distal end of the BFF plume, and pumping effects of KAFB-106234 revealed the following relative to the location and screen interval depth of the Water Authority Data Gap Well:

- A laterally extensive, high hydraulic conductivity braided stream-channel deposit unit exists in the distal end of the EDB plume within the depth interval not being monitored for EDB; the depth interval in which this unit exists is illustrated in **Figure 4**.
- Roto-Sonic drilling and sampling methods are more likely than ARCH methods to provide the geologic data necessary to identify interbedded fine-grained units that may compartmentalize the transport of EDB. The use of Roto-Sonic drilling and sampling methods are recommended for the coring and installation of the Data Gap Well so that the identification of these fine-grained units during coring can be accomplished.
- An EDB data gap exists within the current monitoring well network. This is most visually recognizable between wells 106206 and 106205, where the screened intervals are 593 to 608 ft bgs and 492.5 to 507.5 ft bgs, respectively, leaving a nearly 90-ft interval that remains unmonitored (**Figure 4**). This interval, which overlaps with the channel deposit highlighted in this same Figure, should be considered for the screen interval of the Water Authority's Data Gap Well. Field methods, such as geophysical logging and discrete interval groundwater sampling, should be used to inform the final design of the Water Authority Data Gap Well. Nested well screens should be considered if these data do not identify a specific 15- to 20-ft interval that the Water Authority Data Gap Well should be screened across.
- The area beyond the predicted capture zone of well 106234, illustrated on **Figure 6**, presents the greatest risk to the Ridgecrest Well Field and should be considered for the location of the Water Authority's Data Gap Well. Two possible areas are illustrated that are located near existing BFF wells are provided on **Figure 6** for the Water Authority's consideration. INTERA's recommended selection is the location within Indiana Street, immediately south of Kathryn Avenue. This location is closest to the well 106234 capture zone without being within it, preliminary utility locate information indicates that subsurface utilities should not be an issue, and overhead utilities and/or trees are not present in this area. This location is also

downgradient of BFF deep monitoring wells in the area of interest that have historically identified elevated concentrations of EDB in groundwater.

- Access limitations caused by underground and aboveground utilities, general property access, and business, residential, and traffic nuisances caused by the drilling operations should be factored into the final decision on the location of the Water Authority Data Gap Well.

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FIGURES

⌖ Monitoring Well (66)

⌖ Extraction Well (3)

⌖ Water Supply Well (2)

⌖ Sentinel Well (5)

⌖ KAFB Data Gap Well (5)

— AECOM (2016) Cross Section

Aquifer Zone

△ Shallow (16)

☐ Intermediate (11)

▽ Deep (14)

○ Multiple (3)

○ Other (4)

N

700 0 700

Feet

INTERA

Figure 1
Site Location Map
Water Authority Data Gap Well
Bernalillo County, New Mexico, USA

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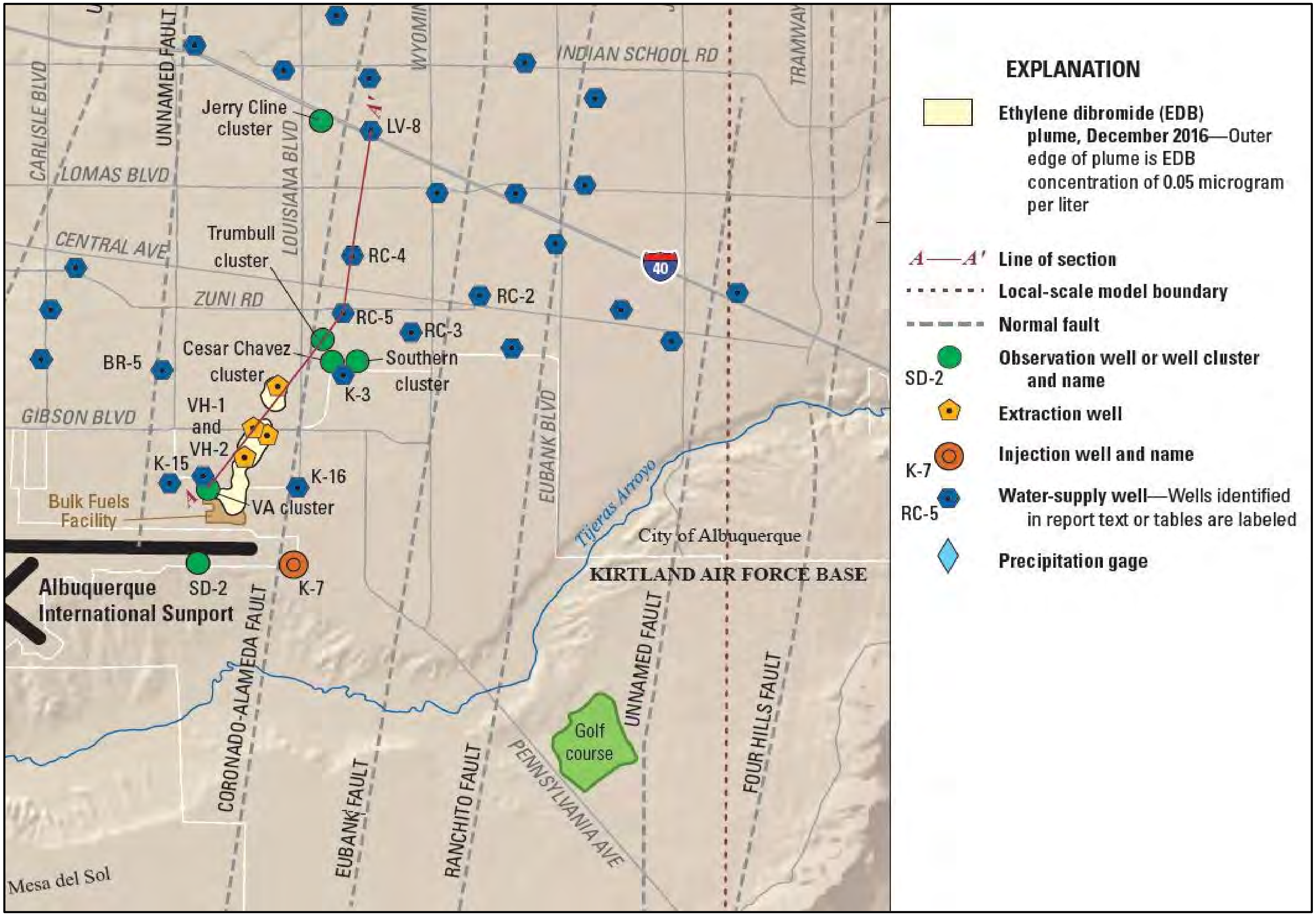

This map has been modified from Myers and Friesz (2019)

INTERA

Figure 2

KAFB BFF, Select Wells, EBD Plume, and Faults

Water Authority Data Gap Well

Bernalillo County, New Mexico, USA

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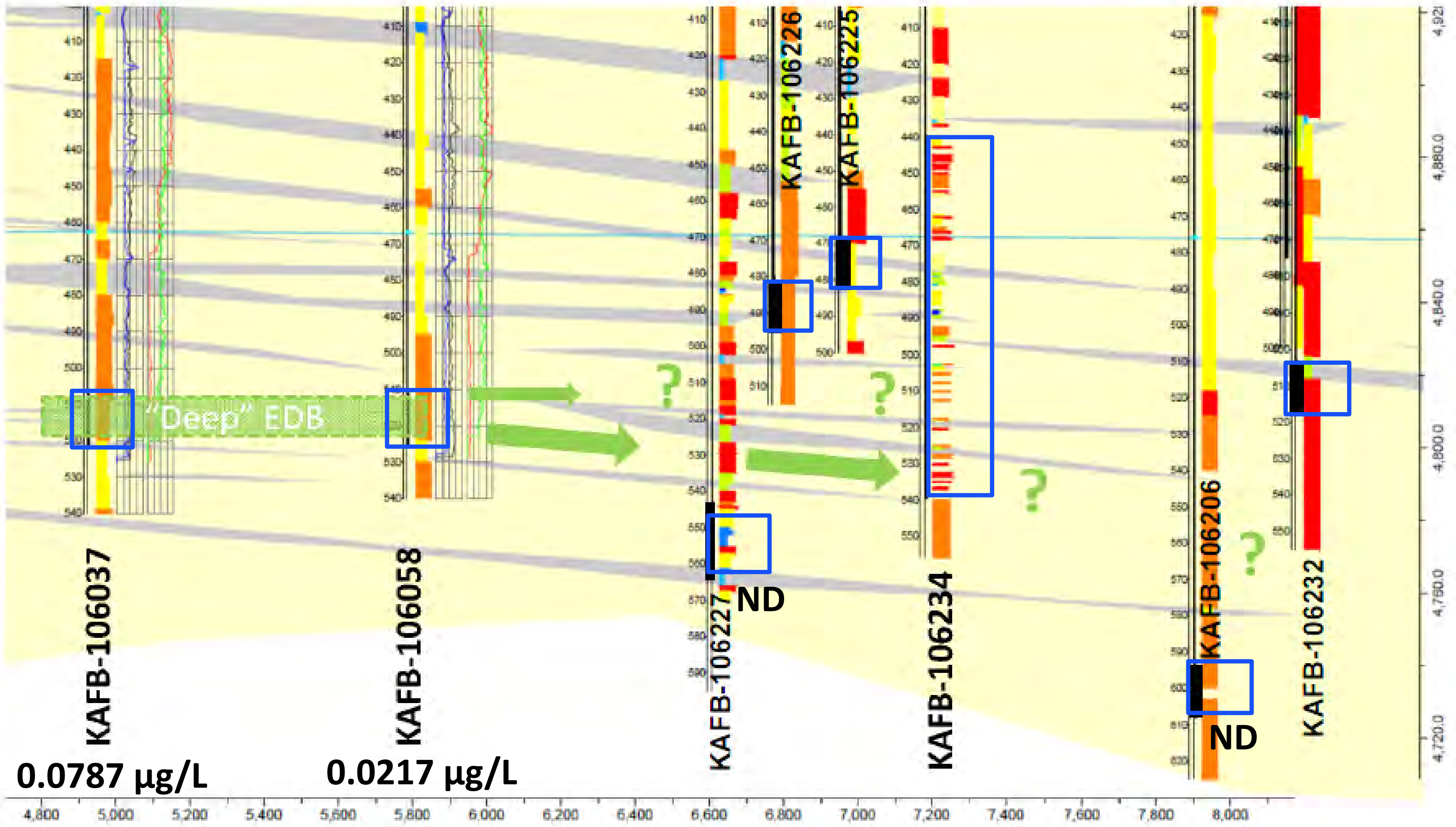

Q4 2015 EDB Concentrations

☐ Screened intervals

Summarized Grain Size Log Index

🟦	Clay; Clay with Sand; Clayey Sand
🟩	Silt; Silt with Sand
🟩	Sandy Silt; Silty Sand
🟧	Sand, Silt, or Clay with fine- or medium-grained Gravel
🟥	Sand, Silt, or Clay with coarse-grained Gravel

Cross-section courtesy of C. Plank, AECOM

INTERA

Figure 3
AECOM (2016) Cross Section
Kirtland Airforce Base Bulk Fuel Facility
Water Authority Data Gap Well
Bernalillo County, New Mexico

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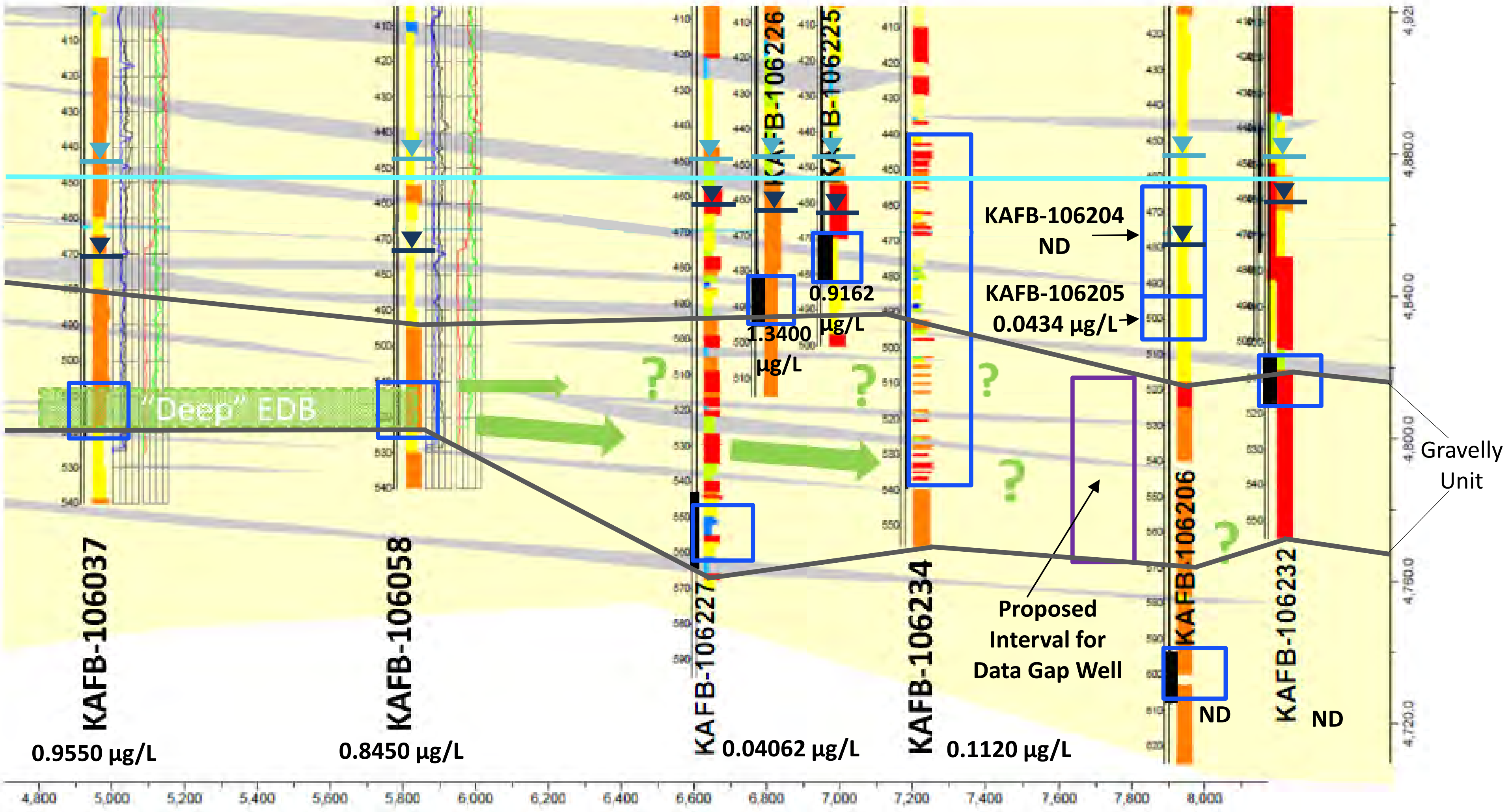


Maximum Historical EDB Concentrations

- ☐ Screened intervals
- ▽ Minimum Historical DTW
- ▼ Maximum Historical DTW
- — 2020 Q4 Water Table Elevation

Summarized Grain Size Log Index

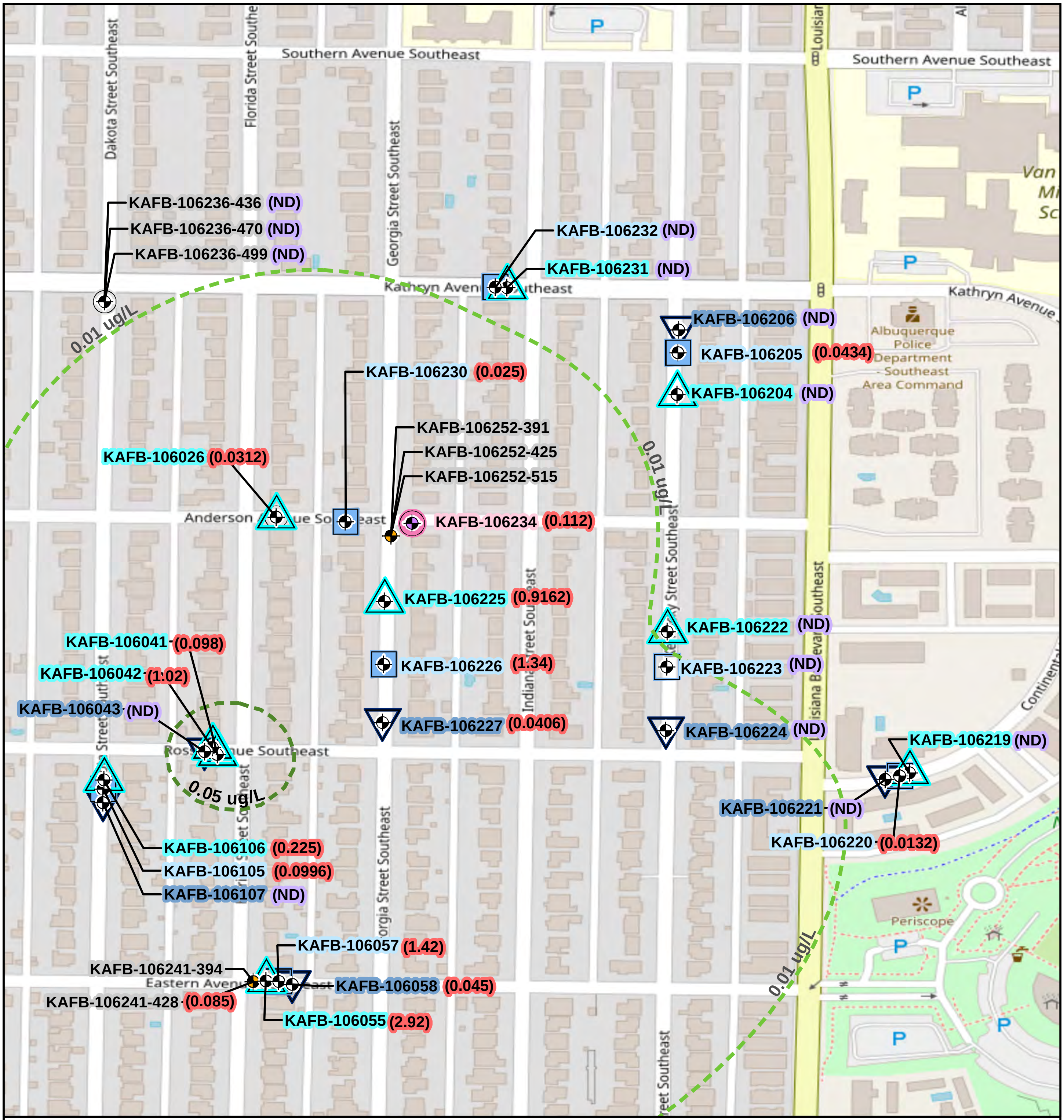
- 🟦 Clay; Clay with Sand; Clayey Sand
- 🟩 Silt; Silt with Sand
- 🟩 Sandy Silt; Silty Sand
- 🟧 Sand, Silt, or Clay with fine- or medium-grained Gravel
- 🟥 Sand, Silt, or Clay with coarse-grained Gravel

Cross-section courtesy of C. Plank, AECOM

INTERA

Figure 4
Modified AECOM (2016) Cross Section
Kirtland Airforce Base Bulk Fuel Facility
Water Authority Data Gap Well
Bernalillo County, New Mexico, USA

S:\ABQ\ABWUA.C009.KAFB\Data_Gap_Well\Graphics\GIS\Map_Docs\cross_section_modified_V2.xlsx



⊕ Monitoring Well

⊕ Extraction Well

⊕ KAFB Data Gap Well

EDB Contours for Top 10 ft Below Water Table in 2020 Q4

- - - 0.01 ug/L

- - - 0.05 ug/L

Aquifer Zone

△ Shallow

☐ Intermediate

▽ Deep

○ Multiple

○ Other

KAFB-106232 (max EDB in µg/L)

0.0132 = detection

ND = non-detection

N

400 0 400

Feet

INTERA

Figure 5
Maximum EDB Concentrations
Water Authority Data Gap Well
Bernalillo County, New Mexico, USA

FILE: S:\ABQ\ABWUA.C009.KAFB\Data_Gap_Well\Graphics\GIS\Map_Docs\05_EDB_maxV2.mxd Date: 11/5/2021

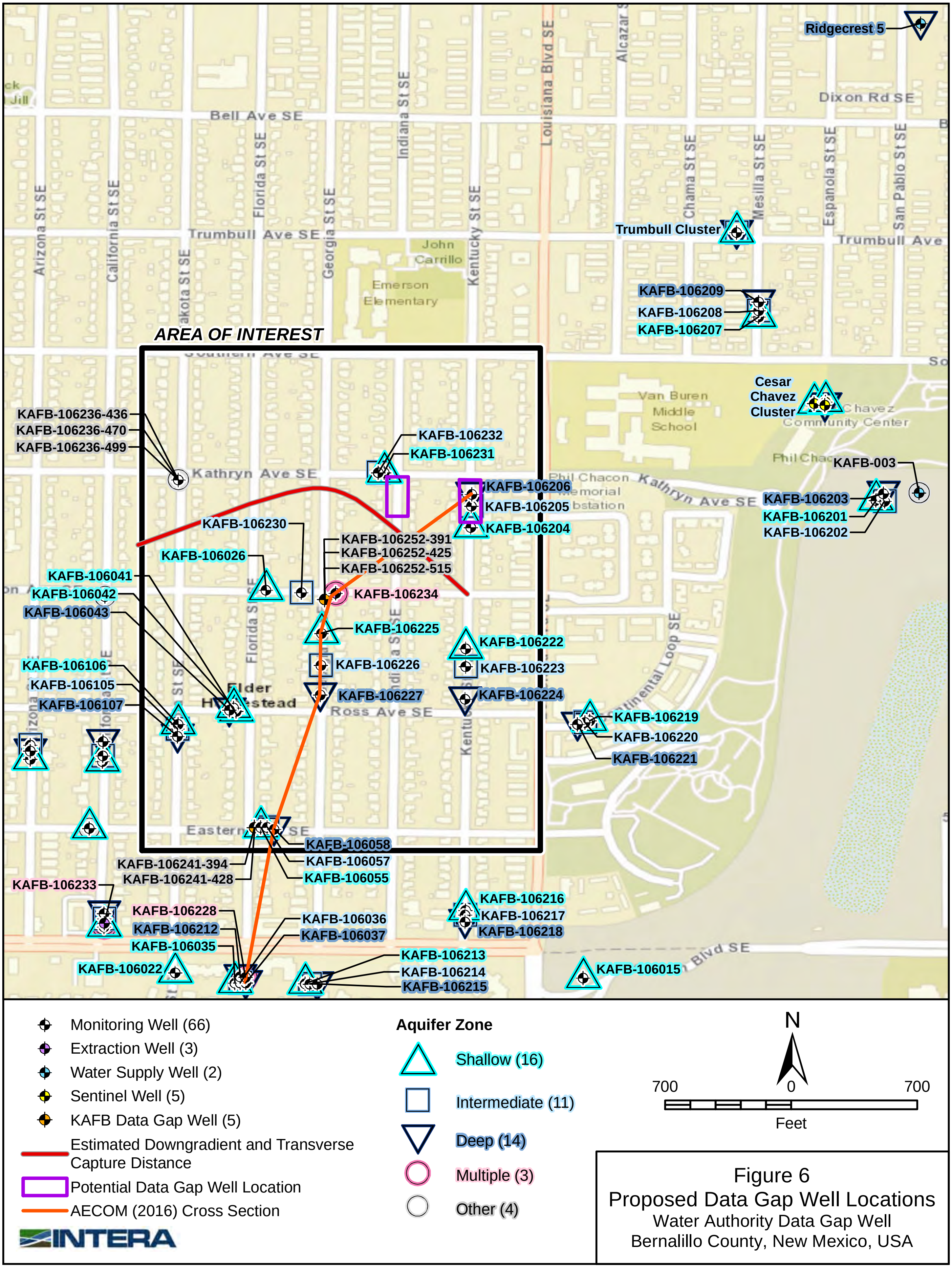


Figure 6
Proposed Data Gap Well Locations
Water Authority Data Gap Well
Bernalillo County, New Mexico, USA

FILE: S:\ABQ\ABWUA.C009.KAFB\Data_Gap_Well\Graphics\GIS\Map_Docs\06_DataGapWells.mxd Date: 11/5/2021

TABLE

TABLE 1
Select Monitoring Well Information and Data
Kirtland Airforce Base Bulk Fuel Facility Water Authority Data Gap Well, Bernalillo County, New Mexico, USA

Well ID*	Aquifer Zone	Ground Surface Elevation (ft amsl)	Top of Screen (ft bgs)	Base of Screen (ft bgs)	Q4 2020 Groundwater Elevaion (ft amsl)	Minimum Groundwater Elevation (ft amsl)	Date of Minimum Groundwater Elevation	Maximum Groundwater Elevation (ft amsl)**	Q4 2020 EDB Concentration (µg/L)	Maximum EDB Concentration (µg/L)	Date of Maximum EDB Concentration
KAFB-106035	Shallow	5321.45	452.0	482.0	4873.70	4852.96	Aug 2011	4888.90	0.06	1.42	Jan 2014
KAFB-106036	Intermediate	5321.76	481.8	496.8	4873.50	4853.20	Aug 2011	4877.17	0.12	0.601	Apr 2014
KAFB-106037	Deep	5322.05	507.0	522.0	4873.10	4853.09	Aug 2011	4876.79	0.09	0.955	Sep 2015
KAFB-106055	Shallow	5325.08	465.8	485.8	4873.87	4852.28	Jul 2011	4878.22	<0.019	2.92	Jan 2013
KAFB-106057	Intermediate	5325.46	484.9	499.9	4873.87	4852.48	Jul 2011	4878.24	<0.019	1.42	Aug 2011
KAFB-106058	Deep	5326.04	511.8	526.8	4873.88	4852.06	Jul 2011	4878.26	<0.019	0.845	Aug 2011
KAFB-106204	Shallow	5332.85	462.5	492.5	4872.92	4854.04	Oct 2012	4878.76	<0.019	ND	-
KAFB-106205	Intermediate	5333.29	492.5	507.5	4872.90	4853.53	Oct 2012	4878.82	<0.019	0.04338	Jan 2018
KAFB-106206	Deep	5333.46	593.5	608.2	4872.91	4853.57	Oct 2012	4878.85	<0.019	ND	-
KAFB-106207	Shallow	5344.25	473.0	503.0	4871.34	4851.82	Oct 2012	4879.35	<0.019	ND	-
KAFB-106208	Intermediate	5343.87	503.0	518.0	4871.29	4851.92	Oct 2012	4879.29	<0.019	ND	-
KAFB-106209	Deep	5343.41	603.0	617.0	4871.51	4851.56	Oct 2012	4879.48	<0.019	ND	-
KAFB-106213	Shallow	5325.28	448.0	478.0	4873.75	4864.00	Apr 2015	4877.55	<0.019	ND	-
KAFB-106214	Intermediate	5325.43	478.2	492.7	4873.87	4863.69	Apr 2015	4877.69	<0.019	ND	-
KAFB-106215[a]	Deep	5325.78	547.0	562.0	4873.94	4863.98	Jun 2015	4877.78	<0.019	ND	-
KAFB-106219	Shallow	5340.41	462.7	492.7	4872.82	4863.27	Apr 2015	4878.34	<0.019	ND	-
KAFB-106220	Intermediate	5340.34	493.0	508.0	4872.84	4863.13	Apr 2015	4878.34	<0.019	0.01324	Jan 2016
KAFB-106221[a]	Deep	5340.09	561.0	576.0	4872.85	4863.85	Jun 2015	4878.30	<0.019	ND	-
KAFB-106222	Shallow	5333.24	457.8	487.8	4872.86	4862.49	Feb 2015	4878.37	<0.019	ND	-
KAFB-106223	Intermediate	5333.95	487.8	502.8	4872.95	4863.89	Apr 2015	4878.50	<0.019	ND	-
KAFB-106224[a]	Deep	5335.07	555.0	570.0	4873.02	4863.97	Jun 2015	4878.47	<0.019	ND	-
KAFB-106225	Shallow	5326.35	450.0	480.0	4873.11	4862.16	Feb 2015	4878.12	0.021	0.91621	Apr 2017
KAFB-106226	Intermediate	5327.30	480.0	495.0	4873.48	4862.84	Mar 2015	4878.46	<0.019	1.34	Oct 2015
KAFB-106227[a]	Deep	5328.08	548.0	563.0	4873.56	4864.30	Jun 2015	4878.47	<0.019	0.04062	Apr 2017
KAFB-106230[a]	Intermediate	5324.51	501.0	516.0	4873.51	4864.58	Oct 2015	4878.43	<0.019	0.025	Nov 2015
KAFB-106231	Shallow	5327.56	440.0	475.0	4873.37	4864.40	Oct 2015	4878.90	<0.019	ND	-
KAFB-106232	Intermediate	5327.19	503.0	518.0	4873.47	4864.98	Oct 2015	4878.98	<0.019	ND	-
KAFB-106234[b]	Extraction	5325.64	439.7	539.7	-	-	-	-	-	0.112	Jan 2016

Notes:

ft = feet, amsl = above mean sea level, bgs = below ground surface, ND = no detect.

* All borings were drillied via Air Rotary Casing Hammer (ARCH) unless noted otherwise.

** All maximum groundwater elevations occurred in Jan 2021

[a] Boring was drilled by ARCH from 0-450 ft bgs and by sonic from 450 ft bgs to total depth.

[b] Boring was drilled mud rotary from 0-435 ft bgs and cored from 435-556 ft bgs.

APPENDIX B

Field Forms

INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS

LOG OF BORING

(Page of)

Project Name:	Date Started :	Driller :	
	Date Completed :	Depth to Water :	
	Drilling Method :	Logged By :	
Project #:	Sampling Method :		
	Drilling Company :		

Depth in Feet	Sample Interval	Sample #	Pen./Rec.	PID (ppm)	**Group** (soil) name (clay, sand, silty sand, etc), percentage of non-predominant soil type, **grading** (coarse-grained soils only), **particle-size** (coarse-grained soils only), **angularity, shape, maximum particle size** (gravel only), **plasticity** (fine-grained soils only; non, low, medium, high), **density** (coarse-grained soils only; very loose, loose, medium dense, dense, very dense), **consistency** (fine-grained soils only; very soft, soft, firm, hard, very hard), **color**, **odor**, **moisture** (dry, moist, wet), **reaction with HCl** (none, weak, strong), **structure**, **cementation**, other (roots, mica, gypsum, caliche nodules, drilling conditions), geologic name (if known). DESCRIPTION	Group Symbol

Notes:

PROJECT NAME: ____ WELL NO.: ____________________
PROJECT NO.: ___________________ DATE: ________________ FORM COMPLETED BY: ____________________

WELL CONSTRUCTION

TOTAL DEPTH BELOW MEASURING POINT (BMP) (FT): _________ BOREHOLE DIAMETER (IN): _______________
TOTAL DEPTH BELOW LAND SURFACE (FT BLS): _______________ WELL DIAMETER INSIDE (IN): _____________
WELL PROTECTOR: ☐ YES ☐ NO PADLOCK NO.: ______________ WELL DIAMETER OUTSIDE (IN): ___________
SAND PACK INTERVAL (BLS) (FT): _____________________________ SCREEN INTERVAL (BLS) (FT): ____________

WATER VOLUME CALCULATION

DATE/TIME OF MEASUREMENT:_______________________
MEASURING POINT:_____________ ELEV.:_______________
WATER LEVEL INSTRUMENT USED:____________________
INITIAL WATER LEVEL (BMP) (FT):_____________________
LINEAR FEET OF WATER:______________________________
LINEAR FEET SATURATED GRAVEL PACK:______________

NOTE: *Quantities are to be calculated prior to development.*

ITEM	**WATER VOLUME**	
	FT^3	**GAL**
Well Casing		
Sand Pack		
Drilling Fluids		
TOTAL		

DEVELOPMENT CRITERIA

METHOD OF DEVELOPMENT: ____
WATER VOLUME TO BE REMOVED (GAL): __________ WATER VOLUME ACTUALLY REMOVED (GAL): _______
TIME DEVELOPMENT STARTED: __________________ TIME DEVELOPMENT COMPLETED: ________________

NOTE: *Development is to be performed in accordance with Standard Operating Procedure No. 8.*

WATER QUALITY INSTRUMENTS

INSTRUMENT	**SERIAL NO.**	**TIME CALIBRATION PERFORMED**	**TECH**	**COMMENTS**

WATER QUALITY READINGS DURING DEVELOPMENT

DATE/TIME	**TOTAL WATER PURGED (gal)**	**TEMP (°C)**	**CONDUCTIVITY (µS/cm)**	**TURB (NTU)***	**pH**	**TECH**	**COMMENTS**

*If measured.
Stabilization = **Temp** ±1°C; **pH** ±0.2 units; **Sp. Cond.** ±10%; **Turb.** ±10%

WATER QUALITY READINGS DURING DEVELOPMENT (continued)

DATE/TIME	TOTAL WATER PURGED (gal)	TEMP (°C)	CONDUCTIVITY (μS/cm)	TURB (NTU)*	pH	TECH	COMMENTS

*If measured.

Stabilization = **Temp** ±1°C; **pH** ±0.2 units; **Sp. Cond.** ±10%; **Turb.** ±10%

Project Name: ______________________ **Project No.:** ______________________

Water Level Instrument: ______________________ **Site Location:** ______________________

Well	Date	Time	Depth to PSH (ft bmp)	Depth to Water (ft bmp)	Total Depth (ft bmp)	Description of Measuring Point	GPS Coordinate Northing	GPS Coordinate Easting	Gauger Initials	Comments

PROJECT NAME: ____ WELL NO.: __________________
PROJECT NO.: _________________ DATE: _______________ FIELD CREW: ____________________________

WATER LEVEL AND WATER COLUMN HEIGHT

TIME	DEPTH TO BOTTOM OF WELL (DTB) (ft btoc)	DEPTH TO WATER (DTW) (ft btoc)	Water Column Height (DTB-DTW) (ft)

ft btoc: feet below top of casing from designated measuring point

PURGE VOLUME

Well Casing Diameter (inches)	Volume/Linear Foot (see conversion table below)	1 Well Volume (gal)	2 Well Volumes (gal)	3 Well Volumes (gal)

VOLUME/LINEAR FOOT (gal/ft) (Use well casing ID)

1” = 0.04	1.5” = 0.09	2” = 0.17	3” = 0.38	4” = 0.66	6” = 1.5	8” = 2.6	10” = 4.1

1 well casing volume = Volume/Linear Foot x Water Column Height

METHOD OF PURGING: ____
METHOD OF SAMPLING: ____

WATER LEVEL/WATER QUALITY INSTRUMENTS USED

INSTRUMENT	SERIAL NO.	TIME CALIBRATION PERFORMED	TECH	COMMENTS

WATER QUALITY READINGS DURING PURGING

TIME	TEMP (°C)	pH	SP. COND. (µS/cm)	TURB. (NTU)*	DO (mg/L)	ORP (mV)	Total Purge Volume (gal)	Comments (color/odor)

*If measured.

Stabilization = **Temp** ±1°C; **pH** ±0.2 units; **Sp. Cond.** ±10%; **Turb.** ±10%

WATER QUALITY READINGS DURING PURGING (continued)

TIME	TEMP (°C)	pH	SP. COND. (µS/cm)	TURB. (NTU)*	DO (mg/L)	ORP (mV)	Total Volume Purged (gal)	Comments (color/odor)

*If measured.

Stabilization = **Temp** ±1°C; **pH** ±0.2 units; **Sp. Cond.** ±10%; **Turb.** ±10%

GROUNDWATER SAMPLING DATA

GROUNDWATER SAMPLE ID: ________________________ DUPLICATE SAMPLE ID: ________________________

Time	Bottle Type	Analytical Method	# of Bottles	Volume	Preservative
		TOTAL:			

Sampler: ___________________________________ ______________________________________

(Printed Name) **(Signature)**

SOP 30: Field Form 7 - SAMPLE CONTROL LOG

Project Name: ______________________________ **Project No.:** ______________________________

Site Location: ______________________________

Field Sample No.	Lab I.D.	Sampler Initials	Date Collected	Time Collected	Sample Media	Depth Interval	Sample Location/ Coordinates	Replicate/ Duplicate Sample? (Y/N)	Corresponding Field Sample No.	Composite? (Y/N)	Comments

Sample Media
01 - SURFACE WATER, 02 - POND BOTTOM WATER, 03 - POND BOTTOM SLUDGE
04 - SOIL, UNDERLYING SOIL, 05 - SURFACE WASTE, 06 - GROUND WATER,
07 - TANK WASTE, 08 - NAPL, 09 - TRIP BLANK, 10 - FIELD BLANK.

>> Select a Laboratory or Service Center <<

#N/A
#N/A
#N/A
##

Chain of Custody Record

eurofins | Environment Testing America

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☐ Other:

TestAmerica Laboratories, Inc. d/b/a Eurofins TestAmerica

Project Manager:

Email:

Tel/Fax:

Site Contact:

Lab Contact:

Date:

Carrier:

COC No:

_______ of ______ COCs

TALS Project #:

Sampler:

For Lab Use Only:
Walk-in Client:
Lab Sampling:

Job / SDG No.:

Client Contact

Your Company Name here
Address
City/State/Zip
(xxx) xxx-xxxx Phone
(xxx) xxx-xxxx FAX
Project Name:
Site:
P O #

Analysis Turnaround Time

☐ CALENDAR DAYS ☐ WORKING DAYS

TAT if different from Below __________

☐ 2 weeks
☐ 1 week
☐ 2 days
☐ 1 day

Sample Identification	**Sample Date**	**Sample Time**	**Sample Type** (C=Comp, G=Grab)	**Matrix**	**# of Cont.**	**Filtered Sample (Y / N)**	**Perform MS / MSD (Y / N)**																		Sample Specific Notes:

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other ____________

Possible Hazard Identification:
Are any samples from a listed EPA Hazardous Waste? Please List any EPA Waste Codes for the sample in the Comments Section if the lab is to dispose of the sample.

☐ Non-Hazard ☐ Flammabl ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)

☐ Return to Client ☐ Disposal by Lab ☐ Archive for__________ Months

Special Instructions/QC Requirements & Comments:

Custody Seals Intact: ☐ Yes ☐ No

Custody Seal No.:

Cooler Temp. (^{o}C): Obs'd:_________ Corr'd:__________ Therm ID No.:____________

Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received in Laboratory by:	Company:	Date/Time:

Form No. CA-C-WI-002, Rev. 4.35, dated 10/6/2020

Chain-of-Custody Record

Client:

Mailing Address:

Phone #:

email or Fax#:

QA/QC Package:

☐ Standard ☐ Level 4 (Full Validation)

Accreditation: ☐ Az Compliance

☐ NELAC ☐ Other________________

☐ EDD (Type) ____________________________

Turn-Around Time:

☐ Standard ☐ **Rush**________________

Project Name:

Project #:

Project Manager:

Sampler:

On Ice: ☐ Yes ☐ No

# of Coolers:

Cooler Temp(including CF):

HALL ENVIRONMENTAL ANALYSIS LABORATORY

www.hallenvironmental.com

4901 Hawkins NE - Albuquerque, NM 87109

Tel. 505-345-3975 Fax 505-345-4107

Analysis Request

Date	Time	Matrix	Sample Name	Container Type and #	Preservative Type	HEAL No.	BTEX / MTBE / TMB's (8021)	TPH:8015D(GRO / DRO / MRO)	8081 Pesticides/8082 PCB's	EDB (Method 504.1)	PAHs by 8310 or 8270SIMS	RCRA 8 Metals	Cl, F, Br, NO_3, NO_2, PO_4, SO_4	8260 (VOA)	8270 (Semi-VOA)	Total Coliform (Present/Absent)						

Date:	Time:	Relinquished by:	Received by: Via: Date Time
Date:	Time:	Relinquished by:	Received by: Via: Date Time

Remarks:

If necessary, samples submitted to Hall Environmental may be subcontracted to other accredited laboratories. This serves as notice of this possibility. Any sub-contracted data will be clearly notated on the analytical report.

APPENDIX C

INTERA’s Standard Operating Procedures

2.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) covers the following decontamination procedures to be implemented by INTERA field personnel and/or the INTERA subcontractor during characterization or remediation of non-radioactive hazardous and non-hazardous environmental sites:

- Project Decontamination Plan (**Section 2.1**);
- Decontamination of field personnel (**Section 2.2**);
- Decontamination of field equipment (**Section 2.3**); and
- Decontamination Effectiveness (**Section 2.4**).

The objective of decontamination procedures is to minimize the potential for cross contamination. Methods outlined in this SOP comply with following ASTM Standard:

- D5088-02(2008), *Standard Practice for Decontamination of Field Equipment Used at Waste Sites* (ASTM, 2008).

This SOP should be used in conjunction with procedures presented in the Site-Specific Health and Safety Plan (SSHASP) and in site-specific investigation planning documents such as a Sampling and Analysis Plan (SAP), Field Sampling Plan (FSP), or Work Plan (WP). This SOP will also be commonly used in conjunction with and is referenced in the following INTERA SOPs:

- 5, *Hollow-Stem Auger Drilling*;
- 6, *Direct Push Drilling*;
- 7, *Monitor Well Installation*;
- 8, *Monitor Well Development*;
- 9, *Monitor Well Gauging*;
- 10, *Monitor Well Groundwater Sampling*;
- 13, *Soil Sampling*;
- 15, *Slug Test Procedure*;
- 19, *Soil Gas Sampling*; and
- 23, *Soil Field Screening*.

2.1 Development of a Project Decontamination Plan

An appropriate project decontamination plan should be established (as part of either the SSHASP or SAP/FSP/WP) prior to personnel or equipment mobilization to areas where the potential for exposure to hazardous substances exists. The decontamination plan for a project should address:

- Appropriate type, number, and layout of decontamination areas;
- Decontamination equipment needs (e.g., drop cloths, plastic sheeting, appropriate wash and rinse solutions, sprayers, waste containers - refer to **Attachment 1** for additional decontamination equipment that may be used at hazardous/non-hazardous waste sites);
- Appropriate decontamination methods;
- Procedures to prevent contamination of clean areas;
- Methods to minimize worker contact with contaminants during removal of Personal Protection Equipment (PPE);
- Methods for disposing of clothing and equipment, as applicable; and
- An emergency decontamination plan, if appropriate

The project decontamination plan should be revised whenever the type of PPE or equipment changes, site conditions change, or site hazards are reassessed based on new information. The decontamination plan specified in investigation planning documents may incorporate the following procedures in whole or part as long as exceptions, additions, and deletions are included.

2.1.1 Establishment of Work Zones

At any site where hazardous materials may be present, three (3) zones of contamination will be formally delineated as follows:

- Clean Zone: contaminant free zone. All access to the site is routed though the clean zone;
- Contamination Reduction Zone: acts as a buffer or intermediate zone where primary decontamination of personnel and/or equipment will be completed; and
- Exclusion Zone: contaminated area or potentially-contaminated area of the site. Access limited to an as needed basis only.

Personnel and equipment, including large equipment such as drill rigs, trucks and earth-moving equipment, in the Exclusion Zone will be decontaminated at the Exclusion Zone exit. Between the Exclusion Zone and the Clean Zone is the Contamination Reduction Zone, which provides a transition zone between the contaminated and clean areas of the site. Primary decontamination will take place at the boundary between the Exclusion Zone and the Contamination Reduction Zone. Personnel will decontaminate themselves and equipment before entering the Clean Zone from the Contamination Reduction Zone. The Clean Zone is an uncontaminated area from which operations will be directed. It is essential that all contamination from the site be kept out of the Clean Zone. In addition, equipment should be clean upon entering the Exclusion Zone. If there is any doubt, equipment, including large equipment such as drill rigs that may be coming from another site, will be decontaminated in the Contamination Reduction Zone before entering the Exclusion Zone to prevent possible cross contamination between unrelated sites.

2.2 Procedure Implementation - Personnel Decontamination

The most effective decontamination procedure for field personnel is contamination avoidance when and wherever possible. As reasonably appropriate and applicable, all project personnel should follow standard work practices that minimize contact with potentially contaminated materials such as:

- Avoid areas of obvious contamination, do not directly touch potentially hazardous substances;
- Use remote sampling, handling, and container-opening techniques (e.g., drum grapplers, pneumatic impact wrenches);
- Protect monitoring and sampling instruments by bagging. Make openings in the bags for sample ports and sensors that must contact site materials;
- Wear disposable outer garments and use disposable equipment; and
- Encase the source of contaminants (i.e., with plastic sheeting or over packs).

At any site, personnel should decontaminate each time they leave an area of suspected or known contamination (i.e., the Exclusion Zone) and whenever they are subjected to above–normal exposure to hazards or contaminated materials. To avoid cross contamination in the Exclusion Zone, personnel decontamination in the form of glove change-out will be implemented between sample locations within a designated Exclusion Zone. Non-disposable sampling equipment will also be decontaminated between sampling locations if it will be used at multiple locations.

Depending on site conditions, personnel decontamination efforts may constitute a simple change-out and disposal of outer PPE garments (i.e., switching sampling gloves) or may be more substantive (i.e., a scrub and wash down). Typical examples of personnel decontamination procedures that may be applicable depending on site conditions are:

- Deposit hand tools and equipment on drop cloth or in other appropriate container pending decontamination;
- Respirators will be removed and placed in plastic bags pending decontamination according to manufacturers' instructions;

- Boots, reusable outer gloves and reusable cover suits will be washed using an appropriate soap such as Alconox™ in a potable water solution before being adequately rinsed with distilled, deionized or potable water, as appropriate;
- All disposable items (e.g., tape, cover suits, and any other disposable materials) will be removed and immediately placed in a container for proper disposal;
- Inner gloves will be removed, turning inside out as they are removed, and disposed of properly; and
- Exposed skin areas such as the hands and face will be washed with soap and distilled, deionized or potable water, as appropriate.

Personnel decontamination will take place in the Contamination Reduction Zone. Specifics regarding the required protocol for personnel decontamination for a site/project shall be provided in the SSHASP.

2.3 Procedure Implementation - Equipment Decontamination

Types of equipment requiring decontamination at any given site may include the following:

- Sampling equipment - will be decontaminated between individual sampling locations to ensure that representative samples are collected;
- Drilling equipment - will be decontaminated at the completion of each boring to ensure that boreholes are not cross contaminated and that contamination is contained in the Exclusion Zone; and
- Tractor, forklift, backhoe and/or other heavy equipment - will be decontaminated to ensure that contamination is contained during site activities.

At a minimum, equipment that has come into direct contact with potentially contaminated media (e.g., auger flights, drill heads, non-disposable sampling equipment) will be decontaminated before leaving the Contamination Reduction Zone by:

- Washing non-disposable sampling equipment with an appropriate detergent solution (based on the site's known or potential contaminants of concern) and a brush made of inert material to remove any particles or surface film;
- Auger flights/probes should be decontaminated prior to re-use using a heated, high-pressure wash operating at a temperature of approximately 212° F and discharging at approximately 5 gallons per minute. Strongly adhered material may require additional scrubbing using a wire or bristle brush. The inside of each auger or probe will also be cleaned with a pressure washer or steam cleaner and, if needed, scrubbed with a wire or bristle brush;

- Drill heads and other large equipment should be decontaminated using a heated, high-pressure wash, if possible, or by scrubbing as described above; and
- Double rinsing thoroughly with control water (typically first rinse with potable water in a wash tub or containment area; second rinse with a spray of distilled or deionized water).

Various solutions applicable to the decontamination of field equipment and materials are listed in **Attachment 2**. Commonly recommended decontamination procedures for various equipment and materials (in order of application) are listed in **Attachment 3**.

For most sites, use of a heavy-duty non-phosphate detergent wash, such as Alconox™, Simple Green™ or an approved equivalent, followed by one or more rinses of distilled/deionized water commonly available from commercial vendors is typical.

Regarding appropriate rinse solutions to use for decontamination purposes, the following should be noted:

1. Distilled water and deionized water are not comparable; use of distilled water is usually acceptable for most investigations. If laboratory grade deionized water is required for a site, this requirement shall be specified in the SAP/FSP/WP.
2. Tap/potable water is defined as water that is determined to be fit for human consumption. Usually this implies that some level of treatment has been performed on the water. For the purpose of implementing decontamination procedures at investigation sites, use of an untreated water supply is not an acceptable substitute for tap/potable water.
3. If metals are a primary constituent of concern at the site, an initial rinse of 0.1 molar nitric acid followed by tap water may be appropriate.
4. If organic compounds are a primary constituent of concern at a site, an initial rinse with methanol, Simple Green™ or other approved equivalent followed by a tap water rinse may be appropriate.
5. Any other additional consideration(s) regarding appropriate rinsate solutions to be implemented for a project shall be provided in the SAP/FSP/WP.

Safety Data Sheets for commonly-applied non-phosphate detergents are provided in **Attachment 4**.

Exceptions/additions to the standard rule are as follows:

- To minimize the spread of contaminated materials at the site, surficial caking of solid contamination on large equipment should be physically removed in the Exclusion Zone (or equivalent) using scrapers, brushes, or other appropriate tools prior to moving the equipment to a designated decontamination area. Smaller equipment can be placed in a wash tub (or other applicable container) in the designated decontamination area for decontamination;

- Delicate instrumentation or sampling equipment sensitive to water will be carefully cleaned with a treated sponge or paper towel as necessary. Care should be taken to prevent equipment damage and may include bagging of equipment during use to minimize direct contact with contaminated material, as appropriate (**Section 2.2**);
- Any vehicle required to enter the Exclusion Zone or used to carry auger flights or push probes will also receive a heated, high–pressure wash in all areas where the auger flights, push probes, or contaminated material come into contact with the vehicle. Vehicle tires may also require decontamination;
- Many recommended solvents are hazardous constituents; therefore, use of these types of solvents should be evaluated with respect to known or suspected site contaminants and applied only on an as needed basis; and
- At sites where the reactivity of sampling equipment to decontamination washes creates concern for the generation of undesirable chemical by-products, the use of dedicated or disposable sampling equipment should be considered.

Allowing decontaminated equipment to air dry on a rack, sawhorse, or clean surface prior to re-use is considered optimal; however, equipment may also be wiped dry with a clean material if needed for immediate re-use. When practical, a sufficient quantity of clean, decontaminated sampling equipment should be made available so that equipment decontamination is not required between each sampling point and, ideally, can be performed in a single event.

Any solid material removed from large equipment during decontamination shall be placed in the appropriate container(s) identified for investigation-derived waste. All wash and rinse solutions shall be containerized and disposed of as specified in the SSHASP or SAP/FSP/WP.

2.4 Effectiveness Testing

Decontamination methods may vary in effectiveness of removing contamination and therefore should be assessed as part of any project at the beginning and periodically throughout the project, as appropriate. Typical methods utilized to determine decontamination effectiveness include:

- Visual observations – notice of stains, discoloration, corrosivity, or dirt;
- Swipe/wipe sampling and field screening for residual constituents; and

- Collection of a rinsate sample from decontaminated equipment.

The primary method to determine effectiveness of decontamination procedures for site personnel is via visual observation and/or self-screening. The primary method to determine effectiveness of decontamination procedures for reasonably-sized site sampling equipment is the collection of one or more equipment rinsate or rinse solution samples. For larger sampling equipment, field screening or swipe/wipe samples shall typically be collected.

Self-screening to determine the effectiveness of personnel decontamination is typically performed using the same screening tool(s) utilized for the active field screening of site samples and should be performed upon entering the Clean Zone, as applicable. Details regarding whether self-screening is appropriate for a site and the procedure and tools needed to perform self-screening shall be specified in the SSHASP.

Whether samples are to be collected from decontaminated equipment and/or used rinse solutions for project quality assurance/quality effectiveness will be established in the SAP/FSP/WP. Most sites/projects will require the collection of at least one equipment rinsate as follows:

- Collect equipment rinsate sample using ASTM International (ASTM) Type II reagent grade water, seal the rinsate sample container with a custody seal, and place the sample in the sample shipment cooler. ASTM Type II reagent grade water is defined as a distillate with the following specifications: Resistivity at 25° C = >1 megohm (MΩ–cm), Total Organic Carbon = <50 parts per billion (ppb); Sodium = <5 ppb; Chloride = <5 ppb; Total Silica= <3 ppb (ASTM, 2011).

2.5 References

ASTM International (ASTM), 2008. Standard Practice for Decontamination of Field Equipment Used at Waste Sites. D5088-02 (Reapproved 2008).

ASTM, 2011. Standard Specification for Reagent Water. D1193-06 (Reapproved 2011).

Martin, William F., Lippitt, John M., Webb, Paul J., 2000. Hazardous Waste Handbook, Third Edition. 288 pp.

2.6 Attachments

Attachment 1: Example Decontamination Equipment Used At Hazardous/Non-Hazardous Waste Sites, As Applicable

Attachment 2: Applications of Various Solutions for Decontamination of Field Equipment and Materials

Attachment 3: Recommended Decontamination Procedures for Common Types of Field Equipment and Materials

Attachment 4: Safety Data Sheets

2.7 Document History

Revision	Effective Date	Lead Author	Summary of Changes
2004.0	1/2004	Taimur Malik	Original version
2004.1	2/2015	Kate Herrell	Revised for inclusion in COA Brownfields QAPP
2004.2	5/2016	Noreen Baker	Minor text revisions, set bottom margin to 1 inch
2004.3	6/2017	Noreen Baker	Revised heading **2.6** to **Attachments** for consistency

Attachment 1

Example Decontamination Equipment Used at Hazardous/Non-Hazardous Waste Sites, As Applicable

Example Decontamination Equipment Used At Hazardous/Non-Hazardous Waste Sites, As Applicable.

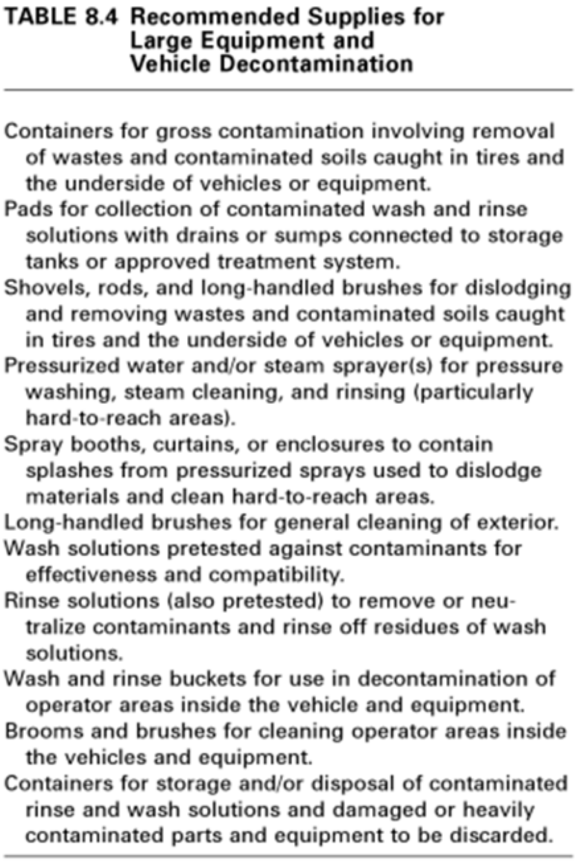


TABLE 8.4 Recommended Supplies for Large Equipment and Vehicle Decontamination

Containers for gross contamination involving removal of wastes and contaminated soils caught in tires and the underside of vehicles or equipment.
Pads for collection of contaminated wash and rinse solutions with drains or sumps connected to storage tanks or approved treatment system.
Shovels, rods, and long-handled brushes for dislodging and removing wastes and contaminated soils caught in tires and the underside of vehicles or equipment.
Pressurized water and/or steam sprayer(s) for pressure washing, steam cleaning, and rinsing (particularly hard-to-reach areas).
Spray booths, curtains, or enclosures to contain splashes from pressurized sprays used to dislodge materials and clean hard-to-reach areas.
Long-handled brushes for general cleaning of exterior.
Wash solutions pretested against contaminants for effectiveness and compatibility.
Rinse solutions (also pretested) to remove or neutralize contaminants and rinse off residues of wash solutions.
Wash and rinse buckets for use in decontamination of operator areas inside the vehicle and equipment.
Brooms and brushes for cleaning operator areas inside the vehicles and equipment.
Containers for storage and/or disposal of contaminated rinse and wash solutions and damaged or heavily contaminated parts and equipment to be discarded.

From: Hazardous Waste Handbook, Third Edition. (Martin, et al., 2000)

Attachment 2

Applications of Various Solutions for Decontamination of Field Equipment and Materials

TABLE 1 Applications of Various Solutions for Decontamination of Field Equipment and Materials[A,B,C]

Solution	Concentrations	Remarks
Portable Water	Tap water (demonstrated to be analyte free)	Used under high pressure or steam to remove heavy mud and dirt, or to rinse off other solutions
Laboratory-grade water	Distilled Deionized Reagengrade distilled and deionized water	
Low sudsing non-phosphate detergents (Liquinox, Detergent 8)	Typical concentrations are 0.5 to 2% solution by volume	General all-purpose cleaner. Detergent 8 is recommended for spray cleaning.
Sodium carbonate (baking soda)	5 to 15% aqueous solution	Used to neutralize either acidic or strongly basic contaminants
Sodium carbonate (washing soda)	10 to 20% aqueous solution	Effective for neutralizing inorganic acids, organic acids, heavy metals, metal processing wastes.
Trisodium phosphate (TSP Oakite)	10% aqueous solution	Similar to sodium carbonate. Good rinsing solution for organic compounds (such as toluene, chloroform, TCE, PBBs, and PCBs).
Calcium hypochlorite (HTH)	10% aqueous solution	Disinfectant, bleaching, and oxidizing agent for pesticides, fungicides, chlorinated phenols, dioxins, cyanides, ammonia and other non-acidic inorganic wastes.
Hydrochloric acid, nitric acid	10% nitric 10% to 20% hydrochloric	Used for inorganic bases, alkali and caustic wastes
Citric, tartaric, oxalic acids or their respective salts	5% solution	Used to clean heavy-metal contaminants
Organic solvents	Concentrated	Used to remove organic compounds that have poor solubility in water, such as oil and grease. do not use a solvent that is one of the analytes of interest or interferes with analyses. Porous materials such as polymers can absorb these solvents.

[A] Examples of commonly recommended cleaning solvents include pesticide-grade" isopropanol, acetone, methanol, hexane, heptane, and ethanol.

[B] Adapted for Mickam et al. (1989), Moberly (1985), and Richter and Collentine (1983).

[C] Many of the solvents listed are themselves hazardous materials. Care should be taken in both use and disposal of these materials.

From: ASTM D5088-02(2008) (ASTM, 2008)

Attachment 3

Recommended Decontamination Procedures for Common Types of Field Equipment and Materials

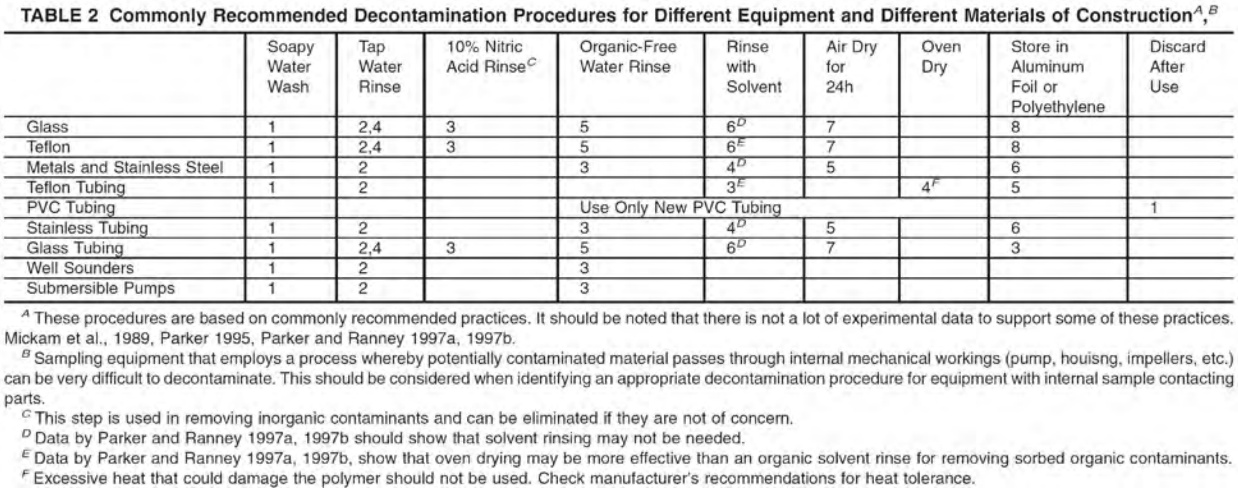


TABLE 2 Commonly Recommended Decontamination Procedures for Different Equipment and Different Materials of Construction[A],[B]

	Soapy Water Wash	Tap Water Rinse	10% Nitric Acid Rinse[C]	Organic-Free Water Rinse	Rinse with Solvent	Air Dry for 24h	Oven Dry	Store in Aluminum Foil or Polyethylene	Discard After Use
Glass	1	2,4	3	5	6[D]	7		8	
Teflon	1	2,4	3	5	6[E]	7		8	
Metals and Stainless Steel	1	2		3	4[D]	5		6	
Teflon Tubing	1	2			3[E]		4[F]	5	
PVC Tubing				Use Only New PVC Tubing					1
Stainless Tubing	1	2		3	4[D]	5		6	
Glass Tubing	1	2,4	3	5	6[D]	7		3	
Well Sounders	1	2		3					
Submersible Pumps	1	2		3					

[A] These procedures are based on commonly recommended practices. It should be noted that there is not a lot of experimental data to support some of these practices. Mickam et al., 1989, Parker 1995, Parker and Ranney 1997a, 1997b.

[B] Sampling equipment that employs a process whereby potentially contaminated material passes through internal mechanical workings (pump, houisng, impellers, etc.) can be very difficult to decontaminate. This should be considered when identifying an appropriate decontamination procedure for equipment with internal sample contacting parts.

[C] This step is used in removing inorganic contaminants and can be eliminated if they are not of concern.

[D] Data by Parker and Ranney 1997a, 1997b should show that solvent rinsing may not be needed.

[E] Data by Parker and Ranney 1997a, 1997b, show that oven drying may be more effective than an organic solvent rinse for removing sorbed organic contaminants.

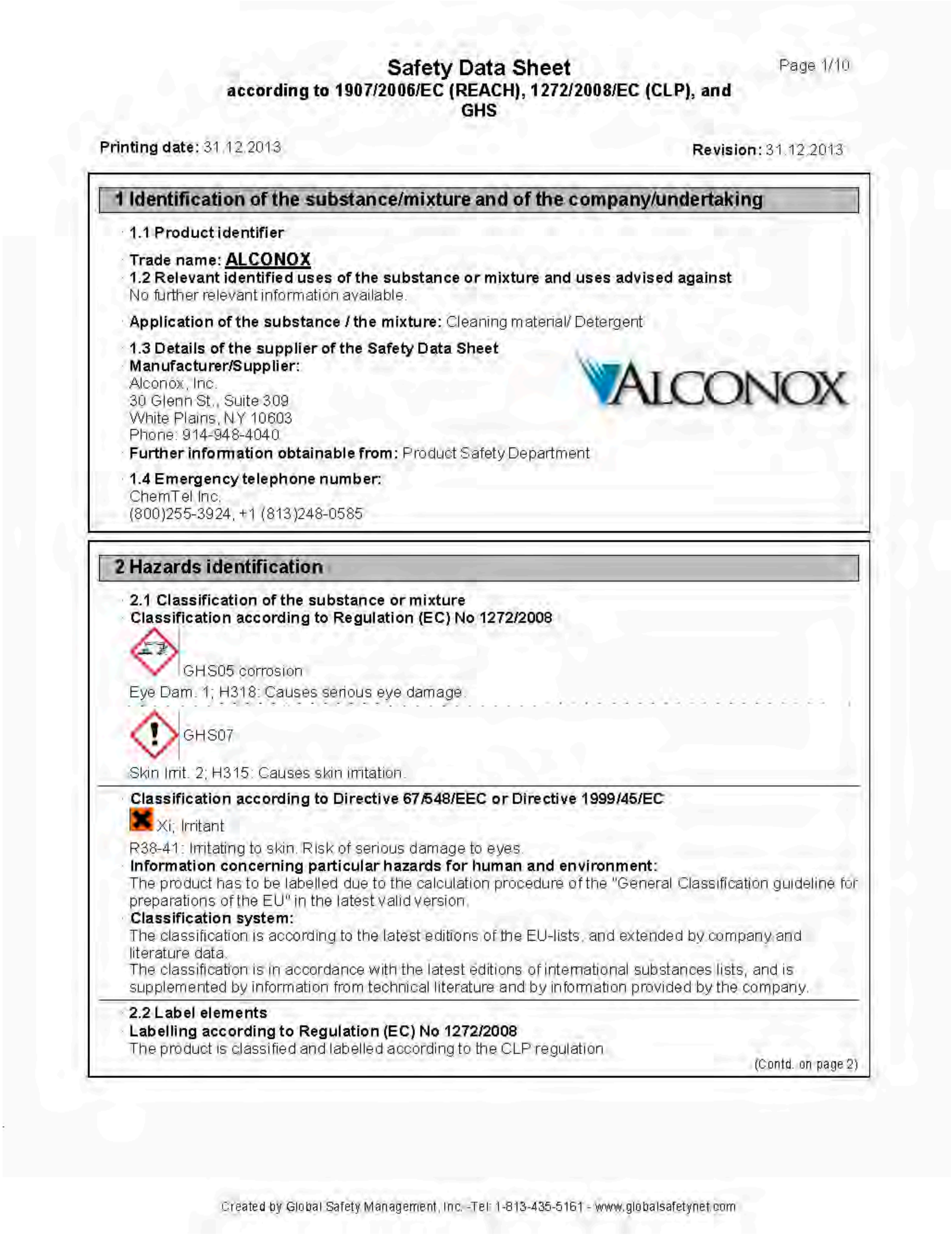
[F] Excessive heat that could damage the polymer should not be used. Check manufacturer's recommendations for heat tolerance.

From: ASTM D5088-02(2008) (ASTM, 2008)

Attachment 4

Safety Data Sheets

ALCONOX™ SDS



Safety Data Sheet
according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), and GHS

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Printing date: 31.12.2013 **Revision:** 31.12.2013

1 Identification of the substance/mixture and of the company/undertaking

- **1.1 Product identifier**
- **Trade name: ALCONOX**
- **1.2 Relevant identified uses of the substance or mixture and uses advised against**
  No further relevant information available.
- **Application of the substance / the mixture:** Cleaning material/ Detergent
- **1.3 Details of the supplier of the Safety Data Sheet**
  Manufacturer/Supplier:
  Alconox, Inc.
  30 Glenn St., Suite 309
  White Plains, NY 10603
  Phone: 914-948-4040
- **Further information obtainable from:** Product Safety Department
- **1.4 Emergency telephone number:**
  ChemTel Inc.
  (800)255-3924, +1 (813)248-0585

2 Hazards identification

- **2.1 Classification of the substance or mixture**
- **Classification according to Regulation (EC) No 1272/2008**

GHS05 corrosion

Eye Dam. 1; H318: Causes serious eye damage.

GHS07

Skin Irrit. 2; H315: Causes skin irritation.

- **Classification according to Directive 67/548/EEC or Directive 1999/45/EC**

Xi; Irritant

R38-41: Irritating to skin. Risk of serious damage to eyes.

- **Information concerning particular hazards for human and environment:**
  The product has to be labelled due to the calculation procedure of the "General Classification guideline for preparations of the EU" in the latest valid version.
- **Classification system:**
  The classification is according to the latest editions of the EU-lists, and extended by company and literature data.
  The classification is in accordance with the latest editions of international substances lists, and is supplemented by information from technical literature and by information provided by the company.

- **2.2 Label elements**
- **Labelling according to Regulation (EC) No 1272/2008**
  The product is classified and labelled according to the CLP regulation.

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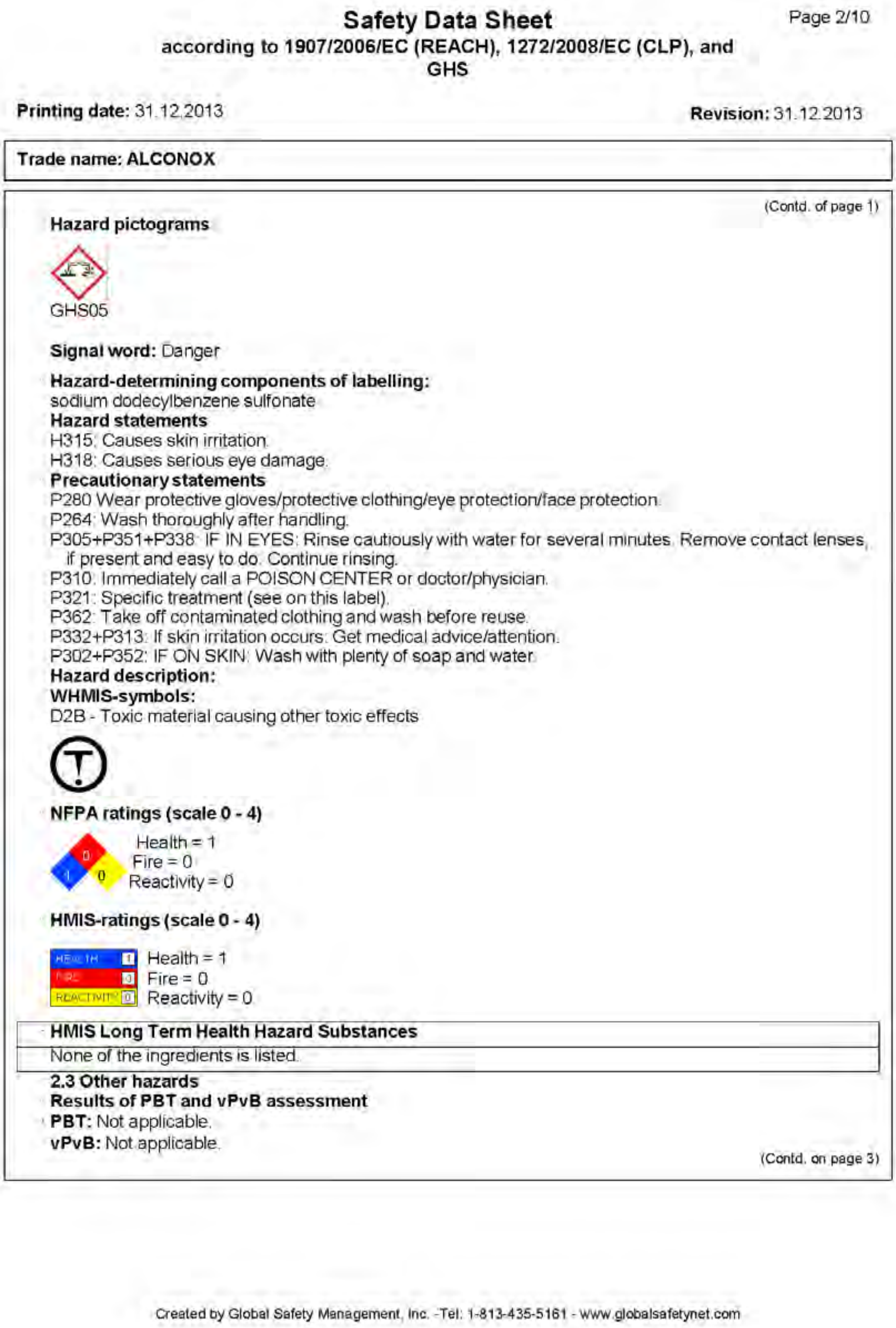

Safety Data Sheet
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Printing date: 31.12.2013 **Revision:** 31.12.2013

Trade name: ALCONOX

(Contd. of page 1)

Hazard pictograms

GHS05

Signal word: Danger

Hazard-determining components of labelling:
sodium dodecylbenzene sulfonate
Hazard statements
H315: Causes skin irritation.
H318: Causes serious eye damage.
Precautionary statements
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P264: Wash thoroughly after handling.
P305+P351+P338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310: Immediately call a POISON CENTER or doctor/physician.
P321: Specific treatment (see on this label).
P362: Take off contaminated clothing and wash before reuse.
P332+P313: If skin irritation occurs: Get medical advice/attention.
P302+P352: IF ON SKIN: Wash with plenty of soap and water.
Hazard description:
WHMIS-symbols:
D2B - Toxic material causing other toxic effects

NFPA ratings (scale 0 - 4)

Health = 1
Fire = 0
Reactivity = 0

HMIS-ratings (scale 0 - 4)

HEALTH 1
FIRE 0
REACTIVITY 0

Health = 1
Fire = 0
Reactivity = 0

HMIS Long Term Health Hazard Substances
None of the ingredients is listed.

2.3 Other hazards
Results of PBT and vPvB assessment
PBT: Not applicable.
vPvB: Not applicable.

(Contd. on page 3)

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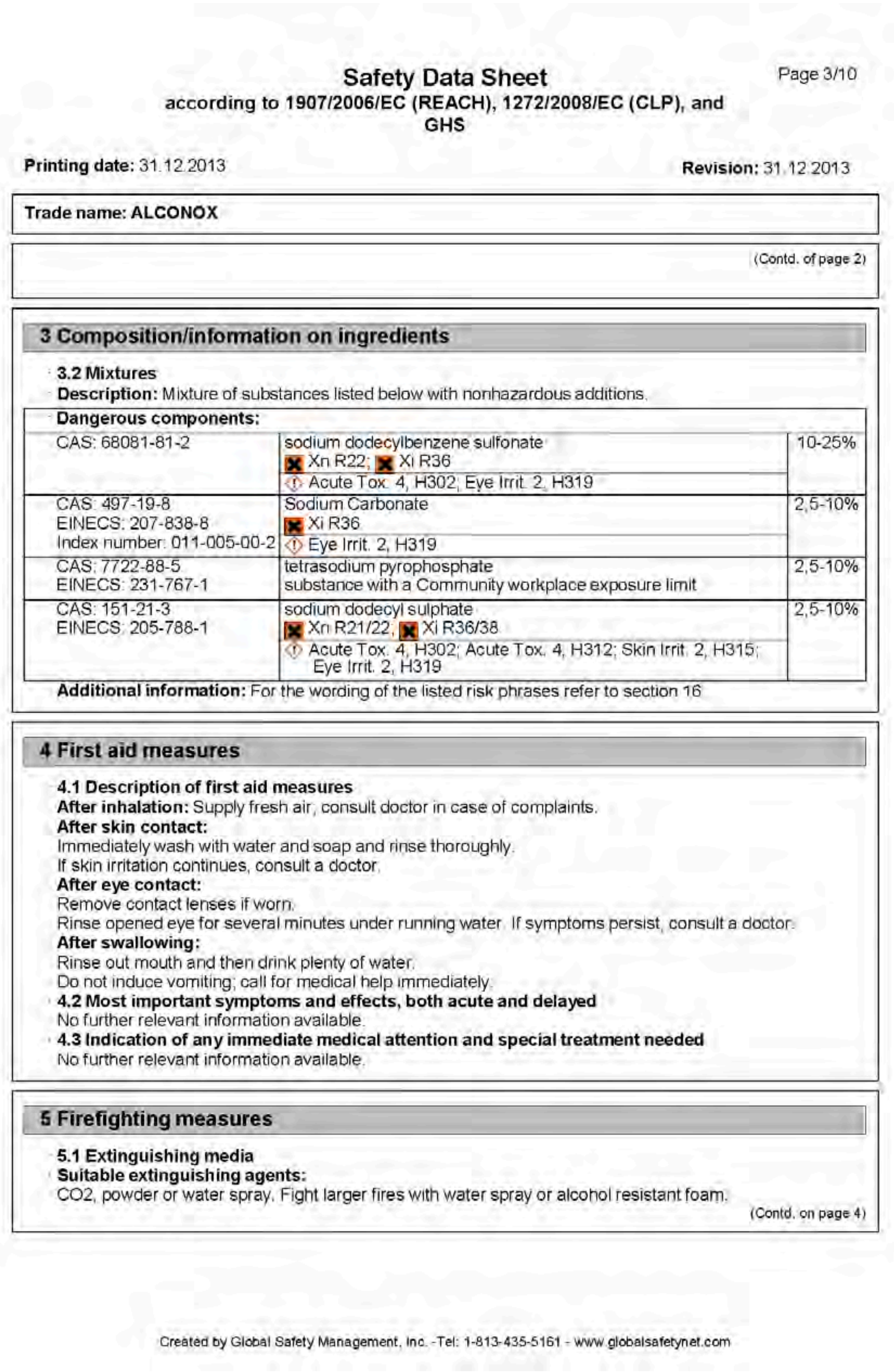

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(Contd. of page 2)

3 Composition/information on ingredients

3.2 Mixtures
Description: Mixture of substances listed below with nonhazardous additions.

Dangerous components:

CAS: 68081-81-2	sodium dodecylbenzene sulfonate ☒ Xn R22; ☒ Xi R36 ⚠ Acute Tox. 4, H302; Eye Irrit. 2, H319	10-25%
CAS: 497-19-8 EINECS: 207-838-8 Index number: 011-005-00-2	Sodium Carbonate ☒ Xi R36 ⚠ Eye Irrit. 2, H319	2,5-10%
CAS: 7722-88-5 EINECS: 231-767-1	tetrasodium pyrophosphate substance with a Community workplace exposure limit	2,5-10%
CAS: 151-21-3 EINECS: 205-788-1	sodium dodecyl sulphate ☒ Xn R21/22; ☒ Xi R36/38 ⚠ Acute Tox. 4, H302; Acute Tox. 4, H312; Skin Irrit. 2, H315; Eye Irrit. 2, H319	2,5-10%

Additional information: For the wording of the listed risk phrases refer to section 16.

4 First aid measures

4.1 Description of first aid measures
After inhalation: Supply fresh air; consult doctor in case of complaints.
After skin contact:
Immediately wash with water and soap and rinse thoroughly.
If skin irritation continues, consult a doctor.
After eye contact:
Remove contact lenses if worn.
Rinse opened eye for several minutes under running water. If symptoms persist, consult a doctor.
After swallowing:
Rinse out mouth and then drink plenty of water.
Do not induce vomiting; call for medical help immediately.
4.2 Most important symptoms and effects, both acute and delayed
No further relevant information available.
4.3 Indication of any immediate medical attention and special treatment needed
No further relevant information available.

5 Firefighting measures

5.1 Extinguishing media
Suitable extinguishing agents:
CO2, powder or water spray. Fight larger fires with water spray or alcohol resistant foam.

(Contd. on page 4)

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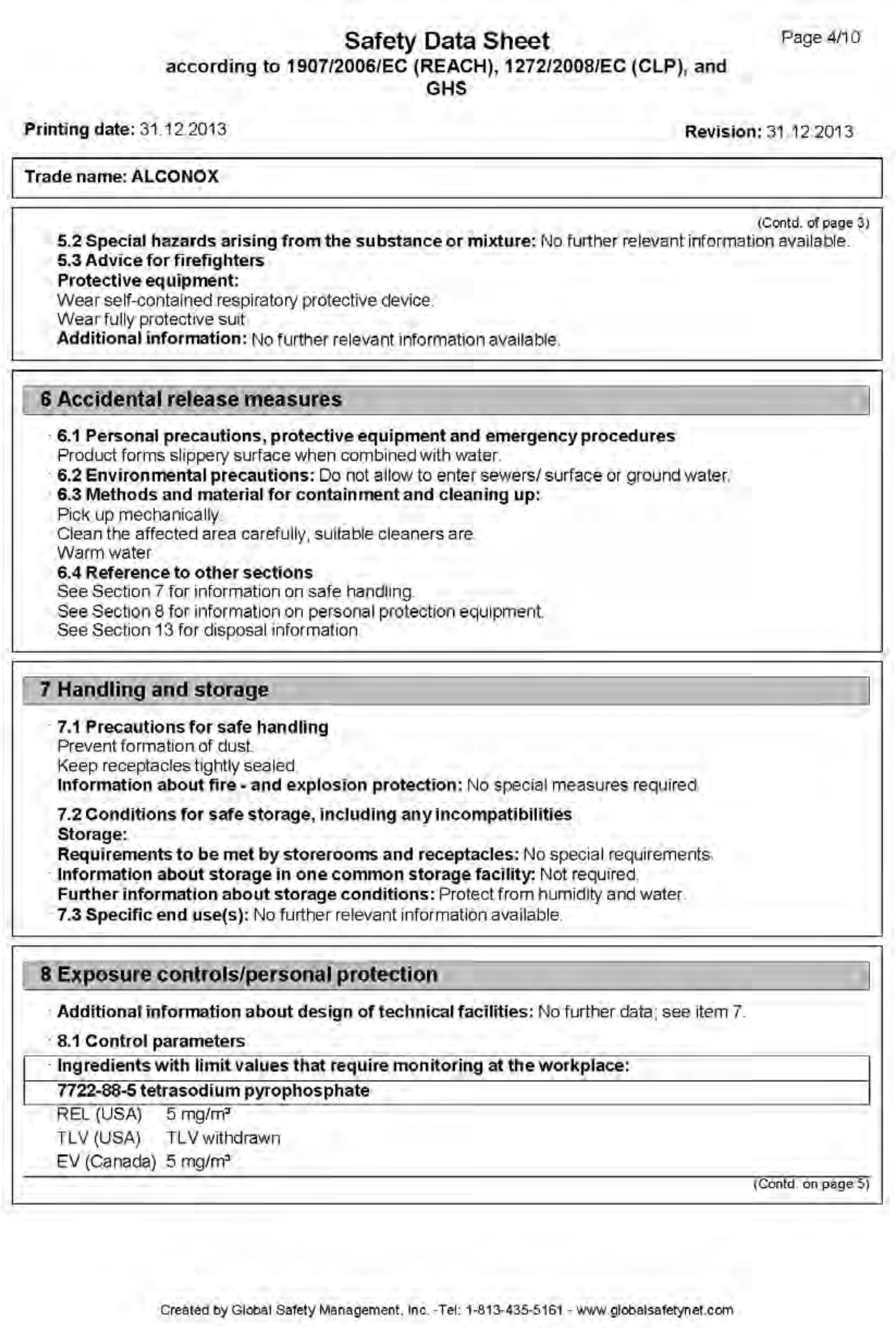

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(Contd. of page 3)

5.2 Special hazards arising from the substance or mixture: No further relevant information available.

5.3 Advice for firefighters

Protective equipment:

Wear self-contained respiratory protective device.

Wear fully protective suit.

Additional information: No further relevant information available.

6 Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures

Product forms slippery surface when combined with water.

6.2 Environmental precautions: Do not allow to enter sewers/ surface or ground water.

6.3 Methods and material for containment and cleaning up:

Pick up mechanically.

Clean the affected area carefully; suitable cleaners are:

Warm water

6.4 Reference to other sections

See Section 7 for information on safe handling.

See Section 8 for information on personal protection equipment.

See Section 13 for disposal information.

7 Handling and storage

7.1 Precautions for safe handling

Prevent formation of dust.

Keep receptacles tightly sealed.

Information about fire - and explosion protection: No special measures required.

7.2 Conditions for safe storage, including any incompatibilities

Storage:

Requirements to be met by storerooms and receptacles: No special requirements.

Information about storage in one common storage facility: Not required.

Further information about storage conditions: Protect from humidity and water.

7.3 Specific end use(s): No further relevant information available.

8 Exposure controls/personal protection

Additional information about design of technical facilities: No further data; see item 7.

8.1 Control parameters

Ingredients with limit values that require monitoring at the workplace:

7722-88-5 tetrasodium pyrophosphate

REL (USA)	5 mg/m³
TLV (USA)	TLV withdrawn
EV (Canada)	5 mg/m³

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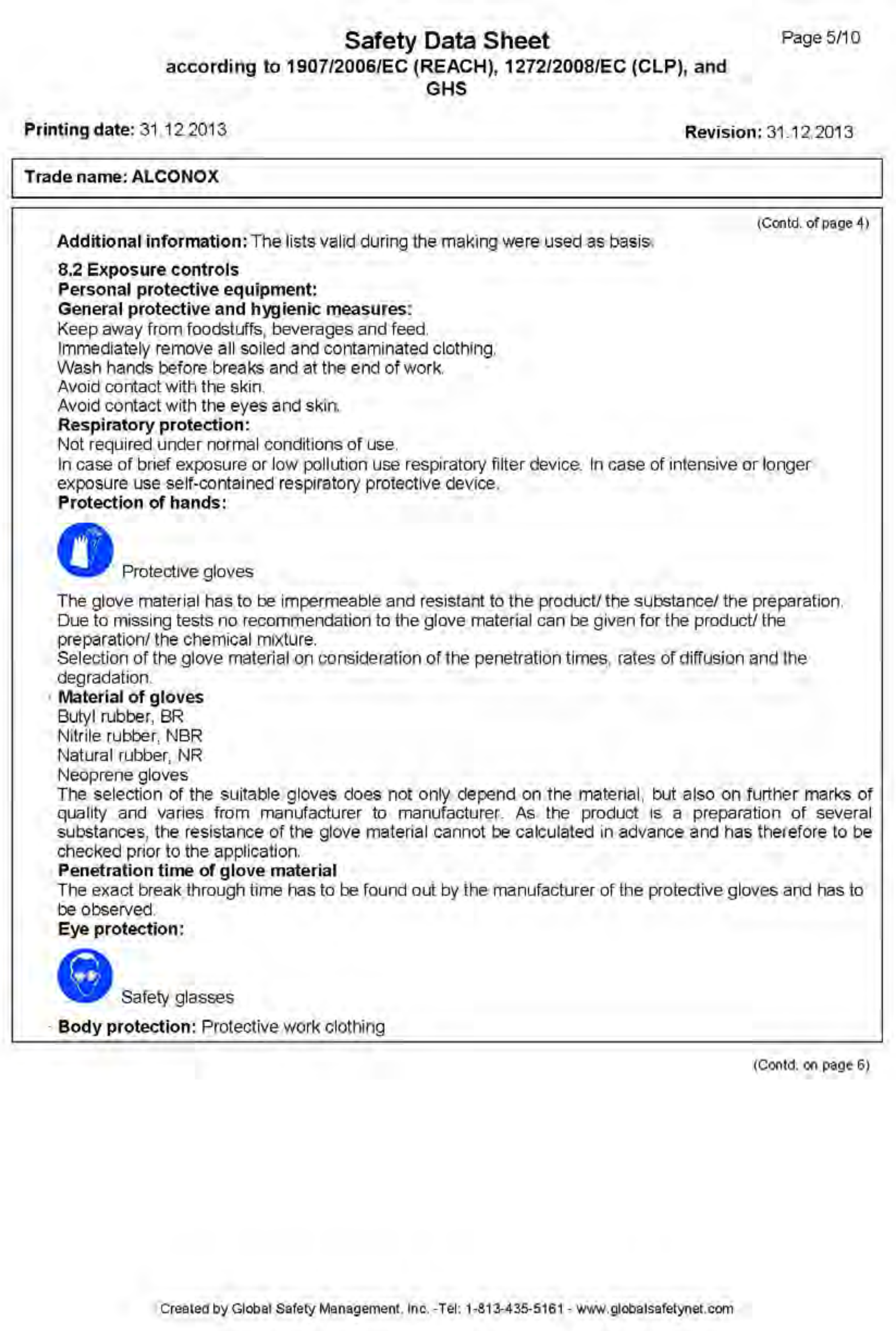

Trade name: ALCONOX

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Additional information: The lists valid during the making were used as basis.

8.2 Exposure controls
Personal protective equipment:
General protective and hygienic measures:
Keep away from foodstuffs, beverages and feed.
Immediately remove all soiled and contaminated clothing.
Wash hands before breaks and at the end of work.
Avoid contact with the skin.
Avoid contact with the eyes and skin.
Respiratory protection:
Not required under normal conditions of use.
In case of brief exposure or low pollution use respiratory filter device. In case of intensive or longer exposure use self-contained respiratory protective device.
Protection of hands:

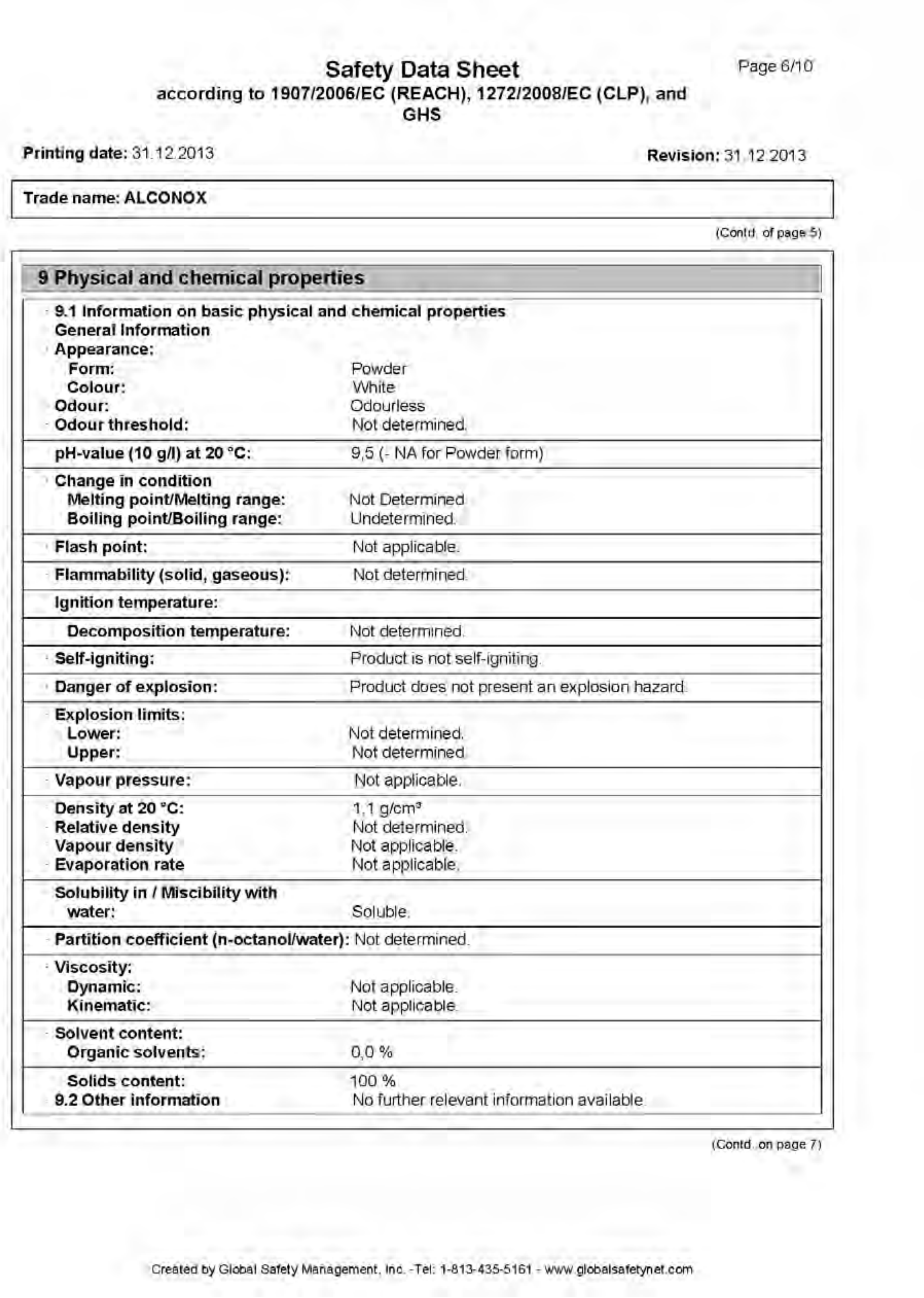
Protective gloves

The glove material has to be impermeable and resistant to the product/ the substance/ the preparation.
Due to missing tests no recommendation to the glove material can be given for the product/ the preparation/ the chemical mixture.
Selection of the glove material on consideration of the penetration times, rates of diffusion and the degradation.
Material of gloves
Butyl rubber, BR
Nitrile rubber, NBR
Natural rubber, NR
Neoprene gloves
The selection of the suitable gloves does not only depend on the material, but also on further marks of quality and varies from manufacturer to manufacturer. As the product is a preparation of several substances, the resistance of the glove material cannot be calculated in advance and has therefore to be checked prior to the application.
Penetration time of glove material
The exact break through time has to be found out by the manufacturer of the protective gloves and has to be observed.
Eye protection:

Safety glasses

Body protection: Protective work clothing

(Contd. on page 6)



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9 Physical and chemical properties

9.1 Information on basic physical and chemical properties	
General Information	
Appearance:	
Form:	Powder
Colour:	White
Odour:	Odourless
Odour threshold:	Not determined.
pH-value (10 g/l) at 20 °C:	9,5 (- NA for Powder form)
Change in condition	
Melting point/Melting range:	Not Determined
Boiling point/Boiling range:	Undetermined.
Flash point:	Not applicable.
Flammability (solid, gaseous):	Not determined.
Ignition temperature:	
Decomposition temperature:	Not determined.
Self-igniting:	Product is not self-igniting.
Danger of explosion:	Product does not present an explosion hazard.
Explosion limits:	
Lower:	Not determined.
Upper:	Not determined.
Vapour pressure:	Not applicable.
Density at 20 °C:	1,1 g/cm³
Relative density	Not determined.
Vapour density	Not applicable.
Evaporation rate	Not applicable.
Solubility in / Miscibility with water:	Soluble.
Partition coefficient (n-octanol/water):	Not determined.
Viscosity:	
Dynamic:	Not applicable.
Kinematic:	Not applicable.
Solvent content:	
Organic solvents:	0,0 %
Solids content:	100 %
9.2 Other information	No further relevant information available.

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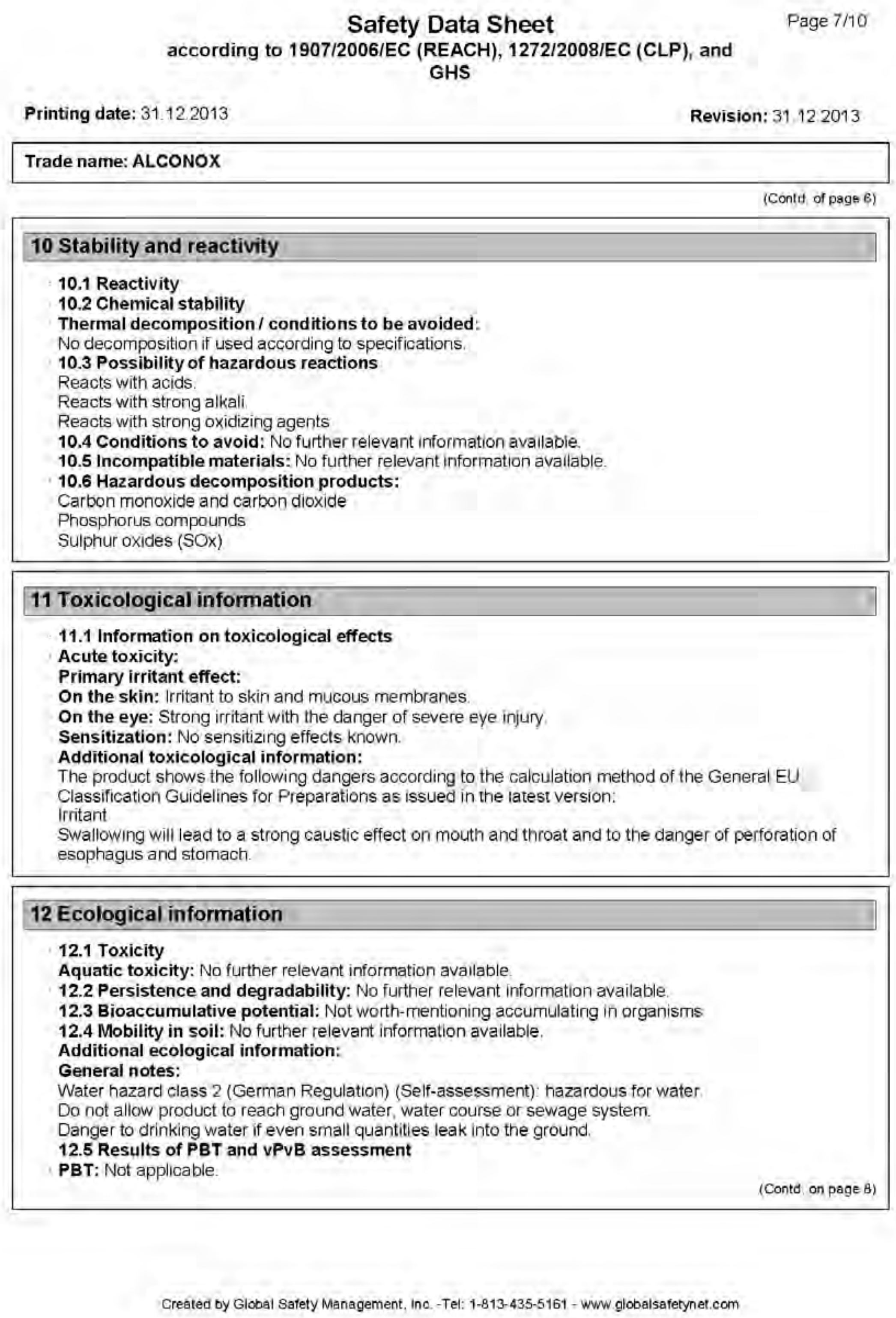

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10 Stability and reactivity

10.1 Reactivity
10.2 Chemical stability
Thermal decomposition / conditions to be avoided:
No decomposition if used according to specifications.
10.3 Possibility of hazardous reactions
Reacts with acids.
Reacts with strong alkali.
Reacts with strong oxidizing agents
10.4 Conditions to avoid: No further relevant information available.
10.5 Incompatible materials: No further relevant information available.
10.6 Hazardous decomposition products:
Carbon monoxide and carbon dioxide
Phosphorus compounds
Sulphur oxides (SOx)

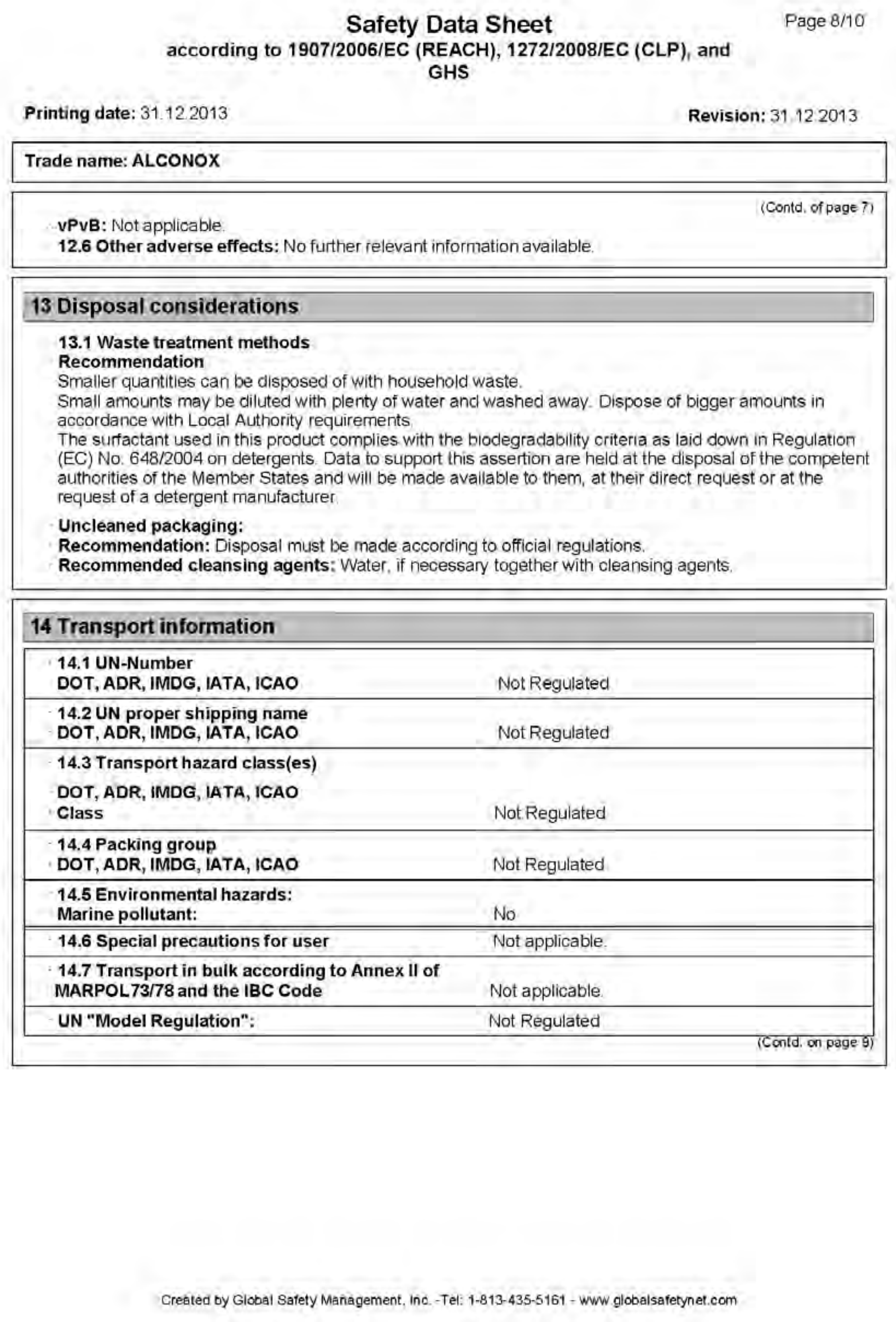
11 Toxicological information

11.1 Information on toxicological effects
Acute toxicity:
Primary irritant effect:
On the skin: Irritant to skin and mucous membranes.
On the eye: Strong irritant with the danger of severe eye injury.
Sensitization: No sensitizing effects known.
Additional toxicological information:
The product shows the following dangers according to the calculation method of the General EU Classification Guidelines for Preparations as issued in the latest version:
Irritant
Swallowing will lead to a strong caustic effect on mouth and throat and to the danger of perforation of esophagus and stomach.

12 Ecological information

12.1 Toxicity
Aquatic toxicity: No further relevant information available.
12.2 Persistence and degradability: No further relevant information available.
12.3 Bioaccumulative potential: Not worth-mentioning accumulating in organisms
12.4 Mobility in soil: No further relevant information available.
Additional ecological information:
General notes:
Water hazard class 2 (German Regulation) (Self-assessment): hazardous for water.
Do not allow product to reach ground water, water course or sewage system.
Danger to drinking water if even small quantities leak into the ground.
12.5 Results of PBT and vPvB assessment
PBT: Not applicable.

(Contd. on page 8)



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vPvB: Not applicable.
12.6 Other adverse effects: No further relevant information available.

13 Disposal considerations

13.1 Waste treatment methods
Recommendation
Smaller quantities can be disposed of with household waste.
Small amounts may be diluted with plenty of water and washed away. Dispose of bigger amounts in accordance with Local Authority requirements.
The surfactant used in this product complies with the biodegradability criteria as laid down in Regulation (EC) No. 648/2004 on detergents. Data to support this assertion are held at the disposal of the competent authorities of the Member States and will be made available to them, at their direct request or at the request of a detergent manufacturer.

Uncleaned packaging:
Recommendation: Disposal must be made according to official regulations.
Recommended cleansing agents: Water, if necessary together with cleansing agents.

14 Transport information

14.1 UN-Number **DOT, ADR, IMDG, IATA, ICAO**	Not Regulated
14.2 UN proper shipping name **DOT, ADR, IMDG, IATA, ICAO**	Not Regulated
14.3 Transport hazard class(es) **DOT, ADR, IMDG, IATA, ICAO** **Class**	Not Regulated
14.4 Packing group **DOT, ADR, IMDG, IATA, ICAO**	Not Regulated
14.5 Environmental hazards: **Marine pollutant:**	No
14.6 Special precautions for user	Not applicable.
14.7 Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code	Not applicable.
UN "Model Regulation":	Not Regulated

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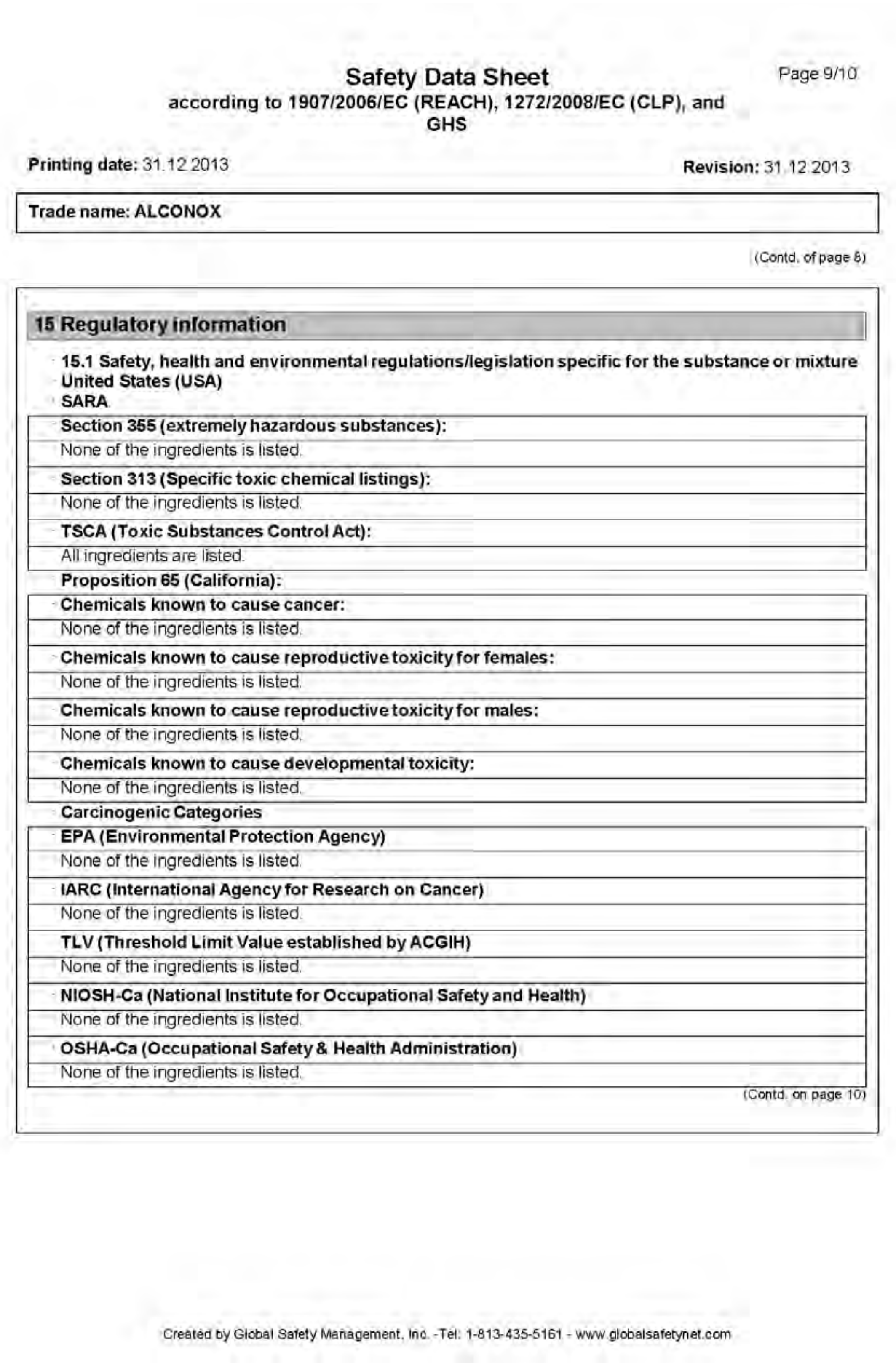

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15 Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

United States (USA)

SARA

Section 355 (extremely hazardous substances):

None of the ingredients is listed.

Section 313 (Specific toxic chemical listings):

None of the ingredients is listed.

TSCA (Toxic Substances Control Act):

All ingredients are listed.

Proposition 65 (California):

Chemicals known to cause cancer:

None of the ingredients is listed.

Chemicals known to cause reproductive toxicity for females:

None of the ingredients is listed.

Chemicals known to cause reproductive toxicity for males:

None of the ingredients is listed.

Chemicals known to cause developmental toxicity:

None of the ingredients is listed.

Carcinogenic Categories

EPA (Environmental Protection Agency)

None of the ingredients is listed.

IARC (International Agency for Research on Cancer)

None of the ingredients is listed.

TLV (Threshold Limit Value established by ACGIH)

None of the ingredients is listed.

NIOSH-Ca (National Institute for Occupational Safety and Health)

None of the ingredients is listed.

OSHA-Ca (Occupational Safety & Health Administration)

None of the ingredients is listed.

(Contd. on page 10)

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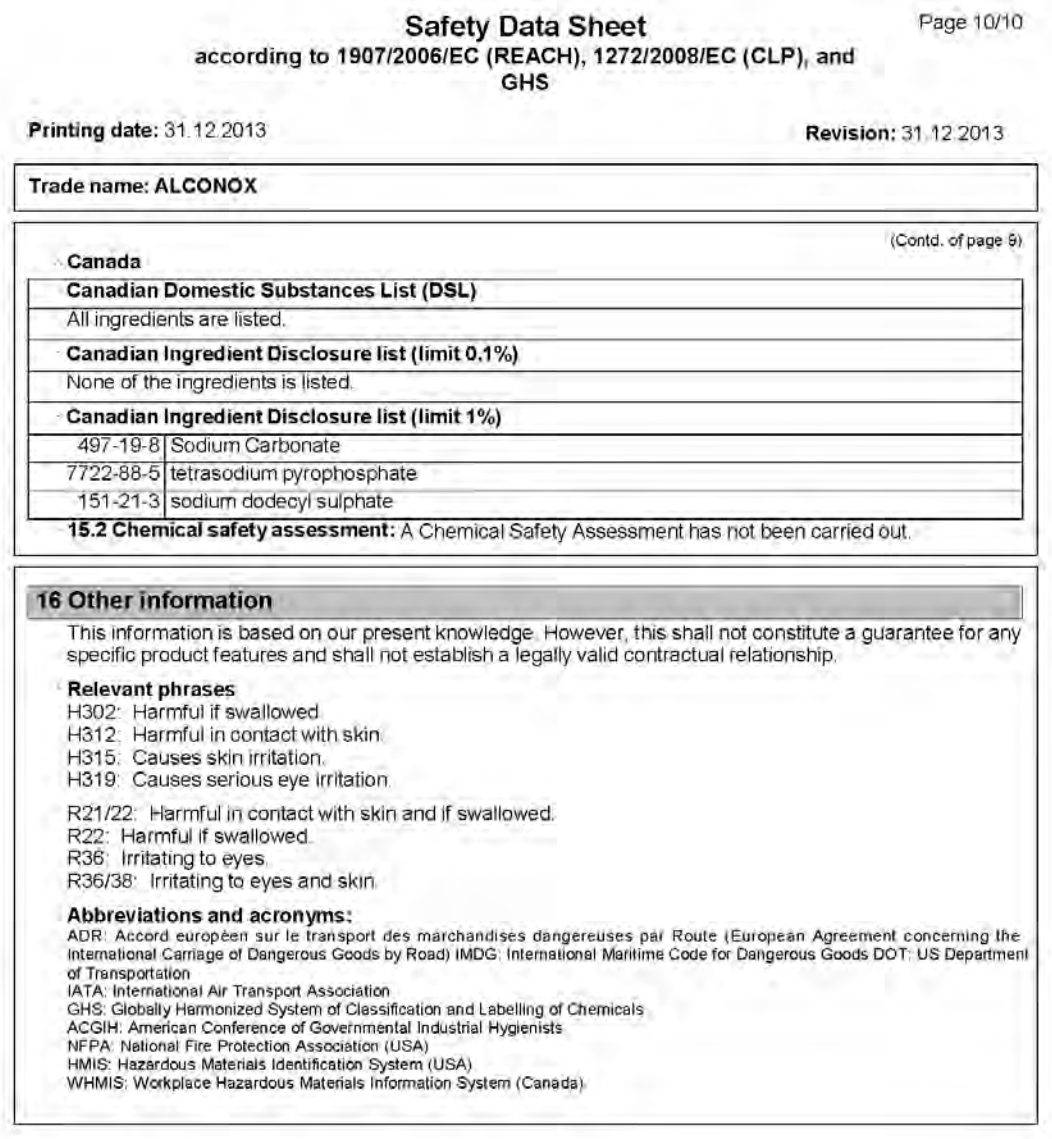

Safety Data Sheet
according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), and GHS

Printing date: 31.12.2013 **Revision:** 31.12.2013

Trade name: ALCONOX

(Contd. of page 9)

Canada

Canadian Domestic Substances List (DSL)	
All ingredients are listed.	
Canadian Ingredient Disclosure list (limit 0.1%)	
None of the ingredients is listed.	
Canadian Ingredient Disclosure list (limit 1%)	
497-19-8	Sodium Carbonate
7722-88-5	tetrasodium pyrophosphate
151-21-3	sodium dodecyl sulphate

15.2 Chemical safety assessment: A Chemical Safety Assessment has not been carried out.

16 Other information

This information is based on our present knowledge. However, this shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.

Relevant phrases
H302: Harmful if swallowed.
H312: Harmful in contact with skin.
H315: Causes skin irritation.
H319: Causes serious eye irritation.

R21/22: Harmful in contact with skin and if swallowed.
R22: Harmful if swallowed.
R36: Irritating to eyes.
R36/38: Irritating to eyes and skin.

Abbreviations and acronyms:
ADR: Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road) IMDG: International Maritime Code for Dangerous Goods DOT: US Department of Transportation
IATA: International Air Transport Association
GHS: Globally Harmonized System of Classification and Labelling of Chemicals
ACGIH: American Conference of Governmental Industrial Hygienists
NFPA: National Fire Protection Association (USA)
HMIS: Hazardous Materials Identification System (USA)
WHMIS: Workplace Hazardous Materials Information System (Canada)

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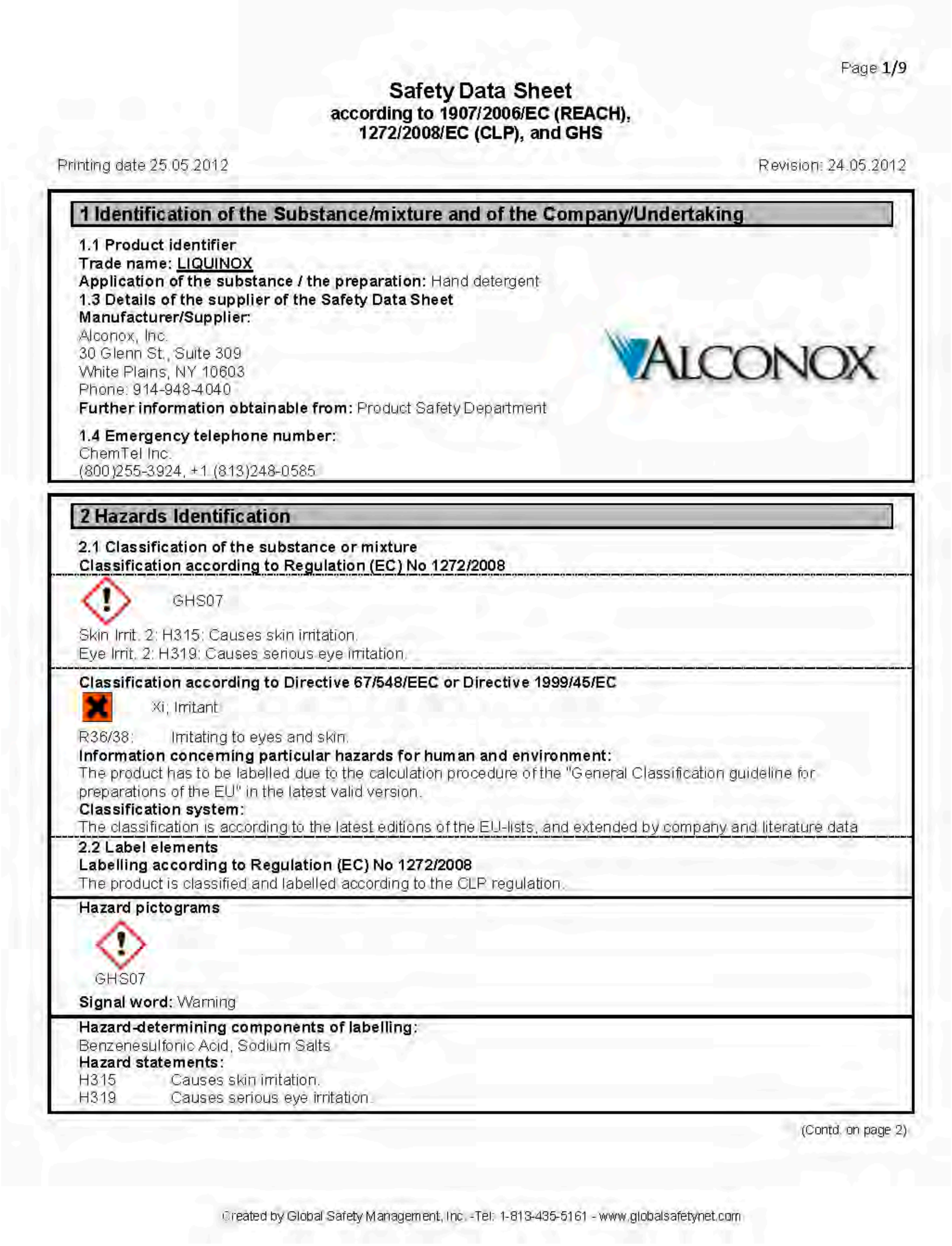
LIQUINOX™ SDS



Safety Data Sheet
according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), and GHS

Printing date 25.05.2012 Revision: 24.05.2012

1 Identification of the Substance/mixture and of the Company/Undertaking

1.1 Product identifier
Trade name: **LIQUINOX**
Application of the substance / the preparation: Hand detergent
1.3 Details of the supplier of the Safety Data Sheet
Manufacturer/Supplier:
Alconox, Inc.
30 Glenn St., Suite 309
White Plains, NY 10603
Phone: 914-948-4040
Further information obtainable from: Product Safety Department

ALCONOX

1.4 Emergency telephone number:
ChemTel Inc.
(800)255-3924, +1 (813)248-0585

2 Hazards Identification

2.1 Classification of the substance or mixture
Classification according to Regulation (EC) No 1272/2008

GHS07

Skin Irrit. 2: H315: Causes skin irritation.
Eye Irrit. 2: H319: Causes serious eye irritation.

Classification according to Directive 67/548/EEC or Directive 1999/45/EC

Xi; Irritant

R36/38: Irritating to eyes and skin.

Information concerning particular hazards for human and environment:
The product has to be labelled due to the calculation procedure of the "General Classification guideline for preparations of the EU" in the latest valid version.
Classification system:
The classification is according to the latest editions of the EU-lists, and extended by company and literature data

2.2 Label elements
Labelling according to Regulation (EC) No 1272/2008
The product is classified and labelled according to the CLP regulation.

Hazard pictograms

GHS07

Signal word: Warning

Hazard-determining components of labelling:
Benzenesulfonic Acid, Sodium Salts
Hazard statements:
H315 Causes skin irritation.
H319 Causes serious eye irritation.

(Contd. on page 2)

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Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), and GHS

Printing date 25.05.2012

Revision: 23.05.2012

Trade name: LIQUINOX

(Contd. of page 1)

Precautionary statements:

P280 Wear protective gloves/protective clothing/eye protection/face protection.
P264 Wash thoroughly after handling.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P321 Specific treatment (see on this label).
P362 Take off contaminated clothing and wash before reuse.
P332+P313 If skin irritation occurs: Get medical advice/attention.
P337+P313 If eye irritation persists: Get medical advice/attention.
P302+P352 IF ON SKIN: Wash with plenty of soap and water.

Hazard description:

WHMIS-symbols:

D2B - Toxic material causing other toxic effects

NFPA ratings (scale 0 - 4)

Health = 1
Fire = 0
Reactivity = 0

HMIS-ratings (scale 0 - 4)

HEALTH	1	Health = 1
FIRE	0	Fire = 0
REACTIVITY	0	Reactivity = 0

2.3 Other hazards

Results of PBT and vPvB assessment

PBT: Not applicable.

vPvB: Not applicable.

3 Composition/Information on Ingredients

3.2 Mixtures

Description: Mixture of substances listed below with nonhazardous additions.

Dangerous components:

CAS: 68081-81-2	Benzenesulfonic Acid, Sodium Salts Xi R38-41 Eye Dam. 1, H318 Skin Irrit. 2, H315	10-25%
CAS: 1300-72-7 EINECS: 215-090-9	Sodium xylenesulphonate Xi R36/37/38 Skin Irrit. 2, H315; Eye Irrit. 2, H319; STOT SE 3, H335	2.5-10%
CAS: 84133-50-6	Alcohol Ethoxylate Xi R36/38 Skin Irrit. 2, H315	2.5-10%

(Contd. on page 3)

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Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), and GHS

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Trade name: LIQUINOX

(Contd. of page 2)

CAS: 68603-42-9 EINECS: 271-657-0	Coconut diethanolamide ☒ Xi R36/38	2.5-10%
CAS: 17572-97-3 EINECS: 241-543-5	Ethylenediaminetetraacetic acid, tripotassium salt ☒ Xi R36/37/38	2.5-10%

Additional information: For the wording of the listed risk phrases refer to section 16.

4 First Aid Measures

4.1 Description of first aid measures

General information:
Take affected persons out into the fresh air.

After inhalation:
Supply fresh air; consult doctor in case of complaints.

After skin contact:
Immediately wash with water and soap and rinse thoroughly.
If skin irritation continues, consult a doctor.

After eye contact:
Remove contact lenses if worn.
Rinse opened eye for several minutes under running water. If symptoms persist, consult a doctor.

After swallowing:
Do not induce vomiting; call for medical help immediately.
Rinse out mouth and then drink plenty of water.
A person vomiting while laying on their back should be turned onto their side.

4.2 Most important symptoms and effects, both acute and delayed:
No further relevant information available.

4.3 Indication of any immediate medical attention and special treatment needed:
No further relevant information available.

5 Firefighting Measures

5.1 Extinguishing media:

Suitable extinguishing agents:
CO2, powder or water spray. Fight larger fires with water spray or alcohol resistant foam.

5.2 Special hazards arising from the substance or mixture:
No further relevant information available.

5.3 Advice for firefighters:

Protective equipment:
Wear self-contained respiratory protective device.
Wear fully protective suit.

6 Accidental Release Measures

6.1 Personal precautions, protective equipment and emergency procedures:
Ensure adequate ventilation
Particular danger of slipping on leaked/spilled product

6.2 Environmental precautions:
Dilute with plenty of water.
Do not allow to enter sewers/ surface or ground water.

(Contd. on page 4)

(Contd. of page 3)

6.3 Methods and material for containment and cleaning up:
Absorb with liquid-binding material (sand, diatomite, acid binders, universal binders, sawdust). Clean the affected area carefully; suitable cleaners are:
Warm water

6.4 Reference to other sections:
See Section 7 for information on safe handling.
See Section 8 for information on personal protection equipment.
See Section 13 for disposal information

7 Handling and Storage

7.1 Precautions for safe handling:
No special measures required.

Information about fire - and explosion protection:
No special measures required.

7.2 Conditions for safe storage, including any incompatibilities:
Storage:
Requirements to be met by storerooms and receptacles: No special requirements.
Information about storage in one common storage facility: Not required.
Further information about storage conditions: None

7.3 Specific end use(s): No further relevant information available.

8 Exposure Controls/Personal Protection

Additional information about design of technical facilities: No further data; see item 7.

8.1 Control parameters

Ingredients with limit values that require monitoring at the workplace:
The product does not contain any relevant quantities of materials with critical values that have to be monitored at the workplace.

Additional information: The lists valid during the making were used as basis.

8.2 Exposure controls:
Personal protective equipment:
General protective and hygienic measures:
Keep away from foodstuffs, beverages and feed.
Immediately remove all soiled and contaminated clothing.
Wash hands before breaks and at the end of work.
Avoid contact with the eyes and skin.

Respiratory protection:
Not required.

Protection of hands:

Protective gloves

The glove material has to be impermeable and resistant to the product/ the substance/ the preparation.
Due to missing tests no recommendation to the glove material can be given for the product/ the preparation/ the chemical mixture.
Selection of the glove material on consideration of the penetration times, rates of diffusion and the degradation

(Contd. on page 5)

Safety Data Sheet

according to 1907/2006/EC (REACH),
1272/2008/EC (CLP), and GHS

Printing date 25.05.2012 Revision: 23.05.2012

Trade name: LIQUINOX

(Contd. of page 4)

Material of gloves:

Natural rubber, NR
Nitrile rubber, NBR
Neoprene gloves

The selection of the suitable gloves does not only depend on the material, but also on further marks of quality and varies from manufacturer to manufacturer. As the product is a preparation of several substances, the resistance of the glove material cannot be calculated in advance and has therefore to be checked prior to the application.

Penetration time of glove material:

The exact break through time has to be found out by the manufacturer of the protective gloves and has to be observed.

Eye protection:

Safety glasses

Goggles recommended during refilling

9 Physical and Chemical Properties

9.1 Information on basic physical and chemical properties:

General Information:	
Appearance:	
Form:	Liquid
Colour:	Light yellow
Odour:	Odourless
Odour threshold:	Not determined.
pH-value at 20°C:	8.5
Change in condition:	
Melting point/Melting range:	Undetermined.
Boiling point/Boiling range:	100°C
Flash point:	Not applicable.
Flammability (solid, gaseous):	Not applicable.
Ignition temperature:	
Decomposition temperature:	Not determined.
Self-igniting:	Product is not selfigniting.
Danger of explosion:	Product does not present an explosion hazard.
Explosion limits:	
Lower:	Not determined.
Upper:	Not determined.
Vapour pressure at 20°C:	23 hPa
Density at 20°C:	1.08 g/cm³
Relative density:	Not determined.
Vapour density:	Not determined.
Evaporation rate:	Not determined.

(Contd. on page 6)

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), and GHS

Printing date 25.05.2012 Revision: 23.05.2012

Trade name: LIQUINOX

(Contd. of page 5)

Solubility in / Miscibility with water:	Fully miscible.
Segregation coefficient (n-octanol/water):	Not determined.
Viscosity:	
Dynamic:	Not determined.
Kinematic:	Not determined.
9.2 Other information:	No further relevant information available.

10 Stability and Reactivity

10.1 Reactivity:

10.2 Chemical stability:

Thermal decomposition / conditions to be avoided:

No decomposition if used according to specifications.

10.3 Possibility of hazardous reactions:

Reacts with strong oxidizing agents.
Reacts with strong acids.

10.4 Conditions to avoid:

No further relevant information available.

10.5 Incompatible materials:

No further relevant information available.

10.6 Hazardous decomposition products:

Carbon monoxide and carbon dioxide
Sulphur oxides (SOx)
Nitrogen oxides

11 Toxicological Information

11.1 Information on toxicological effects:

Acute toxicity:

Primary irritant effect:

On the skin: Irritant to skin and mucous membranes.

On the eye: Strong irritant with the danger of severe eye injury.

Sensitization: No sensitizing effects known.

Additional toxicological information:

The product shows the following dangers according to the calculation method of the General EU Classification Guidelines for Preparations as issued in the latest version:
Irritant

12 Ecological Information

12.1 Toxicity:

Aquatic toxicity: No further relevant information available.

12.2 Persistence and degradability: No further relevant information available.

12.3 Bioaccumulative potential: No further relevant information available.

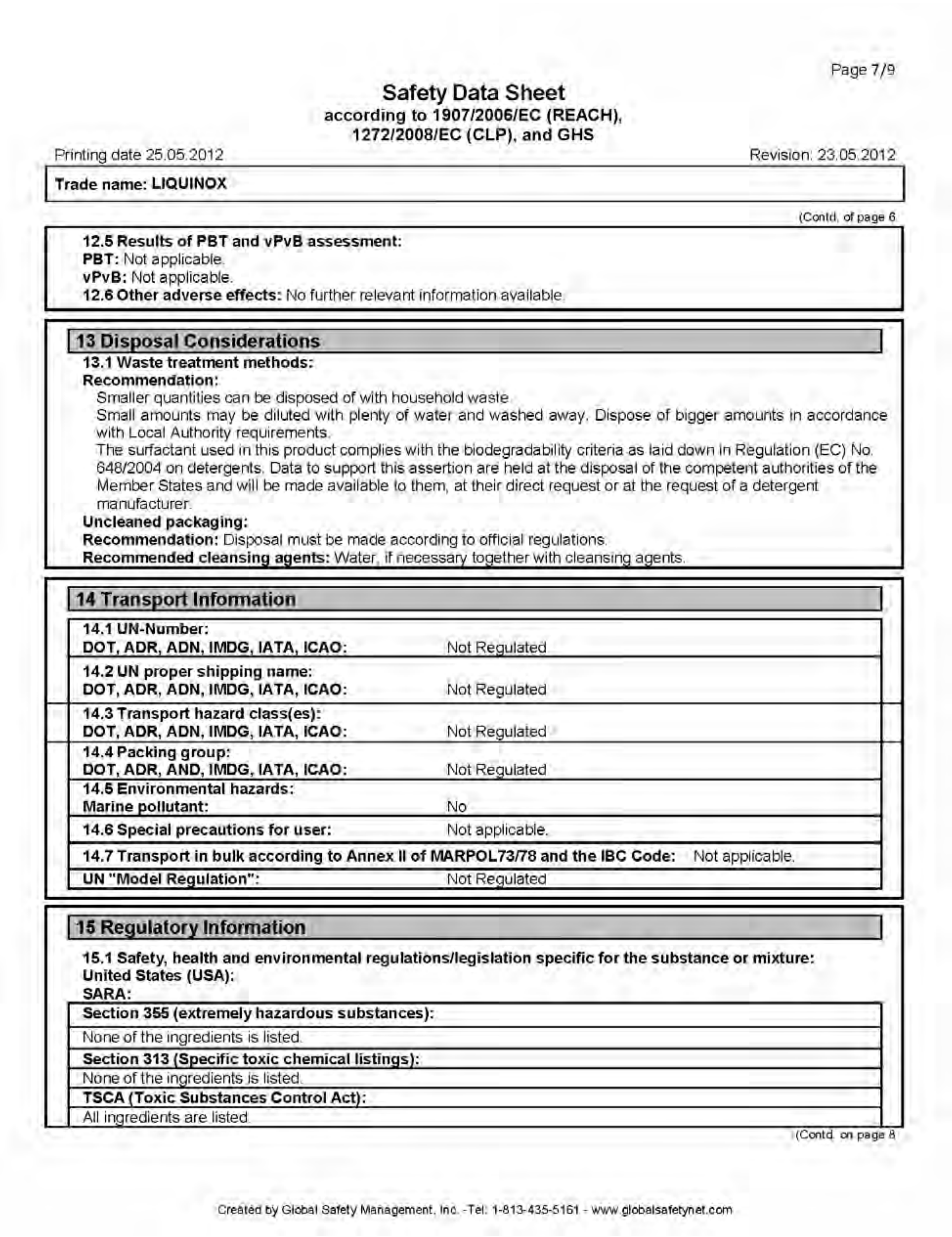
12.4 Mobility in soil: No further relevant information available.

Additional ecological information:

General notes:

Water hazard class 1 (German Regulation) (Self-assessment): slightly hazardous for water
Do not allow undiluted product or large quantities of it to reach ground water, water course or sewage system.
Must not reach sewage water or drainage ditch undiluted or unneutralized.

(Contd. on page 7)



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according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), and GHS

Printing date 25.05.2012 Revision: 23.05.2012

Trade name: LIQUINOX

(Contd. of page 6

12.5 Results of PBT and vPvB assessment:
PBT: Not applicable.
vPvB: Not applicable.
12.6 Other adverse effects: No further relevant information available.

13 Disposal Considerations

13.1 Waste treatment methods:
Recommendation:

Smaller quantities can be disposed of with household waste.
Small amounts may be diluted with plenty of water and washed away. Dispose of bigger amounts in accordance with Local Authority requirements.
The surfactant used in this product complies with the biodegradability criteria as laid down in Regulation (EC) No. 648/2004 on detergents. Data to support this assertion are held at the disposal of the competent authorities of the Member States and will be made available to them, at their direct request or at the request of a detergent manufacturer.

Uncleaned packaging:
Recommendation: Disposal must be made according to official regulations.
Recommended cleansing agents: Water, if necessary together with cleansing agents.

14 Transport Information

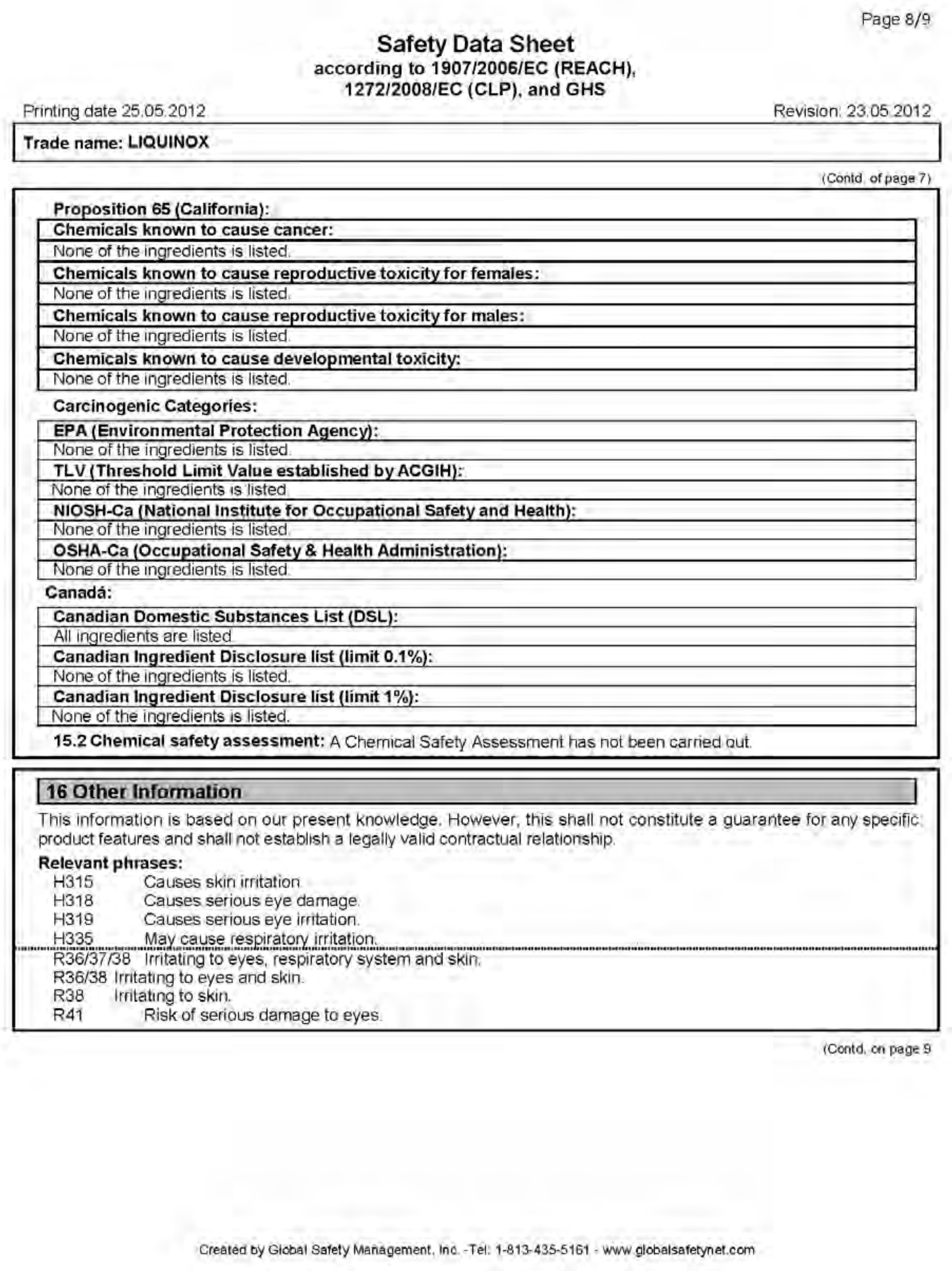
14.1 UN-Number: **DOT, ADR, ADN, IMDG, IATA, ICAO:**	Not Regulated
14.2 UN proper shipping name: **DOT, ADR, ADN, IMDG, IATA, ICAO:**	Not Regulated
14.3 Transport hazard class(es): **DOT, ADR, ADN, IMDG, IATA, ICAO:**	Not Regulated
14.4 Packing group: **DOT, ADR, AND, IMDG, IATA, ICAO:**	Not Regulated
14.5 Environmental hazards: **Marine pollutant:**	No
14.6 Special precautions for user:	Not applicable.
14.7 Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code:	Not applicable.
UN "Model Regulation":	Not Regulated

15 Regulatory Information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture:
United States (USA):
SARA:

Section 355 (extremely hazardous substances):
None of the ingredients is listed.
Section 313 (Specific toxic chemical listings):
None of the ingredients is listed.
TSCA (Toxic Substances Control Act):
All ingredients are listed.

(Contd. on page 8



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Printing date 25.05.2012

Revision: 23.05.2012

Trade name: LIQUINOX

(Contd. of page 7)

Proposition 65 (California):

Chemicals known to cause cancer:	
None of the ingredients is listed.	
Chemicals known to cause reproductive toxicity for females:	
None of the ingredients is listed.	
Chemicals known to cause reproductive toxicity for males:	
None of the ingredients is listed.	
Chemicals known to cause developmental toxicity:	
None of the ingredients is listed.	

Carcinogenic Categories:

EPA (Environmental Protection Agency):
None of the ingredients is listed.
TLV (Threshold Limit Value established by ACGIH):
None of the ingredients is listed.
NIOSH-Ca (National Institute for Occupational Safety and Health):
None of the ingredients is listed.
OSHA-Ca (Occupational Safety & Health Administration):
None of the ingredients is listed.

Canada:

Canadian Domestic Substances List (DSL):
All ingredients are listed.
Canadian Ingredient Disclosure list (limit 0.1%):
None of the ingredients is listed.
Canadian Ingredient Disclosure list (limit 1%):
None of the ingredients is listed.

15.2 Chemical safety assessment: A Chemical Safety Assessment has not been carried out.

16 Other Information

This information is based on our present knowledge. However, this shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.

Relevant phrases:

H315	Causes skin irritation.
H318	Causes serious eye damage.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.
R36/37/38	Irritating to eyes, respiratory system and skin.
R36/38	Irritating to eyes and skin.
R38	Irritating to skin.
R41	Risk of serious damage to eyes.

(Contd. on page 9)

Safety Data Sheet
according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), and GHS

Printing date 25.05.2012 Revision: 23.05.2012

Trade name: LIQUINOX

(Contd. of page 8)

Abbreviations and Acronyms

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road
IMDG: International Maritime Code for Dangerous Goods
DOT: US Department of Transportation
IATA: International Air Transport Association
GHS: Globally Harmonized System of Classification and Labelling of Chemicals
ACGIH: American Conference of Governmental Industrial Hygienists
NFPA: National Fire Protection Association (USA)
HMIS: Hazardous Materials Identification System (USA)
WHMIS: Workplace Hazardous Materials Information System (Canada)
VOC: Volatile Organic Compounds (USA, EU)
LC50: Lethal concentration, 50 percent
LD50: Lethal dose, 50 percent

SIMPLE GREEN™ SDS

Safety Data Sheet: **Simple Green® All-Purpose Cleaner** ★
Version No. 13000-14B Issue Date: September 13, 2014 Supersedes Date: January 7, 2014 *OSHA HCS-2012 / GHS*

Section 1: IDENTIFICATION

Product Name: Simple Green® All-Purpose Cleaner
Additional Names:

Manufacturer's Part Number: **Please refer to Section 16*

Recommended Use: Cleaner & Degreaser for water tolerant surfaces.
Restrictions on Use: Do not use on non-rinsable surfaces.

Company: Sunshine Makers, Inc.
15922 Pacific Coast Highway
Huntington Beach, CA 92649 USA

Telephone: 800-228-0709 • 562-795-6000 *Mon – Fri, 8am – 5pm PST*
Fax: 562-592-3830
Email: info@simplegreen.com

Emergency Phone: Chem-Tel 24-Hour Emergency Service: 800-255-3924

Section 2: HAZARDS IDENTIFICATION

This product is not classified as hazardous under 2012 OSHA Hazard Communication Standards (29 CFR 1910.1200).

OSHA HCS 2012
Label Elements
Signal Word: None **Hazard Symbol(s)/Pictogram(s):** None required

Hazard Statements: None
Precautionary Statements: None
Hazards Not Otherwise Classified (HNOC): None
Other Information: None Known

Section 3: COMPOSITION/INFORMATION ON INGREDIENTS

Ingredient	CAS Number	Percent Range
Water	7732-18-5	> 84.8%*
Ethoxylated Alcohol	68439-46-3	< 5%*
Sodium Citrate	68-04-2	< 5%*
Tetrasodium *N,N*-bis(carboxymethyl)-L-glutamate	51981-21-6	< 1%*
Sodium Carbonate	497-19-8	< 1%*
Citric Acid	77-92-9	< 1%*
Isothiazolinone mixture	55965-84-9	< 0.2%*
Fragrance	Proprietary Mixture	< 1%*
Colorant	Proprietary Mixture	< 1%*

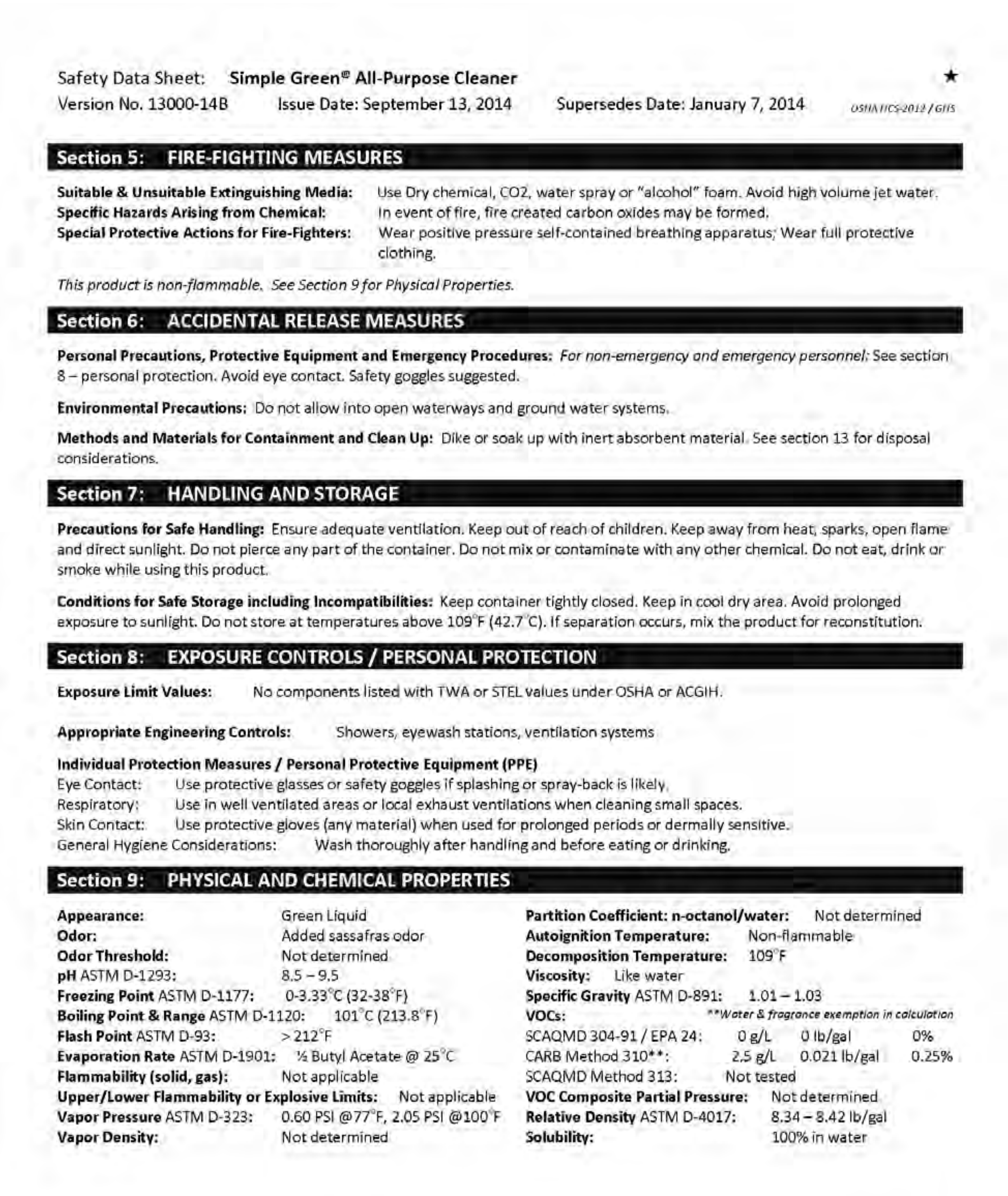
**specific percentages of composition are being withheld as a trade secret*

Section 4: FIRST-AID MEASURES

Inhalation: Not expected to cause respiratory irritation. If adverse effect occurs, move to fresh air.
Skin Contact: Not expected to cause skin irritation. If adverse effect occurs, rinse skin with water.
Eye Contact: Not expected to cause eye irritation. If adverse effect occurs, flush eyes with water.
Ingestion: May cause upset stomach. Drink plenty of water to dilute. See section 11.

Most Important Symptoms/Effects, Acute and Delayed: None known.

Indication of Immediate Medical Attention and Special Treatment Needed, if necessary: Treat symptomatically



Section 5: FIRE-FIGHTING MEASURES

Suitable & Unsuitable Extinguishing Media: Use Dry chemical, CO2, water spray or "alcohol" foam. Avoid high volume jet water.
Specific Hazards Arising from Chemical: In event of fire, fire created carbon oxides may be formed.
Special Protective Actions for Fire-Fighters: Wear positive pressure self-contained breathing apparatus; Wear full protective clothing.

This product is non-flammable. See Section 9 for Physical Properties.

Section 6: ACCIDENTAL RELEASE MEASURES

Personal Precautions, Protective Equipment and Emergency Procedures: *For non-emergency and emergency personnel:* See section 8 – personal protection. Avoid eye contact. Safety goggles suggested.

Environmental Precautions: Do not allow into open waterways and ground water systems.

Methods and Materials for Containment and Clean Up: Dike or soak up with inert absorbent material. See section 13 for disposal considerations.

Section 7: HANDLING AND STORAGE

Precautions for Safe Handling: Ensure adequate ventilation. Keep out of reach of children. Keep away from heat, sparks, open flame and direct sunlight. Do not pierce any part of the container. Do not mix or contaminate with any other chemical. Do not eat, drink or smoke while using this product.

Conditions for Safe Storage including Incompatibilities: Keep container tightly closed. Keep in cool dry area. Avoid prolonged exposure to sunlight. Do not store at temperatures above 109°F (42.7°C). If separation occurs, mix the product for reconstitution.

Section 8: EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Limit Values: No components listed with TWA or STEL values under OSHA or ACGIH.

Appropriate Engineering Controls: Showers, eyewash stations, ventilation systems

Individual Protection Measures / Personal Protective Equipment (PPE)
Eye Contact: Use protective glasses or safety goggles if splashing or spray-back is likely.
Respiratory: Use in well ventilated areas or local exhaust ventilations when cleaning small spaces.
Skin Contact: Use protective gloves (any material) when used for prolonged periods or dermally sensitive.
General Hygiene Considerations: Wash thoroughly after handling and before eating or drinking.

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Green Liquid
Odor:	Added sassafras odor
Odor Threshold:	Not determined
pH ASTM D-1293:	8.5 – 9.5
Freezing Point ASTM D-1177:	0-3.33°C (32-38°F)
Boiling Point & Range ASTM D-1120:	101°C (213.8°F)
Flash Point ASTM D-93:	> 212°F
Evaporation Rate ASTM D-1901:	½ Butyl Acetate @ 25°C
Flammability (solid, gas):	Not applicable
Upper/Lower Flammability or Explosive Limits:	Not applicable
Vapor Pressure ASTM D-323:	0.60 PSI @77°F, 2.05 PSI @100°F
Vapor Density:	Not determined

Partition Coefficient: n-octanol/water:	Not determined		
Autoignition Temperature:	Non-flammable		
Decomposition Temperature:	109°F		
Viscosity:	Like water		
Specific Gravity ASTM D-891:	1.01 – 1.03		
VOCs:	***Water & fragrance exemption in calculation*		
SCAQMD 304-91 / EPA 24:	0 g/L	0 lb/gal	0%
CARB Method 310**:	2.5 g/L	0.021 lb/gal	0.25%
SCAQMD Method 313:	Not tested		
VOC Composite Partial Pressure:	Not determined		
Relative Density ASTM D-4017:	8.34 – 8.42 lb/gal		
Solubility:	100% in water		

Safety Data Sheet: **Simple Green® All-Purpose Cleaner** ★
Version No. 13000-14B Issue Date: September 13, 2014 Supersedes Date: January 7, 2014 *OSHA HCS-2012 / GHS*

Section 10: STABILITY AND REACTIVITY

Reactivity:	Non-reactive.
Chemical Stability:	Stable under normal conditions 70°F (21°C) and 14.7 psig (760 mmHg).
Possibility of Hazardous Reactions:	None known.
Conditions to Avoid:	Excessive heat or cold.
Incompatible Materials:	Do not mix with oxidizers, acids, bathroom cleaners, or disinfecting agents.
Hazardous Decomposition Products:	Normal products of combustion - CO, CO2.

Section 11: TOXICOLOGICAL INFORMATION

Likely Routes of Exposure:	Inhalation -	Overexposure may cause headache.
	Skin Contact -	Not expected to cause irritation, repeated contact may cause dry skin.
	Eye Contact -	Not expected to cause irritation.
	Ingestion -	May cause upset stomach.

Symptoms related to the physical, chemical and toxicological characteristics: no symptoms expected under typical use conditions.
Delayed and immediate effects and or chronic effects from short term exposure: no symptoms expected under typical use conditions.
Delayed and immediate effects and or chronic effects from long term exposure: headache, dry skin, or skin irritation may occur.
Interactive effects: Not known.

Numerical Measures of Toxicity

Acute Toxicity:	Oral LD_{50} (rat)	> 5 g/kg body weight
	Dermal LD_{50} (rabbit)	> 5 g/kg body weight

Calculated via OSHA HCS 2012 / Globally Harmonized System of Classification and Labelling of Chemicals

Skin Corrosion/Irritation:	Non-irritant per Dermal Irritection® assay modeling. No animal testing performed.
Eye Damage/Irritation:	Minimal irritant per Ocular Irritection® assay modeling. No animal testing performed.
Germ Cell Mutagenicity:	Mixture does not classify under this category.
Carcinogenicity:	Mixture does not classify under this category.
Reproductive Toxicity:	Mixture does not classify under this category.
STOT-Single Exposure:	Mixture does not classify under this category.
STOT-Repeated Exposure:	Mixture does not classify under this category.
Aspiration Hazard:	Mixture does not classify under this category.

Section 12: ECOLOGICAL INFORMATION

Ecotoxicity:	Volume of ingredients used does not trigger toxicity classifications under the Globally Harmonized System of Classification and Labelling of Chemicals.
Aquatic:	Aquatic Toxicity - Low, based on OECD 201, 202, 203 + Microtox: EC_{50} & IC_{50} ≥100 mg/L. Volume of ingredients used does not trigger toxicity classifications under the Globally Harmonized System of Classification and Labelling of Chemicals.
Terrestrial:	Not tested on finished formulation.

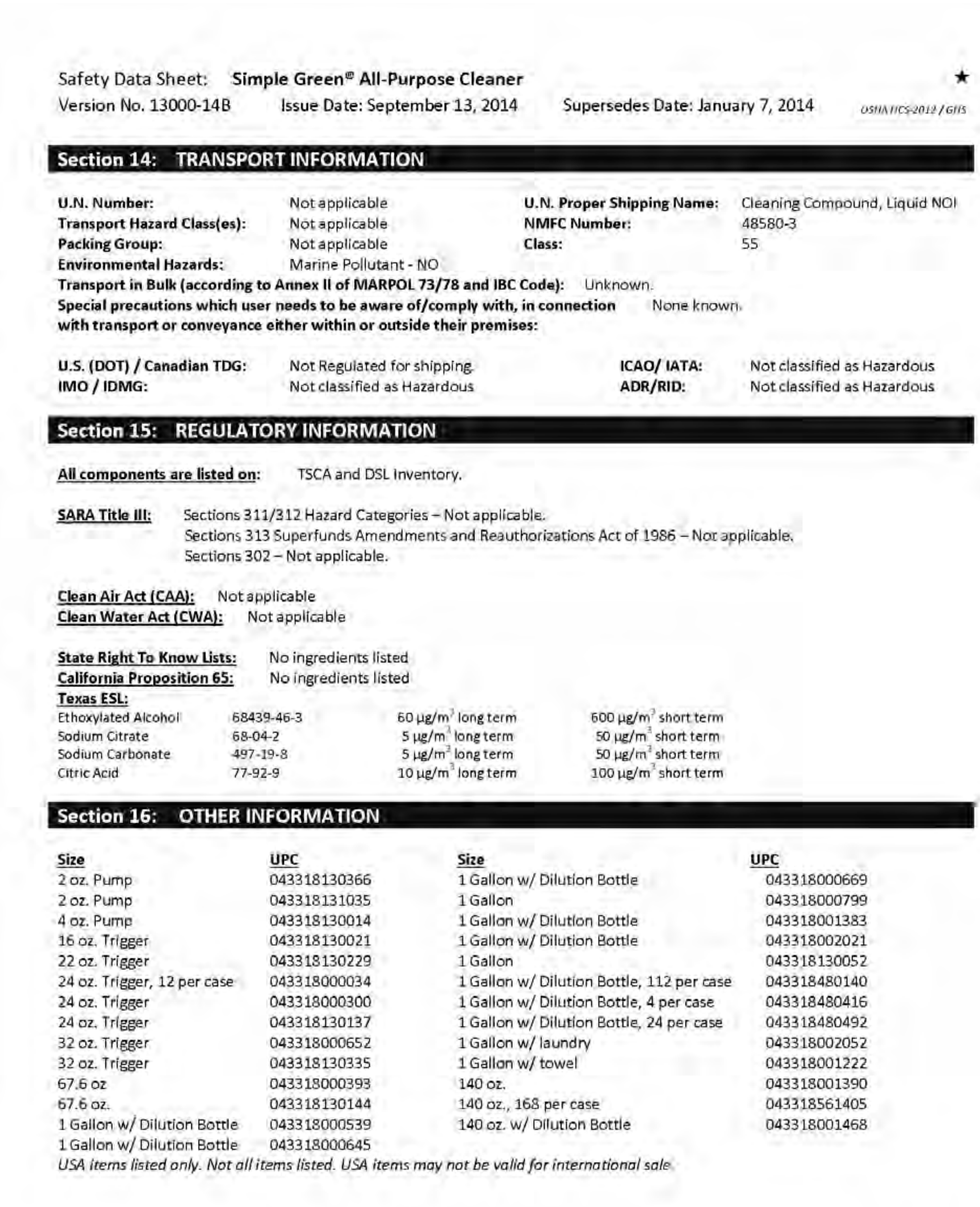
Persistence and Degradability:	Readily Biodegradable per OCED 301D, Closed Bottle Test
Bioaccumulative Potential:	No data available.
Mobility in Soil:	No data available.
Other Adverse Effects:	No data available.

Section 13: DISPOSAL CONSIDERATIONS

Unused or Used Liquid: May be considered hazardous in your area depending on usage and tonnage of disposal – check with local, regional, and or national regulations for appropriate methods of disposal.

Empty Containers: May be offered for recycling.

Never dispose of used degreasing rinsates into lakes, streams, and open bodies of water or storm drains.



Safety Data Sheet: **Simple Green® All-Purpose Cleaner** ★
Version No. 13000-14B Issue Date: September 13, 2014 Supersedes Date: January 7, 2014 *OSHA HCS-2012 / GHS*

Section 14: TRANSPORT INFORMATION

U.N. Number:	Not applicable	**U.N. Proper Shipping Name:**	Cleaning Compound, Liquid NOI
Transport Hazard Class(es):	Not applicable	**NMFC Number:**	48580-3
Packing Group:	Not applicable	**Class:**	55
Environmental Hazards:	Marine Pollutant - NO		

Transport in Bulk (according to Annex II of MARPOL 73/78 and IBC Code): Unknown.

Special precautions which user needs to be aware of/comply with, in connection with transport or conveyance either within or outside their premises: None known.

U.S. (DOT) / Canadian TDG:	Not Regulated for shipping.	**ICAO/ IATA:**	Not classified as Hazardous
IMO / IDMG:	Not classified as Hazardous	**ADR/RID:**	Not classified as Hazardous

Section 15: REGULATORY INFORMATION

All components are listed on: TSCA and DSL Inventory.

SARA Title III: Sections 311/312 Hazard Categories – Not applicable.
Sections 313 Superfunds Amendments and Reauthorizations Act of 1986 – Not applicable.
Sections 302 – Not applicable.

Clean Air Act (CAA): Not applicable
Clean Water Act (CWA): Not applicable

State Right To Know Lists: No ingredients listed
California Proposition 65: No ingredients listed
Texas ESL:

Ethoxylated Alcohol	68439-46-3	60 µg/m^3 long term	600 µg/m^3 short term
Sodium Citrate	68-04-2	5 µg/m^3 long term	50 µg/m^3 short term
Sodium Carbonate	497-19-8	5 µg/m^3 long term	50 µg/m^3 short term
Citric Acid	77-92-9	10 µg/m^3 long term	100 µg/m^3 short term

Section 16: OTHER INFORMATION

Size	UPC	Size	UPC
2 oz. Pump	043318130366	1 Gallon w/ Dilution Bottle	043318000669
2 oz. Pump	043318131035	1 Gallon	043318000799
4 oz. Pump	043318130014	1 Gallon w/ Dilution Bottle	043318001383
16 oz. Trigger	043318130021	1 Gallon w/ Dilution Bottle	043318002021
22 oz. Trigger	043318130229	1 Gallon	043318130052
24 oz. Trigger, 12 per case	043318000034	1 Gallon w/ Dilution Bottle, 112 per case	043318480140
24 oz. Trigger	043318000300	1 Gallon w/ Dilution Bottle, 4 per case	043318480416
24 oz. Trigger	043318130137	1 Gallon w/ Dilution Bottle, 24 per case	043318480492
32 oz. Trigger	043318000652	1 Gallon w/ laundry	043318002052
32 oz. Trigger	043318130335	1 Gallon w/ towel	043318001222
67.6 oz	043318000393	140 oz.	043318001390
67.6 oz.	043318130144	140 oz., 168 per case	043318561405
1 Gallon w/ Dilution Bottle	043318000539	140 oz. w/ Dilution Bottle	043318001468
1 Gallon w/ Dilution Bottle	043318000645		

USA items listed only. Not all items listed. USA items may not be valid for international sale.

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Section 16: OTHER INFORMATION - continued

NFPA:

Health – None
Flammability – Non-flammable
Stability – Stable
Special - None

Acronyms

NTP	National Toxicology Program	IARC	International Agency for Research on Cancer
OSHA	Occupational Safety and Health Administration	CPSC	Consumer Product Safety Commission
TSCA	Toxic Substances Control Act	DSL	Domestic Substances List

Prepared / Revised By: Sunshine Makers, Inc., Regulatory Department.
This SDS has been revised in the following sections: Revised SDS layout

DISCLAIMER: The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

METHANOL SDS

VAL TECH DIAGNOSTICS INC.

Methanol

Safety Data Sheet

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

Date of issue: 07/03/2013 Revision date: 11/15/2013 Supersedes: 10/02/2013 Version: 1.2

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1. Product identifier

Product form	: Substance
Substance name	: Methanol
CAS No	: 67-56-1
Product code	: VT430
Formula	: CH4O
Synonyms	: acetone alcohol / alcohol C1 / alcohol, methyl / carbinol / colonial spirits / columbian spirits / green wood spirits / manhattan spirits / methyl alcohol / methyl hydrate / methyl hydroxide / methylen / methylol / monohydroxymethane / pyroligneous spirit / pyroxylic spirit / wood alcohol / wood naphtha

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the substance/mixture : Solvent

1.3. Details of the supplier of the safety data sheet

Val Tech Diagnostics, A Division of LabChem Inc
Jackson's Pointe Commerce Park Building 1000
1010 Jackson's Pointe Court
Zelienople, PA 16063
T 412-826-5230
F 724-473-0647

1.4. Emergency telephone number

Emergency number : CHEMTREC: 1-800-424-9300 or 011-703-527-3887

SECTION 2: Hazards identification

2.1. Classification of the substance or mixture

GHS-US classification

Flam. Liq. 2	H225
Acute Tox. 3 (Oral)	H301
Acute Tox. 3 (Dermal)	H311
Acute Tox. 3 (Inhalation)	H331
STOT SE 1	H370

2.2. Label elements

GHS-US labelling

Hazard pictograms (GHS-US) :

Signal word (GHS-US) : Danger

Hazard statements (GHS-US) :
H225 - Highly flammable liquid and vapour
H301+H311+H331 - Toxic if swallowed, in contact with skin or if inhaled
H370 - Causes damage to organs (liver, kidneys, central nervous system, optic nerve) (Dermal, oral)

Precautionary statements (GHS-US) :
P210 - Keep away from heat, sparks, open flames, hot surfaces. - No smoking
P233 - Keep container tightly closed
P240 - Ground/bond container and receiving equipment
P241 - Use explosion-proof electrical, ventilating, lighting equipment
P242 - Use only non-sparking tools
P243 - Take precautionary measures against static discharge
P260 - Do not breathe mist, vapours, spray
P264 - Wash exposed skin thoroughly after handling
P270 - Do not eat, drink or smoke when using this product
P271 - Use only outdoors or in a well-ventilated area
P280 - Wear protective gloves, protective clothing, eye protection, face protection

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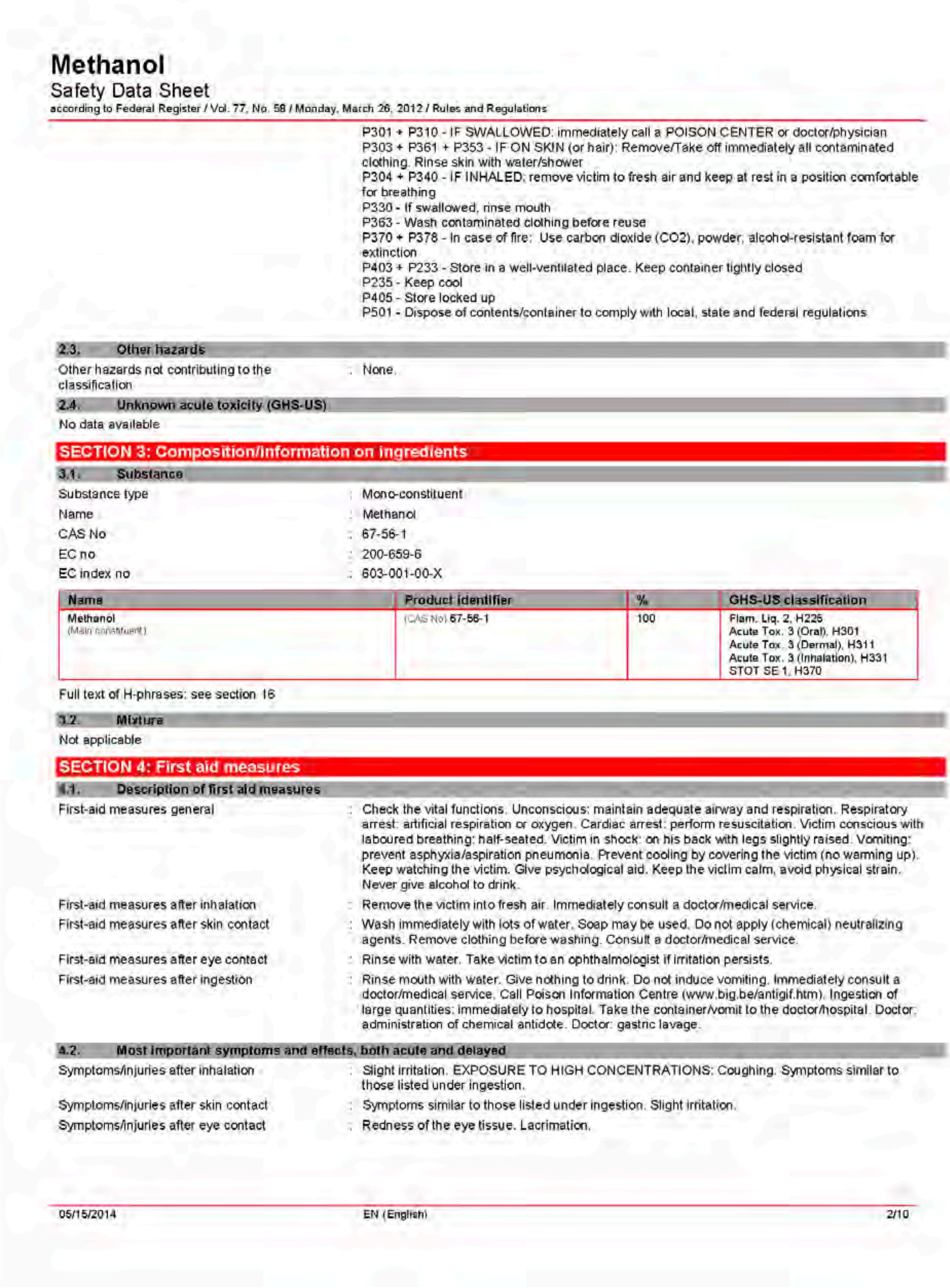

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P301 + P310 - IF SWALLOWED: immediately call a POISON CENTER or doctor/physician
P303 + P361 + P353 - IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower
P304 + P340 - IF INHALED: remove victim to fresh air and keep at rest in a position comfortable for breathing
P330 - If swallowed, rinse mouth
P363 - Wash contaminated clothing before reuse
P370 + P378 - In case of fire: Use carbon dioxide (CO2), powder, alcohol-resistant foam for extinction
P403 + P233 - Store in a well-ventilated place. Keep container tightly closed
P235 - Keep cool
P405 - Store locked up
P501 - Dispose of contents/container to comply with local, state and federal regulations

2.3. Other hazards

Other hazards not contributing to the classification	: None.

2.4. Unknown acute toxicity (GHS-US)

No data available

SECTION 3: Composition/information on ingredients

3.1. Substance

Substance type	: Mono-constituent
Name	: Methanol
CAS No	: 67-56-1
EC no	: 200-659-6
EC index no	: 603-001-00-X

Name	Product identifier	%	GHS-US classification
Methanol (Main constituent)	(CAS No) **67-56-1**	100	Flam. Liq. 2, H225 Acute Tox. 3 (Oral), H301 Acute Tox. 3 (Dermal), H311 Acute Tox. 3 (Inhalation), H331 STOT SE 1, H370

Full text of H-phrases: see section 16

3.2. Mixture

Not applicable

SECTION 4: First aid measures

4.1. Description of first aid measures

First-aid measures general	: Check the vital functions. Unconscious: maintain adequate airway and respiration. Respiratory arrest: artificial respiration or oxygen. Cardiac arrest: perform resuscitation. Victim conscious with laboured breathing: half-seated. Victim in shock: on his back with legs slightly raised. Vomiting: prevent asphyxia/aspiration pneumonia. Prevent cooling by covering the victim (no warming up). Keep watching the victim. Give psychological aid. Keep the victim calm, avoid physical strain. Never give alcohol to drink.
First-aid measures after inhalation	: Remove the victim into fresh air. Immediately consult a doctor/medical service.
First-aid measures after skin contact	: Wash immediately with lots of water. Soap may be used. Do not apply (chemical) neutralizing agents. Remove clothing before washing. Consult a doctor/medical service.
First-aid measures after eye contact	: Rinse with water. Take victim to an ophthalmologist if irritation persists.
First-aid measures after ingestion	: Rinse mouth with water. Give nothing to drink. Do not induce vomiting. Immediately consult a doctor/medical service. Call Poison Information Centre (www.big.be/antigif.htm). Ingestion of large quantities: immediately to hospital. Take the container/vomit to the doctor/hospital. Doctor: administration of chemical antidote. Doctor: gastric lavage.

4.2. Most important symptoms and effects, both acute and delayed

Symptoms/injuries after inhalation	: Slight irritation. EXPOSURE TO HIGH CONCENTRATIONS: Coughing. Symptoms similar to those listed under ingestion.
Symptoms/injuries after skin contact	: Symptoms similar to those listed under ingestion. Slight irritation.
Symptoms/injuries after eye contact	: Redness of the eye tissue. Lacrimation.

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Symptoms/injuries after ingestion	: Nausea. Vomiting. AFTER ABSORPTION OF HIGH QUANTITIES: FOLLOWING SYMPTOMS MAY APPEAR LATER: Change in the haemogramme/blood composition. Headache. Feeling of weakness. Abdominal pain. Muscular pain. Central nervous system depression. Dizziness. Mental confusion. Drunkenness. Coordination disorders. Disturbed motor response. Disturbances of consciousness. Visual disturbances. Blindness. Respiratory difficulties. Cramps/uncontrolled muscular contractions.
Chronic symptoms	: ON CONTINUOUS/REPEATED EXPOSURE/CONTACT: Red skin. Dry skin. Skin rash/inflammation. Headache. Disturbed tactile sensibility. Visual disturbances. Sleeplessness. Gastrointestinal complaints. Cardiac and blood circulation effects.

4.3. Indication of any immediate medical attention and special treatment needed

Hospitalize at once. Until victim can be cared for by specialized staff:

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media	: Preferably: alcohol resistant foam. Water spray. BC powder. Carbon dioxide.
Unsuitable extinguishing media	: Solid water jet ineffective as extinguishing medium.

5.2. Special hazards arising from the substance or mixture

Fire hazard	: DIRECT FIRE HAZARD. Highly flammable. Gas/vapour flammable with air within explosion limits. INDIRECT FIRE HAZARD. May be ignited by sparks.
Explosion hazard	: DIRECT EXPLOSION HAZARD. Gas/vapour explosive with air within explosion limits. INDIRECT EXPLOSION HAZARD. may be ignited by sparks. Reactions with explosion hazards: see "Reactivity Hazard".
Reactivity	: On heating: release of toxic/corrosive/combustible gases/vapours (formaldehyde). Upon combustion: CO and CO2 are formed. Violent to explosive reaction with (some) metal powders and with (strong) oxidizers. Violent exothermic reaction with (some) acids and with (some) halogens compounds.

5.3. Advice for firefighters

Firefighting instructions	: Cool tanks/drums with water spray/remove them into safety. Do not move the load if exposed to heat. Take account of toxic fire-fighting water. Use water moderately and if possible collect or contain it.
Protection during firefighting	: Do not enter fire area without proper protective equipment, including respiratory protection.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

6.1.1. For non-emergency personnel

Protective equipment	: Gas-tight suit.
Emergency procedures	: Keep upwind. Mark the danger area. Consider evacuation. Close doors and windows of adjacent premises. Stop engines and no smoking. No naked flames or sparks. Spark- and explosionproof appliances and lighting equipment. Keep containers closed. Wash contaminated clothes.

6.1.2. For emergency responders

Protective equipment	: Equip cleanup crew with proper protection.
Emergency procedures	: Stop leak if safe to do so. Ventilate area.

6.2. Environmental precautions

Prevent soil and water pollution. Prevent spreading in sewers.

6.3. Methods and material for containment and cleaning up

For containment	: Contain released substance, pump into suitable containers. Consult "Material-handling" to select material of containers. Plug the leak, cut off the supply. Dam up the liquid spill. Try to reduce evaporation. Measure the concentration of the explosive gas-air mixture. Dilute combustible/toxic gases/vapours with water spray. Take account of toxic/corrosive precipitation water. Provide equipment/receptacles with earthing. Do not use compressed air for pumping over spills.
Methods for cleaning up	: Take up liquid spill into a non combustible material e.g.: sand, earth, vermiculite slaked lime or soda ash. Scoop absorbed substance into closing containers. See "Material-handling" for suitable container materials. Carefully collect the spill/leftovers. Damaged/cooled tanks must be emptied. Do not use compressed air for pumping over spills. Clean contaminated surfaces with an excess of water. Take collected spill to manufacturer/competent authority. Wash clothing and equipment after handling.

6.4. Reference to other sections

No additional information available

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SECTION 7: Handling and storage

7.1. Precautions for safe handling

Precautions for safe handling	: Comply with the legal requirements. Remove contaminated clothing immediately. Clean contaminated clothing. Handle uncleaned empty containers as full ones. Thoroughly clean/dry the installation before use. Do not discharge the waste into the drain. Do not use compressed air for pumping over. Use spark-/explosionproof appliances and lighting system. Take precautions against electrostatic charges. Keep away from naked flames/heat. Keep away from ignition sources/sparks. Observe strict hygiene. Keep container tightly closed. Measure the concentration in the air regularly. Work under local exhaust/ventilation.
Hygiene measures	: Do not eat, drink or smoke when using this product. Wash hands and other exposed areas with mild soap and water before eating, drinking or smoking and when leaving work. Wash contaminated clothing before reuse.

7.2. Conditions for safe storage, including any incompatibilities

Incompatible products	: Strong oxidizers. Strong bases. Strong acids. Acid anhydrides. Acid chlorides.
Incompatible materials	: Direct sunlight. Heat sources. Sources of ignition.
Heat and ignition sources	: KEEP SUBSTANCE AWAY FROM: heat sources. ignition sources.
Prohibitions on mixed storage	: KEEP SUBSTANCE AWAY FROM: combustible materials. oxidizing agents. (strong) acids. (strong) bases. halogens. amines. water/moisture.
Storage area	: Store at room temperature. Keep out of direct sunlight. Store in a dry area. Keep container in a well-ventilated place. Fireproof storeroom. Keep locked up. Provide for a tub to collect spills. Provide the tank with earthing. Unauthorized persons are not admitted. Aboveground. Meet the legal requirements.
Special rules on packaging	: SPECIAL REQUIREMENTS: closing. dry. clean. correctly labelled. meet the legal requirements. Secure fragile packagings in solid containers.
Packaging materials	: SUITABLE MATERIAL: steel. stainless steel. iron. glass. MATERIAL TO AVOID: lead. aluminium. zinc. polyethylene. PVC.

7.3. Specific end use(s)

No additional information available

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Methanol (67-56-1)		
USA ACGIH	ACGIH TWA (ppm)	200 ppm
USA ACGIH	ACGIH STEL (ppm)	200 ppm
USA OSHA	OSHA PEL (TWA) (mg/m³)	260 mg/m³
USA OSHA	OSHA PEL (TWA) (ppm)	200 ppm

8.2. Exposure controls

Appropriate engineering controls	: Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure. Keep concentrations well below lower explosion limits.
Personal protective equipment	: Safety glasses. Protective clothing. Gloves. Full protective flameproof clothing. Face shield.
Materials for protective clothing	: GIVE EXCELLENT RESISTANCE: No data available. GIVE GOOD RESISTANCE: polyethylene/ethylenevinylalcohol. styrene-butadiene rubber. viton. GIVE LESS RESISTANCE: chloroprene rubber. chlorinated polyethylene. natural rubber. nitrile rubber/PVC. GIVE POOR RESISTANCE: leather. neoprene. nitrile rubber. polyethylene. PVA. PVC. polyurethane.
Hand protection	: Gloves.
Eye protection	: Combined eye and respiratory protection. Safety glasses.
Skin and body protection	: Head/neck protection. Protective clothing.
Respiratory protection	: Gas mask with filter type AX at conc. in air > exposure limit. Wear gas mask with filter type A if conc. in air > exposure limit. High vapour/gas concentration: self-contained respirator.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state	: Liquid

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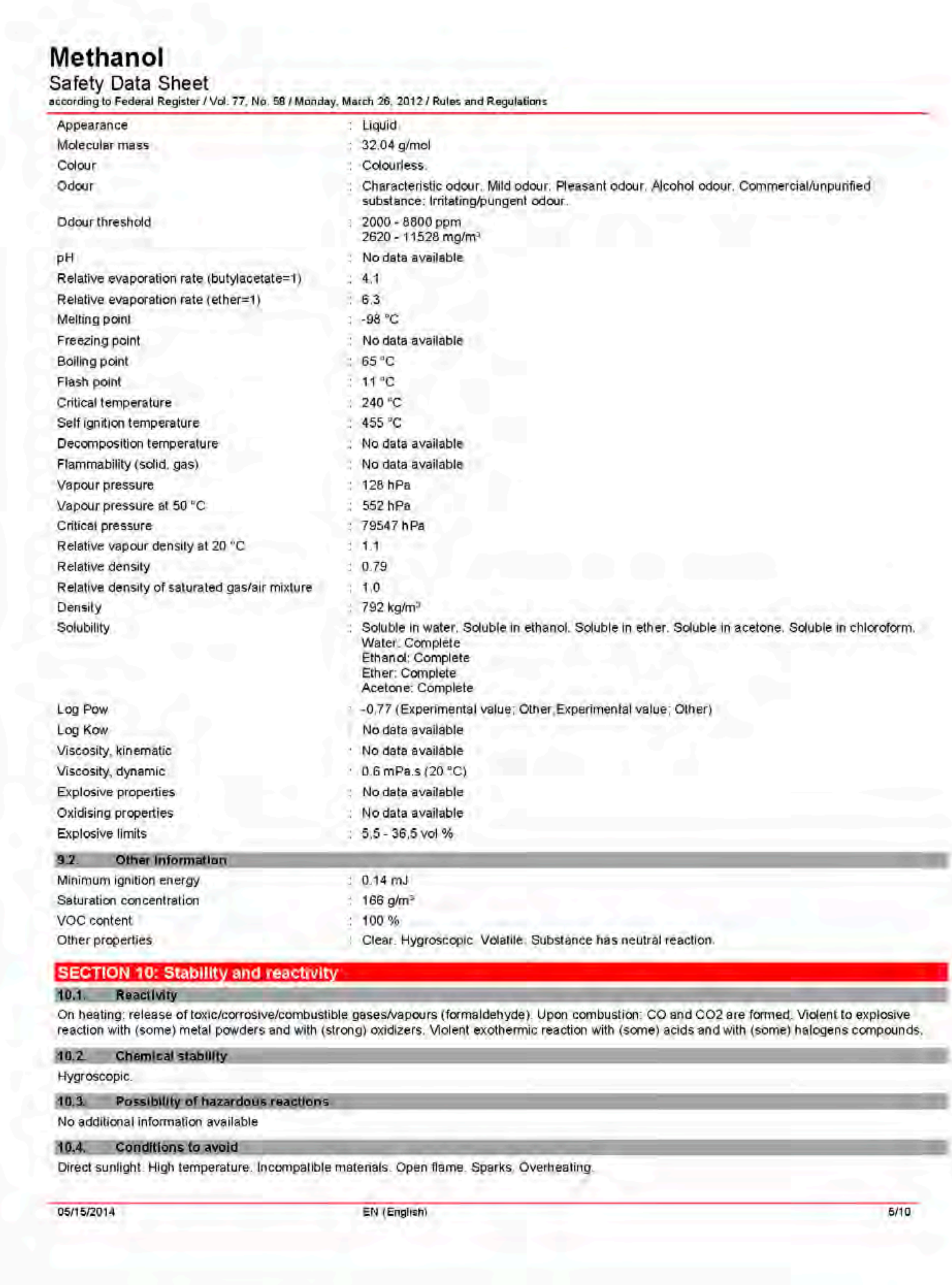

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Appearance	: Liquid
Molecular mass	: 32.04 g/mol
Colour	: Colourless.
Odour	: Characteristic odour. Mild odour. Pleasant odour. Alcohol odour. Commercial/unpurified substance: Irritating/pungent odour.
Odour threshold	: 2000 - 8800 ppm 2620 - 11528 mg/m³
pH	: No data available
Relative evaporation rate (butylacetate=1)	: 4.1
Relative evaporation rate (ether=1)	: 6.3
Melting point	: -98 °C
Freezing point	: No data available
Boiling point	: 65 °C
Flash point	: 11 °C
Critical temperature	: 240 °C
Self ignition temperature	: 455 °C
Decomposition temperature	: No data available
Flammability (solid, gas)	: No data available
Vapour pressure	: 128 hPa
Vapour pressure at 50 °C	: 552 hPa
Critical pressure	: 79547 hPa
Relative vapour density at 20 °C	: 1.1
Relative density	: 0.79
Relative density of saturated gas/air mixture	: 1.0
Density	: 792 kg/m³
Solubility	: Soluble in water. Soluble in ethanol. Soluble in ether. Soluble in acetone. Soluble in chloroform. Water: Complete Ethanol: Complete Ether: Complete Acetone: Complete
Log Pow	: -0.77 (Experimental value; Other,Experimental value; Other)
Log Kow	: No data available
Viscosity, kinematic	: No data available
Viscosity, dynamic	: 0.6 mPa.s (20 °C)
Explosive properties	: No data available
Oxidising properties	: No data available
Explosive limits	: 5.5 - 36.5 vol %

9.2. Other information

Minimum ignition energy	: 0.14 mJ
Saturation concentration	: 166 g/m³
VOC content	: 100 %
Other properties	: Clear. Hygroscopic. Volatile. Substance has neutral reaction.

SECTION 10: Stability and reactivity

10.1. Reactivity

On heating: release of toxic/corrosive/combustible gases/vapours (formaldehyde). Upon combustion: CO and CO2 are formed. Violent to explosive reaction with (some) metal powders and with (strong) oxidizers. Violent exothermic reaction with (some) acids and with (some) halogens compounds.

10.2. Chemical stability

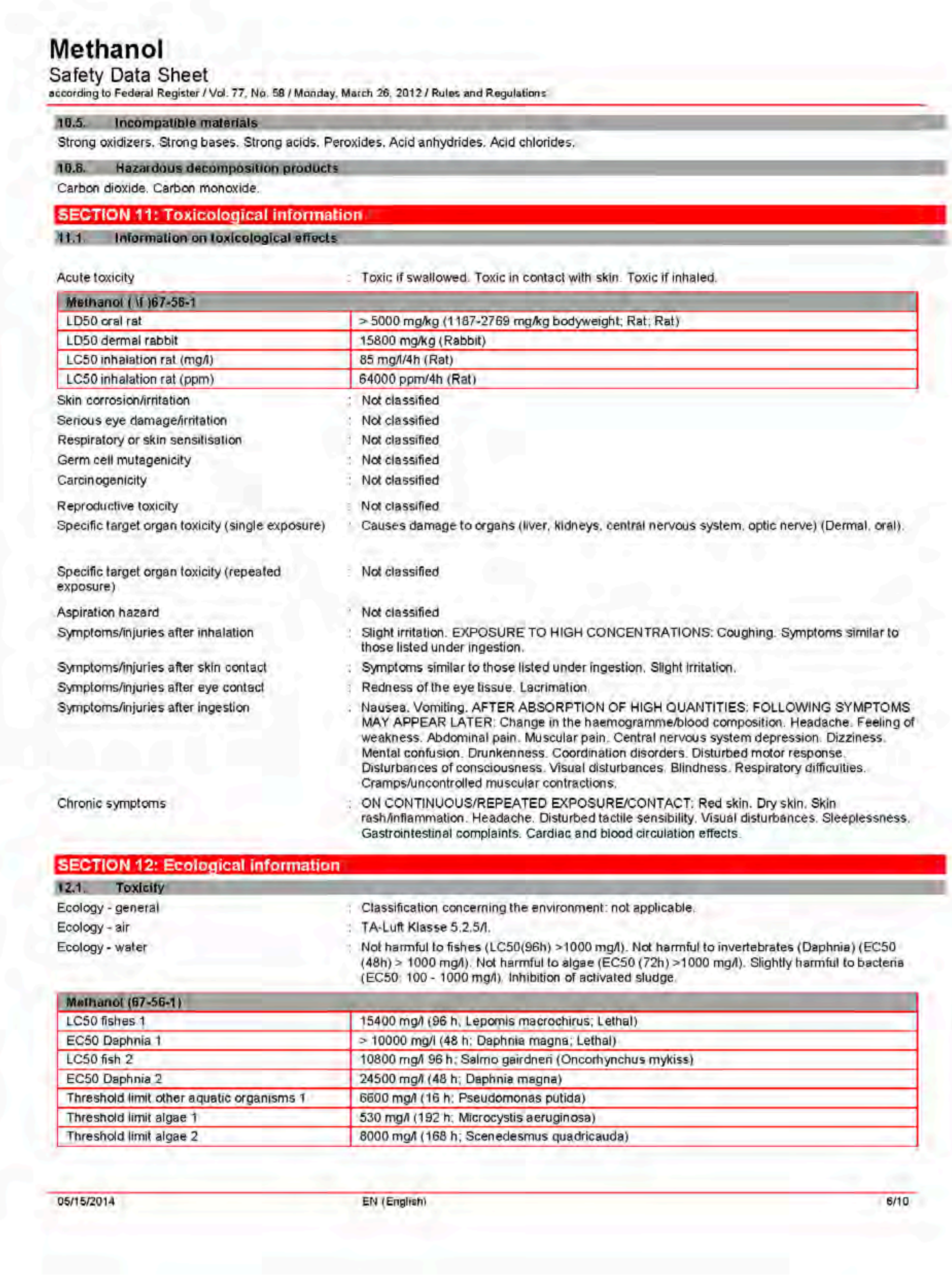
Hygroscopic.

10.3. Possibility of hazardous reactions

No additional information available

10.4. Conditions to avoid

Direct sunlight. High temperature. Incompatible materials. Open flame. Sparks. Overheating.



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10.5. Incompatible materials

Strong oxidizers. Strong bases. Strong acids. Peroxides. Acid anhydrides. Acid chlorides.

10.6. Hazardous decomposition products

Carbon dioxide. Carbon monoxide.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Acute toxicity : Toxic if swallowed. Toxic in contact with skin. Toxic if inhaled.

Methanol (\f)67-56-1	
LD50 oral rat	> 5000 mg/kg (1187-2769 mg/kg bodyweight; Rat; Rat)
LD50 dermal rabbit	15800 mg/kg (Rabbit)
LC50 inhalation rat (mg/l)	85 mg/l/4h (Rat)
LC50 inhalation rat (ppm)	64000 ppm/4h (Rat)

Skin corrosion/irritation : Not classified
Serious eye damage/irritation : Not classified
Respiratory or skin sensitisation : Not classified
Germ cell mutagenicity : Not classified
Carcinogenicity : Not classified
Reproductive toxicity : Not classified
Specific target organ toxicity (single exposure) : Causes damage to organs (liver, kidneys, central nervous system, optic nerve) (Dermal, oral).
Specific target organ toxicity (repeated exposure) : Not classified
Aspiration hazard : Not classified
Symptoms/injuries after inhalation : Slight irritation. EXPOSURE TO HIGH CONCENTRATIONS: Coughing. Symptoms similar to those listed under ingestion.
Symptoms/injuries after skin contact : Symptoms similar to those listed under ingestion. Slight irritation.
Symptoms/injuries after eye contact : Redness of the eye tissue. Lacrimation.
Symptoms/injuries after ingestion : Nausea. Vomiting. AFTER ABSORPTION OF HIGH QUANTITIES: FOLLOWING SYMPTOMS MAY APPEAR LATER: Change in the haemogramme/blood composition. Headache. Feeling of weakness. Abdominal pain. Muscular pain. Central nervous system depression. Dizziness. Mental confusion. Drunkenness. Coordination disorders. Disturbed motor response. Disturbances of consciousness. Visual disturbances. Blindness. Respiratory difficulties. Cramps/uncontrolled muscular contractions.
Chronic symptoms : ON CONTINUOUS/REPEATED EXPOSURE/CONTACT: Red skin. Dry skin. Skin rash/inflammation. Headache. Disturbed tactile sensibility. Visual disturbances. Sleeplessness. Gastrointestinal complaints. Cardiac and blood circulation effects.

SECTION 12: Ecological information

12.1. Toxicity

Ecology - general : Classification concerning the environment: not applicable.
Ecology - air : TA-Luft Klasse 5.2.5/I.
Ecology - water : Not harmful to fishes (LC50(96h) >1000 mg/l). Not harmful to invertebrates (Daphnia) (EC50 (48h) > 1000 mg/l). Not harmful to algae (EC50 (72h) >1000 mg/l). Slightly harmful to bacteria (EC50: 100 - 1000 mg/l). Inhibition of activated sludge.

Methanol (67-56-1)	
LC50 fishes 1	15400 mg/l (96 h; Lepomis macrochirus; Lethal)
EC50 Daphnia 1	> 10000 mg/l (48 h; Daphnia magna; Lethal)
LC50 fish 2	10800 mg/l 96 h; Salmo gairdneri (Oncorhynchus mykiss)
EC50 Daphnia 2	24500 mg/l (48 h; Daphnia magna)
Threshold limit other aquatic organisms 1	6600 mg/l (16 h; Pseudomonas putida)
Threshold limit algae 1	530 mg/l (192 h; Microcystis aeruginosa)
Threshold limit algae 2	8000 mg/l (168 h; Scenedesmus quadricauda)

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12.2. Persistence and degradability

Methanol (67-56-1)	
Persistence and degradability	Readily biodegradable in water. Biodegradable in the soil.
Biochemical oxygen demand (BOD)	0.6 - 1.12 g O^2/g substance
Chemical oxygen demand (COD)	1.42 g O^2/g substance
ThOD	1.5 g O^2/g substance
BOD (% of ThOD)	0.8 % ThOD

12.3. Bioaccumulative potential

Methanol (67-56-1)	
BCF fish 1	< 10 (Leuciscus idus)
Log Pow	-0.77 (Experimental value; Other,Experimental value; Other)
Bioaccumulative potential	Low potential for bioaccumulation (BCF < 500).

12.4. Mobility in soil

Methanol (67-56-1)	
Surface tension	0.023 N/m (20 °C)

12.5. Other adverse effects

No additional information available

SECTION 13: Disposal considerations

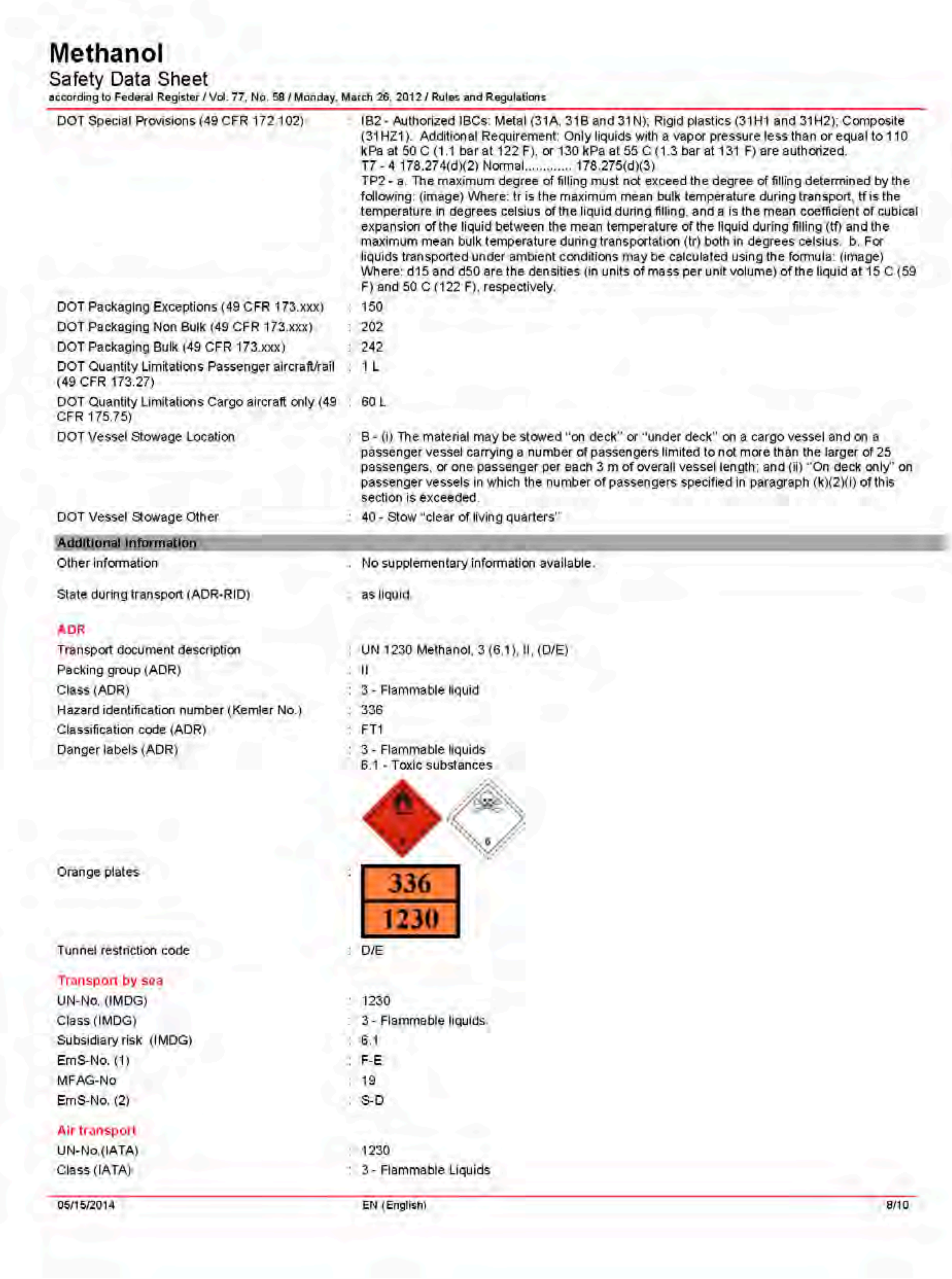
13.1. Waste treatment methods

Waste disposal recommendations	: Remove waste in accordance with local and/or national regulations. Hazardous waste shall not be mixed together with other waste. Different types of hazardous waste shall not be mixed together if this may entail a risk of pollution or create problems for the further management of the waste. Hazardous waste shall be managed responsibly. All entities that store, transport or handle hazardous waste shall take the necessary measures to prevent risks of pollution or damage to people or animals. Recycle by distillation. Incinerate under surveillance with energy recovery. Do not discharge into drains or the environment. Obtain the consent of pollution control authorities before discharging to wastewater treatment plants.
Additional information	: LWCA (the Netherlands): KGA category 06. Hazardous waste according to Directive 2008/98/EC.

SECTION 14: Transport information

In accordance with DOT

Transport document description	: UN1230 Methanol, 3, II
UN-No.(DOT)	: 1230
DOT NA no.	: UN1230
DOT Proper Shipping Name	: Methanol
Department of Transportation (DOT) Hazard Classes	: 3 - Class 3 - Flammable and combustible liquid 49 CFR 173.120
Hazard labels (DOT)	: 3 - Flammable liquid
DOT Symbols	: D - Proper shipping name for domestic use only, or to and from Canada
Packing group (DOT)	: II - Medium Danger



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DOT Special Provisions (49 CFR 172.102)	IB2 - Authorized IBCs: Metal (31A, 31B and 31N); Rigid plastics (31H1 and 31H2); Composite (31HZ1). Additional Requirement: Only liquids with a vapor pressure less than or equal to 110 kPa at 50 C (1.1 bar at 122 F), or 130 kPa at 55 C (1.3 bar at 131 F) are authorized. T7 - 4 178.274(d)(2) Normal............ 178.275(d)(3) TP2 - a. The maximum degree of filling must not exceed the degree of filling determined by the following: (image) Where: tr is the maximum mean bulk temperature during transport, tf is the temperature in degrees celsius of the liquid during filling, and a is the mean coefficient of cubical expansion of the liquid between the mean temperature of the liquid during filling (tf) and the maximum mean bulk temperature during transportation (tr) both in degrees celsius. b. For liquids transported under ambient conditions may be calculated using the formula: (image) Where: d15 and d50 are the densities (in units of mass per unit volume) of the liquid at 15 C (59 F) and 50 C (122 F), respectively.
DOT Packaging Exceptions (49 CFR 173.xxx)	: 150
DOT Packaging Non Bulk (49 CFR 173.xxx)	: 202
DOT Packaging Bulk (49 CFR 173.xxx)	: 242
DOT Quantity Limitations Passenger aircraft/rail (49 CFR 173.27)	: 1 L
DOT Quantity Limitations Cargo aircraft only (49 CFR 175.75)	: 60 L
DOT Vessel Stowage Location	: B - (i) The material may be stowed "on deck" or "under deck" on a cargo vessel and on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers, or one passenger per each 3 m of overall vessel length; and (ii) "On deck only" on passenger vessels in which the number of passengers specified in paragraph (k)(2)(i) of this section is exceeded.
DOT Vessel Stowage Other	: 40 - Stow "clear of living quarters"

Additional information

Other information	: No supplementary information available.
State during transport (ADR-RID)	: as liquid

ADR

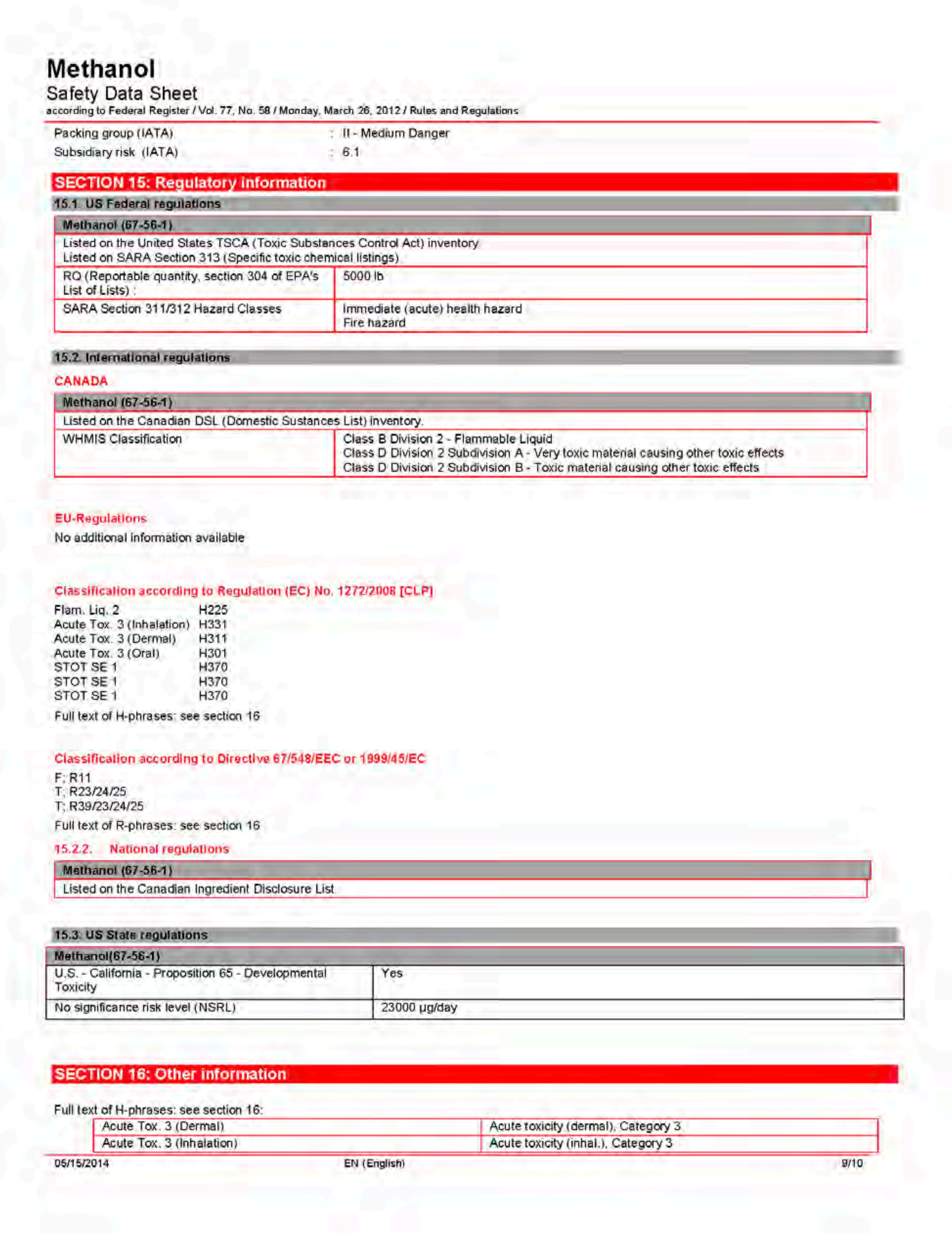
Transport document description	: UN 1230 Methanol, 3 (6.1), II, (D/E)
Packing group (ADR)	: II
Class (ADR)	: 3 - Flammable liquid
Hazard identification number (Kemler No.)	: 336
Classification code (ADR)	: FT1
Danger labels (ADR)	: 3 - Flammable liquids 6.1 - Toxic substances
Orange plates	: 336 1230
Tunnel restriction code	: D/E

Transport by sea

UN-No. (IMDG)	: 1230
Class (IMDG)	: 3 - Flammable liquids.
Subsidiary risk (IMDG)	: 6.1
EmS-No. (1)	: F-E
MFAG-No	: 19
EmS-No. (2)	: S-D

Air transport

UN-No.(IATA)	: 1230
Class (IATA)	: 3 - Flammable Liquids



Methanol

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Packing group (IATA)	: II - Medium Danger
Subsidiary risk (IATA)	: 6.1

SECTION 15: Regulatory information

15.1. US Federal regulations

Methanol (67-56-1)	
Listed on the United States TSCA (Toxic Substances Control Act) inventory Listed on SARA Section 313 (Specific toxic chemical listings)	
RQ (Reportable quantity, section 304 of EPA's List of Lists) :	5000 lb
SARA Section 311/312 Hazard Classes	Immediate (acute) health hazard Fire hazard

15.2. International regulations

CANADA

Methanol (67-56-1)	
Listed on the Canadian DSL (Domestic Sustances List) inventory.	
WHMIS Classification	Class B Division 2 - Flammable Liquid Class D Division 2 Subdivision A - Very toxic material causing other toxic effects Class D Division 2 Subdivision B - Toxic material causing other toxic effects

EU-Regulations

No additional information available

Classification according to Regulation (EC) No. 1272/2008 [CLP]

Flam. Liq. 2	H225
Acute Tox. 3 (Inhalation)	H331
Acute Tox. 3 (Dermal)	H311
Acute Tox. 3 (Oral)	H301
STOT SE 1	H370
STOT SE 1	H370
STOT SE 1	H370

Full text of H-phrases: see section 16

Classification according to Directive 67/548/EEC or 1999/45/EC

F; R11
T; R23/24/25
T; R39/23/24/25

Full text of R-phrases: see section 16

15.2.2. National regulations

Methanol (67-56-1)
Listed on the Canadian Ingredient Disclosure List

15.3. US State regulations

Methanol(67-56-1)	
U.S. - California - Proposition 65 - Developmental Toxicity	Yes
No significance risk level (NSRL)	23000 µg/day

SECTION 16: Other information

Full text of H-phrases: see section 16:

Acute Tox. 3 (Dermal)	Acute toxicity (dermal), Category 3
Acute Tox. 3 (Inhalation)	Acute toxicity (inhal.), Category 3

Methanol

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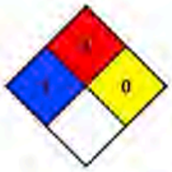
Acute Tox. 3 (Oral)	Acute toxicity (oral), Category 3
Flam. Liq. 2	Flammable liquids, Category 2
STOT SE 1	Specific target organ toxicity — single exposure, Category 1
H225	Highly flammable liquid and vapour
H301	Toxic if swallowed
H311	Toxic in contact with skin
H331	Toxic if inhaled
H370	Causes damage to organs

NFPA health hazard	: 1 - Exposure could cause irritation but only minor residual injury even if no treatment is given.
NFPA fire hazard	: 3 - Liquids and solids that can be ignited under almost all ambient conditions.
NFPA reactivity	: 0 - Normally stable, even under fire exposure conditions, and are not reactive with water.



HMIS III Rating

Health	: 2 Moderate Hazard - Temporary or minor injury may occur
Flammability	: 3 Serious Hazard
Physical	: 0 Minimal Hazard
Personal Protection	: H

SDS US ValTech

NITRIC ACID SDS

Nitric Acid, 10% v/v (1+9)

Safety Data Sheet

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations
Date of issue: 10/31/2013 Version: 1.0

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1. Product identifier

Product form	: Mixture
Product name	: Nitric Acid, 10% v/v (1+9)
Product code	: LC17730

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the substance/mixture	: For laboratory and manufacturing use only.

1.3. Details of the supplier of the safety data sheet

LabChem Inc
Jackson's Pointe Commerce Park Building 1000, 1010 Jackson's Pointe Court
Zelienople, PA 16063 - USA
T 412-826-5230 - F 724-473-0647
info@labchem.com - www.labchem.com

1.4. Emergency telephone number

Emergency number	: CHEMTREC: 1-800-424-9300 or 011-703-527-3887

SECTION 2: Hazards identification

2.1. Classification of the substance or mixture

GHS-US classification

Met. Corr. 1	H290
Skin Corr. 1B	H314
Eye Dam. 1	H318

2.2. Label elements

GHS-US labelling

Hazard pictograms (GHS-US) :

GHS05

Signal word (GHS-US) : Danger

Hazard statements (GHS-US) :
H290 - May be corrosive to metals
H314 - Causes severe skin burns and eye damage

Precautionary statements (GHS-US) :
P234 - Keep only in original container
P260 - Do not breathe mist, vapours, spray
P264 - Wash exposed skin thoroughly after handling
P280 - Wear protective gloves, protective clothing, eye protection, face protection
P301+P330+P331 - IF SWALLOWED: rinse mouth. Do NOT induce vomiting
P303+P361+P353 - IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower
P304+P340 - IF INHALED: remove victim to fresh air and keep at rest in a position comfortable for breathing
P305+P351+P338 - If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P310 - Immediately call a POISON CENTER or doctor/physician
P363 - Wash contaminated clothing before reuse
P390 - Absorb spillage to prevent material damage
P405 - Store locked up
P406 - Store in corrosive resistant container with a resistant inner liner
P501 - Dispose of contents/container to comply with local, state and federal regulations

2.3. Other hazards

Other hazards not contributing to the classification	: None.

2.4. Unknown acute toxicity (GHS-US)

No data available

SECTION 3: Composition/information on ingredients

3.1. Substance

Not applicable

Full text of H-phrases: see section 16

3.2. Mixture

Name	Product identifier	%	GHS-US classification
Water	(CAS No) 7732-18-5	90.5	Not classified
Nitric Acid, 70% w/w	(CAS No) 7697-37-2	9.5	Ox. Liq. 3, H272 Met. Corr. 1, H290 Skin Corr. 1A, H314 Eye Dam. 1, H318

SECTION 4: First aid measures

4.1. Description of first aid measures

First-aid measures general	: Never give anything by mouth to an unconscious person. If you feel unwell, seek medical advice (show the label where possible).
First-aid measures after inhalation	: Remove to fresh air and keep at rest in a position comfortable for breathing. Immediately call a POISON CENTER or doctor/physician.
First-aid measures after skin contact	: Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower. Immediately call a POISON CENTER or doctor/physician.
First-aid measures after eye contact	: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER or doctor/physician.
First-aid measures after ingestion	: Rinse mouth. Do NOT induce vomiting. Immediately call a POISON CENTER or doctor/physician.

4.2. Most important symptoms and effects, both acute and delayed

Symptoms/injuries	: Causes severe skin burns and eye damage.
Symptoms/injuries after eye contact	: Causes serious eye damage.

4.3. Indication of any immediate medical attention and special treatment needed

No additional information available

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media	: Foam. Dry powder. Carbon dioxide. Water spray. Sand.
Unsuitable extinguishing media	: Do not use a heavy water stream.

5.2. Special hazards arising from the substance or mixture

Reactivity	: Thermal decomposition generates : Corrosive vapours.

5.3. Advice for firefighters

Firefighting instructions	: Use water spray or fog for cooling exposed containers. Exercise caution when fighting any chemical fire. Avoid (reject) fire-fighting water to enter environment.
Protection during firefighting	: Do not enter fire area without proper protective equipment, including respiratory protection.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

6.1.1. For non-emergency personnel

Protective equipment	: Protective goggles. Protective clothing. Gloves. Combined gas/dust mask with filter type B/P3.
Emergency procedures	: Evacuate unnecessary personnel.

6.1.2. For emergency responders

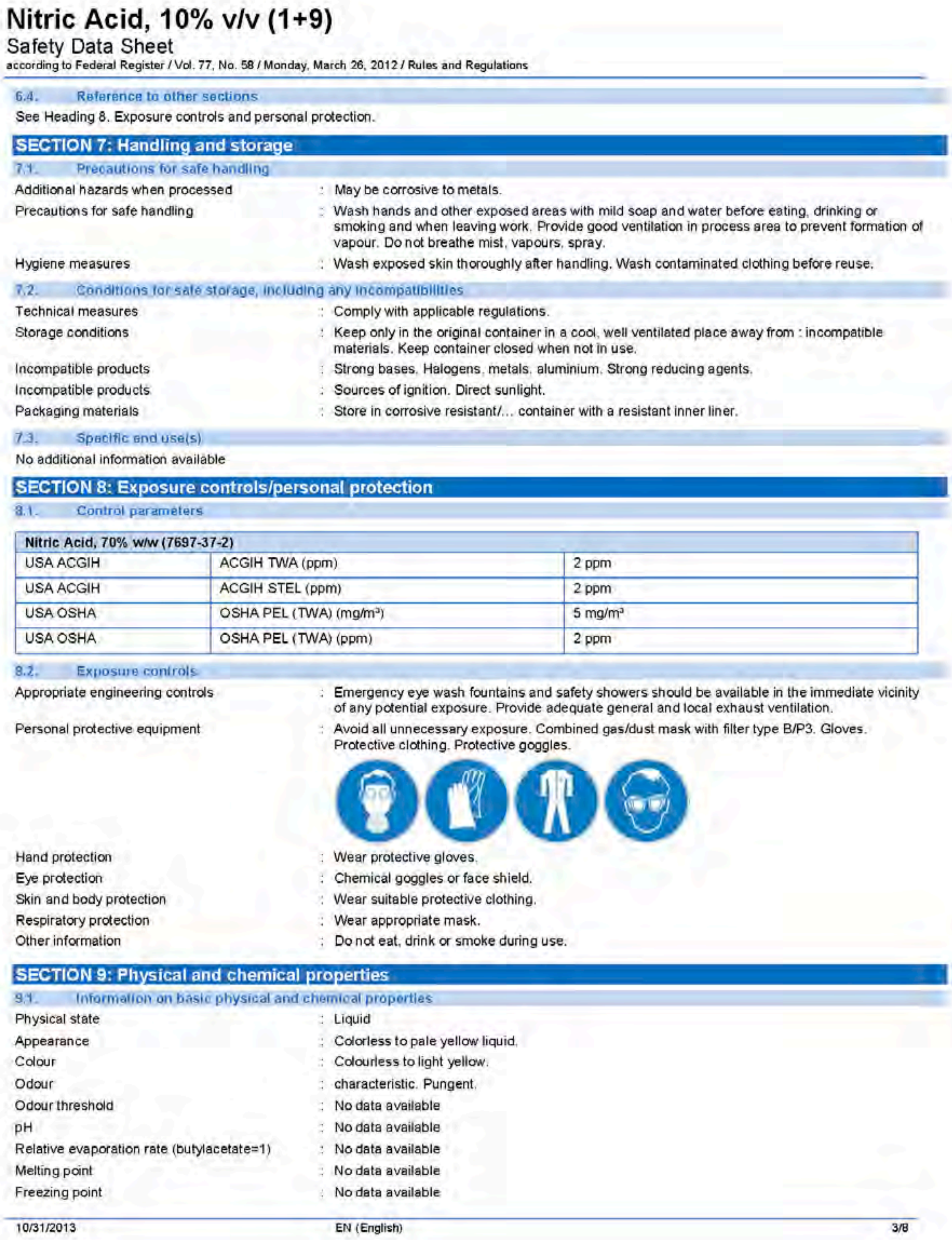
Protective equipment	: Equip cleanup crew with proper protection.
Emergency procedures	: Ventilate area.

6.2. Environmental precautions

Prevent entry to sewers and public waters. Notify authorities if liquid enters sewers or public waters.

6.3. Methods and material for containment and cleaning up

Methods for cleaning up	: Soak up spills with inert solids, such as clay or diatomaceous earth as soon as possible. Collect spillage. Store away from other materials. Absorb spillage to prevent material damage.



Nitric Acid, 10% v/v (1+9)

Safety Data Sheet

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6.4. Reference to other sections

See Heading 8. Exposure controls and personal protection.

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Additional hazards when processed : May be corrosive to metals.

Precautions for safe handling : Wash hands and other exposed areas with mild soap and water before eating, drinking or smoking and when leaving work. Provide good ventilation in process area to prevent formation of vapour. Do not breathe mist, vapours, spray.

Hygiene measures : Wash exposed skin thoroughly after handling. Wash contaminated clothing before reuse.

7.2. Conditions for safe storage, including any incompatibilities

Technical measures : Comply with applicable regulations.

Storage conditions : Keep only in the original container in a cool, well ventilated place away from : incompatible materials. Keep container closed when not in use.

Incompatible products : Strong bases. Halogens. metals. aluminium. Strong reducing agents.

Incompatible products : Sources of ignition. Direct sunlight.

Packaging materials : Store in corrosive resistant/... container with a resistant inner liner.

7.3. Specific end use(s)

No additional information available

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Nitric Acid, 70% w/w (7697-37-2)		
USA ACGIH	ACGIH TWA (ppm)	2 ppm
USA ACGIH	ACGIH STEL (ppm)	2 ppm
USA OSHA	OSHA PEL (TWA) (mg/m³)	5 mg/m³
USA OSHA	OSHA PEL (TWA) (ppm)	2 ppm

8.2. Exposure controls

Appropriate engineering controls : Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure. Provide adequate general and local exhaust ventilation.

Personal protective equipment : Avoid all unnecessary exposure. Combined gas/dust mask with filter type B/P3. Gloves. Protective clothing. Protective goggles.

Hand protection : Wear protective gloves.

Eye protection : Chemical goggles or face shield.

Skin and body protection : Wear suitable protective clothing.

Respiratory protection : Wear appropriate mask.

Other information : Do not eat, drink or smoke during use.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state : Liquid

Appearance : Colorless to pale yellow liquid.

Colour : Colourless to light yellow.

Odour : characteristic. Pungent.

Odour threshold : No data available

pH : No data available

Relative evaporation rate (butylacetate=1) : No data available

Melting point : No data available

Freezing point : No data available

Nitric Acid, 10% v/v (1+9)

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Boiling point	: No data available
Flash point	: No data available
Self ignition temperature	: No data available
Decomposition temperature	: No data available
Flammability (solid, gas)	: No data available
Vapour pressure	: No data available
Relative vapour density at 20 °C	: No data available
Relative density	: No data available
Density	: 1.05 g/ml
Solubility	: Soluble in water.
Log Pow	: No data available
Log Kow	: No data available
Viscosity, kinematic	: 0.99 cSt
Viscosity, dynamic	: No data available
Explosive properties	: No data available
Oxidising properties	: No data available
Explosive limits	: No data available

9.2. Other information

No additional information available

SECTION 10: Stability and reactivity

10.1. Reactivity

Thermal decomposition generates : Corrosive vapours.

10.2. Chemical stability

Not established.

10.3. Possibility of hazardous reactions

Not established.

10.4. Conditions to avoid

Direct sunlight. Extremely high or low temperatures.

10.5. Incompatible materials

Strong reducing agents. Strong bases. metals. aluminium. Ammonia. combustible materials. Halogens.

10.6. Hazardous decomposition products

Nitrogen oxides. Thermal decomposition generates : Corrosive vapours.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Acute toxicity : Not classified

Water (7732-18-5)	
LD50 oral rat	≥ 90000 mg/kg

Skin corrosion/irritation	: Causes severe skin burns and eye damage.
Serious eye damage/irritation	: Causes serious eye damage.
Respiratory or skin sensitisation	: Not classified
Germ cell mutagenicity	: Not classified
Carcinogenicity	: Not classified
Reproductive toxicity	: Not classified
Specific target organ toxicity (single exposure)	: Not classified
Specific target organ toxicity (repeated exposure)	: Not classified
Aspiration hazard	: Not classified

Potential Adverse human health effects and symptoms : Based on available data, the classification criteria are not met.

Symptoms/injuries after eye contact : Causes serious eye damage.

SECTION 12: Ecological information

12.1. Toxicity

Nitric Acid, 70% w/w (7697-37-2)	
LC50 fishes 1	25 - 36 mg/l (96 h; Lepomis macrochirus; Pure substance)
EC50 Daphnia 1	180 mg/l (48 h; Daphnia magna; Pure substance)
LC50 fish 2	72 ppm (Gambusia affinis; Pure substance)
Threshold limit algae 1	> 19 mg/l (Algae; Pure substance)

12.2. Persistence and degradability

Nitric Acid, 10% v/v (1+9)	
Persistence and degradability	Not established.

Nitric Acid, 70% w/w (7697-37-2)	
Persistence and degradability	Biodegradability: not applicable. No (test)data on mobility of the components of the mixture available.
Biochemical oxygen demand (BOD)	Not applicable
Chemical oxygen demand (COD)	Not applicable
ThOD	Not applicable
BOD (% of ThOD)	Not applicable

12.3. Bioaccumulative potential

Nitric Acid, 10% v/v (1+9)	
Bioaccumulative potential	Not established.

Nitric Acid, 70% w/w (7697-37-2)	
BCF fish 1	<= 1 (Pisces)
Log Pow	-2.3 (OECD 107: Partition Coefficient (n-octanol/water): Shake Flask Method)
Bioaccumulative potential	Bioaccumulation: not applicable.

12.4. Mobility in soil

No additional information available

12.5. Other adverse effects

Other information : Avoid release to the environment.

SECTION 13: Disposal considerations

13.1. Waste treatment methods

Waste disposal recommendations : Dispose in a safe manner in accordance with local/national regulations. Dispose of contents/container to comply with local, state and federal regulations.

Ecology - waste materials : Avoid release to the environment.

SECTION 14: Transport information

In accordance with DOT

Transport document description : UN2031 Nitric acid other than (red fuming, with not more than 20 percent nitric acid), 8, II

UN-No.(DOT) : 2031

DOT NA no. : UN2031

DOT Proper Shipping Name : Nitric acid other than
red fuming, with not more than 20 percent nitric acid

Department of Transportation (DOT) Hazard Classes : 8 - Class 8 - Corrosive material 49 CFR 173.136

Hazard labels (DOT)	: 8 - Corrosive substances 
Packing group (DOT)	: II - Medium Danger
DOT Special Provisions (49 CFR 172.102)	: A6 - For combination packagings, if plastic inner packagings are used, they must be packed in tightly closed metal receptacles before packing in outer packagings. B2 - MC 300, MC 301, MC 302, MC 303, MC 305, and MC 306 and DOT 406 cargo tanks are not authorized. B47 - Each tank may have a reclosing pressure relief device having a start-to-discharge pressure setting of 310 kPa (45 psig). B53 - Packagings must be made of either aluminum or steel. IB2 - Authorized IBCs: Metal (31A, 31B and 31N); Rigid plastics (31H1 and 31H2); Composite (31HZ1). Additional Requirement: Only liquids with a vapor pressure less than or equal to 110 kPa at 50 C (1.1 bar at 122 F), or 130 kPa at 55 C (1.3 bar at 131 F) are authorized. T8 - 4 178.274(d)(2) Normal............ Prohibited TP2 - a. The maximum degree of filling must not exceed the degree of filling determined by the following: Degree of filling = 95 / (1 + a (tr - tf)) Where: tr is the maximum mean bulk temperature during transport, tf is the temperature in degrees celsius of the liquid during filling, and is the mean coefficient of cubical expansion of the liquid between the mean temperature of the liquid during filling (tf) and the maximum mean bulk temperature during transportation (tr) both in degrees celsius. b. For liquids transported under ambient conditions may be calculated using the formula: a = (d15 - d50) / 35*d50 Where: d15 and d50 are the densities (in units of mass per unit volume) of the liquid at 15 C (59 F) and 50 C (122 F), respectively. TP12 - This material is considered highly corrosive to steel.
DOT Packaging Exceptions (49 CFR 173.xxx)	: None
DOT Packaging Non Bulk (49 CFR 173.xxx)	: 158
DOT Packaging Bulk (49 CFR 173.xxx)	: 242
DOT Quantity Limitations Passenger aircraft/rail (49 CFR 173.27)	: 1 L
DOT Quantity Limitations Cargo aircraft only (49 CFR 175.75)	: 30 L
DOT Vessel Stowage Location	: D - The material must be stowed "on deck only" on a cargo vessel and on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overall vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded.

Additional information

Other information	: No supplementary information available

ADR

Transport document description	:

Transport by sea

No additional information available

Air transport

No additional information available

SECTION 15: Regulatory information

15.1. US Federal regulations

Nitric Acid, 10% v/v (1+9)	
SARA Section 311/312 Hazard Classes	Immediate (acute) health hazard

Nitric Acid, 70% w/w (7697-37-2)	
Listed on the United States TSCA (Toxic Substances Control Act) inventory Listed on SARA Section 313 (Specific toxic chemical listings)	
RQ (Reportable quantity, section 304 of EPA's List of Lists) :	1000 lb
SARA Section 311/312 Hazard Classes	Immediate (acute) health hazard

15.2. International regulations

CANADA

Nitric Acid, 10% v/v (1+9)	
WHMIS Classification	Class E - Corrosive Material

Nitric Acid, 70% w/w (7697-37-2)	
Listed on the Canadian DSL (Domestic Sustances List) inventory.	
WHMIS Classification	Class E - Corrosive Material Class C - Oxidizing Material

EU-Regulations

No additional information available

Classification according to Regulation (EC) No. 1272/2008 [CLP]

Classification according to Directive 67/548/EEC or 1999/45/EC

Not classified

15.2.2. National regulations

Nitric Acid, 70% w/w (7697-37-2)
Listed on the Canadian Ingredient Disclosure List

15.3. US State regulations

No additional information available

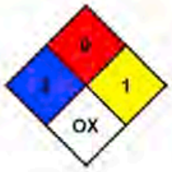
SECTION 16: Other information

Other information : None.

Full text of H-phrases: see section 16:

Eye Dam. 1	Serious eye damage/eye irritation, Category 1
Met. Corr. 1	Corrosive to metals, Category 1
Ox. Liq. 3	Oxidising Liquids, Category 3
Skin Corr. 1A	Skin corrosion/irritation, Category 1A
Skin Corr. 1B	Skin corrosion/irritation, Category 1B
H272	May intensify fire; oxidiser
H290	May be corrosive to metals
H314	Causes severe skin burns and eye damage
H318	Causes serious eye damage

NFPA health hazard	: 3 - Short exposure could cause serious temporary or residual injury even though prompt medical attention was given.
NFPA fire hazard	: 0 - Materials that will not burn.
NFPA reactivity	: 1 - Normally stable, but can become unstable at elevated temperatures and pressures or may react with water with some release of energy, but not violently.
NFPA specific hazard	: OX - This denotes an oxidizer, a chemical which can greatly increase the rate of combustion/fire.



Nitric Acid, 10% v/v (1+9)

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HMIS III Rating

Health : 3 Serious Hazard - Major injury likely unless prompt action is taken and medical treatment is given

Flammability : 0 Minimal Hazard

Physical : 1 Slight Hazard

Personal Protection : H

SDS US (GHS HazCom 2012)

Information in this SDS is from available published sources and is believed to be accurate. No warranty, express or implied, is made and LabChem Inc assumes no liability resulting from the use of this SDS. The user must determine suitability of this information for his application.

7.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) covers common installation methods for a groundwater monitor well that may be implemented by INTERA field personnel during characterization, remediation, or monitoring of environmental sites.

Monitor wells are typically installed for monitoring purposes and as a primary mechanism by which representative groundwater samples are collected. Depending on site conditions, a groundwater monitor well may be screened across one or more interval(s) and the annulus around the well screen is packed with granular material appropriately-sized to reduce the migration of fines into the well. Typically groundwater monitor wells are installed via a two-stage drilling procedure: The upper soil/strata will be sealed from the aquifer using a cement–bentonite grout.

For most environmental characterization and monitoring purposes performed by INTERA personnel, a 2-inch (in) inside diameter (ID) monitor well completed via hollow stem auger (HSA) drilling method is sufficient and the most commonly applied. As such, methods outlined in this SOP are tailored to detail well installation procedures of this size and method; however, installation of monitor wells of different sizes or into borings completed by other methods follow the same general procedures outlined below.

Methods outlined in this SOP comply with the following ASTM Standard:

- D5092-04(2010)e1, *Standard Practice for Design and Installation of Groundwater Monitoring Wells* (ASTM, 2010).

This SOP should be used in conjunction with procedures presented in the Site-Specific Health and Safety Plan (SSHASP) and in site-specific investigation planning documents such as a Sampling and Analysis Plan (SAP), Field Sampling Plan (FSP), or Work Plan (WP). This SOP will also be commonly used in conjunction with and is referenced in the following INTERA SOPs:

- SOP 2, *Decontamination*;
- SOP 5, *Hollow-Stem Auger Drilling*;
- SOP 8 *Monitor Well Development*; and
- SOP 30, *Field Forms*.

7.1 General Monitor Well Construction via HSA

Schematic of a typical 2-in groundwater monitor well (above-ground completion or flush-grade completion) for the purposes of environmental characterization is presented as **Attachment 1**. Soil borings intended for 2-in well installation are typically advanced utilizing 4¼-inch ID HSA with an 8¾-in outside diameter (OD) auger bit. Procedure implementation of the HSA drilling method is detailed in INTERA SOP 5, *Hollow-Stem Auger Drilling.*

The borehole or HSA should be of sufficient diameter so that well construction can proceed without major difficulties. For open boreholes, the annular space should be approximately 2 in to allow the uniform deposition of well materials around the screen and riser, and to allow the passage of tremie pipes and well materials without unduly disturbing the borehole wall. By this means, a 2-in well casing would require a 6" ID borehole.

If the projected total depth (TD) of the well is 20 feet (ft) or greater, the boring may require reaming with 6-in ID HSA with a 10-in OD auger bit. Installation of the well in a larger diameter boring reduces the problem of bridging of the filter pack or bentonite pellets.

Sometimes it is necessary to over-drill the borehole in anticipation of material entering the augers during center bit removal or knocking out of the bottom plug. Normally, 3 to 5 ft is sufficient for over-drilling. If a borehole is inadvertently drilled deeper than desired, it can be backfilled to the design depth with bentonite pellets, chips, or the filter sand that is to be used for the filter pack.

A borehole may also be over-drilled to allow for an extra space for a "sump" area below the well screen. This "sump" area provides a space to attach a 5 or 10 ft section of blank well casing to the bottom of the well screen. The extra space or "sump" below the well screen serves as a catch basin or storage area for sediment that flows into the well and drops out of suspension. As appropriate, these "sumps" are added to the well screens when wells are screened in aquifers that are naturally turbid and will not yield clear formation water (free of visible sediment) even after extensive development. The sediment can then be periodically pumped out of the "sump" preventing the well screen from clogging or "silting up". If sump installation is considered for a site, however, approval should be sought from the applicable regulatory agency prior to installation.

7.2 Application of Surface Casing

Surface casing is used as a means of isolating known or potentially contaminated soil, thus preventing possible downward migration of contamination in the borehole. Surface casing is a secondary casing surrounding a borehole down to the desired TD. It serves as an additional annular seal by not allowing upper intervals of soil to come into contact with advancing drilling and sampling equipment therefore minimizing the potential for cross-contamination.

When surface casing is required, care must be given to selecting the appropriate diameter of surface casing, ream auger, and lead auger to advance the boring to the desired TD. A minimum of a 14-in auger is needed to ream the borehole for installation of 10-in surface casing. This allows for the latter advancement of 4¼-inch ID by 8¾-in OD HSA. Similarly, a 16-in auger is utilized to ream the borehole for installation of a 12-in surface casing. This allows for the latter advancement of 6-in ID by 10-in OD HSA.

To isolate the upper portion of the borehole for installation of a 2–in monitor well, 10–inch diameter, Schedule 40 PVC casing (or other appropriate material) is set to the desired depth to seal off surface contamination. It is preferred that the base of the surface casing be seated in clay if stratigraphy permits.

The bottom of the casing is then sealed with a casing shoe to prevent entry of potentially contaminated water or soil into the casing during subsequent well installation. The casing shoe can be made using PVC coupling half filled with plaster-of-Paris or Portland cement. The shoe can be anchored to the base of the surface casing using stainless–steel sheet metal screws or pop rivets. A stainless–steel centralizer will be placed on the lower portion of the casing to ensure alignment of the casing within the borehole.

7.3 Procedure – Groundwater Monitor Well Installation

The borehole advanced for the purposes of installing a permanent groundwater monitor well should be bored, drilled, or augured as close to vertical as possible, and checked with a plumb bob or level. Deviation from plumb should be within 1° per 50 ft of depth. Slanted boreholes are undesirable and should be noted in the boring logs, final well construction logs, and the field logbook, as appropriate. Template well construction log forms are provided in SOP 30, *Field Forms*.

1. The TD and volume of the borehole, including over-drilling if applicable, should be calculated and the appropriate materials (e.g. selected well casing and screen) procured and inspected prior to drilling and installation.
2. If placement of surface casing is required:
    - Drill borehole larger than the diameter of the surface casing down to the depth desired for the bottom of the surface casing
    - Set surface casing so that it extends from slightly above the ground surface, through the contaminated zone, and into uncontaminated material below
    - Grout the annulus between borehole and surface casing with a cement/bentonite slurry.The slurry can be mixed at a ratio of 6.5 gallons of potable water per 94-pound sack of Type I Portland cement. Bentonite powder should be added to the slurry at a ratio of 3% of the total Portland cement weight. Grout is typically tremied into place utilizing 1¼-in to 1½-in tremie pipe.

   - Wait at least 24 hours for the grout to cure prior to continuing drilling through the cased section of the borehole to the desired TD.

3. After completing the boring to the desired TD, well casing will be placed into the HSA pipe. Schedule 40 PVC (or heavier) or stainless steel (preferred for organic COCs), threaded, flush-joint casing is typically used. Alternate casing material may be utilized as approved by the overseeing regulatory agency. In all cases, the casing material selected for use must be compatible with the anticipated chemistry of the groundwater and identified COCs. Casing sections are typically applied in 5 or 10 ft lengths. When completed, the well casing should extend a minimum of 1 ft above ground surface (if above grade completion) or 6 to 12 in below ground surface [bgs] (if completed below grade).

4. Well screen shall also be inspected prior to placement into the HSA pipe. Individual well screen sections are also typically 5 or 10 ft long and often have 0.010-in slot or 0.020-in slot openings.

   - Unless otherwise approved by the applicable oversight agency, a 20-foot section (maximum) of continuous-slot, machine slotted, or other manufactured PVC or stainless steel well screen shall be installed across the water table.
   - The bottom of the screen must be installed no more than 15 ft below the water table; the top of the well screen must be positioned not less than 5 ft above the water table.
   - For sites requiring a screen length exceeding 20 ft shall be carefully evaluated for the introduction of possible dilution effects during sampling.
   - Well screen slots must be appropriately sized for the formation materials and should be selected to retain 90 percent of the filter pack. A slot size 0.010-in is generally adequate for most installations. Screens created by cutting slots into solid casing with saws or other tools is not acceptable.

5. Before the well screen and casings are placed on the bottom of the borehole, at least 6 in of filter material should be placed at the bottom of the borehole to serve as a firm footing. If geologic conditions warrant and as approved by the appropriate regulatory agency, a 0.5- to 3-ft length of blank casing may also be placed beneath each well screen to act as a sump or reservoir for fine material (**Section 7.1**). All sections of casing and screen will be assembled on site to allow inspection immediately before installation.

6. As applicable, stainless–steel centralizers may be required and are attached to the screen or casing to help center the well in each boring and facilitate the subsequent

placement of the filter pack, the bentonite seal, and the grout in the annulus. Monitoring wells with a TD of less than 50 ft generally do not require centralizers. If centralizers are used, however, they should be placed below the well screen and above the bentonite pellet seal. Specific placement intervals shall be determined based on site-specific conditions.

7. A filter pack (most commonly 16/30 or 20/40 silica sand, yet is dependent on the grain size of the geologic material), is placed in the annulus between the boring wall and the well screen. The purpose of the filter pack is to provide aquifer formation stability, minimize the entry of fine-grained material into the screen, and increase the effective well diameter and water collection zone. Recommended filter pack characteristics for common screen slot sizes is listed in **Attachment 2**.
    - Whenever possible, the filter pack will extend above the top of the screen for a distance equal to 10% of the screen length, or a minimum of 2 ft, to allow for settlement of the filter pack and prevent the migration of the overlying seal material into the intake zone.
    - The filter pack will be placed in such a manner that bridging of the material in the annulus is prevented. For wells deeper than 30 ft, the filter pack must be emplaced by a tremie pipe. Care should be taken not to damage the well screen or casing during placement of the filter pack using either agitation or the tremie pipe.
    - The well should be surged or bailed to settle the filter pack and additional sand added, if necessary, before the bentonite seal is emplaced. If necessary, the filter pack material may be washed into the annular space with potable water to help prevent bridging.
8. A bentonite seal must be constructed immediately above the filter pack by emplacing bentonite chips or pellets (3/8-inch in size or smaller) with no added polymers in a manner that prevents bridging of the chips/pellets in the annular space. This seal is used to isolate the aquifer interval from the upper zones. The bentonite seal must be a minimum of 3 ft thick and hydrated with clean water. Adequate time should be allowed for expansion of the bentonite seal before installation of the annular space seal. One way of determining the appropriate amount of time for the pellets to hydrate, is to fill a clear jar half full with a sample of the pellets delivered to the site. The remaining headspace in the jar will then be filled with potable water. The time required to hydrate the pellets will be recorded. At a minimum, this will be the amount of time that the pellets in the borehole will be allowed to hydrate prior to grouting.

9. The annular space above the bentonite seal will be filled with an approved bentonite-based grout. Annular space seals must extend from the top of the bentonite seal to ground surface (for wells completed above grade) or to a level 3 to 6 in below the top of casing (for wells completed below grade) The grout will approximate Type I Portland cement (95–97%) and powdered bentonite (3–5%). One 94–cubic–pound sack of grout is typically mixed with 7 gallons of potable water. The grout mixture will be placed into the boring via the use of a tremie pipe, tubing, or direct pouring from the surface when appropriate. A tremie pipe must be used when placing sealing materials at depths greater than 20 ft bgs. Pumps may be used to facilitate mixing of the grout and to fill the borehole with grout.

7.4 Procedure – Surface Completion

Depending on site conditions, groundwater monitor wells may be completed either above or below grade. The appropriate surface completion required shall be established in the SAP or equivalent.

For monitor wells finished above grade:

1. A protective steel casing (shroud) and removable locking cap will be installed over the casing. The shroud must be large enough in diameter to allow easy access for removal of the cap.
2. As needed, vent holes may be placed in the shroud and in the riser pipe to allow the boring to communicate with the atmosphere. For the shroud, an approximately ¼–inch hole near the ground surface is recommended to facilitate gas venting and to prevent the accumulation of fluids in the annulus between the well casing and the shroud. The well riser pipe may be vented with an approximately ¼–inch hole near the top of the pipe below the bottom of the protective cap.
3. A concrete pad (2-foot minimum radius, 4-inch minimum thickness) shall be poured around the shroud and wellhead. The concrete and surrounding soil must be sloped to direct rainfall and runoff away from the wellhead (at approximately 2%). The installation of steel posts around the well shroud and wellhead is recommended for monitoring wells finished above grade to protect the wellhead from damage by vehicles or equipment.

Alternatively, monitoring wells may be completed below grade.

1. A manhole cover or well box/vault shall be installed around the well casing and a lockable expandable well cap shall be placed in the top of the casing. The well vault shall be flush-mounted and watertight and, as appropriate, rated to withstand traffic loads.

2. The cover must be secured with at least one bolt and shall indicate that the wellhead of a monitoring well is contained within the vault.
3. A concrete pad (2-foot minimum radius, 4-inch minimum thickness) shall be constructed at the base of the protective casing. The concrete and surrounding soil must be sloped to direct rainfall and runoff away from the wellhead (at approximately 2%).

7.5 References

ASTM International (ASTM), 2010. Standard Practice for Design and Installation of Ground Water Monitoring Wells. D5092-04 (Reapproved 2010)e1.

New Mexico Environment Department (NMED). 2011. New Mexico Environment Department Ground Water Quality Bureau Monitoring Well Construction and Abandonment Guidelines. Revision 1.1. March.

7.6 Other Sources

Environmental Protection Agency. 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitor Wells. USEPA Office of Research and Development. EPA160014-891034. March

———. 2013. Design and Installation of Monitoring Wells. SESDGUID-101-R1. USEPA Science and Ecosystem Support Division Region 4. Revision 1. January 29.

Texas Commission on Environmental Quality. 2001. Standard Operating Procedure No. 5.5 Monitoring Well Installation And Completion. Revision 1. April 29.

7.7 Attachments

Attachment 1: Groundwater Monitor Well Construction Requirements

Attachment 2: Recommended Filter Pack Characteristics for Common Screen Slot Sizes

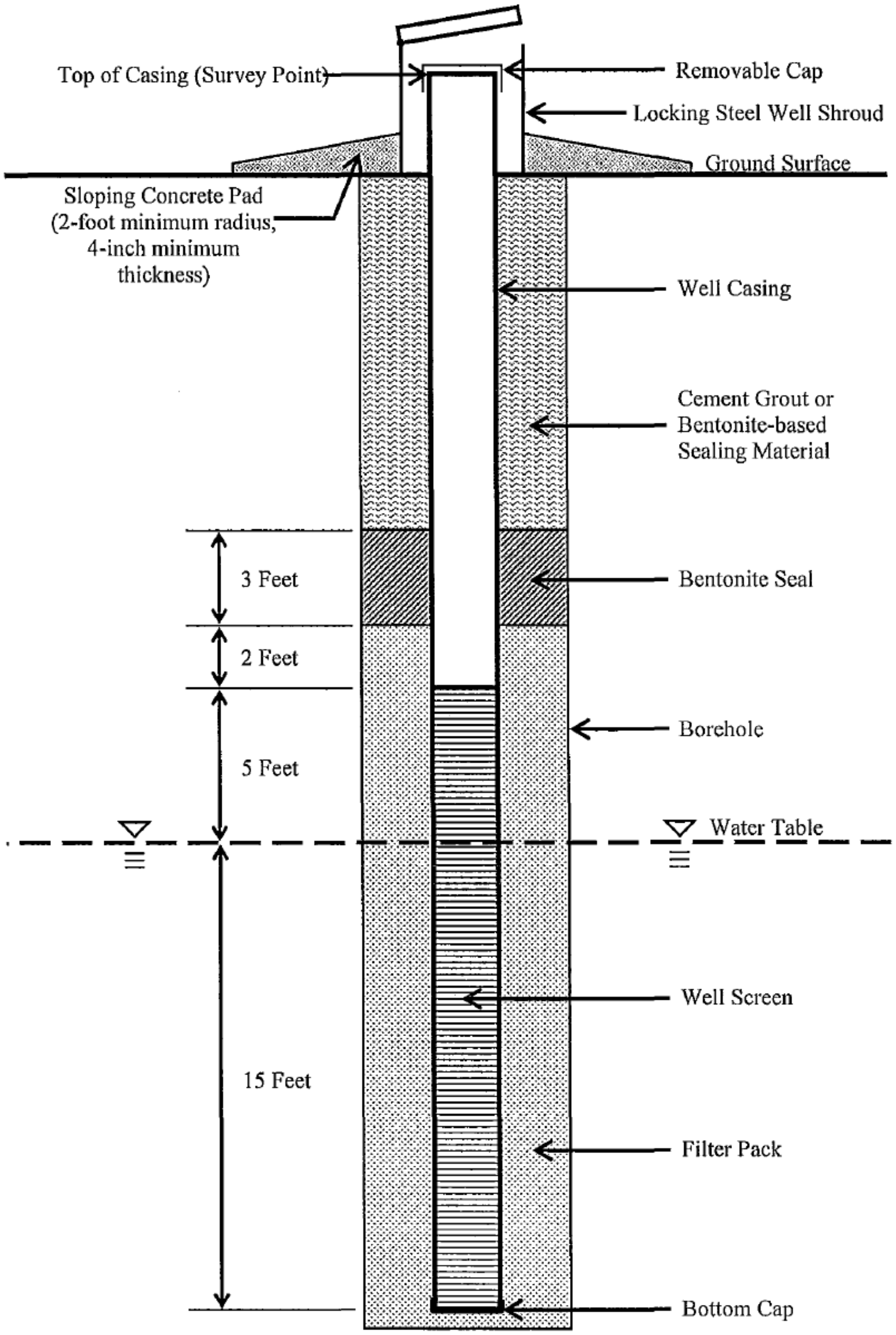
7.8 Document History

Revision	Effective Date	Lead Author	Summary of Changes
2004.0	4/2004	Taimur Malik	Original version
2004.1	2/2015	Kate Herrell	Revised for inclusion in COA Brownfields QAPP
2004.2	6/2017	Noreen Baker	Removed Field Form as an attachment, added reference to SOP 30, Field Forms

Attachment 1

Groundwater Monitor Well Construction Requirements

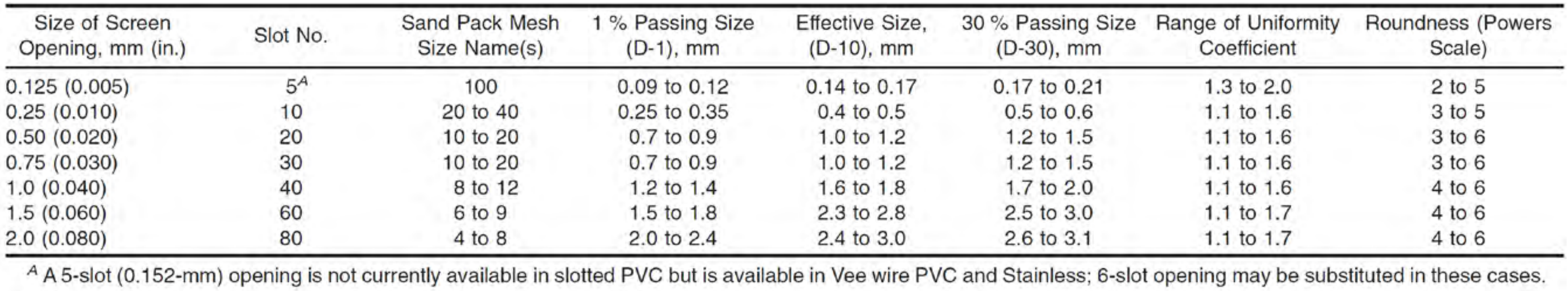
MONITORING WELL SCHEMATIC
(Not to Scale)



Excerpted from (NMED, 2011)

Attachment 2

Recommended Filter Pack Characteristics for Common Screen Slot Sizes



Size of Screen Opening, mm (in.)	Slot No.	Sand Pack Mesh Size Name(s)	1 % Passing Size (D-1), mm	Effective Size, (D-10), mm	30 % Passing Size (D-30), mm	Range of Uniformity Coefficient	Roundness (Powers Scale)
0.125 (0.005)	5[A]	100	0.09 to 0.12	0.14 to 0.17	0.17 to 0.21	1.3 to 2.0	2 to 5
0.25 (0.010)	10	20 to 40	0.25 to 0.35	0.4 to 0.5	0.5 to 0.6	1.1 to 1.6	3 to 5
0.50 (0.020)	20	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
0.75 (0.030)	30	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
1.0 (0.040)	40	8 to 12	1.2 to 1.4	1.6 to 1.8	1.7 to 2.0	1.1 to 1.6	4 to 6
1.5 (0.060)	60	6 to 9	1.5 to 1.8	2.3 to 2.8	2.5 to 3.0	1.1 to 1.7	4 to 6
2.0 (0.080)	80	4 to 8	2.0 to 2.4	2.4 to 3.0	2.6 to 3.1	1.1 to 1.7	4 to 6

[A] A 5-slot (0.152-mm) opening is not currently available in slotted PVC but is available in Vee wire PVC and Stainless; 6-slot opening may be substituted in these cases.

Excerpted from (ASTM, 2004)

8.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) covers common development methods of a groundwater monitor well that may be implemented by INTERA field personnel during characterization, remediation, or monitoring of environmental sites as follows:

- Mechanical Surging (**Section 8.1.1**);
- Air Surging or Jetting (**Section 8.1.2**);
- Pumping (**Section 8.1.3**); and
- Bailing (**Section 8.1.4**).

The intent of well development is to:

- Reduce compaction and intermixing of grain sizes produced during drilling;
- Increase porosity and permeability of the artificial filter pack via removal of any fines introduced near the screen during drilling/well installation; and
- Remove any residual drilling fluids/foreign material from the borehole or the adjacent natural formation.

Common well development methods as outlined in this SOP, used solely or in conjunction, facilitate the movement of water through a well screen thereby moving any residual fines (silt and clay particles) trapped in the filter pack around the well screen into aqueous suspension within the well casing. The sediment-laden water is then removed from the well casing using a pump, bailer, or air compressor.

A groundwater monitor well is determined to be effectively developed upon achievement of one or more of the following criteria, as applicable:

1. At least 3 well casing volumes have been removed and water quality parameters for pH, temperature, and conductivity, as appropriate, have stabilized as defined in **Section 8.3** of this SOP; or
2. Five well casing volumes have been removed.

Development of a groundwater monitor well should occur no earlier than **24 hours** after initial installation to allow enough time for (1) the well's annular seal and grout to properly set and (2) to maximize the hydraulic connection between the well and surrounding aquifer material (TCEQ, 2001). Settling periods longer than 24 hours may be required by different state or federal agencies (EPA, 2001). Settling periods longer than 24 hours may also be required for wells where a more vigorous well development method (e.g. surging) is planned in order to minimize the potential for well development procedures to compromise the annular seal. Site-specific development criteria will be specified in the SAP/FSP/WP.

With the exception of some self-contained drive point samplers as discussed in INTERA SOP 6, *Direct Push Drilling*, a typical groundwater monitor well requires development **prior** to obtaining any necessary water level measurements or water quality samples.

NOTE: The process of well development should not be confused with well purging, the purpose of which is to remove from the well casing stagnant or "old" groundwater not representative of aquifer conditions immediately prior to a sampling event. Wells, if installed, should be developed; alternatively, well purging, as detailed in INTERA SOP 10, *Monitor Well Sampling for Groundwater*, is commonly performed only prior to the collection of a representative groundwater sample.

The methods outline in this SOP also apply to monitor wells in which excessive siltation has occurred. During a well's operation (ranging from months to years), fines may accumulate in the bottom of the well casing and impact the effective hydraulic connectivity of the well with the surrounding aquifer. In this case, well redevelopment may be selected as an attempt to re-establish a complete hydraulic connection.

Methods outlined in this SOP comply with the following ASTM Standard:

- D5521/D5521M-13, *Standard Guide for Development of Groundwater Monitoring Wells in Granular Aquifers* (ASTM, 2013).

This SOP should be used in conjunction with procedures presented in the INTERA Site-Specific Health and Safety Plan (SSHASP) and in site-specific investigation planning documents such as a Sampling and Analysis Plan (SAP), Field Sampling Plan (FSP), or Work Plan (WP). This SOP will also be commonly used with and is referenced in the following INTERA SOPs:

- 2, *Decontamination;*
- 9*, Water Level Gauging;*
- 10, *Monitor Well Sampling for Groundwater*;
- 15, *Slug Test Procedures*; and
- 30, *Field Forms*.

8.1 Common Well Development Methods

The intent of this section is to provide a brief description of the four common well development methods that may be utilized by INTERA field personnel during characterization, or monitoring of environmental sites. These methods as well as other less common methods are available for well development and application considerations are summarized in **Attachment 1**.

Which method(s) is most appropriate for a site/well is dependent on site conditions (e.g., subsurface geology, level of contamination, depth to water (DTW)), equipment limitations (well construction), and any state-specific requirements (e.g., introduction of foreign material, particularly water, or use of vigorous methods with a higher risk of damage to well/formation); however, the chosen method of well development should be selected foremost on its relative success of attaining site data quality objectives, which for most environmental investigations, is obtaining a representative sample of groundwater conditions. For each site, the well development method selected shall be documented in the SAP/FSP/WP.

General field implementation of well development for a site corresponding to one or more of the common well development methods listed below is further detailed in **Section 8.4**.

8.1.1 Mechanical Surging

Mechanical surging is one of the more commonly applied methods of well development and involves forcefully moving water into and out of the well screen, thereby increasing the porosity in the immediate vicinity of the well. Mechanical surging is typically completed using a fitted surge block or, in some cases, a bailer (**Section 8.1.4**) may also be used. A surge block consists of one or more flat rubber rings that fit closely inside the well and seals the well casing interior and is operated like a plunger beneath the water level. Because it seals closely to the casing, it has a very direct positive action on water movement within the well; as such, it is critical that the diameter of the flexible rings chosen for the surge block are sufficient to generate a tight seal within the well casing. For wells where only the casing will be surged, the seal should be sized to be within $^1/_8$ of an inch or ¼ of an inch of the casing inner diameter. For wells where the screen will be surged, it may be appropriate to utilize a less tight block to avoid sandlocking (ASTM, 2013).

To initiate well development via use of a surge block, the block is attached to a rod or pipe of sufficient length to reach the bottom of the well. The block is then sequentially raised and lowered inside the well casing at a predetermined rate and depth, beginning slowly at the top of the well screen, proceeding through the well screen interval, and ending at the base of the well (**Section 8.4**). This repetitive motion forces water through the screen and into the formation, which loosens trapped fines. A pump or bailer may then be used to remove the sediment-laden water in the well casing and the process is repeated until well development criteria, as defined in **Section 8.2** and **Section 8.3** of this SOP and detailed in the SAP/FSP/WP, are achieved.

The process of “swabbing” is similar in effect to mechanical surging but relies mostly on the upward movement of the swab in the well casing so that water is only being pulled into the well and out of the formation. Swabbing is less dependent on applying a “backwash” effect (**Section 8.1.3**) on the well screen/filter pack and care should be taken to avoid pushing water through the screen and into the formation. Swabbing is achieved by slowly advancing the swabbing equipment down the well casing followed by the application of a vacuum/suction on the well screen and surrounding formation with the upstroke.

Some considerations when choosing whether to apply mechanical surging for well development include:

1. Surging via block is best applied for wells screened in formations exhibiting medium to high porosity and hydraulic conductivity, and are relatively uniform in lithology. Also, good and consistent recharge in the well minimizes the potential for damage to the surrounding aquifer as a result of surging actions.
2. Surging may be performed manually for smaller diameter wells that are less than 50 ft deep. For larger and deeper wells, mechanical surging will typically require assistance via a block and tackle or pulley system constructed over the well or a drill rig.
3. Surging via block is not recommended for wells screened in formations exhibiting a high percentage of fines (i.e., low permeability) as plugging of the well screen may result; alternatively, in these instances, use of a bailer should be considered.
4. Sandlocking with the block may occur. Sediments must be removed from the well with a sand bailer. This may cause the sand filter pack around the screen to become displaced to such a degree as to compromise its future ability as a filtering medium. Channels or voids may form near the screen if the filter pack sloughs away during surging.
5. Forcing water through a filter/screen, in general, can be quite vigorous and care should be taken not to damage the well head or screen. In addition, this process may dislodge fines from more impermeable lithological units encountered during drilling and force them into more permeable layers. If applicable, this potential impact may be minimized by completing fewer surging cycles, using a block that is looser fitting, and/or increasing the purge volume or time of development.

8.1.2 Compressed Gas

Compressed gas, generally nitrogen, or filtered air can be used both to surge and to purge a monitor well. Surging via compressed air or gas is implemented by injecting a sudden charge of compressed air into the well with an airline attached to a tank that forces water back through the well screen. Periodically, the air/gas source is turned off to allow for the water column to return into the well casing and to correct any bridging that may have resulted during application. This process is then repeated. Periodically, the airline is pulled up into a pipe string (educator) and the water is pumped from the well using air as the lifting medium (air-lift pumping). The process continues until well development criteria as defined in **Section 8.2** and **Section 8.3** of this SOP. Method variations include leaving the air line in the pipe string or using the well casing as the educator pipe

Compressed gas can also be used for "Jetting," a process by which air is directed at the slots in the well screen to cause turbulence (thereby disturbing fines in the adjacent filter pack). Jetting may be performed in conjunction with air-lift pumping and begins below the well screen of interest and proceeds by slowly moving the nozzle upward along the length of the screen. The hose or pipe installed for Jetting should be equipped with a horizontal (side) discharge nozzle and one or more small holes in the bottom of the hose to enhance the lifting of sediment during jetting.

NOTE: Jetting may also be performed using water as the medium; however, this is often objectionable to many state regulatory agencies as the introduction of non-formation water too often compromises achievement of data quality objectives typical of an environmental site.

Since the compressed gas will be used to "lift" water from the monitor wells, provisions must be made for controlling the discharge from contaminated wells. This is generally accomplished by attaching a "tee" discharge to the top of the casing to control the overflow and providing the necessary containment for discharged water as defined in the SAP or equivalent. Air-lift pumping in contaminated wells must never be applied unless a discharge control apparatus (e.g., educator) and proper containment is identified and provided in advance.

Some considerations to using compressed air/gas for well development include:

1. Highly accommodating - no limitations regarding well diameter or depth to static water, and can be used to develop both shallow and deep wells;
2. Surging via air is best applied for wells screened in relatively uniform formations exhibiting high hydraulic conductivities and is not recommended for wells screened in permeable formations interbedded with clays;
3. In some cases, introduction of external air or gas to the formation/aquifer system may alter the hydrochemistry of the aquifer; this is of special concern in formations exhibiting high permeability; and
4. Surging with air may produce “air locking” in some formations, preventing water from flowing into the well.

8.1.3 Pumping

Pumping may be used either solely or in conjunction with another well development method; however, in most instances, a pump is typically applied as an aid to mechanical surging or bailing unless the pump is dedicated (e.g., permanently installed in the well). Pumping as the sole method of development is typically used at wells completed at depths where other development methods are too cumbersome to implement and/or at wells that contain a large volume of water where a continuous supply of water is expected for proper development.

When developing a well via pumping, pumping must be performed at a rate that is greater than the recharge rate of the well. When the pumping rate exceeds the design capacity of the well, this is referred to as “over pumping”. The well drawdown should be monitored to prevent the well from going dry. Effective development cannot be accomplished if the pump must be shut off to allow the well to recharge. A pump intake hose, placed in the center or towards the top of the well screen, generates suction that effectively acts as a plunger on the well screen, drawing water from the formation, through the filter pack (as applied) and well screen (thereby dislodging trapped fines), into the well casing and up to the surface. The process continues until well development criteria as defined in **Section 8.2** and **Section 8.3** of this SOP are achieved.

Where appropriate, extracted development water from a well may also be redirected back into the well casing to assist with correcting any potential bridging of material that may have occurred over the well area as a result of unidirectional groundwater flow via extraction during pumping. This process is referred to a “backwashing.” Once the well casing is filled to the surface via backwashing, the pump is shut off, and groundwater is allowed to re-equilibrate to static level thus forcing water to re-enter the surrounding formation through the well screen and filter pack. However, it is important to note that suspended sediment must be removed from the extracted groundwater prior to reintroduction into the well. This can be achieved by allowing groundwater to pass through appropriate filtering media or by allowing sediment to settle in an appropriate container (e.g., steel drum) prior to backwashing.

Rawhiding may also be performed during well development via pumping. Rawhiding refers to starting and stopping the pump quickly to produce a rapid change in the water column (pressure head) in the well thereby producing movement similar to surging. If rawhiding is selected, the pump utilized must be able to pump at a rate of at least 5 to 10 gal/min, and the pump should be monitored for excessive damage/wear.

There are many varieties of pumps that can be used for well development including suction lift pumps, electric submersible pumps, and positive displacement pumps. Suction lift pumps include peristaltic pumps, surface centrifugal pumps, and vacuum pumps. Electric submersible pumps include centrifugal submersible pumps, helical rotor (progressing cavity) pumps, and gear pumps. Positive displacement pumps include gas-drive pumps, piston pumps, inertial-lift pumps, and bladder pumps. Electric submersible pumps are the most commonly applied pumps for development of groundwater monitor wells.

Regardless of which type of pump is used, the pumping rate should be low enough to avoid turbulent flow that causes entrainment of fines in the sand pack. In addition, the pump must be capable of moving some solids without damage. Inertial-lift pumps are often preferred for small diameter wells (i.e. <2 inches) due to the surging action of the pumps and their low well yield requirements.

Some considerations to using a pump for well development include:

1. Best applied for deep wells or wells with a high well yield and in combination with backwashing;
2. Limited to the size of the well casing; many pumps necessary to perform effective development may not fit in small diameter wells;
3. Can generate a large volume of investigation derived waste (IDW) that may not be desirable if the IDW requires special disposal and/or treatment;
4. Can cause wear or significant damage to equipment;
5. Development solely via pumping is considered passive development and often will not sufficiently stabilize the formation or surrounding filter pack, remove fine-grained material, or rectify damage done to the formation during drilling/well installation (ASTM, 2013);
6. Not recommended for wells screened in heterogeneous formations consisting of both high and low permeable lithology. Pumping often preferentially develops the most permeable zone(s) and/or zones closest to the top of the well screen thereby resulting in a low well-yield; and
7. Pumping may compact finer sediments in formations with low permeability thus restricting flow into the well.

8.1.4 Bailing

Bailing is typically the preferred method of well development for shallow wells completed in heterogeneous formation(s) and for wells that contain a high volume of suspended sediment that cannot be accommodated by most positive–displacement pumps. Bailing is not as vigorous a well development technique as surging via a surge block but can attain a similar effect and result in less damage/clogging to the well screen in well(s) completed in formations exhibiting a high percentage of fines.

Bailing includes the use of a simple check-valve bailer to remove water from the well. Like other methods, the process of bailing continues until well development criteria as defined in **Section 8.2 and Section 8.3** of this SOP are attained.

Some considerations to using a bailer for well development include:

1. As bailing is a purely manual effort, this method is not recommended for deep wells or wells with a high well yield; and
2. Ideal for developing well(s) screened in low permeable formations as bailing generally will not produce pressures great enough to cause well damage.

8.2 Procedure - Calculations

One of the criteria to achieve proper well development (**Section 8.0**) is defined by the removal (purge) of a minimum of three well casing volumes or up to five well casing volumes. The well casing volume can be defined as the volume of groundwater observed in the well casing under static conditions and can be calculated as follows:

Equation 1:

$$V_{WC} = \frac{\pi D^2 h}{4}$$

Where:

V_{WC} (ft^3) = well casing volume
D (ft) = inner diameter of well casing
h (ft) = height of the water column in the well casing.

The inner diameter of the well casing (D) is a known parameter that can be established by reviewing the well installation documentation for the well. The height of the water column in the well casing (h) is calculated by subtracting the depth to groundwater as measured (in feet) prior to development from the known total depth of the well (in feet) as determined prior to development.

This equation can be modified to reflect common-sized monitor wells as follows:

Equation 2:

$$V_{WC} = h \times a$$

Where:

V_{WC} (gal) = well casing volume
h (ft) = height of the water column in the well casing
a (gal/ft) = the corresponding standard volume calculated per linear foot for a monitor well based on the inner well diameter as given below in **Table 1**.

Table 1: Well Casing Diameter versus Volume of Water*

Well Casing Diameter	Gallons/Linear Foot of Water Column
1	0.041
2	0.163
3	0.367
4	0.653
5	1.02
6	1.469
7	1.999
8	2.611
9	3.305
10	4.08

*Conversion: 1 ft^3 = 7.48 gal; 1 gal = 0.134 ft^3

Consequently, the minimum purge volume (V_P) required to be removed from the well during well development can be calculated as follows:

Equation 3:

$$V_P = V_{WC} \times 3$$

Where:

V_P (gal/ft) = minimum required purge volume for well development
V_{WC} (gal/ft) = well casing volume as calculated by **Equation 1** or **Equation 2**.

In some instances, volume of the filter pack may also be of interest and need to be calculated. The volume of the filter pack can be estimated by calculating the volume of the borehole filter pack less the casing volume.

Filter pack volume is calculated using the following equation:

Equation 4:

$$V_{FP} = \left[\frac{\pi D^2 h}{4} - V_{WC}\right](n)$$

Where:
V_{FP} (ft^3) = filter pack volume
D (ft) = diameter of the borehole
h (ft) = lesser of (a) length of filter pack, or (b) length of water column in well casing
n = filter pack porosity (assume 30%)
V_{WC} (ft^3) = well casing volume (as defined in **Equation 1**)
Well Volume Total = $V_{FP} + V_{WC}$.
Conversion: 1 ft^3 = 7.48 gal; 1 gal = 0.134 ft^3

8.3 Procedure – Measurement of Water Quality Parameters

The other primary criteria for defining the achievement of proper well development (**Section 8.0**) is stabilization of certain water quality parameters as measured in the field. For well development conducted as part of most environmental investigations, this specifically applies to the parameters of pH, specific conductivity, turbidity, and less so, temperature (EPA, 2001).

The intent of utilizing these field parameters in well development is to identify when the physical and/or chemical characteristics of groundwater entering the well begin to reflect that of the surrounding aquifer system. This process also helps establish a baseline to guide further sampling efforts to collect representative groundwater samples.

Numerous instruments are commercially available for measuring water quality parameters. As such, setup and implementation of instruments should follow a basic format that applies consistency of use. Regardless of the brand of meter used, meters should be properly maintained, calibrated, and operated in accordance with the manufacturer’s instructions. Calibrations should be checked prior to each use.

For well development, water quality parameters are considered stable when three consecutive readings are achieved as follows:

- pH: ± 0.2
- Temperature: ±1°C
- Specific conductivity: ±10% (microSiemens per centimeter [μS/cm])
- Turbidity (if measured): ±10% nephelometric turbidity units (NTUs)

NOTE: In assessing acceptable turbidity levels for well development, visual observation is often considered sufficient for most sites. However, depending on the regulatory authority for a project, there may be specific qualitative constraints on achieving clear, formation water during well development. RCRA regulations cite the need to achieve purge water that is at or less than 5 NTUs (EPA, 1992a and b) as observed on a turbidity meter; however, EPA also states that turbidity of 5 NTUs or less is often not attainable for marginal aquifers with high lithological heterogeneity (e.g. interbedded sand and clay) (EPA, 1992a). A more realistic parameter for stabilized turbidity is obtaining consistent readings at or below 50 NTUs (EPA, 2001). If the well cannot yield groundwater within the specified turbidity requirements for that site upon completion of well development, then proper well development must be demonstrated and documented to verify that the observed turbidity is inherent in the aquifer being sampled and not a result of improper well construction or insufficient well development.

Standard practice for measuring water quality parameters in the field are presented in INTERA SOP 10, *Monitor Well Sampling for Groundwater*. Measurement and documentation of water quality parameters during well development should be conducted in accordance with SOP 10, Section 10.4, procedures for high-volume purging.

8.4 Procedure - Well Development

The most effective well development for a groundwater monitor well is often a combination of pumping, over-pumping, or bailing alternated with one or more cycles of surging/backwashing. The exact combination, the total number, and the appropriate timing relationships needed for each cycle to achieve proper well development at a particular site is usually either determined through initial field testing or from previous field experience obtained at sites exhibiting similar hydrogeologic conditions. If applicable, the SAP/FSP/WP developed for the site shall specify the appropriate well development cycles or the need for field testing.

In general, upon determination/selection of an appropriate well development procedure for a site/well, the following steps shall be completed by INTERA staff:

1. Verify equipment required for the selected well development procedure is available, cleaned, and in good working order prior to initiating field efforts. Exact equipment needs will be well specific and will depend on the diameter of the well, the depth to the static water level, and other factors. Some equipment may be provided by the contracted driller responsible for well installation; these items should be coordinated by INTERA with the contracted driller prior to mobilization. Equipment taken to the site by INTERA field staff may include:

    - Personal Protection Equipment (PPE) as specified in the SSHASP;
    - Site map, well completion diagrams, and a copy of the SAP/FSP/WP;
    - Field logbook, waterproof pens, appropriate water level indicator, time-keeping device, camera, and applicable field forms;
    - Well development equipment as designated in the SAP/FSP/WP. Equipment may include: plastic sheeting, disposable tubing, bailer (s), pump, rope, pump controller, flow meter, air compressor/generator, surge block, and pump fittings;
    - Water quality meter(s) as specified in the SAP/FSP/WP;
    - Waste storage containers (e.g., drums, 5-gallon buckets) for temporary or permanent containment of extracted well water and/or

sediment as identified in the SAP/FSP/WP; Include labels and marking pens/tools for proper labeling of waste storage containers.

- Tools for opening well vaults (e.g., socket wrench, screwdriver) and/or managing IDW storage containers (e.g., steel 55-gallon drum[s], 5-gallon bucket[s]); and
- Appropriate personnel and equipment decontamination supplies (INTERA SOP 2, *Decontamination*).

2. Verify/define work zones and IDW storage and containment area(s) for the site as established in the SAP/FSP/WP.
3. Calibrate required field screening or monitoring equipment per the manufacturer's instructions. Calibrate instrumentation required to ascertain water quality parameters.

NOTE: If a site requires additional field screening or personnel monitoring during well development (i.e., high levels of VOCs), this requirement shall be outlined in the SAP/FSP/WP or SSHASP, respectively.

4. As applicable, determine sequence of wells to be developed. If multiple wells are to be developed sequentially at a contaminated site, develop wells in order of least contaminated to most contaminated to minimize the potential for cross contamination and use disposable well development equipment as reasonably achievable.
5. Verify well is appropriately marked (well location ID) and confirm that grout seal has properly set. Stage appropriate sampling equipment. Per the SAP/FSP/WP, obtain and stage the appropriate number and type of IDW container(s). Apply ground cloth or plastic sheeting around location prior to well development initiation, as applicable.
6. Don appropriate PPE. At a minimum this should include gloves, foot, and eye protection. If development is to proceed in close proximity to the drill rig or any other overhead hazards, a hard hat shall also be required and sound-generating equipment, such as a generator, will require hearing protection. Refer to the SSHASP for additional specifics regarding required PPE at a site.
7. Obtain a well TD and DTW measurement from the marked datum point of the well using the appropriate method(s) defined in INTERA SOP 9, *Water Level Gauging*. If appropriate, the thickness of settled sediment may also be measured/calculated. If more than 10% of the well screen is plugged by sediment, staff may consider the use of a bailer to remove sediment prior to continuing development.

8. Calculate the appropriate minimum purge volume (typically 3 well casing volumes) to achieve proper well development using the equations provided in **Section 8.2** of this SOP. Take into consideration any site-specific information such as whether foreign fluids were introduced into the well (i.e., during construction). If fluids were utilized, at least three times the volume of the fluid introduced needs to be removed from the well (in addition to the minimum purge requirement). If an alternate site/well-specific minimum purge volume is required due to known or anticipated site conditions, this variation in the well development requirement shall be identified in the SAP/FSP/WP. Document well casing and purge volume requirements in the field logbook and/or on the appropriate field form (**SOP 30, Field Form 3**).

9. Begin well development using the development procedure selected in the SAP. General implementation of each method detailed in this SOP are discussed below. If an alternate well development method is selected for a site, a discussion on the procedure shall be included in the SAP/FSP/WP.

    - **Mechanical Surging**
        - Bail or pump well to verify that the well will yield water. If water does not enter the well, surging should not be performed as it may cause the well screen to collapse.
        - Insert surge apparatus (block or bailer) into well and lower slowly to the level of static water.
        - Start surging well slowly and gently above well screen using plunger strokes of 3 to 5 feet, using the water column to transmit the surge action to the screened interval.
        - After approximately 5 to 10 surges, remove block and purge well using a pump or bailer.
        - Reinsert block and repeat process slowly increasing both depth and speed of surging.

NOTE: The required velocity of the surge block motion will depend on the tightness of the formation in which the well is installed.

- For wells equipped with long screens (greater than 10 feet), surging should be undertaken along the entire screen length in short intervals (2 to 3 feet) at a time.

- **Compressed Gas**

  - Lower the gas/air line from the cylinder into the well, and place near the bottom of the screened interval.
  - Install discharge control equipment at the well head and set gas/air flow rate to allow continuous discharge from well into the appropriated container (if required).
  - When discharge begins to clear of suspended material, terminate gas/air flow and allow groundwater to flow back into the well casing through the screened interval.
  - Re-establish gas/air flow when the water level in the well has recovered to at or near static level.
  - Occasionally, raise the discharge nozzle into the cased portion of the well to enhance sediment lifting.

- **Pumping**
  - Select pump and pump accessories of appropriate size and required pumping rate.
  - Insert pump and/or pump intake hose into well and place as close to the center of the well screen as possible. Verify that the intake is completely submerged. To minimize sediment clogging, care should be taken not to place pump or intake hose at the base of the well.
  - Initiate pumping at a rate that is greater than the highest rate anticipated for future purging and sampling.
- **Bailing**
  - Select bailer and bailing string of appropriate size, strength, and volume. Use disposable equipment when possible.
  - Lower bailer into the screened interval of the well.
  - Using long slow strokes, raise and lower the bailer in the screened interval, simulating the action of a surge block.
  - Periodically bail standing water from the well to remove silt and clay particles drawn into the well via the surging motion. To avoid potential introduction of contaminants into the well, do not allow the bailing string to contact the ground or other potentially-contaminated surface/material.

10. Upon development initiation, measure initial pH, temperature, turbidity, and specific conductivity of the purge water, as required by the SAP/FSP/WP, in accordance with the procedure outlined in **Section 8.3** of this SOP. Note color, clarity, and odor of the water. Document findings on the appropriate field form or in the field logbook.

11. Continue development procedure and periodically measure required parameters until the minimum purge volume has been achieved (three well casing volumes) and the well parameters have stabilized or the equivalent of five well casing volumes have been removed.

NOTE: if the well is experiencing poor recharge and begins to go dry prior to development completion, reduce the extraction rate and remove any sediments (as applicable) prior to continuing to attempt development. If development cannot be continued, the well will need to re-equilibrate with formation water and a subsequent development period shall be required.

12. Containerize, label, and temporarily store IDW as described in the SAP/FSP/WP until final disposition can be determined.

13. Decontaminate equipment, as necessary, prior to advancing to another location in accordance with INTERA SOP 2, *Decontamination*.

14. Document well development and purge information on the appropriate field form (**SOP 30, Field Form 3 – Well Development and General Data**) and/or in the field logbook, taking care to cite any problems or unusual conditions encountered. Make sure the following information is noted:

    - Well location ID and date(s) of well installation;
    - Date(s) and duration of well development;
    - Water level before and after development and, if possible, 24 hours after well development;
    - TD of well from the marked datum point and any presence of sediment in the well before, during, and after development;
    - Type(s) and quantity of drilling fluids introduced during drilling or development (if any);
    - Field water quality parameters before, during, and after well development;
    - Total volume and physical characteristics of purged water;
    - Type and capacity of pump or bailer used and pumping rates (if applicable); and

  - Description of development method(s) used.

15. Allow groundwater to stabilize at least 24 hours prior to obtaining a final well DTW measurement from the marked datum point of the well using the appropriate method(s) defined in INTERA SOP 9, *Water Level Gauging*.

NOTE: unless otherwise required by the client, temporary monitor wells that will be sampled and plugged and abandoned within 48 hours of installation do not require well development.

8.5 References

ASTM International (ASTM), 2013. Standard Guide for Development of Groundwater Monitoring Wells in Granular Aquifers. D5521/D5521M-13.

Environmental Protection Agency (EPA), 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. USEPA Office of Research and Development. EPA160014-891034. March.

EPA, 1992a. Monitoring Well Development Guidelines for Superfund Project Managers. Office of Solid Waste and Emergency Response. Ground Water Forum Issue Paper. April.

EPA, 1992b. RCRA Ground-Water Monitoring: Draft Technical Guidance. USEPA Office of Solid Waste. USEPA. November.

EPA, 2001. Standard Operating Procedure 2044. Monitor Well Development. Environmental Response Team. Revision 1. October 23.

Texas Commission on Environmental Quality (TCEQ), 2001. TCEQ Remediation Division Superfund Section Field Standard Operating Procedures (SOPs), SOP 5.6 - Monitoring Well Development/Abandonment. Revision 0. December 3.

8.6 Attachments

Attachment 1: Application of Well Development Techniques

8.7 Document History

Revision	Effective Date	Lead Author	Summary of Changes
2004.0	4/2004	Taimur Malik	Original version
2004.1	2/2015	Kate Herrell	Revised for inclusion in COA Brownfields QAPP
2004.2	10/2015	Noreen Baker	Minor text revisions for clarification
2004.3	5/2017	Noreen Baker	Added text regarding well development in temporary wells

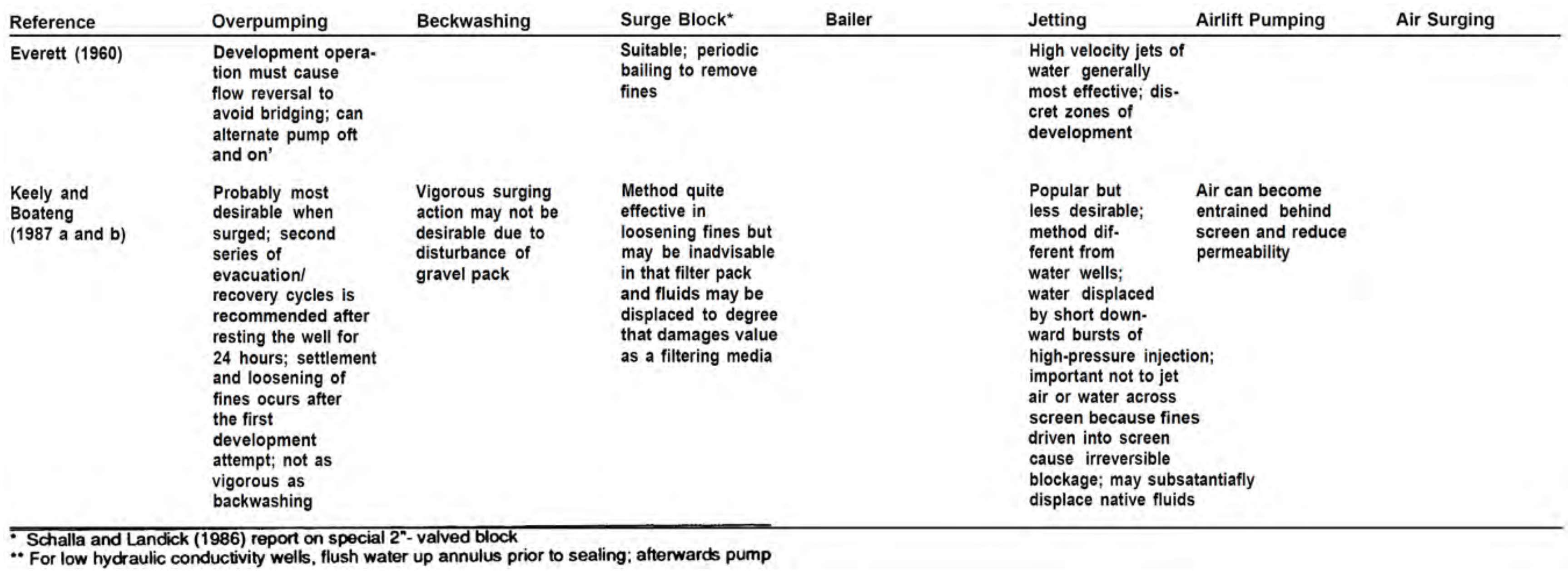
2004.4	7/2017	Noreen Baker	Removed Field Form as an attachment, added reference to SOP 30, Field Forms
2004.5	1/2019	Noreen Baker	Minor grammar correction in Section 8.0.

Attachment 1

Application of Well Development Techniques

Application of Well Development Techniques

Reference	Overpumping	Backwashing	Surge Block*	Bailer	Jetting	Airlift Pumping	Air Surging
gass (1966)	Works best in clean coarse formations and some consolidated rock; problems of water disposal and bridging	Breaks up bridging, low cost & simple; preferentially develops	Can be effective; size made for$\geq$2"-well; preferential development where screen >5'; surge inside screen		Consolidated and unconsolidated application; opens fractures, develops discrete zones; disadvantage is external water needed	Replaces air surging; filter air	Perhaps most widely used; can entrain air in formation so as to reduce permeability, affect water qualify; avoid if possible,
United States Environmental Protection Agency (1966)	Effective development requires flow reversal or surges to avoid bridges	Indirectly indicates method applicable; formation water should be used	Applicable; formation water should be used; in low-yield formation, outside water source can be used if analyzed to evaluate impact	Applicable		Air should not be used	Air should not be used
Barcelona et al. ** (1963)	Productive wells; surging by alternatting pumping and allowing to equilibrate; hard to create must be sufficient entrance velocities; often use with airlift		Productive walk; use care to avoid casing and screen damage	Productive walk; more common than surge blocks but not as effective			Effectiveness depends on geometry of device; air filtered; crew may be exposed to contaminated water; perturbed Eh in sand and gravel not persistent for more than a few weeks
Staff et al. (1901)		Suitable; periodic removal of fines	Suitable; common with cable to of; not easily used on other rigs	Suitable; use sufficiently heavy bailer; advantage of removing fines; may be custom made for small diameters		Suitable	Suitable; avoid injecting air into intake; chemical interference; air pipe never inside screen
National Council of the Paper Industry for Air and Stream Improvement (1961)	Applicable drawback of flow in one direction; smaller wells hard to pump if water level below suction		Applicable; caution against collapse of intake or plugging screen with clay		Methods introducing foreign materials should be avoided (i.e., compressed air or water jets)		



Reference	Overpumping	Beckwashing	Surge Block*	Bailer	Jetting	Airlift Pumping	Air Surging
Everett (1960)	Development operation must cause flow reversal to avoid bridging; can alternate pump oft and on'		Suitable; periodic bailing to remove fines		High velocity jets of water generally most effective; discret zones of development		
Keely and Boateng (1987 a and b)	Probably most desirable when surged; second series of evacuation/ recovery cycles is recommended after resting the well for 24 hours; settlement and loosening of fines ocurs after the first development attempt; not as vigorous as backwashing	Vigorous surging action may not be desirable due to disturbance of gravel pack	Method quite effective in loosening fines but may be inadvisable in that filter pack and fluids may be displaced to degree that damages value as a filtering media		Popular but less desirable; method different from water wells; water displaced by short downward bursts of high-pressure injection; important not to jet air or water across screen because fines driven into screen cause irreversible blockage; may subsatantiafly displace native fluids	Air can become entrained behind screen and reduce permeability	

* Schalla and Landick (1986) report on special 2"- valved block

** For low hydraulic conductivity wells, flush water up annulus prior to sealing; afterwards pump

Excerpted from (EPA, 1991)

9.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) covers the following monitor well gauging activities to be implemented by INTERA field personnel during characterization, remediation, or monitoring of environmental sites:

- Depth to water (DTW) (**Section 9.1**);
- Phase separated hydrocarbon (PSH) levels (**Section 9.2**); and
- Well total depth (TD) (**Section 9.3**).

The objective of this SOP is to promote standardization between monitoring/sample collection events in order to obtain consistent and accurate data inputs for the site/project that can be evaluated over time. As applicable, well gauging data collected at a site may provide a long-term record of:

- Seasonal groundwater fluctuations;
- Presence, location, and thickness of measurable amounts of PSH; and
- Effectiveness of recovery well operations.

This SOP should be used in conjunction with procedures presented in the INTERA Site-Specific Health and Safety Plan (SSHASP) and in site-specific investigation planning documents such as a Sampling and Analysis Plan (SAP), Field Sampling Plan (FSP), or Work Plan (WP). This SOP will also be commonly used with and is referenced in the following INTERA SOPs:

- 1, *Air Monitoring*;
- 2, *Decontamination*;
- 8, *Monitor Well Development*;
- 10, *Monitor Well Sampling for Groundwater*;
- 15, *Slug Test Procedures*;
- 20, *LNAPL Sampling*; and
- 30, *Field Forms*.

9.1 Procedure – Measuring DTW

The following procedure is to be utilized at wells not suspected to contain PSH. Gauging DTW may be performed separately or in conjunction with purging and sampling of a well. If well sampling is also to be performed, DTW measurements should be collected prior to any activity which may alter the water level, such as bailing, pumping or hydraulic testing.

In either case, standard procedure is as follows:

1. Confirm that equipment required for DTW gauging is available, cleaned, and in good working order. Equipment to be taken to the site by the INTERA field staff may include:

    - Water-level indicator such as an electric water-level meter or equivalent that provides measurement accuracy up to one hundredth of a foot (0.01 foot);
    - Socket wrenches, bung wrenches and/or open-end wrenches;
    - Other tools such as screw drivers, hammer, pliers, bolt cutter, and extra batteries, as necessary;
    - Key or combination for monitor well lock;
    - Applicable decontamination equipment as outlined in INTERA SOP 2, *Decontamination*;
    - Appropriate Personal Protection Equipment (PPE) as defined in the SSHASP;
    - Traffic safety equipment (traffic cones, barriers, caution tape and other traffic control equipment), as required;
    - Air monitoring equipment, as appropriate;
    - Field logbook and site plan indicating well locations;
    - Copies of previous well gauging data, if available;
    - Copies of well construction diagrams or table with expected total depths, if available;
    - Weighted metal measuring tape for measurement of total depths, if necessary;
    - Trash bag/waste container for investigation-derived waste (e.g. used paper towels from decontamination of water-level meter between wells); and
    - Plastic sheeting, if appropriate.

2. Determine sequence of wells to be gauged for the site. If applicable, attempt to gauge wells in order of least contaminated to most contaminated to minimize the potential for cross contamination between wells. If chemistry is unknown, measure wells from upgradient to downgradient, if known.

3. Verify well location ID.

4. If applicable, sweep area around the well vault to minimize dislodging loose materials (e.g. rocks and organic debris) into the well vault and potentially into the open well.
5. Place plastic sheeting/drop cloth next to the well to create a clean surface onto which the measurement and sampling equipment can be placed. Do not place tools, equipment, or other materials on the sheet unless they have been cleaned first and do not place tools, equipment or other materials directly on the ground surface or well pad. Plastic sheeting may not be necessary if equipment will not be placed on the ground.
6. Open the monitor well cover/vault, taking care to place loose components (e.g., cover bolts, washers, and tools) in a protected area away from the well opening.
7. Don appropriate PPE. At a minimum, this should include gloves and eye protection. Specifics regarding appropriate PPE for a site is provided in the SSHASP.
8. Upon opening the well cover/vault, monitor atmosphere for hazardous conditions using procedures outlined in INTERA SOP 1, *Air Monitoring*. Depending on known or suspected contaminants of concern at the site, one or more of the following monitoring devices may be appropriate: a photoionization detector (PID), a flame ionization detector (FID), a lower explosive limit (LEL)/oxygen (O_2) meter, and/or a hydrogen sulfide (H_2S) meter. PID monitoring is a common requirement for chlorinated solvent sites; H_2S monitoring is a common requirement at crude oil sites. Specifics regarding the types of monitoring requirements that may be applicable for a site will be documented in the SSHASP.
9. Inspect for insects or any damaged or broken components prior to placing hands in well cover/vault. Remove and/or note in logbook, as appropriate. As appropriate, take a photograph to document any alterations of significance (i.e., top of the well casing might have been altered) and contact Project Manager prior to proceeding.
10. Unlock and/or remove the monitor well cap. Recheck air monitoring readings as described in number 8.
11. Check for the measuring point at the top of the well. The measuring-point location should be clearly marked on the innermost casing (typically a filed or chiseled notch marked with paint or permanent ink) or identified in previous sample-collection records and should correspond to the surveyed well casing rim or other surveyed datum.

   a. If no measuring-point can be identified, establish and mark a measuring point on the north side of the innermost well casing (preferable) or at the highest point. Document location on the appropriate INTERA field form (**SOP 30, Field Form 4 – Monitor Well Gauging Data**) and/or in the field logbook. **NOTE:** The same point should be used for all subsequent gauging efforts.

12. Lower the water-level indicator line into the well casing, taking care to ensure that the line hangs freely in the well casing and does not adhere to the wall of the well casing. For most sites, an electric water-level meter is considered appropriate. Prior to lowering water level meter into the well, turn on the meter to check that it is in working order being careful to follow manufacturer's instructions.
13. Continue to lower the water-level indicator into the well until contact with water is felt or the meter sounds and/or lights. A precise measurement of DTW should be determined to 0.01 foot by repeatedly raising and lowering the line along the measuring point to converge on an exact measurement.
14. Record the final DTW measurement on the appropriate field form (**SOP 30, Field Form 4**) and/or in the field logbook. If the field form is unavailable, data may be recorded in the field logbook along with measurement date and time.

NOTE: If a gauging instrument is missing any footage, make a notation on the gauging form (e.g. "subtract 1 foot from all gaugings" on the form). **Read measurements directly from the tape**; do not make mental adjustments to readings as it could lead to errors. The data can always be corrected post-reading if adequately documented.

15. Retract the water-level indicator line from the well casing while holding paper towels prepared with the appropriate detergent wash and rinse to decontaminate the indicator tape prior to use at another well location. Typically, only the probe and the portion of the tape that has been lowered below the top of the well vault requires decontamination. To decontaminate, pass the line through the paper towel with the section wetted with detergent wash placed nearest to the well head and the section wetted with rinse water placed nearest to the water-level reel. This process is most efficiently accomplished by two people but can be completed in sections by one person. Do not allow tape to contact unprotected ground surface. Complete decontamination by spraying down the probe sides with the detergent solution and end with distilled/deionized water.

9.1.1 Additional Considerations for DTW Gauging Recent Pumping

At sites where groundwater pumping may have recently occurred in the vicinity of the monitor well, subsequent water-level measurements may be appropriate to confirm that site static water level conditions have been documented. In these instances, a second water-level measurement should be taken anywhere from 30 minutes to 60 minutes after the initial measurement to verify that a static water-level measurement was obtained. If static conditions have not been reached, information documenting pumping affects should be included in the field logbook.

Confined Aquifers

At sites where confined aquifers are present and monitor wells are **NOT** vented, the wells need to be opened and allowed to equilibrate for 30 minutes to 60 minutes depending on tightness of the formation being monitored. Tighter formations may require longer time periods to equilibrate.

Sites with Shallow Groundwater Gradients

For sites where the groundwater gradient is extremely shallow and/or groundwater flow direction is of significant concern, special care should be taken to:

- Allow the water level to equilibrate prior to reading after removing well caps;
- Employ the same water-level indicator on all site wells; and
- Obtain DTW measurements for all wells within the minimum possible time.

9.2 Procedure – Measuring Phase-Separated Hydrocarbons (PSH)

The following procedure is to be utilized at wells known or suspected to contain PSH. PSH frequently occurs at hazardous sites as either light non-aqueous phase liquid (LNAPL) and dense non-aqueous phase liquid (DNAPL). If present, LNAPL will float on top of the water column; DNAPL will be present at the base of the water column.

In general, the procedure for gauging PSH levels in a well is the same as that for obtaining DTW measurements but noting and applying the following exceptions:

- Use an oil/water interface probe with separate tones for PSH and water instead of a standard electric water-level meter to obtain a PSH level reading (applicable to both LNAPL and DNAPL);
- A precise measurement of LNAPL should be determined by repeatedly raising and lowering the line along the measuring point to converge on an exact measurement and followed by repeated measurements of the water level to obtain a precise measurement of DTW (note that the order measurement is reversed when obtaining depth to water and PSH measurements in a well where DNAPL is present); and
- Non-disposable equipment that has come into direct contact with water or PSH must be rinsed with methanol or alternative products such as Simple Green® in

accordance with INTERA SOP 2, *Decontamination*, in addition to applying the standard rinses of potable tap and distilled/deionized water.

9.3 Procedure – Measuring TD

Well TD is required to calculate the volume of standing water in the well and to document the amount of siltation that may have occurred. Moreover, measuring well TD provides checks for casing integrity. Corrosion can cause leaking or collapse of the well casing, which could lead to erroneous or misleading water level measurements. Corrosion, silting, and bio fouling can clog well screens and result in a sluggish response or no response to water-level changes, as well as changes in groundwater chemistry.

In general, the procedure for measuring well TD is the same as that for obtaining DTW measurements with the following additions:

- Proper equipment should be utilized to obtain well TD. If possible, TD should be obtained using a weighted metal measuring tape. A water-level indicator with unprotected sensor(s) sensitive to sediment contact should not be used as contact with the bottom of the well may cause damage to the instrument.
- If applicable, have previously available well TD measurements for reference. Being aware of the previously documented well TD can aid in avoiding any unnecessary damage to the gauging instrument used when contact with the bottom is achieved.
- Well TD is typically measured and recorded only to the nearest one-tenth of a foot (0.1 foot) (EPA, 2013). However, state-specific requirements may request measurements to be recorded to 0.01 foot (TCEQ, 2001). Such state-specific requirements shall be addressed in the SAP/FSP/WP.
- If using a water-level indicator with a probe to measure well TD, make sure to add the length of the probe (i.e., 0.10 foot) that extends below the 0.00-foot mark on the indicator tape to the final well TD measurement.
- As required, well TD measurements should be collected after the completion of a sampling event or at least 24-hr prior to sampling. This precaution is to minimize the effects any increased turbidity in the well water (a common result of well TD measurements) may have on sampling results.
- Well TD measurements should be compared to previous well TD records such as those recorded at the time of drilling and well installation to help evaluate the general condition of the well and/or well screen.
- Well TD measurements should be collected for a site at least once a year or as deemed appropriate based on an evaluation of accrued DTW measurements. If

excessive sediment buildup (i.e., exceeds one foot) or a well screen impediment is suspected, redevelopment/replacement of the well may need to be considered.

9.4 References

Environmental Protection Agency (EPA), 2013. Groundwater Level and Well Depth Measurement Operating Procedure. Region 4, Science and Ecosystem Support Division. #SESDPROC-105-R2. January 29.

Texas Commission on Environmental Quality (TCEQ), 2001. TCEQ Remediation Division Superfund Section Field Standard Operating Procedures (SOPs), SOP 7.1 - Water Level/Sediment Measurement. Revision 1. April 25.

9.5 Attachments

None.

9.6 Document History

Revision	Effective Date	Lead Author	Summary of Changes
2006.0	2/2006	Taimur Malik	Original version
2006.1	2/2015	Kate Herrell	Revised for inclusion in COA Brownfields QAPP
2006.2	3/2015	Noreen Baker	Inserted #9 and #10 in Section 9.1 that were inadvertently removed from Revision 01
2006.3	6/2017	Noreen Baker	Removed Field Form as an attachment, added reference to SOP 30, Field Forms

10.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) covers two basic techniques and associated requirements and equipment commonly applied for obtaining a groundwater sample from a permanent groundwater monitor well:

- Well purging via standard high-volume purging techniques (typically equal to 3 to 5 well casing volumes) (**Section 10.4**);
- Well purging via low-flow/micropurging techniques (**Section 10.5**); and
- Collection of a Groundwater Sample (**Section 10.7**).

These techniques may be implemented by INTERA field personnel during characterization, remediation, or monitoring of environmental sites.

Procedures in this SOP do not apply to the following:

- Passive groundwater sampling techniques, and
- Sampling of groundwater monitor wells where free-phase non-aqueous phase liquid (NAPL) is present.

For most environmental purposes, groundwater sampling from a permanent groundwater monitor well is performed in an attempt to obtain one or more samples representative of a site's in-situ aquifer conditions. Data obtained from these samples can subsequently be evaluated to assess the relative presence or absence of various contaminants of concern (COCs) at a site. The objective of this SOP, therefore, is to promote proper application of specific and commonly available groundwater purge and sample methods (**Section 10.6**) and standardize sample groundwater collection techniques (**Section 10.7**) for consistent and accurate data. Unrepresentative samples can lead to misinterpretations of groundwater quality, which may have a significant impact on assessing whether remedial action(s) are required for a site.

In most cases, collection of a "representative" groundwater sample requires the application of a two-step process:

- Step 1: well purging, and
- Step 2: collection and preservation (if required) of the groundwater sample for subsequent COC analysis.

Well purging is the process of removing stagnant or "old" water from the well casing that is likely not representative of true aquifer conditions due to surface infiltration, settling, atmospheric exposure, biologic (biofouling) and/or chemical (volatilization) degradation. The exact method of purging and the degree (i.e., total volume required for extraction) to which purging is conducted for a well is dependent on conditions at the site (e.g., aquifer characteristics, COCs, depth to water [DTW]), well construction, and the well's observed water yield. At some sites where low-flow sampling techniques are applied, no purging of groundwater might be preferred (ASTM, 2019). Selection of appropriate well purge and sample equipment is briefly discussed in **Section 10.1** of this SOP.

NOTE: Purging is not required prior to sampling newly-installed wells. However, groundwater samples should not be collected in newly-installed, permanent wells until the well has been properly developed and has been allowed time to fully recover and re-equilibrate to static conditions (70% to 90% of the original bore volume). Assuming sufficient well recovery has occurred, sampling should occur within 24 hours of well development because the sample(s) to be collected becomes less and less representative of in-situ aquifer conditions as recovery time increases. Unless otherwise specified in a SAP/FSP/WP, groundwater sampling is not recommended for wells that cannot attain sufficient recovery within 24 hours of development.

Collection of a groundwater sample is only initiated upon achievement of calculated well purge volume and/or upon stabilization of selected water quality parameters, whichever are most likely to obtain groundwater samples that meet the site/project data quality objectives (DQOs). Calculation of an appropriate well purge volume is discussed in **Section 10.2** of this SOP. Evaluating water quality parameters and determining appropriate stabilization criteria for each applicable parameter is discussed in **Section 10.3** of this SOP.

Methods outlined in this SOP comply with following ASTM Standards:

- D4448-01, *Standard Guide for Sampling Ground-Water Monitoring Wells* (ASTM, 2019);
- D5903-96, *Standard Guide for Planning and Preparing for a Groundwater Sampling Event* (ASTM, 2012); and
- D6634/D6634M-14, *Standard Guide for the Selection of Purging and Sampling Devices for Groundwater Monitoring Wells* (ASTM, 2014).

This SOP should be used in conjunction with procedures presented in the INTERA Site-Specific Health and Safety Plan (SSHASP) and in site-specific investigation planning documents such as a Sampling and Analysis Plan (SAP), Field Sampling Plan (FSP), or Work Plan (WP). This SOP will also be commonly used with and is referenced in the following INTERA SOPs:

- 1, *Air Monitoring*;
- 2, *Decontamination*;
- 9, *Monitor Well Gauging*; and
- 30, *Field Forms*.

10.1 Selection of Appropriate Well Purge and Sample Equipment

A wide variety of applicable purge and sample equipment is available for the collection of a groundwater sample. These devices facilitate the movement and extraction of groundwater from a well by one of the following mechanisms: grab (e.g., bailer, syringe, thief sampler), suction-lift (e.g., surface-applied centrifugal, vacuum, and peristaltic pumps), inertial-lift (e.g., Waterra pump), and positive displacement (e.g., submersible pump, gas-drive pumps, bladder pump, and piston pump). To select the most appropriate groundwater purging and sampling device(s) for a well, the following must be considered:

- Reliability, durability, ease of operation, and portability of the device;
- Device compatibility with well construction;
- DTW; and
- Potential impact(s) to sample integrity and material compatibility with established COCs.

Operational characteristics of typical groundwater purge and sample devices are listed in **Attachment 1**. Material considerations in the selection of sampling equipment are listed in **Attachment 2**. Basic descriptions of commonly-utilized groundwater purge and sample equipment is provided in the following subsections.

10.1.1 Grab Sampling (down-hole) Collection Devices

Bailers, syringe, and thief (messenger) samplers are all examples of devices used for grab purging and sampling. These devices are lowered into the well casing by cable, rope, chain, or tubing.

Bailers are the most typically applied grab sampler. Bailers are available in a variety of sizes and materials such as PVC, stainless steel, polyethylene, and Teflon® and may be equipped with a single or dual check valve. When choosing a bailer for purging and sampling, care must be taken to select a bailer type and composition that is compatible with site conditions and DQOs (**Attachment 2**). Teflon® bailers are generally the most "inert" while PVC bailers are less expensive and are sufficiently resistant to withstand short term exposure to most common contaminants. **Bailers not comprised of a chemically inert material (such as stainless steel) and not easily decontaminated should not be used to purge and/or sample more than a single well.** In these cases, the use of disposable bailers, usually comprised of polyethylene, are the most practical option.

Some considerations when choosing whether to use a grab sampler for collection:

1. Can easily aerate or agitate the sample causing oxidation, degassing and/or stripping of VOCs, and other alterations to the groundwater chemistry;

2. Can be susceptible to generating artificial variability in accuracy and precision of groundwater sample chemistry due to operator techniques;
3. Can increase sample turbidity and the potential for mixing with stagnant water;
4. Increased potential to introduce surface and down-hole contamination with repeated insertion and extraction of the device through the well casing;
5. Impractical for wells with deep DTWs (> 50 ft bgs) and/or high yields (> 20 gallons). These conditions mandate that long periods be spent during purging and sample collection, or that centrifugal pumps be used; and
6. Typically withdraws water from the top of the water column in the well and this water has already been exposed to the atmosphere. Exposure to the atmosphere can cause volatilization and reactions with carbon dioxide which can cause subsequent lowering of groundwater pH.

10.1.2 Pumping Devices

There are many varieties of pumps that can be used for the collection of a groundwater sample from a monitor well including suction lift pumps, electric submersible pumps, and positive displacement pumps. Below are brief descriptions of the available pump types and their ideal application(s).

- **<u>Suction–Lift Pumps</u>** - Suction-lift pumps include peristaltic pumps, surface centrifugal pumps, and vacuum pumps and are most typically used for purging and less so for sampling. Because the ability of suction-lift pumps to lift water is limited by the available atmospheric pressure, they are only functional for purging and sampling from depths of less than approximately 25 ft bgs at mean sea level. Vacuum pumps and, to a lesser extent surface centrifugal pumps, are not as appropriate as peristaltic pumps when collecting groundwater samples. However, the EPA does not recommend use of any suction–lift pump for the collection of VOC-containing groundwater (ASTM, 2019).
- **<u>Inertial-Lift Pumps</u>** - Inertial-lift pumps are ideal for well development but should not be used to collect volatile–sensitive groundwater samples. The inertial-lift pump is capable of operating efficiently at depths to 30 m (100 ft). It is effective in small diameter wells or direct-push technology probes which are typically 12.5 mm (1⁄2-in.) diameter. The pumping rate ranges from 0 to 7.6 L/min (0 to 2 gal/min) (42), depending on the rate of the up and down pumping stroke and the tube diameter (ASTM, 2019). The Waterra inertial-lift pump is a commonly used inertial-lift pump.
- **<u>Positive Displacement Pumps</u>** - Positive displacement pumps are widely available pumps often useful for groundwater purging and sampling. Positive

displacement pumps include gas-drive pumps, bladder pumps, piston pumps, and electric submersible pumps. The bladder pump is generally considered the best overall type of pump to collect groundwater samples for inorganic and/or organic analyses. Electric submersible pumps are used to purge and sample groundwater from a variety of depths. Electric submersible pumps include centrifugal submersible pumps, helical rotor (progressing cavity) pumps, and gear pumps. Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction-lift capabilities and higher extraction rates than many other methods. Centrifugal submersible pumps are most commonly used yet cause considerable water agitation due to the movement of the impeller(s). Gear pumps are the best-suited electric submersible pumps for groundwater purging and sampling, and one of the best overall pumps for minimizing volatilization of groundwater samples.

The pump of choice for purging is usually a function of the well diameter, DTW, well total depth (TD), and the calculated volume of purge water required. A peristaltic pump is typically used whenever the water level is above the limit of suction, i.e., approximately 25 feet bgs at mean sea level (**NOTE:** there is a loss of one foot of suction lift for every one-thousand-foot increase in elevation). For wells where the water level is below the limit of suction and/or where there is a large volume of water to be purged, a variable speed electric submersible pump is preferred.

Other than pump functionality, two site-specific criteria must also be considered when selecting the most appropriate pump for the activity. First, construction material of the pump and tubing should not contain materials or constituents that interact with potential and/or known COCs or any other constituent of interest that may cause bias in sample results (i.e., false positives) (**Attachment 2**). Second, if the sample is to be analyzed for VOCs, a pump that minimizes sample agitation and subsequent volatilization should be used. The most appropriate pumps under these conditions are the gear pump or the bladder pump.

Regardless of which type of pump is used, the pumping rate should be low enough to avoid turbulent flow. In addition, the pump must be capable of moving some solids without damage. Inertial-lift pumps are often preferred for small diameter wells (i.e., <2 inches) due to the surging action of the pumps and their low well yield requirements.

10.2 Procedure – Calculation of Purge Volume

In most cases, site or project DQOs establish a need to purge some minimal volume of stagnant or old groundwater from a monitor well prior to groundwater sample collection. The amount of water to be purged depends upon well depth, hydraulic properties, purging methodology (standard high-volume [**Section 10.4**] or low-flow [**Section 10.5**]), and program requirements. There is no set number of volumes to be purged that fits all situations. It is generally agreed, however, that for standard high-volume purge and sample techniques, typically a minimum of 3 well casing volumes is required. In most cases, a purge of 3 well casing volumes is acceptable **on the condition** that stabilization of the water quality parameters such as temperature, pH, and specific conductance, is also achieved (**Section 10.3.1**) (EPA, 2003). In instances where stabilization cannot be achieved (i.e., as a result of inherent aquifer characteristics), purging shall typically continue until a total of five well casing volumes are removed or as otherwise directed by the Project Manager (EPA, 2003; EPA, 2013d).

Well casing volume can be defined as the volume of groundwater observed in the well casing under static conditions as follows:

Equation 1:

$$V_{WC} = \frac{\pi D^2 h}{4}$$

Where:

V_{WC} (ft^3) = well casing volume
D (ft) = inner diameter of well casing
h (ft) = height of the water column in the well casing.

NOTE: V_{WC} in units of cubic feet can be converted to gallons by multiplying by 7.48 gal/ft^3.

The inner diameter of the well casing (D) is a known parameter that can be established by reviewing well installation documentation for the well. The height of the water column in the well casing (h) is calculated by subtracting the depth to groundwater as measured (in feet) prior to development or purging from the known TD of the well (in feet) as determined prior to development or purging. The minimum purge volume of three well casings is calculated by taking the well casing volume (in gallons) calculated using **Equation 1** and multiplying by 3.

Alternatively, the well casing volume may be determined using a casing volume per foot factor for the appropriate diameter well as summarized in **Table 1** (EPA, 2013d). The height of the water column in the well casing is multiplied by the appropriate single-well volume factor or triple well volume factor in **Table 1** to determine either the single well casing volume or the triple well casing volume, in gallons, for the well to be purged.

As such, the typical minimum purge volume of three well casings can be easily calculated by multiplying the height of the water column in the well casing by the appropriate triple well volume factor in Column 3 of **Table 1**. Purge volume of five well casings is calculated by multiplying the height of the water column in the well casing by the appropriate single well volume factor in Column 1 and then multiplying by 5.

Table 1: Well Casing Diameter versus Volume of Water

Casing Diameter (inches)	Gallons/ft, One Water Column	Gallons/ft, Three Water Columns
1	0.04	0.12
2	0.16	0.48
3	0.37	1.11
4	0.65	1.98
5	1.02	3.06
6	1.47	4.41
7	1.99	5.97
8	2.61	7.83
9	3.30	9.90
1	4.08	12.24
11	4.93	14.79
12	5.87	17.61

10.3 Procedure – Measurement of Water Quality Parameters

The other critical element used to assess whether the groundwater to be collected from the monitor well is representative of in-situ conditions is the stabilization of certain measured field water quality parameters. Stabilization of field water quality parameters is especially critical when low-flow or micopurging techniques are required to successfully collect a sample.

The intent of utilizing water quality field parameters to drive groundwater sampling is to identify when the physical and/or chemical characteristics of groundwater entering the well begin to reflect that of the surrounding aquifer system. Collection of water quality parameters also helps establish a baseline and inherent quality assurance (QA) for the data being collected that may be used to guide further sampling efforts and identify changes in the systems being evaluated.

Numerous instruments are commercially available for measuring water quality parameters. As such, setup and implementation of instruments should follow a basic format that applies consistency of use. Regardless of the brand of meter used, all meters should be properly maintained, calibrated, and operated in accordance with the manufacturer’s instructions. Calibration fluids for any instrument used should be National Institute of Standards and Technology (NIST)-traceable, and there should be enough volume to conduct one or more daily calibrations throughout the sampling event (as required by the manufacturer’s specifications).

For most sampling efforts, INTERA personnel utilize a multi-parameter water quality meter equipped with a flow-through cell, such as the hand-held YSI meter. These systems contain multiple probes that can measure several parameters simultaneously. Multi-parameter water quality meters have the ability to measure temperature, pH, turbidity, dissolved oxygen (DO), specific conductance, and oxygen-reduction potential (ORP). For some site DQOs, turbidity may be a critical parameter to assess during purging and sampling. In these instances, a separate turbidity meter should be used or turbidity measurements should be read prior to entry into the flow-through cell to avoid potential sediment build-up which can bias the turbidity measurement.

When using a flow-through-cell to measure parameters, sediment build-up and any generation of trapped gas must be monitored (EPA, 2010). Transparent flow-through-cells are preferred because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect parameter values measured within the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities. Record start and stop times and give a brief description of cleaning activities in the field notes.

Throughout the duration of the measurement process, the flow-through-cell must also remain free of any gas bubbles. Entrapped gas may cause the monitoring probes to act erratically. Placing the flow-through-cell at a 45 degree angle with the port facing upward can help minimize this affect. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must remain submerged in water at all times.

10.3.1 Water Quality Parameters and Stabilization Criteria

Water quality parameters that may be monitored in the field include the following: pH, specific conductivity, temperature, turbidity, oxidation-reduction potential (ORP), and dissolved oxygen (DO). Water quality indicator parameters should be monitored continuously during purging, and measurements are typically recorded at intervals of three (3) to five (5) minutes apart. During low-flow purging, care should be taken to ensure that at least one flow-through-cell volume has been turned over between measurements (EPA, 2010). Therefore, depending on the flow rate and flow-through-cell volume, the interval between measurements may need to be increased accordingly.

The following parameters are typically always monitored during well purging: pH, specific conductance, temperature, and sometimes turbidity depending on project objectives. Some recent regional guidance procedures have subsequently removed temperature from the list of required parameters (EPA, 2013d). Due to its susceptibility to quickly re-equilibrate upon collection and the fact that it is often measured in a separate container at the surface rather than in the actual sampling access point, the use of temperature to determine stability is suspect and will not necessarily be representative of actual groundwater conditions. However, other regional regulatory authorities still maintain temperature as a required parameter (TWDB, 2003) as it may be needed to properly interpret other chemical parameter results in certain situations. Whether additional/alternate parameters such as ORP and DO are required shall be established in the SAP/FSP/WP.

Purging is considered complete and sampling may begin when all of the water quality parameters defined for a project have stabilized. Stabilization occurs when three (3) consecutive measurements are within the range of stabilization criteria as set by the EPA or other appropriate regulatory authority. Specific stabilization criteria for standard high-volume purging and low-flow purging are provided below in Section 10.4 and Section 10.5, respectively. General procedures for measuring specific water quality parameters during groundwater sampling activities are described further in **Attachment 3**.

10.4 Procedure – High-Volume Purging

Evacuation of (3) three to (5) five well casing volumes prior to collecting a groundwater sample is the most standard purge application and can be effectively implemented using a variety of instruments and equipment under a variety of site conditions (**Section 10.1**). Ideally, the use of an appropriate pump is preferred over the use of a bailer due to the inherent dependence on an individual operator's technique that may or may not properly minimize turbidity and loss of volatile organic constituents and may result in collection of an unrepresentative sample (EPA, 2013d). However, the low cost and versatility of bailing makes purging and sampling via a bailer a preferred option for many sites.

The general procedure for effective groundwater sampling using a high-volume purge technique to be completed by INTERA staff is presented as follows:

1. Confirm all equipment needed to complete the selected activities is available, cleaned, and in good working order prior to initiating field efforts. Exact equipment needs will be well-specific and will depend on the diameter of the well, the depth to the static water level, and other factors. At a minimum, field equipment should include:
    - Appropriate type and amount of PPE as specified in the SSHASP;
    - Site map, well completion diagrams, and a copy of the SSHASP and SAP/FSP/WP;
    - Field logbook, waterproof pens, appropriate water level indicator, time-keeping device, camera, calculator, applicable field forms (**SOP 30, Field Form 5 – Standard Purging and Sampling Data** or **SOP 30, Field Form 6 – Low Flow Purging and Sampling Data**);

- Well purge and sample equipment as designated in the SAP/FSP/WP. List of potential groundwater purge and sample equipment is provided as **Attachment 4**;
- Water quality meter(s) as specified in the SAP/FSP/WP and extra batteries;
- Waste storage containers (e.g., drums, 5-gallon buckets) for temporary or permanent containment and measurement of extracted well water;
- Tools for opening well vaults (e.g., socket wrench, screwdriver, hammer, bolt cutter) and/or managing selected IDW storage containers (e.g., steel 55-gallon drum[s], 5-galon bucket[s]);
- Appropriate type and volume of personnel and equipment decontamination supplies (INTERA SOP 2, *Decontamination*) to execute the projected activities;
- Traffic safety equipment (traffic cones, barriers, caution tape and other traffic control equipment), as required;
- Air monitoring equipment, as required per the SSHASP;
- Field logbook and site plan indicating well locations;
- Copies of previous well gauging and sample data, if available; and
- Trash bag/waste container for IDW (i.e., used paper towels from decontamination of non-disposable equipment between wells).

2. Verify/define work zones and IDW storage and containment area(s) for the site as established in the SAP/FSP/WP or the SSHASP.
3. Calibrate required field screening or monitoring equipment per the manufacturer’s instructions. Calibrate any instrumentation required to ascertain water quality parameters as identified in the SAP/FSP/WP and as described in **Section 10.3** of this SOP.

NOTE: If a site requires additional field screening or personnel monitoring during well purging (i.e., high levels of VOCs), this requirement shall be outlined in the SAP/FSP/WP or SSHASP, respectively.

4. As applicable, determine sequence of wells to be sampled. If multiple wells are to be sampled at a contaminated site, sample wells in order of least contaminated to most contaminated to minimize the potential for cross contamination and use disposable purge and sample equipment as reasonably achievable. If chemistry is unknown, measure wells from upgradient to downgradient, if possible.

5. Verify the need to collect any QA/quality control samples during the sample collection event. If required, designate appropriate location(s).
6. Upon arrival at a monitor well, note any unusual conditions pertaining to the monitor well including, but not limited to, water ponding in the proximity of the well casing, cracks in the well casing footing, or other surface damage that is identifiable. In the event the well has incurred damage, record observations in the field logbook, photograph damage, and inform site management prior to proceeding.
7. Verify well is appropriately marked (well location identifier). If applicable, sweep area around the well vault to minimize dislodging loose materials (e.g., rocks and organic debris) into the well vault and potentially into the open well.
8. Stage appropriate sampling and monitoring equipment. Per the SAP/FSP/WP, obtain and stage the appropriate number and type of IDW container(s) and/or apply ground cloth or plastic sheeting around location prior to sample initiation. If using a staging cloth, do not place tools, equipment, or other materials on the sheet unless they have been cleaned first.
9. Open the monitor well cover/vault, taking care to place loose components (e.g., cover bolts, washers, and tools) in a protected area away from the well opening.
10. Don appropriate PPE. At a minimum this should include gloves, foot, and eye protection. If sampling is to occur in a zone where overhead hazards exist, a hard hat shall also be worn. Use of any sound-generating equipment, such as a generator, will require hearing protection. Refer to the SSHASP for specifics regarding required PPE at a site.
11. Upon opening the well cover/vault and as applicable, monitor atmosphere for hazardous conditions using procedures outlined in INTERA SOP 1, *Air Monitoring.* Depending on known or suspected COCs, one or more of the following monitoring devices may be appropriate: a photoionization detector (PID), a flame ionization detector (FID), a lower explosive limit (LEL)/oxygen (O_2) meter, and/or a hydrogen sulfide (H_2S) meter. PID monitoring is a common requirement for chlorinated solvent sites; H_2S monitoring is a common requirement at crude oil sites. Specifics regarding the types of monitoring requirements that may be applicable for a site will be documented in the SSHASP.
12. Inspect well vault for insects and note any damaged or broken components prior to placing hands in well cover/vault. Remove and/or note in logbook as appropriate. As appropriate, take a photograph to document any alterations of

significance (i.e., missing well cap, excessive debris in well vault, top of the well casing might have been altered) and inform site management prior to proceeding.

13. Unlock and/or remove monitor well cap and place it upside down on a dry surface to prevent foreign material from being deposited within the well once the cap is replaced. If applicable, re-check air monitoring readings as described in **Step 11**.
14. Obtain a well TD and DTW measurement from the marked datum point of the well using the appropriate method(s) defined in INTERA SOP 9, *Water Level Gauging*.
15. Calculate the appropriate minimum purge volume (typically 3 well casing volumes) to achieve proper well purging using the equations provided in **Section 10.2** of this SOP. If an alternate site/well-specific minimum purge volume is required due to known or anticipated site conditions, this shall be identified in the SAP/FSP/WP. Document well casing and purge volume requirements in the field logbook and/or on the appropriate field form (**SOP 30, Field Form 5 or SOP 30, Field Form 6**).
16. Once an appropriate minimum purge volume has been collected, purging via the selected method of groundwater extraction can proceed in conjunction with the collection and measurement of appropriate field water quality parameters as defined in **Section 10.3** of this SOP and/or the SAP/FSP/WP. Procedure implementation of purging methods most commonly applied by INTERA personnel are provided in **Section 10.6**.

<u>NOTE:</u> In some situations, even if slow purge rates are applied, a well may be fully evacuated of groundwater and go “dry” prior to the minimum purge volume being met. The term “dry” is defined here as insufficient water to collect a complete sample volume. In these instances, different procedures must apply (Yeskis and Zavala, 2002). Full evacuation of the well generally constitutes an adequate purge, and the well can be sampled following sufficient recovery within an appropriate time frame (usually within 24 hours). ***It is not necessary that the well be evacuated three times before it is sampled.*** Measurement of pH, specific conductance, and temperature during collection of the sample should be measured and recorded, as the stabilized measurements for the sampling event (EPA, 2013d).

17. Purging and/or water quality parameter measurements shall continue according to this SOP unless otherwise specified in the SAP/FSP/WP. Typically purging is considered complete and sampling may commence when one of the following conditions have been obtained:
    - The well is purged dry. Sampling should begin no sooner than two hours after purging and after a sufficient volume for a water-quality sample or

after sufficient recovery (commonly 90%) is present (Yeskis and Zavala, 2002).

- Three well casing volumes have been purged and water quality parameters have stabilized (i.e., three (3) consecutive measurements are within the range of stabilization criteria provided below in **Table 2**).
- In instances where stabilization cannot be achieved (i.e., as a result of inherent aquifer characteristics), purging shall typically continue until a total of five well casing volumes are removed.

Table 2: Water Quality Parameter Stabilization Criteria - Standard High Volume Purging

Parameter	Stabilization Criteria	Reference
pH	±0.2 units	
Specific Conductance	±10%	
Temperature	±1°C	
Turbidity	±10% (when turbidity is greater than 10 NTUs)	Yeskis and Zavala, 2002
Oxidation/Reduction Potential (ORP)	±10 millivolts	EPA, 2010 Yeskis and Zavala, 2002
Dissolved Oxygen (DO)	±0.3 milligrams per liter	Yeskis and Zavala, 2002

Note: Stabilization criteria may change depending on project objectives or state-specific/federal criteria (Yeskis and Zavala, 2002), and these criteria will be established in the SAP/FSP/WP.

18. All purge water shall be containerized into a graduated container to measure the purged water volume. Purge water is then either containerized for storage and eventual disposition or spread onto an impermeable surface away from the well and allowed to evaporate. Specifics regarding the handling, storage and disposal of site purge water shall be identified in the SAP/FSP/WP.
19. Upon completion of purging and if well recovery rate is significant enough to obtain a groundwater sample(s), proceed to the collection of groundwater sample(s) as discussed in **Section 10.7** of this SOP.

10.5 Procedure – Micropurging

In general, the goal of low-flow groundwater sampling is to collect water samples that reflect the total mobile organic and inorganic loads (dissolved and colloidal sized fractions) transported through the subsurface under ambient flow conditions, with minimal physical and chemical alterations from sampling operations.

Micropurging is when well purging (and sampling) is performed at very low pumping rates (0.1 - 1.0 L/min) and is volume independent. Purge water is extracted from the well casing only until measured water quality parameters exhibit steady state conditions, which is the primary indicator that water is being drawn directly from the aquifer. Micropurging minimizes hydraulic stress at the well-aquifer interface by maintaining low water-level drawdowns; minimal mixing of the water column and the laminar groundwater flow through the screen provides for a more consistent sample (ASTM, 2019). EPA recommends that both groundwater purging and sampling should invariably be performed at low rates so that the drawdown does not exceed 0.3 feet (EPA, 2010).

Micropurging and low-flow sampling procedures are preferred at sites/wells exhibiting the following conditions:

- Heterogeneous aquifer systems (susceptible preferential recharge and sample bias);
- Wells capable of sustaining a yield approximately equal to the pumping rate;
- VOCs and metals are COCs;
- Inherent turbid aquifer characteristics; and
- Groundwater contains hazardous/toxic constituents requiring treatment/special disposal.

Micropurging is typically performed using adjustable rate, submersible pumps (e.g., centrifugal and bladder pumps) that are constructed of stainless steel or Teflon. As stated in **Section 10.1**, bladder pumps are preferred for sampling groundwater containing VOCs and dissolved gases.

Inertial pumping devices (motor driven or manual) are not recommended for micropurging. These devices frequently cause greater disturbance during purging and sampling, and are less easily controlled than submersible pumps (potentially increasing turbidity and sampling variability). This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

The general procedure for effective groundwater purging using the micropurging technique to be completed by INTERA staff is presented as follows:

1. Follow **Steps 1 through 14** as described for standard high volume purging (**Section 10.4**)
2. Slowly install pump and associated cables, tubing, and electric lines to the designated sample depth (mid-point of the screen or as otherwise specified in the SAP/FSP/WP). Keep pump intake at least 2 feet above the bottom of the well to minimize mobilization of any particulates that may be present. Do not turn on the pump at this time.

<u>NOTE:</u> Tubing placed at the ground surface should be kept as short as possible to minimize latent heating due to sunlight and ambient air exposure. Heating may promote volatilization of any groundwater constituents. If excessive turbidity is anticipated for a well, it may be appropriate to consider installation of the pump the day prior to allow any particulates that were disturbed during pump insertion to settle.

3. Measure water level and record information on the appropriate field form and/or in the field logbook. If applicable, install pressure transducer(s) to track drawdown. Verify that a graduated container is setup and available to accept and measure the total volume of groundwater to be purged.
4. Turn on pump. Start the pump at low speed (i.e., approximately 0.1 L/min) and slowly increase the speed until discharge occurs. Check water level. Check equipment for water leaks and, if present, fix or replace affected equipment.
5. Gradually adjust pump rate to match the well's recharge rate (i.e., until little to no drawdown occurs and the water level has stabilized). As applicable, adjust pumping rate to correspond to rate used during previous sampling event(s). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump to ensure stabilization of the water level. If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue purging.

<u>NOTE:</u> Any required adjustments should ideally be completed in the first fifteen minutes of pumping in order to help minimize purge time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" somewhat as pump flow adjustments are made.

6. Once water levels have stabilized, connect all equipment chosen to monitor the selected water quality field parameters. Typically the minimum required parameters include: temperature, conductivity, pH, and turbidity (**Section 10.3**). If excessive turbidity is anticipated at a well, the well may require extended purging and/or pump installation the day prior (see **Step 2** above) to minimize particulate buildup in the equipment (such as the flow-through-cell).

<u>NOTE:</u> During the early stages of purging, emphasis should be on minimizing and stabilizing pumping stress and recording those adjustments; stabilization of water quality parameters are secondary until water levels have satisfactorily been stabilized.

7. Monitor and record the water level, pumping rate(s), and selected water quality parameters every five minutes (***or as appropriate***) during purging. Record any required pumping rate adjustments (both time and flow rate).

NOTE: Pump flow rate must be able to "turn over" at least one flow-through-cell volume between measurements (i.e., for a 250 mL flow-through-cell with a flow rate of 50 mL/min, the monitoring frequency would be every 5 minutes; for a 500 mL flow-through-cell it would be every 10 minutes). If the cell volume cannot be replaced in the five minute interval, then the time between measurements must be increased accordingly (EPA, 2010).

8. Micropurging is considered complete and sampling may begin when all selected indicator field parameters have stabilized according to the stabilization criteria identified below in **Table 3** or as identified in the SAP/FSP/WP.

Table 3: Water Quality Parameter Stabilization Criteria - Micropurging

Parameter	Stabilization Criteria	Reference
pH	±0.1 units	EPA, 2010
Specific Conductance	±3%	EPA, 2010
Temperature	±3%	EPA, 2010
Turbidity	±10% for values greater than 5 NTU; if three turbidity values are less than 5 NTU, consider the values as stabilized)	EPA, 2010
Oxidation-Reduction Potential (ORP)	±10 millivolts	EPA, 2010
Dissolved Oxygen (DO)	±10% for values greater than 0.5 mg/L; if three DO values are less than 0.5 mg/L, consider the values as stabilized)	EPA, 2010

9. All purge water shall be containerized in a graduated container to measure the purged water volume. Purge water is then either containerized for storage and eventual disposition or spread onto an impermeable surface away from the well and allowed to evaporate. Specifics regarding the handling, storage and disposal of site purge water shall be identified in the SAP/FSP/WP.
10. Upon completion of purging, proceed to the collection of groundwater sample(s) as discussed in **Section 10.7** of this SOP.

10.6 Procedure – Specific Application of Common Purge and Sample Methods

10.6.1 Bailer

1. Obtain a decontaminated or new bailer and rope or cord made out of nylon, polypropylene, or other equivalent material.
2. Tie a bowline knot or equivalent through the bailer loop. Test knot for security and the bailer itself to ensure that all parts are intact before inserting the bailer into the well.
3. Remove the protective wrapping from the bailer.
4. Slowly lower the bailer into the well casing, allowing it to gently immerse into the top of the water column and sink to the bottom of the well.
5. Cut the cord at a proper length. Verify that the bailer rope/cable is of sufficient length as to reach at least 20 feet below the top of the water surface in the monitor well.

NOTE: Bailer or bailer rope should never touch the ground surface at any time during purging and sampling.

6. Once cord/rope is set, begin to raise the bailer slowly by grasping a section of cord using each hand alternately in a "windmill" action. This method requires the sampler's hands to be kept approximately 2 to 3 feet apart and the bailer rope to be alternately looped onto or off each hand as the bailer is raised (and lowered). Alternate methods may be used to raise the bailer including use of a reel or a plastic-lined bucket into which the rope is manually fed.

NOTE: It is critical that bailers be slowly and gently immersed into the top of the water column, particularly during final stages of purging, to minimize turbidity and disturbance of VOCs. If possible, the water should be bailed at a rate slow enough that does not cascade down the sides of the well screen, which causes stripping of VOCs.

7. Upon recovery to the surface, grasp bailer and pour extracted groundwater into a graduated container to measure the purged water volume

10.6.2 Submersible Pump

1. Operate pump according to the manufacturer’s instruction. Attach for use single well dedicated or disposable tubing and any required flow controllers. Refer to SAP/FSP/WP or other site-specific documentation (e.g., field logbook) to identify appropriate pump start-up and purge flow rates.
2. Lower the clean pump to the required depth, as identified by the SAP/FSP/WP. This is typically no more than 3 feet to 5 feet into the water column and towards

the top or center of the well screen. Verify that the pump intake hose is fully immersed and is not contacting sediment.

NOTE: **DO NOT** place the pump assembly deep into the water column as this may short-circuit the purging effort (EPA, 2013d). When purging, water needs to be "pulled" from the formation through the well screen and up through the well casing so that the entire static volume of water is removed. If the pump is placed deep into the water column, the water above the pump may not be removed, and subsequent samples, particularly if collected with a bailer, may not be representative of aquifer conditions.

3. If appropriate, lower and set a water level measuring device into the well casing to monitor drawdown while pumping.
4. Initiate pumping and observe recovery rate. If the recovery rate of the well is faster than the pump rate and no observable draw down occurs, the pump should be raised until the intake is within one foot of the top of the water column for the duration of purging. If the pump rate exceeds the recovery rate of the well, the pump will have to be lowered, as needed, to accommodate the drawdown.
5. Direct the discharge through the flow-through cell and into a graduated container to measure the purged water volume.

10.6.3 Bladder Pump

1. Attach for use single well dedicated or disposable tubing into the vacuum port of the pump head. Ensure a snug fit. This section of tubing should be cut at a length equal to the well depth plus an additional 5 to 10 ft allow for operation of the pump at all possible water level conditions in the well.
2. Lower the pump into the well, using a stainless steel safety line connected to the eye safety stem on the pump (if portable) or a suspension hook on the well head (if dedicated) to the appropriate sample depth (either midpoint of the screen or another depth as designated by the SAP/FSP/WP).
3. Connect the supply line from the compressed gas supply to the control unit. A drive line connects from the control unit to the top of the well (dedicated) or to a reel (portable).
4. Turn on pump and begin purging. Operate pump according to the manufacturer's instruction. Refer to **Section 10.5** of this SOP, the SAP/FSP/WP, or other site-specific documentation (e.g., field logbook) to identify appropriate pump start-up and purge flow rates.

5. For bladder pumps that will be used to collect VOC or dissolved gas samples, it is recommended that the pump be set to deliver long pulses of water during sampling so that one pulse will fill a 40 mL VOC vial.

10.6.4 Peristaltic Pump

6. Attach for use single well dedicated or disposable tubing into the vacuum port of the pump head. Ensure a snug fit. This section of tubing should be cut at a length equal to the well depth plus an additional 5 to 10 feet allow for operation of the pump at all possible water level conditions in the well.
7. Run another (shorter) section of tubing from the pump discharge port to into a graduated container to measure the purged water volume.
8. Place the free end of the tubing into the well until the end of the tubing is just below the surface of the water column.
9. Secure tubing to the well casing or other secure object using electrician's tape or other suitable means. This will prevent the tubing from being lost in the well should the tubing detach from the pump head.
10. Turn on pump to produce a vacuum on the well side of the pump head and begin purging. Operate pump according to the manufacturer’s instruction. Refer to SAP/FSP/WP or other site-specific documentation (e.g., field logbook) to identify appropriate pump start-up and purge flow rates.
11. Observe pump direction to ensure that a vacuum is being applied to the purge line. If the purge line is being pressurized, either switch the tubing at the pump head or reverse the polarity of the cables on the pump or on the battery.
12. If the pumping rate exceeds the recovery rate of the well, continue to lower the tubing into the well, as needed, until the drawdown stabilizes or the well is fully evacuated. If the pump is equipped to modify pump rate, reduce the speed of the pump in an attempt to stabilize drawdown.

NOTE: When using a peristaltic pump for purging, it is important to try and maintain the tubing intake (to the degree possible) towards the uppermost portion of the water column (EPA, 2013d). This is to minimize the potential for short-circuiting the purging effort as there may not be a complete exchange and removal of stagnant water in the portion of the water column residing above the tubing intake. This is particularly important for wells exhibiting recovery rates equal to or very nearly equal to the purge rate.

10.7 Procedure – Groundwater Sample Collection

Sampling is the process of collecting, containerizing, and preserving the groundwater sample after the purging process is complete. Samples from monitor wells are collected either with portable, low-capacity pumps, a bailer, or with other types of sampling devices designed for water quality work (USGS, 2006). Sampling devices can be dedicated for use at a given well or can be installed in the well for the duration of the monitoring effort.

In general, the water level in a well that has been purged using the standard high volume purging method should be allowed to recover to at least 70% of its static volume before a sample is collected. Monitor wells that experience significant drawdown during purging and do not readily recharge within the time frame of a reasonable sampling effort (within a period of one hour) (i.e., slow recovery or low-yield wells) may be left to recharge over whatever time period is deemed necessary for the well to sufficiently recharge to obtain a complete sample, up to a maximum of 24 hours. However, it is important to note the longer the recovery time, the lower the confidence that the sample to be collected can be considered representative of ambient aquifer water composition. Unless otherwise specified in a SAP/FSP/WP, groundwater sampling is not recommended for wells that cannot attain sufficient recovery (commonly 90%) within 24 hours of purging (Yeskis and Zavala, 2002; USGS, 2006).

The general procedure for collecting a groundwater sample from a monitor well after standard high volume purging and sufficient recovery is presented as follows:

1. As required, obtain a final water level measurement and record in the field logbook. This may be needed if sample collection is initiated after a relatively significant amount of time has elapsed since final purging activities (such as overnight).
2. Determine the appropriate groundwater sampling method (e.g., bailer, submersible pump, or peristaltic pump) by referring to the SAP/FSP/WP.

NOTE: Chosen sample collection equipment may be the same as that equipment utilized for well purging; however, the exact equipment chosen for sample collection is primarily dependent on the established DQOs and COCs and the advantages and disadvantages each sample collection method has on best attaining these DQOs. Therefore, it may be appropriate to use one or more alternate methods to achieve the most representative samples.

3. To collect the sample, follow method specific application of the chosen equipment **as listed below** and described in **Section 10.6** of this SOP. Typically, water samples should be collected at or near the midpoint of the well screen.
    - **Groundwater Sampling Via Bailer**

- Slowly lower bailer into the water column, allowing the bailer to fill slowly from the bottom. Take care not to drop or splash the bailer.
- Once the bailer has been lowered to approximately the mid-point of the screen, slowly raise the bailer to minimize creating turbulence in the well and minimize drawing fine-grained sediment into the well. When withdrawing the bailer back to the surface take care not to hit the sides of the well as this may cause flaking of material into the bailer.
- Gently empty water directly from the full bailer into sample containers, taking care not to allow contact between the bailer and the sample container. Apply and use VOA tips, as required, to aid in the controlled filling of 40 mL vials.

- **Groundwater Sampling Via Pump:**

- Pumping rate should be approximately 0.1 L/min (or less). If a greater pumping rate was used for purging, then the pumping rate should be adjusted (reduced) prior to sampling.
- Groundwater should be pumped directly into the sample containers and pump tubing must remain filled with water to avoid aeration of the groundwater. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help ensure that the sample tubing remains water filled. If saturated pump tubing cannot be maintained to the sampling point, collect non-VOC/dissolved gases samples first, then increase flow rate slightly until the water completely fills the tubing to collect the VOC/dissolved gases samples. As applicable (low-flow), record any new drawdown depth and flow rate.

4. During sample collection, groundwater should be transferred directly from the sampling device into the appropriate sample containers (with preservatives as required) supplied by the laboratory, taking care not to allow the sample device to come into contact with the sample container. During transfer, efforts should be made to reduce the flow from either the pump discharge line or the bailer during sample collection to minimize sample agitation. This can often be accomplished by allowing the discharged groundwater to flow gently down the inside of the container.
5. Samples collected for analysis of VOC, acidity and alkalinity must not have any headspace. All other sample containers must be filled with an allowance for headspace as specified by the laboratory. If pre-preserved containers are not

supplied by the laboratory, the appropriate preservative must be added to applicable samples as soon as practical upon collection.

6. For some analyses, such as dissolved metals, the groundwater sample will require pre-filtering prior to preservation. Typically field filtering is accomplished via use of an 0.45 µm in-line membrane filter as follows:
    - Filter approximately 100 mL of sample through filter and dispose of as appropriate.
    - Filter sample directly into a clean sample container, replacing filters as needed to obtain sufficient volume.
    - Preserve immediately according to program methodology requirements.

NOTE: Potential differences may result from variations in filtration procedures used to process water samples for the determination of trace element concentrations. A number of factors associated with filtration can substantially alter "dissolved" trace element concentrations; these include filter pore size, filter type, filter diameter, filtration method, volume of sample processed, suspended sediment concentration, suspended sediment grain-size distribution, concentration of colloids and colloidally associated trace elements, and concentration of organic matter. Therefore, field method application consistency is critical in the comparison of both short-term and long-term results for these types of samples.

7. Unless otherwise specified in the SAP/FSP/WP, collect samples in the following order, as applicable: VOCs, SVOCs, metals, and other inorganics (TCEQ, 2001a; 2001b; and 2013). This order may be changed in situations where effective turbidity levels are difficult to maintain during groundwater sample collection: Removal and insertion of equipment after the purge and prior to actual sampling may negate the low turbidities achieved during purging and elevate turbidity back to unacceptable levels. In these instances, it may be advantageous to collect metals first as per EPA (2013d). The order of sample collection will be specified in the SAP/FSP/WP.
8. Note date and time of each collected sample in the field logbook and/or on the appropriate field form (**SOP 30, Field Form 7 – Sample Control Log** and **SOP 30, Field Form 8 – Chain-of-Custody**). **NOTE:** Chain-of-Custody forms are typically provided by the laboratory being used for the project analyses. **SOP 30, Field Form 8** should only be used in the event laboratory-provided Chain-of-Custody Forms are not available.

9. Confirm that all sample containers are labeled and that the labels are affixed to the sample/sample bag appropriately. Labels should contain the following information:
    - Project name and/or number;
    - Field sample number;
    - Initials of collector;
    - Well ID;
    - Date and time of collection; and
    - Sample type and preservative (if any).
10. Place the sealed and labeled sample container in an appropriate container for storage. Appropriate storage, packaging for shipment, and shipment requirements will be identified in the SAP/FSP/WP and shall be dependent on site COCs, the types of sample containers, and the selected mode of transport.
11. Decontaminate equipment, as necessary, prior to advancing to another location in accordance with INTERA SOP 2, *Decontamination*.
12. Document groundwater purge and collection information on the appropriate field form (**SOP 30, Field Form 5** or **SOP 30, Field Form 6**) and/or in the field logbook, taking care to cite any problems or unusual conditions encountered. Make sure the following information is noted:
    - Well location ID;
    - Water levels before and after purging and prior to sampling;
    - Well volume and purge determinations;
    - Field water quality parameters before, during, and after the event, as applicable;
    - Total volume and physical characteristics of purged water; and
    - Type and capacity of pump or bailer used and pumping rates (if applicable).

Upon completion of a groundwater sampling event:

1. Verify that a completed chain-of-custody form documenting all collected samples and any QA samples is placed in the container for transfer to the specified laboratory.
2. Ship/deliver sample(s) to the specified laboratory for analysis. If delivering samples via third party, verify that custody seals are applied across the opening of shipping containers. This minimizes the potential for tampering with the collected samples

as shipping container(s) cannot be opened without breaking the custody seals. Applied custody seals should contain the following information:

- Collector's signature or initials; and
- Date of shipping.

3. When scheduling for shipment/delivery of sample(s) to the laboratory, observe and comply with all minimum holding–time requirements for degradable constituents. This is especially pertinent if VOC samples were collected as most VOC samples have a less than 48-hour holding time.

10.8 References

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TCEQ, 2013. TCEQ Remediation Division Superfund Section Field Standard Operating Procedures (SOPs), SOP 7.6 - Groundwater Sampling Using a Bailer. Revision 1. August 28.

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US Geological Survey (USGS), 2006. National Field Manual for the Collection of Water-Quality Data: Chapter A4. Collection of Water Samples. Techniques of Water-Resources Investigations (TWRI), Book 9, Handbooks for Water-Resources Investigations. Version 2. Revised September.

Yeskis, Douglas and Zavala, Bernard, 2002. Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Ground Water Forum Issue Paper, United States Environmental Protection Agency.

10.9 Attachments

Attachment 1: Operational Characteristics of Available Purge and Sample Devices

Attachment 2: Material Considerations in Selection of Sampling Equipment

Attachment 3: General Procedures for Measuring Specific Water Quality Parameters

Attachment 4: General Groundwater Sampling Equipment List

10.10 Document History

Revision	Effective Date	Lead Author	Summary of Changes
2004.0	4/2004	Taimur Malik	Original version
2004.1	2/2015	Kate Herrell	Revised for inclusion in COA Brownfields QAPP
2004.2	10/2015	Noreen Baker	Text revisions to clarify different stabilization criteria between standard purging and micropurging.
2004.3	6/2017	Noreen Baker	Removed Field Forms as attachments, added references to SOP 30, Field Forms
2004.4	7/2019	Noreen Baker	Updated reference to ASTM Standard D4448-01 to reflect most recent version.

Attachment 1

Operational Characteristics of Available Purge and Sample Devices

Operational Characteristics of Available Purge and Sample Devices

(English Units)

Device	Type	Approximate Minimum Well Diameter (Inches)	Maximum Lift (Feet)	Maximum Design Flow Rate (gpm)	Typical Flow Rate @ Maximum Lift (gpm)	Minimum Achievable Flow (Discharge) Rate (gpm)	Power Source
Bailer	GS	0.75	No Limit	Highly Variable	Highly Variable	<0.026	Manual or Mechanical
Messenger	GS	1.5	No Limit	Highly Variable	Highly Variable	<0.026	Manual or Mechanical
Syringe	GS	1.5	No Limit	0.26 gals.^{A}	0.26 gals.^{A}	<0.026	Pneumatic
Centrifugal Pump	CP	1.0	25.0	30.0–40.0	Highly Variable	Same as Max.	IC Engine or Electric
Peristaltic Pump	SL	0.5	29.0	12.0	0.1	<0.026	Electric
Centrifugal Submersible Pump	CP	2.0	270	9.0	0.5	<0.026	Electric
		4.0	1700	85.0	1.2	<0.026	Electric
Gas Displacement Pump	PD	0.75	250	9.0	1.0	<0.026	Pneumatic
Bladder Pump	PD	0.75	1000	3.5	0.1	<0.026	Pneumatic
Single-Acting Piston Pump	PD	2.0	400	5.0	4.5	<0.026	Pneumatic/Mechanical
Dual-Acting Piston Pump	PD	1.5	1000	2.0	0.4	<0.026	Pneumatic
Progressive Cavity Submersible Pump	PD	2.0	180	1.2	0.3	<0.026	Electric
Gear Submersible Pump	PD	2.0	125	1.4	0.1	<0.026	Electric
		3.0	175	1.7	0.1	<0.026	Electric
Inertial Lift Pump	IL	0.75	260	4.0	4.0	<0.026	Manual, Electric or IC Engine

(Metric Units)

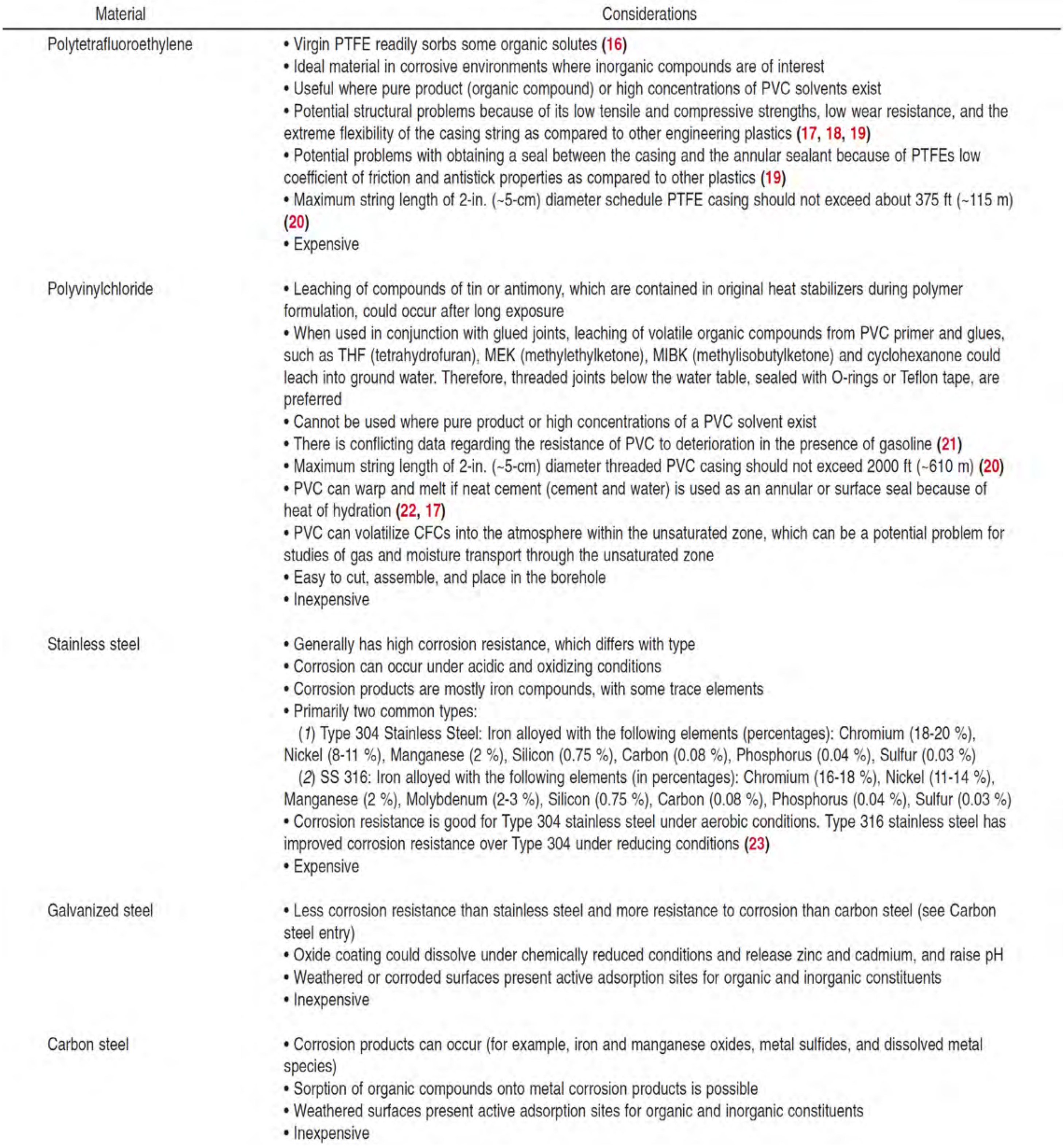
Device	Type	Approximate Minimum Well Diameter (Inches)	Maximum Lift (Feet)	Maximum Design Flow Rate (gpm)	Typical Flow Rate @ Maximum Lift (gpm)	Minimum Achievable Flow (Discharge) Rate (gpm)	Power Source
Bailer	GS	19	No Limit	Highly Variable	Highly Variable	<0.1	Manual or Mechanical
Messenger	GS	38.0	No Limit	Highly Variable	Highly Variable	<0.1	Manual or Mechanical
Syringe	GS	38.0	No Limit	1.0 liter^A	1.0 liter^A	<0.1	Pneumatic
Centrifugal Pump	CP	25.0	7.6	115–150	Highly Variable	Same as Max.	IC Engine or Electric
Peristaltic Pump	SL	12.0	8.8	45.0	0.4	<0.1	Electric
Centrifugal Submersible Pump	CP	50.0	80	34.0	2.0	<0.1	Electric
		100	520	322	4.5	<0.1	Electric
Gas Displacement Pump	PD	19	75.0	34.0	4.0	<0.1	Pneumatic
Bladder Pump	PD	19	305	13.0	0.4	<0.1	Pneumatic
Single-Acting Piston Pump	PD	50.0	125	19.0	17.0	<0.1	Pneumatic/Mechanical
Dual-Acting Piston Pump	PD	38.0	305	7.5	1.5	<0.1	Pneumatic
Progressive Cavity Submersible Pump	PD	50.0	55.0	4.5	1.0	<0.1	Electric
Gear Submersible Pump	PD	50.0	40.0	5.3	0.4	<0.1	Electric
		76.0	5.0	6.4	0.4	<0.1	Electric
Inertial Lift Pump	IL	19.0	80.0	15.0	15.0	<0.1	Manual, Electric or IC Engine

Excerpted from (ASTM, 2006)

Attachment 2

Material Considerations in Selection of Sampling Equipment

Material Considerations in Selection of Sampling Equipment (ASTM, 2019)



Material	Considerations
Polytetrafluoroethylene	• Virgin PTFE readily sorbs some organic solutes (16) • Ideal material in corrosive environments where inorganic compounds are of interest • Useful where pure product (organic compound) or high concentrations of PVC solvents exist • Potential structural problems because of its low tensile and compressive strengths, low wear resistance, and the extreme flexibility of the casing string as compared to other engineering plastics (17, 18, 19) • Potential problems with obtaining a seal between the casing and the annular sealant because of PTFEs low coefficient of friction and antistick properties as compared to other plastics (19) • Maximum string length of 2-in. (~5-cm) diameter schedule PTFE casing should not exceed about 375 ft (~115 m) (20) • Expensive
Polyvinylchloride	• Leaching of compounds of tin or antimony, which are contained in original heat stabilizers during polymer formulation, could occur after long exposure • When used in conjunction with glued joints, leaching of volatile organic compounds from PVC primer and glues, such as THF (tetrahydrofuran), MEK (methylethylketone), MIBK (methylisobutylketone) and cyclohexanone could leach into ground water. Therefore, threaded joints below the water table, sealed with O-rings or Teflon tape, are preferred • Cannot be used where pure product or high concentrations of a PVC solvent exist • There is conflicting data regarding the resistance of PVC to deterioration in the presence of gasoline (21) • Maximum string length of 2-in. (~5-cm) diameter threaded PVC casing should not exceed 2000 ft (~610 m) (20) • PVC can warp and melt if neat cement (cement and water) is used as an annular or surface seal because of heat of hydration (22, 17) • PVC can volatilize CFCs into the atmosphere within the unsaturated zone, which can be a potential problem for studies of gas and moisture transport through the unsaturated zone • Easy to cut, assemble, and place in the borehole • Inexpensive
Stainless steel	• Generally has high corrosion resistance, which differs with type • Corrosion can occur under acidic and oxidizing conditions • Corrosion products are mostly iron compounds, with some trace elements • Primarily two common types: (*1*) Type 304 Stainless Steel: Iron alloyed with the following elements (percentages): Chromium (18-20 %), Nickel (8-11 %), Manganese (2 %), Silicon (0.75 %), Carbon (0.08 %), Phosphorus (0.04 %), Sulfur (0.03 %) (*2*) SS 316: Iron alloyed with the following elements (in percentages): Chromium (16-18 %), Nickel (11-14 %), Manganese (2 %), Molybdenum (2-3 %), Silicon (0.75 %), Carbon (0.08 %), Phosphorus (0.04 %), Sulfur (0.03 %) • Corrosion resistance is good for Type 304 stainless steel under aerobic conditions. Type 316 stainless steel has improved corrosion resistance over Type 304 under reducing conditions (23) • Expensive
Galvanized steel	• Less corrosion resistance than stainless steel and more resistance to corrosion than carbon steel (see Carbon steel entry) • Oxide coating could dissolve under chemically reduced conditions and release zinc and cadmium, and raise pH • Weathered or corroded surfaces present active adsorption sites for organic and inorganic constituents • Inexpensive
Carbon steel	• Corrosion products can occur (for example, iron and manganese oxides, metal sulfides, and dissolved metal species) • Sorption of organic compounds onto metal corrosion products is possible • Weathered surfaces present active adsorption sites for organic and inorganic constituents • Inexpensive

Attachment 3

General Procedures for Measuring Specific Water Quality Parameters

Temperature

Temperature is a measure of hot or cold on a defined scale through use of a thermometer. Field temperature measurements may be made with a field thermometer, equipment thermistor, or NIST-traceable thermometer. At a minimum, the temperature measurement device should be capable of measuring in 0.1°C increments (EPA, 2014b). Whichever type of thermometer is applied, it should be calibrated prior to use, if possible.

Temperature measurement devices such as field thermometers and equipment thermistors will be verified against a NIST-traceable thermometer prior to use and should agree within ± 4.0°C. Measurement devices such as pH, conductivity and DO meter thermistors that also include an internal temperature sensor will also be verified against a NIST-traceable thermometer before each use.

To measure temperature in a groundwater sample:

- Clean probe end with de-ionized water and immerse into sample.
- If not measuring in-situ, swirl the thermometer in the sample to facilitate mixing and equilibration.
- Allow thermometer to equilibrate with the sample for at least one minute.
- Suspend the thermometer away from the sides and bottom to observe the reading.
- Record the reading in the field logbook and/or on the appropriate field form. Temperature units are typically recorded in °C and should be recorded to the nearest tenth (0.1).

CONVERSION FORMULAS:

$$^{\circ}\mathrm{F} = (1.8 \times n^{\circ}\mathrm{C}) + 32$$

or

$$^{\circ}\mathrm{C} = 0.56 \times (n^{\circ}\mathrm{F} - 32)$$

Where:

n = reported measurement in either ˚C or ˚F, as appropriate.

10.10.1 pH

pH is defined as the negative logarithm of the effective hydrogen-ion concentration and is used to express both acidity and alkalinity on a scale with a defined range of 0 (acid) to 14 (base) with 7 representing neutrality. For water sampling, pH is typically measured by a pH meter equipped with a temperature-compensation adjustment and capable of reproducing readings to within 0.2 standard units. All pH meters used in field operations will be maintained and operated in accordance with the manufacturer's instructions and any required calibration and verification checks will be documented and maintained in a logbook prior to use. Ambient temperature in the immediate vicinity of the pH meter should also be measured and recorded in the field logbook to verify that the instrument is being operated within the manufacturer's specified range of operating temperatures.

For most pH meters, at a minimum, a two-point calibration should be conducted prior to use to ensure the accuracy of the meter. The following basic guidelines for pH meter calibration/verification are taken from a regional EPA SOP and are provided as an example (EPA, 2013a):

1. Verify the meter's internal temperature sensor (thermistor) against a NIST-traceable thermometer and note any differences between the thermistor and the NIST-traceable thermometer in the logbook. If the temperatures do not agree within ± 4°C, the unit or probe must be repaired or replaced. Alternatively, if the meter can be used in a manual temperature compensation mode, the NIST-traceable thermometer may be used for temperature readings and the necessary corrections applied. Check and record the temperatures of the standards and the samples.
2. If the pH range of the sample is not known, the pH of the sample to be tested should be estimated either from historical data or by using a four-color pH indicator paper or equivalent. Using this information, calibrate the pH meter with the buffers that bracket the expected pH range. Buffer solutions are commonly pH 4, 7 and 10. It may be possible to configure the pH meter so that it can be standardized with buffers other than those in the default configuration.
3. Immerse the probe in the first buffer solution and calibrate the meter to read the correct pH. After the initial buffer calibration, calibrate the meter using other buffer solutions, as appropriate. Rinse the probe with de-ionized water and blot dry or otherwise remove excess rinse water between the different buffer solutions. Record the buffer values and temperatures used to calibrate the meter.
4. Rinse the probe with de-ionized water, blot dry or otherwise remove excess rinse water and immerse it into the appropriate buffer and read as a sample. If the meter reads within ± 0.2 S.U. of the known value of the buffer, record the value indicated by the meter. If the meter is outside of the acceptable accuracy range, it should be recalibrated. If it is still outside of the acceptable accuracy range after the second calibration, the electrode and/or meter may need to be replaced and/or a consult with technical support from the instrument's manufacturer may be necessary.
5. Once the meter has been properly calibrated and verified (**Steps 1-4 above**), it is ready for use. Rinse the probe with de-ionized water and store it according to manufacturer's recommendations.

<u>NOTE:</u> Unless the manufacturer indicates that the meter maintains its calibration upon shut down, meters must be re-calibrated if they need to be turned off during a period of use.

Procedure for measuring pH in the field is as follows:

- Collect sample. If the meter's thermistor is to be used for the temperature of record for the measurement activity, the temperature should be read as soon as the reading stabilizes and prior to measuring pH.
- Immerse the probe in sample, keeping it away from the sides and bottom of the sample container. Allow ample time for the probe to equilibrate with the sample.
- While suspending the probe away from the sides and bottom of the sample container, record the pH. Units of pH are standard units and should be recorded to the nearest tenth (0.1).
- Rinse probe with de-ionized water and store in container filled with de-ionized water until next sample.
- As appropriate, periodically check the pH by rinsing probe with de-ionized water, blot dry or otherwise remove excess rinse water and immerse it into an appropriate buffer solution. If the measured pH differs by ≥ 0.2, the meter must be recalibrated.
- Perform a post calibration at the end of the day and record all findings in the field logbook and/or on the appropriate field form.

<u>Specific Conductance</u>

Specific conductance is a measure of the ability of an aqueous solution to conduct an electric current and is customarily reported in microSiemens per centimeter (µS/cm) at 25° C. Like pH, specific conductance is typically measured by a meter equipped with a temperature-compensation adjustment as conductivity is affected by temperature. If an instrument that does not automatically compensate for temperature is used, the user should document temperature first so that appropriate adjustments can be made in accordance with the manufacturer's instructions and/or method.

All meters used in field operations will be maintained and operated in accordance with the manufacturer's instructions and any required calibration and verification checks will be documented and maintained in a logbook prior to use. Ambient temperature in the immediate vicinity of the meter should also be measured and recorded in the field logbook to insure the instrument is being operated within the manufacturer's specified range of operating temperatures. The following basic guidelines for meter calibration/verification are taken from a regional EPA SOP and are provided as an example (EPA, 2012).

1. Verify the meter's internal temperature sensor (thermistor) against a NIST-traceable thermometer and note any differences between the thermistor and the NIST-traceable thermometer in the logbook. If the temperatures do not agree within ± 4°C, the unit or probe must be repaired or replaced. Alternatively, if the meter can be used in a manual temperature compensation mode, the NIST-traceable thermometer may be used for temperature readings and the necessary corrections applied. Check and record the temperatures of the standards and the samples.
2. Rinse the probe with de-ionized water and blot dry before conducting subsequent calibration and verification checks.
3. Immerse the probe in the first standard solution and calibrate or verify the meter against that solution. Fresh standards should be used for each calibration. After the initial standard, calibrate and/or verify the meter using additional standards, as appropriate. Rinse the probe with de-ionized water and blot dry or otherwise remove excess rinse water between the different standards. Record the standard values/temperatures used to calibrate or verify the meter.
4. For a properly calibrated meter, meter readings should be within ± 10 % of the standard solution(s) known values. If reading are outside this limit and cannot be corrected by adjusting the cell constant of the probe, the meter or probe may need to be replaced and/or a consult with technical support from the instrument's manufacturer may be necessary.
5. After calibration is complete, place the probe back into the calibration standard used and record a post-calibration reading. Record a post calibration reading for each standard used. If the meter is not accurate to within ± 10 % of the standard solution(s) known values, it should be recalibrated. If it is still outside of the acceptable accuracy range after the second calibration, the meter or probe may need to be replaced and/or a consult with technical support from the instrument's manufacturer may be necessary.
6. Once the meter has been properly calibrated and verified (**Steps 1-5 above**), it is ready for use. Rinse the probe with de-ionized water and store it according to manufacturer's recommendations.

Procedure for measuring conductivity in the field is as follows:

- Collect sample. Check and record temperature. Adjustment temperature to reflect that of sample if required.
- Fully immerse probe in the sample keeping it away from the sides and bottom of the container.

- Record the result in the field logbook or the appropriate field form. Results should be reported to the nearest 10 for readings below 1,000 μS/cm and to the nearest 100 for readings above 1,000 μS/cm. Note that some meters will automatically change units from μS/cm to mS/cm and care should be taken to record readings using the correct units.
- Rinse probe with de-ionized water and store in container filled with de-ionized water until next sample.
- As appropriate, periodically check the specific conductance by rinsing probe with de-ionized water, blot dry or otherwise remove excess rinse water and immerse it into an appropriate standard solution. If the measured conductivity differs by ± 10 %, the meter must be recalibrated.
- Perform a post calibration at the end of the day and record all findings in the field logbook and/or on the appropriate field form.

Dissolved Oxygen

Dissolved oxygen can be defined as the volume of oxygen contained in a volume of water. DO readings can be very sensitive since the solubility of oxygen in water is dependent on water temperature, salinity and pressure. As water temperature decreases, oxygen solubility increases; as salinity increases, oxygen solubility decreases, and as atmospheric pressure decreases, oxygen solubility decreases.

As such, DO should be measured in-situ or down hole whenever possible. If in-situ measurements are not possible, precautions should be taken to minimize the time the sample is exposed to ambient air. DO readings should not exceed the saturation limit of oxygen in water (8 to 10 mg/L); if readings greater than 10 mg/L are observed, the meter is probably not functioning correctly.

Several methods utilizing a variety of technologies are available for measuring DO, specifically Clark cell probes and luminescent probes (EPA, 2014a). Clark cell probes utilize an oxygen permeable membrane that covers an electrolytic cell consisting of a cathode and an anode. The anode acts as a reference electrode. After passing through the permeable membrane, the oxygen is reduced by an applied potential voltage that is referenced to the anode. The reduction current at the cathode is directly proportional to the partial pressure of oxygen in liquid, expressed as %-air saturation. The concentration of oxygen, in mg/l, is calculated based on the %-air saturation reading and the solubility of oxygen in water at the sample temperature.

Luminescent probes employ a light emitting diode (LED) to provide incident light, which excites the oxygen-sensitive luminescent-dye molecule substrate of the sensor. After dissipation of the excitation energy, longer-wavelength light is emitted (luminescence).

The magnitude of steady-state luminescence (intensity) is measured by the sensor and is inversely proportional to the dissolved oxygen concentration.

For any system, all instruments used in field operations will be maintained and operated in accordance with the manufacturer's instructions and any required calibration and verification checks will be documented and maintained in a logbook prior to use.

In general, calibrating for DO should be conducted at temperatures and pressures as close as possible to those of the sample media for the most accurate measurements and the temperature probe or thermistor should be verified using a NIST-traceable thermometer prior to each calibration. Most DO meters utilize a one-point calibration generally performed using either water-saturated air or air-saturated water.

When using the water-saturated air method, the probe should be placed in a 100% relative humidity environment and the temperature and DO readings should be allowed to equilibrate. After equilibration, the meter should be set to read the appropriate DO concentration based on the temperature and barometric pressure.

When using air-saturated water for calibration, an aeration device such as an aquarium pump with a diffusion stone should be placed in a vessel containing tap water. The water in the vessel should be aerated for a minimum of one hour at a constant temperature. Saturation should be verified by placing the DO probe in the vessel and monitoring the temperature and DO readings for stabilization. Avoid placing the probe in the direct stream of air bubbles. Bubbles can accumulate on the probe surface and cause erroneous readings. Once the water is saturated, the temperature of the water and the barometric pressure can be used to determine the DO value. The meter can then be set to read that value.

The procedure for collecting a DO sample is as follows:

- Inspect membrane of the DO meter for air bubbles and/or holes. If air bubbles or holes exist, replace the membrane.
- Calibrate the instrument in accordance with manufacturer’s specifications (typically to a percent)
- Collect sample. Measure the temperature of the sample and adjust the temperature setting of the DO meter, if applicable.
- Record the reading in the field logbook or on the appropriate field form. DO is measured in units of mg/L. Results should be reported to the nearest tenth (0.1).
- As appropriate, periodically check DO calibration throughout the course of a day’s activities to quantify potential instrument drift.

  - Perform a post calibration at the end of the day and record all findings in the field logbook and on the appropriate field form.

Oxidation-Reduction Potential

Oxidation is the process of liberating electrons or gaining oxygen. Examples of oxidation include conversion of elemental iron to rust, elemental sulfur to sulfate, and elemental hydrogen to water. Reduction is the process of gaining electrons resulting in the charge on some atomic unit in the species to be reduced. Oxidation-reduction potential (ORP) or redox potential is a measure of the intensity or activity of a medium to mediate reactions of important elements in biological systems (e.g., O, N, Mn, Fe, S, and C) and other metallic elements. ORP is measured in millivolts (mv).

In aqueous solutions, a numerically positive ORP represents an environment conducive to the oxidation of an introduced substance by reduction of the original media; conversely, a numerically negative ORP represents an environment conducive to the reduction of an introduced substance by oxidation of the original media. However, like pH, ORP represents an intensity factor. It does not characterize the capacity of the system for oxidation or reduction in much the same way that pH does not characterize the buffering capacity (EPA, 2013c).

ORP measurements should be conducted in a fashion that prevents the addition or loss of any potential oxidants or reductants as readings could be compromised by exposing the sample to air or allowing H_2S to off-gas from anoxic samples. Like DO, ORP measurements should be conducted in situ or by using a flow-through cell whenever possible.

Instruments/meters used to measure ORP are the practical implementation of electrochemical cells, which use metal electrodes in a solution to generate an electric current or voltage. When interpreted properly, ORP combined with other conventional water quality parameters is useful in developing a more complete understanding of water chemistry. However, in most environmental media, ORP will not reach equilibrium due to low concentrations or interferences from multiple species. Consequently, ORP measurements are generally considered semi-quantitative in environmental media, unless certain conditions exist.

If ORP is to be utilized for a specific site, a determination of whether the instrument requires verification or calibration shall be established in the corresponding SAP or equivalent. In most applications, the ORP information is required only to be semi-quantitative; as such, the selected instrument can be calibrated to standard solutions appropriate for the project using the manufacturer’s recommended procedure. One minute after calibration, the instrument should display a stable reading within +/-10mV of the predicted reading.

<u>NOTE:</u> Special care should be taken when calibrating or verifying ORP instruments as the reagents commonly used in the preparation of ORP calibration standards are toxic. Avoid unnecessary exposure to these materials through the use of protective clothing, eye wear and gloves. If ORP calibrations are required per the site DQOs, refer to the specific Personal Protection Equipment (PPE) requirements outlined in the SSHASP.

The procedure for measuring ORP is as follows:

- Inspect membrane for air bubbles and/or holes. If air bubbles or holes exist, replace the membrane.
- Calibrate the instrument in accordance with manufacturer's specifications.
- Collect sample. Measure the temperature and pH of the sample at the same time the ORP is measured. ORP may need to be measured in an upright positon to assure salt bridge flow is maintained.
- Record the reading in the field logbook or on the appropriate field form. Results should be reported to the nearest mV.
- As appropriate, periodically check DO calibration throughout the course of a day's activities to quantify potential instrument drift.
- Perform a post calibration at the end of the day and record all findings in the field logbook and on the appropriate field form.

<u>NOTE</u>: In the absence of a specified reference scale, ORP data has no meaning. Therefore, the reference scale used should always be specified in reporting or discussing ORP data. ORP measurements converted to a hydrogen scale can be reported as "Eh". Data reported as the direct field measurement without correction might be described as "ORP referenced to Ag/AgCl electrode" or "EAg/AgCl".

To apply corrections to obtain Eh from a direct field measurement of ORP, the known half-cell potential of the reference electrode is required and the measurement adjusted as follows:

<u>Equation 4:</u>

$$E_{h,sample} = ORP_{sample} + H$$

Where:

$E_{h,sample}$ (mV) = ORP measurement relative to Standard Hydrogen Electrode (SHE)
ORP_{sample} (mV) = ORP field measurement
H = half-cell potential of reference electrode as utilized for measurement.

The half-cell potential of a silver/silver chloride reference electrode at various temperatures and with various molarities of potassium chloride (KCl) filling solutions is presented on **Table 3** (EPA, 2013c). YSI sondes and Thermo electrodes typically use 4M KCl filling solutions; Eureka sondes typically use 3.3M KCl filling solutions.

Table 3: Half-Cell Potential of Ag/AgCl Reference Electrode

T(°C)	**Molarity of KCl filling solution**			
	3M	3.3M*	3.5M	Sat/4M
10	220	217	215	214
15	216	214	212	209
20	213	210	208	204
25	**209**	**207**	**205**	**199**
30	205	203	201	194
35	202	199	197	189
40	198	195	193	184

*interpolated values

Turbidity

Turbidity is caused by suspended and colloidal matter such as clay, silt, organic and inorganic matter and microscopic organisms. Many methods are available for the measurement of turbidity including turbidimeters and optical probes. Turbidity is measured by determining the amount of scatter when a light is passed through a sample and is represented in units identified as nephelometric turbidity units (NTUs).

Many brands of instruments are commercially available for the measurement of turbidity incorporating a wide variety of technologies. The manufacturer’s instruction manual should be consulted for specific procedures regarding their calibration, maintenance and use. Calibration of any instrument used for measurement of turbidity must be conducted and/or verified prior to each use or on a daily basis, whichever is most appropriate. Depending on the instrument, the verification and calibration can differ slightly. If the instrument readings do not agree within ± 10 % of the calibration standards, the unit must be recalibrated, repaired or replaced (EPA, 2013b).

Depending on the meter, the sample measurement procedure for turbidity can differ slightly. The following procedure is a commonly applied procedure for measuring turbidity in grab samples.

- Rinse the sample cell with de-ionized water.
- Collect a representative sample and pour off enough to fill the cell to the identified fill line and replace the cap on the cell.
- Wipe off excess water and any streaks with a soft, lint-free cloth such as lens paper.

- Turn instrument on. Place the meter on a flat, sturdy surface. Do not hold the instrument while making measurements.
- Insert the sample cell in the instrument so the diamond or orientation mark aligns with the raised orientation mark in the front of the cell compartment. Close lid.
- If appropriate, select manual or automatic range selection by pressing the range key.
- If appropriate, select signal averaging mode by pressing the Signal Average key. Use signal average mode if the sample causes a noisy signal (display changes constantly).
- Press Read. The display will show ---- NTU. Then the turbidity is displayed in NTU. After the lamp symbol turns off, record the result in the field logbook or on the appropriate field form. Units should be recorded to the nearest whole unit.
- Rinse the cell with de-ionized water or rinse out with sample water prior to the next reading.
- As appropriate, periodically check the turbidity by rinsing probe with de-ionized water, blot dry or otherwise remove excess rinse water and immerse it into an appropriate standard solution. If the measured turbidity differs by ± 10 %, the meter must be recalibrated.
- Perform a post calibration at the end of the day and record all findings in the field logbook and on the appropriate field form.

NOTE: In assessing acceptable turbidity levels, visual observation is often considered sufficient for most sites. Depending on the DQOs and regulatory authority for a project, however, there may be specific quantitative constraints on achieving clear, artifact-free water. RCRA regulations cite the need to achieve purge water that is at or less than 5 NTUs (EPA, 1992a and b) as observed on a turbidity meter; however, for marginal aquifers with high lithological heterogeneity (i.e., interbedded sand and clay), this is often not attainable (EPA, 1992a). However, when samples are collected for metals, semivolatile organic compounds (SVOCs), and pesticides, every effort must be made to reduce turbidity to 10 NTUs or less (not just the stabilization of turbidity) prior to the collection of the water sample (Yeskis and Zavala, 2002; TCEQ, 1998). If turbidity cannot be reduced below 10 NTUs, groundwater samples may be filtered in the field using a filter that is not less than 10.0 microns (TCEQ, 1998).

Attachment 4

General Groundwater Sampling Equipment List

General Groundwater Sampling Equipment List

The following list identifies the types of instruments, equipment, supplies, and documents that may be used for a range of groundwater sampling applications. A project-specific equipment list will be selected from this list, based on project DQOs and sample point conditions.

1. Sampling vehicle with various pumps, electrical generator, air compressor, hoses, clean water tank, decontamination equipment, etc.
2. Portable pump with water discharge tubing and power source (i.e., Geotech GeoSub pump electric submersible, Monsoon DC powered pump, or equivalent)
3. Dedicated pumps (i.e., stainless steel bladder pump and dedicated electric submersible pumps [for wells that are too deep for bladder pumps])
4. Bailer (diameters 1” to 4”; materials of construction are HDPE, PVC, and stainless steel) with rope (i.e., stainless steel bailer with dedicated rope or cable)
5. Cutting knife
6. Portable generator and extension cord
7. Portable air compressor (up to 150 psi)
8. Water-quality indicator parameter instrument(s) (YSI 556 or equivalent) to measure the selected parameters per the SAP or equivalent
9. Calibration fluids for water-quality parameter meter(s)
10. Turbidity meter
11. Flow-through cell and tubing
12. Water level measurement device of appropriate length
13. Water filtration apparatus, as needed (Masterflex or equivalent peristaltic pump (for use with bailed samples) and 0.45µ filters)
14. Decontamination equipment for bailer and portable pumps (i.e., two 5-gallon buckets, distilled or deionized [DI] water, liquinox or other approved cleaner as identified in INTERA SOP 2, *Decontamination*)
15. Sample coolers for field storage and shipping
16. Sample containers

17. Laboratory-supplied preservatives in containers
18. Ice
19. Analyte list corresponding to laboratory bottle order
20. Sample container labels
21. Custody seals (if required per SAP/FSP/WP)
22. Chain-of-Custody form(s) (**SOP 30, Field Form 8**)
23. Water-sampling field data report forms (**SOP 30, Field Form 5** or **SOP 30, Field Form 6**)
24. Sample control logs (if required) (**SOP 30, Field Form 7**)

13.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) covers the following aspects of manual shallow soil sampling to be implemented by INTERA field personnel during characterization, remediation, or monitoring of environmental sites:

- Collection of a representative shallow soil sample via the following methods (**Section 13.1**):
    a. Hand trowel/scoop/spoon
    b. Hand auger
    c. Hand-driven soil core sampler or probe
- Sample homogenization and preservation (**Sections 13.2.1 and 13.2.2**); and
- Collection of soil for VOC analysis (**Section 13.2.3**).

This SOP also covers the following aspects of power-assisted soil sampling to be implemented by INTERA field personnel during characterization, remediation, or monitoring of environmental sites:

- Collection of a representative deep soil sample via the following methods (**Section 13.3**):
    a. Hollow stem auger drilling;
    b. Direct push drilling; and
    c. Rotary drilling and coring.

Shallow soils are generally classified as soils occurring between ground surface and the depth at which sample collection using manual methods becomes impractical. The most common shallow soil interval classifications are from 0.0 to 6.0 inches below ground surface (bgs) (0.0 to 0.5 ft bgs) and from 6 to 12 inches bgs (0.5 to 1.0 ft bgs); however, project specific data quality objectives may dictate alternate intervals. The next interval of shallow soil commonly sampled is typically site-specific, but often begins at 12 inches bgs (or 1.0 ft bgs) and extends to the site-specific depth at which sample collection using manual methods becomes impractical. For the purposes of this SOP, the term *Shallow Soil* encompasses soil from the 0- to 1-foot interval as well as deeper intervals representative of the shallow soil as defined for a particular site. Deeper soil encompasses any soil that is not defined as shallow soil and cannot be samples by manual methods.

The objective of this SOP is to promote standardization between sample collection events in order to obtain consistent and accurate data representative of site conditions. Methods outlined in this SOP comply with the following ASTM Standards:

- D4547-09, *Standard Guide for Sampling Waste and Soils for Volatile Organic Compounds* (ASTM, 2009a);
- D4700-91(2006), *Standard Guide for Soil Sampling from the Vadose Zone* (ASTM, 2006);
- D5633-04(2012), *Standard Practice for Sampling with a Scoop* (ASTM, 2012);
- D6418-09, *Standard Practice for Using the Disposable En Core Sampler for Sampling and Storing Soil for Volatile Organic Analysis* (ASTM, 2009b); and
- D6907-05(2010), *Standard Practice for Sampling Soils and Contaminated Media with Hand-Operated Bucket Augers* (ASTM, 2010).

This SOP should be used in conjunction with procedures presented in the INTERA Site-Specific Health and Safety Plan (SSHASP) and in site-specific investigation planning documents such as a Sampling and Analysis Plan (SAP), Field Sampling Plan (FSP), or Work Plan (WP). This SOP will also be commonly used with and is referenced in the following INTERA SOPs:

- 1, *Air Monitoring*;
- 2, *Decontamination*;
- 5, *Hollow Stem Auger Drilling*;
- 6, *Direct Push Drilling*;
- 10, *Rotary Drilling and Coring*;
- 23, *Soil Field Screening*; and
- 30, *Field Forms*.

13.1 Procedure – Manual Collection of a Representative *Shallow Soil* Sample

Shallow Soil samples may be collected for onsite field screening/offsite chemical analysis by one or more the following methods:

- **Hand Trowel/Scoop/Spoon** – By itself, commonly used to obtain a disturbed sample at true ground surface. Trowels can also be used in conjunction with power-assisted soil sampling equipment to obtain a disturbed sample from deeper within the soil column. A clean stainless–steel scoop, spoon, trowel or an appropriate disposable trowel is used to remove equal portions of soil from the interval of interest.
- **Hand Auger** – Commonly used to obtain a disturbed sample at or near the ground surface. A clean, stainless–steel hand auger with or without handle extension(s) is used to advance the auger to the desired interval of interest. The auger is advanced by simultaneously pushing and turning in a clockwise direction

using an attached handle. Upon reaching desired depth, the auger itself, a stainless–steel trowel, spatula, or knife; or a combination of these tools; may be used to remove and collect a representative sample.

- **Hand-Driven Soil Probe** – Commonly used to collect small diameter samples at or near the ground surface to assess soil profiles or moisture. Can be used with or without a liner depending on site data quality objectives as identified in the SAP/FSP/WP. Unlike the hand auger, a soil probe is typically advanced manually by pushing or pounding rather than twisting. For hard or compacted soils, an adaptation to use a hammer or slide hammer may be necessary.
- **Hand-Driven Soil Core Sampler** – Commonly used to collect virtually undisturbed core samples for soil profiling and chemical analysis. Includes both split core and multi stage core sampling equipment options. Core can be extracted from the ground surface or from a designated interval in a pre-augered borehole. Most soil core samplers require the use of a removable liner. Like the soil probe, a soil core sampler is advanced by pushing or pounding and typically requires extra force via a hammer or slide hammer.

The specific *Shallow Soil* sample collection method to be applied at a particular site is dependent on known or suspected site contaminants of concern and the site data quality objectives as specified in the SAP/FSP/WP.

With any of these *Shallow Soil* sample collection methods, the following standard implementation procedure can generally be applied.

1. Confirm that equipment required for the designated *Shallow Soil* sample collection method is available, cleaned, and in good working order prior to initiating sample collection efforts. Equipment to be taken to the site by the INTERA field staff may include:
    - Personal Protection Equipment (PPE) as specified in the SSHASP;
    - Site map and, if applicable, a copy of the SAP/FSP/WP;
    - Stakes and flagging, as required;
    - Drop cloths, plastic sheeting, clean cutting surface, and buckets, as required;
    - Borehole casing, if required;
    - Field logbook, waterproof pens, measuring device, and a time-keeping device;
    - Soil Boring Log, if required (**SOP 30, Field Form 1**);

- Sample collection equipment (e.g., stainless-steel trowel, scoop, spoon or hand auger; sampler liners and end caps; En core® samplers; extension rods; hammer/slide hammer, Ziploc bags; and/or stainless-steel bowl) as designated in the SAP/FSP/WP;
- Field screening equipment as specified in the SSHASP and/or the SAP/FSP/WP;
- Laboratory-supplied preservatives, sample extraction tools (e.g., syringes), and quality assurance samples (i.e., field trip blank for volatiles), as appropriate;
- Personnel and equipment decontamination supplies (INTERA SOP 2, *Decontamination*);
- Sample containers, labels, and custody seals;
- Sample Control Logs (**SOP 30, Field Form 7**);
- Laboratory Chain-of-Custody forms (**SOP 30, Field Form 8**);
- Coolers or other appropriate containers designated for sample storage and transport;
- Ice for sample preservation; and
- GPS unit or measuring tape for recording sample location.

NOTE: If field screening is required per the SSHASP and/or SAP/FSP/WP, confirm that instrumentation is properly calibrated per the manufacturer's instructions and that the calibration procedure and results are recorded in the field logbook.

2. Determine sequence of locations to be sampled for the site. If applicable, attempt to collect soil samples in order of least contaminated to most contaminated to minimize the potential for cross contamination. Verify the need to collect any quality assurance/quality control samples during the sample collection event. If required, select appropriate locations.
3. Verify sample location ID is marked. If applicable, ID sample location with flagging or tape. Record location in the field logbook.
4. Don appropriate PPE. At a minimum, this should include appropriate gloves and foot and eye protection. Specifics regarding appropriate PPE for a site is provided in the SSHASP.
5. Remove any overburden material present (e.g., thick, matted root zone, gravel, concrete, or equivalent obstruction). If necessary, a shovel or other similar tool may be used to remove vegetation from the sampling point or to create a shallow

excavation. If a shovel is used, however, care should be given to verify that the shovel is composed of a nonreactive material and to segregate any soil that may have contacted the shovel to minimize reactivity or contamination of the site sample.

NOTE: This is especially important at sites where metals may be a contaminant of concern.

6. If advancing to depth and as appropriate, place drop cloth or bucket next to the sample location to collect and contain any excavated soil to minimize the effects of possible contaminant leaching.

NOTE: In situations where the hand-augured borehole may become unstable and collapse, drive an appropriate-sized casing into the ground **prior to** advancement. The inside diameter of the casing should be slightly larger than the diameter of the hand auger to be used. The casing should be driven to a depth no greater than the top of the sample interval and material inside the casing should be removed with the hand auger. The hand auger can then be inserted into the borehole and turned below the bottom of the casing to obtain a representative sample.

7. Advance to the first designated sampling interval using the appropriate tools designated for the project. The depth measurement for the sample begins at the top of the soil horizon, immediately following any removed materials.
8. Once the desired sample interval is reached, verify depth with a measuring device and record in the logbook. As appropriate, conduct field screening of the soil sample interval prior to sample collection. Appropriate field screening methods for constituents of concern in the soil sample shall be outlined in the SAP/FSP/WP and executed in accordance with INTERA SOP 23, *Soil Field Screening*. Appropriate field screening methods for personnel monitoring or site monitoring shall be outlined in the SSHASP and executed in accordance with INTERA SOP 1, *Air Monitoring*. Record field screening readings in the field logbook and/or on the Soil Boring Log.
9. If required, log and describe borehole on the Soil Boring Log.
10. If appropriate, change out PPE and verify that clean and appropriate sample collection tool and containers are readily available prior to collecting a representative sample.

NOTE: Step 10 is particularly important for sites where trace concentrations of constituents are anticipated. Whether this step is required at a site will be specified in the SAP/FSP/WP.

11. Collect representative soil from the desired sample interval of interest, removing any rocks or other large obstructions. Provide sample description on the sample control log, if required. If applicable, homogenize sample in a stainless-steel bowl or equivalent container prior to placing in the appropriate sample container (refer to **Section 13.2**).

If sampling exposed ground surface (e.g. 0.0 ft bgs) and windblown contamination is not of interest, scrape off the first few centimeters prior to collecting the sample to ensure that the sample collected for analysis does not contain wind-blown material but is an in-situ soil sample that is representative of the location.

If sampling one or more intervals below the top of the soil horizon (i.e., >0.0 ft bgs), ensure that any smeared soil surface is scraped and removed prior to sample collection. If sampling directly from an auger bucket, discard the upper portion of the sample that may contain material that sloughed from the borehole wall. These actions are necessary to minimize the effects of contaminant migration interferences due to smearing of material via the auger bucket during advancement to the desired sample depth.

If sampling using a core retrieval method (e.g., soil probe or sol core sampler), make sure to discard the top 2.5 cm of the core as this may represent material collected before penetration of the interval of interest.

12. If samples are to be analyzed for VOCs, VOC sample collection shall be conducted **FIRST** and in a manner that minimizes disturbance of the sample; disturbing the sample increases the propensity for volatilization/loss of contaminants. Additional specifics regarding the collection of a VOC soil sample is provided below in **Section 13.2.3**.

NOTE: If project data quality objectives specify the collection of VOC sample(s) only, an additional soil sample may need to be collected for laboratory determination of percent solids. This requirement, if applicable, should be established in the SAP. Additional details regarding this requirement are provided below in **Section 13.2.3**.

13. Place required samples in appropriate clean sample containers and cap securely. Note the date, time, and corresponding depth interval of each collected sample in the field logbook and/or on the appropriate sample control log/chain-of-custody form.

If a sample is collected using a liner, such as an acetate sleeve, either remove the soil core from the liner or cut and cap the liner at the sample interval of interest. Notate top and bottom of core. If sample requires VOC analysis, cap the liner as quickly as possible and send intact to the laboratory, where the interval of interest can be tested with the minimum loss of VOCs.

NOTE: It is critical that the orientation of any core sample (top and bottom) is clearly notated to ensure that the proper interval is selected for analysis.

14. Verify that sample containers are labeled and that labels are affixed to the sample/sample bag appropriately. Labels should contain the following information:
    - Project name and/or number;
    - Field sample number;
    - Depth interval, if applicable;
    - Initials of collector;
    - Date and time of collection;
    - Sample type and preservative (if any); and
    - Desired analyses.
15. Place the sealed and labeled sample container in an appropriate container for storage. Appropriate storage, packaging for shipment, and shipment requirements will be identified in the SAP/FSP/WP and shall be dependent on site contaminants of concern, the types of sample containers, and the selected mode of transport.
16. Decontaminate equipment, as necessary, prior to collecting additional samples at another location in accordance with INTERA SOP 2, *Decontamination*.
17. Confirm that a completed chain-of-custody form documenting all collected samples and any quality assurance samples is placed in the container for transfer to the specified laboratory.
18. Ship/deliver sample(s) to the specified laboratory for analysis. If delivering samples via third party, verify that custody seals are applied across the opening of shipping containers. This minimizes the potential for tampering with the collected samples as shipping container(s) cannot be opened without breaking the custody seals. Applied custody seals should contain the following information:
    - Collector's signature or initials; and
    - Date of shipping.
19. When scheduling for shipment/delivery of sample(s) to the laboratory, make sure to observe and comply with all minimum holding time requirements for degradable constituents. This is especially pertinent if VOC samples were collected as most VOC samples have a less than 48-hour holding time.

13.2 Additional Considerations for the Collection of a Representative *Shallow Soil* Sample

13.2.1 Homogenization

With the exception of VOC samples, all soil samples should be thoroughly mixed to ensure that the sample is as representative as possible of in-situ conditions. **Samples for VOC analysis are not homogenized as homogenization increases volatilization losses.**

The most common method of mixing soils is referred to as *Quartering*. Quartering is applied as follows:

1. In a round stainless-steel bowl (preferred) or equivalent container, divide primary sample into quarters and individually mix each quarter.
2. Once mixed, combine and mix two quarters into a half.
3. Combine remaining two quarters into another half.
4. Combine and mix each half to produce a homogenous matrix.
5. Repeat **Steps 1** through **3** several times until the sample is adequately mixed.

Adequate mixing is achieved by stirring the material in a circular fashion, reversing direction, and occasionally turning the material over.

If more than one sample container is to be filled from a homogenized mix, a similar-sized spoonful of soil should be placed in each container in sequence until all containers are filled.

If collecting composite samples, ensure that each aliquot of soil collected from each location of interest is of the approximately the same volume. This is necessary to minimize the potential for inadvertently introducing a location bias to the composite sample.

13.2.2 Preservation

Preservation of soil samples is required only for samples intended for VOC analysis. Methanol (CH_3OH) is the most commonly applied preservative but sodium bisulfate ($NaHS0_4$) may also be applied, particularly in samples where low levels of VOC concentrations are expected. Specifics regarding which preservative is most appropriate for a site will be coordinated with the specified laboratory and documented in the SAP/FSP/WP. If preservation is required, pre-weighed sample vials, containing purge-and-trap grade preservative, shall be supplied by the specified laboratory. Disposable syringes or plug samplers, if required, shall also be provided by the specified laboratory.

13.2.3 Soil Samples for Volatile Organic Compounds (VOC) Analysis

VOC soil samples may be collected via various methods and sample containers including: En Core® sampler, syringes, stainless-steel spatula, standard 2-oz. soil VOC container, or laboratory-prepared 40 mL vials. General guidelines for collecting a VOC soil sample are as follows.

- Ideally, a VOC soil sample should be collected in-situ (i.e., directly from the sampling interval or auger bucket via an En Core® sampler or syringe) or placed in the final sample container immediately following extraction.
- Try to maintain as consistent a grain size as possible: Avoid rocks or other large obstructions.
- Pack sample container to achieve as little headspace as possible. When sampling directly with an En Core® sampler, verify that the sampler is full prior to immediately capping and locking the ends.
- If direct extraction is not possible, immediately place soil into an intermediate container certified clean (typically provided by a laboratory) and seal with no headspace to reduce volatilization losses. The final VOC sample can then be taken from this intermediate container via the appropriate tool (e.g. En Core® sampler, syringe, stainless-steel spoon) within 30-minutes of collection.
- Some VOCs samples may require field preservation/extraction via CH_3OH or $NaHS0_4$. If preservation is required, pre-weighed sample vials, containing purge-and-trap grade preservative, shall be supplied by the laboratory. Disposable syringes, if required, shall also be provided by the laboratory.
- During sample collection, take care to confirm that neither the sample nor the sample container (especially the rim) come into contact with any contaminated surface. Verify that the final sample container is tightly capped and labeled.
- As required, collect an additional sample (minimum of 2 oz.) for the determination of percent solids. The site/project sampling team must ensure that the laboratory has sufficient material to determine percent solids in the VOC soil sample to correct the analytical results to dry weight as well as assess preservative compatibility (**Section 13.2.4**). This step is only required if other requested soil sample analyses are either not collected or do not require a percent solids determination. The need for collecting an extra sample for percent solids determination shall be documented in the SAP/FSP/WP.
- Upon collection, immediately place sample(s) in a cooler containing double–bagged ice or frozen ice packs. Prepare sample and shipping container for

delivery/shipment to the specified laboratory within 24 hours of sample collection.

Specifics regarding each type of sample container that may be applied for the collection of a soil VOC sample are as follows:

1. **En Core®** - Read and follow manufacturer's instructions to ensure proper operation of the En Core® sampler and T-handle. Fill sampler completely verifying that no air is trapped in the sampler behind the sample as this can compromise the integrity of the sample. Scrape the bottom of the core chamber with a knife/spatula to create a flush surface and wipe outside surfaces with a clean tissue/cloth to ensure sealing surfaces are clean. Cap and lock sampler while still attached to T-handle by sliding cap onto the core chamber via a twisting motion. The cap is locked when the grooves on the locking arms seat over the ridge on the core chamber. Secure sampler in original foil bag. Label appropriately and place foil bag in a plastic bag and seal with custody tape, if required.

2. **40-mL vial via Syringe** - Transfer approximately 3.7 cc (roughly 5 grams) of sample material to a 40-mL pre-prepared vial taking care not to drop soil on the rim of the vial. Add preservative if required. Gently agitate until soil is immersed in preservative. Do not excessively shake as this may volatilize the sample. Label appropriately and secure container in bubble wrap and in a plastic bag. If custody seal is required, place directly on plastic bag not on sample. When using a syringe, take care not to trap air behind the sample prior to extrusion, as this will adversely affect the sample.

3. **40-mL vial via Stainless-Steel Spatula/Spoon** - Add between 4.5 and 5.5 grams (approximate) of sample material to 40 mL pre-prepared container taking care not to drop soil on the rim of the vial. Add preservative if required. Gently agitate until soil is immersed in preservative. Do not excessively shake as this may volatilize the sample05. Label appropriately and secure container in bubble wrap and in a plastic bag. If custody seal is required, place directly on plastic bag not on sample.

4. **2-oz. glass septum jar via Stainless-Steel Spatula/Spoon** – Pack sample quickly and completely into the pre-prepared container eliminating any headspace. Label appropriately and secure container in bubble wrap and in a plastic bag. If custody seal is required, place directly around sample jar.

Note: Although the collection of a bulk sample for VOC analysis is listed as an option above (#4), it is the least recommended method and should be used only when other VOC sample collection methods cannot be applied. This sampling procedure is least desirable because it fails to achieve accountability of all VOC phases. Samples collected via a spatula-type device fail to control surface area exposure and almost always compromises the sealing surface of the container rim (by becoming soiled) thus preventing a vapor-tight seal during storage. Pilot testing has shown that the final reported VOC concentrations in samples collected via this method can be as inaccurate as less than 10% of the true in-situ VOC concentrations.

13.2.4 Effervescence

Some soils may contain carbonate that will generate carbon dioxide gas (CO_2) when in contact with an acid preservative. This reaction can be easily identified by noting the degree at which a sample effervesces upon contact with the preservative (i.e., the rapid formation of bubbles). Generation of CO_2 is a concern, especially for a site/project that anticipates low level concentrations of VOCs, as the act of effervescing may drive off the VOCs and cause sample containers to fail due to increased pressure within the container.

If carbonates are anticipated, the effervescence potential (the potential for the soil sample to rapidly form CO_2 upon contact with the preservative) of the projected sample material with the selected preservative may need to be assessed for quality assurance. An assessment of sample effervescence should be performed prior to sampling by collecting a test sample in one of two ways:

1. Moisten approximately 1 gram of sample material placed on a watch glass or similar surface with water. Stir to remove any trapped air. Add drop-wise a cold solution of 4N HCl to moistened material. Observe for effervescence using a hand lens.
2. Add test sample to a pre-weighed and pre-preserved vial. Observe for effervescence using a hand lens.

Alternately, the sampling team may prepare to collect each sample both preserved and unpreserved, as needed, or all samples unpreserved.

If preservation of the sample results in effervescence, then preservation by acidification is not acceptable, and the sample(s) must be collected unpreserved. If effervescence occurs and only pre-preserved sample vials are available, the preservative solution may be placed into an appropriate hazardous waste container, and the vials triple rinsed with organic free water. An appropriate amount of organic free water, equal to the amount of preservative solution, should be placed into the vial. The sample may then be collected as an unpreserved sample.

Note: The amount of organic free water placed into the vials will have to be accurately measured.

13.3 Procedure – Power-Assisted Collection of a Representative *Deep Soil* Sample

Deep Soil samples may be collected for onsite field screening/offsite chemical analysis by using one or more the following power-assisted soil core collection methods:

- **Shelby Tube** – A 2-inch, 3-inch, or 5-inch OD thin wall tube sampler equipped with a cutting edge at the toe, a check valve, and pressure vents. Used most commonly for the retrieval of core in cohesive material for the collection of a relatively undisturbed core(s). Attaches to the base of the drill stem and is lowered into the annular space within the HSA column. The sampler is then hydraulically advanced into undisturbed material ahead of the cutting bit of the lead auger flight to approximately 6 inches less than the sampler length. The check valve and pressure vents create a vacuum that retains the soil core in the sampler as it is retracted to the surface. Typically, Shelby tubes are available in 3 and 4.5 foot lengths.
- **Split–Spoon/SPT** – A 2-inch OD hollow tube that is split lengthwise into two halves and equipped with hardened metal drive shoe with opening. Used most commonly for the retrieval of core in non-cohesive material as this type of sampler can be equipped with a sand catcher to prevent loss of core material during retraction to the surface. Core samples collected in this manner are considered disturbed. Attaches to the base of the drill stem and is lowered into the annular space within the HSA column. The sampler is then hydraulically advanced into the undisturbed material ahead of the cutting bit of the lead auger flight with a 140-pound (64 kg) hammer falling 30 inches. The number of hammer strikes (also referred to as blow counts) required to advance the length of the sampler for 6 inches are typically recorded. Split-spoon samplers are typically available in 1.5 and 2.5 foot lengths.
- **Continuous Core Barrel Sampler** – Includes both solid and split versions. Split barrels are similar in appearance and function to the split–spoon, except they rotate with the lead auger while advancing downward thus allowing for continuous core collection. Typically, the core barrel samplers are available in 2.5 foot or 5 foot lengths. May be used with or without liners. Rotation of the sampler is independently controlled by a bearing assembly that is connected either directly to the HSA column (in a wireline system) or the central rod (in a rod system). Controlling the rotation of the sampler is particularly important for obtaining intact core samples.

The specific *Deep Soil* sample collection method to be applied at a particular site is dependent on known or suspected site contaminants of concern and the site data quality objectives as specified in the SAP/FSP/WP and will be accomplished in conjunction with drilling procedures outlined in the following INTERA SOPs: 5, *Hollow Stem Auger Drilling*; 6, *Direct Push Drilling*; and 10, *Rotary Drilling and Coring*.

Once soil core has been retrieved from a borehole and documented per the above noted SOPs, collection of soil samples for onsite or offsite analyses occurs via the same general procedures provided above in Sections 13.1 and 13.2 in terms of sample collection, containerization, preservation, labeling, storage and shipment with the exception that the minimum level of PPE will include a hard hat and hearing protection.

13.4 References

ASTM International (ASTM), 2006. Standard Guide for Soil Sampling from the Vadose Zone. D4700-91 (Reapproved 2006).

ASTM, 2009a. Standard Guide for Sampling Waste and Soils for Volatile Organic Compounds. D4547-09.

ASTM, 2009b. Standard Practice for Using the Disposable En Core Sampler for Sampling and Storing Soil for Volatile Organic Analysis. D6418-09.

ASTM, 2010. Standard Practice for Sampling Soils and Contaminated Media with Hand-Operated Bucket Augers. D6907-05 (Reapproved 2010).

ASTM, 2012. Standard Practice for Sampling with a Scoop. D5633-04 (Reapproved 2012).

13.5 Attachments

None.

13.6 Document History

Revision	Effective Date	Lead Author	Summary of Changes
2004.0	4/2004	Taimur Malik	Original version
2004.1	2/2015	Kate Herrell	Revised for inclusion in COA Brownfields QAPP
2004.2	11/2016	Noreen Baker	Changed “Sample Collection Log” to “Sample Control Log”
2004.3	6/2017	Noreen Baker	Removed Field Forms as attachments, added references to SOP 30, Field Forms

15.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) provides procedures to be implemented by INTERA field personnel when conducting a slug test. A slug test is a commonly used method for determining hydraulic conductivity (K). The slug test consists of creating an instantaneous change in the water level in a borehole or well by suddenly either introducing or removing a known volume (of a solid or of water) and then observing the recovery of the water level over time. This SOP is specifically designed for conduct of a slug test using a solid slug rather than a slug of water, and this SOP assumes that a pressure transducer and electronic data logger will be used to measure water levels over the duration of the test.

Slug tests may be conducted in either open boreholes or in screened monitor/water wells. For simplicity, the term “well” as used in the remainder of this SOP refers to either a well or a borehole. Slug tests are typically applicable in aquifer materials with low hydraulic conductivity, especially those generally considered unsuitable for hydraulic testing with pumping tests.

Slug-test data are representative only of aquifer properties immediately adjacent to the well. Since hydraulic conductivity typically varies spatially within an aquifer, numerous wells across a site should be slug tested to determine the average and the range of hydraulic conductivity.

Two sets of slug-test data can be obtained from a well by continuously recording data when the slug (typically a solid cylinder) is inserted and when the slug is removed. Slug insertion causes an upward displacement of the water level in the well. The displaced water flows from the well into the surrounding formation as the water level responds to the head differential between the well and the surrounding formation. When the water level has returned to a steady-state condition, the slug may be instantaneously removed from the well which results in water flow from the formation into the well in response to the head differential between the formation and the well. Water levels are recorded throughout the slug insertion, slug removal, and water-level response phases of the test.

Time-versus-water-level data for either slug injection (i.e., falling head) or slug removal (i.e., rising head) tests can then be analyzed for confined aquifers, while typically only slug removal data are analyzed in unconfined aquifers. Slug-injection tests in unconfined aquifers are affected by air entrapment in the pore spaces immediately above the water table that the displaced water tries to infiltrate. Data from such slug-injection tests should be considered less accurate or more qualitative in nature.

Methods outlined in this SOP comply with the following ASTM and regulatory standards:

- D4044/D4044M-15, Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers (ASTM, 2015a);
- D1785-15, Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120 (ASTM, 2015b); and
- Standard Operating Procedure NO. 16.1, Slug Test, Texas Commission on Environmental Quality, 8/28/2013 (TCEQ, 2013).

This SOP should be used in conjunction with procedures presented in the Site-Specific Health and Safety Plan (SSHASP) and in site-specific investigation planning documents such as a Sampling and Analysis Plan (SAP), Field Sampling Plan (FSP), or Work Plan (WP). This SOP will also be commonly used in conjunction with and is referenced in the following INTERA SOPs:

- 2, *Decontamination*,
- 8, *Monitor Well Development*,
- 9, *Monitor Well Gauging*, and
- 30, *Field Forms*.

15.1 Design Considerations

Before conducting a slug test, it is necessary to determine the slug volume required to produce a head change in the well that will adequately stress the aquifer. In general, larger slugs are required for aquifers that are highly transmissive, while smaller slugs are adequate for aquifers that are poorly transmissive. Typically, a head rise of 1 to 3 feet in the well is sufficient to stress the aquifer and provide reliable data. Excessive head change should be avoided to reduce the possibility of introducing large frictional losses in the well and to avoid mechanically damaging the aquifer material.

While solid cylinders can be purchased from various manufacturers, they can also be constructed to fit a variety of needs. Solid slugs are commonly constructed from a section of PVC casing or stainless steel pipe that is capped on either end and partially or completely filled with sand.

Example calculations for determination of slug volume and head rise for typical slugs used in 2-inch and 4-inch wells are provided below. The head change determined using the calculation below is most representative in aquifers with lower permeability materials. In higher permeability materials, slug size may need to be increased if the actual head change in the field is significantly less than one foot.

<u>Specifications for a 1 ¼” stainless steel slug (1.660” OD) for insertion into a 2-inch schedule 40 PVC well (2.067” ID):</u>

Well diameter (ID in feet) [D_W]: 0.1723
Slug diameter (OD in feet) [D_S]: 0.1383
Slug length (feet) [h_S]: 4.0

Determine slug volume, V_s, using the following equation:

$$V_s = \frac{\pi D_s^2 h_s}{4}$$

Slug volume = 0.0601 cuft

Determine head rise, h, using the following equation:

$$h = \frac{4V_s}{\pi D_w^2}$$

Head rise = 2.6 feet.

<u>Specifications for a 2-inch schedule 40 PVC slug (2.375” OD) for insertion into a 4.0-inch ID schedule 40 PVC well (4.026” ID):</u>

Well diameter (ID in feet) [D_W]: 0.3355
Slug diameter (OD in feet) [D_S]: 0.1979
Slug length (feet) [h_S]: 6.0

Determine slug volume, V_s, using the following equation:

$$V_s = \frac{\pi D_s^2 h_s}{4}$$

Slug volume = 0.1846 cuft

Determine head rise, h, using the following equation:

$$h = \frac{4V_s}{\pi D_w^2}$$

Head rise = 2.1 feet.

NOTE: Specifications used above for 2-inch and 4-inch schedule 40 PVC were taken from ASTM () and The Engineering Toolbox (2017a), and specifications for the stainless steel pipe were taken from The Engineering Toolbox (2017b).

The initial head change assumes that the line used to lower and retrieve the slug is as small as possible so that its volume is considered negligible.

One aspect that should be considered when calculating the instantaneous head change in the well is the assumption that the water displacement occurs only in the well, with no loss to the formation (in the case of slug injection) or contribution from the formation (in the case of slug withdrawal). For wells in aquifers with higher transmissivities, the instantaneous change in the well will undoubtedly be affected by outflow to or inflow from the aquifer, resulting in an initial head change that is less than calculated from the slug dimensions. As noted above, this uncertainty can be compensated by increasing the size of the slug if the actual head change in the field is significantly less than one foot.

Prior to slug testing, the well must be adequately developed (or re-developed) to provide the most representative results. Failure to perform adequate development may result in low-biased determinations of formation hydraulic conductivity. If necessary, well development should be conducted in accordance with **INTERA SOP 8, *Monitor Well Development***.

15.2 Equipment

The equipment necessary to conduct a slug test includes:

- Keys to well locks and well information (boring logs and well construction diagrams);
- Electronic water level indicator accurate to 0.01 feet, i.e., Solinst eline or equivalent;
- Pressure transducer, cable, and associated electronic data logger, such as an In-Situ Level TROLL and Hermit data logger or equivalent. Transducer type and cable lengths are determined based on site-specific conditions;
- Barometric pressure transducer (optional);
- 1” PVC transducer access tube for use as a transducer carrier (optional). Following instantaneous slug removal/injection, the water level oscillations in the 1” access tube will be damped compared to the water level in the larger diameter wells resulting in data with less uncertainty (NOTE: length of access tube is sized so that the bottom of the access tube can be set 3 feet above the bottom of the well);
- Hacksaw (to cut access tubes, as needed);
- S-hooks and cordless drill (optional, used in conjunction with access tube);
- Laptop computer with external storage capabilities for data backup, i.e., CDs and/or flash drives;
- Solid stainless steel or PVC slug of known volume that will easily fit into the well;
- Slug retrieval line such as nylon rope or other suitable material;
- Tripod or ladder with pully to assist in slug insertion and removal;
- Nylon measuring tape accurate to 0.1 feet (200’ or more);
- Duct tape;
- Digital watch with stopwatch function;
- Field logbook and waterproof/permanent pens;
- Field forms;
- Assorted tools (screw drivers, pliers, utility knife, etc.), metal clipboard, calculator;

- Decontamination supplies including distilled water, Alconox, and paper towels as needed per site conditions;
- First aid kit and appropriate PPE;
- Plastic sheeting and trash bags; and
- Backup equipment, if feasible..

15.3 Procedure – Slug Test

Record the following information in the field logbook before the test begins:

- well identification number;
- depth to water;
- elevation of the measuring point relative to land surface;
- land surface elevation (if known);
- date and time of test;
- well depth, top/bottom depth of well screen, borehole radius, casing and well-screen radius, radius of the filter pack, and filter pack specs (i.e., 20/40 sand, etc.);
- the name of the aquifer being tested;
- the volume of the solid slug added or removed from the well;
- depth of transducer (if being used);
- the identification numbers of the measuring equipment used for the test; and
- the names of personnel conducting the test.

The general field procedure for the slug-withdrawal test, appropriate for confined and unconfined aquifers, is as follows:

1. Remove the well cap and determine the static water level in the well by measuring the depth to water periodically (minimum of three measurements, typically at 5 minute intervals) over a 15-minute period. Measurements should be obtained to the nearest 0.01 feet. If depth to water readings are not the same, i.e., vary by more than 0.01 feet, continue obtaining depth to water readings until the static water level has been achieved and sufficiently verified by three measurements at 5-minute intervals.
2. Record depth to water measurements on the appropriate field form (**SOP 30, *Field Forms* [Field Form 4]**) and/or in the field logbook. If the field form is unavailable, data may be recorded in the field logbook along with measurement date and time. Depth to water measurements will be obtained according to procedures defined in **INTERA SOP 9, *Monitor Well Gauging***.

NOTE: When monitoring a confined aquifer with a well that was not vented to the atmosphere, is very important to allow enough time for the water in the well to reach equilibrium with atmospheric pressure.

3. Remove any existing equipment in the well such as dedicated pumps, access tubes, etc.
4. If using, install 1" PVC transducer access tube with the bottom of the access tube set at 3 feet above the bottom of well. The tube may be attached by drilling a hole in the side of the access tube at the length necessary for the tubing to reach the desired depth then hanging the tubing from the well casing using an S-hook or similar device. Tape the S-hook to the well using duct tape. The access tube should be installed along the side of well to leave as much room as possible for insertion of the slug.
5. Install transducer in the 1" PVC transducer access tube two feet above the bottom of the tube. Secure the transducer to the top of the access tube using an S-hook attached to the transducer cable. Tape the cable S-hook to the access tube to ensure the transducer does not move during the test. Do not fold or crimp the cable.
6. If not using a PVC tranducer access tube, install the transducer so that it is at least two feet above the bottom of the well. Secure the transducer to the top of the well casing using an S-hook attached to the transducer cable. Tape the S-hook and cable to the well casing to ensure the transducer does not move during the test. Do not fold or crimp the cable.

NOTE: Care should be taken to place the transducer low enough in the well that it does not come in contact with the solid slug. Ensure that the depth of submergence does not exceed the design range of the transducer. The transducer should remain submerged throughout the test.

7. Connect the transducer to the data logger and connect the data logger to the laptop computer. The laptop computer, using software specific to the data logger, will be used to set up the test and view test data in the field. Enter the initial water level, transducer information, and test information as required. Set the transducer to record at one minute intervals.
8. Measure the depth to water with the eline at 5 minute intervals, comparing with the transducer readings, until the water has returned to the static level. Confirm the static water level in the well by measuring the depth to water three times over a 15-minute period. If the depth to water readings are not the same, continue obtaining depth to water readings until the static water level has been

achieved and verified by three water level measurements each 5 minutes apart. Record depth to water measurements on **Field Form 4 (SOP 30)** and/or in the field logbook.

9. Attach retrieval line to the slug and verify it will not detach during use.
10. Lower the slug into the well such that the bottom of the slug is just above the static water level and mark the retrieval line at the spot where it contacts the top of the well casing. Gently lower the slug into the well such that it is fully submerged, about one foot below the static water level. This is accomplished by lowering the slug an amount that is equivalent to the slug length plus one foot. Mark the retrieval line at the spot where it contacts the top of the well casing and the slug is fully submerged. This mark may be usefull if a slug injection test is also being considered.
11. While the slug is submerged, periodically measure the depth to water with the eline, comparing with the transducer readings, until the water has returned to the original static level. Record depth to water measurements on **Field Form 4 (SOP 30)** and/or in the field logbook.
12. Set transducer to record logarithmically at the start of slug removal. Typical logarithmic measurement frequencies are as follows:

Elapsed Time	Measurement Interval
0 to 2 sec	every 0.2 sec
2 to 20 sec	every 1 sec
20 to 120 sec	every 5 sec
2 to 10 min	every 30 sec
10 min to 120 min (2 hr)	every 2 min
2 hr to end of test	every 10 min
NOTE: if transducers are not used to record water level data, manual measurements using an eline should be done using the same frequency as above except the frequency will be every 30 sec for the first 10 minutes. Record measurements to the nearest 0.01 foot on **Field Form 4** (**SOP 30**) and/or in the field logbook.	

Typical measurement frequency modified from TCEQ (2013). These frequencies should be followed unless otherwise specified in site-specific investigation planning documents such as SAP, FSP, or WP.

13. "Instantaneously" remove the slug from the well to lower the water level. It is important to remove the slug as quickly as possible because the analysis assumes an instantaneous change in water level. This is accomplished by using a retrieval system such as a pulley on a tripod (or suspended from a ladder). It is also important to minimize pressure transients in the well casing caused by raising the slug too quickly. Experience has shown that slug removal should be done with an even extraction rate over a period of less than approximately 5 seconds. Note that slug-injections are more prone to creating pressure transients than slug-withdrawal tests. This is due to the intial impact of the slug on the water surface which causes repeated wave deflections off the well casing.
14. Record the time when the slug is removed from the well in the field logbook.
15. Measure and record the depth to water using the transducer until recovery has reached at least 90% of the pre-test static water level.
16. Remove all slug test equipment from the well. Replace well cap and lock well. Decontaminate slug test equipment, as necessary per site conditions and in accordance with **INTERA SOP 2, *Decontamination***.
17. Back up test data to CDs or flash drives.

The general field procedure for the slug-injection test, which is more appropriate for confined aquifers, is very similar to the procedures specified for the slug-withdrawal test. Rather than than submerging the slug in Step #10, stop when the slug has been lowered it to just above the static water level. Skip Step #11. Then, rather than quickly removing the slug in Step #13, quickly submerge it and follow remaining steps as applicable for slug insertion.

15.4 Data Analysis

Several analytical solution methods are available for analysis of slug test data, such as Bouwer-Rice for unconfined and confined aquifers (Bouwer and Rice,1976; Bouwer, 1989), Cooper-Bredehoeft-Papadopulos for confined aquifers (Cooper et al., 1967; Papadopulos et al., 1973), and Hvorslev for unconfined and confined aquifers (Hvorslev, 1951). Some texts helpful in the analysis of slug-test data include Dawson and Istok (1991), Kruseman and de Ridder (1991), and Fetter (1988).

Where possible, several methods of slug-test analysis are often used to increase confidence in the hydraulic conductivity value(s) at a site. According to Campbell and others (1990), the Hvorslev method produces reasonable approximations of hydraulic conductivity. The Bouwer and Rice method of analysis produces conservatively low, yet internally consistent, values of hydraulic conductivity (Welby, 1992; Brown and

Narasimhan, 1995). It accounts for more of the physical parameters associated with a slug test than the Hvorslev method and compares favorably with the Cooper-Bredehoeft-Papadopulos method (Campbell et al., 1990). The Cooper-Bredehoeft-Papadopulos method is widely used and is considered to be the most technically correct method with respect to the physical parameters affecting a slug test. This method uses a family of type curves in which the type curve that most closely fits the slug test data is selected. The reliability of the results is only as good as the "fit" obtained between the type curve and the field data. It is not uncommon for portions of the field data to fit more than one type curve. In contrast to the other above-mentioned methods, a successful application of the Cooper-Bredehoeft-Papadopulos method requires a greater number of water-level data points over the full duration of the slug test. The Cooper-Bredehoeft-Papadopulos method can also be used to provide storativity values that may be accurate to an order of magnitude, depending on how closely the field data match the particular type curves.

All of the above analytical methods are typically available in software packages such as AQTESOLV™ (2017).

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15.6 Attachments

None.

15.7 Document History

Revision	Effective Date	Lead Author	Summary of Changes
2004.0	1/2004	Taimur Malik	Original version
2004.1	6/2017	Noreen Baker	Revised section **15.5** to **Attachments** for consistency
2004.2	9/2017	Noreen Baker, Gerry Grisak, Barbara Rigney	Revised and updated in preparation for slug tests at TVA Cumberland.

APPENDIX D

Eon Products Inc’s Standard Operating Procedures

Standard Operating Procedures
for
GROUNDWATER SAMPLING USING PASSIVE DIFFUSION SAMPLERS

I. Purpose

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

II. General Materials Requirements

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

III. Diffusion Sampler Function

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

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

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

IV. Diffusion Sampler Installed Depth

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

V. Diffusion Samplers Filled with Deionized Water

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

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

VI. Diffusion Sampler Residence Time Requirements

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

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

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

VII. Diffusion Sampler Installation Assemblies

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

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

B. To order pre-made PDB assemblies, provide the supplier with the following information:

   a. Well identification (ID)
   b. Well diameter
   c. Total depth of well at the time of installment
      (feet below Top of casing (ft bTOC)
   d. Screened interval (ft bTOC)
   e. Number of samplers per well and desired sampling depths of each
   f. Ship-to address and purchase order number (project number)

C. Each standard dedicated diffusion sampling assembly, as provided by the supplier, should include the following:

   a. diffusion sampler bag (disposable)

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

VIII. Filling and Transporting Passive Diffusion Samplers

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

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

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

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

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

IX. Installing Suspension Tethers and Diffusion Samplers

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

a. Unpackage the spooled tether. The weights should be attached to the ring on the leading end of the rope. If not, find the correct weight and attach.

b. Find the Well ID Tag located on the spooled tether. Match the ID tag to the well ID.

c. Place the weighted leading end of the suspension tether into the well and slowly lower until a small diameter (~.50-in) stainless steel ring is located on the tether. A second ring should be located further up the rope at a distance slightly more than the length of the sampler.

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

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

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

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

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

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

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

X. Retrieving and Sampling Diffusion Samplers

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

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

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

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

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

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

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

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

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

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

XI. Decontamination and Disposal

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

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

XII. Other Considerations

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

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

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

VII. References

EON Products, Inc.

Phone: (800) 474-2490

Web: www.eonpro.comEmail:

Email: Info@eoonpro.com

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

United States Geologic Survey (USGS)

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

Interstate Technology Regulatory Council (ITRC)

Passive Sampling team

- **Tech-Reg Document**

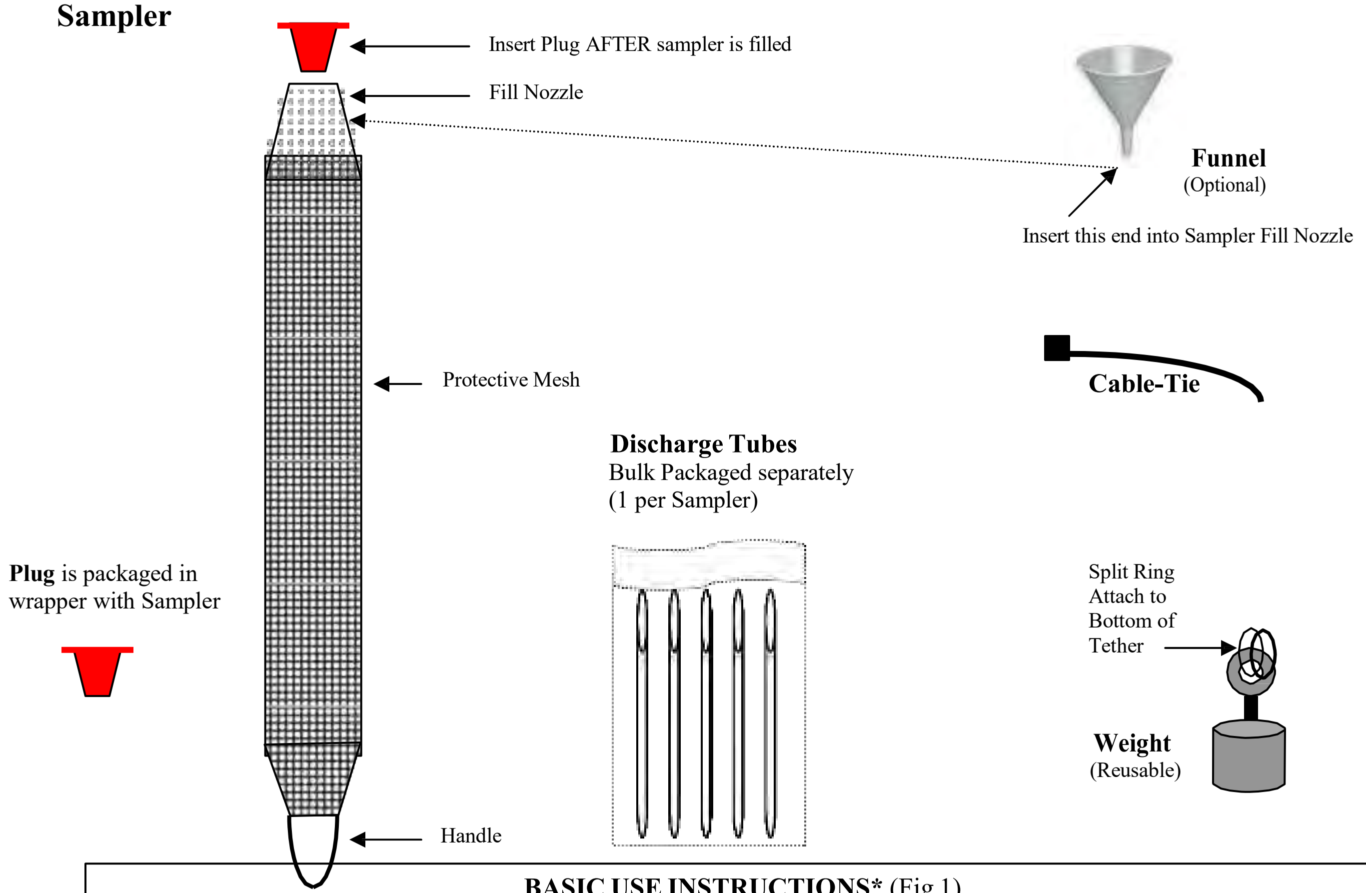
  Technical and Regulatory Guidance Document for Using Polyethylene Diffusion Bag Samplers to Monitor Volatile Organic Compounds in Groundwater (2002)

- **Technology Overview**

  Technology Overview of Passive Sampler Technologies (2006)

EQUILIBRATOR ™
Diffusion Sampler Instructions

Equilibrator Sampler **Accessory Items**



BASIC USE INSTRUCTIONS* (Fig 1)

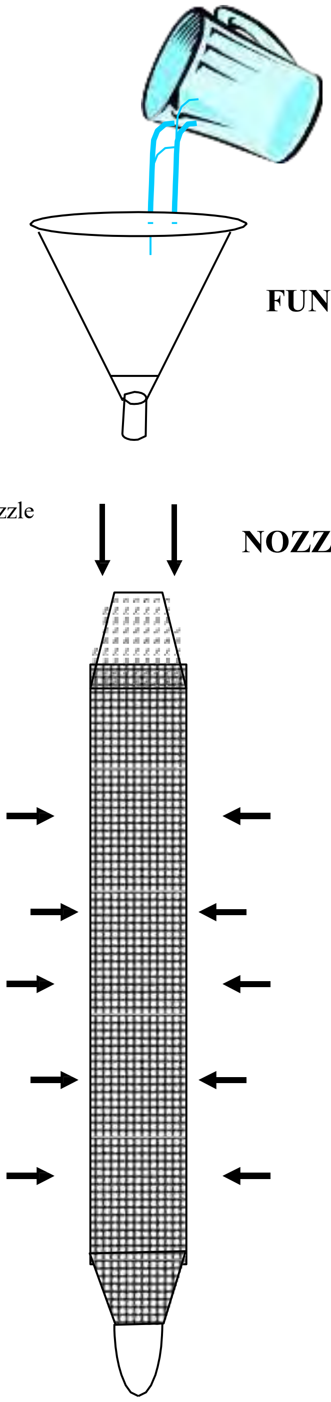
1. **Fill the Sampler with deionized water** until the entire assembly is completely full of water. To use the funnel, insert the tip into the Sampler and pour deionized water into the tube. Fill the Sampler until water rises and stands at least two inches up the funnel to expand the Sampler to its maximum capacity. ***Gently squeeze and add more water to expand the membrane and remove air pockets. Repeat as needed until completely full.*** *Disclosure Statement – When filling the Sampler, we recommend that you hold the Sampler firmly at the top as close to nozzle tip as possible to prevent unnecessary stress on inside poly bag which could cause a leak to develop.*
2. **Insert the Plug firmly into the Sampler,** until the rim of the plug is as close to the nozzle as possible.
3. **Attach a Weight to the bottom of the Tether or Hanger.**
4. **Attach the Equilibrator(s) to the Tether line.** If installing on a factory prepared tether, locate the small (1/2" diameter) stainless steel rings that are attached to the Tether line. The rings will be separated by approximately 2/3 the length of the sampler. Use a Cable-Tie through the lower of two adjacent rings and through handle. Use a second Cable-Tie through upper of two adjacent rings and through a section of mesh below the fill nozzle in the softer part of the filled sampler. Tighten the Cable-Ties and snip off excess. Continue with each Sampler. If the factory did not prepare the Tether, then securely attach the Sampler(s) to the tether using cable ties at the intended location(s).
5. **Lower the Tether with Sampler(s) attached into the well.** Locate Sampler(s) below the water surface, in the screen flow zone of the well. Attach the top of the suspension cord to a well cap or other secure location at the top of the well. Leave Sampler in place for a time suitable for equilibration, a minimum of 2 weeks required.
6. **Upon retrieval: Discharge sample immediately** to avoid loss of volatile compounds. Select a point on the Sampler near the handle/bottom of sampler. Press one end of the Discharge Tube firmly into the clear polyethylene membrane at a downward angle until it pierces the membrane. ***Discharge small amount to waste to purge discharge tube.***

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

800-474-2490

EQUILIBRATOR ™
Diffusion Sampler Instructions

STEP 1



2. Pour DI Water into Sampler

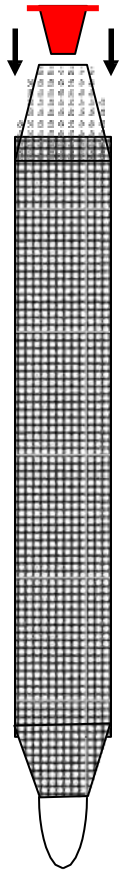
FUNNEL

1. Insert Fill Funnel into Sampler Nozzle

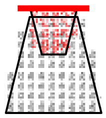
NOZZLE

3. Squeeze Sampler & release multiple times to release air and expand volume. Add water & repeat as needed to fill.

STEP 2



1. Press Plug firmly into nozzle



PRESS PLUG INTO NOZZLE UNTIL RED RIM TOUCHES WHITE NOZZLE

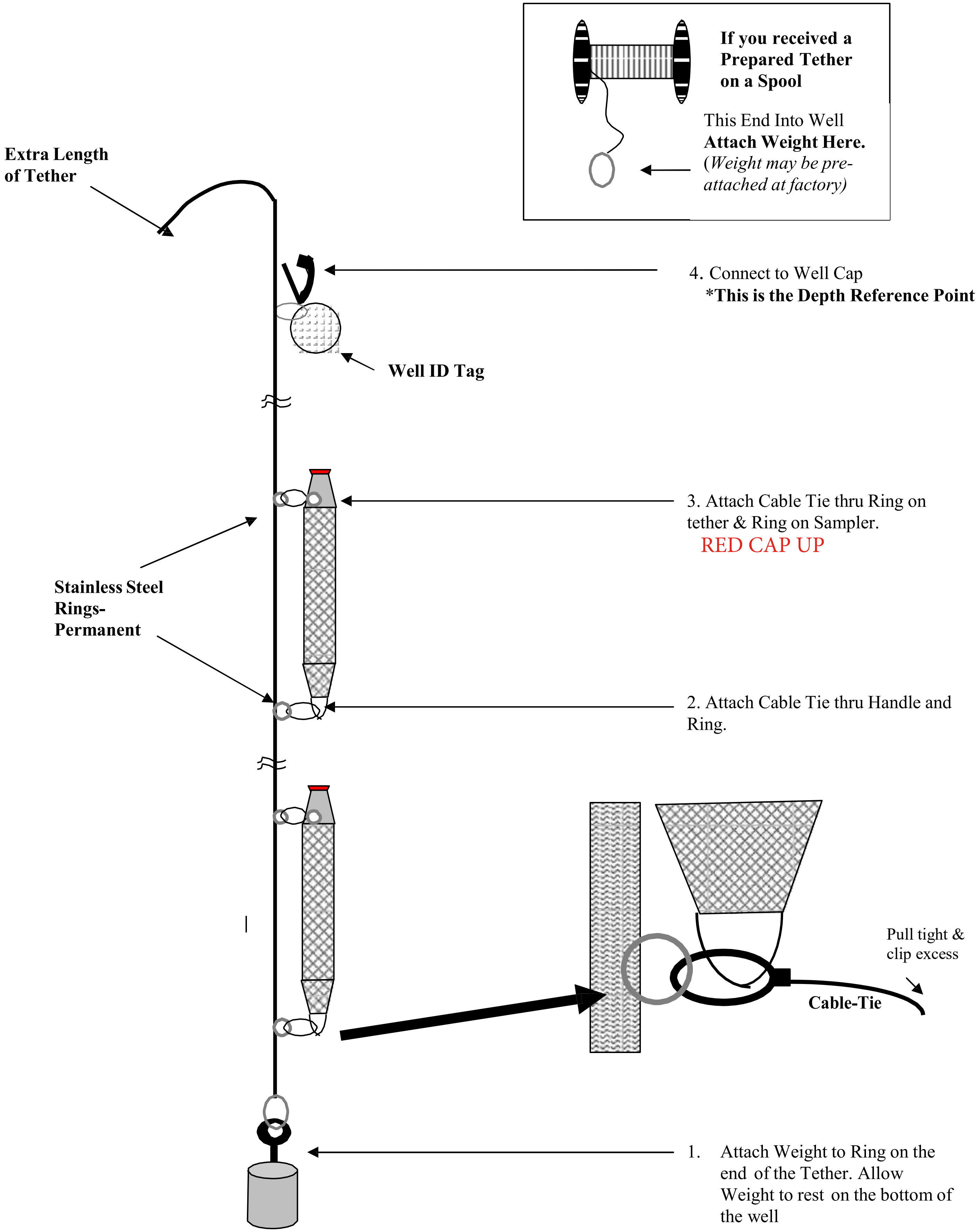
1. Fill the Sampler with deionized water until the entire assembly is completely full of water. To use the Funnel, insert the short nozzle into the Sampler and pour deionized water into the tube. Fill the Sampler until water rises and stands at least two inches up the funnel to expand the Sampler to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

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

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

EON PRODUCTS INC.

EQUILIBRATOR ™
Diffusion Sampler Instructions



If you received a Prepared Tether on a Spool

This End Into Well
Attach Weight Here.
(*Weight may be pre-attached at factory)*

4. Connect to Well Cap
   ***This is the Depth Reference Point**

3. Attach Cable Tie thru Ring on tether & Ring on Sampler.
   RED CAP UP

2. Attach Cable Tie thru Handle and Ring.

1. Attach Weight to Ring on the end of the Tether. Allow Weight to rest on the bottom of the well

EON PRODUCTS INC.

EQUILIBRATOR™
Diffusion Sampler Instructions

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

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

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

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

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

Why Use a Blank?

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

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

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

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

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

800-474-2490

Discharging a Sample from the Equilibrator™ Passive Diffusion Sampler

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

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

Hints:

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

EQUILIBRATOR™
Diffusion Sampler Instructions

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

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

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

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

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

Why Use a Blank?

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

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

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

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

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

800-474-2490

Procedure for use of Dual Membrane Passive Diffusion Samplers (DMPDBs) in Groundwater Monitoring Wells

Compounds of Concern, Sample Volume, Sampler Placement

1. Verify that the compounds of concern (COC) to be sampled are compatible with the DMPDB sampling method.
    a. Most standard COCs may be sampled, including; VOCs, Semi-VOCs, Metals, Ions, Inorganics, 1,4 dioxane and PFAS.
2. Determine the lab minimum volume requirements for analysis of the COC and verify that the sampler selected provides at least the required volume.
    a. Lab sample volume requirements vary by lab and method[1]
3. Verify that the wells to be sampled are completed with 2-inch schedule 40 or larger casing and screen or at least 2-inches in borehole diameter if completed in fractured bedrock.
4. For wells completed in unconsolidated materials with well screen, verify:
    a. The water level before placing or removing samplers.
        i. If the well contains DMPDBs or other passive samplers that are secured to the well cap only remove the cap far enough to allow entry of the water level probe and so the DMPDB's do not come out of the water as that will change the water level.
    b. The intended sample zone is within the saturated portion of the well screen and,
    c. There is an adequate saturated screen interval to accommodate a weight below the DMPDB and a minimum of 3 to 6-inches of saturated screen above the top of the DMPDB when installed at the sampling interval and,
    d. That the sampler will remain completely submerged during groundwater fluctuation that may occur.
    e. No portion of the DMPDB is exposed to the air or is in the casing when installed at the sample interval.
5. For wells completed in open boreholes and fractured rock, verify;
    a. The water level before placing or removing samplers.
        i. If the well contains DMPDBs or other passive samplers that are secured to the well cap only remove the cap far enough to allow entry of the water level probe and so the DMPDB's do not come out of the water as that will change the water level.
    b. The intended sample zone is within the saturated portion of the well and preferably, adjacent to known cracks or fissures that may contribute water to the well,
    c. There is water in the open borehole to accommodate a weight below the DMPDB and a minimum of 3 to 6-inches of well water above the top of the DMPDB when installed at the sampling interval and,
    d. That the sampler will remain completely submerged during groundwater fluctuation that may occur.
    e. No portion of the DMPDB is exposed to the air or is in the casing when installed at the sample interval.

Sampler Locations, Number of Samplers, Profiling, Duplicates

6. For a first-time installation of passive samplers of any type, in wells with saturated sampling intervals of 10-feet or longer, AND in which there is no historical or interval related sample chemistry data, consideration should be given to installing at least two samplers to determine whether there is vertical stratification of compounds and/or concentration across the saturated screen. The information from one round of sampling using multiple samplers to profile the well can be used to select optimum sampler placement for one sampler for future events, or whether multiple intervals should be monitored in keeping with project Data Quality Objectives (DQOs).

   a. When larger well fields, with similar well construction and aquifer details are monitored, it may be sufficient to select several representative wells for profiling and use the results for selecting sampler placements across the field, rather than profile each well.
   b. When profiling, at a minimum place one DMPDB in the upper 5-feet of the saturated screen sample interval and one in the bottom 5-feet of the saturated sample interval. Additional samplers may be installed mid-interval for more detailed profiling. It is generally accepted that *without previously obtained information about well conditions and potential contaminant stratification,* one passive sampler should not be called on to represent more than a 5-foot interval. Alternatively, known information about the well may suggest that a single sampler will accurately represent sample intervals of 20 feet or more.

7. Multiple DMPDBs may be used in a well to continuously profile the well and monitor discrete intervals.
   a. In wells where multiple DMPDBs are to be installed in series along the length of saturated screen to profile the well, verify that the criteria in #2 or #3 above are met for each DMPDB installed.
8. For wells having diameters of 2-inches or larger, duplicate samples may be obtained by placing two or more DMPDBs in series, one above the other, in the sample interval and the placement criteria in #2 or #3 above are met for all samplers. For wells having diameters of 4-inches or larger, duplicate samples may be obtained by placing two or more DMPDBs side by side at the same sample interval.

Suspension Tethers

9. DMPDB samplers should be installed on a weighted suspension tether that has been configured to match the well depth, sample interval and method of attaching to the well cap at the top of the well. Tethers should be constructed of polypropylene, stainless steel or other chemically resistant material and are considered re-usable if properly constructed. Nylon is to be avoided because it absorbs water and elongates, and is often dusted with whiteners for appearance.
   a. EON provides inexpensive custom Suspension Tether manufacturing that includes weights, sampler attachment points on the tether at the selected sample interval, Well ID tags, Well Caps to which the tether is attached and a spool for winding the tether when retrieving.
   b. For most installations, the tether is configured so that the weight is attached to the bottom of the tether and rests on the bottom of the well.
      i. The weight should be selected to overcome the slight buoyance of samplers and the effects of friction as the DMPDBs are lowered into position.
      ii. In most cases a minimum of 20 ounces of weight is recommended.
      iii. Weights should be made of stainless steel.
   c. Attachment points are typically made of small diameter stainless steel rings attached to the tether so as to be secure, on at a location for the top of the sampler and one for the bottom of the sampler, so that when the sampler is attached to both rings and the weight is resting on the well bottom, the sampler is in the designated sample interval.
   d. DMPDB samplers are attached to the connection points using zip-ties. (see # 13 below)
   e. Temporary or field installed attachment loops may be constructed using a short (4 to 8-inches) zip-tie, through the braid of the tether, formed into a loop about 0.50-inch diameter.
   f. An optional Well ID tag should be attached to the tether at the location of the reference (or 0.00-ft) measuring point.

- g. The Well Cap should be fitted with a ring or “eye” screw fitted into the bottom of the cap and strong enough to hold the DMPDB samplers when installed. The top of the tether is connected to the ring on the well cap at a position that allows the bottom weight to rest on the bottom of the well with minimum slack in the line.

DMPDB Sampler Preparation, Filling, Installing

10. The DMPDB sampler should be prepared for use by carefully removing it from the protective wrapper, being careful not to cut or puncture the membranes that run along the length of the sampler.
    - a. Remove the Red Cap and locate the fill kit (funnel with extension tube).
    - b. Find the small package of “juice-box” straws packaged in bulk with the DMPDB and place them in a location where they will be available when the samplers are removed from the well for sampling.
    - c. Find the small package of Zip-Ties packaged in bulk that will be used to attach the DMPDBs to the tether line during installation.
11. Rinse the funnel with deionized water and insert the extension tube into the white nozzle at the top of the sampler. The bottom of the extension tube should be at or lower than the bottom of the upper membrane which is at the location of the securing band around the sampler about 6-inches from the top of the sampler. Hold the DMPDB in the vertical orientation with the white nozzle up.
    - a. DMPDB samplers may optionally be rinsed with deionized water if protocols require, however, because the DMPDB is in residence long enough to equilibrate with the surrounding water, it is unlikely that any “incidental” contact with the environment will affect the sample representation.
    - b. For the standard DMPDB with the mesh-type upper membrane, fill the sampler with deionized water (typically ASTM Type-1) to the top of the securing band or until water starts to seep out the sampler. The upper membrane is not to be filled. (Other membrane combinations of the DMPDB may be filled to the top)
    - c. Make sure the bottom “tail” of the sampler has water in it by alternately squeezing the air out of the tail and “bouncing” the sampler slightly.
12. Holding the DMPDB around the white nozzle, place the Red Cap in the Nozzle and press it fully into the Nozzle with the palm or thumb of the hand. If that proves too difficult, use a small rubber mallet, and gently tap the cap firmly into place.
    - a. Filled samplers can be temporarily stored in an upright position using clean 5 -gallon pails or other, suitable container or hang from a tripod by the vertical strap.
13. Before installing the DMPDBs, secure the top of the tether to the well cap connection point to prevent the tether from accidentally slipping into the well. The tether can also be tied-off to a tripod or other stationary device. It is recommended that the well cap be attached to the top of the tether as a protection against losing the tether down the well.
14. Place the weighted end of the tether inside the well casing and lower until the first attachment ring is above the top of the casing.
15. If multiple DMPDB samplers are to be installed on the same tether, start by installing the bottom DMPDB first. Pick up a filled DMPDB, keeping it in the vertical position and attach the DMPDB alongside suspension tether using two zip-ties as follows;
    - a. At the bottom of the DMPDB is a stainless-steel ring. One zip-tie is attached through the ring on the DMPDB and through the bottom connection ring on the tether.

- b. One zip-tie is placed around the black vertical strap above the top of the DMPDB and through the second ring on the tether and zipped tightly so as not to slip upward past the stop-block on the black strap. Photographic instructions are provided by EON.
- c. If multiple PDBS are installed in one well, lower the tether as each sampler is attached to the tether, attach the next DMPDB and repeat until all are attached.
- d. Continue lowering the tether until the well cap can be secured to the top of the casing. Place any extra rope (often there is extra tether above the well cap to facilitate field adjustments) into the casing below the well cap. The well cap should be secured so that surface water runoff does not enter the well during sampling. Tether line should not be placed between the cap and casing as this presents a water pathway.

Residence Time, Sample Recovery

16. The samplers should be left in place, undisturbed for a residence time that allows for diffusion of COCs to reach equilibrium between the groundwater flowing through the well and the contents inside the DMPDB. Because diffusion is driven by concentration gradients, the sampler will maintain equilibrium with the groundwater if well concentrations change. Each COC has its own rate of diffusion so there will be a lag time of a few hours to a few days to regain equilibrium if well concentrations changes occur rapidly. After the initial equilibration period, the DMPDB will always represent the concentration of each COC during the past 1 to 7 days. Generally recommended minimum residence times, taking into account the disturbance occurring to flow in the well when samplers are installed and equilibration time through the membranes;
    - a. VOCs Minimum: two weeks
    - b. Semi-VOCs, Inorganics, Metals, Ions, Minimum: three weeks
    - c. 1,4-Dioxane, PFAS, Minimum: three weeks (may be les for fast recharge wells)
    - d. As a cost saving measure, it is recommended that samplers be installed during one event and left in place until the next event. At the next event, the sampler is recovered, sampled and a new sampler installed. This reduces field mobilizations.
17. Immediately prior to sampler recovery and before removing samplers from the well, the water level in the well should be measured.
18. Remove the DMPDB samplers by first un-securing the well cap and pulling the tether upward from the well until the first DMPDB appears.
    - a. Take care to secure the tether as it is being pulled up to prevent it, and the sampler(s) from slipping down the well.
    - b. Take care to keep the tether clean and away from contamination.
    - c. The use of spool is recommended to hold tether as it is being removed from the well.
19. Follow guidelines and protocols for sample handling
    - a. Decant the DMPDB (see below) immediately upon remove from the well. Do not leave samplers in the air, buckets coolers, etc prior to sampling.
    - b. As with all sampling methods, do not discharge DMPDB samplers near sources of contamination, including airborne compounds, auto exhaust, etc.
    - c. Handle all lab containers and samples according to protocols.
20. Grab the DMPDB near the top of the sampler and around the white nozzle, keeping it vertical while lifting it out of the well. Follow cleanliness and sample handling protocols established for the site.

a. When multiple DMPDBs are on the same tether, if possible, leave the lower samplers in the well while decanting from each upper sampler.
b. Using a set of snips, carefully cut the zip-ties that secure the sampler to the tether rings or loops. If using zip-tie loops through the tether do not cut those, only cut the ties that connect between the sampler and the loop or tether connection ring.
c. Alternately, secure the tether with the DMPDB from one of the arms of a tripod so the sampler is securely hanging in the air.
d. Place a bucket under the DMPDB to capture small amounts of sample water that may release during sampling.
e. Open the lab provided sampling containers to be filled by this sampler and place them closely nearby.
f. Locate the small diameter "juice-box" straws that were packaged with the samplers.
g. Hold the DMPDB vertical and select a location about 1/3rd to ½ way down the filled length.
h. Taking one straw, point the straw away from any person and pierce through the membrane and the perforated tube at the selected location. It may require a small amount of force and finesse to pierce the membrane and push through the perforated tube.
i. Immediately place the sample container under the straw and fill the container. The straw and sampler may be manipulated up and down or tilting to control the flow. Squeezing the water from the "tail" Control will improve with practice.
j. When the DMPDB has drained to the level of the straw and flow ceases, remove the straw, and pierce the membrane again lower on the sampler body to obtain more sample.
k. When sampling is complete, dispose of sampler according to local and project requirements.

Install New DMDPB Samplers

21. Reinstall new samplers while the tether is removed from the well, following installation procedures beginning at #10 above.

Passive Sampling References:

These references explain the principles that apply to passive groundwater sampling in general and contain information about specific passive sampling methods and devices that may or may not be commercially available.

- User's Guide for Polyethylene-Based Passive diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells. Don A. Vroblesky, U.S. Geological Survey, 2001

- Technical and Regulatory Guidance for Using Polyethylene Diffusion Bag Samplers to Monitor Volatile organic Compounds in Groundwater. ITRC, February 2004

- Results Report for the Demonstration of No-Purge Groundwater Sampling Devices at Former McClellan Air Force Base, California. Parsons, October 2005

- Technology Overview of Passive Sampler Technologies, ITRC March 2006

- Protocol for Use of Five Passive Samplers to Sample for a Variety of Contaminants in Groundwater, ITRC, February 2007

- Passive Sampling of Groundwater Wells for Determination of Water Chemistry, Imbrigiotta, T.E., and Harte, P.T., 2020 U.S. Geological Survey, 2020

- ITRC Fact Sheet: Sampling and Analysis 1,4 Dioxane, ITRC, March 2020

- Laboratory Bench Test and Side bu Side Field Comparison of Results for the DMPDB. Various references, EON Products, Inc. https://www.eonpro.com/documents-resources/

Footnotes:

1. Minimum Lab Sample Volume Requirements Table, Protocol for Use of Five Passive Samplers to Sample for a Variety of Contaminants in Groundwater, Appendix A, ITRC, February 2007