7.4.1 The most predominant liner material in used is clear medical grade Polyvinyl Chloride (PVC). The clear liner has the advantage of exposing the soil core to visual examination after recovery. Smearing of soil in the liner does occur and liners should be opened and examined and required subsamples taken. Liners are available in plastics, TFE-fluorocarbon, brass, and stainless steel. Other materials can be used as testing needs dictate, however, since there is limited concern when immediate subsamples are taken on chemical test results, there may be no need for more expensive non-reactive liner materials such as TFE-fluorocarbon or brass. Verify that liner materials meet local regulatory requirements and specifications in the project sampling plan and quality assurance plan.

7.5 *Cutting Shoes*—The Cutting Shoe is one of the most important parts affecting the quality and Recovery (9.5.4) of the soil specimens. General purpose cutting shoes work well in most formations but if core recovery is poor, then one should change the cutting shoe and liner design to optimize the sample recovery and quality. The Clearance Ratio (Ratio of ID of Cutting Shoe to ID of Liner) is the most important parameter for optimizing sample recovery and quality. In general higher clearance ratios are required in dense soil formations while lower ones can be used in softer formations. The cutting angle of the shoe also influences the sample quality. Sharper cutting shoes work better in fine grained formations but they are not as durable. Appendix X1 gives additional information on Cutting Shoe design. Contact your manufacturer if you have questions regarding recovery and quality issues.

7.6 *Sample Containers*—Sample containers should be prescribed according to the anticipated use of the sample specimen. Samples taken for chemical testing may require clean containers with specific preservatives (see 5.2). Practice D3694 and EPA SW-846 (**4**) provides information on some of the special containers and preservation techniques required for these containers generally will be cleaned to specific criteria. Samples for geotechnical testing require certain minimum volumes and specific handling techniques. Practice D4220 offers guidance for sample handling of samples submitted for geotechnical physical testing.

7.7 *Direct Push Power Sources*—Soil probing percussion driving systems, penetrometer drive systems, and rotary drilling equipment may be used to drive casings and direct push soil sampling devices. The equipment should be capable of applying sufficient static force, or dynamic force, or both, to advance the sampler to the required depth to gather the desired sample. The system must have adequate retraction force to remove the sampler and extension/drive rods once the selected strata has been penetrated. Rotation of the drill string can be added during insertion, as well as during retraction if the drive system can impart rotation.

7.7.1 *Retraction Force*—The retraction force can be applied by direct mechanical pull back using the hydraulic system of the power source; line pull methods using mechanical or hydraulic powered winches, or cathead and rope windlass type devices. Winches used with direct push technology should have a minimum of 900 kg [2000 lb] top layer rating capacity and a line speed of 120 m/min [400 ft/min] to provide effective tool handling. Direct push sampling tools can be retracted by back pounding using weights similar to those of standard penetration testing practices. Backpounding to recover samples can affect recovery and cause disturbances to the sample. Other forms of extraction, such as jacking, that do not cause undue disturbance to the sample, are preferable.

7.7.2 *Percussion Devices*—Percussion devices for use with direct push methods are hydraulically-operated hammers, air-operated hammers, and mechanically-operated hammers. Hydraulically-operated hammers should have sufficient energy to be effective in moving the samplers through the subsurface strata. The maximum energy application is dependent on the tools used. Hammer energy that exceeds tool tolerance will result in tool damage or loss and will not achieve the goal of collecting high quality samples. Air-operated hammers should be capable of delivering sufficient energy, as well. Hammer systems utilizing hydraulic oil or air should be operated in the range specified by the manufacturer. Manually-operated hammers can be used to advance direct push tools. These hammers can be operated mechanically or manually using cathead and rope. These systems generally involve using 63.5 kg [140 lb], standard penetration (see Test Method D1586) hammers, which can work well for direct push sampling. In operation, these hammers tend to be slower than hydraulic hammers and can cause tool damage if direct push tools are not designed to take the heavy blows associated with these hammers. The hydraulic- and air-operated hammers strike up to 2000 blows/min. In addition to the energy transferred, the rapid hammer action sets up a vibratory effect, which also aids in penetration. This vibratory effect, along with the percussive effort, may disturb some soil samples.

7.7.3 *Static Push Systems*—Cone penetrometer systems are an example of static push systems. They impart energy to the sampler and extension rods by using hydraulic rams to apply pressure. The pressure applied is limited to the reactive weight of the drive vehicle. Some portable systems use screwed in augers to anchor the machine for CPT testing (D6067). The earth augers provide the reaction force to advance the CPT probe. Retraction of the sampler and extension rods is by static pull from the hydraulic rams.

7.7.4 *Vibratory/Sonic Systems*—Sonic systems (D6914) utilize a vibratory device, which is attached to the top of the sampler extension rods. Reactive pressure and vibratory action are applied to the sampler extensions moving the sampler into the formation. In certain formations, sample recovery and formation penetration is expedited; however, all formations do not react the same to vibratory penetration methods.

7.7.4.1 *Sonic or Resonance Drilling Systems*—These are high powered vibratory systems that can be effective in advancing large diameter single or dual tube systems. They generally have depth capabilities beyond the smaller direct push systems.

7.7.5 *Rotary Drilling Equipment*—Direct push systems are readily adaptable to rotary drill units (D6286). The drill units offer a ready hydraulic system to operate percussion hammers, as well as reactive weight for static push. Drill units with direct push adaptations also offer drilling techniques should obstacles be encountered while using direct push technology. Large drill units may have reactive weights that can exceed the tool capacity, thereby resulting in damaged tools. Typical rotary drilling equipment is larger and more massive than smaller direct push equipment which can lead to limitations with site access and slower relocation times.

8. Conditioning

8.1 *Decontamination*—Sampling equipment that will contact the soil to be sampled should be cleaned and decontaminated before and after the sampling event (D5088). Extension rods should be cleaned prior to each boring to avoid the transfer of contaminants and to ease the connecting of joints. Thread maintenance is necessary to ensure long service life of the tools. Sample liners should be kept in a sealed or clean environment prior to use. All ancillary tools used in the sampling process should be cleaned thoroughly, and if contaminants are encountered, decontaminated before leaving the site. It should not be assumed that new tools are clean. They should be cleaned and decontaminated before use. Decontamination should be performed following procedures outlined in Practice D5088 along with any site safety plans, sampling protocols, or regulatory requirements.

8.2 *Tool Selection*—Prior to dispatch to the project site an inventory of the necessary sampling tools should be made. Sample liners, containers, sampling tools, and ancillary equipment should be checked to ensure its proper operation for the work program prescribed. Sampling is expedited by having two or more samplers on site. Since samples can be recovered quite fast, a supply of samplers will allow a boring to be completed so other functions can be performed while samples are being processed. Various Cutting Shoes and Liners should be available to optimize soil sampling Recovery and quality on site. A backup tool system adaptable to and within the capabilities of the power source should be available should the original planned method prove unworkable. Materials for proper sealing of boreholes should always be available at the site (D6011 section 9 Completion)

9. Procedure

9.1 While procedures for direct push soil sampling with two common direct push methods are outlined here, other systems may be available. As long as the basic principles of practice relating to sampler construction and use are followed, other systems may be acceptable.

9.2 *General Set-Up*—Select the boring location and check for underground and overhead utilities and other site obstructions. Establish a reference point on the site for datum measurements, and set the direct push unit over the boring location. Stabilize and level the unit, raise the drill mast or frame into the drilling position, and attach the hammer assembly to the drill head if not permanently attached. Attach the anvil assembly in the prescribed manner, slide the direct push unit into position over the borehole, save a portion of the sliding distance for alignment during tool advancement, and ready the tools for insertion.

9.2.1 *Tool Preparation*—Inspect the direct push tools before using, and clean and decontaminate as necessary. Inspect drive shoes for damaged cutting edges, dents, or thread failures as these conditions can cause loss of sample recovery and slow the advancement rate. Where permissible, lubricate rod joints with appropriate safe products, but clean water only may be the best option. Many organic lubricants can result in interferences with analytical tests to be performed on the collected samples (**22**). Verify that any lubricants used will not cause analytical interference or result in false positives before applying to the tools. Check impact surfaces for cracks or other damage that could result in failure during operations. Assemble samples and install where required, install sample retainers where needed, and install and secure sampler pistons to ensure proper operation where needed.

9.2.2 *Sample Processing*—Sample processing should follow a standard procedure to ensure quality control requirements are met (5.2). View sample in the original sampling device, if possible. Open the sampling device with care to keep disturbance to a minimum. When using liners or thin wall tubes, protect ends to prevent samples from falling out or being disturbed by movement within the liner. Measure recovery accurately, containerize as specified in the work plan or applicable ASTM procedures, and label recovered samples with sufficient information for proper identification. When collecting samples for volatile chemical analysis, sample specimens must be contained and preserved as soon as possible to prevent loss of these components. Follow work plan instructions or other appropriate documents (see Practice D6640) when processing samples collected for chemical analysis.

9.3 *Dual Tube System*—Assemble the outer casing with the cutting/drive shoe on the bottom. Assemble the sampler and liner, if used, and attach the sampler to the extension rods. Connect the drive head to the top of the sampler extension rods, and insert the sampler assembly into the outer casing. Position the outer casing and sampler assembly under the drill head, and move the drill head downward to bring pressure on the tool string. If soil conditions allow, advance the sampler/casing assembly into the soil at a steady controlled rate slow enough to allow the soil to be cut by the shoe and move up inside the sample barrel. If advancement is too rapid, it can result in loss of recovery because of soil friction and plugging in the shoe. Occasional hammer action during the push may help recovery by agitating the sample surface. If soil conditions prevent smooth static push advancement, activate the hammer to advance the sampler. Apply a continuous pressure while hammering to expedite soil penetration. The pressure required is controlled by subsurface conditions. Applications of excessive down pressure may result in the direct push unit being shifted off the borehole causing misalignment with possible tool damage. Stop the hammer at completion of advancement of the measured sampling barrel length. Release the pressure and move the drill head off the drive head. Attach a pulling device to the extension rods or position the hammer bail and retrieve the sampler from the borehole. At the surface remove the sampler from the extension rods and process. Soil classification is accomplished easily using split barrel samplers as the specimen is available readily for viewing, physical inspection and subsampling when the barrel is opened. However, unnecessary exposure of the sample to the atmosphere will lead to loss of volatile contaminants. If Liners are used they should be split of sections removed for soil classification and subsampling. Clean, decontaminate, and reassemble the sampler. Reattach the sampler to the extension rod, add the necessary extension rod and outer casing to reach the next sampling interval, and sound the borehole for free water before each sample interval. If water is present, it may be necessary to change sampling tools and select a sealed Single Tube sampler . Unequal pressure inside the casing may result in blow-in of material disturbing the soil immediately below the casing. Lower the sampler to its proper position, add the drive heads, and repeat the procedure. If it is desired that the pass through certain strata without sampling, install an extension drive point in lieu of the sampler (see Fig. 5). When the sampling interval is reached, remove the point and install the sampler. Advance the sampler as described. Upon completion of the borehole, remove the outer casing after instrumentation has been set or as the borehole is sealed as described in Section 10.

9.3.1 *Dual Tube System—Other Samplers:*

9.3.1.1 *Thin Wall Tubes*—Thin wall tubes (Practice D1587) can be used with the dual tube system. Attach the tube to the tube head using removable screws. Attach the tube assembly to the extension rods and position at the base of the outer casing shoe protruding a minimum of 6.25 mm [0.25 in.] to contact the soil ahead of the outer casing. Advance the tube, with or without the outer casing, at a steady rate similar to the requirements of Practice D1587. At completion of the advancement interval, let the tube remain stationary for 1 min. Rotate the tube slowly two revolutions to shear off the sample. Remove the tube from the borehole, measure recovery, and classify soil. The thin wall tube can be field extruded for on-site analysis or sealed in accordance with Practice D4220 and sent to the laboratory for processing. Samples for environmental testing generally require the subsampling and preservation of samples in controlled containers. Soil samples generally are removed from the sampling device for storage and shipping. Thin wall tubes should be cleaned and decontaminated before and after use.

9.3.1.2 *Sealed Single Tube Piston Sampler*—A Sealed Single Tube piston sampler can be used inside the Dual Tube system. This type of sampler may be required when 1.) there is water level inside the Dual Tube and a chemical testing requires virtually no possibility of cross contamination, or 2.) when the borehole becomes unstable and the continued use of the open tube sampling system cannot assure a sample of the native soils without other slough or heave in the recovered sample. Follow the section 9.4 for operation of Single Tube samplers inside of the Dual Tube.

9.3.1.3 *Open Barrel Samplers*—Use Open Single Tube barrel samplers (Figure 5 a) in advance of the outer casing where the soil conditions could cause swelling of split barrel samplers, or where friction against the outer casing precludes its advancement and sampling must still be accomplished. The sampler requires the use of liners for removal of the sample. The sampler must be cleaned and decontaminated before use.

9.3.1.4 *Standard Penetration Test Split Barrel Sampler (D1586)*—Attach the split spoon to an extension rod or drill rod. Using a mechanical or hydraulic hammer drive the sampler into the soil the desired increment, as long as that increment does not exceed the sampler chamber length. Remove the sampler from the borehole, disassemble, and process sample. Standard split barrel samplers can be used, as long as borehole wall integrity can be maintained and the additional friction can be overcome. If caving or sloughing occurs, the sampler tip should be sealed or other sampling tools used

9.4 *Single Tube System—*

9.4.1 *Sealed Sampler (see Figs. 3-7)*—Insert or attach the sample liner to the shoe, and insert the assembly into the solid barrel sampler. Install sample retaining basket if desired. Attach the latch coupling or sampler head to the sampler barrel, and attach the piston assembly with point and "O" rings if free water is present, to the latching mechanism or holder. Insert the piston or packer into the liner to its proper position so the point leads the sampler shoe. Set latch, charge packer, or install locking pin, and attach assembled sampler to drive rod. Add drive head and position under the hammer anvil. Apply down pressure, hammer if needed, to penetrate soil strata above the sampling zone. When the sampling zone is reached, insert the piston latch release and recovery tool, removing the piston, or insert the locking pin removal/extension rods through the drive rods, turn counterclockwise, and remove the piston locking pin so the piston can float on top of the sample, or release any other piston holding device. Direct push or activate the hammer to advance the sampler the desired increment. Retrieve the sampler from the borehole by withdrawing the extension/drive rods. Remove the shoe, and withdraw the sample liner with sample for processing. Clean and decontaminate the sampler, reload as described, and repeat the procedure. Extreme stress is applied to the piston when driving through dense soils. If the piston releases prematurely, the sample will not be recovered from the correct interval, and a resample attempt must be made. The piston sampler can be used as a re-entry grouting tool for sealing boreholes on completion if it is equipped with a removable piston.

9.5 *Quality Control:*

9.5.1 *Quality Control*—Quality control measures are necessary to ensure that sample integrity is maintained and that project data quality objectives are accomplished. By following good engineering principles and applying common sense, reliable site characterizations can be accomplished.

9.5.2 *Water Checks*—Water seeping into the direct push casing or connecting rods from contaminated zones may influence testing results. Periodically check for groundwater before inserting samplers into borehole or into outer casings in the two tube system. If water is encountered, it may be necessary to switch to the sealed piston type samplers to protect sample integrity. Sealed piston type samples may not always be water tight. Sealing of rod or casing joints can prevent groundwater from entering through the joints.

9.5.3 *Datum Points*—Establishment of a good datum reference is essential to providing reliable sample interval depths and elevators. Select datum reference points that are sufficiently protected from the work effort, and that can be located for future reference. Field measurements should be to 0.1 ft (3.05 mm). Measure extension rods as the bore advances to locate sample depth. Mark rods before driving each sample interval to determine accurate measurement of sample recovery and to accurately log borehole depth.

9.5.4 *Sample Recovery*—Record and report sample recovery for every sampling event. The Recovery is defined as the recovered sample length divided by the push/drive length as a percent. Sample recovery should be monitored closely and results documented. Poor recovery could indicate a change in sampling method is needed, that improper sampling practices are being conducted, or that sampling tools are incorrect. Adjust Cutting Shoes and liners to optimize sample recovery in the field (see 7.5 and Appendix X1). Sample recovery involves both volume and condition. Poor sample recovery should cause an immediate review of the sampling program.

9.5.5 *Decontamination*—Follow established decontamination procedures. Taking shortcuts may result in erroneous or suspect data.

9.5.6 *Equipment Rinsate Samples*—Equipment rinsate samples should be collected from decontaminated samplers Periodically during the sampling program in accordance with the quality assurance plan requirements. Clean water of known quality is poured over and through the assembled or partially assembled sampler so that all surfaces having potential sample contact, including liners, are rinsed. The rinse water is collected in the appropriate clean sample containers and preserved for analysis. The rinsate samples should be analyzed for the same analytes as the soil and sediment samples or groundwater samples. The rinsate samples will provide documentation that decontamination procedures are adequate and that cross contamination is controlled. For high priority sites and large projects it may be prudent to have rinsate samples analyzed on a quick turn-around basis to verify that sample integrity is maintained during the sampling program.

9.5.7 *Replicate Borings*—It is recommended that at a minimum one in twenty borings be replicated to provide some basic quality control on the repeatability of the boring and sampling process. Spacing between replicate borings should be on the order of 3 to 5 ft [1 to 1.5 m]. The same sampling techniques and tooling should be used in the replicate boring. This practice also will provide insight into: 1) lateral variability of soil and sediment strata and 2) heterogeneity of contaminant distribution for geo-environmental investigations.

10. Completion and Sealing

10.1 *Completion*—For boreholes receiving permanent monitoring devices, completion should be in accordance with Practice D5092, Guide D6724 or Practice D6725, site work plan, and or regulatory requirements.

10.2 *Borehole Sealing*—Seal direct push boreholes to minimize preferential pathways for containment migration. State regulations will generally prescribe acceptable grout mixtures and placement techniques; refer to local regulations for the state or county where the work is conducted. Additional information and guidance on borehole sealing can be found in Guide D5299, D6001 and Practice D6725. Recent work (Lackey et al., 2009 (**23**), Ross 2010 (**24**)) have found that bentonite slurries often will dessicate and crack when emplaced in the vadose zone, especially in semi-arid to arid settings. When sealing boreholes in the vadose zone it was found that neat cement, cement-sand mixtures or bentonite chip provided the best seal to minimize fluid movement along the borehole (Lackey et al., 2009 (**23**)).Regulations generally direct bottom up borehole sealing as it is the surest and most permanent method for complete sealing. High pressure grouting is available for use with direct push technology for bottom up borehole sealing.

10.2.1 *Sealing by Slurry, Two Tube System*—Sound the borehole for free water. If water exists in the casing, place the appropriate tremie tube or extension rods, open-ended, to the bottom of the outer casing. Mix the slurry to standard specifications prescribed by regulation or work plan. Pump slurry through the tremie tube or extension/drive rod until it appears at the surface of the outer casing. Slowly retract the outer casing and tremie tube while maintaining a head of grout in the borehole. Keep the grout level inside the outer casing as the tools are retracted to prevent borehole wall collapse and poor integrity seal. If no free water exists in the borehole, the slurry can be placed by gravity. Top off the borehole as the outer casing as it is removed.

10.2.1.1 *Slurry Mixes*—Slurry mixes used for slurry grouting of direct push boreholes may be of lower viscosity when small diameter tremie pipes are required. Usable mixes are 6 to 8 gal [22.7 to 30.28 L] of water/94-lb (42.64-kg) bag of cement with 5 lb [2.27 kg] of bentonite or 24 to 36 gal [90.84 to 136.28 L] of water to 50 lb [22.68 kg] of bentonite.

10.2.2 *Sealing by Gravity—Dual Tube System*—Measure the cased hole to ensure it is open to depth. Slowly add bentonite chips or granular bentonite to fill the casing approximately 2 ft. Withdraw the casing 2 ft and recheck depth. Hydrate the bentonite by adding water. Repeat this procedure as the outer casing is withdrawn. The bentonite must be below the bottom of the casing during hydration. Wetness inside the rods may affect the flow of granular bentonite to the bottom of the casing. A tremie tube may be used to add water for hydration of dry bentonite. Fill the top foot of the borehole with material that is the same as exists in that zone.

10.2.3 *Borehole Sealing Single Tube System:*

10.2.3.1 *Gravity Sealing from Surface*—If the soil strata penetrated has sufficient wall strength to maintain an open hole, and the borings ends at or above the local water table, then it may be possible to add sealing materials from the surface. Dry bentonite chips or granular bentonite can be placed by gravity. The borehole depth and volume should be determined and the borehole sounded every 5 ft [1.5 m] to ensure bridging has not occurred. The bentonite should be hydrated by adding approximately 1 gallon [1.0 L] of clean water for each 5 ft of filled borehole. Seal the surface with native material.

10.2.3.2 *Wet Grout Mix Tremie Sealing*—Tremie sealing methods can be used with single tube systems when borehole wall strength is sufficient to maintain an open hole or when extension rods with an expendable point are used to reenter the borehole. The grout pipe should be inserted immediately after the direct push tools are withdrawn or through the annulus of the extension rods that have been reinserted down the borehole for grouting. Care must be taken to not plug the end of the grout pipe. Side discharge grout pipes also can be used to prevent plugging.

10.2.4 *Re-Entry Grouting*—If the borehole walls are not stable, the borehole can be re-entered by static pushing grouting tools, such as an expendable point attached to the extension/drive rods to the bottom of the original borehole. Pump a slurry through the rods as they are withdrawn. High pressure grouting equipment may be beneficial in pumping standard slurry mixes through small diameter gravity pipes. Care must be taken to ensure the original borehole is being sealed.

11. Reports: Test Data Sheets/Forms

11.1 Fields records must be kept for each soil sampling event. These records are documented on field data sheets to show the depths of drilling and sampling events to the nearest 5 cm (0.1 ft), recovery in percent to 2-3 significant digits, and records on sample processing, subsampling locations, and visual soil classification. Soil samples can be classified in accordance with Practice D2487 and/or D2488 or other methods as required for the investigation. Prepare the final report log in accordance with standards set in Guide D5434 listing the parameters required for the field investigation program. List all contaminants identified, instrument readings taken, and comments on sampler advancement. Record any special field tests performed and sample processing procedures beyond those normally used in the defined investigation. Record borehole sealing procedures, materials used, and mix formulas on the boring log. Survey or otherwise locate the boring site to provide a permanent record of its replacement.

11.2 *Backfilling Record*—Record the method of sealing, materials used, and volume of materials placed in each borehole. This information can be added to the field boring log or recorded on a separate abandonment form.

12. Keywords

12.1 decontamination; direct push; groundwater; sealing; soil and sediment sampling

APPENDIX

(Nonmandatory Information)

X1. FACTORS INFLUENCING SAMPLE RECOVERY IN DIRECT PUSH SOIL SAMPLING

X1.1 The major factors influencing sample recovery in Direct Push Soil Sampling are the Cutting Shoe inside diameter and shape, and the Liner inside diameter and length. The other major factor is to soil formation to be sampled including the soil type, particle size, cohesiveness, and stress history. The combination of Cutting Shoe and Liner should be optimized and matched to the soil formations to be sampled. It is important that prior to sampling that different equipment be available to match the soil formation in the field.

X1.2 Soil recovery (9.5.4) in direct push sampling is rarely close to the ideal 100% desired. The predominant use of long sample drive lengths of 1 to 1.5 m (3 to 5 ft) often results in less than desirable recovery. Shortening sample lengths will improve the recovery but that is rarely done. Recoveries of more than 100 % often occur in Direct Push Soil Sampling because of the large clearance ratios between the cutting shoe and liner. Extremely high recoveries can occur in heavily over consolidated clays that tend to expand. Conversely, recoveries of less than 100 % can occur in low density and low plasticity soils. Clean sands silts below groundwater may liquefy and run or fall out of the sampling tube during retraction of the sampler and as it clears water level. In cases of running sands the basket retianers should be used to help retain the soil.

X1.3 The Cutting Shoe is the most important feature that controls the sample recovery. Cutting Shoes are designed to have a smaller diameter opening than the Liner to help reduce the friction of the core inside the Liner. The ratio of inside diameter of the cutting shoe to the inside diameter of the liner is called the Clearance Ratio. If sample recovery in a soil formation is poor the operator should change the Cutting Shoe to match the formation.

X1.4 Research on intact soil sampling indicates the angle of the cutting shoe (Sharpness) should be less than 10 degrees for intact sampling. Most direct push cutting shoes are blunt with much flatter cutting angles and rounded cutting angles because they need to be very strong and durable to withstand the impact forces of Direct Push. These blunt surfaces transmit shock waves and possible bearing capacity failure in from of the cutting shoe edge and cause disturbance to the soil before it enters the shoe and barrel. In some dense plastic soils this can cause extreme expansion of the cores. If these symptoms occur in fine grained formations a sharpened cutting shoe may result in higher quality cores.

X1.5 Manufactures provide differing styles of cutting shoes that can be used in difficult soil deposits. Figures X1.1 through X1.6 show some examples of the Cutting Shoe designs for different formations. Consult your manufacturer for advice on cutting shoes for the soils to be tested.

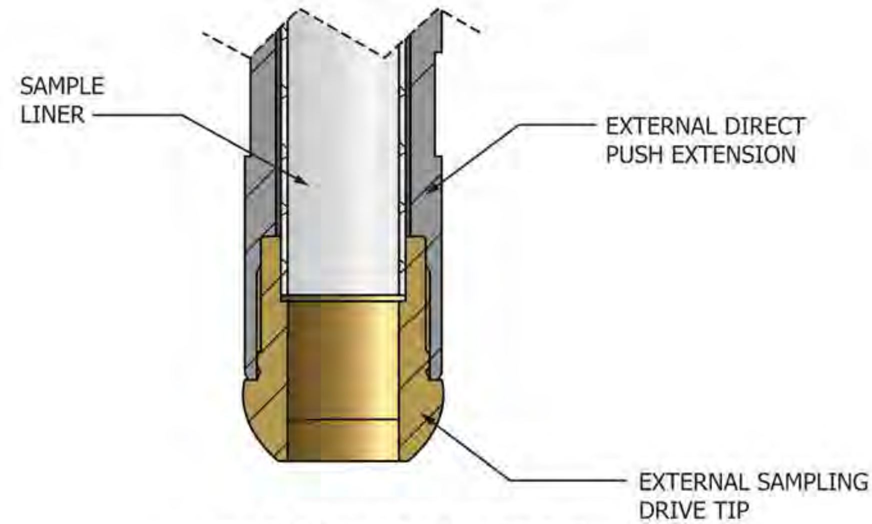

FIG. X1.1 Typical Sand and Silt Cutting Shoe

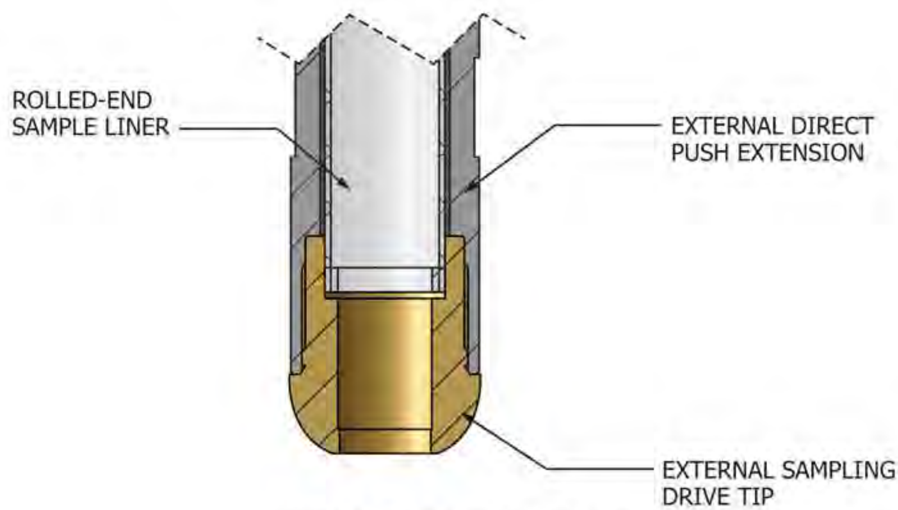

FIG. X1.2 Typical Clay Cutting Shoe

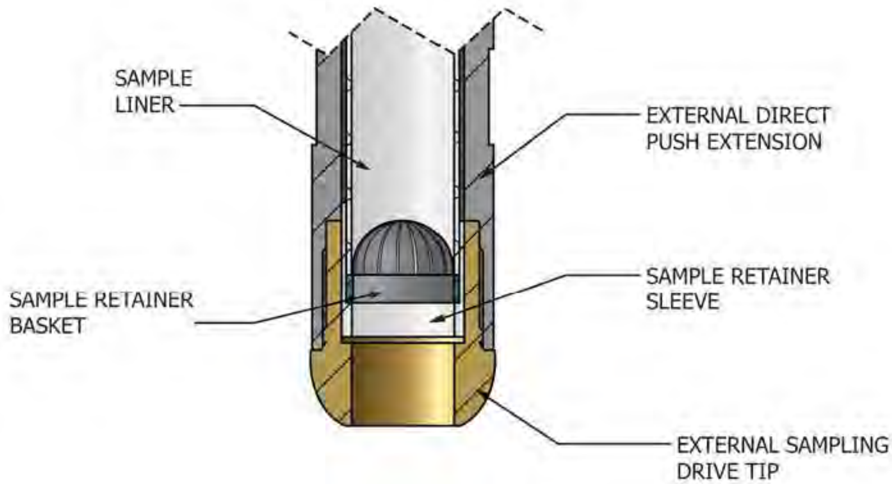

FIG. X1.3 Cutting Shoe for Loose Sand and Silts—Note Basket Retainer

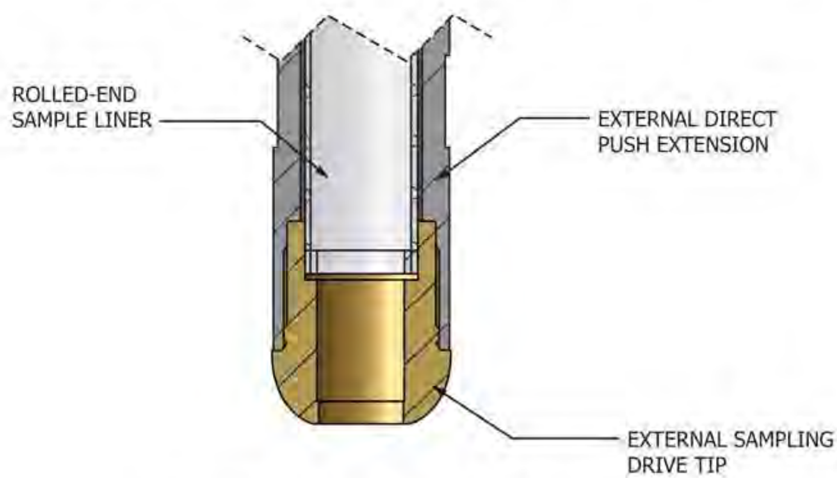

FIG. X1.4 Cutting Shoe for Very Loose Sands and Silts

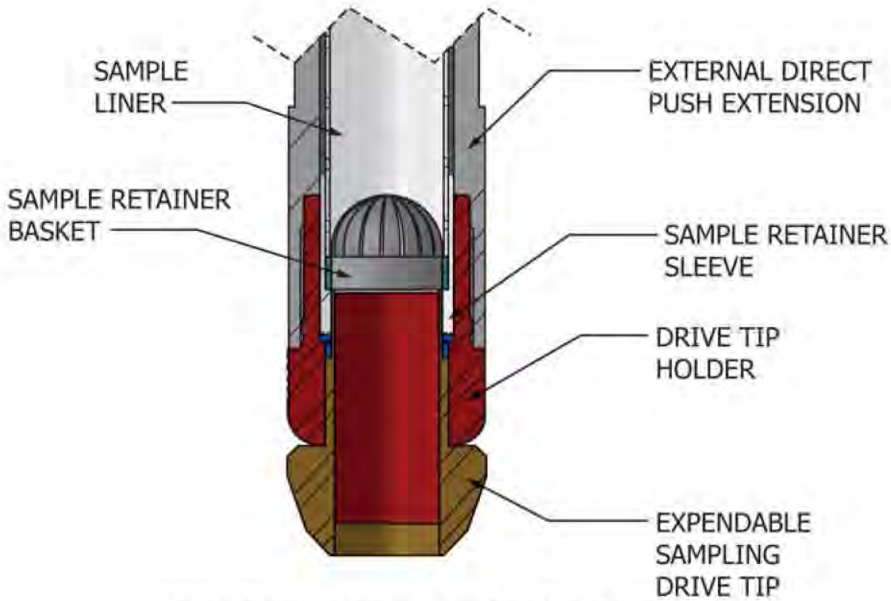

FIG. X1.5 Cutting Shoe for Stiff Over-Consolidated Clays

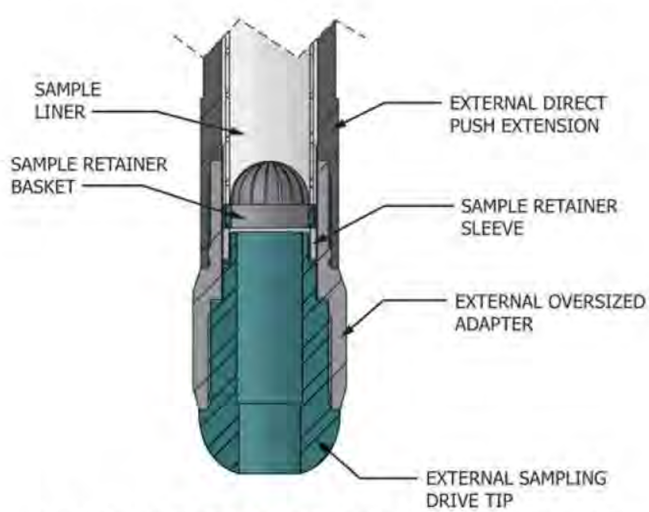

FIG. X1.6 Expendable Cutting Shoe Design for Stiff Clays

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CATEGORY 8: SOIL SAMPLING

Section 8.3

Appendix B-1 Sample Collection Parameters for Metals and Classical Chemistry Parameters

Appendix B-1
Sample Collection Parameters for Metals and Classical Chemistry Parameters

Target Analyte/Method	Matrix	Containers	Volume/Mass	Special Note(s)	Preservative	Holding Time[1]
Metals/ICP-AES	Water	Polyethylene or Glass	1 Liter		Acidify to pH < 2 w/HNO_3 & Cool to 4°C immediately after collection.	[1]
	Soil/ Sediment	Polyethylene or Glass	100 grams		Cool to 4°C immediately after collection.	[1]
Metals/ICP-MS	Water	Polyethylene or Glass	1 Liter		Acidify to pH < 2 w/HNO3 & Cool to 4°C immediately after collection.[2]	[1]
	Soil/ Sediment	Polyethylene or Glass	100 grams		Cool to 4°C immediately after collection.	[1]
Mercury/Cold Vapor AA	Water	Polyethylene or Glass	1 Liter	Sampling devices and sample containers must be free of mercury.	Acidify to pH < 2 w/HNO_3 immediately after collection.	28 days
	Soil/ Sediment		100 grams	Sampling devices and sample containers must be free of mercury.	Cool to 4°C immediately after collection.	28 days
Cyanide/Spectro-photometric Determination[3]	Water	Polyethylene or Glass	2 Liters		Immediately upon collection, add 0.6g ascorbic acid for each liter of sample collected (to neutralize residual chlorine). Add NaOH until pH > 12 and Cool to 4°C immediately after collection.	[1]

[1] For all metals except for mercury and Cr^{6+} the holding time is 6 months. The holding time for mercury is 28 days, and the holding time for Cr^{6+} is 24 hours. This holding time is calculated from the time of sample collection. It is recommended that samplers ship samples to the lab the same day that they are collected, or as soon as possible thereafter.

[2] Note that the sampler may be required to filter the sample through a 0.45-um pore diameter membrane filter at the time of collection. Use a portion of the sample to rinse the filter flask, discard this portion and collect the required volume of filtrate. Then preserve as described above. This occurs when the lab will be testing for dissolved elements.

[3] Sulfides adversely affect the analytical procedure. The following can be done to test for and neutralize sulfides. Place a drop of the sample on lead acetate test paper to detect the presence of sulfides. If sulfides are present, treat 25 mL more of the sample than that required for the cyanide determination with powdered cadmium carbonate or lead carbonate. Yellow cadmium sulfide precipitates if the sample contains sulfide. Repeat this operation until a drop of the treated sample solution does not darken

Target Analyte/Method	Matrix	Containers	Volume/Mass	Special Note(s)	Preservative	Holding Time[1]
	Soil/ Sediment	Polyethylene or Glass	100 grams		Cool to 4°C immediately after collection.	1
Hexavalent Chromium/Atomic Absorption Spectroscopy	Water	Polyethylene or Glass	500 mL		Cool to 4°C immediately after collection.	24 hours
	Soil/ Sediment	Polyethylene or Glass	100 grams		Cool to 4°C immediately after collection.	24 hours
Hexavalent Chromium/Ion Chromatography	Water	125 mL Narrow Mouth, High-Density Polypropylene Containers or Equivalent	100 mL		Adjust pH to 9-9.5 by drop-wise addition of buffer solution and Cool to 4°C immediately after collection.[4]	24 hours
	Soil/ Sediment	Polyethylene or Glass	100 grams		Cool at 4°C immediately after collection	24 hours
TPH/Fluorocarbon-113 Extraction and IR analysis	Water -do not collect composite samples.	Glass bottle	1 Liter		If more than 4 hours will pass between sampling and analysis, preserve by the addition of 5 mL 1:1 HC1. If more than 48 hours will pass between sampling and analysis, cool to 4°C immediately after collection.	1
	Soil/ Sediment	Glass bottles	100 grams		Cool to 4°C immediately after collection.	1

the lead acetate test paper. Filter the solution through a dry filter paper into a dry beaker, and from the filtrate measure the sample to be used for analysis. Avoid a large excess of cadmium carbonate and a long contact time in order to minimize a loss by complexation or occlusion of cyanide on the precipitated material.

[4] Note that the sampler may be required to filter the sample through a 0.45-um pore diameter membrane filter at the time of collection. Use a portion of the sample to rinse the filter flask, discard this portion and collect the required volume of filtrate. Then preserve as described above. This occurs when the lab will be testing for dissolved elements.

CATEGORY 9: SONIC, HSA, USCS

Section 9.1

Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices

Designation: D 5784 – 95 (Reapproved 2006)

Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[1]

This standard is issued under the fixed designation D 5784; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers how hollow-stem auger-drilling systems may be used for geoenvironmental exploration and installation of subsurface water-quality monitoring devices.

1.2 Hollow-stem auger drilling for geoenvironmental exploration and monitoring device installations often involves safety planning, administration, and documentation. This guide does not purport to specifically address exploration and site safety.

NOTE 1—This guide does not include considerations for geotechnical site that are addressed in a separate Guide.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 1452 Practice for Soil Investigation and Sampling by Auger Borings

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils

D 1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

D 2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

D 3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils

D 4428/D 4428M Test Methods for Crosshole Seismic Testing

D 5088 Practices for Decontamination of Field Equipment Used at Waste Sites

D 5092 Practice for Design and Installation of Ground Water Monitoring Wells

D 5099 Test Methods for Rubber—Measurement of Processing Properties Using Capillary Rheometry

D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock

3. Terminology

3.1 *Definitions:*

3.1.1 Terminology used within this guide is in accordance with Terminology D 653. Definitions of additional terms may be found in Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

Current edition approved July 1, 2006. Published July 2006. Originally approved in 1995. Last previous edition approved ni 2000 as D 5784 – 95 (2000).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.1 *bentonite*—the common name for drilling fluid additives and well-construction products consisting mostly of naturally occurring montmorillonite. Some bentonite products have chemical additives that may affect water-quality analyses.

3.2.2 *bentonite granules and chips*—irregularly shaped particles of bentonite (free from additives) that have been dried and separated into a specific size range.

3.2.3 *bentonite pellets*—roughly spherical- or disk-shaped units of compressed bentonite powder (some pellet manufacturers coat the bentonite with chemicals that may affect the water-quality analysis).

3.2.4 *coefficient of uniformity*— C_u (D), the ratio D_{60}/D_{10}, where D_{60} is the particle diameter corresponding to 60 % finer on the cumulative particle-size distribution curve, and D_{10} is the particle diameter corresponding to 10 % finer on the cumulative particle-size distribution curve.

3.2.5 *continuous-sampling devices*—barrel-type samplers that fit within the lead auger of the hollow-auger column. The sampler barrel fills with material as the augers advance.

3.2.6 *drill hole*—a cylindrical hole advanced into the subsurface by mechanical means. Also known as borehole or boring.

3.2.7 *drawworks*—a power-driven winch, or several winches, usually equipped with a clutch and brake system(s) for hoisting or lowering a drilling string.

3.2.8 *filter pack*—also known as a gravel pack or a primary filter pack in the practice of monitoring-well installations. The gravel pack is usually granular material, having specified grain-size characteristics, that is placed between a monitoring device and the borehole wall. The basic purpose of the filter pack or gravel envelope is to act as: (*1*) a nonclogging filter when the aquifer is not suited to natural development or, (*2*) act as a formation stabilizer when the aquifer is suitable for natural development.

3.2.8.1 *Discussion*—Under most circumstances a clean, quartz sand or gravel should be used. In some cases a pre-packed screen may be used.

3.2.9 *fluid-injection devices*—usually consist of various auger components or drill-rig attachments that may be used to inject a fluid within a hollow-auger column during drilling.

3.2.10 *grout packer*—an inflatable or expandable annular plug that is attached to a tremie pipe, usually positioned immediately above the discharge end of the pipe.

3.2.11 *grout shoe*—a drillable plug containing a check valve that is positioned within the lowermost section of a casing column. Grout is injected through the check valve to fill the annular space between the casing and the borehole wall or another casing.

3.2.11.1 *Discussion*—The composition of the drillable plug should be known and documented.

3.2.12 *hoisting line*—or drilling line, is wire rope used on the drawworks to hoist and lower the drill string.

3.2.13 *in situ testing devices*—sensors or probes, used to obtain mechanical or chemical-test data, that are typically pushed, rotated, or driven below the bottom of a borehole following completion of an increment of drilling. However, some in situ testing devices (such as electronic pressure transducers, gas-lift samplers, tensiometers, and and so forth) may require lowering and setting of the device(s) in a preexisting borehole by means of a suspension line or a string of lowering rods or pipe. Centralizers may be required to correctly position the device(s) in the borehole.

3.2.14 *intermittent-sampling devices*—usually barrel-type samplers that may be rotated, driven, or pushed below the bottom of a borehole with drill rods or with a wireline system to lower, drive, and retrieve the sampler following completion of an increment of drilling. The user is referred to the following ASTM standards relating to suggested sampling methods and procedures: Practice D 1452, Test Method D 1586, Practice D 3550, and Practice D 1587.

3.2.15 *mast*—or derrick, on a drilling rig is used for supporting the crown block, top drive, pulldown chains, hoisting lines, and so forth. It must be constructed to safely carry the expected loads encountered in drilling and completion of wells of the diameter and depth for which the rig manufacturer specifies the equipment.

3.2.16 *Discussion*—To allow for contingencies, it is recommended that the rated capacity of the mast should be at least twice the anticipated weight load or normal pulling load.

3.2.17 *piezometer*—an instrument for measuring pressure head.

3.2.18 *subsurface water-quality monitoring device*— an instrument placed below ground surface to obtain a sample for analyses of the chemical, biological, or radiological characteristics of subsurface pore water or to make in-situ measurements.

4. Significance and Use

4.1 Hollow-stem auger drilling may be used in support of geoenvironmental exploration (Practice D 3550, Test Method D 4428/D 4428M) and for installation of subsurface water-quality monitoring devices in unconsolidated materials. Hollow-stem auger drilling may be selected over other methods based on the advantages over other methods. These advantages include: the ability to drill without the addition of drilling fluid(s) to the subsurface, and hole stability for sampling purposes (see Test Methods D 1586, D 1587, D 2487, and D 2488) and monitor-well construction in unconsolidated to poorly indurated materials. This drilling method is generally restricted to the drilling of shallow, unconsolidated materials or softer rocks. The hollow-stem drilling method is a favorable method to be used for obtaining cores and samples and for the installation of monitoring devices in many, but not all geologic environments.

NOTE 2—In many geologic environments the hollow-stem auger drilling method can be used for drilling, sampling, and monitoring-device installations without the addition of fluids to the borehole. However, in cases where heaving water-bearing sands or silts are encountered, the addition of water or drilling mud to the hollow-auger column may become necessary to inhibit the piping of these fluid-like materials into the augers. These drilling conditions, if encountered, should be documented.

4.1.1 The application of hollow-stem augers to geoenvironmental exploration may involve ground water and soil sampling, in-situ or pore-fluid testing, or utilization of the hollow-auger column as a casing for subsequent drilling activities in unconsolidated or consolidated materials (Test Method D 2113).

NOTE 3—The user may install a monitoring device within the same auger borehole wherein sampling or in-situ or pore-fluid testing was performed.

4.1.2 The hollow-stem auger column may be used as a temporary casing for installation of a subsurface water-quality monitoring device. The monitoring device is usually installed as the hollow-auger column is removed from the borehole.

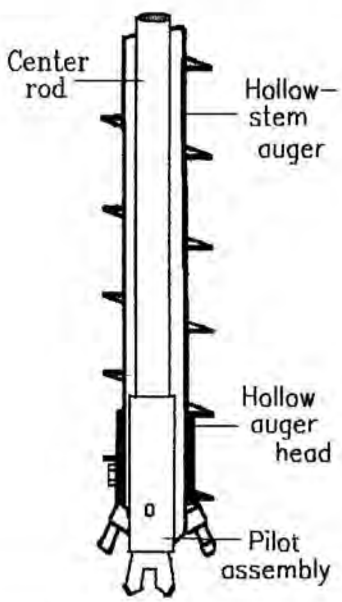
4.2 The subsurface water-quality monitoring devices that are addressed in this guide consist generally of a screened or porous intake device and riser pipe(s) that are usually installed with a filter pack to enhance the longevity of the intake unit, and with isolation seals and low-permeability backfill to deter the movement of fluids or infiltration of surface water between hydrologic units penetrated by the borehole (see Practice D 5092). Inasmuch as a piezometer is primarily a device used for measuring subsurface hydraulic heads, the conversion of a piezometer to a water-quality monitoring device should be made only after consideration of the overall quality and integrity of the installation, to include the quality of materials that will contact sampled water or gas.

NOTE 4—Both water-quality monitoring devices and piezometers should have adequate casing seals, annular isolation seals, and backfills to deter the movement of fluids between hydrologic units.

5. Apparatus

5.1 Each auger section of the hollow-stem auger-column assembly consists of a cylindrical tube with continuous helical flighting rigidly attached to the outer surface of the tube (see Fig. 1). The hollow-auger section has a coupling at each end for attachment of a hollow-auger head to the bottom end of the lead auger section and for attachment of additional auger sections at the top end to make up the articulated hollow-stem auger column.

NOTE 5—The inside diameter of the hollow-stem auger column is usually selected to provide an opening large enough for insertion of monitoring-device components such as the screened intake and filter pack and installation devices such as a tremie pipe. When media sampling is required, the optimum opening should permit easy insertion and retraction of a sampler or core barrel. When a monitoring device is installed, the annular opening should provide easy insertion of a pipe with an inside diameter large enough for placing completion materials adjacent to the riser.



NOTE 1—Various pilot assemblies not shown here may vary.

FIG. 1 Sketch Showing Basic Hollow-Stem Auger Components

5.1.1 *Hollow-Auger Head*, attached to the lead auger of the hollow-auger column and usually contains replaceable, abrasion-resistant cutters or teeth (see Fig. 1). As the hollow-auger head is rotated, it cuts and directs the cuttings to the auger flights which convey the cuttings to the surface.

5.1.2 *Auger-Drive Assembly*, attaches to the uppermost hollow-auger section and transfers rotary power and axial force from the drill rig to the auger-column assembly.

5.1.3 *Pilot Assembly*, may consist of: (*1*) an auger head aperture-plugging device with or without a center cutting head, or (*2*) a sampling device that is used to sample simultaneously with advancement of the auger column.

5.1.4 *Auxiliary Components of a Hollow-Auger Drilling System*, consist of various devices such as auger-connector wrenches, auger forks, hoisting hooks, and fluid-injection swivels or adapters.

5.2 *Drill Rig*, used to rotate and advance the auger column. The drill rig should be capable of applying the rated power at a rotary velocity of 50 to 100 r/min. The drill rig should have a feed stroke of at least the effective length of the auger sections plus the effective length of the auger couplings plus about 100 mm (4 in.).

6. Drilling Procedures

6.1 As a prelude to and throughout the drilling process stabilize the drill rig and raise the drill-rig mast. Attach an initial assembly of hollow-auger components (see Fig. 1) to the rotary drive of the drill rig.

NOTE 6—The drill rig, drilling and sampling tools, the rotary gear or chain case, the spindle, and all components of the rotary drive above the auger column should be cleaned and decontaminated prior to drilling according to Practice D 5088. All lubricated rotary gear or chain cases should be monitored for leaks during drilling. Any lubricants used should be documented. Lubricants with organic or metallic constituents that could be interpreted as contaminants if detected in a soil or water sample should not be used on auger couplings. Any instances of possible contamination should be documented.

6.2 Push the auger-column assembly below the ground surface and initiate rotation at a low velocity.

NOTE 7—If surface contamination is suspected, special drilling procedures may be required to deter transport of contaminated materials downhole. For example, the augers and auger head may be removed and cleaned according to Practice D 5088 following drilling of the initial increments. Complete removal of the augers from a boring may allow caving and cross contamination of materials (especially below the water table). When augers are reinserted, attempts should be made to note if caving or sloughing, or both, has occurred in the borehole and the information documented.

6.3 Then continue drilling, usually at a rotary velocity of about 50 to 100 r/min, and to a depth where intermittent sampling or in situ testing is required, or until the drive assembly is advanced to within about 0.15 to 0.45 m (6 to 18 in.) of the ground surface. Soil sampling is usually accomplished by either of two methods: (*1*) removing the pilot assembly, if being used, and inserting and driving a sampler through the hollow stem of the auger column, or (*2*) using a continuous sampling device within the lead auger section. In the latter case the sampler barrel fills with material as the hollow-auger column is advanced. It should be noted that the pilot assembly and any sampling devices should be cleaned and decontaminated according to Practice D 5088 after each use and prior to reinsertion in the hollow-auger column. Water sampling can also be done through the hollow-stem augers when using augers with watertight connections to prevent fluid leakage from occurring at the connections: (*1*) by allowing the auger column to fill with water through the use of a screened lead auger section; (*2*) by allowing the auger column to fill from the bottom; (*3*) by using a soil-penetrating water sampling device that can be lowered into the hollow-auger column and either driven, rotated, or pushed out through the bottom or lead auger into the undisturbed material below the auger head.

NOTE 8—Under some circumstances it may be effective to drill without using a pilot assembly. If a pilot assembly is not used, however, and water is not injected into the auger column simultaneously with advancement, material will often enter the hollow stem of the auger column. The addition of water to the auger column during drilling may deter material entrance but, on the other hand, may also affect both the mechanical and chemical characteristics of soil samples and the quality of water samples. Therefore, if water is added and the chemistry determined, the approximate volume(s) added over specific intervals and the water chemistry should be documented.

6.4 Accomplish drilling at greater depths by attaching additional hollow-auger sections to the top of the previously advanced hollow-auger column assembly.

NOTE 9—Cuttings are removed periodically from around the top of the auger column. Soil cuttings above the ground water may be representative of deposits being penetrated if proper cuttings-return rates are maintained. Cuttings from below the ground water surface are likely to be mixed from varying formations in the hole and are usually not representative of deposits at the end of the auger if cuttings are sampled for classification (see Practice D 2488) and relation to lithology report and document the intervals sampled. If drilling is performed in contaminated soil and cuttings control is required, drilling through a hole in a sheet of plywood or similar material held securely above the borehole by the stabilizing jacks of the drill rig will usually facilitate cuttings control. Containment and disposal of contaminated and potentially contaminated drilling fluids and associated cuttings should be in accordance with applicable regulations.

6.5 When drilling must progress through material suspected of being contaminated, installation of single or multiple (nested) casings may be required to isolate zones of suspected contamination. Install isolation casings in a predrilled borehole or by using a casing advancement method. However, when attempting to auger inside the casing, the column of cuttings return may cause the augers to bind in the casing. Then install a grout seal usually by applying the grout at the bottom of the annulus with the aid of a tremie pipe, and a grout shoe or a grout packer. Allow the grout to set before drilling activities are continued.

7. Installation of Monitoring Devices

7.1 Subsurface water-quality monitoring devices are generally installed using hollow-stem augers following the three-step procedure shown in Fig. 2. The three steps are: (*1*) drilling, with or without sampling, (*2*) removal of the pilot assembly, if being used, and insertion of the monitoring device, and (*3*)

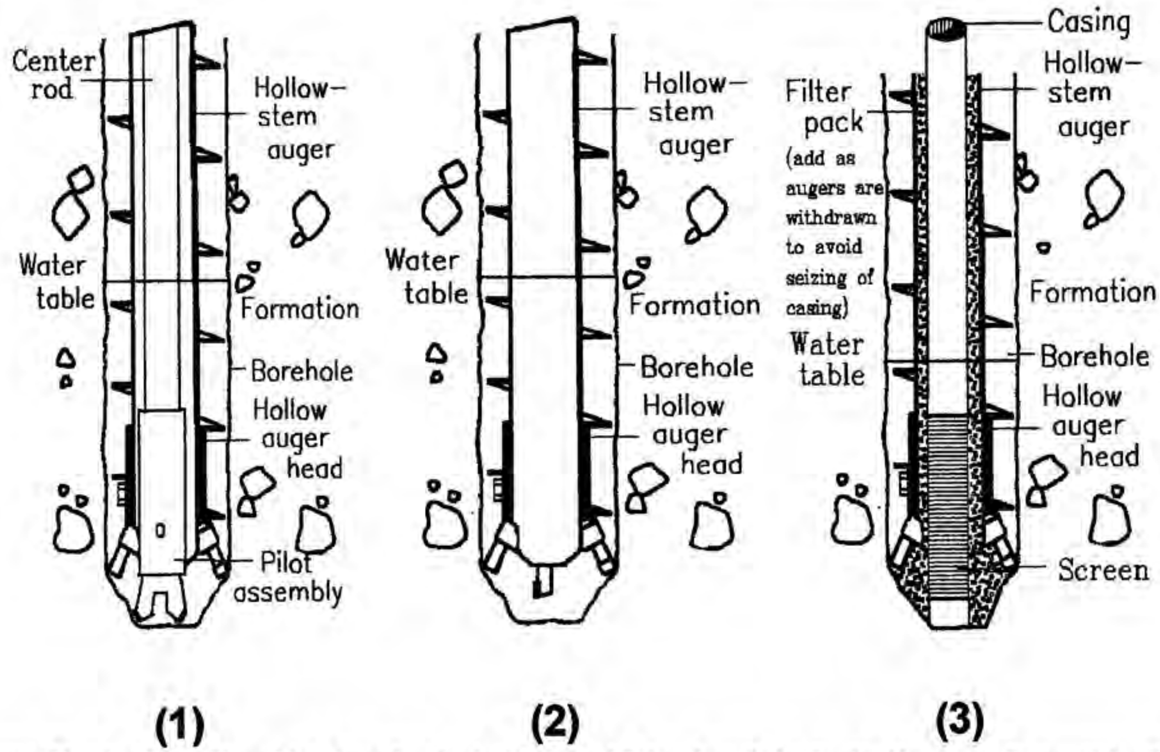


FIG. 2 Sketch Showing Basic Three-Step Procedure for Installation of Subsurface Water-Quality Monitoring Device Using the Hollow-Stem Auger Drilling Method

incremental removal of the hollow-auger column as completion materials such as filter pack, annular seals, and backfill are installed as required.

NOTE 10—Removal of the pilot assembly following an increment of drilling or prior to installation of a monitoring device should be performed so that the entrance of material into the bottom of the hollowauger stem is minimized. The efficacy of pilot assembly removal will depend upon several principal factors: (*1*) the character of the soil at the auger head, (*2*) the water levels inside and outside the auger prior to removal of the pilot assembly, (*3*) the type of pilot assembly used (special designs of pilot assemblies can be used to reduce the suction effect of removing the pilot bit), and (*4*) the speed of removal. As drilling progresses in saturated, granular materials, it usually becomes progressively more difficult to maintain the stability of the material below the auger column because of unbalanced hydraulic heads. The stability of the material below the auger head may be enhanced by using special pilot assemblies or injecting water of known chemistry into the hollow auger during drilling. The injection of water into a borehole usually requires consideration and documentation of the effects of injected water on (*1*) quality of subsequent chemical analyses of sampled water, and (*2*) the possible addition of moisture or contaminants to sampled materials.

7.1.1 If materials enter the bottom of the auger hollow stem during removal of the pilot assembly, remove it with a bailer, drive sampler, or other device.

NOTE 11—If heaving occurs, the amount of material entering the hollow-stem auger column should be documented. The effective use of a bailer may require the addition of a fluid to the auger stem.

7.1.2 If sampling or in situ testing is not required during drilling for installation of a monitoring device, advance the boring (for some geologic conditions) by using an expendable knockout plate or plug of known chemistry instead of a pilot assembly.

NOTE 12—Knockout plates or plugs usually remain in the ground close to the monitoring device. Therefore, the material components for knockout plates or plugs should be selected based on their possible effects on subsequent measurements or analyses and the information documented. It may be necessary to fill or partially fill the auger stem with water of known chemistry to prevent blow-in, piping, or sanding in at the time of the plate or plug removal. Refer to Note 7 for considerations regarding adding water to the hollow-auger stem.

7.1.3 Use an auger head with an integral, hinged aperture cover to deter entrance of materials into the auger stem.

7.2 Assemble water-quality monitoring devices, with attached fluid conductors (risers), and suspend in tension prior to placement of filter pack and during placement of filter pack in the borehole (with the least possible addition of contaminants).

7.2.1 Some materials, such as screens and risers, may require cleaning or decontamination, or both, at the job site (see Practice D 5088).

7.2.2 Prior to installation, store all monitoring device materials under cover and place upwind and well away from the drill rig and other sources of potential contamination such as electrical generators, air compressors, or industrial machinery.

7.2.3 Clean hoisting tools, particularly wire rope and hoisting swivels, and decontaminate according to Practice D 5088 before using.

7.3 Select filter materials, bentonite pellets, granules and chips, and grouts and install to specific subsurface monitoring requirements. The thickness of the emplaced materials and extension of the materials above the top of the screen should be sufficient to adequately seal the well and monitoring device(s) against contamination effects of fluid movement between hydrologic units and infiltration of surface contaminants.

7.3.1 Filter packs for monitoring devices are typically installed by withdrawing the hollow augers in small increments, while simultaneously adding small increments of filter material. Record the total volume of filter materials installed and the depth to the upper surface of the filter pack and compare to calculated volumes of material required for completion. Consider any discrepancies occurring between the actual volume of material used and the calculated volume required prior to proceeding to ensure proper completion. If filter material bridges within the hollow auger-riser annulus during installation, use tamping rods or other tamping devices to dislodge the bridge.

NOTE 13—Filter packs for monitoring devices installed in a saturated zone are typically selected on the basis of the grain size characteristics of the hydrologic unit adjacent to the screened intake (screen size should be less than the grain size of the formation adjacent to the screened intake). Filter-pack material is often inserted from above ground surface within the annulus of the hollow auger and the riser and is distributed by gravity around the screened intake. Filter-pack material with a uniformity coefficient of less than 2.5 is ordinarily selected to minimize in-place segregation of grain sizes. For some circumstances, such as installations under water in uniform, fine to very fine sand soils, the filter should be installed with a tremie pipe to minimize segregation of particle sizes. Filter packs for vadose-zone monitoring devices may be predominantly silt sized. These filter materials are often mixed with water of known quality, inserted through a tremie pipe, and tamped into place around the device.

NOTE 14—Effective installation of the filter pack, the seal above the filter pack, and the grout above the seal may be difficult to achieve. Consideration should be given to allow for sufficient annular space between the monitoring device and the hollow-stem auger to accommodate the tremie pipe. Under some circumstances, the filter pack may be more successfully installed by injecting or inserting water of known chemistry into the hollow-auger annulus either before or during incremental pull-back of the auger column. Enough water should be injected to both fill the space previously occupied by the auger flights and to maintain or slightly increase the head within the auger-hollow stem. This additional head within the auger-hollow stem provides an outward seepage force on the wall of the borehole as the augers are retracted. The additional head deters caving prior to installation of filter or seal materials. Approximate volumes of water used and water losses should be documented.

7.4 Usually place sealing materials consisting of either bentonite pellets, chips, or granules directly above the filter pack.

NOTE 15—It may be effective, when granular filters are used, to install a thin, fine sand, secondary filter either below the annular seal or both above and below the seal. These secondary filters are installed to protect the monitoring device, primary filter pack, and seal from intrusion of grout installed above the seal.

NOTE 16—A measured volume of water of known chemistry is often placed in the annulus on top of a dry bentonite seal to initiate hydration; however, hydration of a seal may require from 6 to 24 h.

7.5 The backfill that is placed above the annular seal is usually a bentonite- or cement-base grout.

NOTE 17—Grouts should be designed and installed in consideration of the ambient hydrogeologic conditions. The constituents should be selected and documented according to specific performance requirements. Typical grout mixtures are given in Practice D 5092 and Test Method D 4428/D 4428M.

NOTE 18—Grouting equipment and pipes should be cleaned and decontaminated according to Practice D 5088 prior to use and should be constructed of materials that do not "leach" significant amounts of contaminants to the grout.

7.5.1 When a tremie pipe is used, control its initial position and grouting pressures to prevent materials from being jetted into underlying seal(s) and filter(s) (use of a tremie pipe having a plugged bottom and side-discharge ports should be considered to minimize bottom-jetting problems).

7.5.2 After placement of the initial 1.5 to 3 m (5 to 10 ft) of grout above the underlying filter or seal, discharge additional grout at a depth of about 1.5 to 3 m below the grout surface.

NOTE 19—The need for chemical analysis of samples of each grout component and the final mixture should be considered and documented.

7.5.3 Install the grout from the bottom of the borehole to the top of the borehole so as to displace fluids in the borehole.

8. Development

8.1 Most monitoring device installations should be developed to remove suspended solids from disturbance of geologic materials during installation and to improve the hydraulic characteristics of the filter pack and the hydrologic unit adjacent to the intake. The method(s) selected and time expended to develop the installation and changes in quality of water discharged at the surface should be observed and recorded.

NOTE 20—Under most circumstances, development should be initiated as soon as possible following grouting and well completion operations. For suggested well-development methods and techniques, the user is referred to Test Method D 5099. However, time should be allowed for setting of grout.

9. Field Report and Project Control

9.1 The field report should include information recommended under Guide D 5434, and identified as necessary and pertinent to the needs of the exploration program.

9.2 Other information in addition to Guide D 5434 should be considered if deemed appropriate and necessary to the requirements of the exploration program. Additional information should be considered as follows:

9.2.1 *Drilling Methods*:

9.2.1.1 Description of the hollow-stem auger system,

9.2.1.2 Type, quantities, and locations in the borehole of use of water or additives added,

9.2.1.3 Description of cuttings return, including quantities, and

9.2.1.4 Descriptions of drilling conditions related to rotation rates, and general ease of drilling as related to subsurface materials encountered.

9.2.2 *Sampling*—Document conditions of the bottom of the borehole prior to sampling and report any slough or cuttings present in the recovered sample.

9.2.3 *In Situ Testing*:

9.2.3.1 For devices inserted below the bottom of the borehole, document the depths below the bottom of the hole and any unusual conditions during testing, and

9.2.3.2 For devices testing or seating at the borehole wall, report any unusual conditions of the borehole wall.

9.2.4 *Installations*—A description of well-completion materials and placement methods, approximate volumes placed, depth intervals of placement, methods of confirming placement, and areas of difficulty of material placement or unusual occurrences.

10. Keywords

10.1 drilling; geoenvironmental exploration; ground water; vadose zone

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL REFERENCES

Acker, W. L., III, *Basic Procedures for Soil Sampling and Core Drilling*, Acker Drill Co., P.O. Box 830,Scranton, PA 18501, 1974

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CATEGORY 9: SONIC, HSA, USCS

<u>Section 9.2</u>

Standard Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices.

Designation: D6914 – 04 (Reapproved 2010)

Standard Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices[1]

This standard is issued under the fixed designation D6914; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers procedures for using sonic drilling methods in the conducting of geoenvironmental exploration for site characterization and in the installation of subsurface monitoring devices.

1.2 The use of the sonic drilling method for geoenvironmental exploration and monitoring-device installation may often involve preliminary site research and safety planning, administration, and documentation. This guide does not purport to specifically address site exploration planning and site safety.

1.3 Soil or Rock samples collected by sonic methods are classed as group A or group B in accordance with Practices D4220. Other sampling methods may be used in conjunction with the sonic method to collect samples classed as group C and Group D.

1.4 The values stated in SI units are to be regarded as standard. The inch-pound units given in parentheses are for information only.

1.5 This practice offers a set of instructions for performing one or more specific operations. It is a description of the present state-of-the-art practice of sonic drilling. It does not recommend this method as a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.6 This practice does not purport to comprehensively address all the methods and the issues associated with drilling practices. Users should seek qualified professionals for decisions as to the proper equipment and methods that would be most successful for their site investigation. Other methods may be available for drilling and sampling of soil, and qualified professionals should have the flexibility to exercise judgment as to possible alternatives not covered in this practice. This practice is current at the time of issue, but new alternative methods may become available prior to revisions, therefore, users should consult manufacturers or sonic drilling services providers prior to specifying program requirements.

1.7 *This practice does not purport to address all the safety concerns, if any, associated with its use and may involve use of hazardous materials, equipment, and operations. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.* For good safety practice, consult applicable OSHA regulations and drilling safety guides.[2,3,4]

2. Referenced Documents [5]

2.1 *ASTM Standards—Soil Classification:*

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock

2.2 *ASTM Standards—Drilling Methods:*

D1452 Practice for Soil Exploration and Sampling by Auger Borings

D5088 Practice for Decontamination of Field Equipment Used at Waste Sites

D5299 Guide for Decommissioning of Ground Water Wells,

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

Current edition approved July 1, 2010. Published September 2010. Originally approved in 2004. Last previous edition approved in 2004 as D6914–04$^{\varepsilon 1}$. DOI: 10.1520/D6914-04R10.

[2] "Drilling Safety Guide," National Drilling Association.

[3] "Drillers Handbook," Thomas C. Ruda and Peter Bosscher, National Drilling Association.

[4] "Innovative Technology Summary Report," April 1995, U.S. Department of Energy.

[5] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities

D5791 Guide for Using Probability Sampling Methods in Studies of Indoor Air Quality in Buildings

D5782 Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5784 Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D6151 Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling

D6286 Guide for Selection of Drilling Methods for Environmental Site Characterization

2.3 *ASTM Standards—Soil Sampling:*

D420 Guide to Site Characterization for Engineering Design and Construction Purposes

D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils

D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils

D3694 Practices for Preparation of Sample Containers and for Preservation of Organic Constituents

D4220 Practices for Preserving and Transporting Soil Samples

D4700 Guide for Soil Sampling from the Vadose Zone

D6169 Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations

2.4 *ASTM Standards—Aquifer Testing:*

D4044 Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers

D4050 Test Method for (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems

D5092 Practice for Design and Installation of Ground Water Monitoring Wells

2.5 *ASTM Standards—Other:*

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

3. Terminology

3.1 Terminology used within this guide is in accordance with Terminology D653. Definitions of additional terms may be found in Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *amplitude*—range of drill bit movement necessary to overcome formation elasticity.

3.2.2 *bit face design*—the practice of changing the drill bit face to be neutral to, include, exclude, or shear the material being penetrated.

3.2.3 *forced vibration*—the tendency of one object to force an adjoining or interconnected object into vibrational motion.

3.2.4 *harmonic*—the point in a drill string where a special frequency creates a standing wave pattern throughout the string.

3.2.5 *hertz*—international unit of frequency, equal to one cycle per second.

3.2.6 *hydraulic extraction*—the removal of the sample specimen from the solid sampling barrel by the application of fluid.

3.2.7 *natural frequency*—the frequency or frequencies at which an object tends to vibrate when disturbed.

3.2.8 *resonance*—when one object (sine generator) vibrating at the natural frequency of a second object (drill pipe or casing) forces the second object into vibrational motion.

3.2.9 *sine wave*—a wave form corresponding to a single-frequency periodic oscillation.

3.2.10 *sinusoidal force*—energy force generated by an oscillator that is transmitted to the drill tool string.

3.2.11 *sonic*—the practice of using high frequency vibration as the primary force to advance drill tools through subsurface formations.

3.2.12 *standing wave pattern*—a vibratory pattern created within the drill string where the vibrating frequency of a carrier causes a reflected wave from one end of the drill string to interfere with incidental waves from the source in such a manner that at specific points along the drill string it appears to be standing still. The resulting disturbance is a regular pattern.

4. Summary of Practice

4.1 Sonic drilling is the utilization of high frequency vibration aided by down pressure and rotation to advance drilling tools through various subsurface formations. All objects have a natural frequency or set of frequencies at which they will vibrate when disturbed. The natural frequency is dependant upon the properties of the material the object is made of and the length of the object. The sonic drill head provides the disturbance to the drilling tools causing them to vibrate. To achieve penetration of the formation the strata is fractured, sheared, or displaced. The high frequency vibration can cause the soil in contact with the drill bit and drilling casing string to liquefy and flow away allowing the casing to pass through with reduced friction. Rotation of the drill string is primarily for even distribution of the applied energy, to control bit wear, and to help maintain borehole alignment. The use of vibratory technology reduces the amount of drill cuttings, provides rapid formation penetration, and the recovery of a continuous core sample of formation specimens for field analysis and laboratory testing. Boreholes generated by sonic drilling can be fitted with various subsurface condition monitoring devices. Numerous sampling techniques can also be used with this system including thin walled tubes, split barrel samplers, and *in-situ* groundwater sampling devices. Fig. 1 demonstrates the general principle of sonic drilling.

5. Significance and Use

5.1 Sonic drilling is used for geoenvironmental investigative programs. It is well suited for environmental projects of a production-orientated nature. Disposal of drilling spoils is a

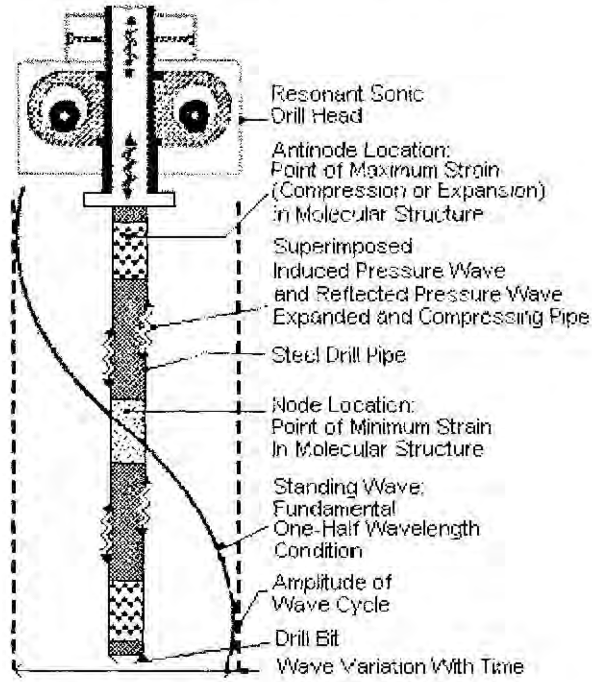

FIG. 1 General Principle of Sonic Drilling

major cost element in any environmental project. Sonic drilling offers the benefit of significantly reduced drill cuttings and reduced fluid production. Sonic drilling offers rapid formation penetration thereby increasing production. It can reduce field-work time generating overall project cost reductions. The continuous core sample recovered provides a representative lithological column for review and analysis. Sonic drilling readily lends itself to environmental instrumentation installation and to *in-situ* testing. The advantage of a clean cased hole without the use of drilling fluids provides for increased efficiency in instrumentation installation. The ability to cause vibration to the casing string eliminates the complication of backfill bridging common to other drilling methods and reduces the risk of casing lockup allowing for easy casing withdrawal during grouting. The clean borehole reduces well development time. Pumping tests can be performed as needed prior to well screen placement to insure proper screen location. The sonic method is readily utilized in multiple cased well applications which are required to prevent aquifer cross contamination. Notwithstanding the possibility of vibratory effects on the surrounding formations, the same sonic drilling plus factors for environmental monitoring device installations carry over for geotechnical instrumentation as well. The installation of inclinometers, vibrating wire piezometers, settlement gauges, and the like can be accomplished efficiently with the sonic method.

5.2 The cutting action, as the sonic drilling bit passes through the formation, may cause disturbance to the soil structure along the borehole wall. The vibratory action of directing the sample into the sample barrel and then vibrating it back out can cause distortion of the specimen. Core samples can be hydraulically extracted from the sample barrel to reduce distortion. The use of split barrels, with or without liners, may improve the sample condition but may not completely remove the vibratory effect. When penetrating rock formations, the vibration may create mechanical fractures that can affect structural analysis for permeability and thereby not reflect the true *in-situ* condition. Sonic drilling in rock will require the use of air or fluid to remove drill cuttings from the face of the bit, as they generally cannot be forced into the formation. Samples collected by the dry sonic coring method from dense, dry, consolidated or cemented formations may be subjected to drilling induced heat. Heat is generated by the impact of the bit on the formation and the friction created when the core barrel is forced into the formation. The sampling barrel is advanced without drilling fluid whenever possible. Therefore, in very dense formations, drilling fluids may have to be used to remove drill cuttings from the bit face and to control drilling generated heat. In dry, dense formations precautions to control drilling generated heat may be necessary to avoid affecting contaminant presence. The affects of drilling generated heat can be mitigated by shortening sampling runs, changing vibration level and rotation speed, using cooled sampling barrels, collecting larger diameter samples to reduce affect on the interior of the sample, and using fluid coring methods or by using alternate sampling methods such as the standard penetration test type samplers at specific intervals. Heat generated while casing the borehole through dense formations after the core sample has been extracted can be alleviated by potable water injection and/or by using crowd-in casing bits that shear the formation with minimal resistance. Should borehole wall densification be a concern it can be alleviated by potable water injection, by borehole wall scraping with the casing bit, by using a crowd-in style bit, or by injecting natural clay break-down compounds.

5.3 Other uses for the sonic drilling method include mineral investigations. Bulk samples can be collected continuously, quite rapidly, in known quantities to assess mineral content. Aggregate deposits can be accurately defined by using large diameter continuous core samplers that gather representative samples. A limited amount of rock can be effectively penetrated and crushability determined. In construction, projects include freeze tube installations for deep tunnel shafts, piezometers, small diameter piles, dewatering wells, foundation anchors with grouting, and foundation movement monitoring instrumentation. Sonic drills can be used to set potable water production wells. However, production may not equal more conventional potable well drilling techniques because of the need to transport drill cuttings to the surface in short increments. Sonic drill units presently in use are in various sizes and most are truck mounted. Sonic drills can be skid or all-terrain vehicle mounted to access difficult areas.

5.4 Sonic drills can be adapted to such other drill methods as conventional rotary (Guide D1583, Guide D5782), down hole air hammer work (Guide D5782), diamond bit rock coring; conventional and wireline (Practice D2113), direct push probing (Guide D6001, Guide D6286), thin wall tube sampling (Practice D1587), and standard penetration test split barrel sampling (Practice D1586). The sonic drilling equipment offers more adaptability than most existing drilling systems. However, it is important to keep in mind that the technique the machine is designed for is the one at which it will be the most efficient. Long term use of sonic drills for other drilling methods may not be cost effective.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors. Practice D3740 was developed for agencies engaged in the testing and/or inspection of soils and rock. As such, it is not totally applicable to agencies performing this practice. However, user of this practice should recognize that the framework of Practice D3740 is appropriate for evaluating the quality of an agency performing this practice. Currently there is no known qualifying national authority that inspects agencies that perform this practice.

6. Criteria for Selection

6.1 Important criteria to consider when selecting the sonic drilling method include the following:

6.1.1 Diameter of borehole,

6.1.2 Sample quality (Class A, B, C, D) for laboratory physical testing (Refer to Practices D4220),

6.1.3 Sample handling requirements such as containers, preservation requirements,

6.1.4 Subsurface conditions anticipated: soil type or rock type/hardness,

6.1.5 Groundwater depth anticipated,

6.1.6 Boring depth,

6.1.7 Instrumentation requirements,

6.1.8 Chemical composition of soil and contained pore fluids,

6.1.9 Available funds,

6.1.10 Estimated cost,

6.1.11 Time constraints,

6.1.12 History of method performance under anticipated conditions (consult experienced users and manufacturers),

6.1.13 Site accessibility,

6.1.14 Decontamination requirements,

6.1.15 Grouting requirements, local regulations, and

6.1.16 Amount of and disposal costs for generated drill cuttings and drilling wastes.

7. Apparatus

7.1 *Sonic Head*—The sonic drill head contains a sine generator, sine generator drive mechanism, lubrication system to reduce friction and control heat in the head, vibration isolation device, drill string rotating mechanism, and a connection to the drill string. The sine generator must be capable of producing sufficient energy to force movement in the drill string to accomplish the fracturing, shearing or displacement necessary for the borehole to be advanced as shown in Fig. 1.

7.1.1 *Sine Generator*—The sine generator uses eccentric, counter rotating balance weights that are timed to direct 100 percent of the vibration at 0 degrees and at 180 degrees (Figs. 2 and 3). The sine generator is powered hydraulically and generally operates at frequencies between 0 and 185 hertz delivering a full range of energy outputs for advancement of up to 30.48 cm (12 in.) drill casing.

7.1.2 *Lubrication System*—The lubrication system is fitted with oil coolers of sufficient capacity to keep the hydraulic fluid at an allowable operating range as recommended by the oil supplier.

7.1.3 *Vibration Isolation System*—In order to transmit the maximum vibratory energy to the drill string and not damage the drilling rig the vibration applied to the drill tools must be isolated from the drill rig as shown in Figs. 2 and 3. This can be accomplished by using air charged springs, manual disk springs, or such other methods as will meet that goal.

7.2 *Drilling Tools*—A significant variety of tooling is necessary to accomplish the sonic drilling program. The tools consist of drill rods, drill casing, sampler barrels, sampler bits, casing bits, direct push sampling probes, borehole water sample collection systems, etc. Individual drillers and companies have in-house tooling designed for specific purposes and projects. If these specialized tools provide high quality sampling and efficient drilling processes they are acceptable to the practice.

7.2.1 *Drilling Rods and Casing*—Drilling rods are used to propel and recover the sampling barrels. Drill rods are the most handled tools. The common sizes are 5.08 cm (2.0 in.) to 10.16 cm (4.0 in.) O.D. × 60.98 cm (2.0 ft), 1.524 m (5.0 ft), 3.38 m (10.0 ft), and 6.096 m (20.0 ft) lengths. Annular space between casing and rod is not critical allowing the same sized drill rod to be used with various sized sampling barrels. Current sonic drilling technology can be used to set drill casing in various sizes from 1.27 cm (0.5 in.) up to 30.48 cm (12.0 in.) nominal depending on project requirements.

7.2.2 *Sampler Barrel*—Sampler barrels (a.k.a. core barrels) are used to recover formation specimens and to clean the inside of the drill casing. Sampler barrels are either solid tubes or split barrels of various diameters and lengths. The sampling barrels

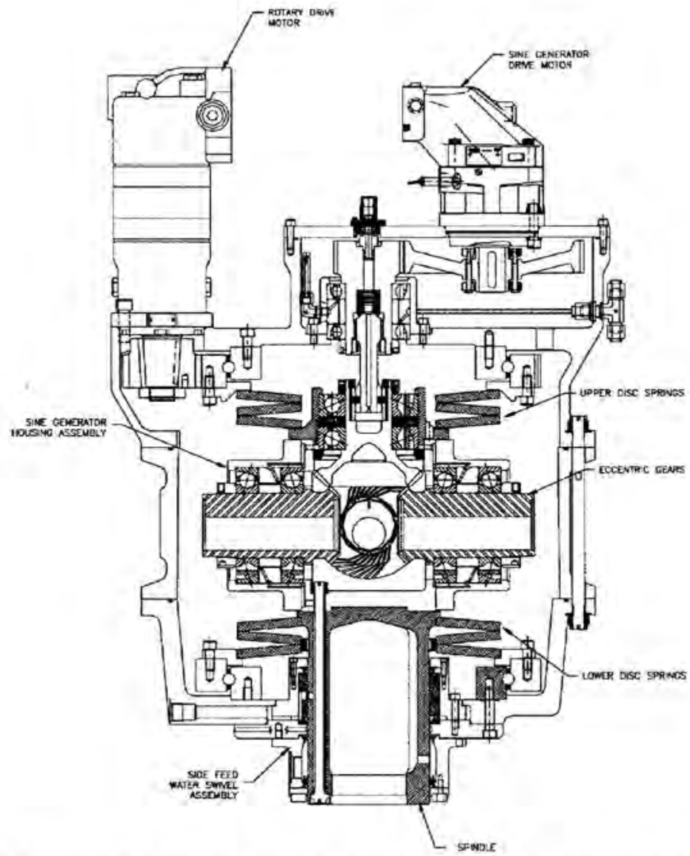

FIG. 2 Typical Sonic Drill Head with Disk Spring Form of Isolation System

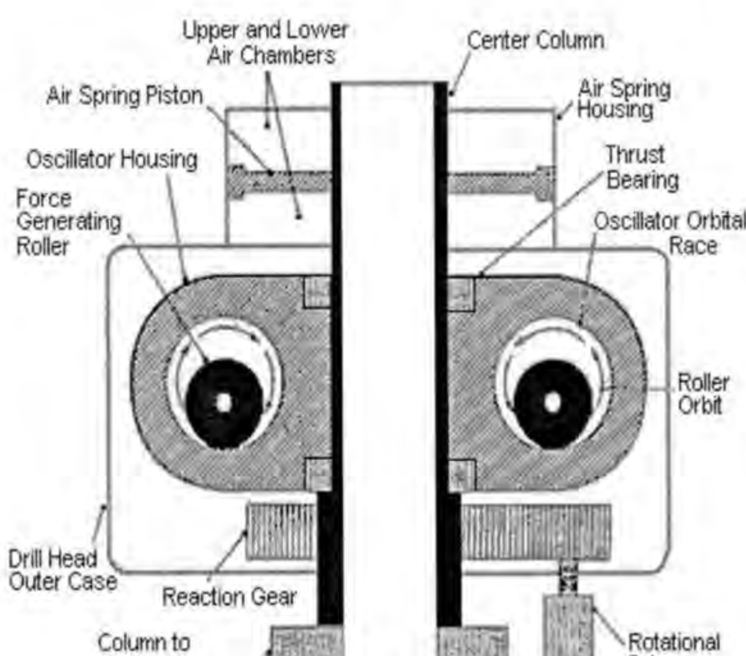

FIG. 3 Typical Sonic Drill Head with Air Spring Form of Isolation System

are generally sized to match the inside diameter of the various sizes of drill casing and to fulfill project requirements. The barrel is fitted with a drill bit/cutting shoe that holds the borehole alignment as it passes through the outer casing into the formation.

7.2.2.1 *Solid Barrels*—Solid sampler barrels are a solid length of tubing with thread sections on each end. They are available in various sizes and lengths. Typical sampling runs are 3.048 to 6.096 m (10.0 to 20.0 ft) in length. Sampling run length can be adjusted to provide the most optimum sample recovery. Sampler barrels can be joined to increase the length of sampling increment. In some formations there is a tendency to lose recovery with longer core run lengths while in others longer core runs may improve recovery. Samples of loose unconsolidated granular formations can be consolidated by the vibratory action. In loose or soft formations the inability of the soil structure to support the force necessary to move the material into the barrel can cause that material to be forced into the formation.

7.2.2.2 *Split Barrel Samplers*—Split barrel samplers are tubes that are split lengthwise with thread sections on both ends. The split sections utilize a tongue & groove feature that interlocks to prevent lateral movement between the two halves of the tube. Split barrel samplers are available in various diameters and lengths. While split barrel samplers provide a better format to view the specimen and may subject it to less disturbance, they do receive vibratory action during penetration. Depending on the method of construction, split barrels have a tendency to spread open in hard formations. They are quite heavy when fully loaded and may require special handling techniques. Liners, clear butyl or polyethylene based plastic, or stainless steel are available for use with split barrel and solid barrel samplers.

7.2.2.3 Standard formation sampling devices can be used in conjunction with the sonic drill rig for geotechnical applications. The standard penetration test D1586 can be performed if the unit is equipped with a cathead or an automatic-hammer 63.523 kg (140 lb). The hydraulically activated, D6519, as well as manual, fixed piston, thin wall tube samplers D1587 can be used if the unit is equipped with a fluid pump of sufficient capacity. Sonic drills are generally equipped with winch lines for using sampling tools in geotechnical drilling programs.

7.2.3 *Casing Drill Bits*—Drill bits are attached to the leading section of drill casing. Their function is to provide a cutting edge to assist in moving the casing through the various formations encountered and to direct the movement of formation materials during the making of the boring. The face of the drill bit follows one of three basic directional designs: (*1*) "Crowd-in" move most of the material encountered at the drill face into the borehole or casing as it is advanced. This style of bit face provides the best service in dense, dry, or cohesive formations as it helps reduce formation compaction and friction; (*2*) "Crowd-out" moves most of the material encountered at the drill face into the borehole wall. This design works better in softer and more granular, sands, gravels, and silt formations; and (*3*) "Neutral" allows the bit face material to choose the path of least resistance. Different bit face configurations are used to effectively penetrate different formations. The general-purpose bit face is fitted with carbide buttons spaced equally across and around the bit face. Fig. 4 shows a typical carbide button faced bit. The carbide buttoned bit works well in most formations and is considered a general-purpose bit. Carbide buttons are well suited for the impact action that occurs in sonic drilling. Other configurations include welded carbide chips and blocks in a matrix, saw tooth shapes both hard surfaced and plain, and tearing shoe designs with large irregular carbides for working in construction debris and penetrating refuse in landfills. Each of these designs has a useful purpose and can be quite effective at penetrating their respective formations.

7.2.4 *Sample Barrel Bit*—The sample barrel bit is designed to both penetrate the formation and to shape the sample so it will pass through the bit into the sample barrel with the least amount of friction or compression. The bit may be constructed with serrated, carbide buttoned, or some other form of roughened inside diameter surface, or with a machined space for a retainer basket to assist in the retention of the sample. The interior of the sampler bit should have a minimum inside diameter 3.175 mm (0.125 in.) less than the inside diameter of the sampling barrel to allow the passage of the sample into the core barrel with the least amount of resistance so as to not impede recovery or create unnecessary disturbance to the sample. The cutting face of the bit used should be the design best suited to the formation being penetrated. For dense formations with cobbles and boulders a bit face with carbide buttons may be used. For soft formations a serrated face, sharpened to force the cuttings away from the bit, works well. The choice of bit face type and sample retention method is governed by the characteristics of the formation and should be optimized as the borehole progresses to insure the highest recovery percentage with the least possible sample disturbance.

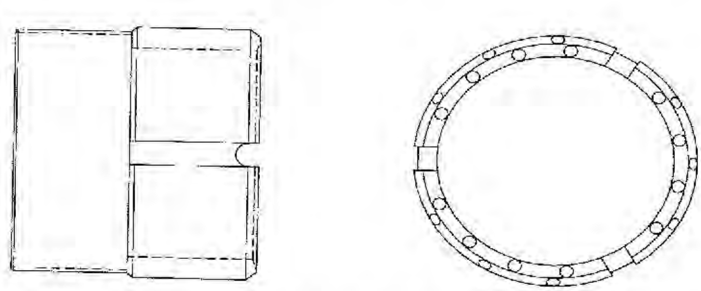

FIG. 4 Sonic Casing Bit

7.2.5 *Direct Push Sampling Tools*—Sonic drilling is a direct push drilling method as well. Therefore, soil sampling, soil vapor sampling, and water sampling tools similar to those used in the direct push industry are also available to the sonic drilling practice. *In-situ* water sampling tools are constructed using a screened inner stem attached to a point that is surrounded by an outer drive pipe. The point is the same diameter as the outer drive pipe to prevent the creation of an enlarged annular space that could provide an avenue for cross contamination between aquifers. The inner screen assembly is sealed from the formation during installation by an outer drive pipe fitted with "o" rings. With the friction of the soil holding the point in place while being driven to depth, the screen section is then exposed to the formation by pulling back on the outer drive pipe. The inner tube can have an inside diameter of 5.08 cm (2.0 in.) to 10.16 cm (4.0 in.) or larger to allow for larger capacity sampling pumps. Using higher capacity pumps accelerates the purging process and allows for rapid sampling from deep formations. The water sampling probes can be fitted with disposable points to allow for pressure grouting or installation of small diameter monitor wells.

7.3 *Sonic Drill Rig*—The sonic drill rig is similar to other drilling rigs in that it is a machine attached to a frame mounted on some form of carrier. The unit can be driven by a power take off assembly from the carrier engine or by an auxiliary engine. The unit has a feed frame for moving the drill head up and down to apply feed and retract pressure to the drill string and a mast for tool handling. Some units are equipped with automated tool handling devices. The sonic drill head is powered hydraulically. In addition to the sonic head, the feed system, drill fluid pumps, rod handling systems, and other auxiliary equipment demand power as well. Therefore, the power supply must be capable of providing the horsepower necessary to drive the system. The horsepower requirement is based on the desired productive capacity of the drill. The carrying vehicle must have sufficient gross vehicle weight to support the drill structure, rod handling equipment, fluid pumps, air compressors, and such tool storage as deck space allows.

7.3.1 *Drill Tower*—The drill rig may have a tower for extracting tools from the borehole. Tower lengths can vary, however, higher towers allow for longer tool pulls. The drill rig should have sufficient retraction power to lift a full-length string of the largest rated diameter drill tools from the deepest rated depth plus an additional 50 % or more of that total weight.

7.3.2 *Tool Handling*—Sonic drills traditionally use several different sizes of tooling. The units are generally equipped with some form of tool handling devices. Some units are equipped with a pivotal sonic head. This allows the head to tilt up 90 degrees to vertical so drill rod or casing can be aligned to the spindle for mechanical attachment. The length is then raised and rotated back to vertical for attachment to the drill string. Other units use mechanical rod loaders which position drill rods or casing for hook up. Wire rope winches can be used for drill rod tripping. Units using the winch method are generally fitted with a slide tray that can accommodate up to 6.096 m (20.0 ft) lengths of drill rod for reducing sample barrel retrieval time.

7.3.2.1 *Tool Joint Wrench and Rod Holder Table*—A key component of the sonic drill is the tool joint make-up, breakout, and rod holding table. The upper vice of the tool joint should be capable of bi-directional rotation to both close and open the tool joints. The throat of the joint wrench must be large enough to accommodate the largest rated O.D. tooling of the drill. The throat clearance may be accomplished by jaw retraction or by installing different sized jaws. The lower jaw assembly and its supporting members should be capable of supporting the total weight of the maximum O.D tooling at the maximum depth rating of the machine. The upper jaw may include some form of high-speed rod spinning device to expedite rod disconnection.

7.3.3 *Auxiliary Equipment*—Sonic drill units require a fluid pump or pumps depending on the anticipated work program. The pumps serve many purposes; to push drilling fluids down the bore hole for lubrication and bit face cuttings removal while advancing the outer casing over core barrels in certain formations, when rock drilling to assist in the removal of cuttings, for bit cooling and cuttings removal while diamond bit rock coring, for mixing of drill fluids and grouts, for grouting of instrumentation, to grout (backfill) bore holes, and for equipment cleaning. Drill fluid injection is generally more predominate when installing casing in saturated granular formations to maintain pressure equalization than when drilling more cohesive formations. The primary purpose of injecting fluids is to keep the inside of the drilling casing clean as it is advanced over the sampling barrel. Normally drill fluids are not recycled during sonic drilling so volume generated is generally small. As the sonic drilled borings can go to considerable depth it is recommended that the unit have a least one positive displacement type pump. If a second fluid pump is desired, it should be capable of supplying 1380 kN/m^2 (200 psi) for mixing and for cleaning. Progressive cavity, or peristaltic pumps, work well for this purpose. All fluid pumps should be equipped with pressure indicating gauges and pressure relief valves set at the necessary level to protect the pumps from damage and to prevent fracturing of the formation. Air compressors are sometimes used in conjunction with sonic drilling. They are utilized when operating down hole hammers or other air drilling methods to penetrate formations not conducive to penetration by sonic methods. Pressure requirements are governed by tool requirements, depth, and bore diameter, see Guide D3740. General tools needed to operate the sonic drill unit include rod lifting tools, pipe wrenches, fluid swivels, and handtools for general maintenance and repair. Other useful equipment would include portable or hydraulic powered arc welders, acetylene torches, steam cleaners, and portable generators. Portable fluid pumps and tanks are also useful for fluid containment and transfer.

7.4 *Expendable Supplies*—Expendable supplies are items such as monitor well materials, bentonite, cement, and their proper uses are described in referenced ASTM standards. They are not addressed in this practice.

8. Conditioning

8.1 *General*—Preparation of the sonic rotary drill unit for project work starts with a thorough check of the drill's operating system. This includes the inspection, testing, and repair of all emergency shutdown switches and other safety devices. The performance of regular routine maintenance procedures including fluid level checks, lubrication, hydraulic hose inspection, leakage repairs, and the inspection of the physical components with necessary repairs completed. A thorough cleaning of the drill unit is also recommended. Operating tools should be inspected, repaired if necessary, and inventoried, to insure that an adequate supply is on hand for the project. Drilling tools, casing, rods, bits, etc., should be checked for proper repair, and loaded in sufficient quantities to complete the project. It is recommended that additional tooling, beyond that required for the project, be taken to the site to reduce down time from breakage or damage, and to allow for increases in work effort that may occur because of site conditions.

NOTE 2—The items in Section 8 regarding inspection, cleaning, inventory, repair, storage, transportation, decontamination, equipment checks, and necessary supplies are primarily related to contractor efficiency. This is only a partial list of activities that are considered good drilling practice to prepare for drilling and are offered for consideration by users. It is recognized that strict conformance with these items is not imperative for sonic drilling and does not necessarily correlate to the quality of the work.

8.1.1 *Equipment Movement*—All tools, materials, and equipment needed for the project shall be loaded in a safe manner and secured in compliance with U.S. Department of Transportation, state, and local regulations. The drilling rig, support vehicles, and auxiliary equipment shall be brought to the project site fully fueled and ready for operation. Extra tooling, required instrumentation installation supplies, and other expendables should be stored in a central location in a safe and secure manner. The materials should be stored in a clean dry area in their original containers until transported to the decontamination area for cleaning if necessary or to the actual drill site for installation. All packaging debris, damaged or contaminated materials, and miscellaneous trash accumulate during drilling operations shall be containerized and disposed of properly.

8.2 *Decontamination*—If the drilling rig and tooling are to be used on a chemically contaminated site, site specific decontamination procedures must be followed. For general decontamination information refer to Practice D5088 for recommended procedures.

8.3 *Sampling Barrels*—The sampling barrels are in various lengths, generally 1.532 m (5.0 ft), 3.048 m (10 ft), or 6.096 m (20 ft). Barrels should be in equal increments to facilitate the accuracy of borehole depth measurements. Sampling barrels are either solid or split styles.

8.3.1 *Solid Sampling Barrels*—Check the barrel thread section for thread condition, dents, kinks, or excessive wear that could result in the loss of the barrel or the sampling shoe, or in improper assembly that will result in a reduction of energy transfer. The barrel body should be straight, without dents or wrench burrs that could cause injury. The inside of the barrel should be clean, free of any debris, rust build-up, or any obstructions.

8.3.2 *Split Sampling Barrels*—Check barrel thread section for thread condition, dents, kinks or excessive wear that could result in the loss of the barrel or sampling shoe, or in improper assembly that will result in a reduction of energy transfer. The barrel body sections should be straight, without dents, kinks, or wrench burrs that could cause injury. The split tongue and grooves must be clean and free from dents, kinks or burrs. The split barrels halves should fit together snugly without bowing or spreading. The inside of the barrel halves must be clean and free of any obstructions.

8.3.3 *Sampler Barrel Heads and Bits*—Sampler barrel heads should be checked for thread condition to insure proper assembly to facilitate energy transfer. Sampler barrel bits are constructed in different configurations for use in the various formations encountered. The proper bit should be selected for the anticipated formation to be encountered. The cutting face should be free of dents, without cracks, non-manufactured grooves, or indentations. The interior of the bit should be free of obstructions that would impede the movement of the sample in the barrel. Designs in the bit to aid in recovery are permitted. Bits designed for use with basket retainers should have clean undamaged shoulders for receiving basket retainers. Check to see that the required tolerance is present.

8.3.4 *Drilling Without Sampling*—When sonic drilling without sampling is desired the solid sampling barrel bit can be modified to incorporate a drive point. When the maximum boring depth is reached, the sampling barrel is over drilled with the casing to depth and the sampling barrel is removed before setting instrumentation. If a disposable drive point is used, the sampling barrel is withdrawn the length of the point and the point knocked out. Then borehole activities such as water sampling and setting monitor wells or other devices can be accomplished.

8.3.5 *Tool Selection*—Prior to dispatch to the project site, an inventory of the necessary tooling in the proper sizes, expendable items, and instrumentation supplies should be made. Drilling is an inexact science and as such planning should include provisions for possible contingencies that may arise based on the knowledge one can gather about the project and the geology of the site. Routinely used supplies such as drill casing and sample barrel bits, rod lifters, environmentally safe thread lubrication, sampler barrel couplers, and project specific materials should be available so work can proceed unimpeded. If using split barrels or thin wall tubes a sufficient number should be on hand so sample examination does not delay drilling. Expendable supplies such as sample retainer baskets, sample storage bags, or other containers, and other project specific materials should to be available in sufficient quantities so work can progress smoothly. Specialized sampling tools, necessary for project specific requirements, should be checked, cleaned and available in the required number. Refer to Guide D420 for additional information on soil sampling tool selection. Materials for proper sealing of boreholes should always be available at the site.

9. Procedure

9.1 *General Set Up*—A safety meeting and site/project information meeting is held. A complete set of job safety analyses procedures is reviewed; Utility clearance information is reviewed. The drill crew puts on the required personal protective safety gear. The drill foreman makes a general site reconnaissance and specifically reviews the borehole location before moving any equipment onto the site. All underground and overhead utilities locations are checked and all members of the drill crew receive knowledge of their whereabouts. Any overhead obstructions that may impede drill rig setup and operation are noted. The travel path to the boring location is evaluated for the safe movement of the equipment. Move the drill rig and service vehicles to the borehole location. Unload any auxiliary equipment or supplies from the drill that would interfere with the rig setup. Level the drill unit. The leveling jacks should have sufficiently sized ground contact pads to spread the load and prevent settling during drilling that can cause misalignment of the drill tools. Once the drill is level, raise and secure the mast. If drilling fluids are to be collected position a fluid containment vessel. Position the service vehicles as necessary for efficient tool handling and drilling support. Hook up any pumps, hoses, and position working tools as necessary.

9.1.1 *Drilling Methods*—Sonic drilling can be performed wet, using a drilling medium, or dry. The choice of method is determined by project requirements, formations to be penetrated, and the depth to be achieved. In sonic drilling, the sampling barrel is advanced dry except for those occasions when actual rock or concrete penetration is occurring and drill-cutting removal is necessary to prevent tool lockup. Bouldery formations and weathered bedrock can be drilled dry as long as they will allow the cuttings at the bit face to be forced into the formation without friction causing excessive heat or impeding penetration of the formation. Drilling progresses by fracturing, shearing, or displacement. Fracturing occurs when drilling through formations with cobbles, boulders, or rock formations. Shearing occurs when penetrating dense silt, clay, or soft shale. Displacement occurs in granular formations when the material is liquefied and moves away from the bit and casing, or up the casing or sampling barrel. In sonic drilling, as in other drilling practices, a combination of methods may be necessary to complete the project.

9.1.2 *Tool Preparation*—Attach the proper bit for the formation anticipated to the sampling barrel. Connect the sampling barrel to the drill head and tighten the drill bit and the sampling barrel to the drill head. Check the plumb of the casing in relation to the drill rig. The pre-torquing, or tightening of rod joints is essential to the transmission of energy through the rod string when using sonic technology. All drill rod and casing joints should be pre-torqued to the manufactures rated capacity and/or to a level equal to the maximum amount of force that the sonic head can impart. Failure to do so can result in a loss of energy as well as damage to the threaded joint and/or loss of tooling. It is generally necessary to rotate the drilling casing to provide for even bit wear, control borehole alignment, and to facilitate removal of the casing and samplers from the borehole on completion. Slow rotation speed is satisfactory as speed is not a controlling factor in advancing the tools. In certain formations rotation of the sampling barrel during core sampling may be necessary.

9.2 *Sample Barrel Insertion*—Advance the sample barrel into and through the topsoil, pavement, or other surface material. Withdraw the sampler from the borehole and remove initial penetration material. Reinsert the sampling barrel, apply down pressure, activate the sine generator, and began rotation if needed. Note bottom limit of penetration and adjust as needed by using various rod lengths to achieve desired sampling increment end point. It is desirable to end sample increments at the even meter (foot), or centimeter (one-half foot) increments for ease of bore hole measurements. Accurate measurements are critical to determine recovery, locate strata changes, and determine proper instrumentation location in the borehole.

9.2.1 *Sampling-Solid Barrel*—At the completion of the sampling run, stop down pressure, stop the sine generator and any rotation of the sampling barrel. If necessary disconnect from the sampling barrel and install casing over the sampling barrel. Extract the sampling barrel from the borehole using the drill head or such other method as will expedite the movement of the sampling barrel to the surface. At the surface, reattach the sampling barrel to the sine generator and position the sampling barrel to remove the sample. Remove the bit, protecting the bottom of sampling barrel to prevent any material from dropping out. Remove any material in the sampling bit and place it in the sample receiving bag in the correct orientation. Slide the sample bag over the sampling barrel the full remaining length of the bag so the sample does not fall. Allow the sample to flow into the bag by activating the sine generator as needed to vibrate the sample from the barrel. Keep the sample bag as close to the bottom of the sample barrel as possible while it fills to reduce sample dropping distance causing as little disturbance as possible. Samples are generally deposited in 61 m (2.0 ft) to 1.524 m (5.0 ft) length plastic bags for review, logging and analysis. Sample bag length should not exceed 1.524 m (5.0 ft) as the weight of the specimen collected becomes very difficult to handle without causing excessive disturbance. Change sample bags as needed until all sample is removed from the barrel. It is important that all material collected be contained for recovery measurements and for disposal. Accurate measurements of sample recovery are achievable with the solid barrel sampling method of sample collection if certain practices are followed. In some formations more precise measurements of recovery can be made using clear plastic sampler liners. Hydraulic extraction of the sample from the solid barrel sampler can also be utilized in some formations. The nature of sonic vibration and bit face displacement can cause some disturbance in granular and in other soils. This should be kept in mind when measuring recovery and examining core samples. Such measurements are best judged by experienced equipment operators and knowledgeable field logging personnel who are knowledgeable in recognizing the differences in disturbed verses non-disturbed formation materials. Clean the sampling barrel by flushing with clean water or decontaminating as necessary. If project needs require full decontamination remove the used sampling barrel to the decontamination area, attach a cleaned sampling barrel to the drill head, add the drill bit and tighten it, and reinsert the sample barrel into the borehole to the depth of the previously sampled increment. Repeat the sampling process. It may be advantageous to rotate the sampling barrel as is withdrawn from the borehole to aid in extraction. However, rotation during extraction should only be used when necessary to retrieve the sampling tools to avoid disturbing the sample or causing it to fall from the sampling barrel. In some formations it may be necessary to activate the sine generator to facilitate withdrawal of the sample barrel. Once the sample is collected however, any action applied could cause disturbance to the sample. All such actions should be avoided wherever possible.

9.2.2 *Sampling-Split Barrel*—The procedure for using split barrel samplers is the same as solid barrel samplers except that the split barrel design it is not able to accept heavy down pressure or high friction resistance rotation. The limits of the split barrel are easily exceeded and caution must be exercised when utilizing these tools. Split barrel samplers offer the potential for reducing sample disturbance as the sample is removed from the core barrel. Sample removal and cleaning follow the procedures in referenced ASTM standards. Measuring sample recovery may be more accurate with the split barrel as result of generally shorter run length and the ability to visibly observe the material being measured in the barrel before it is removed.

9.3 *Drilling with Casing*—It is generally necessary to stabilize the borehole with an outer casing to control caving or slough, to facilitate sample collection, to protect against aquifer cross contamination, to provide a controlled environment for well or instrumentation installation, and to insure proper bottom up grouting. Casing is either installed using drilling fluid or installed dry depending on the formation being penetrated. Casing is available in a variety of lengths and diameters common to the drilling industry to fit a range of project requirements. The casing is either advanced over the sampling barrel when using drilling fluid or after the sample barrel has been removed from the borehole when drilling dry. Proportional sizing of the sampling barrel to the casing is required to insure that the casing is properly cleaned.

9.3.1 *Drilling Casing Wet*—Various drilling fluids can be used to advance the casing ranging from clean potable water to specialized drilling fluids. The choice of fluid is dictated by the formation and the project requirements. There is generally no recirculation of the drilling fluid during sonic drilling. The drilling fluid serves several functions. It helps keep debris and drill cuttings from entering the casing; it provides a lubrication film between the outside of the casing and the formation materials; It removes drill cuttings from the face of the bit and from the borehole annulus; and the fluid helps to keep the sample barrel and the casing from becoming sand locked as the casing passes over the barrel. It is important that the annular space between the sampler barrel and the casing bit be kept to a minimum. This prevents material from moving into the annular space, reduces the amount of drilling fluid needed, and helps maintain borehole alignment. The drilling fluid is also used to maintain a pressure equalization head inside the casing to prevent any inflow of formation materials.

9.3.1.1 *Casing Insertion Wet*—The sampling barrel is advanced to the required depth increment as described previously. The drill head is disconnected from the sampling rod string. A plug is placed in the drill rod box to protect the threads and prevent any drill fluid from entering the sampling rod string. An equal length of drill casing is attached to the drill head and hoisted into position over the sampling rod string. As the casing is advanced using downpressure, rotation and vibration, drilling fluid is pumped into the casing string. The casing is advanced to the base of the sampling barrel shoe. Advancement is stopped. The drill head is disconnected from the casing and reconnected to the sampling barrel tool string. The sampling barrel is then removed and the sample extracted. The sampling barrel is cleaned and then reinserted, additional drill string added, and the sample barrel advanced to the next increment. Then the casing installation procedure is repeated. There is a slight amount of contact between the top of the sampling increment and the drilling fluid when the sample barrel is withdrawn. However, as no drilling fluid is recycled, the composition of the drilling fluid remains known and controlled. As soon as the sample specimen begins to enter the barrel the fluid in the barrel is pushed upward and the sides of the sample barrel are sweep clean by the friction of the passing soil.

9.3.1.2 *Bore Hole Slough or Cave-In*—As with all drilling methods there are times when special techniques are needed to maintain control of the bore hole. In certain formations, if the head pressure in the borehole is not equalized, the groundwater will carry formation materials in as it equalizes in the borehole. If project constraints do not allow the adding of compensating fluids other techniques must be employed. To provide room for the deposited material a second sampling barrel can be added on top of the first. As the materials are essentially liquefied along the barrel surface there is relatively little influence exerted on the lower portions of the sample from the upper portions. However, to insure sample quality and integrity every effort should be made to eliminate as much cave-in as possible.

9.3.1.3 *Drilling Casing Dry*—When installing casing dry, advance the sampling barrel through the scheduled interval. Remove the sample barrel and process the sample. Connect the drill head to the casing and advance the casing to the bottom of the previously sampled increment. Disconnect from the casing. Insert the sample barrel and vibrate through the borehole material in the casing to the top of the next scheduled sampling increment. Remove the sampling barrel and clean it in accordance with project requirements. Reinsert the sampling barrel and advance it to the end of the next sampling increment. Then repeat the procedure. In certain formations a double length sample barrel can be utilized to both remove the borehole material and to continuously sample the next increment in one tool trip. Whenever slough is encountered in the borehole it should be measured and properly noted on the boring log. Determining the need for cleanout runs with the core barrel is primarily a driller skill.

9.4 *Bore Hole Testing*—The sonic drilling method lends itself well to many forms of borehole testing in most formations primarily because of the clean cased hole provided and from the versatility of the machine. Actual procedures for water and aquifer testing, or other formation properties investigation procedures are given in referenced ASTM standard and will not be individually addresses here. The very high level of energy that can be imparted to the drill bit by the sonic drill gives it the ability to advance casing and core barrels into very dense formations. In these dense formations, when drilling dry, the borehole wall may be affected by the forcing of soil particles into it. Should this condition be of concern it can be alleviated by using potable water injection while advancing the casing, by using a crowd in style bit that directs materials sheared from the borehole wall into the casing, by borehole wall scraping with the casing bit, or by injecting natural clay breakdown compounds.

9.4.1 Pump testing to determine aquifer characteristics, Test Method D4050, is easily accomplished because of the clean hole and the minimal disturbance that is caused to the formation. This results in a rapidly clearing formation that reaches its maximum production rate quickly. Minimum turbidity with rapid production results in less development water for disposal and expedited test results. This is especially significant when setting smaller diameter wells, which can only accommodate low volume pumps. Slug tests, Test Method D4044, can also readily be preformed because of the clean borehole wall.

9.4.2 *Well Installation*—Wells, Practice D5092, of various sizes can be set using the sonic method. Advantages are that in many formations the casing in the screened zone can be set without fluid to keep the formation clean and to reduce development and/or pumping time. The vibratory effect can be used to good advantage to settle filterpack material around the screen and eliminate bridging of backfill materials as the casing is removed.

9.4.3 *Other Instrumentation*—Any type of instrumentation that can be set with any other drilling method can be set with sonic drilling. *In-situ* borehole tests such as pressure meters D4719, vane shear devices D2573, permeability testing using packers D4630, etc., can be used with the sonic method as long as the borehole wall is prepared in accordance with the proper ASTM standard. When utilizing these types of testing methods it may be necessary to advance the casing into the borehole using water injection and a crowd in bit to minimize sonic drilling's effect on soil pore pressure.

9.5 *Incorporating Other Drilling Practices*—The sonic drill rig easily accommodates other drilling methods should they be needed to satisfactorily complete projects. Rock coring adaptations can be incorporated to do diamond bit coring either wireline or conventional. Sonic drills generally have low rotary rpm ratings. Adequate speeds for rock coring can be acquired through a gear driven speed multiplier, a high-speed coring head, 2-speed rotation motors, or if available, adjustment to the rotational output of the sonic drill head. Downhole hammers can be readily adapted to the sonic drill with the incorporation of a compressed air source. The low rpm rating works very well with downhole hammer. As the sonic drill offers all basic drill functions air or fluid rotary techniques can be easily adapted as well. Standard soil sampling techniques can be utilized with the sonic drill. Split barrel sampling with standard penetration tests, thin walled tubes, and the like can be easily incorporated.

10. Completion and Sealing

10.1 Information on the sealing of boreholes can be found in Guide D5299, and in Guides D5791, D5782, D5783, and D5784. State or local regulations may control both the method and the materials for borehole sealing.

11. Record Keeping

11.1 *Field Report*—The field report may consist of boring log or a report of the sampling event and a description of the sample. Soil samples can be classified in accordance with Practice D2488 or other methods as required for the investigation. Prepare the log in accordance with Guide D5434, which lists the parameters required for the field investigation program. List all information related to drilling and the sampling event, including depth, fluid injection, drilling parameters, sampling Intervals, recovery, strength index readings such as pocket pentrometer, classification of soil, and any comments on sampler or casing advancement. If a computer collects drill performance data, add identifying marks to log so correct information can be downloaded and incorporated into the final log as necessary.

12. Keywords

12.1 drilling; resonance; soil and rock sampling; sonic; subsurface exploration

CATEGORY 9: SONIC, HSA, USCS

Section 9.3

Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

Designation: D 2487 – 06

Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)[1]

This standard is issued under the fixed designation D 2487; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice describes a system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

NOTE 1—Use of this standard will result in a single classification group symbol and group name except when a soil contains 5 to 12 % fines or when the plot of the liquid limit and plasticity index values falls into the crosshatched area of the plasticity chart. In these two cases, a dual symbol is used, for example, GP-GM, CL-ML. When the laboratory test results indicate that the soil is close to another soil classification group, the borderline condition can be indicated with two symbols separated by a slash. The first symbol should be the one based on this standard, for example, CL/CH, GM/SM, SC/CL. Borderline symbols are particularly useful when the liquid limit value of clayey soils is close to 50. These soils can have expansive characteristics and the use of a borderline symbol (CL/CH, CH/CL) will alert the user of the assigned classifications of expansive potential.

1.2 The group symbol portion of this system is based on laboratory tests performed on the portion of a soil sample passing the 3-in. (75-mm) sieve (see Specification E 11).

1.3 As a classification system, this standard is limited to naturally occurring soils.

NOTE 2—The group names and symbols used in this test method may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. See Appendix X2.

1.4 This standard is for qualitative application only.

NOTE 3—When quantitative information is required for detailed designs of important structures, this test method must be supplemented by laboratory tests or other quantitative data to determine performance characteristics under expected field conditions.

1.5 This standard is the ASTM version of the Unified Soil Classification System. The basis for the classification scheme is the Airfield Classification System developed by A. Casagrande in the early 1940's.[2] It became known as the Unified Soil Classification System when several U.S. Government Agencies adopted a modified version of the Airfield System in 1952.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 420 Guide to Site Characterization for Engineering Design and Construction Purposes

D 422 Test Method for Particle-Size Analysis of Soils

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

[1] This standard is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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[2] Casagrande, A., "Classification and Identification of Soils," *Transactions*, ASCE, 1948, p. 901.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

D 1140 Test Method for Amount of Material in Soils Finer Than the No. 200 (75-µm) Sieve
D 2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)
D 4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D 4427 Classification of Peat Samples by Laboratory Testing
D 6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 4—For particles retained on a 3-in. (75-mm) U.S. standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) U.S. standard sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1 *clay*—soil passing a No. 200 (75-µm) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line.

3.1.2 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve with the following subdivisions:

Coarse—passes 3-in. (75-mm) sieve and retained on ¾-in. (19-mm) sieve, and

Fine—passes ¾-in. (19-mm) sieve and retained on No. 4 (4.75-mm) sieve.

3.1.3 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.4 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.5 *peat*—a soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.6 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) U.S. standard sieve with the following subdivisions:

Coarse—passes No. 4 (4.75-mm) sieve and retained on No. 10 (2.00-mm) sieve,

Medium—passes No. 10 (2.00-mm) sieve and retained on No. 40 (425-µm) sieve, and

Fine—passes No. 40 (425-µm) sieve and retained on No. 200 (75-µm) sieve.

3.1.7 *silt*—soil passing a No. 200 (75-µm) U.S. standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4 or if the plot of plasticity index versus liquid limit falls below the "A" line.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coefficient of curvature, Cc*—the ratio $(D_{30})^2/(D_{10} \times D_{60})$, where D_{60}, D_{30}, and D_{10} are the particle sizes corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

3.2.2 *coefficient of uniformity, Cu*—the ratio D_{60}/D_{10}, where D_{60} and D_{10} are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

4. Summary

4.1 As illustrated in Table 1, this classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions are further subdivided into a total of 15 basic soil groups.

TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
COARSE-GRAINED SOILS	Gravels	Clean Gravels	Cu ≥ 4 and 1 ≤ Cc ≤ 3[C]	GW	Well-graded gravel[D]
More than 50 % retained on No. 200 sieve	More than 50 % of coarse fraction retained on No. 4 sieve	Less than 5 % fines[E]	Cu < 4 and/or 1 > Cc > 3[C]	GP	Poorly graded gravel[D]
		Gravels with Fines	Fines classify as ML or MH	GM	Silty gravel[D,F,G]

TABLE 1 *Continued*

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
		More than 12 % fines[E]	Fines classify as CL or CH	,urule;1>GC	Clayey gravel[D,F,G]
	Sands	Clean Sands	$Cu \geq 6$ and $1 \leq Cc \leq 3$[C]	SW	Well-graded sand[H]
	50 % or more of coarse	Less than 5 % fines[I]	$Cu < 6$ and/or $1 > Cc > 3$[C]	SP	Poorly graded sand[H]
	fraction passes No. 4 sieve	Sands with Fines	Fines classify as ML or MH	SM	Silty sand[F,G,H]
		More than 12 % fines[I]	Fines classify as CL or CH	SC	Clayey sand[F,G,H]
FINE-GRAINED SOILS	Silts and Clays	inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K,L,M]
50 % or more passes the No.	Liquid limit less than 50		PI < 4 or plots below "A" line[J]	ML	Silt[K,L,M]
200 seive		organic	$\frac{\text{Liquid limit – oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OL	Organic clay[K,L,M,N]
				OL	Organic silt[K,L,M,O]
	Silts and Clays	inorganic	PI plots on or above "A" line	CH	Fat clay[K,L,M]
	Liquid limit 50 or more		PI plots below "A" line	MH	Elastic silt[K,L,M]
		organic	$\frac{\text{Liquid limit – oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OH	Organic clay[K,L,M,P]
					Organic silt[K,L,M,Q]
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve.
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$
[D] If soil contains ≥15 % sand, add "with sand" to group name.
[E] Gravels with 5 to 12 % fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay
[F] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[G] If fines are organic, add "with organic fines" to group name.
[H] If soil contains ≥15 % gravel, add "with gravel" to group name.
[I] Sands with 5 to 12 % fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay
[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.
[K] If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[L] If soil contains ≥30 % plus No. 200, predominantly sand, add "sand " to group name.
[M] If soil contains ≥30 % plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 4 and plots on or above "A" line.
[O] PI < 4 or plots below "A" line.
[P] PI plots on or above "A" line.
[Q] PI plots below "A" line.

4.2 Based on the results of visual observations and prescribed laboratory tests, a soil is catalogued according to the basic soil groups, assigned a group symbol(s) and name, and thereby classified. The flow charts, Fig. 1 for fine-grained soils, and Fig. 3 for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name.

5. Significance and Use

5.1 This standard classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index.

5.2 The assigning of a group name and symbol(s) along with the descriptive information required in Practice D 2488 can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.3 The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. This standard provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

5.4 This standard may also be used as an aid in training personnel in the use of Practice D 2488.

5.5 This standard may be used in combination with Practice D 4083 when working with frozen soils.

NOTE 5—Notwithstanding the statements on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing

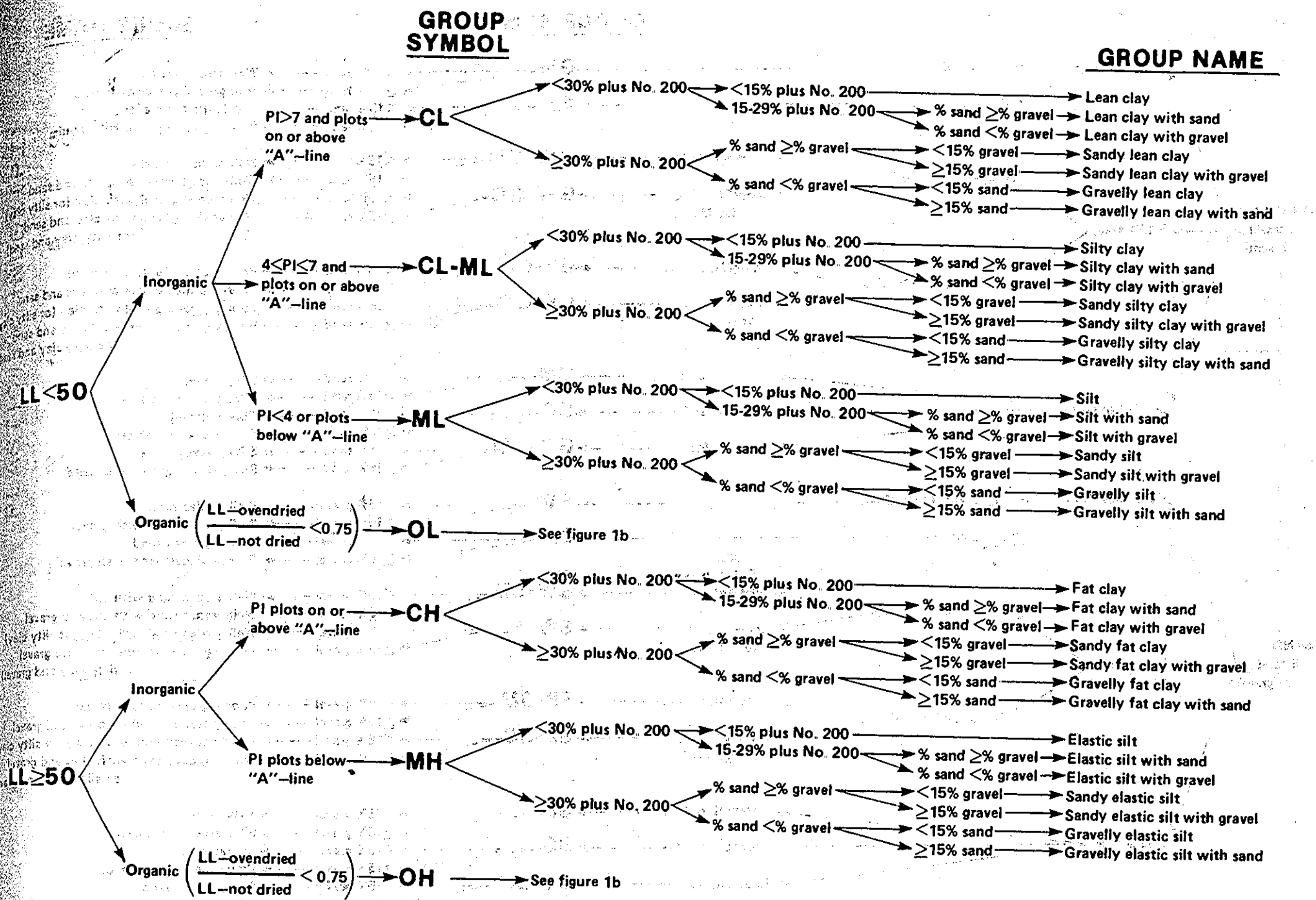


FIG. 1 Flow Chart for Classifying Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

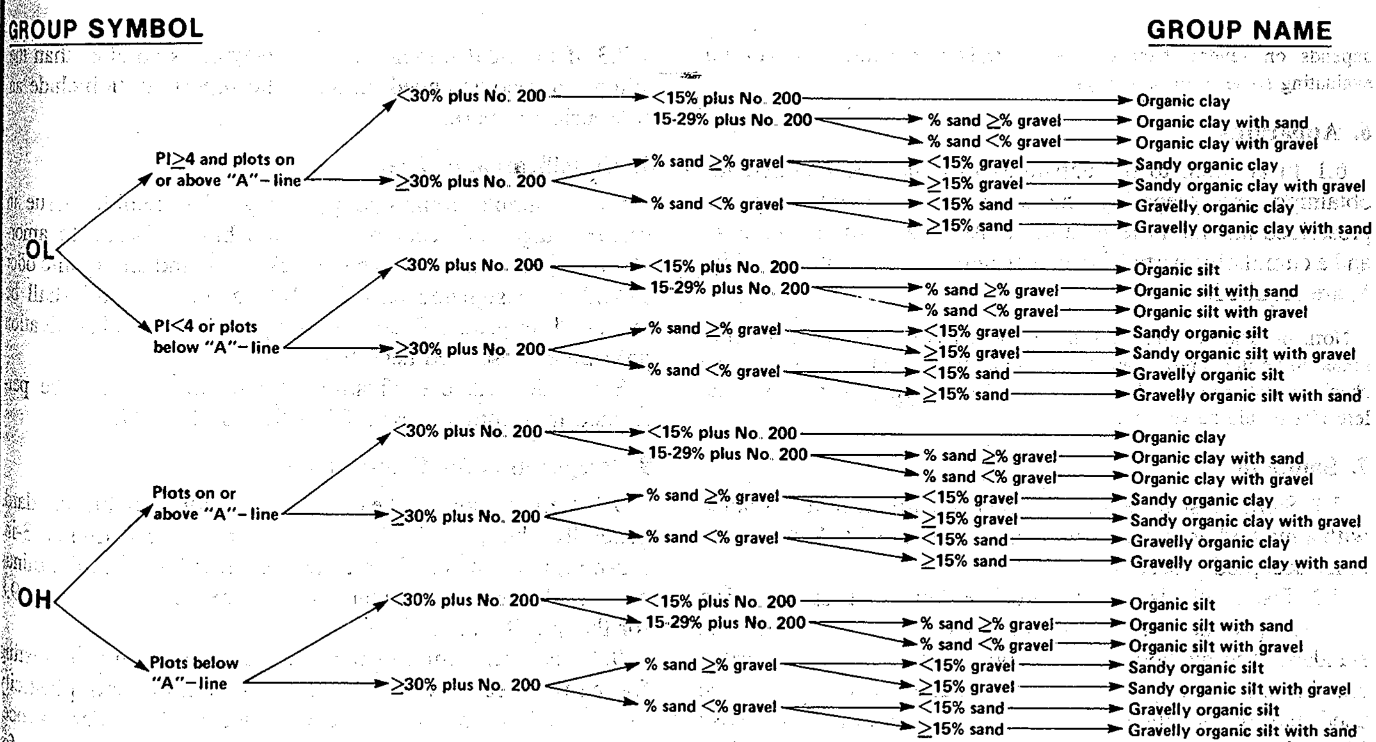


FIG. 2 Flow Chart for Classifying Organic Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

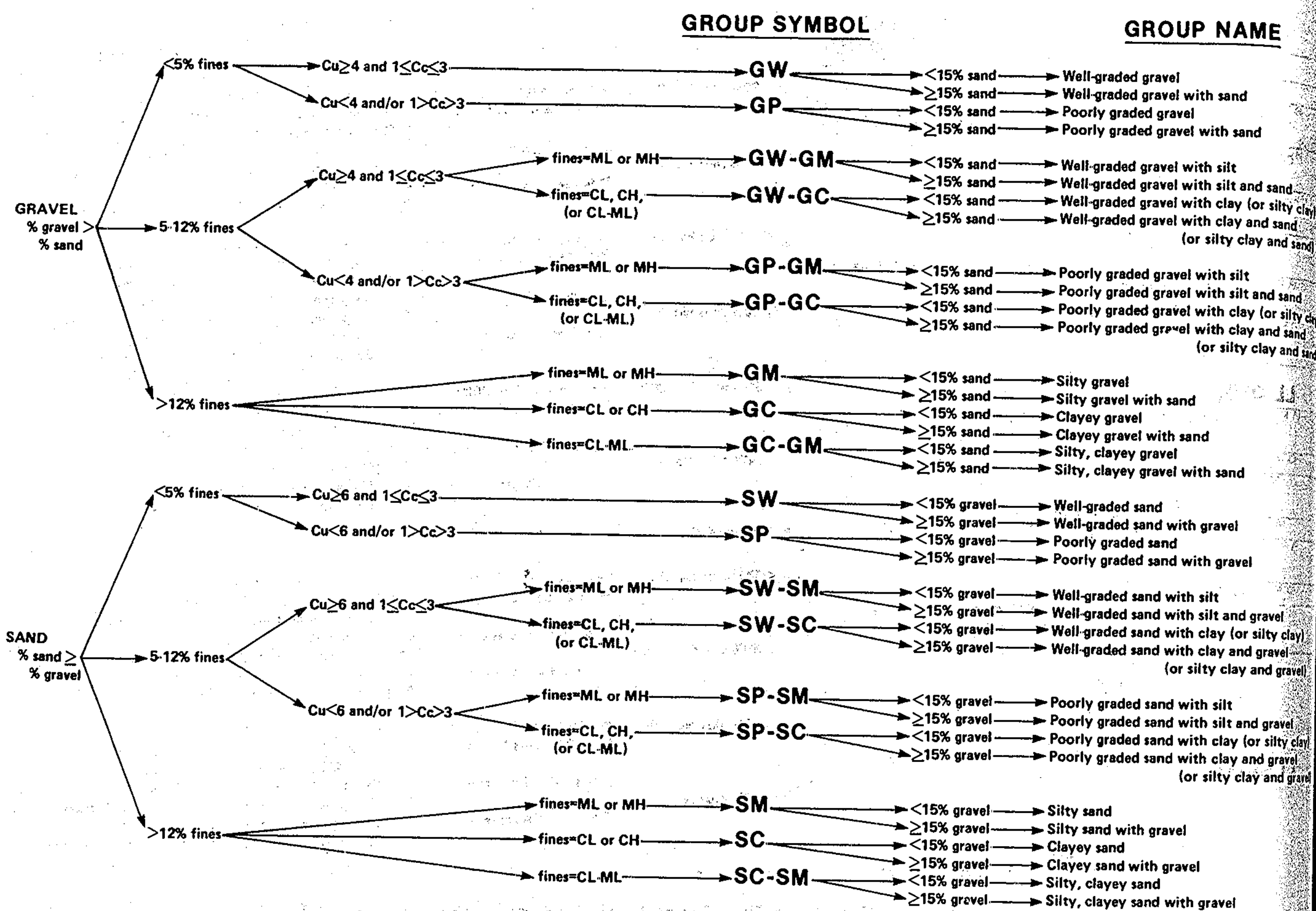


FIG. 3 Flow Chart for Classifying Coarse-Grained Soils (More Than 50 % Retained on No. 200 Sieve)

depends on several factors; Practice D 3740 provides a means for evaluating some of those factors.

6. Apparatus

6.1 In addition to the apparatus that may be required for obtaining and preparing the samples and conducting the prescribed laboratory tests, a plasticity chart, similar to Fig. 4, and a cumulative particle-size distribution curve, similar to Fig. 5, are required.

NOTE 6—The "U" line shown on Fig. 4 has been empirically determined to be the approximate "upper limit" for natural soils. It is a good check against erroneous data, and any test results that plot above or to the left of it should be verified.

7. Sampling

7.1 Samples shall be obtained and identified in accordance with a method or methods, recommended in Guide D 420 or by other accepted procedures.

7.2 Test Methods D 6913 provides guidance on selecting size of specimen. Two test methods are provided in this standard. The methods differ in the significant digits recorded and the size of the specimen (mass) required. The method to be used may be specified by the requesting authority; otherwise Method A shall be performed. Whenever possible, the field samples should have weights two to four times larger than shown.

7.3 If the field sample or test specimen is smaller than the minimum recommended amount, the report shall include an appropriate remark.

8. Classification of Peat

8.1 A sample composed primarily of vegetable tissue in various stages of decomposition and has a fibrous to amorphous texture, a dark-brown to black color, and an organic odor should be designated as a highly organic soil and shall be classified as peat, PT, and not subjected to the classification procedures described hereafter.

8.2 If desired, classification of type of peat can be performed in accordance with Classification D 4427.

9. Preparation for Classification

9.1 Before a soil can be classified according to this standard, generally the particle-size distribution of the minus 3-in. (75-mm) material and the plasticity characteristics of the minus No. 40 (425-μm) sieve material must be determined. See 9.8 for the specific required tests.

9.2 The preparation of the soil specimen(s) and the testing for particle-size distribution and liquid limit and plasticity index shall be in accordance with accepted standard procedures. Two procedures for preparation of the soil specimens for testing for soil classification purposes are given in Appendixes X3 and X4. Appendix X3 describes the wet preparation method

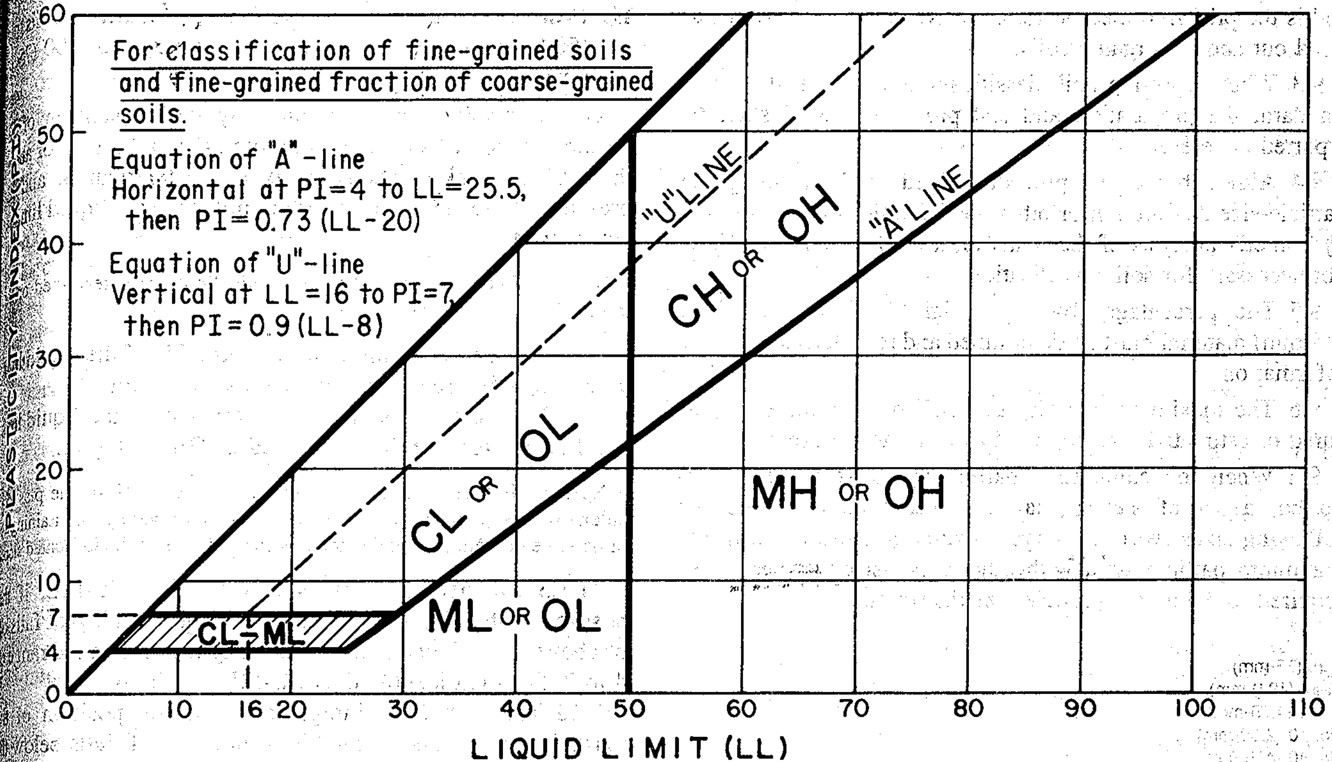
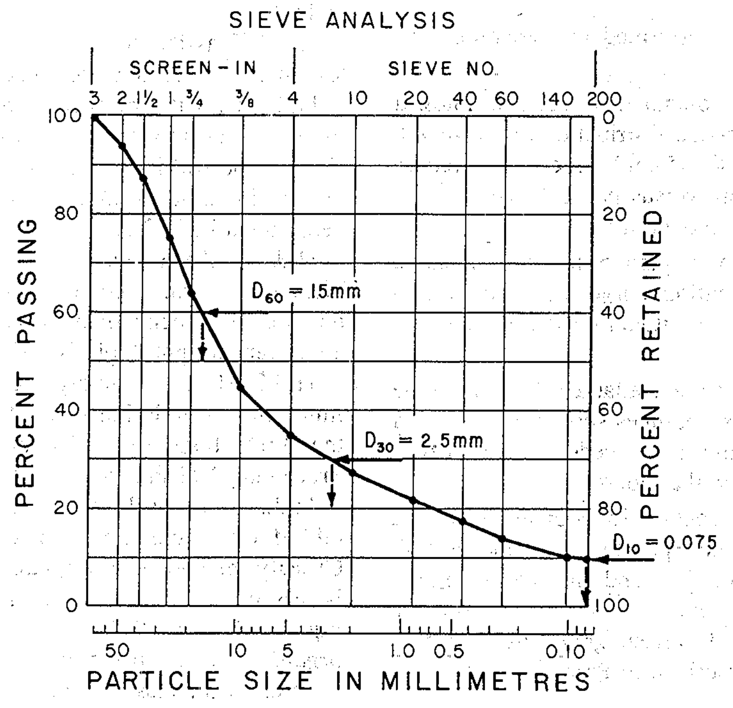


FIG. 4 Plasticity Chart



$$Cu = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \qquad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$$

FIG. 5 Cumulative Particle-Size Plot

and is the preferred method for cohesive soils that have never dried out and for organic soils.

9.3 When reporting soil classifications determined by this standard, the preparation and test procedures used shall be reported or referenced.

9.4 Although the test procedure used in determining the particle-size distribution or other considerations may require a hydrometer analysis of the material, a hydrometer analysis is not necessary for soil classification.

9.5 The percentage (by dry weight) of any plus 3-in. (75-mm) material must be determined and reported as auxiliary information.

9.6 The maximum particle size shall be determined (measured or estimated) and reported as auxiliary information.

9.7 When the cumulative particle-size distribution is required, a set of sieves shall be used which include the following sizes (with the largest size commensurate with the maximum particle size) with other sieve sizes as needed or required to define the particle-size distribution:

3-in. (75-mm)
¾-in. (19.0-mm)
No. 4 (4.75-mm)
No. 10 (2.00-mm)
No. 40 (425-μm)
No. 200 (75-μm)

9.8 The tests required to be performed in preparation for classification are as follows:

9.8.1 For soils estimated to contain less than 5 % fines, a plot of the cumulative particle-size distribution curve of the fraction coarser than the No. 200 (75-μm) sieve is required. A semi-log plot of percent passing versus partical-size or sieve size/sieve number is plotted as shown in Fig. 5.

9.8.2 For soils estimated to contain 5 to 15 % fines, a cumulative particle-size distribution curve, as described in 9.8.1, is required, and the liquid limit and plasticity index are required.

9.8.2.1 If sufficient material is not available to determine the liquid limit and plasticity index, the fines should be estimated to be either silty or clayey using the procedures described in Practice D 2488 and so noted in the report.

9.8.3 For soils estimated to contain 15 % or more fines, a determination of the percent fines, percent sand, and percent gravel is required, and the liquid limit and plasticity index are required. For soils estimated to contain 90 % fines or more, the percent fines, percent sand, and percent gravel may be estimated using the procedures described in Practice D 2488 and so noted in the report.

10. Preliminary Classification Procedure

10.1 Class the soil as fine-grained if 50 % or more by dry weight of the test specimen passes the No. 200 (75-μm) sieve and follow Section 3.1.2.

10.2 Class the soil as coarse-grained if more than 50 % by dry weight of the test specimen is retained on the No. 200 (75-μm) sieve and follow Section 12.

11. Procedure for Classification of Fine-Grained Soils (50 % or more by dry weight passing the No. 200 (75-μm) sieve)

11.1 The soil is an inorganic clay if the position of the plasticity index versus liquid limit plot, Fig. 4, falls on or above the "A" line, the plasticity index is greater than 4, and the presence of organic matter does not influence the liquid limit as determined in 11.3.2.

NOTE 7—The plasticity index and liquid limit are determined on the minus No. 40 (425 μm) sieve material.

11.1.1 Classify the soil as a *lean clay,* CL, if the liquid limit is less than 50. See area identified as CL on Fig. 4.

11.1.2 Classify the soil as a *fat clay,* CH, if the liquid limit is 50 or greater. See area identified as CH on Fig. 4.

NOTE 8—In cases where the liquid limit exceeds 110 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scale on both axes and extending the "A" line at the indicated slope.

11.1.3 Classify the soil as a *silty clay,* CL-ML, if the position of the plasticity index versus liquid limit plot falls on or above the "A" line and the plasticity index is in the range of 4 to 7. See area identified as CL-ML on Fig. 4.

11.2 The soil is an inorganic silt if the position of the plasticity index versus liquid limit plot, Fig. 4, falls below the "A" line or the plasticity index is less than 4, and presence of organic matter does not influence the liquid limit as determined in 11.3.2.

11.2.1 Classify the soil as a *silt,* ML, if the liquid limit is less than 50. See area identified as ML on Fig. 4.

11.2.2 Classify the soil as an *elastic silt,* MH, if the liquid limit is 50 or greater. See area identified as MH on Fig. 4.

11.3 The soil is an organic silt or clay if organic matter is present in sufficient amounts to influence the liquid limit as determined in 11.3.2.

11.3.1 If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test shall be performed on a test specimen which has been oven dried at 110 ± 5°C to a constant weight, typically over night.

11.3.2 The soil is an organic silt or organic clay if the liquid limit after oven drying is less than 75 % of the liquid limit of the original specimen determined before oven drying (see Procedure B of Practice D 2217).

11.3.3 Classify the soil as an *organic silt* or *organic clay,* OL, if the liquid limit (not oven dried) is less than 50 %. Classify the soil as an *organic silt,* OL, if the plasticity index is less than 4, or the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay,* OL, if the plasticity index is 4 or greater and the position of the plasticity index versus liquid limit plot falls on or above the "A" line. See area identified as OL (or CL-ML) on Fig. 4.

11.3.4 Classify the soil as an *organic clay* or *organic silt,* OH, if the liquid limit (not oven dried) is 50 or greater. Classify the soil as an *organic silt,* OH, if the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay,* OH, if the position of the plasticity index versus liquid-limit plot falls on or above the "A" line. See area identified as OH on Fig. 4.

11.4 If less than 30 % but 15 % or more of the test specimen is retained on the No. 200 (75-μm) sieve, the words "with sand" or "with gravel" (whichever is predominant) shall be added to the group name. For example, lean clay with sand, CL; silt with gravel, ML. If the percent of sand is equal to the percent of gravel, use "with sand."

11.5 If 30 % or more of the test specimen is retained on the No. 200 (75-μm) sieve, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if 30 % or more of the test specimen is retained on the No. 200 (75-μm) sieve and the coarse-grained portion is predominantly sand. Add the word "gravelly" if 30 % or more of the test specimen is retained on the No. 200 (75-μm) sieve and the coarse-grained portion is predominantly gravel. For example, sandy lean clay, CL; gravelly fat clay, CH; sandy silt, ML. If the percent of sand is equal to the percent of gravel, use "sandy."

12. Procedure for Classification of Coarse-Grained Soils (more than 50 % retained on the No. 200 (75-μm) sieve)

12.1 Class the soil as gravel if more than 50 % of the coarse fraction [plus No. 200 (75-μm) sieve] is retained on the No. 4 (4.75-mm) sieve.

12.2 Class the soil as sand if 50 % or more of the coarse fraction [plus No. 200 (75-μm) sieve] passes the No. 4 (4.75-mm) sieve.

12.3 If 12 % or less of the test specimen passes the No. 200 (75-μm) sieve, plot the cumulative particle-size distribution, Fig. 5, and compute the coefficient of uniformity, *Cu*, and coefficient of curvature, *Cc*, as given in Eqs 1 and 2.

$$Cu = D_{60}/D_{10} \quad (1)$$

$$Cc = (D_{30})^2/(D_{10} \times D_{60}) \quad (2)$$

where:

D_{10}, D_{30}, and D_{60} = the particle-size diameters corresponding to 10, 30, and 60 %, respectively, passing on the cumulative particle-size distribution curve, Fig. 5.

NOTE 9—It may be necessary to extrapolate the curve to obtain the D_{10} diameter.

12.3.1 If less than 5 % of the test specimen passes the No. 200 (75-μm) sieve, classify the soil as a *well-graded gravel*, GW, or *well-graded sand*, SW, if Cu is greater than or equal to 4.0 for gravel or greater than 6.0 for sand, and Cc is at least 1.0 but not more than 3.0.

12.3.2 If less than 5 % of the test specimen passes the No. 200 (75-μm) sieve, classify the soil as *poorly graded gravel*, GP, or *poorly graded sand*, SP, if either the *Cu* or the *Cc* criteria for well-graded soils are not satisfied.

12.4 If more than 12 % of the test specimen passes the No. 200 (75-μm) sieve, the soil shall be considered a coarse-grained soil with fines. The fines are determined to be either clayey or silty based on the plasticity index versus liquid limit plot on Fig. 4. (See 9.8.2.1 if insufficient material available for testing) (see Note 7).

12.4.1 Classify the soil as a *clayey gravel*, GC, or *clayey sand*, SC, if the fines are clayey, that is, the position of the plasticity index versus liquid limit plot, Fig. 4, falls on or above the "A" line and the plasticity index is greater than 7.

12.4.2 Classify the soil as a *silty gravel*, GM, or *silty sand*, SM, if the fines are silty, that is, the position of the plasticity index versus liquid limit plot, Fig. 4, falls below the "A" line or the plasticity index is less than 4.

12.4.3 If the fines plot as a silty clay, CL-ML, classify the soil as a *silty, clayey gravel*, GC-GM, if it is a gravel or a *silty, clayey sand*, SC-SM, if it is a sand.

12.5 If 5 to 12 % of the test specimen passes the No. 200 (75-μm) sieve, give the soil a dual classification using two group symbols.

12.5.1 The first group symbol shall correspond to that for a gravel or sand having less than 5 % fines (GW, GP, SW, SP), and the second symbol shall correspond to a gravel or sand having more than 12 % fines (GC, GM, SC, SM).

12.5.2 The group name shall correspond to the first group symbol plus "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example, well-graded gravel with clay, GW-GC; poorly graded sand with silt, SP-SM (See 9.8.2.1 if insufficient material available for testing).

NOTE 10—If the fines plot as a *silty clay*, CL-ML, the second group symbol should be either GC or SC. For example, a poorly graded sand with 10 % fines, a liquid limit of 20, and a plasticity index of 6 would be classified as a poorly graded sand with silty clay, SP-SC.

12.6 If the specimen is predominantly sand or gravel but contains 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example, poorly graded gravel with sand, clayey sand with gravel.

12.7 If the field sample contained any cobbles or boulders or both, the words "with cobbles," or "with cobbles and boulders" shall be added to the group name. For example, silty gravel with cobbles, GM.

13. Report

13.1 The report should include the group name, group symbol, and the results of the laboratory tests. The particle-size distribution shall be given in terms of percent of gravel, sand, and fines. The plot of the cumulative particle-size distribution curve shall be reported if used in classifying the soil. Report appropriate descriptive information according to the procedures in Practice D 2488. A local or commercial name or geologic interpretation for the material may be added at the end of the descriptive information if identified as such. The test procedures used shall be referenced.

NOTE 11—*Example: Clayey Gravel with Sand and Cobbles* (GC)—46 % fine to coarse, hard, subrounded gravel; 30 % fine to coarse, hard, subrounded sand; 24 % clayey fines, LL = 38, PI = 19; weak reaction with HCl; original field sample had 4 % hard, subrounded cobbles; maximum dimension 150 mm.

In-Place Conditions—firm, homogeneous, dry, brown,
Geologic Interpretation—alluvial fan.

NOTE 12—Other examples of soil descriptions are given in Appendix X1.

14. Precision and Bias

14.1 Criteria for acceptability depends on the precision and bias of Test Methods D 422, D 1140 and D 4318.

15. Keywords

15.1 Atterberg limits; classification; clay; gradation; gravel; laboratory classification; organic soils; sand; silt; soil classification; soil tests

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF DESCRIPTIONS USING SOIL CLASSIFICATION

X1.1 The following examples show how the information required in 13.1 can be reported. The appropriate descriptive information from Practice D 2488 is included for illustrative purposes. The additional descriptive terms that would accompany the soil classification should be based on the intended use of the classification and the individual circumstances.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—73 % fine to coarse, hard, subangular gravel; 23 % fine to coarse, hard, subangular sand; 4 % fines; Cc = 2.7, Cu = 12.4.

X1.1.2 *Silty Sand with Gravel (SM)*—61 % predominantly fine sand; 23 % silty fines, LL = 33, PI = 6; 16 % fine, hard, subrounded gravel; no reaction with HCl; (field sample smaller than recommended). *In-Place Conditions*—Firm, stratified and contains lenses of silt 1 to 2 in. thick, moist, brown to gray; in-place density = 106 lb/ft^3 and in-place moisture = 9 %.

X1.1.3 *Organic Clay (OL)*—100 % fines, LL (not dried) = 32, LL (oven dried) = 21, PI (not dried) = 10; wet, dark brown, organic odor, weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—74 % fine to coarse, hard, subangular reddish sand; 26 % organic and silty dark-brown fines, LL (not dried) = 37, LL (oven dried) = 26, PI (not dried) = 6, wet, weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—78 % fine to coarse, hard, subrounded to subangular gravel; 16 % fine to coarse, hard, subrounded to subangular sand; 6 % silty (estimated) fines; moist, brown; no reaction with HCl; original field sample had 7 % hard, subrounded cobbles and 2 % hard, subrounded boulders with a maximum dimension of 18 in.

X2. USING SOIL CLASSIFICATION AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, ETC.

X2.1 The group names and symbols used in this standard may be used as a descriptive system applied to materials that exist in situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, etc.).

X2.2 Materials such as shells, crushed rock, slag, etc., should be identified as such. However, the procedures used in this standard for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, a classification in accordance with this standard may be assigned to aid in describing the material.

X2.3 If a classification is used, the group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how soil classifications could be incorporated into a description system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2- to 4-in. pieces of shale from power auger hole, dry, brown, no reaction with HCl. After laboratory processing by slaking in water for 24 h, material classified as "Sandy Lean Clay (CL)"—61 % clayey fines, LL = 37, PI = 16; 33 % fine to medium sand; 6 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"—91 % fine to medium sand; 9 % silty (estimated) fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—65 % gravel-size broken shells; 31 % sand and sand-size shell pieces; 4 % fines; Cc = 2.4, Cu = 1.9; would be classified as "Poorly Graded Gravel with Sand (GP)".

X2.4.4 *Crushed Rock*—Processed gravel and cobbles from Pit No. 7; "Poorly Graded Gravel (GP)"—89 % fine, hard, angular gravel-size particles; 11 % coarse, hard, angular sand-size particles, dry, tan; no reaction with HCl; Cc = 2.4, Cu = 0.9.

X3. PREPARATION AND TESTING FOR CLASSIFICATION PURPOSES BY THE WET METHOD

X3.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification using a wet-preparation procedure.

X3.2 Samples prepared in accordance with this procedure should contain as much of their natural water content as possible and every effort should be made during obtaining, preparing, and transportating the samples to maintain the natural moisture.

X3.3 The procedures to be followed in this standard assume that the field sample contains fines, sand, gravel, and plus 3-in. (75-mm) particles and the cumulative particle-size distribution plus the liquid limit and plasticity index values are required (see 9.8). Some of the following steps may be omitted when they are not applicable to the soil being tested.

X3.4 If the soil contains plus No. 200 (75-µm) particles that would degrade during dry sieving, use a test procedure for determining the particle-size characteristics that prevents this degradation.

X3.5 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X3.6 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X3.6.1 Separate the field sample into two fractions on a 3-in. (75-mm) sieve, being careful to maintain the natural water content in the minus 3-in. (75-mm) fraction. Any particles adhering to the plus 3-in. (75-mm) particles shall be brushed or wiped off and placed in the fraction passing the 3-in. (75-mm) sieve.

X3.6.2 Determine the air-dry or oven-dry weight of the fraction retained on the 3-in. (75-mm) sieve. Determine the total (wet) weight of the fraction passing the 3-in. (75-mm) sieve.

X3.6.3 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve. Determine the water content, in accordance with Test Method D 2216, of a representative specimen with a minimum dry weight as required in 7.2. Save the water-content specimen for determination of the particle-size analysis in accordance with X3.8.

X3.6.4 Compute the dry weight of the fraction passing the 3-in. (75-mm) sieve based on the water content and total (wet) weight. Compute the total dry weight of the sample and calculate the percentage of material retained on the 3-in. (75-mm) sieve.

X3.7 Determine the liquid limit and plasticity index as follows:

X3.7.1 If the soil disaggregates readily, mix on a clean, hard surface and select a representative sample by quartering in accordance with Practice C 702.

X3.7.1.1 If the soil contains coarse-grained particles coated with and bound together by tough clayey material, take extreme care in obtaining a representative portion of the No. 40 (425-µm) fraction. Typically, a larger portion than normal has to be selected, such as the minimum weights required in 7.2.

X3.7.1.2 To obtain a representative specimen of a basically cohesive soil, it may be advantageous to pass the soil through a ¾-in. (19-mm) sieve or other convenient size so the material can be more easily mixed and then quartered or split to obtain the representative specimen.

X3.7.2 Process the representative specimen in accordance with Procedure B of Practice D 2217.

X3.7.3 Perform the liquid-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test.

X3.7.4 Perform the plastic-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test, and calculate the plasticity index.

X3.8 Determine the particle-size distribution as follows:

X3.8.1 If the water content of the fraction passing the 3-in. (75-mm) sieve was required (X3.6.3), use the water-content specimen for determining the particle-size distribution. Otherwise, select a representative specimen in accordance with Practice C 702 with a minimum dry weight as required in 7.2.

X3.8.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 422. See 9.7 for the set of required sieves.

X3.8.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method C 136. See 9.7 for the set of required sieves. The specimen should be soaked until all clayey aggregations have softened and then washed in accordance with Test Method C 117 prior to performing the particle-size distribution.

X3.8.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method C 117, being sure to soak the specimen long enough to soften all clayey aggregations, followed by Test Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75-µm) sieve.

X3.8.5 Calculate the percent fines, percent sand, and percent gravel in the minus 3-in. (75-mm) fraction for classification purposes.

X4. AIR-DRIED METHOD OF PREPARATION OF SOILS FOR TESTING FOR CLASSIFICATION PURPOSES

X4.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification when air-drying the soil before testing is specified or desired or when the natural moisture content is near that of an air-dried state.

X4.2 If the soil contains organic matter or mineral colloids that are irreversibly affected by air drying, the wet-preparation method as described in Appendix X3 should be used.

X4.3 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X4.4 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X4.4.1 Air dry and weigh the field sample.

X4.4.2 Separate the field sample into two fractions on a 3-in. (75-mm) sieve.

X4.4.3 Weigh the two fractions and compute the percentage of the plus 3-in. (75-mm) material in the field sample.

X4.5 Determine the particle-size distribution and liquid limit and plasticity index as follows (see 9.8 for when these tests are required):

X4.5.1 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve.

X4.5.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 422. See 9.7 for the set of sieves that is required.

X4.5.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 1140 followed by Test Method C 136. See 9.7 for the set of sieves that is required.

X4.5.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method D 1140 followed by Test Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75-μm) sieve.

X4.5.5 If required, determine the liquid limit and the plasticity index of the test specimen in accordance with Test Method D 4318.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

Prefix	Suffix
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = cobbles
	b = boulders

X5.4 The soil classification symbol is to be enclosed in parentheses. Some examples would be:

Group Symbol and Full Name	Abbreviated
CL, Sandy lean clay	s(CL)
SP-Sm, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2000) that may impact the use of this standard.

(1) Added Test Method D 6913 to Section 2 and 7.2.
(2) Corrected 7.2 in selecting size of a sample.
(3) Corrected Example X2.4.3.

Designation: D 2488 – 06

Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)[1]

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (see Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements see Section 8.

1.6 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 1452 Practice for Soil Investigation and Sampling by Auger Borings

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils

D 1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

D 2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Nov. 1, 2006. Published November 2006. Originally approved in 1966. Last previous edition approved in 2000 as D 2488 – 00.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard.

3.1.1 *clay*—soil passing a No. 200 (75-μm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.2 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a ¾-in. (19-mm) sieve.

fine—passes a ¾-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.3 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.4 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.5 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.6 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-μm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-μm) sieve.

fine—passes a No. 40 (425-μm) sieve and is retained on a No. 200 (75-μm) sieve.

3.1.7 *silt*—soil passing a No. 200 (75-μm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the "A" line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Fig. 1a and Fig. 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

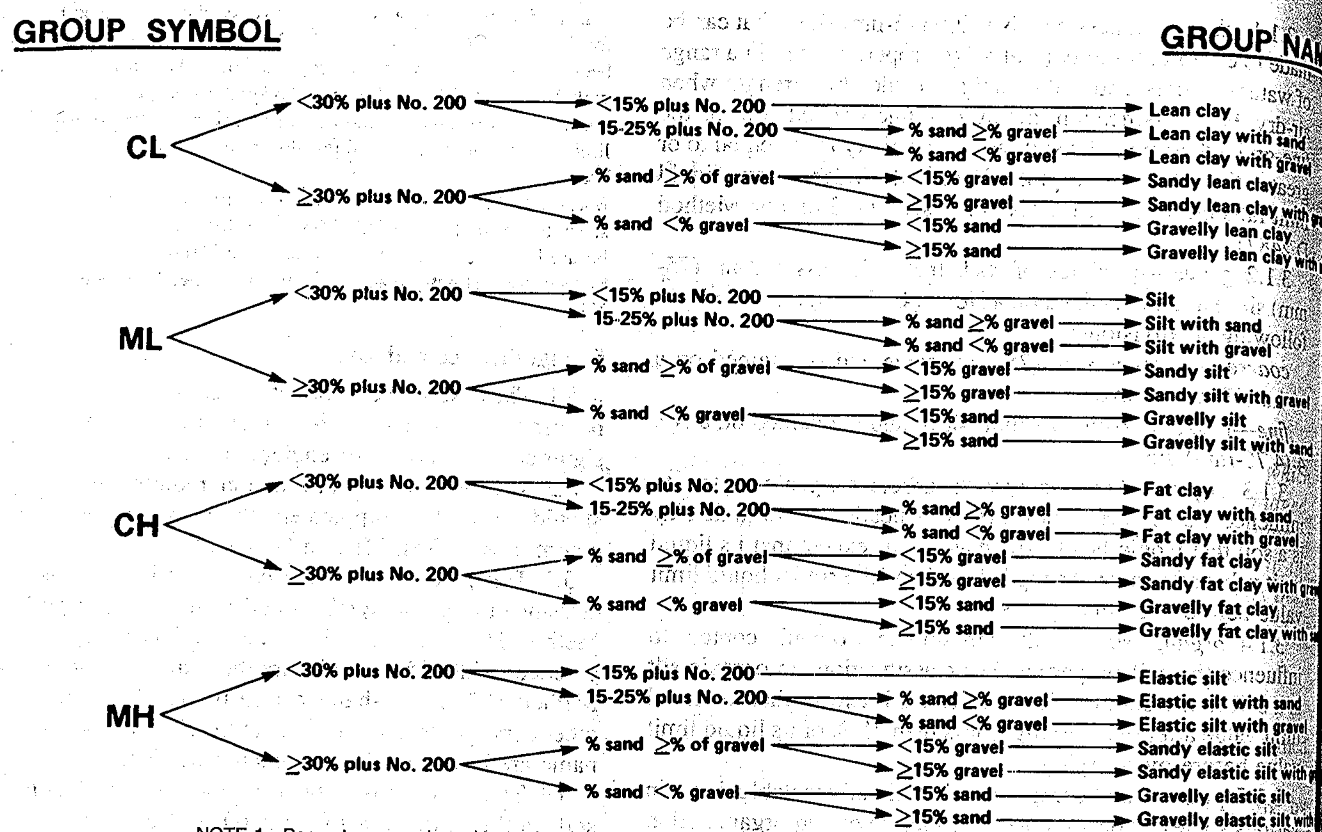
NOTE 5—Notwithstanding the statements on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing depends on several factors; Practice D 3740 provides a means for evaluating some of those factors.

6. Apparatus

6.1 *Required Apparatus*:

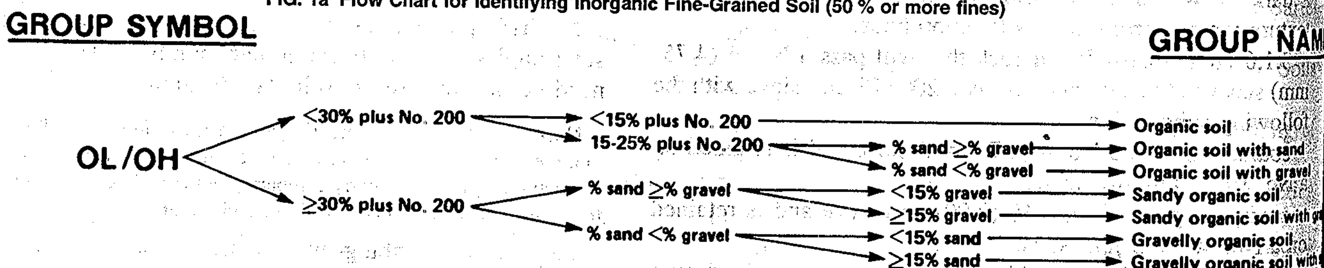
6.1.1 *Pocket Knife or Small Spatula.*

6.2 *Useful Auxiliary Apparatus*:



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1 b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)

.2.1 *Small Test Tube and Stopper* (or jar with a lid).
.2.2 *Small Hand Lens.*

Reagents

.1 *Purity of Water*—Unless otherwise indicated, references vater shall be understood to mean water from a city water ply or natural source, including non-potable water.

.2 *Hydrochloric Acid*—A small bottle of dilute hydrochlo- acid, HCl, one part HCl (10 *N*) to three parts water (This gent is optional for use with this practice). See Section 8.

Safety Precautions

.1 When preparing the dilute HCl solution of one part centrated hydrochloric acid (10 *N*) to three parts of distilled er, slowly add acid into water following necessary safety cautions. Handle with caution and store safely. If solution es into contact with the skin, rinse thoroughly with water.

2 **Caution**—Do not add water to acid.

9. Sampling

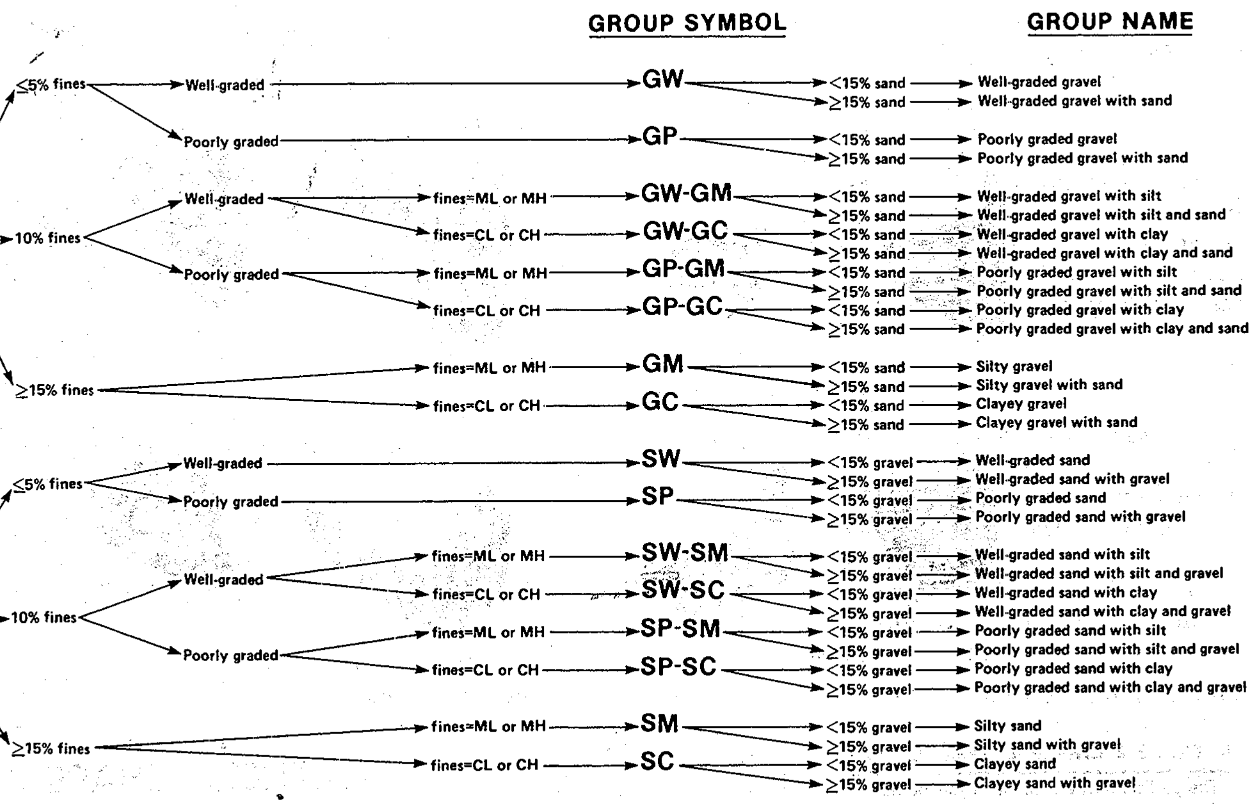
9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 6—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Test Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 7—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

...mum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (3⁄8 in.)	200 g (0.5 lb)
19.0 mm (3⁄4 in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 8—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceeding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

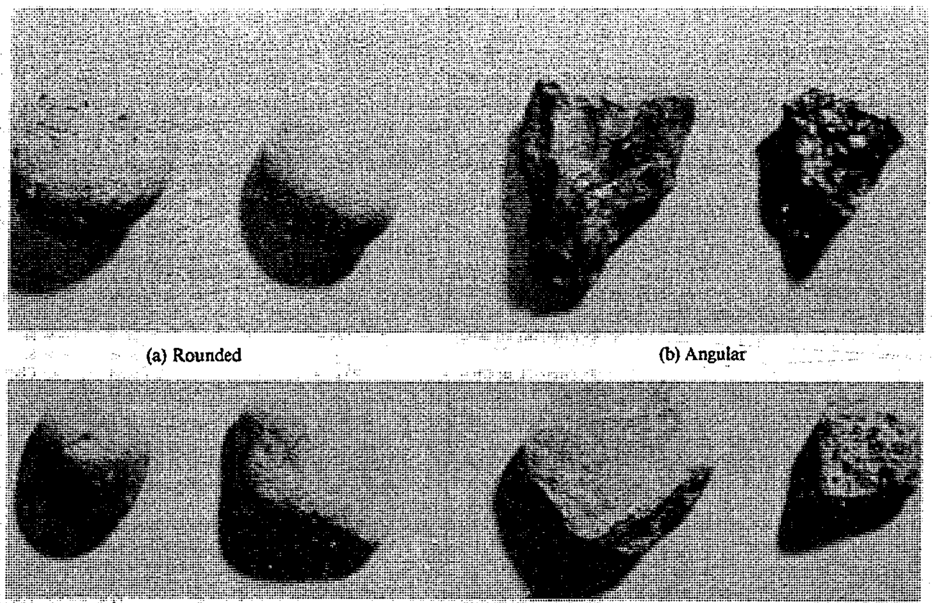
TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the critera in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.



(a) Rounded (b) Angular

(c) Subrounded (d) Subangular

FIG. 3 Typical Angularity of Bulky Grains

TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

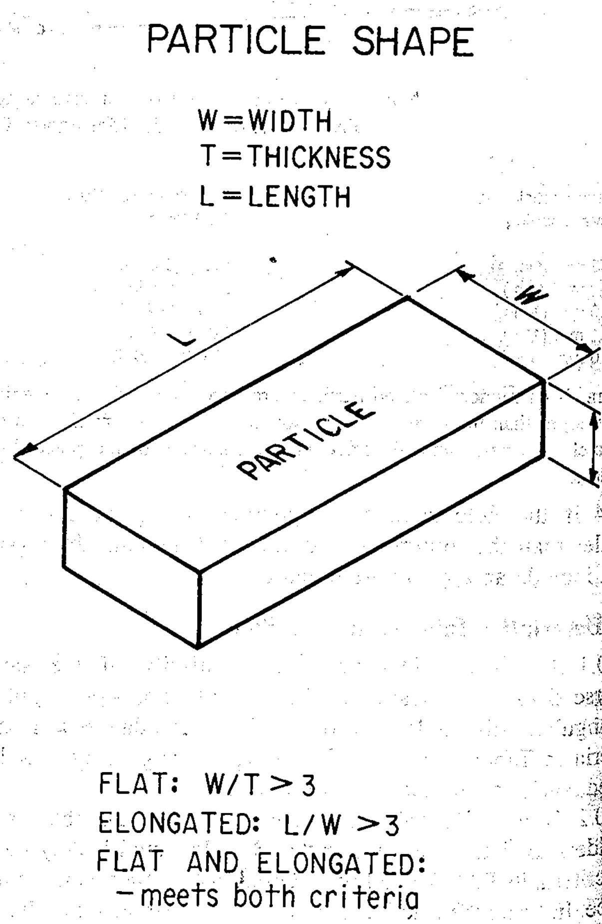


FIG. 4 Criteria for Particle Shape

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1½ in. (will pass a 1½-in. square opening but not a ¾-in. square opening).

TABLE 3 Criteria for Describing Moisture Condition

...ption	Criteria
...ry	Absence of moisture, dusty, dry to the touch
...ist	Damp but no visible water
...et	Visible free water, usually soil is below water table

TABLE 4 Criteria for Describing the Reaction With HCl

...ription	Criteria
...ne	No visible reaction
...ak	Some reaction, with bubbles forming slowly
...ong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
...ry soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼ in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
...ry hard	Thumbnail will not indent soil

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 9—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 10—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 *Dry Strength*:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 11—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accorance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 *Dilatancy*:

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 *Toughness*:

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about ⅛ in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of abou in. The thread will crumble at a diameter of ⅛ in. when the s is near the plastic limit. Note the pressure required to roll thread near the plastic limit. Also, note the strength of thread. After the thread crumbles, the pieces should be lump together and kneaded until the lump crumbles. Note toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump low, medium, or high in accordance with the criteria in Ta 10.

14.5 *Plasticity*—On the basis of observations made dur the toughness test, describe the plasticity of the material accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *orga* fine-grained soil (see 14.8). If inorganic, follow the steps giv in 14.7.

14.7 *Identification of Inorganic Fine-Grained Soils*:

14.7.1 Identify the soil as a *lean clay*, CL, if the soil h medium to high dry strength, no or slow dilatancy, and medi toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has hi to very high dry strength, no dilatancy, and high toughness a plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to lo dry strength, slow to rapid dilatancy, and low toughness a plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil h low to medium dry strength, no to slow dilatancy, and low medium toughness and plasticity (see Table 12).

NOTE 12—These properties are similar to those for a lean cl However, the silt will dry quickly on the hand and have a smooth, si feel when dry. Some soils that would classify as MH in accordance w the criteria in Test Method D 2487 are visually difficult to distinguish fr lean clays, CL. It may be necessary to perform laboratory testing f proper identification.

14.8 *Identification of Organic Fine-Grained Soils*:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the s contains enough organic particles to influence the soil prop ties. Organic soils usually have a dark brown to black color a may have an organic odor. Often, organic soils will cha

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 13—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Fig. 1a and Fig. 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Fig. 1a and Fig. 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils

(Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 14—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 15—Other examples of soil descriptions and identification are given in Appendix X1 and Appendix X2.

NOTE 16—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
   Gravel—fine, coarse
   Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong

For intact samples:

18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray; in-place density 106 lb/ft^3; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incororated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown.

X2.4.3 *Broken Shells*—About 60 % uniformly graded gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % nonplastic fines; "Poorly Graded Gravel with Silt and Sand (GP-GM)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

Prefix:	*Suffix:*
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

Group Symbol and Full Name	*Abbreviated*
CL, Sandy lean clay	s(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2000) that may impact the use of this standard.

(1) Revised footnote numbering in Reference Section.

(2) Revised classification example in X2.4.2 and X2.4.3.

CATEGORY 10: SURFACE WATER SAMPLING, FLOW

Section 10.1

Field Sampling Guidance Document #1225 Surface Water Sampling

U.S.EPA REGION 9 LABORATORY

RICHMOND, CALIFORNIA

FIELD SAMPLING GUIDANCE DOCUMENT #1225

<u>SURFACE WATER SAMPLING</u>

TABLE OF CONTENTS

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) is applicable to the collection of representative liquid samples, both aqueous and nonaqueous from streams, rivers, lakes, ponds, lagoons, embayments, and surface impoundments. It includes samples collected from depth, as well as samples collected at the surface.

2.0 METHOD SUMMARY

Sampling situations vary widely, and, therefore, no universal sampling procedure can be recommended.

However, sampling of both aqueous and non-aqueous liquids from the above mentioned sources is generally accomplished through the use of one of the following samplers or techniques:

- Dip sampler
- Direct method
- Discrete Depth samplers; e.g., Kemmerer or Van Dorn bottles
- Peristaltic pumps
- Stormwater collection devices

These sampling techniques will allow for the collection of representative samples from the majority of surface waters and impoundments encountered.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Once samples have been collected, follow these procedures:

1. Transfer the sample(s) into suitable labeled sample containers.
2. Preserve the sample if appropriate, or use pre-preserved sample bottles.
3. Cap the container, put it in a Ziploc plastic bag and place it on ice in a cooler.
4. Record all pertinent data in the site logbook and on a field data sheet.
5. Complete the chain of custody form.
6. Attach custody seals to the cooler prior to shipment.
7. Decontaminate all sampling equipment prior to the collection of additional samples.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

There are two primary interferences or potential problems with surface water sampling. These include cross-contamination of samples and improper sample collection.

- Cross-contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. Another suitable method can be to work collecting samples from low to high concentration, should this information be available. If this is not possible or practical, then decontamination of sampling equipment is necessary. Refer to SOP (#109), Sampling Equipment Decontamination.

- Improper sample collection can involve using contaminated equipment, disturbance of the stream or impoundment substrate, and sampling in an obviously disturbed area.

Following proper decontamination procedures and minimizing disturbance of the sample site will eliminate these problems.

5.0 EQUIPMENT/APPARATUS

Equipment needed for collection of surface water samples includes:

- Dip sampler
- Kemmerer or Van Dorn bottles
- Line and messengers
- Peristaltic pumps
- Stormwater samplers
- Sample collection bottles
- Sample bottle preservatives
- Ziploc bags
- Ice
- Cooler(s)
- Chain of custody forms, field data sheets
- Decontamination equipment
- Maps/plot plan
- Safety equipment
- Compass
- Tape measure
- Survey stakes, flags, or buoys and anchors
- Camera and film
- Logbook/waterproof pen
- Sample bottle labels

6.0 REAGENTS

Reagents will be utilized for preservation of samples and for decontamination of sampling equipment. Required preservatives are specified by the analysis to be performed. Decontamination solutions are specified in SOP#109, Sampling Equipment Decontamination.

7.0 PROCEDURES

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and which equipment and supplies are needed.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or preclean equipment, and ensure that it is in working order.
4. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site-specific health and safety plan.
6. Use stakes, flags, or buoys to identify and mark all sampling locations. If required, the proposed locations may be adjusted based onsite access, property boundaries, and surface obstructions.

7.2 Sampling Considerations

The physical location of the investigator when collecting a sample may dictate the equipment to be used. If surface water samples are required, direct dipping of the sample container into the stream is desirable. This is possible, however, only from a small boat, a pier, etc., or by wading in the stream. Wading, however, may cause the re-suspension of bottom deposits and bias the sample. Wading is acceptable if the stream has a noticeable current (is not impounded), and the samples are collected while facing upstream. If the stream is too deep to wade, or if the sample must be collected from more than one water depth, or the sample must be collected from a bridge, etc., supplemental sampling equipment must be used.

Representative Samples

In order to collect a representative sample, the hydrology and morphometrics (e.g., measurements of volume, depth, etc.) of a stream or impoundment should be determined prior to sampling. This will aid in determining the presence of phases or layers in lagoons or impoundments, flow patterns in streams, and appropriate sample locations and depths.

Water quality data should be collected in impoundments to determine if stratification is present. Measurements of dissolved oxygen, pH, and temperature can indicate if strata exist which would effect analytical results. Conductivity and oxidation-reduction potential can also assist in the interpretation of analytical data and the selection of sampling sites and depths anytime surface water samples are collected. Measurements should be collected at 1-meter (maximum) intervals from the substrate to the surface using an appropriate instrument, such as a Hydrolab (or equivalent).

Generally, the deciding factors in the selection of a sampling device for sampling liquids in streams, rivers, lakes, ponds, lagoons, and surface impoundments are:

- Will the sample be collected from the shore or from a boat on the impoundment?
- What is the desired depth at which the sample is to be collected?
- What is the overall depth and flow direction of river or stream?
- What is the chemical nature of the analyte(s) of concern? Do they float on the water surface (collect by skimming the surface) or are they miscible (soluble) and are more likely to be present at depths (collect sub-surface)?

Sampler Composition

The appropriate sampling device must be of a proper composition. Samplers constructed of glass, stainless steel, PVC of PFTE (Teflon®) should be used based upon the analyses to be performed. For example, devices which are free of metal surfaces should be used for collecting samples for metal analyses.

7.3 SAMPLE COLLECTION

7.3.1 Dip Sampler

A dip sampler (Figure 1) is useful for situations where a sample is to be recovered from an outfall pipe or along a lagoon bank where direct access is limited. The long handle on such a device allows access from a discrete location. Sampling procedures are as follows:

1. Assemble the device in accordance with the manufacturer's instructions.
2. Extend the device to the sample location and collect the sample.
3. Retrieve the sampler and transfer the sample to the appropriate sample container.

7.3.2 Direct Method

For streams, rivers, lakes, and other surface waters, the direct method may be utilized to collect water samples from the surface. This method is not to be used for sampling lagoons or other impoundments where contact with contaminants are a concern.

Using adequate protective clothing, access the sampling station by appropriate means. For shallow stream stations, **the sampler should face upstream and collect the sample without disturbing the sediment**. Surface water samples should always be collected prior to a sediment sample at the same location. The collector submerses the closed sample container, opens the bottle to collect the sample and then caps the bottle while sub-surface. The collection bottle may be rinsed two times by the sample water. For lakes and other impoundments, collect the sample under the water surface avoiding surface debris and the boat wake.

When using the direct method, do not use pre-preserved sample bottles as the collection method may dilute the concentration of preservative necessary for proper sample preservation.

7.3.3 Discrete Depth Samplers

When discrete samples are desired from a specific depth, and the parameters to be measured do not require a Teflon® coated sampler, a standard Kemmerer or Van Dorn sampler may be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the ends of the sampler open while being lowered in a vertical position, thus allowing free passage of water through the cylinder. The Van Dorn sampler is plastic and is lowered in a horizontal position. In each case, a messenger is sent down a rope when the sampler is at the designated depth, to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill respective sample containers. With a rubber tube attached to the valve, dissolved oxygen sample bottles can be properly filled by allowing an overflow of the water being collected. With multiple depth samples, care should be taken not to stir up the bottom sediment and thus bias the sample.

1. Using a properly decontaminated Kemmerer or Van Dorn bottle, set the sampling device so that the sampling end pieces are pulled away from the sampling tube, allowing the water to be sampled to pass through this tube.
2. Lower the pre-set sampling device to the predetermined depth. Avoid bottom disturbance.
3. When the discrete sampler bottle is at the required depth, send down the messenger, closing the sampling device.
4. Retrieve the sampler and discharge the first 10 to 20 mL to clear any potential contamination on the valve. Transfer the sample to the appropriate sample container.
5. Be sure to use special attachments available on some discrete samplers to distribute small volumes at low flow rates; e.g., VOCs at 100 to 200 mL/ min.

7.3.4 Peristaltic Pump Samplers

Another device that can be effectively used to sample a water column is the peristaltic pump/vacuum jug system. The use of a metal conduit to which the tubing is attached, allows for the collection of a vertical sample (down to about a 25 foot depth) which is representative of the water column. Commercially available pumps vary in size and capability, with some being designed specifically for the simultaneous collection of multiple water samples.

The battery-powered "ISCO" sampler is one such peristaltic pump. It is designed to collect discreet samples into 24 polyethylene or glass bottles at preset intervals. Some ISCO models can be configured to collect samples into a single container. To operate the compositor:

1. Place collection jars in appropriate positions in compositor. Add ice.
2. Connect sample hose and strainer and position in waste stream.
3. Adjust bottle position to '1'.
4. Adjust head, tube lengths and width to appropriate settings.
5. Set sample volume; e.g., approx. 300 mL.
6. Set time interval to 60 minutes.
7. Check that pump is functioning in 'forward' position.
8. Turn switch to auto.
9. After first sample is collected, check to see that an adequate volume was collected.
10. Place lid on ISCO and place custody seals over the closures so that no tampering occurs.
11. If the sampler is not in a secure area, secure the sampler with lock and chain.

7.3.5 Stormwater Samplers

Recently, commercial stormwater samplers have become available. These samplers collect a "first flush" sample in one bottle and a "time weighted" composite sample in the second bottle. Typically the composite sampler is set (by the user) to take a 200 mL sample every 10 minutes until the composite sample bottle is full. Thus it is actually two separate samplers in one; designed to meet the regulatory guidelines. It can be triggered (by sensor) to begin collecting samples by either rainfall or water level increase.

1. Set the Sampler in an upright position.
2. Be sure the water sensor is plugged into the jack on the lower right side of the control panel.
3. Check to be sure the two float switches in the bottle cap are properly connected. Plug the lead from the bottle cap into the socket on the bottom of the controller housing.
4. Remove the battery charger from the sampler enclosure.
5. Turn on the sampler with the toggle switch on the right side of the controller enclosure.

6. Press the right side sampler button to activate the right side sample pump.
7. Press the left side sampler button to activate the left side sample pump.
8. Check to be sure the sample pumps af fully charged.
9. Verify the sample size to be collected once the storm sampler has been set up. It is dependent upon the vertical distance between the water and the sampler.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance activities which apply to the implementation of these procedures. However, the following general QA/QC procedures apply:

- All data must be documented on field data sheets or within site logbooks.
- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA and specific health and safety procedures.

More specifically, when sampling lagoons or surface impoundments containing know or suspected hazardous substances, take adequate precautions. The sampling team member collecting the sample should not get too close to the edge of the impoundment, where bank failure may cause him or her to lose their balance. The person performing the sampling should be on a lifeline and be wearing adequate protective equipment. When conducting sampling from a boat in an impoundment or flowing waters, follow appropriate boating safety procedures.

CATEGORY 10: SURFACE WATER SAMPLING, FLOW

<u>Section 10.2</u>

Standard Operating Procedure for Streamflow Measurement

STANDARD OPERATING PROCEDURE
FOR
STREAMFLOW MEASUREMENT

Compiled by Forrest John
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Region 6, Dallas, Texas

Introduction

For sites where a flow measurement is necessary, always measure flow, read the USGS flow gage, or obtain a flow value at a later date from the USGS. Measure and record flow after recording visual observations. Do not collect water samples in the area disturbed during a flow measurement. At sites with a USGS flow gage, observe and record the gage height to the nearest hundredth of a foot in the field logbook. Contact the office responsible for the gage and obtain the flow (in cubic feet per second) that corresponds to the gage height. If there is any doubt about the accuracy of the gage-height reading, sampling personnel should measure the flow if possible. USGS gage heights can be measured by one of the three methods: staff gage, wire weight, or bubble gage. Staff gages are black and white steel plates with the appearance of large measuring tapes bolted to a stable structure. Gradations in feet, tenths of a foot, and two-tenths of a foot should be recorded (where the water level hits the gage) to the nearest hundredth of a foot. Wire-weight gages house a weight attached by wire cable to a graduated reel (gradations are tenths and hundredths of a foot) with a counter at one end. The weight should be lowered to touch the surface of the water (causing a slight ripple). At that position, the counter value should be recorded to the nearest whole number and the point indicated by the stylus on the graduated reel to the nearest hundredth of a foot. The wire-weight gage could be a movable type to accommodate braided streams. If the gage needs to be moved, use the correction value on the bridge near the repositioned gage location.

Bubble gages are installed in USGS gage houses, which are locked with a USGS key. The bubble gage uses a data logger attached to a pressure transducer system to indicate gage height in feet. Gage houses can also contain stilling wells with staff gages on the inside wall of the well. If no nearby USGS flow gages can be accessed to determine streamflow, personnel should measure flow. A summary description of the conventional current-meter flow-measurement procedure is included here for general guidance (mid-section method to determine discharge). A current-meter measurement is the summation of the products of individual subsection areas of the stream cross section and their respective average velocities. In the mid-section method of computing a flow measurement, it is assumed that the velocity sample at each vertical represents the mean velocity in the individual subsection areas.

Streamflow Measurement

Flow-measurement equipment required includes: (1) current meter or flowmeter, (2) top-setting wading rod (marked in tenths of a foot), and (3) tape measure or tagline (marked in tenths of a foot). The current meter or flowmeter brands or equivalent can be: Marsh-McBirney electronic, Montedoro-Whitney electronic, Price pygmy (with timer and beeper), Price meter, Type AA (with Columbus weight) or YSI FlowTracker Handheld ADV.

Determining the Number of Flow Cross Sections

The first step in streamflow measurement is selecting a cross section across the total width of the stream. Select a straight reach where the streambed is uniform and relatively free of boulders and aquatic growth. The flow should be uniform and free of eddies, dead water near banks, and excessive turbulence. Determine the width of the stream by stringing a measuring tape from bank to bank at right angles to the direction of flow. Next, determine the spacing or width of the verticals. ***Space the verticals so that no subsection has more than 10 percent of the total discharge***. If the stream width is less than 5 ft, use vertical spacing widths of 0.5 ft. If the stream width is greater than 5 ft, the minimum number of verticals is 10 to 25. The preferred number of verticals is 20 to 30.

Determining the Mid-Point of the Cross Section

To determine the mid-point of a cross section, for example, divide the cross section width in half, if the total stream width is 26 feet with 20 cross sections and each cross section width is equal to 1.3 feet. Divide 1.3 feet in half and the mid-point of the first section is 0.65 feet. In this example, the tape at waters edge is set at zero feet. By adding 0.65 to zero, the mid-point of the first section is 0.65 feet. Each subsequent mid-point is found by adding the section with (1.3 feet) to the previous mid-point. For example, the first mid-point = 0.65+0.0 = 0.65 feet; the second mid-point = 0.65+1.3 = 1.95 feet; the last midpoint = 24.05+1.3 = 25.35 feet.

Adjusting the Sensor Depth at a cross Section

Adjust the position of the sensor to the correct depth at each mid-point. The purpose of the top setting wading rod is to allow the user to easily set the sensor at 20%, 60% and 80% of the total depth. The total depth can be measured with the depth gauge rod (see Figure 2). Each single mark represents 0.10 foot, each double mark represents 0.5 foot, and each triple mark represents 1.00 foot.

Depths ≤ 2.5 Feet: If the depth is less than 2.5 feet, only one measurement id required at each measurement section. To set the sensor at 60% of the depth, line up the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod. For example, if the total depth is 2.0 feet, then line up the 2 on the foot scale with the 0 on the tenth scale.

Depths >2.5 Feet: If the depth is greater than 2.5 feet, two measurements should be taken at 20% and 80% of the total depth. To set the sensor at 20% of the depth, multiply the total depth by two. For example, the total depth is 2.7 feet the rod would be set at 5.4 feet. Line up the 5 on the foot scale and the 4 on the tenth scale.

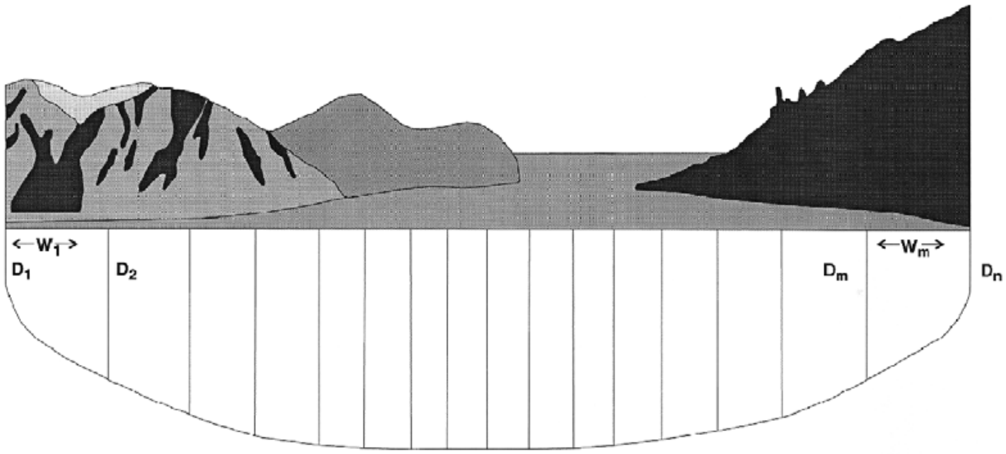
To set the sensor at 80% of the depth, divide the total depth by two. For example, the total depth is 2.7 feet the rod would be set at 1.35 feet. Line up the 1 on the foot scale with the 0.35 on the tenth scale. The average of the two velocity measurements is used in the flow calculation.

Measuring Velocity

The wading rod should be kept vertical and the flow sensor kept perpendicular to the tape rather than perpendicular to the flow while measuring velocity with an electronic flowmeter. When using a pygmy meter, the instrument should be perpendicular to the flow. Move to the next vertical and repeat the procedure until you reach the opposite bank.

Calculating Flow

Once the velocity, depth, and distance of the cross section have been determined, the mid-section method can be used for determining the discharge (formula in fig. 1). Compute the discharge in each increment by multiplying the averaged velocity or single velocity in streams less than 2.5 ft deep in each increment by the increment width and averaged depth (or single depth in streams less than 2.5 ft deep). (Note that the first and last increments are located at the edge of the stream and have a depth and velocity of zero.) Add the discharges for each increment to compute total stream discharge. Record the flow in liters (or cubic feet or cubic meters) per second in your field book.



$$Q = \left(\frac{D_1 + D_2}{2}\right)\left(\frac{V_1 + V_2}{2}\right)W_1 + \ldots + \left(\frac{D_m + D_n}{2}\right)\left(\frac{V_m + V_n}{2}\right)W_m$$

Q = discharge, D = depth, V = velocity, W = width (Rantz and others, 1982)

Figure 1. Stream cross section illustrating mid-section method to determine discharge.

STREAM FLOW (DISCHARGE) MEASUREMENT FORM

Stream Date

Station Description

Time Begin Time Ended Meter Type

Observers Stream Width[1] Section Width

Observations

Section Midpoint (ft)(m)	Section Depth (ft)(m)(cm)	Observational Depth[2] ft-m-cm	Velocity		Area W x D (ft^2) (m^2)	Flow (Q) V x A (m^3/s) (ft^3)
			At Point (ft/s) (m/s)	Average (ft/s) (m/s)		
①						
②						
③						
④						
⑤						
⑥						
⑦						
⑧						
⑨						
⑩						
					Total Discharge (ΣQ)(ft^3/s)	

[1]Make a minimum of 10 measurements when the total width is > 5.0 ft., 20 measurements preferred.

[2]Measure at 60% of depth from surface where < 2.5 ft. deep. Measure at 20% and 80% of depth in waters > 2.5 ft. deep.

Table 2. General Guidelines for selecting equipment on the basis of construction material and target analyte(s)

[✔, generally appropriate for use shown; Si, silica; Cr, chromium; Ni, nickel; Fe, iron; Mn, manganese; Mo, molybdenum; CFC, chlorofluorocarbon; B, boron]

Construction material for sampling equipment		Target analyte(s)	
Material	**Description**	**Inorganic**	**Organic**
Plastics[1]			
Fluorocarbon ploymers[2] (other varies available for differing applications)	Chemically inert for most analytes	✔ (potential source of fluoride)	✔ (Sorption of some organics)
Polypropylene	Relatively inert for inorganic analytes	✔ (not appropriate for Hg)	**Do not use**
Polypropylene (linear)	Relatively inert for inorganic analytes	✔ (not appropriate for Hg)	**Do not use**
Polyvinyl chloride (PVC)	Relatively inert for inorganic analytes	✔ (not appropriate for Hg)	**Do not use**
Silicone	Very porous. Relatively inert for most inorganic analytes	✔ (potential source of Si)	**Do not use**
Metals			
Stainless steel 316 (SS 316)	SS-316-metal having the greatest corrosion resistance. Comes in various grades. Used for submersible pump casing.	✔ (Potential source of Cr, Ni, Fe, and possible Mn and Mo) **Do not use** for surface water unless encasted in plastic.	✔ Do not use if corroded[3]
Stainless steel 304	Similar to SS-316, but less corrosion resistant	**Do not use**	✔ Do not use if corroded[3]
Other metals: brass, iron, copper, aluminum, galvanized and carbon steels	Refrigeration-grade copper or aluminum tubing are used routinely for collection of CFC samples	**Do not use**	✔ Routinely used for CFCs Do not use if corroded[3]
Glass			
Glass, borosilicate (laboratory grade)	Relatively inert. Potential sorption of analytes	✔ **Do not use** for trace element analyses. Potential source of B and Si	✔

[1]Plastic used in connection with inorganic trace-element sampling should be uncolored or white. Tubing used for trace metal sampling should be cleaned by soaking in 5-10 percent HCl solution for 8-24 hours, rinsing with reagent water (metals free) and allowed to air dry in mercury-free environment. After drying, the tubing is doubled-bagged in clear polyethylene bags, serialized with a unique number, and stored until used.

[2] Fluorocarbon polymers include materials such as Teflon™, Kynar™, and Tefzel™ that are relatively inert for sampling inorganic or organic analytes. Only fluoropolymer should be used for samples that will analyzed for mercury because mercury vapors can diffuse in or out of other materials, resulting in either contaminated or biased results.

[3] Corroded/weathered surfaces are active sorption sites for organic compounds.

Table 3. Summary of grab sample collection methods, preservation, storage and handling requirements

PARAMETERS	CONTAINERS	SAMPLE VOLUME (mL)	PRESERVATION	MAXIMUM HOLDING TIME
WATER				
ROUTINE WATER SAMPLE				
Alkalinity	Cubitainer or Glass	100	Cool to 4 ^{0}C, dark	14 days
Total Suspended Solids/Suspended Solids	Cubitainer or Glass	400	Cool to 4 ^{0}C, dark	7 days
Chloride (Cl)	Cubitainer or Glass	100	None required	28 days
Sulfate (SO_4)	Cubitainer or Glass	100	Cool to 4 ^{0}C, dark	28 days
Orthophosphate (OPO_4)	Cubitainer or Glass	150	Filter ASAP; Cool to 4 ^{0}C, dark	48 hours
Nitrate + **Nitrite** (NO_3 + NO_2)	Cubitainer or Glass	150	1-2 mL conc. H_2SO_4 to pH <2, and Cool to 4 ^{0}C, dark	28 days
Ammonia (NH_3)	Cubitainer or Glass	150	1-2 mL conc. H_2SO_4 to pH <2, and Cool to 4 ^{0}C, dark	28 days
Total Phosphorus (TPO_4)	Cubitainer or Glass	150	1-2 mL conc. H_2SO_4 to pH <2, and Cool to 4 ^{0}C, dark	28 days
Total Organic Carbon (TOC)	Cubitainer or Glass	100	1-2 mL conc. H_2SO_4 to pH <2, and Cool to 4 ^{0}C, dark	28 days
Chlorophyll *a*	Quart cubitainer	1,000	Cool to 4 ^{0}C, dark	Filter 48 hours Filters may be stored frozen up to 30 days
Nitrite	Quart cubitainer	50	Cool to 4 ^{0}C, dark	48 hours
Total Dissolved Solids	Quart cubitainer	250	Cool to 4 ^{0}C, dark	7 days
Hardness	Quart cubitainer	250	2 mL conc. HNO_3 to pH<2; Cool to 4 ^{0}C, dark **OR** 2 mL conc. H_2SO_4 to pH <2; Cool to 4 ^{0}C, dark	6 months
ROUTINE WATER SAMPLE COLLECTION PROCEDURE				
◦Label container before collection with a unique sample identifier number, Station Location, Date and Sample Type ◦Place an **X** on the container lid to identify the acidified sample. ◦Open containers by pulling apart. Pre-rinsing cubitainers with ambient water is not necessary. ◦Fill each container with ambient water by submerging container approximately one foot below the surface mid-stream until filled. ◦Place sample on ice immediately. Acidify the **X** container as soon as possible. ◦Place on ice and ship as soon as possible.				

Table 3. Summary of grab sample collection methods, preservation, storage and handling requirements–Continued

PARAMETERS	CONTAINERS	SAMPLE VOLUME (mL)	PRESERVATION	MAXIMUM HOLDING TIME
		WATER		
		NON-ROUTINE WATER SAMPLES		
OIL AND GREASE	Glass container with teflon lined lid rinsed with hexane or methylene chloride	1,000	2 mL conc. H_2SO_4 to pH <2; cool to 4 ^{0}C, dark	28 days
PHENOLS	Glass container with teflon lined lid	1,000	2 mL conc. H_2SO_4 to pH <2; cool to 4 ^{0}C, dark	28 days
BIOCHEMICAL OXYGEN DEMAND	Gallon cubitainer	> 4,000	Cool to 4 ^{0}C; add 1g FAS crystals per liter if residual chlorine present	48 hours
CHEMICAL OXYGEN DEMAND	Quart cubitainer	110	2 mL conc. H_2SO_4 to pH <2; cool to 4 ^{0}C, dark	28 days
		METALS-IN-WATER		
DISSOLVED (except Hg)	HNO_3 cleaned quart plastic container	1,000	Filter at sample site with 0.45 micron in-line filter[1] into ultra-pure[2] HNO_3 preacidified container to pH<2	6 months
DISSOLVED MERCURY	HNO_3 cleaned quart plastic container	1,000	Filter at sample site with 0.45 micron in-line filter[1] into ultra-pure[2] HNO_3 preacidified container to pH<2	28 days
TOTAL (except Hg)	HNO_3 cleaned quart plastic container	1,000	Preacidified container with 5 mL ultra-pure[2] HNO_3 to pH<2	6 months
TOTAL MERCURY (Hg)	HNO_3 cleaned quart plastic container	600	Preacidified container with 5 mL ultra-pure[2] HNO_3 to pH<2	28 days
HEXAVALENT CHROMIUM (filtered)	Plastic or glass	600	Cool to 4 ^{0}C, dark	24 hours; must notify lab in advance

METALS-IN-WATER SAMPLE COLLECTION PROCEDURES

DISSOLVED METALS (includes Hexavalent Chromium)
◦Put on ***powder-free*** latex, polyethylene, or vinyl gloves using Clean Hands/Dirty Hands technique.
◦Assemble pump[3], tubing, and filter.
◦Immerse intake tubing directly into water 1ft. and pump approx. 500 mL of ambient water to flush tubing and filter.
◦Fill precleaned, preacidified container with 600-1,000 mL of filtrate leaving some head space.
TOTAL METALS
◦Put on ***powder-free*** latex, polyethylene, or vinyl gloves using Clean Hands/Dirty Hands technique.
◦Assemble pump, and tubing without filter.
◦Immerse intake tubing directly into water 1ft. and pump approx. 500 mL of ambient water to flush tubing
◦Fill precleaned, preacidified container with 600-1,000 mL of filtrate leaving some head space.
NOTES
[1]Capsule Filter: 15 mm diameter or larger, tortuous path capsule filters, Gelman Supor™ 12175, or equivalent (Ref. EPA Method 1669).
[2]Nitric Acid, Ultra-pure, commercially known as Ultrex™, Ultrapure Reagent.
[3]Pump and pump apparatus–Required for use with the container method. Peristaltic pump–115 a.c., 12 volt d.c., internal battery, variable speed, single head, Cole-Parmer, portable, Masterflex L/S™, Catalog No. H-07570-10 drive with Quick Load pump head, Cat. No. H-07021-24, or equivalent (Ref. EPA Method 1669).

Table 3. Summary of grab sample collection methods, preservation, storage and handling requirements–Continued

PARAMETERS	CONTAINERS	SAMPLE VOLUME (mL)	PRESERVATION	MAXIMUM HOLDING TIME
ORGANICS/PESTICIDES-IN-WATER				
VOLATILE ORGANICS (VOA)	Two 40-mL VOA vials	80	Cool to 4 ^{0}C, dark; or 2-4 drops[1] HCl to pH<2, cool to 4 ^{0}C, dark for BTEX	14 days
ORGANICS **PESTICIDES & HEBICIDES** Organophosphorus Pesticides Organochlorine Pesticcides Chlorinated Herbicides **SEMI-VOLATILE ORGANICS**	1-qt. glass container with teflon lined lid per sample type; *must be prerinsed with hexane,* acetone, or methylene *chloride*	1,000 **Each sample type requires 1,000 mL in a separate container**	Cool to 4 ^{0}C, dark If chlorine is present, add 0.1 g sodium thiosulfate	7 days until extraction and 40 days after extraction
ORGANICS-IN-WATER COLLECTION PROCEDURES				
1Label each container before collection with tag no./unique sample identifier number, Station Location, Date, and “ORGANICS: Organophosphorus Pesticides, Organochlorine Pesticides, or Chlorinated Herbicides” or “SEMI-VOLATILE” (depending on the sample type). ◦Fill to the top. Put in dark and on ice. ◦Fill quart container(s) to the top. Put in dark and on ice.				
BIOLOGICAL				
TOXICITY IN WATER	Two 1-gallon cubitainers	8,000 mL	Cool to 4 ^{0}C, dark	36 hours
TOXICITY SAMPLE COLLECTION PROCEDURES				
WATER ◦Label containers before collection with Station Location, Date, and Sample Type. ◦Open cubitainer by pulling apart. Pre-rinsing cubitainers with ambient water is not necessary. ◦Fill each container with ambient water by submerging container approx. 1-ft. below the surface mid-stream until filled. ◦Place on ice and ship as soon as possible. **NOTES** [1]Prior to preserving with HCl, discuss with laboratory personnel; preserved samples may cause damage to analytical equipment. If sample is analyzed within 48 hours, preservation may not be required.				

CATEGORY 10: SURFACE WATER SAMPLING, FLOW

Section 10.3

Standard Operating Procedure for Surface Water Sampling

DOCUMENT TYPE: Standard Operating Procedure

TITLE: Surface Water Sampling

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Date:	July 26, 2004

1. Scope and Application

1.1 This standard operating procedure must be followed when collecting and storing samples for laboratory analysis.

1.2 Samples must be collected in such a way that no foreign material is introduced into the sample and no material of interest escapes from the sample prior to analysis.

2. Summary of Procedure

2.1 Acquire sample containers (Refer to Sample Submission SOP # GP007).

2.2 Do all necessary preparation prior to sampling.

2.3 Assemble all equipment (see 4. Equipment and Supplies).

2.4 Collect QA samples.

2.5 Perform field analyses.

2.6 Obtain samples using dip sampler and certified clean collection bottle.

2.7 Store samples at 4^{o} C.

2.8 Submit samples to laboratory (Refer to Sample Submission SOP # GP007).

3. Comments

3.1 If sample bottles are requested, the *29 Palms Laboratory* provides only certified clean containers.

3.2 Samples collected by/for the 29 Palms Tribal EPA will use only certified clean collection bottles, including the dip sampler collection bottle.

3.3 These are the sample bottles and preservatives previously received and recommended for each of the following analyses:

- ***3.3.1*** Volatile Organic Carbon- (2) 40 mL amber glass vials containing HCl
- ***3.3.2*** Microbiology- 100 mL sterile HDPE containers with sodium thiosulfate tablet
- ***3.3.3*** Metals- 500 mL HDPE bottle containing HNO3
- ***3.3.4*** Physical Properties- 500 mL HDPE bottle
- ***3.3.5*** Total Organic Carbon- 100 mL amber glass containing H2SO4
- ***3.3.6*** General Minerals- 1000 mL HDPE bottle
- ***3.3.7*** Cyanide- 500 mL HDPE bottle containing NaOH
- ***3.3.8*** Radionuclides- (2) 1000 mL HDPE bottles containing HNO3
- ***3.3.9*** Organophosphorus/Organochlorine Pesticides- 1000 mL amber glass
- ***3.3.10*** Methylcarbamate Pesticides- 1000 mL amber glass (containing chloroacetic acid for EPA method 8318)

3.4 Disturbance of the sample site is to be avoided and samples should be collected facing upstream.

3.5 The safety of the sampler must be considered when hazardous substances may be present. Samplers will wear gloves during sampling and are required to wash hands immediately following their return from the field.

4. Equipment/Supplies

Equipment that is necessary for the collection of surface water samples includes:

4.1 Folding chairs
4.2 Folding table
4.3 Canopy
4.4 Tape measure (25 ft.)
4.5 Dip sampler with certified clean HDPE 900 mL collection bottle
4.6 pH meter with probe
4.7 pH standards (4.00, 7.00, 10.00 + 7.00 for ICV/CCV)
4.8 Conductivity meter with probe
4.9 Conductivity standards (100, 1000 and 10, 000 + 1000 for ICV/CCV- µS/cm)
4.10 Batteries (9 volt and AA)
4.11 Kimwipes
4.12 2 deionized (dI) water bottles
4.13 6 250 mL beakers
4.14 3 boxes dI water
4.15 1 L sterile water
4.16 Sample bottle set
4.17 Waste water container
4.18 Ice chests with frozen blue ice
4.19 Latex gloves
4.20 Ziploc bags
4.21 Packing material
4.22 Trash bag
4.23 GPS unit
4.24 Camera
4.25 Logbooks
- ***4.25.1*** Surface Water Monitoring
- ***4.25.2*** Sample Collection
- ***4.25.3*** GPS
- ***4.25.4*** HACH pH Meter
- ***4.25.5*** VWR EC Meter/HACH Conductivity Meter

4.26 2 Waterproof (Sharpie) pens and 2 black ink writing pens
4.27 Chain of Custody forms
4.28 Sample Team box
4.29 Water or Gatorade in cooler

5. Procedure

5.1 *Prior to sampling*, obtain sample bottle set from laboratory or laboratories (see SOP #GP007 Laboratory Sample Submission).

5.2 Notify sampling personnel of sampling event plan (date and location).

5.3 Take inventory of standards for field analyses (pH, conductivity, turbidity and dissolved oxygen).

5.4 Order standards if necessary.

5.5 Take inventory of deionized (dI) water and gloves. Order if necessary.

5.6 Organize sample bottles, labeling each appropriately with indelible marker.

5.7 Each label should include the following information:

5.8 Client name and analyte for which analysis requested.

5.9 Unique sample number and description, including whether it is a grab or composite.

5.10 Date and time of sampling (completed in the field with a permanent marker).

5.11 Initials of sampler (completed in the field with a permanent marker).

5.12 Place colored tape on lids of field blanks and equipment blanks to identify these bottles to be filled with dI water (sterile dI for microbiology samples).

5.13 Verify presence of preservatives in bottles (see 3.3).

5.14 Enter all relevant information in Sample Collection Logbook #32A.

5.15 Enter all relevant information in laboratory Chain of Custody form(s).

5.16 Prepare sterile water by autoclaving dI water in I L glass bottle for 30 minutes (see SOP #MP001 Autoclave Operation).

5.17 Arrangements with laboratories must be made to transfer samples collected.

- **5.17.1** Applied Physics and Chemistry Laboratories (APCL) samples are delivered to Beaumont, where samples are relinquished to a courier within 6 hours of collection if micro samples are included.
- **5.17.2** Agriculture Priority Pollutants Laboratories (APPL) samples are shipped via Federal Express.

5.18 Load red trailer with equipment (see 4.0).

5.19 Purchase Gatorade and batteries for meters if necessary.

5.20 On the day of sampling, prior to departure, prepare ice chests with frozen blue ice to keep samples at 4^{o} from the time of sampling until they are received by laboratory.

5.21 Once at site, collect GPS data on sample collection location (refer to SOP #SP003 GPS Data Collection) and record in GPS logbook according to Field Record Template for Surface Water Sampling.

5.22 Collect flow rate data and record in Surface Water Monitoring Logbook #21A according to Field Record Template for Surface Water Sampling.

5.23 Set up analysis station, making sure all instrumentation is in the shade.

5.24 Calibrate field analysis meters: pH, conductivity, turbidity and dissolved oxygen (if applicable- see SOP associated with analysis).

5.25 Collect field blanks by pouring dI water directly into sample collection bottles designated for that purpose, using sterile dI water for micro.

5.25.1 Field blanks are included to account for anything in the immediate environment (contaminants, airborne particulates, etc.) that could affect sample results.

5.26 Collect equipment blanks by first pouring dI water into dip sampler collection bottle, then into sample collection bottle, using sterile dI water for micro.

5.26.1 An equipment blank is a sample consisting of reagent grade water poured into the transfer bottle prior to sampling, collected and submitted for analysis so that any contamination present in the bottle can be accounted for.

5.27 Analyze surface water sample using calibrated meters, recording results in Surface Water Monitoring Logbook #21A according to Field Record Template for Surface Water Sampling.

5.28 Record all other information included in Field Record Template for Surface Water Sampling into Surface Water Monitoring Logbook #21A.

5.29 *Grab samples* of surface water will be collected using the following method:

5.29.1 Do not rinse sample bottle prior to sample collection.

5.29.2 Collect samples in containers provided, filling nearly full without overflowing.

5.29.3 Samples of surface water should be collected from flowing, not stagnant water, if possible.

5.29.4 If the sample site does not have a current, be careful not to disturb sediment.

5.29.5 Using the dip sampler and collection bottle, carefully place bottle in current facing upstream and allow filling.

5.29.5.1 If there is no current, create a current artificially by pushing the bottle forward horizontally.

5.29.5.2 For shallow waters, such as streams, springs, seeps or other types of discharges, attempt to sample the water without touching any solids.

5.29.6 Carefully remove cap of sample bottle, avoiding contamination by hands or particles in air by holding on outside surface with inside surface facing down.

5.29.7 Collect sample by carefully pouring out contents of collection bottle into sample bottle.

5.29.8 Replace cap and store at 4^{o}C in closed ice chests containing frozen blue ice.

5.29.9 Send to laboratory within 6 hours if microbiological samples were collected. (Refer to Sample Submission SOP- GP007 for more instructions)

5.30 *Composite samples* of surface water may be collected using the following method:

5.30.1 Following the collection of an equipment blank (see 5.22), a single bottle is used to collect the sample portions over a period of time or over a specified area.

5.30.2 Repeat the collection using the same bottle each time, being careful to avoid contamination.

6. Bibliography

6.1 *29 Palms Laboratory* Quality Assurance Plan, Section 7.

6.2 U.S. EPA Region 9 Laboratory Field Sampling Guidance Document #1225.

DOCUMENT TYPE:	Standard Operating Procedure	
DOCUMENT CLASS:	Sampling Procedure	
TITLE:	Stream Gaging	
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Table of Contents

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1. **Purpose**
   1.1. In conjunction with water quality testing, stream gaging provides hydrologic information about local surface waters that may prove useful in many ways. Possible uses include:
   - Characterizing current water-quality conditions
   - Determining input rates of various pollutants into lakes, reservoirs, or estuaries
   - Computing the loads of sediment and chemical constituents
   - Understanding biological effects of contamination
   - Setting permit discharge requirements of treated wastewaters
   - Setting minimum flow requirements for meeting aquatic life goals
   - Developing, maintaining, or operating recreational facilities
   - Evaluating surface and ground water interaction
   - Undertaking scientific studies of long-term changes in the hydrologic cycle

   1.2. Stream gaging in the field involves measurement of the stream velocity (based on the revolutions of the stream gage) for each cross-sectional segment of the stream, and compilation of each segment's velocity over the entire width of the stream.

   1.3. As with any scientific or mathematical endeavor, the precision and accuracy of the results is only as reliable as the precision and accuracy of the data. Reliable stream gage data is dependent on the care and consistency field personnel apply to their field stream gaging techniques. This Standard Operating Procedure for stream gaging has been prepared to provide a degree of Quality Assurance and ensure the acquisition of reliable stream flow data by field personnel.

2. **Intended Use and Limitations**
   2.1. This SOP was prepared for use as part of the Whitewater River Monitoring Project (project) being conducted by the Tribal EPA of the Twenty-nine Palms Band of Mission Indians.
   2.2. It was specifically prepared for use at various locations within the lower portion of the Whitewater River, from approximately the location of the Coachella Valley Sanitary District Wastewater Treatment Plant to the mouth of the Whitewater River at the Salton Sea.
   2.3. This SOP is designed for use with the equipment available to the Tribal EPA on this project, notably the Rickly Model 6200 USGS Type AA Current Meter, the Rickly Model 6205 USGS Pygmy Meter, the companion AquaCalc 5000 Basic Stream Flow Computer, and associated accessories.
   2.4. If a different stream gaging system is used, the specific operating procedures described in this SOP for the stream gaging equipment will not apply.

3. **Preparation**
   3.1. Prior to leaving for the field site, preparations should be made which anticipate weather, safety, equipment, and other supply needs.
   3.2. In addition to apparel appropriate to the climate, the following should be packed for transport to the site.

4. **Equipment**
   - Current Meters (2 – Rickly Type AA and Rickly Pygmy)
   - Top Set Wading Rod Assembly

- Sounding weight and hand line assembly, including sounding weight hanger
- Extra bolts, pins, and pivots
- AquaCalc 5000 Basic Stream Flow Computer
- Extra 9 volt battery
- Field copy of SOP for Stream Gaging including Figures and Appendices
- GPS unit
- Digital camera (optional)
- Flat head screwdriver
- Several (4 to 6) 36” to 48” metal stakes
- Hammer (2 pound+)
- Length of rope long enough to accommodate width of the stream, plus 20 feet
- Reel tape measure long enough to accommodate width of the stream
- Second measuring tape with weight tied to one end (for bridge gaging)
- Incrementally marked depth rod that exceeds maximum depth of stream (for boat gaging)
- Two small tarps
- Clipboard
- Calculator
- Duffel bags or backpacks for equipment and supplies
- Chair

5. **Consumable Supplies**
   - Several dozen zip ties and cutter
   - Blank data log forms (Appendices A-1 and A-2)
   - Waterproof pens

6. **Safety Gear/Decontamination Supplies**
   - Waterproof gloves
   - Waterproof boots and/or waders (preferably with steel soles)
   - Protective eyewear
   - One length of rope to be used as a safety line
   - 1-gallon multi-sprayer bottle (with spray wand) filled with a 0.001% bleach/water decontamination solution
   - 1-gallon multi-sprayer (with spray wand) filled with tap water for rinsing equipment and gear following decontamination.
   - 1-gallon multi-sprayer bottle (with spray wand) filled with distilled water for rinsing equipment and gear following decontamination
   - Small plastic tarp
   - Lightweight ladder for stream access
   - Personal Floatation Device (if the water is more than knee deep or moving quickly)
   - Drinking water
   - Sunscreen lotion
   - Bug spray
   - Umbrella (optional)

7. Personnel

7.1. A well-organized team need not be extensive, but safety should be the first consideration in determining the number of personnel needed at a site.
7.2. A minimum of a current meter technician (CMT) and a Data Recorder (DR) are recommended.
7.3. In the cases of deeper streams with stronger currents, or when a boat is being utilized, a third person may be required.
7.4. Prior to the start of field activities, a Team Leader should be designated, usually the most senior person at the site.
7.5. A Health and Safety Officer (HSO) should also be designated, usually the Team Leader.
7.6. If hazardous materials may be encountered, a site-specific Health and Safety Plan should also have been prepared (not included as part of this SOP). If hazardous materials are not expected, the main duty of the HSO will be related to physical safety hazards, such as fast moving water, and safe ingress and egress. A Health and Safety Meeting should be held prior to starting the field work to discuss issues such as likely sources of hazards, mitigation procedures, location and directions to closest emergency medical center, and appropriate safety apparel.
7.7. Each staff member must be outfitted with safety apparel appropriate to the task. Some examples of safety apparel include rubber gloves, rubber boots (rubber waders for the CMT), a personal floatation device (life preserver), and protective eyewear.

8. Site Procedures

The general areas for gaging the stream will have been selected as part of the project setup, but the exact location of the measurement will need to be selected based on field conditions. Once the location is selected, gaging the stream is a straightforward process.

Choosing a Transect Location

Stream gaging measurements are performed along a "transect" of the stream, which is essentially a cross-section of the stream at a specific location. Measurements of the length and depth along the transect is important because the area of the stream cross-section is an important part of the calculation of stream discharge rate. The transect location should be chosen based on a variety of general criteria ranging from point-source outfalls of concern, stream morphology, accessibility, safety concerns, and location of pre-established gaging stations. Once chosen, a transect location should be documented to provide a basis for repetition and comparison with previous or future studies.

Stream specific criteria for selecting a transect location include looking for particular characteristics such as (1) a well defined bank; (2) few obstructions in the channel; and (3) no eddies or still water. Conversely, turbulent water should also be avoided, if possible. The stream should be free flowing and unrestricted by obstructions upstream or downstream, which might cause flow diversion or flow backup. A smooth streambed profile, one of relatively consistent depth across its width, is optimal. The depth of the stream must be adequate for the immersion of the current meter. Clear away any movable objects along the profile, which may interfere with the accuracy of the readings by altering the flow of the stream. Removal of channel obstructions, i.e., woody debris, rocks, or other obstructions, is permissible provided enough time is allowed for stream flow re-stabilization before flow measurements are recorded.

If a series of readings are to be taken at a particular transect in the future, it is advisable to install a staff gage in order to provide a relationship between discharge and stream stage over time. A staff gage can be mounted on a pre-existing structure, such as a bridge abutment, or could be a three to four-foot stake with a simple measuring scale stapled to it or painted on it. This stake would be hammered into the ground within the bounds of the flowing stream, preferably in calm or still water to provide accurate readings.

Setup

Once a transect location is selected, the gaging equipment should be laid out as close to the transect as safety allows.

- Lay out two tarps near the area where readings are to be performed, one for equipment, and one for staff seating and miscellaneous supplies.
- Unload equipment and setup the workstation, allowing for easy access to needed materials.
- If contaminants are expected (such as pathogens), establish a decontamination area with the third tarp where staff will be exiting the stream. Place the sprayer bottles with bleach solution and distilled rinse water in this area. If the banks of the stream are steep, place the ladder against the bank for safe ingress and egress.

Setting up the Transect

The following procedures describe the process for setting up the transect.

- Setup the transect endpoints by driving a stake into the ground on each side of the stream. The resulting transect should be at right angles to the stream flow.
- Stretch the rope across the stream and fasten to each stake, ensuring the rope remains taut and as near the surface of the water as possible.
- Facing upstream, align the zero increment of the tape measure with the left edge of water and secure the measuring tape to the rope across the width of the stream using zip ties. If available, fasten the side of the tape measure marked in tenth of foot increments face-up. It may be convenient to fasten the tape measure to the rope at the specific locations where measurements will be taken.
- Measure the total width of the stream.
- Determine the spacing of the stream velocity readings based on the width of the stream. The reading locations should be equal distances apart, with 20 to 30 readings for streams wider than 20 feet, and at one-foot intervals for streams less than 20 feet wide. To minimize the potential for mistakes, the spacings should be whole number increments. For example, if a stream is 46 feet wide, a spacing of 2 feet (24 readings including both edges) would be preferred to a spacing of 1½ feet (30 readings). The first and last reading locations for each transect should fall at or outside of the left and right edges of the water and will have zero flow and zero depth.

If a boat will be used to take the readings because the stream is deep or moving swiftly, the boat must be stabilized against lateral movement at each transect station. A rope tied to existing secure objects such as trees, guardrails, or other stationary objects (one on either side of the stream) should be attached to the boat through cleats on the boat. The objects should be about as far upstream of the transect as the width of the stream. The ropes must be independently adjustable on the boat to allow for freedom of movement along the transect yet stability from downstream or lateral drift. If stationary objects are not available, vehicles, securely driven stakes, or two secure anchors on each stream bank may be necessary. Motors should not be used because of the potential for them to affect the velocity readings.

Transect Data Log

The recorder will complete the Transect Data Log (Appendix A-1 or A-2). Prior to taking readings, record general information such as:

- Global Positioning System (GPS) reading at the first measuring point;
- Streambed conditions (muddy, rocky, etc), by circling the appropriate description(s) on the Transect Data Log;
- Sketch the transect location and vicinity, citing distance from a fixed object in the vicinity for repeat visits; width of the stream channel, width of stream flow (edge of water to edge of water), and spacing between measuring points. Fill in the "distance" column using the selected spacings, to avoid confusion during the actual measurements;
- Date;
- Job name, job number, or other project identifiers;
- Transect number and location; and,
- Personnel.

Equipment Assembly

Make a determination as to which flow meter is to be used, based on depths and strength of flow. The Type AA Current Meter is not recommended for stream depth less than one foot. The Pygmy Meter should be used for wading measurements in shallow streams, flumes, and canals where depth of water is too shallow for the Type AA Current Meter to perform accurately. The Pygmy can only be used with a wading rod. The Type AA can be used with either a wading rod or a cable (hand line), and therefore is the preferred meter is deep water. The following chart may aid in the selection of an appropriate flow meter.

Stream Depth (feet)	Meter	RELATIVE DEPTHS
2.5 and above	Type AA	0.2 and 0.8
1.5 – 2.5	Either Meter	0.6
0.3 – 1.5	Pygmy	0.6

Relative Depth refers to the depth at which the readings are taken, and are expressed as decimal fractions of the total depth of the stream at each measuring point, measured down from the stream surface. For streams less than 2.5 feet deep, the readings are taken at 0.6 of the depth of the stream, and for streams deeper than 2.5 feet, the readings are taken at 0.2 and 0.8 of the depth of the stream. (For example, if the stream was 2 feet deep, one reading would be taken at 1.2 feet below the surface of the stream. If the stream was 10 feet deep, readings would be taken at both 2 feet and 8 feet below the surface of the stream).

The streambed profile may include isolated instances of extreme depth or shallowness. It is best to not change meters to accommodate these few extremes. The flow in an extremely shallow portion of an otherwise deep stream is not a significant portion of the total flow, so skipping extremely shallow measurements does not introduce significant error in the readings.

If the water is deeper than four feet, or moving too quickly to ensure solid footing, then the readings should be taken from a bridge or a small boat using the Type AA Current Meter (including the tailpiece, hand line, and sounding weight).

Once an appropriate meter has been selected, setup the meter as described below.

Pygmy Current Meter

- In storage and travel mode, the pygmy meter is equipped with a brass pivot (Figure 1, #14) that restricts the movement of the meter to prevent damage. The brass pivot **MUST** be removed and replaced with the stainless steel pivot prior to use. To remove the brass pivot, hold the yolk (#6) in an inverted position so that the brass pivot is facing up and loosen the setscrew (#15). While holding the bucket-wheel assembly in place, gently remove the brass pivot and replace with the stainless steel pivot. Fasten the set screw just enough to hold the pivot and bucket-wheel assembly in place, and conduct a spin test (below).
- A spin test must be conducted to assure free movement of the bucket wheel (#12). Hold the bucket wheel axis in an upright vertical position and give the wheel a quick turn by hand to start it spinning. If operating properly, the Pygmy should spin for about 1½ minutes, with a minimum spin of ½ minute before coming to a gradual stop.
- If the wheel does not spin freely or does not come to a gradual stop, adjust the stainless steel pivot by first loosening the set screw (#16) and then adjust the pivot adjusting nut (#17) in a clockwise direction until a free spin is achieved.
- When free spin is achieved, re-tighten the setscrew and re-conduct the spin test. If proper free spin is not achieved, repeat the steps until the recommended time of free spin and a gradual stop is achieved.

If necessary, see Appendix B for lubrication and maintenance details (Buchanan and Somers, p.8).

Type AA Current Meter

The Type AA Current Meter contains a brass raising-nut instead of the brass pivot, which serves as a lock for travel and storage purposes (Figure 2, #15). A spin test must be performed prior to field use. Turning the brass raising-nut in a clockwise direction will loosen the bucket-wheel assembly for the spin test. Hold the bucket wheel axis in an upright vertical position and give the wheel a quick turn by hand to start it spinning. If operating properly, the Type AA should spin for about 4 minutes with a 1½ minute minimum before coming to a gradual stop. If the wheel is not spinning freely, or the stop is not gradual, hold the meter in an inverted position with pivot (#17) uppermost and follow these steps:

- Release the keeper screw (#19).

- Loosen the pivot-adjusting nut (#18) a few turns.
- Release the setscrew (#7).
- Fully insert the pivot until all vertical play of the hub assembly is eliminated.
- Temporarily tighten set screw (#7)
- Tighten pivot-adjusting nut (#18) until it makes contact with the yoke (#8).
- Slightly loosen the set screw (#7)
- Tighten the pivot adjusting nut (#18) ¼ turn
- Tighten the keeper screw (#19).
- Push pivot inward as far as it will go and tighten setscrew (#7)

Repeat the steps until the recommended time of free spin and a gradual stop is achieved. If necessary, see Appendix B for lubrication and maintenance details.

Fastening Flow Meter to Wading Rod

Both the Pygmy and Type AA Flow Meters attach to the wading rod in the same manner:

- Slip the yoke stem over the shaft mount, which is found on the sliding rod attachment at the lower end of the wading rod.
- Tighten the setscrew.
- Attach the contact wire from the sliding rod to the appropriate contact binding post, #5 for the Pygmy. The Type AA offers two options, the single-contact binding post (#4), or the penta-contact binding post (#5). When using the Aquacalc, attach the contact wire to single-contact binding post (#4). Select the Penta-contact binding post (#5) only if the headset is to be used and the flow rate is expected to exceed 2.5 feet/second.
- For stability purposes, the optional tailfin assembly may be fastened to the bottom of the wading rod on the tailfin shaft, opposite the yoke stem shaft mount. Assemble the two-piece tailfin by sliding the interlocking fins together, making sure the fins are inserted into the proper channels of the opposing tailfin piece. Lock the two pieces together by turning the lock (located on only one of fins) 180 degrees, until the two pieces are securely fastened together. Fasten the assembled tailpiece to the tailfin shaft at the bottom of the wading rod and tighten the setscrew. Use of the tailpiece is optional for Type AA use and is not to be used with the Pygmy flow meter.

Connecting the AquaCalc to the Wading Rod

Connecting the AquaCalc to the wading rod is the same for both Pygmy and Type AA flow meters:

- Turn off the AquaCalc by pressing and holding the “Off” key.
- Plug the current meter cable into both the AquaCalc and the wading rod. The round 8-pin connector on the current meter cable attaches to the AquaCalc’s pigtail, and the current meter cable jack connects to the brass receiving post at the top of the wading rod.

- A Velcro strip on the back of the AquCalc attaches to an adjustable platform on the top of the wading rod once the measuring process begins so that the CMT can use both hands to operate the equipment.

Connecting the Type AA Current Meter to the Sounding Weight and Hand line

The Type AA Current Meter with attached tailfin piece (see 5.5.3 above) connects to the sounding weight and hand line via the following steps:

- Lay the sounding weight on the ground with its dorsal fin up.
- Slide the lower end of the sounding weight hanger into the slot in the top of the sounding weight and fasten in place by turning in the threaded securing pin in a clockwise direction until tight.
- Slide the sounding weight hanger into the slot on the Type AA Current Meter, with the tailfin piece facing in the same direction as the sounding weight fins. Screw the meter into place, hole #15 for a 15-pound weight, and hole #30 for a 30-pound weight.
- Slip the top end of the sounding weight hanger into the slot on the connector at the end of the hand line. Secure the hanger in place with the pin and cotter pin.
- Attach the contact wire as described in 5.5.3.
- A cable and cable jack is affixed to the hand line. The cable jack connects to the current meter cable, which then connects to the AquaCalc pigtail as described in 5.5.4. Be sure the AquaCalc is off before connecting it to the meter.

9. Programming the AquaCalc

The AquaCalc 5000 Operating Instructions manual is included as Appendix C (JBS Instruments). It is recommended personnel read the manual and become familiar with some basic procedures and capabilities of the stream flow computer prior to beginning field gaging. The following is a summary of the basic steps needed for simple data acquisition using the AquaCalc 5000. For more detailed instructions and additional information, refer to the Operating Instructions manual in Appendix C.

Prior to data collection, a field test of the current meter and AquaCalc is required to ensure proper operation. This involves an estimated visual count of bucket wheel revolutions as compared to revolutions calculated by the AquaCalc.

- Turn on the AquaCalc by pressing “On” key. At the date/time screen, press and hold “Erase” key to erase old data. Press “Enter” to clear the computer memory and select default settings. The most important default settings, which may need to be changed to accommodate site conditions, are:
    - 0.6 depth reading
    - Measure time 40 seconds
    - Turbulent flow reset
    - Meter type Price (Type) AA 1:1 ST2 (ST2 refers to meters made after 1992).

- Redefine settings as needed by pressing "Menu" key to access main menu. From main menu press "1 (1=TrInfo)," then "Enter" to scroll through available options. Some of these options are not necessary to data acquisition and are not discussed here. See Appendix C for more details.
- Perform a field test to confirm proper connection of meter and AquaCalc.
  1. Turn on AquaCalc by pressing "On" key.
  2. Press "Menu" twice to access main menu.
  3. Select 1 for "TrInfo"
  4. A default measurement time of 40 seconds will display. Press "+" and reset measurement time to 10 seconds. Press "Enter" to accept new setting.
  5. Go to Measurement Display by pressing "Menu" three times. This screen displays settings for a specific transect.
  6. The default transect and Observation are each #1. Press #3 (Next Observe) and the display will show Transect 1 at Observation 2.
  7. Spin the bucket wheel slowly enough that a visual count of the revolutions can be made over a period of 10 seconds. Press "Measurement" key and begin counting revolutions. An assistant may be helpful as the timekeeper. The visual count and the AquaCalc count should agree (within the limits of human accuracy).
  8. If the count totals do not agree, check the electrical connections and retest. If they still do not agree, refer to the Appendix C troubleshooting segment.
  9. Clear the observation by pressing and holding erase until the screen prompts confirmation of erasure and press Enter (Note: this action erases all observations on that transect from that observation upward). Reset the measurement time to 40 seconds by following steps 2 through 4 above.

10. Data Collection

<u>Use of Current Meter</u>

The measuring points on each transect are referred to as Observations. The first observation should be at or to the left of the left edge of the water (when facing upstream). This observation should have a depth reading of zero, and no velocity measurement is taken. The same applies to the last observation on the transect, at or beyond the right edge of water when facing upstream. The CMT should position her/himself downstream of the current meter, if wading or in the boat, beginning the actual first reading at Observation 2. The CMT should stand at a 45-degree angle to the stream and meter location to reduce backwash interference with the current meter.

<u>Setting parameters</u>

The CMT programs the AquaCalc with parameters for site specific transects by following these steps:

- Turn on the AquaCalc
- Confirm that date and time is correct. If it is not, refer to Appendix C for more instruction.
- Press "Menu" key once to access Measurement Display
- The default settings are Transect 1, Observation 1, at Observation Depth 0.6.

- To edit Transect number, press "Go to Transect #(1)" and change number to the appropriate number.
- Confirm that the Observation number is #2. To edit Observation number, press "Go to Observe #(2)" and change number to the appropriate number.
- Set distance from edge of stream flow by pressing "Set Distance" key and entering distance in feet to the nearest tenth.
- Measure stream depth
  1. Wading Rod Method:
     Place wading rod in stream so that the base plate rests on the streambed; depth can be read from the marks (slashes) on the hexagonal wading rod (Rod A)
     - Three slashes = 1 foot increments
     - Two slashes = ½ foot increments
     - One slash = 0.1 foot increments
  2. Boat Method:
     - Measure stream depth by direct reading of incrementally marked measuring rod resting on the bottom of the streambed.
  3. Bridge Method:
     - Lower the weighted measuring tape to the bottom of the stream and make note of the depth to a set reference point on the bridge.
     - Raise the weighted measuring tape to the surface of the stream and make note of the depth to the same reference point on the bridge.
     - Subtract the second depth from the first depth to calculate the depth of the stream.
- If the stream depth is less than 2½ feet, proceed to Section 7.1.2 to edit Location Depth. If stream depth is greater than 2½ feet, proceed to Section 7.1.3 to edit Location Depth.

<u>Measurements taken at 0.6 Settings</u>

For streams less than 2½ feet average depth, the wading rod method should be used, with one reading taken at each observation point at 0.6 of the depth of the stream, measured down from the water surface.

1. To edit Observation Depth setting, press the "Observe Depth" key until "6" appears in the display window (to indicate 0.6 of the stream depth).

2. Set depth of water by pressing "Set Depth" key and enter depth in feet to the nearest hundredth, then press Enter to accept.

3. After entering depth of stream into the AquaCalc, the wading rod must be adjusted to position the current meter at the appropriate depth in the stream. The wading rod consists of two parallel rods, one hexagonal rod that rests on the bottom of the stream, and one round rod to which the meter is attached. To set the meter at the appropriate depth, the position of the round rod must be adjusted by pressing the rod release tab (the rubber button with embossed star at top of wading rod handle) to allow movement of the rod. The cast metal scale at the top of the wading rod handle is divided into 10 increments, which represent tenths of feet in stream depth. Rod B is marked incrementally from zero to eight, which represent feet of stream depth. <u>Using the</u>

actual depth of the stream, align the appropriate foot depth increment on Rod B with the appropriate fraction increment on the wading rod handle. For example, if the stream is 3.5 feet deep, aligning the 3 marker on Rob B with the 0.5 marking on the scale on the wading rod will set the meter at the appropriate depth for a stream 3.5 feet deep (2.1 feet from the top, 1.4 feet from the bottom). Note that the spacing of the markings are not real-world distances, but are scaled to allow direct adjustments for stream bed depths.

4. After the meter is set at the appropriate depth, the stream velocity is measured by pressing "Measure". AquaCalc will take 40 seconds (default setting) to count revolutions and calculate a mean velocity for that Observation. This completes the first observation. The data will be displayed on the AquaCalc screen, and stored in memory for later use.

5. At each Observation point along a transect, the data should also be recorded on a Transect Data Log (Appendix A-1) as a backup. This is best accomplished by having the CMT read the data to the DR. The data obtained at each observation point are:
   - Observation number
   - Distance value (if not already recorded)
   - Stream depth
   - Velocity

6. Upon completion of an Observation, check the readout on the AquaCalc to be sure that all of the settings were correct and the information was recorded properly. If not, a repeat Observation must be made.

7. The CMT now moves to the next Observation point for the next reading. Steps 1 through 7 above, are repeated at each observation point until the entire transect has been measured.

To recap Observation procedures:

1. Confirm that AquaCalc Observation number agrees with transect observation number (location on transect).
2. Enter distance along transect into the computer.
3. Enter depth of stream into the computer.
4. Adjust rods to put current meter at appropriate height in stream.
5. Measure velocity.
6. Record values on Transect Data Log as a backup to computerized version.
7. Confirm accuracy of reading.

Measurements taken at 0.2 and 0.8

For streams with an average depth exceeding 2½ feet, two readings will be taken at each Observation, one at 0.2 times the depth from the water surface, and the second at 0.8 times the depth from the water surface. Note: this is twice and half the distance, respectively, from the bottom of the stream as compared to the 0.6 reading

1. Edit Observation Depth setting by pressing the "Observe Depth" key until "2" appears in the display window (to indicate 0.2 of the stream depth).

2. Measure the depth of the stream and set depth of water by pressing "Set Depth" key and entering the total depth of the stream in feet, to the nearest hundredth.

3. Adjust the depth of the meter to 0.2 the depth of the stream.

A. Wading Rod Method

The wading rod must be adjusted to position the current meter at the appropriate depths in the stream, similar to the procedure discussed above in 7.1.2.3, except that there are two readings, one at ½ and one at 2 times the depth of the single reading. The wading rod consists of two parallel rods, one hexagonal rod that rests on the bottom of the stream, and one round rod to which the meter is attached. To set the meter at the appropriate depths, the position of the round rod must be adjusted by pressing the rod release tab (the rubber button with embossed star at top of wading rod handle) to allow movement of the rod. The cast metal scale at the top of the wading rod handle is divided into 10 increments, which represent tenths of feet in stream depth. Rod B is marked incrementally from zero to eight, which represent feet of stream depth. Align the appropriate foot depth increment on Rod B with the appropriate fraction increment on the wading rod handle, <u>using ½ the actual depth of the stream for the 0.8 reading, and 2 times the actual depth of the stream for the 0.2 reading</u>. For example, if the stream is 2.6 feet deep, align the 1 marker on Rod B with the 0.3 marking on the scale on the wading rod for the 0.8 reading, and set the 5 mark on Rod B at the 0.2 mark on the scale for 0.2 reading.

B. Boat or Bridge Method

Measure the depth of the stream at the Observation point by measuring the difference in distance from a common measuring point (such as the guard-rail on the bridge) to both the stream surface and the bottom of the stream. Record these values on the version of the Transect Data Log for use on a bridge or boat (Appendix A-2). Manually multiply the depth of the stream by 0.2 and 0.8 to obtain the depth at which to place the meter. Add these distance values to the reading for the distance to the surface of the stream, and lower the meter to the appropriate depth for each reading starting with the 0.2 reading.

4. When all settings have been entered and the meter is at the correct depth, take the first velocity reading by pressing the "Measure" key. AquaCalc will take 40 seconds (default setting) to count revolutions and calculate a mean velocity for that Observation. This completes the 0.2 Observation for that location.

5. CMT should read the data to the recorder, and then the DR confirms that the data was accurately recorded on the Transect Data Log (Appendix A-2) by reading the values back to the CMT. These data are to include:
   - Observation number
   - The Distance value

- Stream depth
- Reading depths
- Velocity

6. Confirm that the AquaCalc has recorded the information accurately. If not, a repeat observation must be made.

7. Edit the Observation Depth setting to 0.8 by pressing the “Observe Depth” key until “8” appears in the display window.
8. Adjust the depth of the meter to 0.8 of the total depth of the stream.

   A. Wading Rod Method
   For the 0.8 readings, divide the stream depth by two, and align the resulting number on Rod B with the mark on the scale on the hexagonal rod, as described above.

   B. Boat or Bridge Method
   Manually hang the meter at 0.8 times the depth of the stream.

9. Take the second velocity reading by pressing the “Measure” key. AquaCalc will take 40 seconds (default setting) to count revolutions and calculate a mean velocity for that observation. This completes the 0.8 observation for that location.

10. Confirm that the AquaCalc has recorded the information accurately. If not, a repeat observation must be made.

11. Record the readings on the Transect Data Log (Appendix A-2) as a backup to the AquaCalc. The CMT should read the data to the recorder, and then the DR confirms that the data was accurately recorded by reading the values back to the CMT. These data are to include:
    - Observation number
    - The Distance value
    - Stream depth
    - Reading depths
    - Velocity

12. The CMT now moves to Observation 3 for the second reading. Repeat steps 1 through 11, above, at each location along the transect until the entire transect has been measured.

In summary, at each location along a transect:

1. Confirm that AquaCalc Observation number agrees with actual location.
2. Confirm that observation depth is set at “2”.
3. Enter distance into the AquaCalc.
4. Enter depth into the AquaCalc.
5. Adjust current meter to appropriate height in the stream (0.2 of total depth).
6. Measure velocity.
7. Relate observations to recorder.

8. Confirm accuracy of reading.
9. Edit observation depth to “8”.
10. Enter next depth at same location.
11. Adjust meter to appropriate height in the stream (0.8 of total depth).
12. Measure velocity.
13. Relate observations to recorder.
14. Confirm accuracy of reading.
15. Move to the next location along the transect and repeat this procedure.

11. Decontamination and Maintenance

Any equipment, supplies, or apparel, which has been exposed to potentially contaminated stream water must be decontaminated. Using the plastic tarp as a makeshift basin, spray these items with the 0.001% bleach solution. Follow with a rinse of tap water and a second rinse of distilled water to remove the bleach and protect equipment (and skin) from damage. Dispose of the wash water appropriately.

After each transect is completed or sooner if problems occur, perform maintenance on the stream gaging equipment in accordance with manufacturers recommendations. Maintenance procedures are as follows (*Discharge Measurements at Gaging Stations*, Buchanan and Somers, p.8):

> Before and after each discharge measurement, examine the meter cups or vanes, pivot and bearing, and shaft for damage, wear, or faulty alignment. Before using the meter, check its balance if on a hanger, check the alignment of the rotor axis with a hanger or wading rod, and adjust the conductor wire to prevent interference with meter balance and rotor spin.
>
> Clean and oil meters daily when in use. If measurements are made in water carrying noticeable suspended sediment, clean the meter immediately after each measurement. Surfaces to be cleaned and oiled are the pivot bearing, pentagear teeth and shaft, cylindrical shaft bearing, and thrust bearing at the cap.
>
> After oiling, spin the rotor to make certain it operates freely. If the rotor stops abruptly, find the cause and correct the trouble before using the meter. On notes for each measurement, record the duration of spin. Obvious decrease in spin duration indicates need for attention to the bearings.
>
> The pivot needs replacement more often than other meter parts. Examine the pivot after each measurement. Replace a fractured, rough, or worn pivot.
>
> Keep the pivot and pivot bearing separated except during measurements. Use the raising nut if provided, or, for pygmy meters, replace the pivot by the brass plug.
>
> Most minor repairs can be made in the field. Repair attempts, however, should be limited only to minor damages. This is particularly true of the rotor because minor dents in the bucket wheel or cups can have a large influence on the meter rating. Unless minor dents in the cups can be straightened out to “like new” condition, the entire rotor should be replace with a new one.

Badly sprung yokes, bent yoke stems, misaligned bearings and tailpieces, should be reconditioned in shops equipped with the specialized facilities needed.

12. Calculations

Calculate the Total Discharge (Q) at a transect location after completion of all readings by pressing "Calculate Discharge" key on the AquaCalc. For a mathematical explanation of discharge calculation procedures, refer to Appendix C. The AquaCalc requires Datalink software (supplied with purchase) to download the data into a PC in either Windows or DOS formats. Field data may be printed from the Datalink format or imported to Microsoft Excel. The data can be customized in Excel to fit a specific table format or for electronic data storage.

13. Records

A three-ring project binder is to be maintained as an organized compilation of the project, including the field Transect Data Logs, printout of the computerized data, Appendices B and C, and a log of maintenance and servicing of equipment. Entries in the maintenance log should include:

- Date and description of routine maintenance (cleaning, lubrication, battery check)
- Date and description of instrument problems and symptoms
- Date and description of corrective action taken
- Servicing recommendations

14. Review of Standard Operating Procedure

This Standard Operating Procedure for stream gaging is a work in progress and is subject to a minimum annual review for accuracy, and/or changes in equipment and/or procedure. Documentation of review by the project Quality Assurance Officer is maintained within this document preceding the Table of Contents.

15. References

Buchanan, Thomas J., and William P. Somers, *Discharge Measurements at Gaging Stations*, Book 3, Chapter A8, Techniques of Water-Resource Investigations of the United States Geological Survey - Applications of Hydraulics, 1984.

JBS Instruments, *AquaCalc 5000 Basic Stream Flow Computer Operating Instructions Manual*, April 2000.

Rickly Hydrological Company, product information and equipment.

United States Geological Survey, *Overview of the Stream-Gaging Program,* U.S. Geological Survey Circular 1123, 1995.

Sampling Procedures

Most samples received by 29 Palms Laboratory will have been taken by the cllient.
29 Palms Laboratory will provide to the client:

1. Appropriate certified clean sample containers that are traceable by lot to sources
2. Labels
3. Shipping containers
4. Chain-of-Custody forms
5. Method specific sampling instructions that include handling, preservation, and storage procedures

All samples should be handled and preserved in accordance with the method of analysis (See table I).
Samples known to be highly contaminated should be shipped according to DOT regulations for the . transport of hazardous materials.
Due to extreme weather conditions in the Coachella Valley where 29 Palms Laboratory is located, all samples requiring preservation should be immediately kept on ice in an ice chest at time of sampling.
Care should be taken to ensure that samples remain on ice during delivery to the laboratory.

TABLE I - CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

EPA METHOD	METHOD NAME	CONTAINER	SAMPLE AMOUNT	PRESERVATION	MAXIMUM HOLDING TIME
100-Series	Physical Properties				
120.1	Conductance	Polyethylene, Glass	100 ml	Cool, 4^oC	28 Days
150.1	pH	Polyethylene, Glass	25 ml	None	Analyze Immediately
160.1	Residue, Filterable	Polyethylene, Glass	100 ml	Cool, 4^oC	7 Days
200-Series	Total Metals	Polyethylene, Glass	100 ml	HNO_3 to pH <2	6 Months
300-Series	Non-Metallics				
325.3	Chloride	Polyethylene, Glass	50 ml	None	28 Days
340.1	Fluoride	Polyethylene, Glass	300 ml	None	28 Days
352.1	Nitrate	Polyethylene, Glass	100 ml	Cool, 4^oC	48 Hrs.
365.3	Orthophosphate	Polyethylene, Glass	50 ml	Filter on site, Cool, 4^oC	48 Hrs.
365.3	Total Phosphate	Polyethylene, Glass	50 ml	Cool, 4^oC, H2SO4 to pH <2	28 Days
375.4	Sulfate	Polyethylene, Glass	50 ml	Cool, 4^oC	28 Days
600-Series	Organics				
608	Organochlorine Pesticides	Amber Glass with Teflon-Lined Caps	1 liter	Cool, 4^oC 0.008% Sodium Thiosulfate	Extracted by 7 Days Analyzed by 40 Days
632	Carbamate Pesticides	Amber Glass with Teflon-Lined Caps	1 liter	Cool, 4^oC 0.008% Sodium Thiosulfate	Extracted by 7 Days Analyzed by 40 Days
8000-Series	Organics				
8081A	Organochlorine				
	Pesticides Solid -	8 oz. Glass	50 grams	Cool, 4^oC	14 Days
	Liquid -	Amber Glass with Teflon-Lined Caps	1 liter	Cool, 4^oC 0.008% Sodium Thiosulfate	Extracted by 7 Days Analyzed by 40 Days
8141A	Organophosphorus				
	Pesticides Solid -	8 oz. Glass	50 grams	Cool, 4^oC	14 Days
	Liquid -	Amber Glass with Teflon-Lined Caps	1 liter	Cool, 4^oC 0.008% Sodium Thiosulfate pH to 5-8 with NaOH or H_2SO_4	Extracted by 7 Days Analyzed by 40 Days
8318	Carbamate				
	Pesticides Solid -	8 oz. Glass	50 grams	Cool, 4^oC	14 Days
	Liquid -	Amber Glass with Teflon-Lined Caps	1 liter	Cool, 4^oC 0.008% Sodium Thiosulfate pH to 4-5 with 0.1 N Chloroacetic Acid	Extracted by 7 Days Analyzed by 40 Days

CATEGORY 10: SURFACE WATER SAMPLING, FLOW

Section 10.4

MRI SOP

In-Situ Inc.

Innovations in
Water Monitoring

Aqua TROLL® CTD Data Loggers

Conductivity, Temperature, Plus Water Level Logging

Conductivity measurements can be used to characterize water quality changes relative to a baseline or to estimate the concentration of contaminants. The In-Situ® Aqua TROLL 100 and Aqua TROLL 200 Instruments measure and log conductivity and temperature. The Aqua TROLL 200 adds water level logging.

Rugged, Compact Design

- Use in harsh environments. Titanium construction resists fouling and is chemical- and corrosion-resistant.
- Deploy 1.83-cm (0.72-in) diameter instruments into narrow wells.

Extended Deployments

- Reduce power consumption. Batteries have a typical life of 5 years when reading every 15 minutes. 8-36 VDC input is compatible with external batteries and solar power.
- Use the TROLL® Shield Antifouling System to reduce biofouling and extend deployments by up to 6 weeks.

Accurate Results

- Use dynamic density compensation to collect accurate water level data in environments where salinity values may vary.
- Receive factory-calibrated instruments that are validated with NIST®-traceable standards.
- Deploy for long-term monitoring. Instruments operate with very low drift.

Flexible Communications

- Integrate into telemetry and SCADA systems. Outputs include standard Modbus/RS485, SDI-12, and 4-20 mA.
- Easily connect to RuggedReader® Handheld PC or PC.
- Use RuggedCable® Systems with titanium twist-lock connectors for quick, reliable connections.
- Simplify instrument setup, automate site management, and view real-time results with Win-Situ® Software.

Applications

- Aquifer storage and recovery systems
- Coastal deployments—Saltwater intrusion monitoring, storm surge analysis, and estuary/wetland research
- Remediation site and mine water monitoring
- Stormwater monitoring programs

Aqua TROLL® 100 and 200 Data Loggers

	Aqua TROLL 100 and 200 Instruments	
Temperature ranges[1]	Operational: -5 to 50° C (23 to 122° F) Storage: -40 to 65° C (-40 to 149° F) Calibrated: 0 to 50° C (32 to 122° F)	
Max. pressure for Aqua TROLL 100	500 psi (1153 ft)	
Dimensions & weight	Diameter (OD): 1.83 cm (0.72 in). Length: 31.5 cm (12.4 in) Weight: 0.5 kg (1.0 lb)	
Materials	Titanium body and sensors, Delrin® nose cone, and PVC conductivity cell	
Output options	Modbus/RS485, SDI-12, and 4-20 mA	
Battery type & life[2]	3.6V lithium. 5 years or 200,000 readings[3]	
External power	8-36 VDC	
Memory **Data records[4]** **Data logs**	4.0 MB 190,000 50	
Log types[5]	Linear, Linear Average, and Event	
Fastest logging rate	Linear: 1 per minute. Linear Average: 1 per minute. Event: 1 per second	
Fastest output rate	1 per second	
Conductivity Sensor	Type: Balanced 4-electrode cell	
Methods	EPA Method 120.1; Standard Methods 2510	
Range, accuracy, & resolution	Range: 5 to 100,000 µS/cm Accuracy: ±0.5% of reading + 1 µS/cm when reading less than 80,000 µS/cm ±1.0% of reading when reading above 80,000 µS/cm Resolution: 0.1 µS/cm	
Parameters supported[6]	*Range*	*Units*
Actual conductivity	5 to 100,000 µS/cm	µS/cm, mS/cm
Specific conductivity[7]	5 to 100,000 µS/cm	µS/cm, mS/cm
Salinity[8]	0 to 42 PSU	PSU
Total dissolved solids	0 to 82 ppt	ppt, ppm
Resistivity	10 to 200,000 Ohms-cm	Ohms-cm
Density (water salinity)	0.98 to 1.14 g/cm³	g/cm³
Pressure/Level Sensor[9]	Type: Piezoresistive. Pressure/level are available only on the Aqua TROLL 200 Instrument.	
Range	*Absolute (non-vented)* 30 psia: 11 m (35 ft) 100 psia: 60 m (197 ft) 300 psia: 200 m (658 ft) 500 psia: 341 m (1120 ft)	*Gauged (vented)* 5 psig: 3.5 m (11.5 ft) 15 psig: 11 m (35 ft) 30 psig: 21 m (69 ft) 100 psig: 70 m (231 ft) 300 psig: 210 m (692 ft) 500 psig: 351 m (1153 ft)
Burst pressure	Maximum 2x range; burst > 3x range	
Accuracy & resolution[10]	Accuracy @ 15° C: ±0.05% full scale (FS)[11] Accuracy 0 to 50° C: ±0.1% FS[12] Resolution: 0.005% FS or better	
Units of measure	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH_2O, inH_2O. Level: in, ft, mm, cm, m	
Temperature Sensor		
Method	EPA Method 170.1	
Accuracy & resolution	Accuracy: ±0.1° C. Resolution: 0.01° C or better	
Units of measure	Celsius or Fahrenheit	
Warranty	2 years. Up to 5-year extended warranties available—please call for details.	

TROLL® Shield System Extends Deployments

When used at coastal and high-fouling sites, the TROLL Shield Antifouling System fights biofouling of the Aqua TROLL Instrument and its conductivity cell. Reduced sensor fouling extends deployments by up to 6 weeks and improves instrument accuracy and performance. Use the coiled copper guard with both the Aqua TROLL 100 and 200 Instruments. Use the copper nose cone with the Aqua TROLL 200. For optimum performance, replace the guard every 6 months.

24/7 Support

In-Situ technical specialists assist with instrument setup, application support, and troubleshooting. Call for free technical support.

1 Temperature range for non-freezing liquids
2 Typical battery life when used within the factory-calibrated temperature range
3 1 reading = date/time plus all available parameters polled or logged from device
4 1 data record = date/time plus 3 parameters logged (no wrapping) from device
5 External power or battery pack is recommended when using Linear Average or Event logging modes.
6 Parameters derived from temperature at 25° C and actual conductivity range of 5 to 100,000 µS/cm with a ±0.5% + 1 µS/cm accuracy
7 Derived from Standard Methods 2510B
8 Defined by the Practical Salinity Scale 1978; Standard Methods 2520B
9 Real-time level compensation based on water density
10 Accuracy with 4-20 mA output option: ±0.25% FS
11 Across factory-calibrated pressure range
12 Across factory-calibrated pressure and temperature ranges

Specifications are subject to change without notice.

In-Situ Inc.

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Versatile, multiparameter handheld instrument

Rugged and reliable, the YSI 556 MPS (Multiprobe System) combines the versatility of an easy-to-use, easy-to-read handheld unit with all the functionality of a multiparameter system.

- Simultaneously measures dissolved oxygen, pH, conductivity, temperature, and ORP
- Field-replaceable electrodes
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- GLP assisting, records calibration data in memory
- Available with 4, 10, and 20-m cable lengths
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- RS-232 interface for PC connection

The 556 has multiple language capabilities and graphing!

Options to Fit Your Applications!

- Battery Options – The unit is powered by alkaline batteries or an optional rechargeable battery pack with quick-charge feature.
- Optional Barometer – Internal barometer can be user-calibrated and displayed along with other data, used in dissolved oxygen calibrations, and logged to memory for tracking changes in barometric pressure. (Choose 556-02)
- Optional Flow Cell - The 5083 flow cell can be used for ground water applications or anytime water is pumped for sampling.
- Carrying Case – The instrument comes standard with YSI 5061, a soft-sided carrying case with enough space for the 556, a 20-meter cable, and calibrating supplies. An optional 5080 hard-sided carrying case is also available.
- Confidence Solution® - Quality assurance ensured. Quickly check conductivity, pH, and ORP readings with one solution.

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ISO 14001

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5563 MPS Sensor Specifications

Dissolved Oxygen (% saturation)	Sensor Type	Steady state polarographic
	Range	0 to 500% air saturation
	Accuracy	0 to 200% air saturation, ± 2% of the reading or ±2% air saturation, whichever is greater; 200 to 500% air saturation, ± 6% of the reading
	Resolution	0.1% air saturation
Dissolved Oxygen (mg/L)	Sensor Type	Steady state polarographic
	Range	0 to 50 mg/L
	Accuracy	0 to 20 mg/L, ± 2% of the reading or ±0.2 mg/L, whichever is greater; 20 to 50 mg/L, ± 6% of the reading
	Resolution	0.01 mg/L
Temperature	Sensor Type	YSI Temperature Precision™ thermistor
	Range	-5 to 45°C
	Accuracy	± 0.15°C
	Resolution	0.1°C
Conductivity	Sensor Type	4-electrode cell with autoranging
	Range	0 to 200 mS/cm
	Accuracy	± 0.5% of reading or ± 0.001 mS/cm; whichever is greater (4-meter cable) ± 1.0% of reading or ± 0.001 mS/cm; whichever is greater (20-meter cable)
	Resolution	0.001 mS/cm to 0.1 mS/cm (range-dependent)
Salinity	Sensor Type	Calculated from conductivity and temperature
	Range	0 to 70 ppt
	Accuracy	± 1.0% of reading or ±0.1 ppt, whichever is greater
	Resolution	0.01 ppt
pH (optional)	Sensor Type	Glass combination electrode
	Range	0 to 14 units
	Accuracy	±0.2 units
	Resolution	0.01 units
ORP (optional)	Sensor Type	Platinum button
	Range	-999 to +999 mV
	Accuracy	± 20 mV
	Resolution	0.1 mV
Total Dissolved Solids (TDS)	Sensor Type	Calculated from conductivity (variable constant, default 0.65)
	Range	0 to 100 g/L
	Resolution	4 digits
Barometer (optional)	Range	500 to 800 mm Hg
	Accuracy	± 3 mm Hg within ± 10°C temperature range from calibration point
	Resolution	0.1 mm Hg

YSI 556 Instrument Specifications

Size	11.9 cm width x 22.9 cm lenth (4.7 in. x 9 in.)
Weight with batteries	2.1 lbs. (916 grams)
Power	4 alkaline C-cells; optional rechargeable pack
Cables	4-, 10-, and 20-m (13.1, 32.8, 65.6 ft.) lengths
Warranty	3-year instrument; 1-year probes and cables
Communication Port	RS-232 Serial
Data Logger	49,000 data sets, date and time stamp, manual or logging, with user-selectable intervals

556 Ordering Information (Order all items separately)

556-01	Instrument (with 5061 large, soft-sided carrying case)
556-02	Instrument with barometer option (with 5061 carrying case)
5563-4	4-m cable and DO/temp/conductivity
5563-10	10-m cable and DO/temp/conductivity
5563-20	20-m cable and DO/temp/conductivity
5564	pH Probe for any 5563 cable
5565	pH/ORP Probe for any 5563 cable
6118	Rechargeable battery pack kit (includes battery, adapter, charger)
614	Ultra clamp, C-clamp mount
616	Charger, cigarette lighter
4654	Tripod (small tripod for instrument)
5060	Small carrying case, soft-sided (fits instrument and 4-m cable)
5065	Form-fitted carrrier with shoulder strap
5080	Small carrying case, hard-sided (fits instrument, 4-m cable, flow cell, batteries, membrane kit, calibration bottles)
5083	Flow cell
5085	Hands-free harness
5580	Confidence Solution® (insure probe accuracy with a simple field-check for conductivity, pH, and ORP)

The 5080 carrying case with 556, 5563-4 cable, and 5083 flow cell.

MHE Products PushPoint Sampler (US Pat. # 6,470,967)
Operators Manual and Applications Guide

Ver. 2.01 2/15/03

Models: PP27, PP14, PPX36, PPX72

Introduction

The groundwater/surface water interface (GSI) has been a research interest of mine for the past decade. This transitional zone is usually rich in biomass and may play a predominant role in the bioattenuation of contaminated groundwater entering surface water bodies. Usually these biologic processes have limited effectiveness in attenuating highly contaminated groundwater, leaving a plume of parent contamination and metabolic byproducts that eventually expresses itself in receiving waters - usually classified as non-point sources of pollution because of the uncertainty of the discharge area. Reliance on conventional technology and techniques to perform a detailed investigation required extensive effort and burdensome equipment.

Sampling at each location usually takes 5 minutes, allowing a small crew to collect dozens of samples in an afternoon. These samples can be analyzed in the field for real-time information useful in directing field investigations and research. The work that I have conducted at several contamination sites indicates that many groundwater plumes discharge in surface water bodies in 2-3' of water depth - accessible to investigators wearing hip boots or waders. Many plumes, especially Light Non-Aqueous Phase Liquid (LNAPL) plumes can be delineated by collection of samples in very shallow water or from under beaches. My initial experience has shown that Dense Non-Aqueous Phase Liquid (DNAPL) contaminant plumes express themselves in the shallow, near-shore water as well, even though the on-shore depth of the contaminant mass was deep in the aquifer.

Directions

Look at Figure 1.

As you can see, the PushPoint device is a very simple, precisely machined tool consisting of a tubular body fashioned with a screened zone at one end and a sampling port at the other. The bore of the PushPoint body is fitted with a guard-rod that gives structural support to the PushPoint and prevents plugging and deformation of the screened zone during insertion into sediments. The PushPoint is made of 316 stainless steel assuring compatibility with most sampling environments. The screened-zone consists of a series of interlaced machined slots which form a short screened-zone with approximately 20% open area.

Operation of the device is not difficult. One simply holds the device in a manner that squeezes the two handles towards each other to maintain the guard-rod fully inserted in the PushPoint body during the insertion process (as shown in Figure 2). Holding the device in this manner, push the PushPoint into the sediments or beach to the desired depth using a gentle twisting motion. When the desired depth is reached (or you hit refusal, usually at an aquitard) remove the guard-rod from the PushPoint body without disturbing the position of the deployed sampler. Once the guard-rod has been removed from the PushPoint, it SHOULD NOT be reinserted into the device until the bore of the PushPoint has been thoroughly cleansed of all sand, silt, etc.

Attach a syringe or peristaltic pump to the PushPoint sample-port (see Figure 3) and withdraw water at a low-flow sampling rate (50-200 ml/min.). The first 20-50 ml of groundwater will be turbid. This is the "development" water and should be discarded. Once non-turbid aliquots have been withdrawn, representative samples can be collected for on-site and off-site analysis.

Cleaning and Maintenance

I cannot stress how important cleanliness and linearity are to the working life of the instrument. The PushPoint was designed as an indefinitely reusable device; potentially able to be reused hundreds of times. The tolerance between the guard-rod and the bore of the PushPoint is very small. Increases in this tolerance through abrasion and damage may allow silty material into this annular space, eventually jamming the guard-rod into the bore - maybe permanently!

Excess wear and abrasion can also be introduced if the guard-rod is inserted frequently when the PushPoint body is bent. All the small bends should be "undone" prior to reinsertion of guard-rod to avoid scraping the sides of the bore causing burrs. Before reinsertion of the guard-rod into the cleaned PushPoint, the device should be "straight as an arrow". Use caution when straightening the screened-zone, it is somewhat delicate without the guard-rod inside it, and can be broken through repeated bending. Similarly, the guard-rod should be bend-free and clean when inserted into the bore of the device. When a clean and straight PushPoint is assembled, the guard-rod should slide fairly easily through the PushPoint bore and its handle should seat against the sampling port.

Clean the exterior of the guard-rod and PushPoint body and screened-zone with a stiff brush and cleaning solution (soapy water).Cleaning and decontamination of the bore of the instrument is easily accomplished using the cleaning adapter provided. Remove the spray nozzle of a "garden sprayer" filled with cleaning solution. Connect the adapter as shown in Figure 4. Insert the sampling port of the PushPoint to the adapter and squirt ~ 100 ml of pressurized cleaning solution backwards through the sampler and out the screened-zone into a waste receptacle. Gently push the guard rod into the bore of the PushPoint to its end to dislodge any bridged material. Re-rinse the bore with cleaning solution. Follow this with a distilled water and/or methanol rinse. Reinsert the guard-rod and the device is ready to be used again.

In some instances it may be advantageous to force the cleaning solution through the screened-zone and out the sampling port. To do so, gently insert the screened-zone of the PushPoint into the cleaning adapter, making sure not to bend the screened-zone, until the entire screened-zone is within the adapter. The screened-zone is somewhat fragile. To avoid damage, do not bend the screen-zone during insertion into the adapter. Squirt cleaning solution through the sampler to a waste receptacle.

Helpful Hints, Information, and Cautions

- Multiple depths can be sampled in one hole if samples are collected, in order, from deepest to shallowest. Insert the sampler using a twisting motion until you reach refusal. Remove the guard-rod. **Do not push the sampler further into the sediments once the guard-rod has been removed as this may damage the screened-zone and plug the device with sediment**. Once sampling has been completed at this deepest depth, the PushPoint can be partially pulled from the hole to a new sampling elevation. Remember, to prevent screened-zone damage, do not to insert the PushPoint into the sediments without the guard-rod inserted into the PushPoint body. Alternately, multiple holes can be used to collect samples from multiple depths at a particular sampling location. If vertical sampling is performed in one hole, it is recommended that some type be device such as a sampling platform be used to prevent lateral movement and slippage of the PushPoint as sampling is conducted near the top of the hole (see Figure 3). This offsets the leverage of the instrument and reduces hole degeneration. A simple platform would be a plate of steel with a 3/16" dia. hole through its center and would serve the fundamental purpose of maintaining a rigid hole opening . MHE offers a 8" dia., heavy-duty steel sampling platform engineered for the precise sampling depth requirements of field research. If repeated shallow sampling is to be conducted, it may be more convenient to use a shorter sampler (i.e. MHE - PP14").

- If you wish to reuse the PushPoint sampler at a particular sampling location and want to clean the bore quickly while you're there so that the guard-rod may be safely reinserted, you can use a syringe filled with surface water or DI water to backflush the bore several times before reinserting the guard-rod. Use at least 100 ml of water. If you have too much trouble reinserting the guard-rod (i.e. grit), it will be necessary to use the standard cleaning procedures.
- If the screened-zone of the PushPoint becomes plugged while inserted in the sediments due to passage through "something", it is frequently possible to hydraulically/pneumatically shock the screened-zone free of adhering material while it is inserted into the sediments. Attach a large-volume (50 ml) syringe to the sampling port. In a quick motion, pull the syringe plunger most of the way back (creating a vacuum) and then immediately release the plunger - the plunger will slam to a neutral position, sending a shock wave through the bore of the PushPoint and may alleviate the problem.
- The PushPoint can be used as a piezometer to determine the static head of the groundwater and hence, the potential direction of groundwater movement. To do this, a tube is connected to the sample port as shown in Figure 5. A continuous stream of water is established from the syringe (or pump) to the screened-zone by pumping out any air remaining in the PushPoint /tubing. When the tube is disconnected from syringe, the static water level in the tube will represent the static water level at the depth that the screened-zone occupies. In some discharge areas I have found several feet of head differential, and when the tubing is removed, the PushPoint flows like a miniature artesian well.
- It is frequently possible to push the PushPoint through thin lenses of low-permeably material and collect samples from below them and gather valuable geochemical samples. At many of the sites where the PushPoint has been used, sampling from just below a layer of fine sand/silt/clay, one occasionally encounters seemingly large pockets of gas that seem to have coalesced and collected under this less permeable stratum. Analysis of these pockets may provide additional insight to predominant biological processes. It is likely true that the concentration of volatile chemicals in the groundwater has equilibrated with these bubbles which means that their presence in a sampling stream or syringe would not significantly affect the concentration of dissolved volatile organic chemicals (VOC's). In fact, if one assumes that equilibrium conditions exist, the concentration of VOC's in the bubbles is directly related the concentration in the surrounding groundwater. An different condition may exist if the groundwater is supersaturated with bacterial metabolic waste gasses and the negative pressure exerted by the pump (or syringe) initiates degassing of dissolved gasses from the groundwater. In this instance, VOC's would partition from the groundwater to the bubbles as they are formed in the sampling tubing (this is fairly evident if occurring). The consequence of this condition is that part of the dissolved contaminant mass has partitioned into the gas phase and unless the gas-phase is captured, quantified and accounted for, the native VOC concentration of the groundwater is not reflected by analysis of the groundwater alone. If this condition exists, the degassing effect can be minimized by decreasing the sampling rate to a rate more easily yielded by the sampled formation. With experience, it is easy to distinguish which of these conditions (or combination of conditions) exist and to what extent they affect sample quality.
- The internal volume of a PushPoint PP27 is approx. 1.5 ml. A 50 ml syringe full of distilled water, decon water, methanol, etc. will push about 33 volumes through the bore.
- When straightening the screened zone it is sometimes helpful to flush out the bore of the device with a cleaning solution and then insert the guard-rod to the area of the bend in the screened-zone. Gently unbend the portion of the screened-zone nearest the rod and carefully advance the rod to the next bend. After the rod has been fully inserted into the screened-zone perform the final screened-zone, straightening until the guard-rod slides freely through it.
- If the sampling port of the PushPoint is above the static level of the water body, each time you remove the syringe or pump from the PushPoint sampling port, air will fill the bore of the PushPoint, allowing the water level in the bore to reach its static head. To avoid this plug of air from entering the subsequent syringe, attach a pinch clamp and/or a 3-way valve between the sampling port and the syringe or pump inlet as shown in Figure 7.
- I have conducted dye tests (concentrated uranine dye) by injecting concentrated dye under a perforated 1.5' diameter disk through which the PushPoint was inserted from depths of 3" - 12" into sediments. The goal of these tests was to determine whether or not surface water and dye are drawn into samples collected in near surface sediments (i.e. whether a cone of depression is formed). The results indicated

that no surface water is drawn into samples even though sampling was conducted with a peristaltic pump at its maximum rate of 600 ml/min for several minutes.

- I usually couple my field investigations with global positioning system (GPS) identification of the sampling location. If conditions permit, a pin flag can be placed at the sampling location for later location by GPS - I usually use sub-meter grade GPS for this surveying. GPS can then used in the future to relocate previously sampled location even if certain site physical characteristics have changed (eroding shorelines, etc.). If long-term study of a shoreline is planned it will be useful to have an elevation benchmark established on shore that can be used as a reference. The elevation of the sampling locations can then accurately measured. This may be helpful in areas where sediment levels are not stable such as in erosional areas.
- Sampling by syringe has many advantages. This is my preferred field method due to its simplicity and versatility. It is useful to be able to collect several 50 ml syringes full of groundwater, store them on ice and perform the sample transfer to VOA vial, etc. under more controlled conditions. To transfer sample to a VOA vial, place the end of the transfer tube (Figure 8) to the bottom of the VOA vial. Dispense sample into the VOA vial and slowly withdraw the transfer tube from the vial maintaining the mouth of the transfer tube just below the sample surface. When the transfer tube is almost out of the vial, continue to dispense sample and leave an "anti-meniscus" of sample above the rim of the vial. Add several drops of HCl (which will displace a few drops of sample) and cap. If VOC samples are to be collected and/or stored temporarily in a syringe, I recommend 100% polyethylene/polypropylene ("two piece") syringes such as those made by Henke Sass Wolf GMBH (NormJect ®, 50 ml)) configured as shown in Figure 8. From personal experience I have found that small amounts of aromatic compounds (BTEX) can leach from the rubber parts of the rubber-tipped plunger found in common medical syringes. Rubber-tipped plunger syringes have less side-wall resistance and work much smoother than the 100% polyethylene/polypropylene syringes so I use medical syringes for "development" of the PushPoint. Standard medical syringes also work well for collecting samples for non-VOC analysis. I utilize handheld meters for pH, conductivity, redox, DO, etc. One can dispense sample from the syringe into these types of instruments for field measurements. The disposable syringes may be cleaned and reused several times, but because they are a friction fit; prolonged reuse results in scoring of the barrel which eventually causes air leaks.
- The 50 ml, 100% polyethylene/polypropylene "two piece" syringes mentioned above can be purchased directly from MHE, configured with tubing, clamp, and stopper as was the example syringe included with your order, or customized to suit your individual needs. If you would to make your own, the syringes that I am currently using are purchased from National Scientific. The tubing is Tygon 1/4"OD x 1/8" ID. Be sure to use some type of clamp at the tubing mouth to ensure a good seal at the sampler port. The entire syringe assemblies are now available from MHE at a reasonable cost.
- Headspace GC analysis of VOC's can be easily accomplished using 100% polyethylene/polypropylene syringes. Dispense all but 25 ml of the sampled groundwater from the syringe. Refill the syringe to the 50 ml mark with ambient air and then stopper the tubing (and heat the syringe in a water bath if desired) as shown in Figure 9. Shake the syringe assembly to equilibrate the VOC's in the sample with the contained atmosphere. Insert a GC syringe needle through the transfer tube into the sample syringe headspace and withdraw a sample for GC analysis.
- Occasionally a small amount sand and silt is withdrawn into the syringe or pump sampling stream, even after proper "development" of the PushPoint. This may be due to the nature of the geologic formation. This fine material is probably already at equilibrium with the surrounding groundwater and tests have shown that its presence should not influence analysis of VOC's in the groundwater sample. The sample can be transferred to its shipping container without this silt if the syringe is dispensed in such a manner as to let the solid material settle out in the syringe and not carry over to the shipping vial.
- The PushPoint has been used very successfully for underwater investigations using SCUBA equipment and a series of 100% polyethylene syringes. Once again, GPS equipment was used for location of the position that the divers collected groundwater samples of contaminant plume expression in the lake. Underwater notes (temperature, depth, observations, etc.) can be written directly on the sample syringes if they are pre-prepared with a strip of Scotch Magic Transparent Tape applied down the syringe body and writing is done with a soft pencil.

- The PushPoint may be used to inject nutrients or dyes into the sediments for field trials of biologic or geochemical testing or tracing groundwater paths. Simply insert the PushPoint to the desired depth, and after the guard-rod has been removed, connect a syringe or pump and slowly inject the desired fluid into the sediments, perhaps followed by a small amount of native groundwater to flush the instrument.
- The PushPoint is constructed of 316 stainless steel as mentioned previously. There are two places where the stainless parts are silver soldered together, the handle of the guard-rod and the handle on the PushPoint sampler. If the investigator is collecting samples for metals analysis, the silver solder joint on the guard-rod may impart trace levels metallic residue to the sampling port mouth. This has never caused a problem but the possibility exists. The silver solder that I use is Safety-Silv 45 which contains silver (45%), copper (30%),and zinc (25%). MSDS available upon request. In the unlikely event that these metals cause contamination of samples, MHE can produce specialty guard-rods that are not silver soldered. What can I say, these devices were originally built to sample for VOC's.
- These devices can be dedicated as semi-permanent underwater monitoring devices. If a PushPoint is inserted to the desired depth through a plate (such as the sampling platform mentioned earlier) that can lock the sampler at the correct insertion depth, a vinyl cap can be placed over the mouth of the sampler, and the sampler can be dedicated to that location so that future samples can be withdrawn when desired.
- It has been useful to carry several samplers in "quivers" made of 2" PVC tubing….one tube for (10-15) clean/assembled samplers and one tube for used samplers and their separated guard-rods. This arrangement protects both the investigators and the instruments.
- I have been using a Myron 6P Ultrameter available from www.ColeParmer.com for most of my work. This instrument measures pH, specific conductance, ORP, temperature, and TDS using only a few milliliters of sample and is perfectly suited to samples dispensed by syringe. The instrument is waterproof to 3 m. There will soon be a link on the MHEproducts.com web page.
- I have been using the Chemetrics Vacu-Vial technique (www.Chemtrics.com) in conjunction with Pushpoint sampling. I use this for dissolved oxygen and dissolved iron measurements. Many other analytical tests are also available such as nitrate, phenols, etc.. This analytical technique also works very well with samples collected in syringes. The sample is dispensed into a plastic cone until it overflows. The tip of an evacuated ampoule containing the necessary reagents is broken off at the bottom of the cone allowing the vacuum in the ampoule to pull in a aliquot of sample that has not contacted the atmosphere. The ampoule is shaken and is then is then placed as a cuvette into a handheld spectrophotometer. The results are nearly instantaneous and are displayed in ppm. There will soon be a link on the MHEproducts.com web page.

I hope that users will find many useful and innovative uses for this device. If you have other helpful information, uses, and advice concerning these samplers, please write or e-mail suggestions to me for inclusion in future manual revisions. I have finally started a web site: www.MHEproducts.com and have posted pictures, new products, and the latest version of this manual.

Thanks. MHE

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Figure 1

the PushPoint sampler

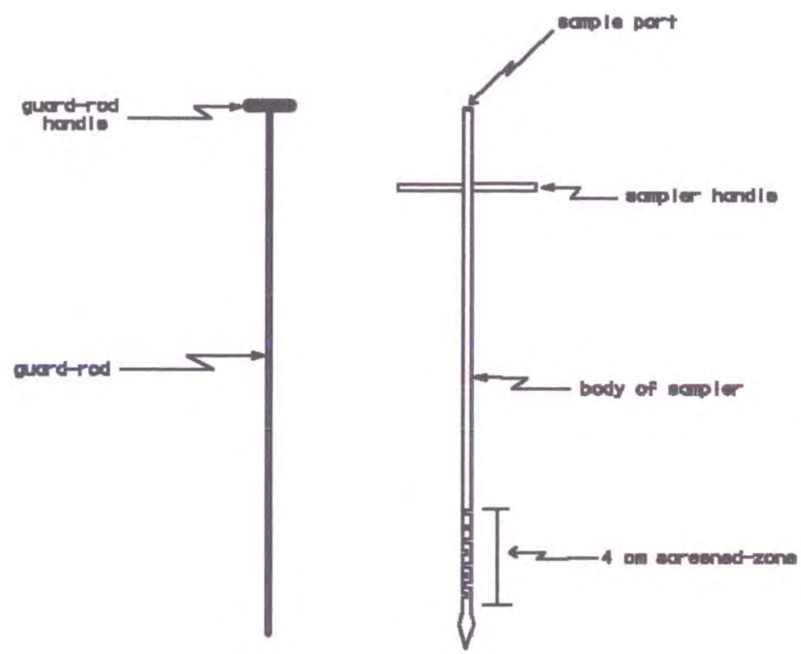


Fig. 1a

disassembled sampler

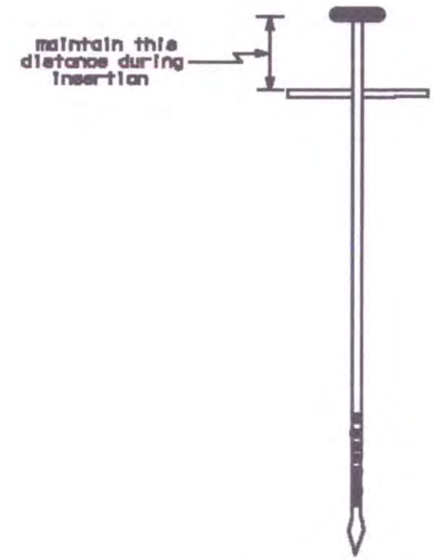


Fig. 1b

assembled sampler

MHE Products.com

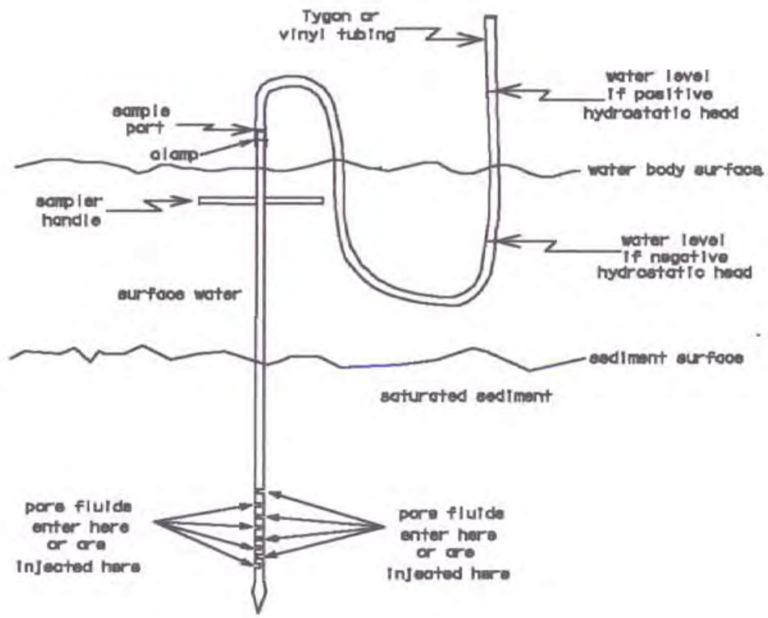


Figure 5

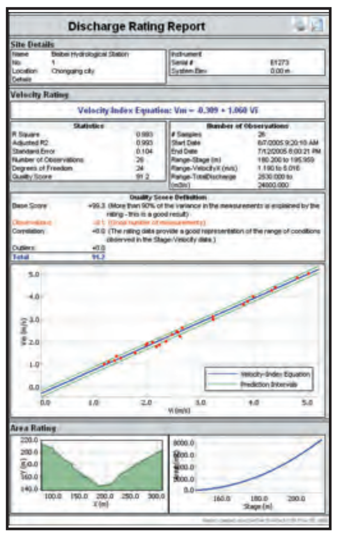
MHE Products.com

FlowTracker®

No other wading discharge device on the market comes with more useful options and accessories, making the FlowTracker a complete, turn-key solution.

The SonTek Deluxe wading rod, featuring a sturdy grip and bubble level

Rugged case provided with optional top-setting rod



FlowPack Velocity Indexing report software

Standard Features

- Low-profile 2-D ADV water velocity sensor on 2m flexible cable (measure in depths down to 2cm (1 inch))
- Automatic discharge computation protocols (ISO/USGS mid-section, mean-section, and Japanese)
- Handheld keypad interface with real-time display
- Velocity methods: ISO, USGS, under ice, Kreps, 5-point, and multipoint
- Languages supported: English, Spanish, German, Italian, and French
- Recorder space: up to 64 discharge measurements or over 150,000 individual velocity samples
- Data Set Documentation: up to 20 values of time-stamped user comments including gauge height and rated flow
- QA/QC: automated data review and discharge uncertainty calculations
- Communication protocol: RS232
- Software: Windows software with diag-nostic beam-check, recorder access, data visualization and customizable reports
- Compatible with FlowPack Velocity Indexing software
- Temperature sensor
- Hard plastic case

SonTek
YSI incorporated

SonTek/YSI
9940 Summer Ridge Road
San Diego, CA 92121
Tel: +1 (858) 546-8327
Fax: + (858) 546-8150
Email: inquiry@sontek.com
www.sontek.com

Optional Features

- 2-D/3-D ADV side-looking probe
- 5m flexible cable
- Deluxe SonTek two piece, top-setting wading rod kit (1.2m/4ft or 2.4m/8ft) including case and mounting brackets
- Wading rod mounting bracket for controller/keypad
- Offset mounting bracket for ADV probe

Specifications

- Velocity range: ±0.001 to 4.0 m/s (±0.003 to 13 ft/s)
- Velocity resolution: 0.0001 m/s
- Velocity accuracy: ±1% of measured velocity, ±0.25 cm/s
- Sampling volume location: 10 cm from center transducer
- Power supply: 8 AA batteries
- Typical battery life: 25+ hours continuous operation (alkaline batteries)
- Weight: 1.8 kg/4.0 lbs
- Probe width: 130 mm (5.1 inches)
- Handheld controller/keypad: temporarily submersible to 1m
- Operating temperature: -20° to 50° C
- Storage temperature: -20° to 50° C

SmartQC

SmartQC is a built-in quality control feature that gives you the added assurance your FlowTracker data is correct. With each measurement, data is compared to a variety of adaptive QC criteria to ensure the best measurement possible.

SmartQC is our exclusive promise your SonTek/YSI system is performing at optimum standards and that your data is precise, reliable and exceeds your service expectations.

SonTek/YSI, founded in 1992 and advancing environmental science in over 100 countries, manufactures affordable, reliable acoustic Doppler instrumentation for water velocity measurement in oceans, rivers, lakes, harbors, estuaries, and laboratories. Headquarters are located in San Diego, California. Additional information can be found at www.sontek.com. SonTek/YSI is an employee-owned company.

The FlowTracker is made in the USA. Lit. code S01-05-0411

FlowTracker®
Handheld ADV®

FlowTracker®
Handheld ADV®

Sound Principles. Good Advice.

Wading Discharge Measurement Device

Portable. Precise. Practical.

Designed with the field user in mind, this handheld ADV® (Acoustic Doppler Velocimeter) measures 2D or 3D currents, attaches easily to wading rods, and features an automatic discharge computation using a variety of international methods, including ISO and USGS standards. At the end of the data run, just press a button and the FlowTracker calculates the discharge for you!

The FlowTracker is the ideal solution if you're looking for:

- Help in challenging outdoor conditions
- A way to avoid recurring calibration/maintenance
- Tough equipment that doesn't break down all the time
- Unmatched performance in shallow water and low flows
- An easy-to-use interface
- Fewer steps to follow
- Built-in quality checks (SmartQC) so you know your data is right.

The handy FlowTracker keypad is custom-designed for both discharge measurements and general purpose water velocity. Featuring provisions for starting edges, multiple channels, and even ice covered water, it is ready for any environmental situation. In addition, the FlowTracker's intelligent algorithm automatically prompts you for the proper measurement method based on your previous measurement stations.

FlowTracker Software Speaks Your Language

The FlowTracker comes with user-friendly, data analysis software that helps you produce attractive, customizable and professional reports in minutes. FlowTracker software also supports several languages, making it an ideal solution for international applications.

Example of FlowTracker discharge software and reports

FlowTracker in the Field

With rugged construction for any climate and a backlit display easily read during both day and night, the FlowTracker goes wherever you need it to go.

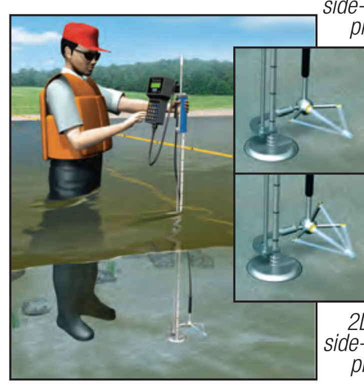
- Natural Streams
- Irrigation Canals
- Mining Channels
- Water Treatment
- Weirs/Flumes
- Storm Water
- Open Channels
- Lakes

The FlowTracker Advantage

It doesn't matter if you are new to acoustic Doppler technology, or an old familiar friend, the FlowTracker provides unparalleled benefits you will only find with SonTek/YSI systems. Here is some of what sets the FlowTracker apart.

- Multi-language instrument and software (English, Spanish, French, Italian, and German)
- Proven velocity precision - accurate to as low as 0.001 m/s (0.003 ft/s) and up to 4.0 m/s (13 ft/s)
- Automatic discharge calculation - International techniques, including ISO and USGS standards
- Record changing gauge heights and rated flows, with comments in each measurement
- Automatic discharge uncertainty calculation to ISO standard. **A FlowTracker First!**
- Measure velocities in water as shallow as 2 cm (less than an 1 inch)
- Keypad interface with real-time velocity and flow display
- Automatic quality control for accurate data collection
- Two or three dimensional velocity measurement
- Recorded data is shielded from power loss
- Lightweight, rugged, and waterproof
- No calibration required - ever!
- Built-in temperature sensor

2D side-looking probe



2D/3D side-looking probe

Example of typical stance and technique when using the FlowTracker

River Discharge and Flow

Spot Current Sampling

Irrigation Canals

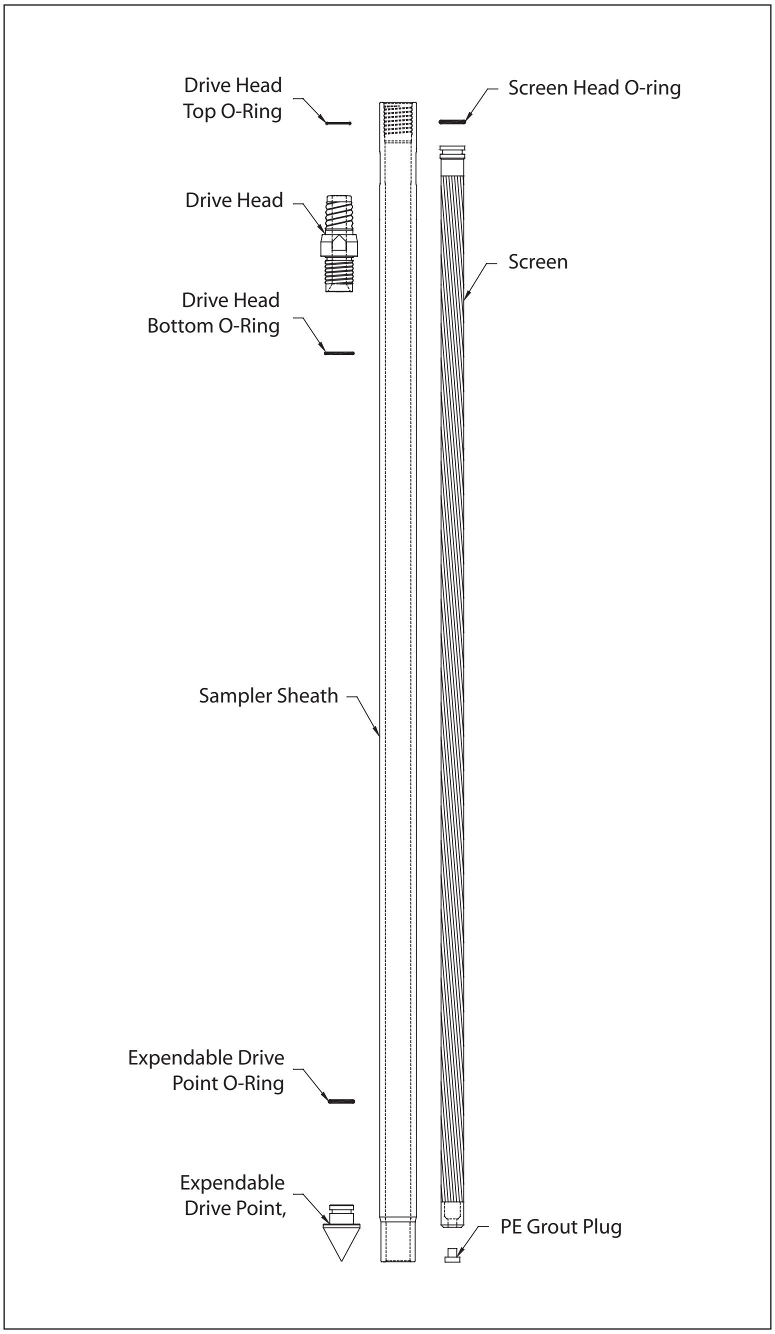
SonTek®
YSI incorporated

GEOPROBE® SCREEN POINT 16 GROUNDWATER SAMPLER

STANDARD OPERATING PROCEDURE

Technical Bulletin No. MK3142

PREPARED: November, 2006



GEOPROBE® SCREEN POINT 16 GROUNDWATER SAMPLER PARTS

Geoprobe Systems®

Geoprobe® and Geoprobe Systems®, Macro-Core® and Direct Image® are Registered Trademarks of Kejr, Inc., Salina, Kansas

Screen Point 16 Groundwater Sampler is manufactured under U.S. Patent 5,612,498

1.0 OBJECTIVE

The objective of this procedure is to drive a sealed stainless steel or PVC screen to depth, deploy the screen, obtain a representative water sample from the screen interval, and grout the probe hole during abandonment. The Screen Point 16 Groundwater Sampler enables the operator to conduct abandonment grouting that meets American Society for Testing and Materials (ASTM) Method D 5299 requirements for decommissioning wells and borings for environmental activities (ASTM 1993).

2.0 BACKGROUND

2.1 Definitions

Geoprobe®: A brand name of high quality, hydraulically powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and monitoring, soil conductivity and contaminant logging, grouting, and materials injection.

Screen Point 16 (SP16) Groundwater Sampler: A direct push device consisting of a PVC or stainless steel screen that is driven to depth within a sealed, steel sheath and then deployed for the collection of representative groundwater samples. The assembled SP16 Sampler is approximately 51.5 inches (1308 mm) long with an OD of 1.625 inches (41 mm). Upon deployment, up to 41 inches (1041 mm) of screen can be exposed to the formation. The Screen Point 16 Groundwater Sampler is designed for use with 1.5-inch probe rods and machines equipped with the more powerful GH60 Hydraulic Hammer. Operators with GH40 Series hammers may chose to use this sampler in soils where driving is difficult.

Rod Grip Pull System: An attachment mounted on the hydraulic hammer of a direct push machine which makes it possible to retract the tool string with extension rods or flexible tubing protruding from the top of the probe rods. The Rod Grip Pull System includes a pull block with rod grip jaws that are bolted directly to the machine. A removable handle assembly straddles the tool string while hooking onto the pull block to effectively grip the probe rods as the hammer is raised. A separate handle assembly is required for each probe rod diameter.

2.2 Discussion

In this procedure, the assembled Screen Point 16 Groundwater Sampler (Fig. 2.1A) is threaded onto the leading end of a Geoprobe® probe rod and advanced into the subsurface with a Geoprobe® direct push machine. Additional probe rods are added incrementally and advanced until the desired sampling interval is reached. While the sampler is advanced to depth, O-ring seals at each rod joint, the drive head, and the expendable drive point provide a watertight system. This system eliminates the threat of formation fluids entering the screen before deployment and assures sample integrity.

Once at the desired sampling interval, extension rods are sent downhole until the leading rod contacts the bottom of the sampler screen. The tool string is then retracted approximately 44 inches (1118 mm) while the screen is held in place with the extension rods (Fig. 2.1B). As the tool string is retracted, the expendable point is released from the sampler sheath. The tool string and sheath may be retracted the full length of the screen or as little as a few inches if a small sampling interval is desired.

There are three types of screens that can be used in the Screen Point 16 Groundwater Sampler. Two of the these, a stainless steel screen with a standard slot size of 0.004 inches (0.10 mm) and a PVC screen with a standard slot size of 0.010 inches (0.25 mm), are recovered with the tool string after sampling. The third screen is also manufactured from PVC with a standard slot size of 0.010 inches (0.25 mm), but is designed to be left downhole when sampling is complete. This disposable screen has an exposed screen length of approximately 43 inches (1092 mm). The two screens that are recovered with the sampler both have an exposed screen length of approximately 41 inches (1041 mm).

(continued on following page)

An O-ring on the head of the stainless steel screens maintains a seal at the top of the screen. As a result, any liquid entering the sampler during screen deployment must first pass through the screen. PVC screens do not require an O-ring because the tolerance between the screen head and sampler sheath is near that of the screen slot size.

The screens are constructed such that flexible tubing, a mini-bailer, or a small-diameter bladder pump can be inserted into the screen cavity. This makes direct sampling possible from anywhere within the saturated zone. A removable plug in the lower end of the screens allows the user to grout as the sampler is extracted for further use.

Groundwater samples can be obtained in a number of ways. A common method utilizes polyethylene (TB25L) or Teflon® (TB25T) tubing and a Check Valve Assembly (GW4210). The check valve (with check ball) is attached to one end of the tubing and inserted down the casing until it is immersed in groundwater. Water is pumped through the tubing and to the ground surface by oscillating the tubing up and down.

An alternative means of collecting groundwater samples is to attach a peristaltic or vacuum pump to the tubing. This method is limited in that water can be pumped to the surface from a maximum depth of approximately 26 feet (8 m). Another technique for groundwater sampling is to use a stainless steel Mini-Bailer Assembly (GW41). The mini-bailer is lowered down the inside of the casing below the water level where it fills with water and is then retrieved from the casing.

The latest option for collecting groundwater from the SP16 sampler is to utilize a Geoprobe® MB470 Series Mechanical Bladder Pump (MBP)*. The MBP may be used to meet requirements of the low-flow sampling protocol (Puls and Barcelona 1996, ASTM 2003). Through participation in a U.S. EPA Environmental Technology Verification study, it was confirmed that the MB470 can provide representative samples (EPA 2003).

**The Mechanical Bladder Pump is manufactured under U.S. Patent No. 6,877,965 issued April 12, 2005.*

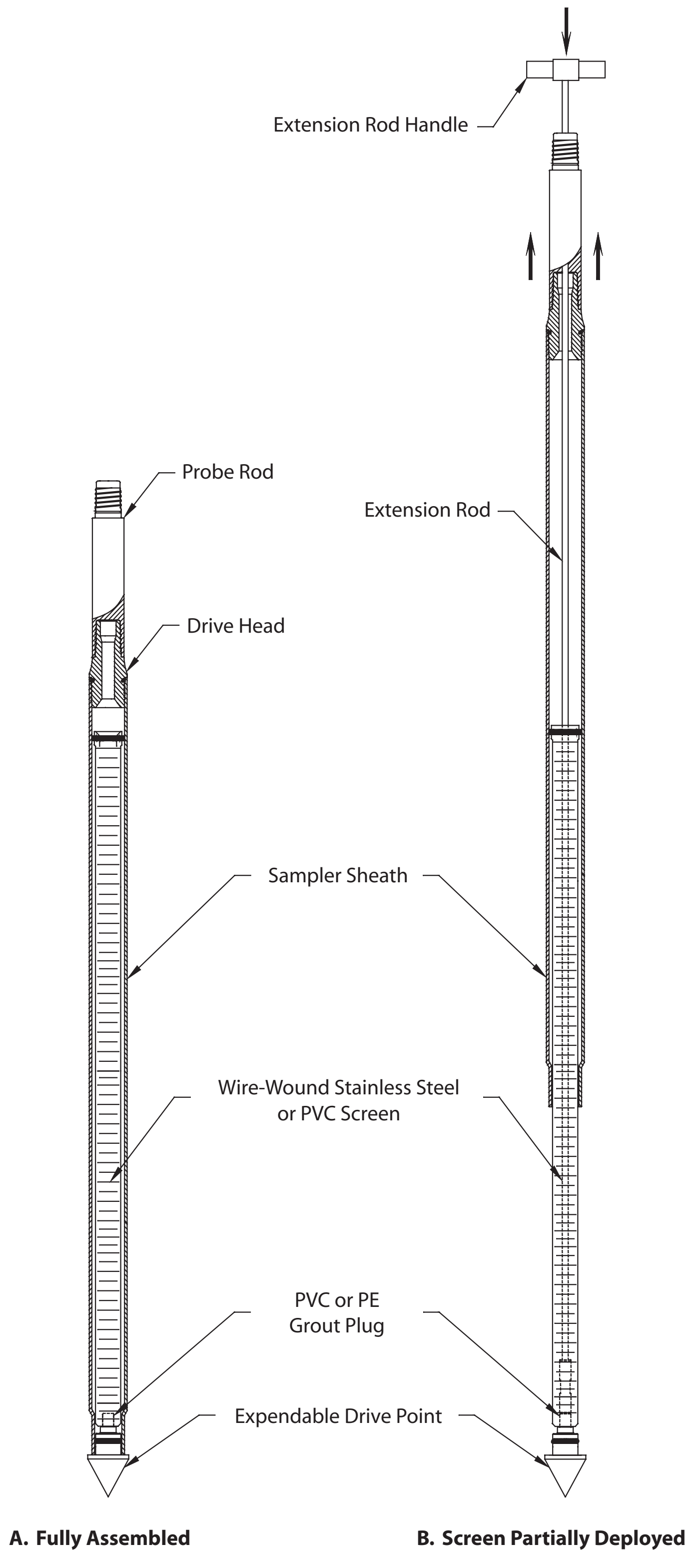


FIGURE 2.1
Screen Point 16 Groundwater Sampler

3.0 TOOLS AND EQUIPMENT

The following tools and equipment can be used to successfully recover representative groundwater samples with the Geoprobe® Screen Point 16 Groundwater Sampler. Refer to Figures 3.1 and 3.2 for identification of the specified parts. Tools are listed below for the most common SP16 / 1.5-inch probe rod configurations. Additional parts for optional rod sizes and accessories are listed in Appendix A.

SP16 Sampler Parts	**Part Number**
SP16 Sampler Sheath	15187
SP16 Drive Head, 0.5-inch bore, 1.5-inch rods*	18307
SP16 O-ring Service Kit, 1.5-inch rods *(includes 4 each of the O-ring packets below)*	15844
O-rings for Top of SP16 Drive Head, 1.5-inch rods only (Pkt. of 25)	*15389*
O-rings for Bottom of SP16 Drive Head (Pkt. of 25)	*13196*
O-rings for GW1520 Screen Head (Pkt. of 25)	*GW1520R*
O-rings for SP16 Expendable Drive Point (Pkt. of 25)	*GW1555R*
Screen, Wire-Wound Stainless Steel, 4-Slot*	GW1520
Grout Plugs, PE (Pkg. of 25)	GW1552K
Expendable Drive Points, steel, 1.625-inch OD (Pkg. of 25)*	GW1555K
Screen Point 16 Groundwater Sampler Kit, 1.5-inch Probe Rods *(includes 1 each of: 15187, 18307, 15844, GW1520, GW1535, GW1540, GW1555K, and GW1552K)*	15770

Probe Rods and Probe Rod Accessories	**Part Number**
Drive Cap, 1.5-inch probe rods, threadless, (for GH60 Hammer)	12787
Pull Cap, 1.5-inch probe rods	15090
Probe Rod, 1.5-inch x 60-inch*	11121

Extension Rods and Extension Rod Accessories	**Part Number**
Screen Push Adapter	GW1535
Grout Plug Push Adapter	GW1540
Extension Rod, 60-inch*	10073
Extension Rod Coupler	AT68
Extension Rod Handle	AT69
Extension Rod Jig	AT690
Extension Rod Quick Link Coupler, pin	AT695
Extension Rod Quick Link Coupler, box	AT696

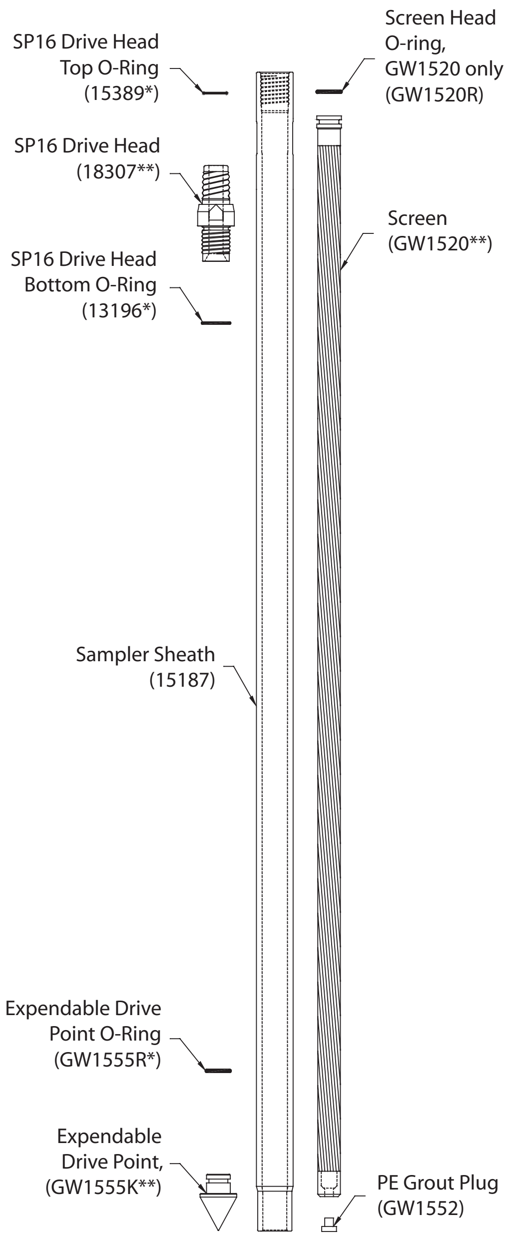
Grout Accessories	**Part Number**
Grout Nozzle, for 0.375-inch OD tubing	GW1545
High-Pressure Nylon Tubing, 0.375-inch OD / 0.25-inch ID, 100-ft. (30 m)	11633
Grout Machine, self-contained*	GS1000
Grout System Accessories Package, 1.5-inch rods	GS1015

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.375-inch OD, 500 ft.*	TB25L
Check Valve Assembly, 0.375-inch OD Tubing*	GW4210
Water Level Meter, 0.438-inch OD Probe, 100 ft. cable*	GW2000
Mechanical Bladder Pump**	MB470
Mini Bailer Assembly, stainless steel	GW41

Additional Tools	**Part Number**
Adjustable Wrench, 6.0-inch	FA200
Adjustable Wrench, 10.0-inch	FA201
Pipe Wrenches	NA

* See Appendix A for additional tooling options.

** Refer to the Standard Operating Procedure (SOP) for the Mechanical Bladder Pump (Technical Bulletin No. MK3013) for additional tooling needs.



* Included in the SP16 O-ring Service Kit (15844)
** Part numbers show most common tool configuration. See Appendix A for alternative parts.

FIGURE 3.1
SP16 Sampler Parts

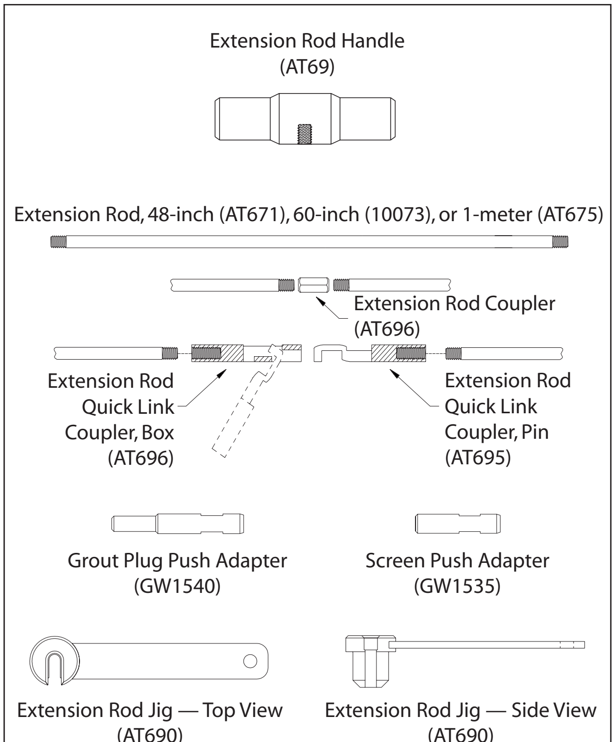


FIGURE 3.2
Geoprobe® Extension Rods and Accessories

4.0 OPERATION

4.1 Basic Operation

The SP16 sampler utilize a stainless steel or PVC screen which is encased in an alloy steel sampler sheath. An expendable drive point is placed in the lower end of the sheath while a drive head is attached to the top. O-rings on the drive head and expendable point provide a watertight sheath which keeps contaminants out of the system as the sampler is driven to depth.

Once the sampling interval is reached, extension rods equipped with a screen push adapter are inserted down the ID of the probe rods. The tool string is then retracted up to 44 inches (1118 mm) while the screen is held in place with the extension rods. The system is now ready for groundwater sampling. When sampling is complete, a removable plug in the bottom of the screen allows for grouting below the sampler as the tool string is retrieved.

4.2 Sampler Options

The Screen Point 15 and Screen Point 16 Groundwater Samplers are nearly identical. Subtle differences in the design of the SP16 sampler make it more durable than the earlier SP15 system. Operators of GH60-equipped machines should always utilize SP16 tooling. Operators of machines equipped with GH40 Series hammers may also choose SP16 tooling when sampling in difficult probing conditions.

A 1.75-inch OD Expendable Drive Point (17066K) and Disposable PVC Screen (16089) provide two useful options for the SP16 sampler. The 1.75-inch drive point may be used when soil conditions make it difficult to remove the sampler after driving to depth. The disposable PVC screen may be left downhole after sampling (when regulations permit) to eliminate the time required for screen decontamination.

4.3 Decontamination

In order to collect representative groundwater samples, all sampler parts must be thoroughly cleaned before and after each use. Scrub all metal parts using a stiff brush and a nonphosphate soap solution. Steam cleaning may be substituted for hand-washing if available. Rinse with distilled water and allow to air-dry before assembly.

4.4 SP16 Sampler Assembly (Figure 4.1)

Part numbers are listed for a standard SP16 sampler using 1.5-inch probe rods. Refer to Page 6 for screen and drive head alternatives.

1. Place an O-ring on a steel expendable drive point (GW1555K). Firmly seat the expendable point in the necked end of a sampler sheath (15187).

2. Install a PE Grout Plug (GW1552) in the bottom end of a Wire-wound Stainless Steel Screen (GW1520). Place a GW1520R O-ring in the groove on the top end of the screen.

3. Slide the screen inside of the sampler sheath with the grout plug toward the bottom of the sampler. Ensure that the expendable point was not displaced by the screen.

4. Install a bottom O-ring (13196) on a Drive Head (18307 or 15188). Thread the drive head into the sampler sheath using an adjustable wrench if necessary to ensure complete engagement of the threads. Attach a Drive Cap (12787 or 15590) to the top of the drive head.

   NOTE: The 18307 drive head should be used whenever possible as the smaller 0.5-inch ID provides a greater material cross-section for increased durability.

Sampler assembly is complete.

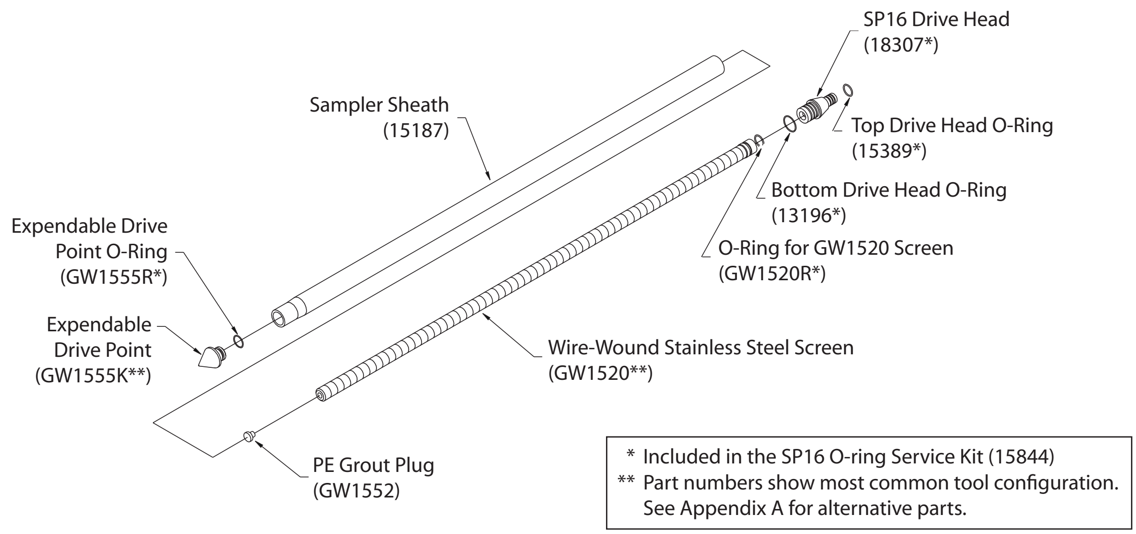


FIGURE 4.1
Screen Point 16 Groundwater Sampler Assembly

4.5 Advancing the SP16 Sampler

To provide adequate room for screen deployment with the Rod Grip Pull System, the probe derrick should be extended a little over halfway out of the carrier vehicle when positioning for operation.

1. Begin by placing the assembled sampler (Fig. 2.1.A) in the driving position beneath the hydraulic hammer of the direct push machine as shown in Figure 4.2.

2. Advance the sampler with the throttle control at slow speed for the first few feet to ensure that the sampler is aligned properly. Switch to fast speed for the remainder of the probe stroke.

3. Completely raise the hammer assembly. Remove the drive cap and place an O-ring in the top groove of the drive head. Distilled water may be used to lubricate the O-ring if needed.

Add a probe rod (length to be determined by operator) and reattach the drive cap to the rod string. Drive the sampler the entire length of the new rod with the throttle control at fast speed.

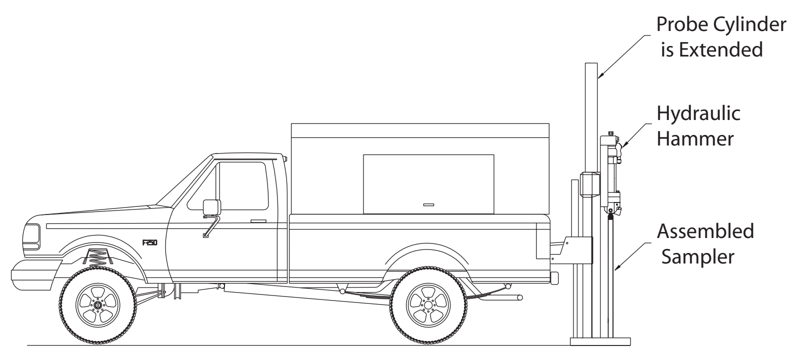


FIGURE 4.2
Screen Point 16 Groundwater Sampler in Driving Position

4. Repeat Step 3 until the desired sampling interval is reached. Approximately 12 inches (305 mm) of the last probe rod must extend above the ground surface to allow attachment of the puller assembly. A 12-inch (305 mm) rod may be added if the tool string is over-driven.

5. Remove the drive cap and retract the probe derrick away from the tool string.

4.6 Screen Deployment

1. Thread a screen push adapter (GW1535) on an extension rod of suitable length (AT671, 10073, or AT675). Attach a threaded coupler (AT68) to the other end of the extension rod. Lower the extension rod inside of the probe rod taking care not to drop it down the tool string. An extension rod jig (AT690) may be used to hold the rods.

2. Add extension rods until the adapter contacts the bottom of the screen. To speed up this step, it is recommended that Extension Rod Quick Links (AT695 and AT696) are used at every other rod joint.

3. Ensure that at least 48 inches (1219 mm) of extension rod protrudes from the probe rod. Thread an extension rod handle (AT69) on the top extension rod.

4. Maneuver the probe assembly into position for pulling.

5. Raise (pull) the tool string while physically holding the screen in place with the extension rods (Fig. 4.3.B). A slight knock with the extension rod string will help to dislodge the expendable point and start the screen moving inside the sheath.

   Raise the hammer and tool string about 44 inches (1118 cm) if using a GW1520 or GW1530 screen. At this point the screen head will contact the necked portion of the sampler sheath (Fig. 4.3.C.) and the extension rods will rise with the probe rods. Use care when deploying a PVC screen so as not to break the screen when it contacts the bottom of the sampler sheath.

   The Disposable Screen (16089) will extend completely out of the sheath if the tool string is raised more than 45 inches (1143 mm). Measure and mark this distance on the top extension rod to avoid losing the screen during deployment.

6. Remove the rod grip handle, lower the hammer assembly, and retract the probe derrick. Remove the top extension rod (with handle) and top probe rod. Finally, extract all extension rods.

7. Groundwater samples can now be collected with a mini-bailer, peristaltic or vacuum pump, tubing bottom check valve assembly, bladder pump, or other acceptable small diameter sampling device.

   When inserting tubing or a bladder pump down the rod string, ensure that it enters the screen interval. The leading end of the tubing or bladder pump will sometimes catch at the screen head giving the illusion that the bottom of the screen has been reached. An up-and-down motion combined with rotation helps move the tubing or bladder pump past the lip and into the screen.

4.7 Abandonment Grouting for GW1520 and GW1530 Screens

The SP16 Sampler can meet ASTM D 5299 requirements for abandoning environmental wells or borings when grouting is conducted properly. A removable grout plug makes it possible to deploy tubing through the bottom of GW1520 and GW1530 screens. A GS500 or GS1000 Grout Machine is then used to pump grout into the open probe hole as the sampler is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations.

1. Maneuver the probe assembly into position for pulling. Attach the rod grip puller to the top probe rod. Raise the tool string approximately 4 to 6 inches (102 to 152 cm) to allow removal of the grout plug.

2. Thread the Grout Plug Push Adapter (GW1540) onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the grout plug at the bottom of the screen. Attach the handle to the top extension rod. When the extension rods are slightly raised and lowered, a relatively soft rebound should be felt as the adapter contacts the grout plug. This is especially true when using a PVC screen.

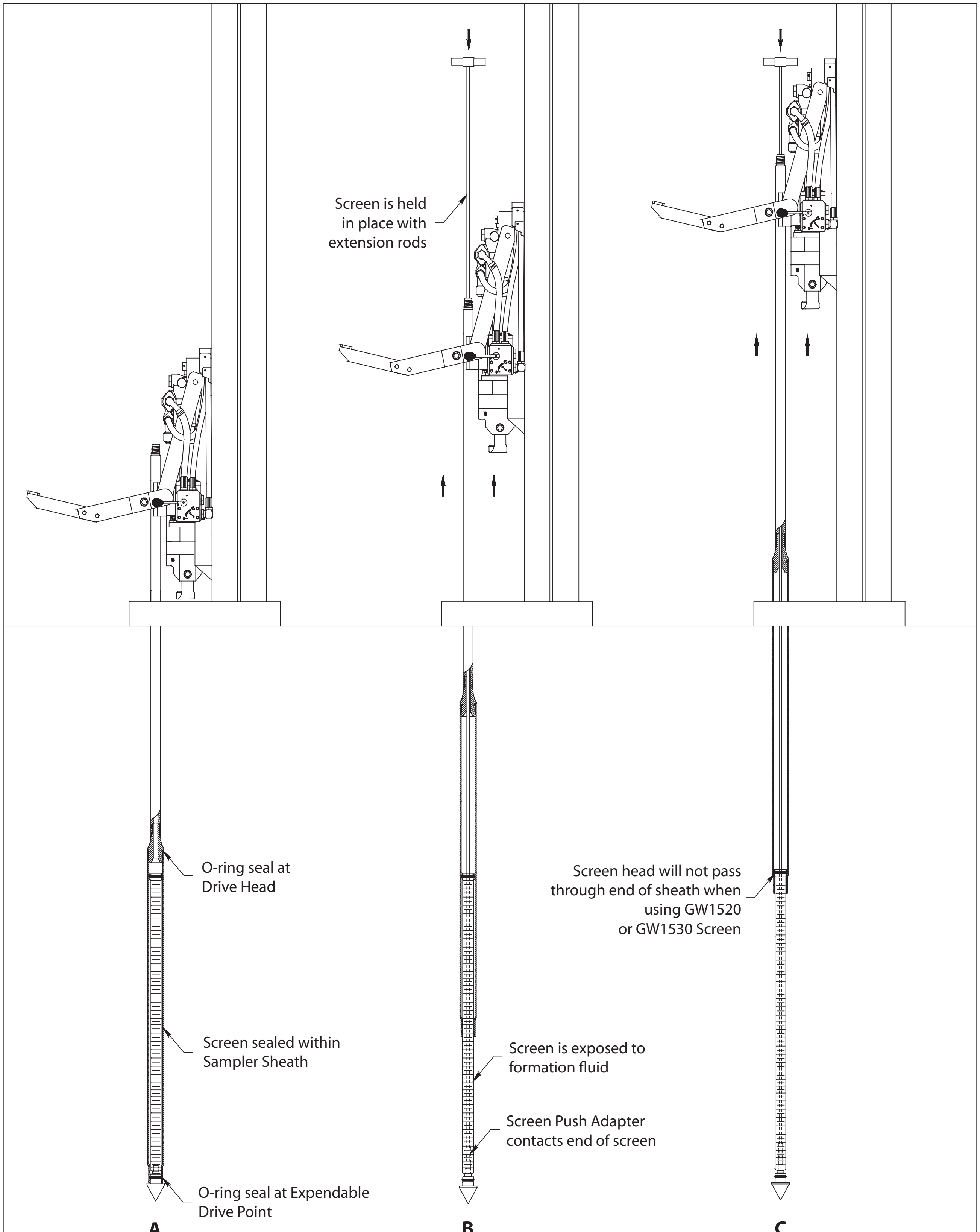


FIGURE 4.3
Screen Deployment for SP16 Sampler

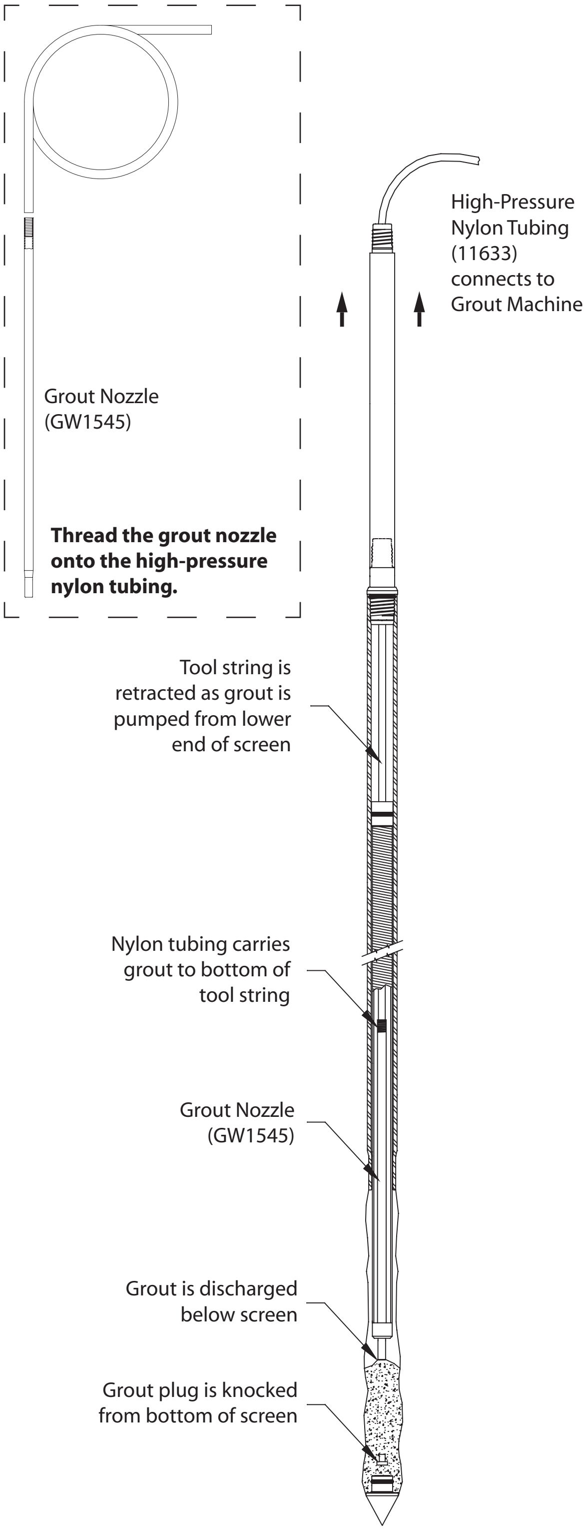


FIGURE 4.4
Grouting the SP16 Sampler With a GW1520 or GW1530 Screen

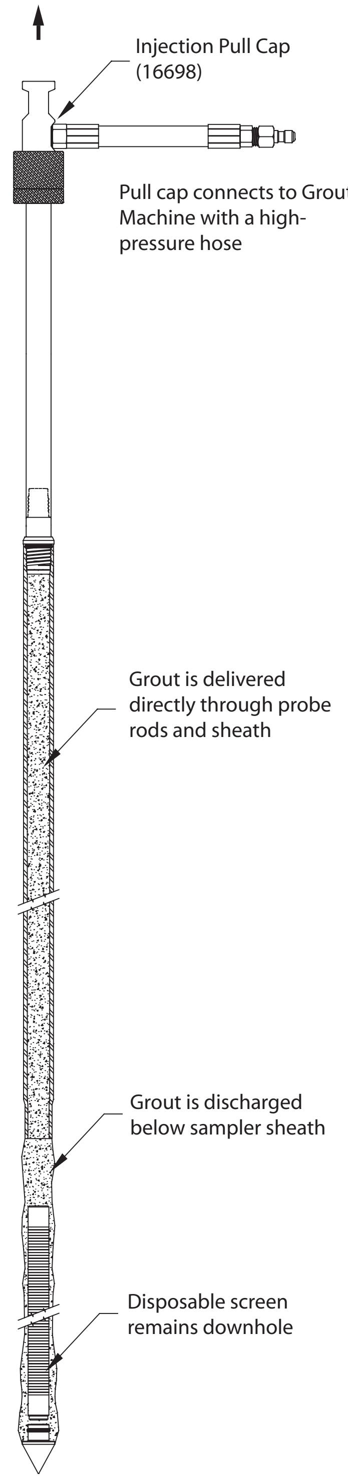


FIGURE 4.5
Grouting the SP16 Sampler With a 16089 Disposable Screen

3. Place a mark on the extension rod even with the top of the probe rod. Apply downward pressure on the extension rods and push the grout plug out of the screen. The mark placed on the extension rod should now be below the top of the probe rod. Remove all extension rods.

   Note: When working with a stainless steel screen, it may be necessary to raise and quickly lower the extension rods to jar the grout plug free. When the plug is successfully removed, a metal-on-metal sensation may be noted as the extension rods are gently "bounced" within the probe rods.

4. A Grout Nozzle (GW1545) is now connected to High-Pressure Nylon Tubing (11633) and inserted down through the probe rods to the bottom of the screen (Fig. 4.4). It may be necessary to pump a small amount of clean water through the tubing during deployment to jet out sediments that settled in the bottom of the screen. Resistance will sometimes be felt as the grout nozzle passes through the drive head. Rotate the tubing while moving it up-and-down to ensure that the nozzle has reached the bottom of the screen and is not hung up on the drive head.

   ***Note:** All probe rods remain strung on the tubing as the tool string is pulled. Provide extra tubing length to allow sufficient room to lay the rods on the ground as they are removed. An additional 20 feet is generally enough.*

5. Operate the grout pump while pulling the first rod with the rod grip pull system. Coordinate pumping and pulling rates so that grout fills the void left by the sampler. After pulling the first rod, release the rod grip handle, fully lower the hammer, and regrip the tool string. Unthread the top probe and slide it over the tubing placing it on the ground near the end of the tubing.

6. Repeat Step 5 until the sampler is retrieved. Do not bend or kink the tubing when pulling and laying out the probe rods. Sharp bends create weak spots in the tubing which may burst when pumping grout. Remember to operate the grout pump only when pulling the rod string. The probe hole is thus filled with grout from the bottom up as the rods are extracted.

7. Promptly clean all probe rods and sampler parts before the grout sets up and clogs the equipment.

4.8 Abandonment Grouting for the 16089 Disposable Screen

ASTM D 5299 requirements can also be met for the SP16 samplers when using the 16089 disposable screen. Because the screen remains downhole after sampling, the operator may choose either to deliver grout to the bottom of the tool string with nylon tubing or pump grout directly through the probe rods using an Injection Pull Cap (16698). A GS500 or GS1000 Grout Machine is needed to pump grout into the open probe hole as the sampler is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations.

1. Maneuver the probe assembly into position for pulling with the rod grip puller.

2. Thread the screen push adapter onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the bottom of the screen. Attach the handle to the top extension rod.

3. The disposable screen must be extended at least 46 inches (1168 mm) to clear the bottom of the sampler sheath. Considering the length of screen deployed in Section 4.7, determine the remaining distance required to fully extend the screen from the sheath. Mark this distance on the top extension rod.

4. Pull the tool string up to the mark on the top extension rod while holding the disposable screen in place.

   The screen is now fully deployed and the sampler is ready for abandonment grouting. Apply grout to the bottom of the tool string during retrieval using either flexible tubing (as described in Section 4.7) or an injection pull cap (Fig. 4.5). This section continues with a description of grouting with a pull cap.

5. Remove the rod grip handle and maneuver the probe assembly directly over the tool string. Thread an Injection Pull Cap (16698) onto the top probe rod and close the hammer pull latch over the top of the pull cap.

6. Connect the pull cap to a Geoprobe® grout machine using a high-pressure grout hose.

7. Operate the pump to fill the entire tool string with grout. When a sufficient volume has been pumped to fill the tool string, begin pulling the rods and sampler while continuing to operate the grout pump. Considering the known pump volume and sampler cross-section, time tooling withdrawal to slightly "overpump" grout into the subsurface. This will ensure that all voids are filled during sampler retrieval.

   The grouting process can lubricate the probe hole sufficiently to cause the tool string to slide back downhole when disconnected from the pull cap. Prevent this by withdrawing the tool string with the rod grip puller while maintaining a connection to the grout machine with the pull cap.

4.9 Retrieving the Screen Point 16 Sampler

If grouting is not required, the Screen Point 16 Sampler can be retrieved by pulling the probe rods as with most other Geoprobe® applications. The Rod Grip Pull System should be used for this process as it allows the operator to remove rods without completely releasing the tool string. This avoids having the probe rods fall back downhole when released during the pulling procedure. A standard Pull Cap (15164) may still be used if preferred. Refer to the Owner's Manual for your Geoprobe® direct push machine for specific instructions on pulling the tool string.

5.0 REFERENCES

American Society of Testing and Materials (ASTM), 2003. D6771-02 Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations. ASTM, West Conshocken, PA. (www.astm.org)

American Society of Testing and Materials (ASTM), 1993. ASTM 5299 *Standard Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.* ASTM West Conshohocken, PA. (www.astm.org)

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Geoprobe Systems®, 2006, *Model MB470 Mechanical Bladder Pump Standard Operating Procedure (SOP), Technical Bulletin No. MK3013.*

Puls, Robert W., and Michael J. Barcelona, 1996. Ground Water Issue: Low-Flow (Minimal Drawdown) Ground Water Sampling Procedures. EPA/540/S-95/504. April.

U.S. Environmental Protection Agency (EPA), 2003. Environmental Technology Verification Report: Geoprobe Inc., Mechanical Bladder Pump Model MB470. Office of Research and Development, Washington, D.C. EPA/600R-03/086. August.

Appendix A
ALTERNATIVE PARTS

The following parts are available to meet unique soil conditions. See section 3.0 for a complete listing of the common tool configurations for the Geoprobe® Screen Point 16 Groundwater Sampler.

SP16 Sampler Parts and Accessories	**Part Number**
SP16 Drive Head, 0.625-inch bore, 1.5-inch rods	15188
Expendable Drive Points, aluminum, 1.625-inch OD (Pkg. of 25)	GW1555ALK
Expendable Drive Points, steel, 1.75-inch OD (Pkg. of 25)	17066K
Screen, PVC, 10-Slot	GW1530
Screen, Disposable, PVC, 10-Slot	16089

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.25-inch OD, 500 ft.	TB17L
Polyethylene Tubing, 0.5-inch OD, 500 ft.	TB37L
Polyethylene Tubing, 0.625-inch OD, 50 ft.	TB50L
Check Valve Assembly, 0.25-inch OD Tubing	GW4240
Check Valve Assembly, 0.5-inch OD Tubing	GW4220
Check Valve Assembly, 0.625-inch OD Tubing	GW4230
Water Level Meter, 0.375-inch OD Probe, 100-ft. cable	GW2001
Water Level Meter, 0.438-inch OD Probe, 200-ft. cable	GW2002
Water Level Meter, 0.375-inch OD Probe, 200-ft. cable	GW2003
Water Level Meter, 0.438-inch OD Probe, 30-m cable	GW2005
Water Level Meter, 0.438-inch OD Probe, 60-m cable	GW2007
Water Level Meter, 0.375-inch OD Probe, 60-m cable	GE2008

Grouting Accessories	**Part Number**
Grout Machine, auxiliary-powered	GS500

Probe Rods, Extension Rods, and Accessories	**Part Number**
Probe Rod, 1.5-inch x 1-meter	17899
Probe Rod, 1.5-inch x 48-inch	13359
Drive Cap, 1.5-inch rods (for GH40 Series Hammer)	15590
Rod Grip Pull Handle, 1.5-inch Probe Rods (for GH40 Series Hammer)	GH1555
Extension Rod, 48-inch	AT671
Extension Rod, 1-meter	AT675

Equipment and tool specifications, including weights, dimensions, materials, and operating specifications included in this brochure are subject to change without notice. Where specifications are critical to your application, please consult Geoprobe Systems®.

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CATEGORY 11: SURVEYING

Section 11.1

GPS Pathfinder Systems User Guide

GPS Pathfinder® Systems

User Guide

Trimble®

Version 2.00
Revision A
Part Number 40889-10-ENG
April 2004

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– Reorient or relocate the receiving antenna.
– Increase the separation between the equipment and the receiver.
– Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
– Consult the dealer or an experienced radio/TV technician for help.

Changes and modifications not expressly approved by the manufacturer or registrant of this equipment can void your authority to operate this equipment under Federal Communications Commission rules.

Contents

CHAPTER

1

Introduction

In this chapter:

- Welcome
- About the Product
- Related Information
- Technical Assistance
- Your Comments

Welcome

Welcome to the *GPS Pathfinder Systems User Guide*. This manual describes how to use Trimble® GPS Pathfinder® Pro XR, Pro XRS, and Power receivers.

Even if you have used other Global Positioning System (GPS) products before, Trimble recommends that you spend some time reading this manual to learn about the special features of this product.

If you are not familiar with GPS, visit our website for an interactive look at Trimble and GPS at www.trimble.com

About the Product

GPS Pathfinder Pro XR, Pro XRS, and Power receivers are high-end receivers that are capable of submeter accuracy. They are capable of utilizing a range of accurate real-time correction sources and the rugged design ensures that they function effectively in all GPS conditions and all environments.

These receivers can use:

- free-to-air real-time corrections from radio beacons and satellite-based augmentation services such as Wide Area Augmentation System (WAAS) and the European Geostationary Navigation Overlay System (EGNOS)
- subscription-based satellite differential services, such as OmniSTAR
- external correction sources, such as virtual reference stations (VRS)

GPS Pathfinder Pro XR, Pro XRS, and Power receivers can easily be fitted into the custom-designed ergonomic backpack or onto your vehicle.

Related Information

Sources of related information include the following:

- Release notes – The release notes describe new features of the product, information not included in the manuals, and any changes to the manuals.
- Trimble training courses – Consider a training course to help you use your GPS system to its fullest potential. For more information, go to the Trimble website at www.trimble.com/training.html.

Technical Assistance

If you have a problem and cannot find the information you need in the product documentation, *contact your local dealer.* Alternatively, request technical support using the Trimble website at www.trimble.com/support.html

Your Comments

Your feedback about the supporting documentation helps us to improve it with each revision. E-mail your comments to ReaderFeedback@trimble.com.

CHAPTER

2

Product Overview

In this chapter:

- Introduction
- What is GPS?
- What is the GPS Pathfinder Pro XR Receiver?
- What is the GPS Pathfinder Pro XRS Receiver?
- What is the GPS Pathfinder Power Receiver?
- What Can the GPS Pathfinder Systems Receivers Do?
- Standard GPS Pathfinder Pro XR and Pro XRS Features
- Standard GPS Pathfinder Power Features
- Antenna Options

Introduction

Trimble GPS Pathfinder Systems are effective tools to collect, update, and process data. They integrate seamlessly with industry-standard GIS systems, providing you with timely, accurate data for decision-making.

They can be operated with a variety of field devices and field software to suit your workflow:

- Field device – choose a Trimble GIS TSCe™, or a Trimble Recon™, or GeoExplorer® Series handheld. Alternatively, choose a user-supplied field device.
- Software – choose Trimble TerraSync™, software for a complete solution from the field to the office and back, or Trimble GPS Pathfinder Tools SDK to build your own application that is totally customized to your needs. Alternatively, choose off-the-shelf GPS field software.

With GPS Pathfinder Systems receivers, you can use the integrated real-time differential GPS sources to provide submeter position accuracy on a second-by-second basis, or choose post-processed DGPS for even higher accuracy.

NMEA-0183 messages and raw measurements in TSIP (Trimble Standard Interface Protocol) are also available, offering optimal flexibility when interfacing with other instruments.

What is GPS?

The Global Positioning System (GPS) is a satellite-based positioning system operated by the U.S. Department of Defense (DoD). Over 24 operational NAVSTAR satellites orbit the earth every 12 hours, providing worldwide, all-weather, 24-hour time and position information.

For more information about GPS concepts, refer to the Mapping Systems General Reference at www.trimble.com/pathfindersys.html.

What is the GPS Pathfinder Pro XR Receiver?

The GPS Pathfinder Pro XR receiver includes a differential GPS receiver module and a fully automatic, dual-channel MSK beacon receiver module for receiving DGPS (Differential GPS) broadcasts conforming to the IALA (International Association of Lighthouse Authorities) standard. These components are packaged within a lightweight, rugged, weatherproof housing.

What is the GPS Pathfinder Pro XRS Receiver?

The GPS Pathfinder Pro XRS receiver is Trimble's most versatile real-time GPS mapping receiver in the GPS Pathfinder Systems family. By combining a GPS receiver, an MSK beacon differential receiver, and a satellite differential receiver in a single housing, the GPS Pathfinder Pro XRS receiver offers unsurpassed flexibility for choosing a source for real-time differential corrections. One receiver and antenna is all that is required for the flexibility of receiving GPS signals, MSK beacon differential corrections, and satellite differential corrections.

What is the GPS Pathfinder Power Receiver?

The GPS Pathfinder Power receiver combines high-performance GPS reception with real-time satellite differential capabilities in a small, lightweight, durable, waterproof housing. The unit integrates both the receiver and the antenna in the same housing, making it the most comfortable and lightweight receiver in the GPS Pathfinder Systems family.

What Can the GPS Pathfinder Systems Receivers Do?

The GPS Pathfinder Systems receivers, with Trimble controlling software, make an ideal system for all GIS data collection and maintenance projects. The system allows you to collect precise data for utility, urban, and natural resource databases. As the demand for accurate and up-to-date position and attribute information increases, the system allows you to update existing GIS data, ensuring that decisions made with the GIS are based upon the most accurate, current, and reliable data available.

The foundation of the GPS Pathfinder Systems receivers is precise GPS positioning technology. The GPS receivers feature 12 parallel channels for continuous satellite tracking. Using differential GPS, the GPS Pathfinder Systems receivers deliver differentially corrected C/A code positions to submeter accuracy on a second-by-second basis under the most challenging operating conditions.

Integrated Satellite Based Augmentation System (SBAS) receiver

Satellite Based Augmentation System (SBAS) support is integrated into the GPS Pathfinder Pro XR, Pro XRS, and Power receiver. It allows you free access to real-time solutions transmitted from geostationary SBAS satellites, such as the Wide Area Augmentation System (WAAS) in the United States and the European Geostationary Navigation Overlay Service (EGNOS) in Europe.

Integrated beacon receiver

The MSK beacon receiver is included in the GPS Pathfinder Pro XR and Pro XRS receivers. It allows you free access to real-time solutions transmitted from DGPS radiobeacons operating in the MF (medium frequency) band from 283.5 kHz to 325 kHz. The integrated MSK beacon receiver is an advanced dual-channel radiobeacon receiver. It tracks broadcasts from DGPS radiobeacons conforming to the IALA Standard. The beacon receiver uses its *all-digital signal processing* techniques to track and demodulate signals from DGPS radiobeacons.

For an up-to-date list of beacon stations, visit the following Web page:

- www.trimble.com/findbeacon.asp

Integrated satellite differential receiver

The integrated satellite differential capability of the GPS Pathfinder Pro XRS and Power receivers decodes and uses satellite differential corrections to provide submeter position accuracy. To receive and decode these satellite signals, you must subscribe to a satellite differential correction service. The GPS Pathfinder Pro XRS and Power receivers support the OmniSTAR satellite differential correction services. For information on obtaining a subscription, subscription rates, and satellite coverage maps, visit www.omnistar.com

Once you have a subscription, you activate the service through an on-the-air signal or an encrypted activation message entered into the controlling software.

Satellite differential signals provide valid corrections over a large area. Integrated virtual reference/base station (VRS/VBS) technology permits the satellite corrections to be uniformly accurate over the entire satellite coverage area, without the degradation in accuracy associated with increasing distance from fixed reference stations.

Satellite differential signals are line-of-sight and can be blocked by mountains, buildings, or tree canopy. Wet canopy, from a heavy rain, reduces the signals even more. The same environmental factors that affect the GPS signal, such as radar and microwave transmitters, can interfere with the satellite signal. Power lines usually have no effect.

External differential correction receiver

The GPS Pathfinder Systems receivers can also receive differential corrections from any external differential correction receiver that communicates in the standard RTCM SC-104 data format.

Standard GPS Pathfinder Pro XR and Pro XRS Features

The GPS Pathfinder Pro XR and Pro XRS receivers offer the following:

- 12-channel DGPS receiver with EVEREST™ multipath rejection technology, L1 C/A code tracking with carrier-phase smoothing, and instantaneous full-wavelength carrier-phase measurements.
- Submeter accuracy – Typically horizontal accuracy less than 50 cm RMS with GPS Pathfinder Office software postprocessing. This requires data to be collected with a minimum of 4 satellites, maximum PDOP of 6, minimum SNR of 4, minimum elevation of 15 degrees, and reasonable multipath conditions.
- Integrated WAAS/EGNOS differential corrections
- 1 Hz position and velocity update rate.
- Velocity computations incorporate carrier-phase data.
- Time to First Fix typically less than 30 seconds.
- Two RS-232 serial ports.
- NMEA-0183 output to external NMEA devices (supported messages are ALM, GGA, GLL, GSA, GSV, VTG, and ZDA).
- RTCM-SC 104 input from an external differential correction receiver.
- TSIP protocol to/from the field device.
- Fully automatic and manual beacon operating modes, fast acquisition of differential beacon signals.

- Immunity to MSK jamming signals, advanced techniques for combating atmospheric noise in the beacon receiver.
- Integrated GPS/MSK beacon antenna.
- User-upgradeable receiver firmware.
- Receiver manual.
- CE Mark compliance.

Additional GPS Pathfinder Pro XRS receiver features

The GPS Pathfinder Pro XRS GPS/MSK/beacon/satellite differential receiver offers the items previously listed, and also:

- Integrated L-band satellite differential correction receiver
- Combined L1 GPS/beacon/satellite differential antenna

Standard GPS Pathfinder Power Features

The GPS Pathfinder Power receiver offers the following standard features:

- Integrated 12-channel L1 GPS receiver/antenna with EVEREST multipath rejection technology, C/A code tracking with carrier-phase smoothing, and full-wavelength carrier-phase measurements.
- Submeter accuracy – Typically horizontal accuracy less than 1 m RMS with GPS Pathfinder Office software postprocessing. This requires data to be collected with a minimum of 4 satellites, maximum PDOP of 6, minimum SNR of 4, minimum elevation of 15 degrees, and reasonable multipath conditions.
- Integrated WAAS/EGNOS differential corrections
- 1 Hz position and velocity update.
- Velocity computations incorporate carrier-phase data.
- Time to First Fix typically less than 30 seconds.

- Two RS-232 serial ports.
- NMEA-0183 output to external NMEA devices (supported messages are ALM, GGA, GLL, GSA, GSV, VTG, and ZDA).
- RTCM-SC 104 input from an external differential correction receiver, for example the Beacon-on-a-Belt (BoB™) receiver.
- TSIP Protocol to or from the field device.
- Integrated L-band satellite differential correction receiver.
- Integrated L1 GPS/satellite differential antenna—this active antenna filters out unwanted signals and amplifies the L1 GPS and satellite differential signals.
- User-upgradeable receiver firmware.
- Receiver manual.
- CE Mark compliance.

Antenna Options

There are three antenna options for the GPS Pathfinder Systems receivers:

This antenna …	is used with this receiver …	See …
Integrated GPS/MSK beacon antenna	GPS Pathfinder Pro XR	page 12
Combined L1 GPS/beacon/ satellite differential antenna	GPS Pathfinder Pro XRS	page 14
Integrated L1 GPS/satellite differential antenna	GPS Pathfinder Power	page 15

Integrated GPS/MSK beacon antenna

The GPS Pathfinder Pro XR receiver integrated GPS/MSK beacon antenna (P/N 29653-00) features two antenna components:

- L1 GPS antenna

This active antenna is designed to filter out unwanted signals and amplify the L1 GPS signal for transmission over the antenna cable to the receiver.

- MSK H-field loop beacon antenna

  This antenna features a pre-amplifier for filtering out signal interference such as AM radio broadcasts and noise from switching power supplies. After filtering, the pre-amplifier amplifies the MF signal for transmission over the same antenna cable to the beacon receiver.

The coaxial antenna cable also carries DC power to the pre-amplifier of both the L1 GPS and beacon antennas over the center conductor of the cable.

The L1 GPS antenna and a beacon antenna are integrated into a single antenna assembly, as shown in Figure 2.1. The antenna assembly is completely weatherproof and is designed to withstand harsh environmental conditions.

Figure 2.1 Integrated GPS/MSK beacon antenna (for the GPS Pathfinder Pro XR receiver)

Combined L1 GPS/beacon/satellite differential antenna

The GPS Pathfinder Pro XRS receiver integrated L1 GPS/beacon/satellite differential antenna (P/N 33580-50) features two antenna components:

- L1 GPS/satellite differential antenna

  This active antenna is designed to filter out unwanted signals and amplify the L1 GPS and satellite differential signals for transmission over the antenna cable to the receiver.
- MSK H-field loop beacon antenna

  This antenna features a pre-amplifier for filtering out signal interference such as AM radio broadcasts and noise from switching power supplies. After filtering, the pre-amplifier amplifies the MF signal for transmission over the same antenna cable to the beacon receiver.

The coaxial antenna cable also carries DC power to the pre-amplifier of both the L1 GPS/satellite differential and beacon antennas over the center conductor of the cable.

The antenna assembly integrates the L1 GPS/satellite differential antenna and a beacon antenna into a single antenna assembly, as shown in Figure 2.2. The antenna assembly is completely weatherproof and is designed to withstand harsh environmental conditions.

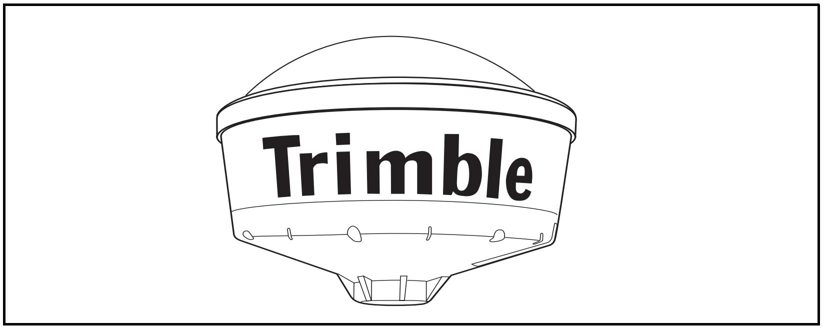


Figure 2.2 Combined L1 GPS/beacon/satellite differential antenna (for the GPS Pathfinder Pro XRS receiver)

Integrated L1 GPS/satellite differential antenna

The GPS Pathfinder Power receiver’s integrated L1 GPS/satellite differential antenna shares its housing with the GPS receiver. The active antenna filters out unwanted signals and amplifies the L1 GPS and satellite differential signals.

The combined GPS receiver and integrated L1 GPS/satellite differential antenna assembly (P/N 38198-50) is shown in Figure 2.3. It is completely weatherproof and is designed to withstand harsh environmental conditions.

Figure 2.3 Integrated L1 GPS/satellite differential antenna (for the GPS Pathfinder Power receiver)

CHAPTER

3

Accuracy

In this chapter:

Introduction

The GPS Pathfinder Systems receivers calculate very accurate GPS positions on a second-by-second basis. After postprocessed differential correction, the horizontal accuracy of each position for the GPS Pathfinder Pro XR and Pro XRS receivers is better than 50 cm (RMS) + 1 part per million (ppm) times the distance between the base and the rover. For the GPS Pathfinder Power receiver, the horizontal accuracy is submeter (RMS) + 1 ppm. Using real-time corrections, each position can be as accurate as submeter with the GPS Pathfinder Systems, but is subject to a number of operational conditions.

***Note –** RMS means that approximately 63% of the positions are within the specified value.*

Differential GPS Positioning Techniques

Differential GPS (DGPS) requires two or more receivers. One receiver, called the reference station, is located at a known point to determine the GPS measurement errors and compute corrections to these errors. An unlimited number of mobile GPS Pathfinder Systems receivers, commonly called *rovers*, collect GPS data at unknown locations within the vicinity of the reference station. Errors common at both the reference and rover receivers are corrected with DGPS either in real time or during postprocessing.

***Note –** For more information about GPS and DGPS, review the All About GPS tutorial on the Trimble website at www.trimble.com.*

The GPS Pathfinder Systems receivers, in combination with Trimble controlling software and the GPS Pathfinder Office software, provide three ways of obtaining submeter positions:

- Real-time DGPS
- Postprocessed DGPS
- Postprocessed real-time DGPS

The accuracy figures given in the sections below are obtained under the following conditions:

- Number of satellites used: ≥ 4
- PDOP: ≤ 6
- Signal-to-noise ratio: ≥ 4
- Satellite elevation mask: ≥ 15°
- Reference station receiver is a Trimble GPS Pathfinder Pro XL, Pro XR, Pro XRS, 4700, 4800, 5700, 5800, 4600 LS™, Series 4000 GPS receiver, DSM™, Reference Station, or equivalent.
- Synchronized measurements are logged at the reference station.
- The logging interval for the roving receiver is the same as, or a multiple of, the logging interval at the reference station.
- The reference station uses the correct antenna.

Real-Time DGPS

When using real-time DGPS, the reference station broadcasts the correction values to the rovers within coverage range, through a transmitter such as a radiobeacon (beacon DGPS) or a satellite (satellite DGPS). The rover applies the corrections to its position in real time.

The positions calculated by the GPS Pathfinder Systems receivers using real-time DGPS are of submeter accuracy + 1 ppm. If you use a provider of real-time DGPS that uses VRS/VBS techniques, there is no degradation associated with distance from the reference station, and the accuracy always stays at the submeter level (RMS).

GPS Pathfinder Systems also supports corrections from satellite-based augmentation systems (SBAS) such as WAAS and EGNOS.

For information on postprocessing GPS data collected with real-time DGPS, see Postprocessed real-time DGPS, page 20.

Postprocessed DGPS

When real-time DGPS is not available, or is available only part of the time, you have to postprocess the autonomous GPS data in your rover file to obtain the stated accuracy. When using postprocessed DGPS, the reference station stores the correction values in base data files on a computer.

Many reference station owners provide their base data to the community through the Internet or other means of communication. Often this means that you do not have to set up your own reference station for postprocessed DGPS, but can use an existing one. For a list of available reference stations, visit the Trimble website www.trimble.com/trs/findtrs.asp.

Postprocessed real-time DGPS

Postprocessed DGPS positions are generally more accurate than DGPS positions obtained in real time. If you collect SuperCorrect records as well as GPS positions using Trimble TerraSync or GPScorrect™ software, or applications developed using the GPS Pathfinder Tools SDK, you can use the SuperCorrect option in the GPS Pathfinder Office software to process the data if the accuracy of the real-time DGPS positions is not sufficient, provided that you have access to suitable reference station base files.

The accuracy using postprocessed real-time DGPS is the same as for postprocessed DGPS (see the previous section).

Factors Affecting Postprocessed DGPS Accuracy

The accuracy that you obtain after data collection depends on several factors, including:

- Number of visible satellites
- Multipath
- Distance between reference station and rover receivers

- Position Dilution of Precision (PDOP)
- Signal-to-noise ratio (SNR)
- Satellite elevations
- Occupation time at a point
- Receiver type at reference station
- Accuracy of the reference station position
- Synchronized measurements are logged at the reference station.
- The logging interval for the roving receiver is the same as, or a multiple of, the logging interval at the reference station.
- The reference station uses the correct antenna.

Number of visible satellites

Generally, you need a minimum of four satellites to get a good position. If you have five or more satellites, accuracy increases by a small amount. You can obtain positions from only three satellites by supplying a height value manually. However, Trimble recommends that you do not use this method, as an inaccurate height can significantly reduce horizontal accuracy.

Note – *The TerraSync software always uses a minimum of four satellites. You cannot configure this setting.*

When the number of visible satellites drops below the required number, the controlling software stops logging positions and displays the message Too few satellites.

Multipath

GPS signals are sometimes reflected off nearby objects, particularly metallic objects, creating false or erroneous results. This phenomenon is known as *multipath*. Severe multipath may cause position errors of many meters, while mild multipath may cause small, undetectable errors. For optimal accuracy, collect data in an environment that is free of large reflective surfaces, such as buildings and trees. EVEREST multipath reduction technology in the receiver helps reduce the effects of multipath.

Distance between reference station and rover

When you postprocess GPS Pathfinder Pro XR and Pro XRS data using the GPS Pathfinder Office software Differential Correction utility, the horizontal accuracy of the positions received is 50 cm (RMS) at a 1 km base line (distance from reference station). For the GPS Power receiver, the horizontal accuracy of the positions received is submeter (RMS) at a 1 km base line.

Accuracy degrades by 1 ppm as the distance between the reference station and the rover increases. This means that 1 mm of degradation occurs for every kilometer between the reference station and the rover. For example, you must collect data within 500 km (310 miles) of your reference station to obtain submeter accuracy for the GPS Pathfinder Pro XR and Pro XRS receiver.

PDOP

PDOP (Position Dilution of Precision) is a unitless measure of the current satellite geometry. It indicates when the most accurate results are provided. When satellites are spread around the sky, the PDOP value is low, and the computed position is more accurate. When the satellites are grouped closely together, the PDOP value is high, and the computed position is less accurate. The lower the PDOP value, the more accurate the GPS positions.

You can configure the PDOP mask so that if the PDOP exceeds the mask value, the controlling software stops logging positions. A PDOP mask of 6 is required for submeter accuracy.

SNR

SNR (signal-to-noise ratio) is a measure of the satellite signal strength relative to the background noise. A strong signal with low noise provides better accuracy. You can raise the SNR mask so that weak signals with an SNR below the mask are excluded from the position computation. In areas of dense canopy, the SNR mask can be lowered so that you can collect GPS positions, although you may not achieve submeter accuracy. For best results, the recommended setting for the SNR mask is 4.

Elevation mask

When a satellite is low on the horizon, the GPS signals must travel further through the atmosphere, delaying reception by the receiver. To minimize noisy data, adjust the elevation mask. Satellites below the mask are excluded from the position computation. For best results, the recommended setting is 15°.

Occupation period

The GPS Pathfinder Systems receivers achieve the specified horizontal accuracy with a one-second occupation time.

Note – *To achieve higher levels of accuracy using a GPS Pathfinder Systems receiver, collect carrier-phase data and postprocess using the GPS Pathfinder Office software.*

Receiver type

The following Trimble receiver models use Maxwell™ technology and, when used as the reference station, yield submeter accuracy with GPS Pathfinder Systems receivers:

- GPS Pathfinder Pro XRS
- GPS Pathfinder Pro XR
- GPS Pathfinder Pro XL

- 5800 GPS receiver
- 5700 GPS receiver
- 4800 GPS receiver
- 4700 GPS receiver
- 4600 LS Surveyor
- 4000 series receiver
- DSM Reference Station

Warning – If the GPS receiver at the reference station has fewer than 12 channels, you may be unable to differentially correct some of your data. If the reference station is not capable of logging data from all of the satellites the rover is using, the data collected by the rover cannot be differentially corrected using postprocessing.

Accuracy of the reference station position

Any inaccuracy in the reference station position is reflected in your rover position accuracy. For information on the accuracy of your local DGPS reference station coordinates, contact the provider of that service, and check the Integrity Index in the GPS Pathfinder Office version 3.00 Differential Correction utility when selecting a new base station provider.

The Integrity Index provides you with an indication as to the quality of available base data in comparison to other available sources. Poor base data can result from a number of factors, such as an incorrect reference position, bad environmental location, or a large distance between the base and rover receivers. Base data downloaded from each station is analyzed to formulate the quality indicator values and three key measures are taken into account:

- Bias (the measure of distance between an averaged GPS position and a specified reference position)
- Precision (the measure of the spread of actual GPS positions)
- The distance between the base and rover receivers

Use the Integrity Index to avoid selecting base data that may provide an inferior differential correction result. The quality indicator has a range of 0 to 100, where 0 represents low quality base data and 100 represents high quality base data. For more information, refer to the GPS Pathfinder Office 3.00 Differential Correction Help.

Synchronized measurements

To obtain optimal accuracy from differential correction, the reference station must record reference data (or output differential corrections) from synchronized measurements. Synchronized measurements occur when the reference station receiver and rover receivers simultaneously make measurements to all the satellites they are tracking.

When you use one of the receivers listed in Receiver type, page 23, as a reference station receiver, the data is always synchronized. When measurements are not synchronized, there is no equivalent reference station position measured at exactly the same time as the rover position. A simultaneous reference station position must be interpolated, which reduces accuracy.

Logging intervals

Ideally, the logging interval at the reference station should be the same as the logging interval at the rover. For example, if the reference station is using a 5-second logging interval, the rover logging interval should be 5 seconds. The rover logging interval can also be a direct integer multiple of the interval at the reference station. For example, if the reference station is logging every 5 seconds, the rover can log every 10 seconds.

If the rover logging interval is not synchronized with the reference station, the accuracy of the GPS positions logged by the rover may not be submeter. This is because the reference station measurements must be interpolated to correct the roving receiver’s measurements. For more information, see Synchronized measurements, page 25.

If the synchronized measurement logging interval at the reference is 1 second, you can use any logging interval at the rover. However, this generates a large file at the reference station. If the computer or data collector at the reference station runs out of space, you cannot differentially correct any rover data collected after the base file ends.

When disk space is at a premium, the best option is a 5-second logging interval for synchronized measurement data at the reference station and a 5-second logging interval for positions at the rover. This is frequent enough to be practical at the rover and uses the default reference station logging interval, which results in base files that are not too large.

Table 3.1 gives examples of various reference station and rover intervals and their effect on accuracy. They are valid for both postprocessed and real-time corrections.

Table 3.1 Logging Interval Accuracy

Reference station interval (seconds)	Rover interval (seconds)	Base data interpolated?	Notes
1	1	No	Recommended for best accuracy.
5	5	No	Recommended if reference station disk space is at a premium.
1	3, or 5, or 6, etc.	No	The rover interval is a direct integer multiple of the reference station interval.
5	10	No	The rover interval is a direct integer multiple of the reference station interval.
5	1	Yes	Base data is interpolated at seconds 1, 2, 3, and 4. A slight degradation of accuracy occurs with interpolation. One in five of the rover positions is not interpolated.

Factors Affecting Real-Time DGPS Accuracy

Real-time DGPS offers similar accuracies to postprocessed GPS. However, in addition to the factors discussed in Factors Affecting Postprocessed DGPS Accuracy, page 20, there are other factors that affect the accuracy of real-time DGPS positions. These factors include:

- Update rate of the corrections
- Corrections based on a different datum

Update rate of the corrections

The frequency, or rate, at which the RTCM differential correction messages are output from the reference station affects the accuracy of the GPS positions recorded by the roving receiver. The latency of the corrections (that is, the time it takes for up-to-date information to get from the reference station to the rover) also affects the rover position accuracy.

Datum of corrections

Errors can occur if the reference stations use a datum other than WGS-84 as the basis for the DGPS corrections. The error introduced by using a reference station that transmits coordinates using a different datum is generally quite small. However, in some places the margin of error can be 5–10 meters. To avoid this type of error, set Trimble controlling software to collect SuperCorrect data. You can then postprocess the real-time DGPS positions if required.

CHAPTER

4

Real-Time DGPS Components

In this chapter:

Introduction

The GPS Pathfinder Systems receivers have integrated real-time DGPS, making it simple for you to collect or maintain your GPS data in real time. This chapter introduces the advanced operating characteristics of the MSK beacon component of the GPS Pathfinder Pro XR and Pro XRS receivers. It outlines how to activate a satellite differential component of the GPS Pathfinder Pro XRS and Power receivers. It also explains how Satellite Based Augmentation Systems (SBAS) are used by GPS Pathfinder Systems receivers.

GPS Pathfinder Pro XR and Pro XRS Beacon Components

The International Association of Lighthouse Authorities (IALA) has established a standard for modulating DGPS corrections in the RTCM SC-104 format on marine radiobeacon broadcasts using minimum shift keying (MSK) modulation.

The differential beacons are a subset of the large number of existing marine radiobeacons, which operate in the 283.5 to 325 kHz band. The MSK beacon component of the GPS Pathfinder Pro XR and Pro XRS receivers is a radiobeacon receiver that tracks and demodulates differential beacon broadcasts conforming to the IALA standard.

Real-Time DGPS Beacon Components

Real-time DGPS beacons require the following three components for a complete system architecture (see Figure 4.1):

- DGPS reference station
- Broadcast site
- GPS/MSK beacon equipment

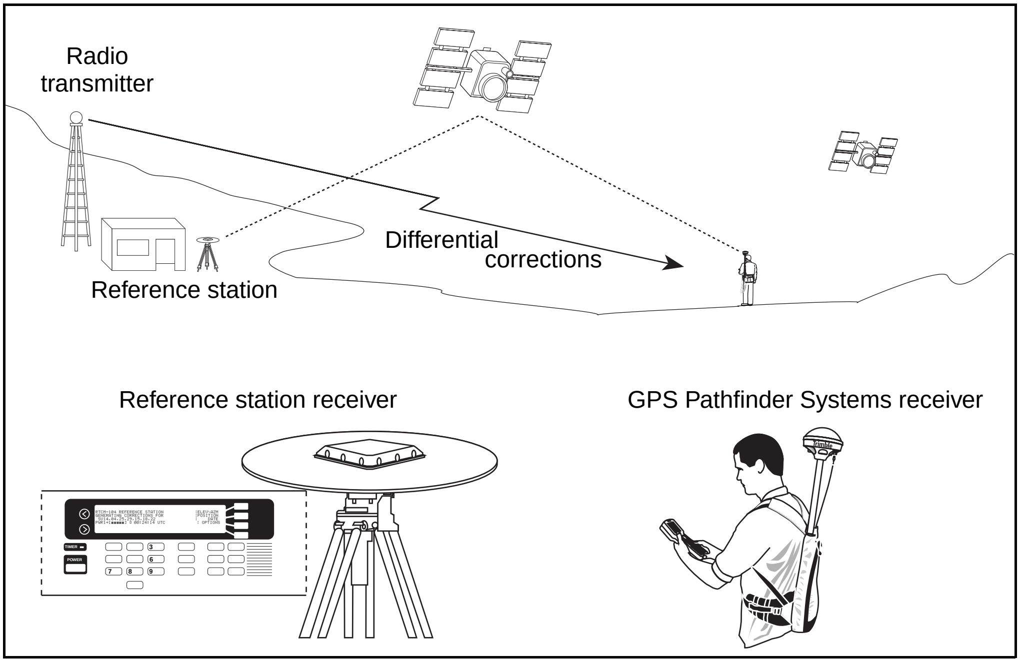


Figure 4.1 Components of a DGPS system

DGPS reference station

DGPS relies on GPS error corrections calculated by a reference station placed at a precisely known location. The reference station measures the ranges to each satellite and calculates the magnitude and rate of change of error in each measurement based on its known location.

Broadcast site

A broadcast site is a radio beacon transmitting correction data in the 283.5 to 325 kHz band. The GPS error corrections from the reference station are modulated on the radio beacon broadcast using minimum shift keying (MSK) modulation.

GPS/MSK beacon equipment

The MSK beacon component of the GPS Pathfinder Pro XR and Pro XRS receivers tracks and demodulates the DGPS broadcasts from differential beacons, and outputs the DGPS corrections to the GPS component in the industry standard RTCM SC-104 format. The GPS component of the GPS Pathfinder Pro XR and Pro XRS receivers applies the DGPS corrections output from the MSK beacon component to achieve accurate position and velocity measurements.

Advanced DGPS System Components

In addition to the three DGPS components listed in Real-Time DGPS Beacon Components, page 30, a DGPS service can have advanced components:

- Integrity monitor
- Control station

Integrity monitor

An integrity monitor is a precisely located GPS receiver and MSK beacon receiver that applies differential corrections. The differentially corrected position is compared to its known location to determine if the corrections broadcast from the reference station are within the preset tolerance.

Control station

Some DGPS services maintain centralized control sites to administer the DGPS service elements.

MSK Beacon Receiver Signal Processing

MSK signal processing is broken down into five stages:

- MSK pre-filtering
- MSK automatic gain control
- MSK analog-to-digital conversion
- MSK digital signal processing
- MSK I/O processing

MSK pre-filtering

The MSK pre-filter rejects additional interference in the MF signal that was not attenuated by the pre-amplifier filter or was picked up by the antenna cable.

MSK automatic gain control

This stage automatically amplifies the filtered MF signal to an optimal level for the analog-to-digital conversion stage.

MSK analog-to-digital conversion

The analog MF signals are converted into digital signals for the digital signal processing stage. Unlike most other receivers, the MSK receiver uses a wide-band conversion. This technique improves acquisition performance by allowing a broader range of beacon signals to pass to the signal processing stage for evaluation. The wide-band technique also improves signal processing by eliminating the need for dedicated mixing stages that can generate non-linearities in the frequencies of interest.

In addition, the wide-band analog-to-digital conversion enables the use of special digital noise reduction techniques for handling impulse noise. This permits a highly adaptable and optimized response to impulse noise such as lightning.

MSK digital signal processing

Controlled by proprietary processing algorithms, the MSK digital signal processor (DSP) digitally filters the wide-band sample, selects the best beacon signal, and passes the selected signal through a matched filter to the I/O processor. In addition, the DSP measures signal level, noise level, and frequency offset.

During the signal acquisition process, the DSP employs a 128-point FFT (Fast Fourier Transform) algorithm for evaluating the spectral content of the digitized signal. The FFT algorithm orders the beacon signals by relative strength. By filtering and squaring the signals before the FFT stage, the MSK modulation rate and the transmitter versus receiver frequency offset for a particular beacon may be determined. This signal processing technique permits rapid acquisition of the most powerful MSK signal and automatic identification of the modulation rate.

In tracking mode, the DSP rejects out-of-channel interference by selectively filtering the desired MSK signal. This technique allows the MSK receiver to track a weak differential beacon in the presence of much stronger signals from other radiobeacons. The DSP applies dual, low-noise, second-order, phase-locked loops for tracking the MSK carrier phase and symbol phase. The DSP coherently demodulates the MSK signal using a MSK matched filter. The matched filter offers optimal performance in a Gaussian noise environment. In addition, the DSP employs a proprietary noise cancellation technique for combating impulse noise.

MSK I/O processing

The MSK I/O processor monitors the integrity of the data signal from the DSP, formats the RTCM SC-104 data messages, and outputs the data.

Worldwide DGPS Beacon Coverage

For an up-to-date list of beacon stations around the world, refer to the following Web page:

- www.trimble.com/findbeacon.asp

Activating the OmniSTAR Satellite Differential Service

To activate the OmniSTAR satellite differential service, do the following:

1. Prepare the GPS Pathfinder Pro XRS or Power receiver:
   - Connect the controlling software to the receiver and begin tracking GPS satellites with a clear view of the sky.
   - Follow the directions in the software's user documentation to obtain the OmniSTAR ID for the receiver. Write the ID down.
2. Call OmniSTAR and give them:
   - your location (for example, Sunnyvale, California, USA)
   - the OmniSTAR ID that you obtained from the controlling software

   OmniSTAR gives you:
   - the OmniSTAR satellite and frequency for your local area
   - a 24-digit activation code

Note – *For phone numbers and further details on how to access the Fugro-OmniSTAR service, refer to the OmniSTAR booklet that accompanies your GPS Pathfinder Systems receiver, or visit the OmniSTAR website at www.omnistar.com.*

3. Follow the directions in the controlling software's user documentation to configure the receiver, so that it is ready to receive corrections from your regional OmniSTAR satellite.

Warning – Make sure that you enter the 24-digit code correctly. Typographic errors prevent successful activation.

4. Wait up to 45 minutes for the activation process to complete.

Note – *If the activation process does not complete within 45 minutes, call Fugro-OmniSTAR and report your problem.*

Note – *The 45 minute wait period is for activation only. Once activated, OmniSTAR corrections begin less than 10 seconds after configuring the receiver to receive them.*

Satellite Based Augmentation Systems (SBAS)

Satellite Based Augmentation Systems (SBAS) such as the Wide Area Augmentation System (WAAS) and the European Geostationary Navigation Overlay System (EGNOS), consist of networks of ground reference stations and a number of geostationary satellites. They broadcast signals in the GPS band providing free-to-air differential correction services that increase the reliability, integrity and precision of GPS signals.

WAAS was created by the Federal Aviation Administration (FAA) as a free-to-air differential correction service for the aviation industry in the United States. For more information, refer to the Wide Area Augmentation System (WAAS) FAQ at www.trimble.com/geoxt.html.

EGNOS is a joint project of the European Space Agency (ESA), the European Commission (EC), and Eurocontrol, the European Organization for the Safety of Air Navigation. EGNOS is the European equivalent of WAAS in the USA.

The GPS Pathfinder Systems receivers track WAAS satellites between 30^{o} West and 180^{o} West, and track EGNOS satellites between 30^{o} West and 90^{o} East.

GPS Pathfinder Office software reports EGNOS-corrected positions as WAAS-corrected positions.

CHAPTER

5

Equipment

In this chapter:

- Introduction
- GPS Pathfinder Pro XR and Pro XRS Front Panel
- GPS Pathfinder Pro XR and Pro XRS Back Panel
- GPS Pathfinder Power Housing
- GPS Pathfinder Pro XR Cabling
- GPS Pathfinder Pro XRS Cabling
- GPS Pathfinder Power Cabling
- Backpack
- Optional Range Poles and Tripods
- Optional Vehicle Kit

Introduction

This chapter outlines the various components of the GPS Pathfinder Systems receivers and shows how to connect your receiver and field device to create a mapping system.

GPS Pathfinder Pro XR and Pro XRS Front Panel

The GPS Pathfinder Pro XR and Pro XRS receiver front panel, shown in Figure 5.1, is mounted in a weatherproof housing.

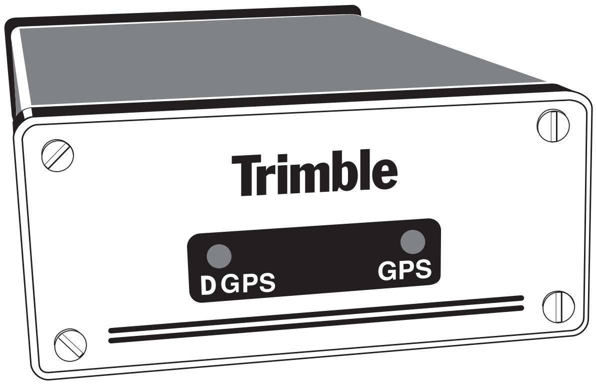


Figure 5.1 GPS Pathfinder Pro XR and Pro XRS front panel

Status lights

The two status lights on the front panel of the GPS Pathfinder Pro XR and Pro XRS receivers provide the status information listed in Table 5.1.

Table 5.1 GPS Pathfinder Pro XR and Pro XRS Status Lights

	GPS	DGPS
Off	Unit not powered up	Unit not powered up, or DGPS function is disabled
Flashing Yellow	Tracking satellites	Searching for DGPS signals from MSK radio beacon, SBAS (WAAS/EGNOS) satellite, or external real-time source
Flashing Green		Searching for DGPS signals from satellite differential provider (Not applicable for Pro XR receiver)
Solid Yellow	Performing position fixes using autonomous GPS	Differential corrections are being received from MSK radio beacon, SBAS (WAAS/EGNOS) satellite, or external real-time source
Solid Green	Performing position fixes using differential GPS	Differential corrections are being received from satellite differential provider (Not applicable for Pro XR receiver)

GPS Pathfinder Pro XR and Pro XRS Back Panel

The GPS Pathfinder Pro XR and Pro XRS receivers have two serial communications (RS232) ports and an antenna cable port. The serial communications ports, shown in Figure 5.2, are 12-pin male bulkhead connectors located on the back panel of the receiver.

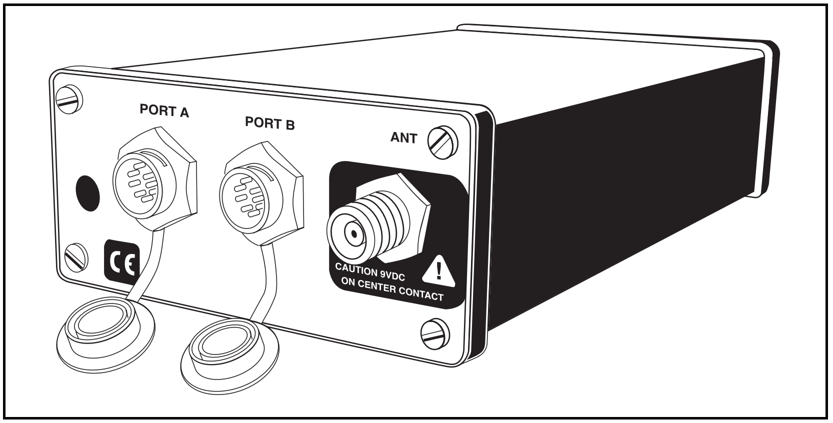


Figure 5.2 GPS Pathfinder Pro XR and Pro XRS receiver back panel

Port A

Port A offers RS-232 communication standards. It is designed for NMEA-0183 output and RTCM input.

Port B

Port B also offers RS-232 communication standards. It is designed for two-way data flow, external sensor input, and power.

Antenna port

The antenna connector is a TNC female connector located on the far right on the back panel of the GPS Pathfinder Pro XR and Pro XRS receiver.

GPS Pathfinder Power Housing

Figure 5.3 shows the GPS Pathfinder Power receiver mounted in its weatherproof housing.

Figure 5.3 GPS Pathfinder Power housing

The GPS Pathfinder Power receiver has one physical port, as shown in Figure 5.4. This port combines two RS-232 serial communications ports (Port A and Port B), one 1 PPS port, and power input.

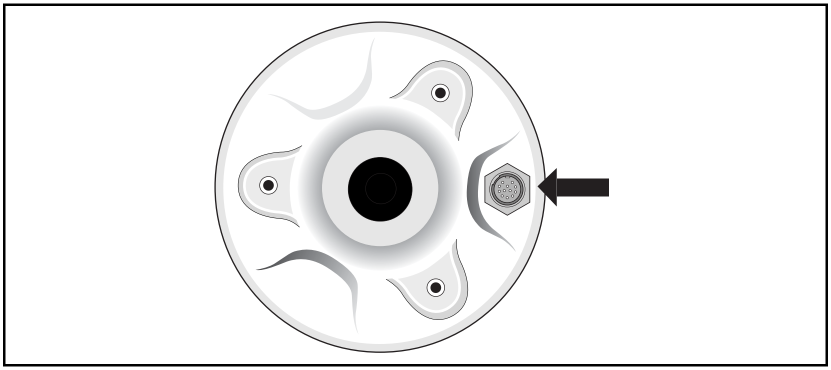


Figure 5.4 GPS Pathfinder Power port

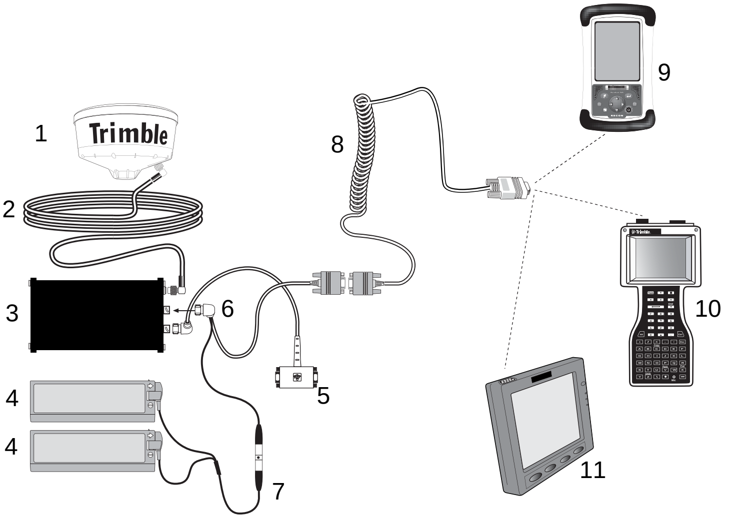
The port is a 12-pin male bulkhead connector:

- Port A is set by default to output NMEA-0183 messages and receive RTCM SC-104 correction data. The port can also be setup to communicate Trimble’s format TSIP (Trimble Standard Interface Protocol).
- Port B is set by default to input and output TSIP messages.

You do not need to connect an antenna cable to this receiver, because the antenna and receiver are built into and connected within the same housing. For pinout information for the port, see Appendix B, Specifications.

GPS Pathfinder Pro XR Cabling

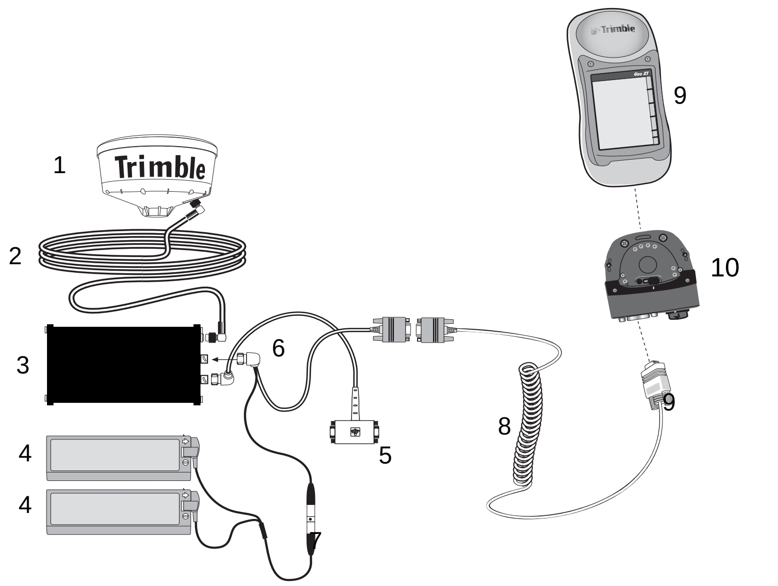
To use a GPS Pathfinder Pro XR receiver with a TSCe or Trimble Recon handheld, or a field device with standard serial port, connect the system as shown in Figure 5.5.



1	P/N 29653-00	Integrated GPS/beacon antenna
2	P/N 22628	Antenna cable
3	P/N 46090-11	12-channel Pro XR receiver
4	P/N 17466	Camcorder batteries
5	P/N 30232-00	NMEA/RTCM cable
6	P/N 30231-00	Data/power cable
7	P/N 24333	Dual battery cable
8	P/N 45052	GPS Pathfinder field device cable
9	P/N 49675-20	Trimble Recon handheld
10	P/N 45268-50	TSCe field device
11	Field device with standard serial port	

Figure 5.5 GPS Pathfinder Pro XR receiver / field device connection diagram

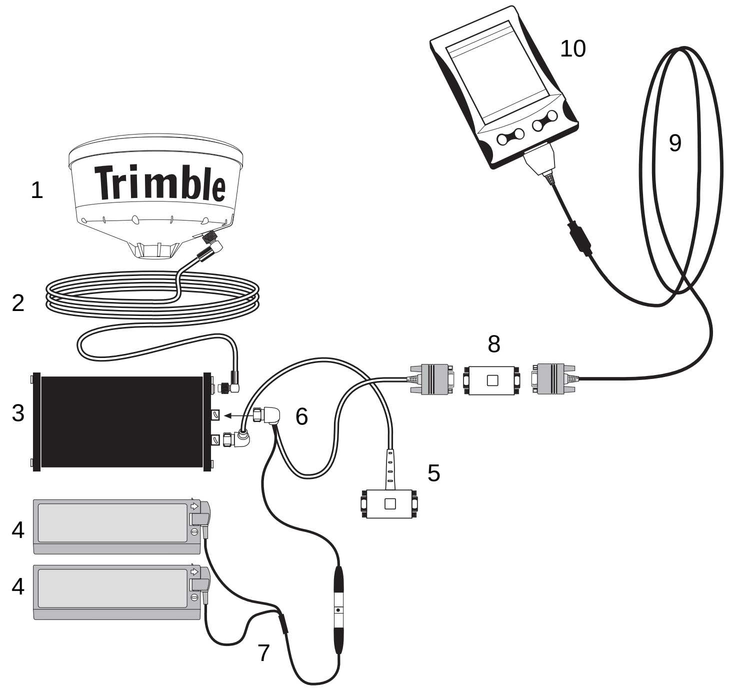
To use a GPS Pathfinder Pro XR receiver with a Trimble GeoXT or GeoXM, connect the system as shown in Figure 5.6.



1	P/N29653-00	Integrated GPS/beacon antenna
2	P/N 22628	Antenna cable
3	P/N 46090-11	12-channel Pro XR receiver
4	P/N 17466	Camcorder batteries
5	P/N 30232-00	NMEA/RTCM cable
6	P/N 30231-00	Data/power cable
7	P/N 24333	Dual battery cable
8	P/N 45052	GPS Pathfinder field device data cable
9	P/N 49050-xx	GeoXT/GeoXM field device
10	P/N 46509-00	GeoExplorer Series serial clip

Figure 5.6 GPS Pathfinder Pro XR receiver / GeoXT and GeoXM connection diagram

To use a GPS Pathfinder Pro XR receiver with a field device that has a customized serial port, connect the system as shown in Figure 5.7.

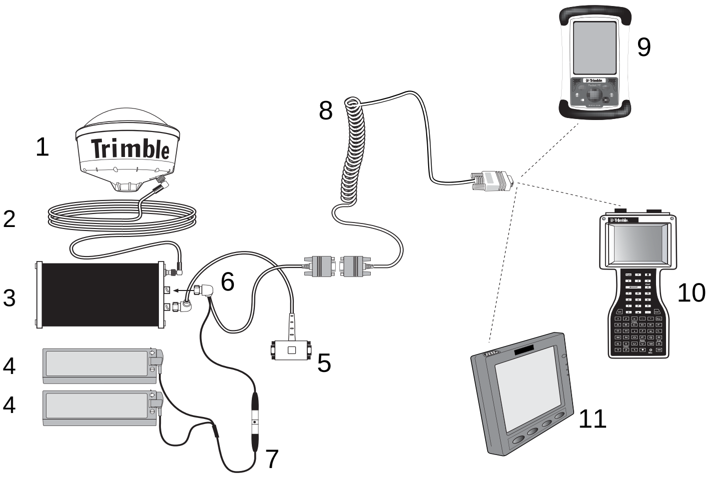


1	P/N 29653-00	Integrated GPS/beacon antenna
2	P/N 22628	Antenna cable
3	P/N 46090-11	12-channel Pro XR receiver
4	P/N 17466	Camcorder batteries
5	P/N 30232-00	NMEA/RTCM cable
6	P/N 30231-00	Data/power cable
7	P/N 24333	Dual battery cable
8	P/N 43197	Null modem adapter
9	Custom data cable	
10	Field device with custom serial port	

Figure 5.7 GPS Pathfinder Pro XR receiver / field device with custom serial port connection diagram

GPS Pathfinder Pro XRS Cabling

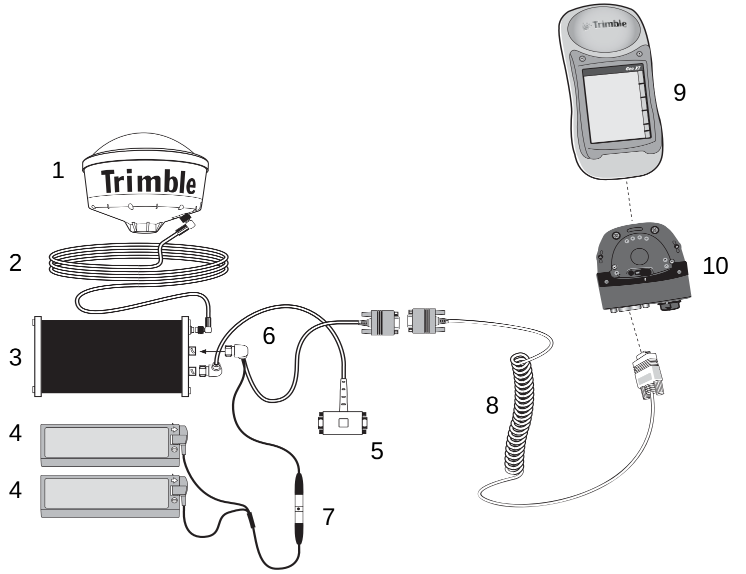
To use a GPS Pathfinder Pro XRS receiver with a TSCe or Trimble Recon handheld or a field device with standard serial port, connect the system as shown in Figure 5.8.



1	P/N 33580-50	Combined L1 GPS/MSK beacon/ satellite differential antenna
2	P/N 22628	Antenna cable
3	P/N 33302-53	12-channel Pro XRS receiver
4	P/N 17466	Camcorder batteries
5	P/N 30232-00	NMEA/RTCM cable
6	P/N 30231-00	Data/power cable
7	P/N 24333	Dual battery cable
8	P/N 45052	GPS Pathfinder field device cable
9	P/N 49675-20	Trimble Recon handheld
10	P/N 45268-50	TSCe field device
11	Field device with standard serial port	

Figure 5.8 GPS Pathfinder Pro XRS receiver / field device connection diagram

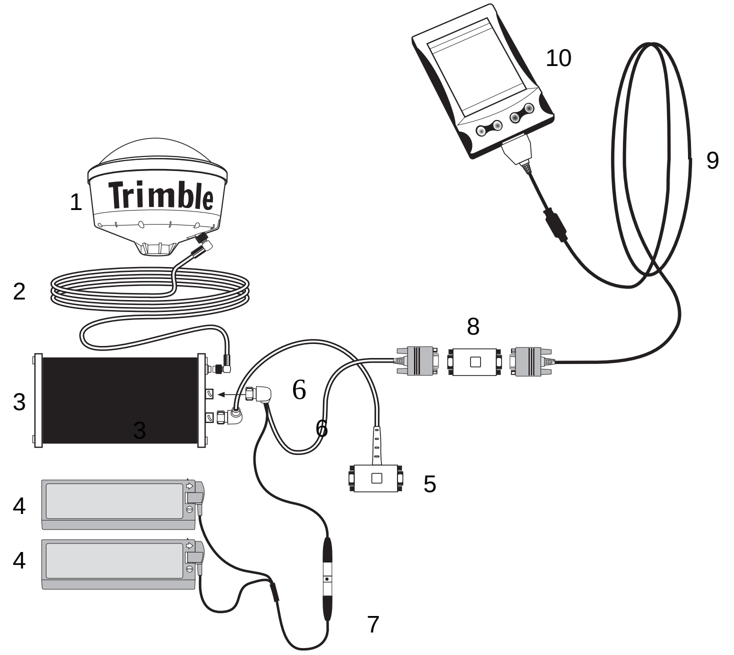
To use a GPS Pathfinder Pro XRS receiver with a Trimble GeoXT or GeoXM, connect the system as shown in Figure 5.9.



1	P/N 33580-50	Combined L1 GPS/MSK beacon/ satellite differential antenna
2	P/N 22628	Antenna cable
3	P/N 33302-53	12-channel Pro XRS receiver
4	P/N 17466	Camcorder batteries
5	P/N 30232-00	NMEA/RTCM cable
6	P/N 30231-00	Data/power cable
7	P/N 24333	Dual battery cable
8	P/N 45052	GPS Pathfinder field device data cable
9	P/N 49050-xx	GeoXT/GeoXM field device
10	P/N 46509-00	GeoExplorer Series serial clip

Figure 5.9 GPS Pathfinder Pro XRS receiver / GeoXT and GeoXM connection diagram

To use a GPS Pathfinder Pro XRS receiver with a field device that has a customized serial port, connect the system as shown in Figure 5.10.

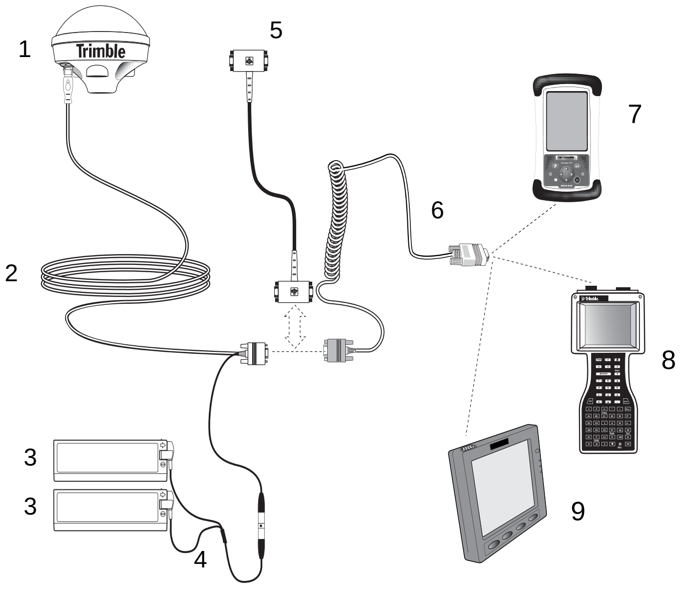


1	P/N 33580-50	Combined L1 GPS/MSK beacon/ satellite differential antenna
2	P/N 22628	Antenna cable
3	P/N 33302-53	12-channel GPS Pro XRS receiver
4	P/N 17466	Camcorder batteries
5	P/N 30232-00	NMEA/RTCM cable
6	P/N 30231-00	Data/power cable
7	P/N 24333	Dual battery cable
8	P/N 43197	Null modem adapter
9	Custom data cable	
10	Field device with custom serial port	

Figure 5.10 GPS Pathfinder Pro XRS receiver / field device with custom serial port connection diagram

GPS Pathfinder Power Cabling

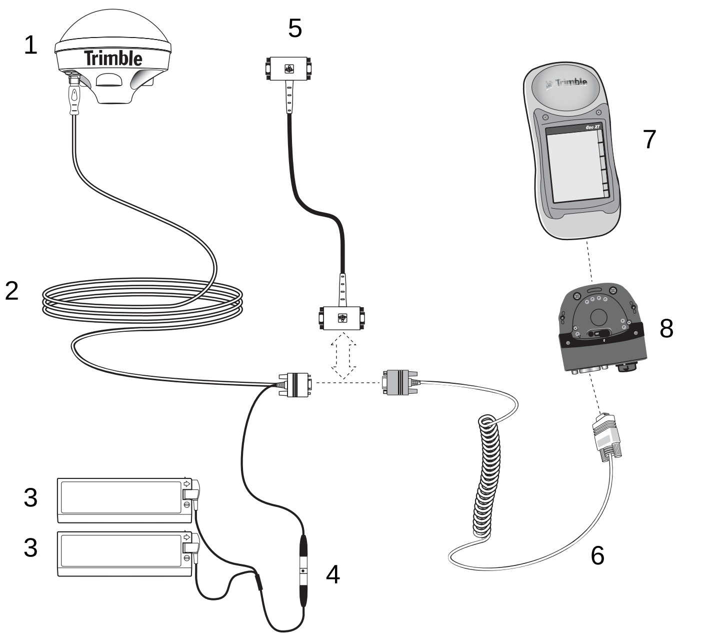
To use a GPS Pathfinder Power receiver with a TSCe or Trimble Recon handheld, or a field device with standard serial port, connect the system as shown in Figure 5.11. Use the RTCM/NMEA cable (P/N 40887-00) only if you need to cable in RTCM corrections and/or output NMEA data from the receiver.



1	P/N 29653-00	Integrated GPS/beacon antenna
2	P/N 22628	Antenna cable
3	P/N 17466	Camcorder batteries
4	P/N 24333	Dual battery cable
5	P/N 40887-00	RTCM/NMEA cable
6	P/N 45052	GPS Pathfinder field device cable
7	P/N 49675-50	Trimble Recon handheld
8	P/N 45268-50	TSCe field device
9	Field device with standard serial port	

Figure 5.11 GPS Pathfinder Power receiver / field device connection diagram

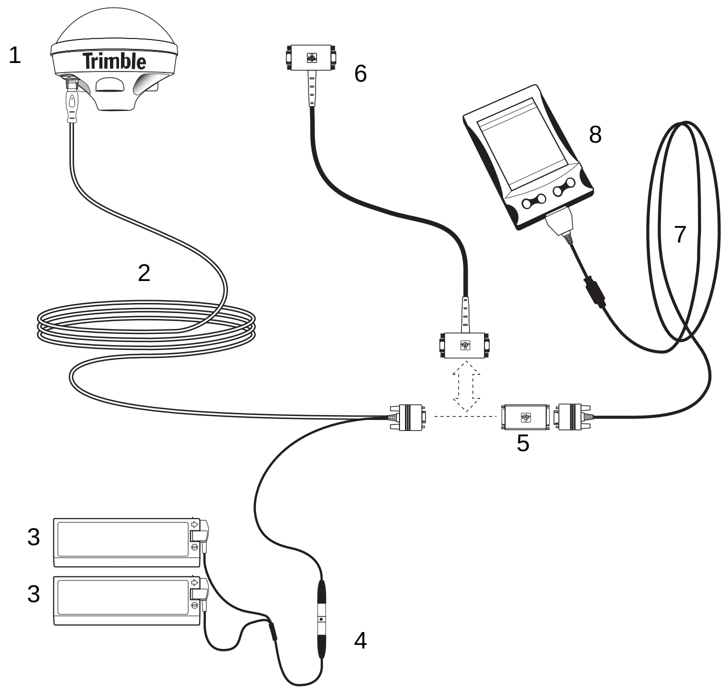
To use a GPS Pathfinder Power receiver with a Trimble GeoXT or GeoXM, connect the system as shown in Figure 5.12



1	P/N 38198-50	GPS Pathfinder Power receiver
2	P/N 40492-00	Data/power cable
3	P/N 17466	Camcorder batteries
4	P/N 24333	Dual battery cable
5	P/N 40887-00	RTCM/NMEA cable
6	P/N 45052	GPS Pathfinder Power field device data cable
7	P/N 49050-xx	GeoXT/GeoXM field device
8	P/N 46509-00	GeoExplorer Series serial clip

Figure 5.12 GPS Pathfinder Power receiver /GeoXT and GeoXM connection diagram

To use a GPS Pathfinder Power receiver with a field device that has a customized serial port, connect the system as shown in Figure 5.13. Use the RTCM/NMEA cable (P/N 40887-00) only if you need to cable in RTCM corrections and/or output NMEA data from the receiver.



1	P/N 38198-50	GPS Pathfinder Power receiver
2	P/N 40492-00	Data/power cable
3	P/N 17466	Camcorder batteries
4	P/N 24333	Dual battery cable
5	P/N 43197	Null modem adapter
6	P/N 40887-00	RTCM/NMEA cable
7	Custom data cable	
8	Field device with custom serial port	

Figure 5.13 GPS Pathfinder Power receiver / field device with custom serial port connection diagram

Backpack

An ergonomic backpack is included with each GPS Pathfinder Systems receiver. Use this comfortable backpack to carry the receiver/antenna, batteries, and field device.

Loading GPS Pathfinder Pro XR and Pro XRS equipment into the backpack

Figure 5.14 illustrates the features inside the backpack.

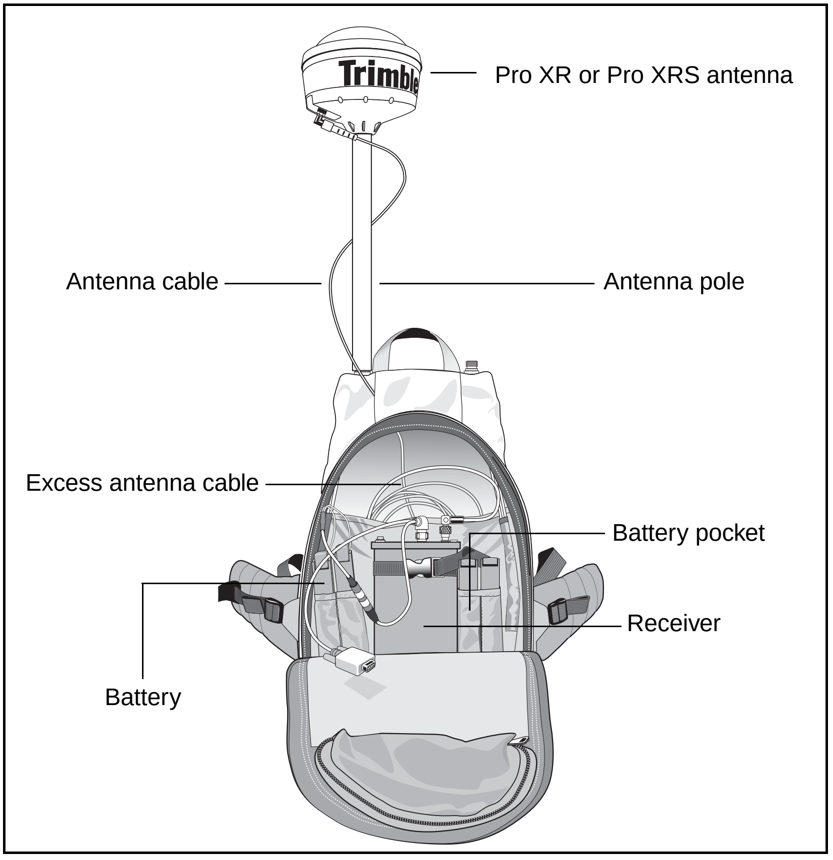


Figure 5.14 GPS Pathfinder Pro XR and Pro XRS receiver in the backpack

To load the GPS equipment into the backpack, open the backpack and follow these steps:

1. Place the Pathfinder Pro XR or Pro XRS receiver in the center of the backpack, between the battery pockets. Position it with the back panel face up and clip the receiver in place with the retaining straps.
2. Attach the data/power cable (P/N 30231-00) to receiver Port B.
3. Place two (or four, if needed) fully charged batteries in the backpack. One battery goes in each of the battery pockets, with the connector clips facing up, towards the front.
4. Clip the battery cable (P/N 24333) to two batteries and connect the 3-pin connector to the data/power cable.

   The other two batteries act as spares if required.
5. Screw the antenna pole(s) onto one of the antenna mounts.

   The poles need to be high enough for the Pathfinder Pro XR or Pro XRS antenna to be above your head.
6. Install the Pathfinder Pro XR or Pro XRS antenna on top of the antenna pole.
7. Attach the antenna cable (P/N 22628) to the port labeled “Ant” on the receiver.
8. Thread the other end of the antenna cable through the antenna cable outlets and attach it to the antenna.
9. Place the excess antenna cable in the device pocket.
10. From the outside of the backpack, insert the DE9 connector of the field device data cable through the data cable outlet.
11. Connect the DE9 connector on the receiver data/power cable (P/N 30231-00) to the DE9 connector on the field device data cable.

    For more information, see GPS Pathfinder Pro XR Cabling, page 43, or GPS Pathfinder Pro XRS Cabling, page 46.

12. Pull the data cable through the cable retainer loops on the side of the backpack.
13. Connect the field device cable to the field device.
14. Close all compartments.

Loading GPS Pathfinder Power Equipment into the backpack

Figure 5.15 illustrates the features inside the backpack.

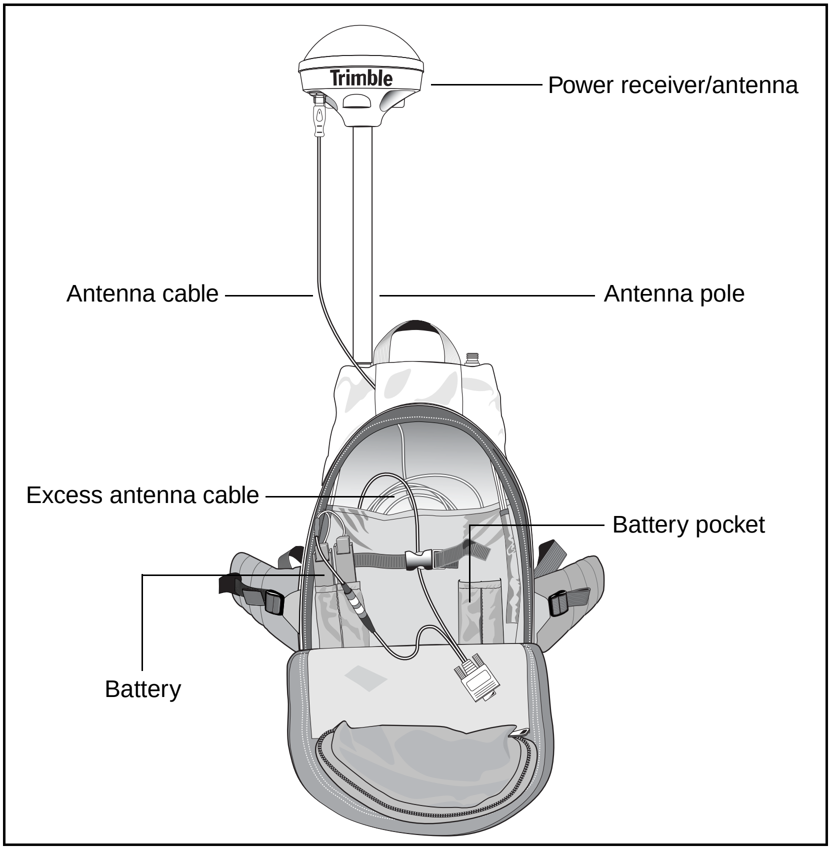


Figure 5.15 GPS Pathfinder Power receiver in the backpack

To load the GPS equipment into the backpack, open the backpack and follow these steps:

1. Place two fully charged batteries in the backpack. One battery goes in each of the battery pockets, with the connector clips facing up, towards the front.
2. Connect the battery cable (P/N 24333) to the two batteries in the battery pockets.
3. Screw the antenna pole(s) onto one of the antenna mounts.

   The poles need to be high enough for the GPS Pathfinder Power receiver to be above your head.
4. Install the GPS Pathfinder Power receiver on top of the antenna pole.
5. From the outside of the backpack, insert the DE9 connector of the field device data cable through the data cable outlet.
6. Pull the cable through the data cable strain relief retainer and pull it tight.
7. Place the receiver data/power cable (P/N 40492-00) in the sleeve pocket.
8. Pull its bulkhead cable connector out of the backpack through one of the antenna cable outlets.
9. Connect the bulkhead connector to the GPS Pathfinder Power receiver on top of the pole.
10. Connect the TA3 connector on the receiver data/power cable to battery cable (P/N 24333). Place the excess cable in the sleeve pocket.
11. Connect the DE9 connector on the receiver data/power cable (P/N 40492-00) to the DE9 connector on the field device data cable.

    For more information, see GPS Pathfinder Power Cabling, page 49.

Alternatively, if you need to use the RTCM/NMEA cable (P/N 40887-00), follow these steps instead:

– Connect the DE9 connector on the receiver data/power cable (P/N 40492-00) to the DE9 connector on the RTCM/NMEA cable (P/N 40887-00) labeled “To Receiver”.

– Connect the DE9 connector on the RTCM/NMEA cable labeled “To Data Logger” to the DE9 connector on the field device data cable.

  For more information, see GPS Pathfinder Power Cabling, page 49.

– If required, connect the port of the RTCM/NMEA cable labeled “RTCM In” to the external differential correction receiver.

– If required, connect the port of the RTCM/NMEA cable labeled “Data Out” to the device requiring NMEA.

12. Pull the data cable through the cable retainer loops on the side of the backpack.
13. Connect the field device cable to the field device.
14. Close all compartments.

Fitting the backpack

Figure 5.16 illustrates the front and back views of the backpack.

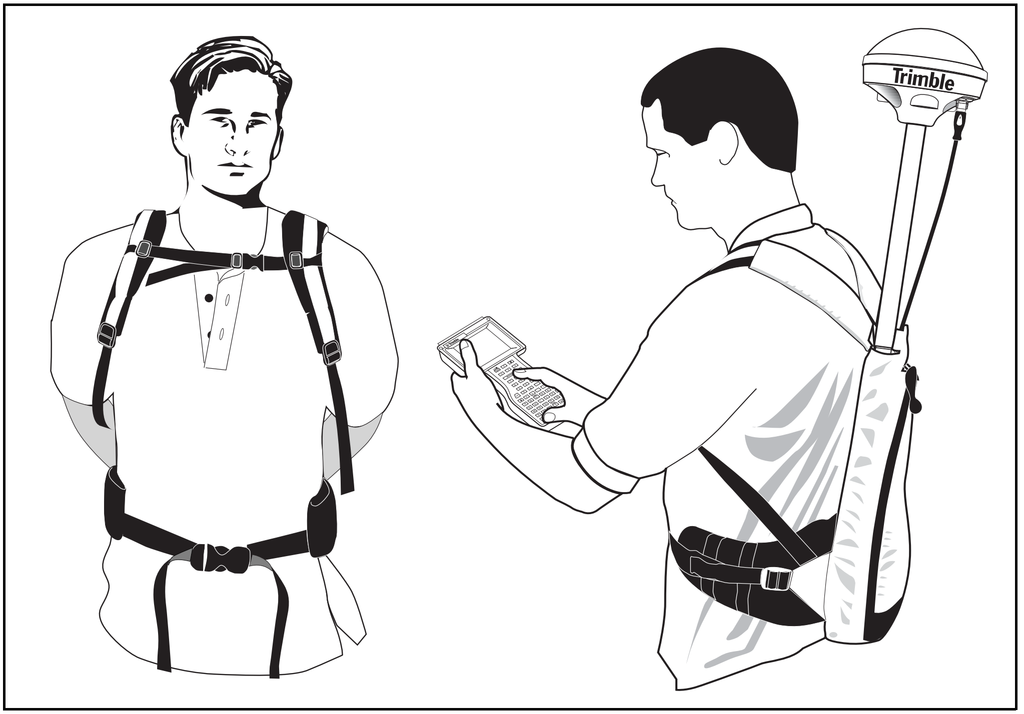


Figure 5.16 Backpack adjustment front and back views

It is important that the Trimble backpack fits you for maximum comfort and efficiency. To optimize the fit of the backpack:

1. Load the GPS equipment into the backpack (see Loading GPS Pathfinder Pro XR and Pro XRS equipment into the backpack, page 52, or Loading GPS Pathfinder Power Equipment into the backpack, page 54).
2. Loosen the hip belt, the stabilizer straps, and the shoulder straps.

3. Position the hip belt so that the top of the belt is at the same height as the top of your hip bone.
4. Tighten the hip belt until it is firmly around your hip.
5. Tighten the shoulder pads by pulling down on the shoulder pad adjustment straps.

   The straps should be firm but not cutting in under your arm.
6. Adjust the height of your chest strap to be positioned just below your collarbones.

   The chest strap helps to keep your backpack in the right place on your body and is also used to fine-tune the shoulder straps to the most comfortable position.

Note – *The harness is designed to follow your movements rather than resist them. However, you may want to minimize the backpack movement when balance is critical (for example, when climbing in rocky areas). To do this, tighten the side stabilizer straps.*

Caring for the backpack

To maintain the durability of the Trimble backpack and protect its waterproofing:

- Clean it regularly with a soft brush and warm water to remove dirt and other foreign material.
- Dry the backpack thoroughly before storing it to avoid the risk of mildew.
- Store it in a well-ventilated, dry area away from direct sunlight or heat.

Warning – Do not use soap detergents or other solvents. These can attack and damage the fabrics. Do not machine-wash the backpack.

Optional Range Poles and Tripods

Range poles and tripods are very useful when collecting carrier-phase data. With a range pole or tripod you can measure the antenna height more accurately and hold the antenna still more easily than you can with an antenna mounted on the backpack.

Optional Vehicle Kit

The optional vehicle kit contains useful accessories for working in a car, boat, or plane, including:

- magnetic mount
- vehicle power cable
- quick-release for the antenna

APPENDIX

A

Upgrading Receiver Firmware

In this appendix:

- Introduction
- Downloading the Firmware Files
- Connecting the Receiver to a Personal Computer
- Upgrading the Receiver Firmware

Introduction

This appendix describes how to upgrade the firmware in the GPS Pathfinder Systems receivers. To do this:

1. Download the upgrade files.
2. Connect the receiver to a personal computer.
3. Upgrade the firmware from the personal computer, using the upgrade files.

Downloading the Firmware Files

1. Go to the Trimble website at www.trimble.com/support.html
2. Select the link for the product that you own and then click **Downloads**
3. Click the appropriate link to download the firmware file:

To upgrade the firmware for this receiver …	download this file …
GPS Pathfinder Pro XR	XR_*nnn*.exe
GPS Pathfinder Pro XRS	XRS_*nnn*.exe
GPS Pathfinder Power	PPW_*nnn*.exe

The *nnn* in the filename represents the firmware version. For example, XR_*170*.exe is the filename for version 1.70 of the GPS Pathfinder XR.

***Note –** Some older Pro XR receivers (P/N 29654-xx) and Pro XRS receivers (P/N 33302-50) cannot be upgraded to version 1.70 firmware.*

The file that you download is a self-extracting zip file. To extract the files it contains, run the downloaded executable files from DOS or Windows. The following files are extracted:

- A firmware file with a .tnr extension

- Release Notes for that firmware release
- The latest version of the Flashloader100 software

Note – *The Flashloader100 version number is not related to the receiver firmware version.*

You must install the latest version of the Flashloader100 software before you can upgrade the receiver firmware. To install Flashloader100, run the fl100v*nnn*.exe from within Windows, and follow the instructions on the screen.

Connecting the Receiver to a Personal Computer

1. Connect the TA3 (male) connector on the GPS receiver data/power cable P/N 30231-00) to the AC power adaptor (P/N 31197 or P/N 38483).
2. Connect the AC power adaptor to a suitable AC power outlet.
3. Connect the DE-9 connector on the GPS receiver data/power cable (P/N 30231-00) to COM port 1 or COM port 2 on the computer.
4. Connect the GPS receiver data/power cable to the receiver. If necessary, use a standard serial cable to extend the reach of the data/power cable to the computer.

Warning – Pin 9 of the DE-9 connector on the receiver data/power cable is powered by the receiver at 12 volts DC with 1 amp capability. Before connecting this pin to the computer, refer to the documentation for the computer.

Upgrading the Receiver Firmware

To upgrade the receiver firmware, use a personal computer with the Flash Loader 100 software installed and the appropriate .tnr file. For details on which files you need, see Downloading the Firmware Files, page 62.

1. On the computer, start the Flash Loader 100 software using one of the following methods:

   – Double-click the Flash Loader 100 desktop icon.

   – Select Flash Loader 100 from the Programs menu.

   By default, the software assumes that the receiver is connected to COM1 on your computer.

   To change this manually, select Options / Settings from the menu. Alternatively, click **Find Device** to let Flash Loader 100 determine which port the receiver is connected to.

2. Select the *Upload new firmware to receiver* check box.

   A standard *File Open* dialog appears.

3. Navigate to the folder where you saved the .tnr file that you downloaded from the Trimble website. Select the file and click **OK**.

   The software will take a few seconds to process this file.

4. Click **Proceed** to transfer the new firmware to the receiver.

   This may take several minutes.

5. When the process is complete, click the cross in the top right corner of the window to close the Flash Loader 100 program.

Warning – Do not turn off the computer, disconnect power to the receiver, or disconnect the cables between the computer and the receiver. Doing this will interrupt the upgrade process.

APPENDIX

B

Specifications

In this appendix:

- Introduction
- Specifications
- Pinouts

Introduction

This appendix lists specifications for GPS Pathfinder Systems receivers and antennas, and pinouts for cables that are supplied with the receivers.

Specifications

Table B.1 lists specifications for the GPS Pathfinder Pro XR and Pro XRS receiver.

Table B.1 GPS Pathfinder Pro XR and Pro XRS receiver specifications

Parameter	Specification
General	12 channel, L1/CA code tracking with carrier phase filtered measurements and multibit digitizer
Update Rate	1 Hz
Time to First Fix	< 30 seconds, typical
Size	11.1 cm × 5.1 cm × 19.5 cm (4.4" × 2.0" × 7.7")
Weight	0.76 kg (1.68 lb)
Power	XR 6 W (maximum) XRS 7 W (maximum) both 10 to 32 VDC
Temperature	–20 °C to 65 °C (–4 °F to 149 °F) operating –30 °C to 85 °C (–22 °F to 185 °F) storage
Humidity	100% non-condensing
Casing	Dustproof, splashproof, shock-resistant, sealed to 5psi

Table B.2 list specifications for the GPS Pathfinder Pro XR antenna.

Table B.2 Integrated GPS/beacon antenna specifications

Parameter	Specification
General	Right-hand, circular polarized; omnidirectional; hemispherical coverage
Size	15.5 cm diameter × 10.8 cm high (6.1" × 4.2")
Weight	0.49 kg (1.08 lb)
Temperature	–20 °C to 65 °C (–4 °F to 149 °F) operating –40 °C to 85 °C (–40 °F to 185 °F) storage
Humidity	100% fully sealed
Casing	Dustproof, waterproof, shock resistant

Table B.3 lists specifications for the GPS Pathfinder Pro XRS antenna.

Table B.3 Combined L1 GPS/beacon/satellite differential antenna specifications

Parameter	Specification
General	Right-hand, circular polarized; omnidirectional; hemispherical coverage
Size	15.5 cm diameter × 14 cm high (6.1" × 5.5")
Weight	0.55 kg (1.2 lb)
Temperature	–20 °C to 65 °C (–4 °F to 149 °F) operating –40 °C to 85 °C (–40 °F to 185 °F) storage
Humidity	100% fully sealed
Casing	Dustproof, waterproof, shock resistant

Table B.4 lists specifications for the GPS Pathfinder Power combined receiver and antenna.

Table B.4 GPS Pathfinder Power combined receiver and antenna specifications

Parameter	Specification
General	12-channel, L1/CA code tracking with carrier-phase filtered measurements
Update Rate	1 Hz
Time to First Fix	< 30 seconds, typical
Size	15.2 cm diameter × 12.7 cm high (6" × 5")
Weight	0.625 kg (1.38lbs)
Power	3.1 W, 9 to 32 V
Temperature	–30 °C to 60 °C (–22 °F to 140 °F) operating –40 °C to 80 °C (–40 °F to 176 °F) storage
Humidity	100% fully sealed
Casing	Fully sealed, dustproof, waterproof, shock resistant

Pinouts

Table B.5 lists the pinouts for the GPS Pathfinder Pro XR and Pro XRS receiver’s data/power cable.

Table B.5 Data/power cable pinout (P/N 30231-00)

To GPS Pathfinder Pro XR and Pro XRS receiver				Field Device		Input Power		
Conn P1			**7 Cond Cbl #1**	**Conn P2 DE9-F**		**2 Conn Cbl #2**	**Conn P3 TA3-M**	
Event In	1	in	—	—		—	—	
TXD out	2		Orange	2	RXD	—	—	
RXD	3	in	Red	3	TXD	—	—	
Chg Ctrl	4	in	Black	4	DTR	—	—	
Sig Gnd in/out	5		Shield	5	Sig Gnd	—	—	
DSR out	6		Yellow	6	DSR	—	—	
Pwr On	7	in	Brown	7	RTS	—	—	
CTS out	8		Green	8	CTS	—	—	
Charge out	9		Blue	9	RI	—	—	
V+ In	10	in	—	—		White	1	V+ In
V– In	11	in	—	—		Black	2	V– Out
PPS —	12		—	—		—	—	

Table B.6 lists the pinouts for the GPS Pathfinder Power combined receiver and antenna's data/power cable.

Table B.6 Data/power cable pinout (P/N 40492-00)

To GPS Pathfinder Power combined receiver and antenna			To Field Device		Input Power	
Color Scheme	**P1 Conn ConXall-F**	**P1 Desc.**	**P2 Conn DE9-F**	**P2 Desc.**	**P3 Conn TA3-M**	**P3 Desc.**
Orange	2	Data Out Port A →	6			
Red	3	Data In Port A ←	8			
Yellow	6	Data Out Port B →	2			
Brown	7	Pwr on ←	7			
Green	8	Data In Port B ←	3			
Black	10	V+ In	9	V+ In	1(Wht)	V+ Out from battery
Blue	12	PPS →	1	PPS		
Shield	5,11	Sig Gnd, V– In	5, Body	Sig Gnd	2(Blk)	V– Out from battery
No Connect	1,4,9		4			

Table B.7 lists the pinouts for the GPS Pathfinder Pro XR and Pro XRS receiver’s NMEA/RTCM cable.

Table B.7 NMEA/RTCM cable pinout (P/N30232-00)

To GPS Pathfinder Pro XR and Pro XRS receiver				NMEA/RTCM output connectors		
Conn P1			**9 Cond Cbl #1**	**Conn P2 DE9-M**	**7 Conn Cbl #1**	**Conn P3 DE9-F**
Event In	1	in	—	—	—	—
TX– (232)	2	out	—	—	Orange	2 TXD
RX– (232)	3	in	Red	2 RXD	—	—
Chg Ctrl	4	in	—	—	Shield	
Sig Gnd	5	in/out	Shield	5 Sig Gnd	—	5 Sig Gnd
TX+ (422)	6	out	—	—	—	
Pwr On	7	in	—	—	—	—
RX+ (422)	8	out	—	—	—	—
Charge	9	out	Yellow	9 Pwr	—	—
V+ In	10	in	—	—	—	—
V– In	11	in	—	—	—	—
PPS	12	—	—	—	Brown	4 DTR

Table B.8 lists the pinouts for the GPS Pathfinder Power combined receiver and antenna’s NMEA/RTCM cable.

Table B.8 NMEA/RTCM cable pinout (P/N 40887-00)

To GPS Pathfinder Power combined receiver and antenna’s data/power cable (P/N 40492-00)			To Field Device cable	To NMEA device	To RTCM device
Color Scheme	**P1 Conn DE9-M**	**P1 Description**	**P2 Conn DE9-F**	**P3 Conn DE9-F**	**P4 Conn DE-M**
Blue	1	1 PPS →		4	
Black	2	Data In to data logger →	2		
Black	3	Data Out from data logger ←	3		
Shield	5	Sig Gnd ↔	5	5	5
Red	6	Data In to NMEA device →		2	
Black	7	Power On ←	7		
Black	8	Data Out from RTCM device ←			2
Green	9	V+ In ↔	9 (BLK)		9
No Connect	4		1,4,6,8	1,3,6, 7,8,9	1,3,4, 6,7,8

Table B.9 lists the pinouts for the field device data cable.

Table B.9 Field device data cable pinout (P/N 45052)

To GPS Pathfinder Pro XR, Pro XRS, or Power receiver			Field device		
Conn P1 DE9-F			**7 Cond Cbl #1**	**Conn P2 DE9-M**	
Event In	1	out	White	1	CD
TXD	2	in	Orange	2	RXD
RXD	3	out	Red	3	TXD
Chg Ctrl	4	out	Black	4	DTR
Sig Gnd	5	in/out	Shield	5	Sig Gnd
DSR	6	in	—	6	DSR
Pwr On	7	out	Brown	7	RTS
CTS	8	in	Green	8	CTS
Charge	9		NC	9	NC

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CATEGORY 11: SURVEYING

Section 11.2

GPS Site Surveying Standard Operating Procedure Manual – Attachment G

GPS SITE SURVEYING STANDARD OPERATING PROCEDURE MANUAL

Attachment G

Prepared by
Sterling Field Support Center

Updated April 6, 2012

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service/Office of Operational Systems
Field Systems Operations Center/Observing Systems Branch

GPS SURVEYING DRAFT

Procedure for Survey of TRS/ART Location, Radiosonde Release Location, SPS GPS Antenna Location, and PDB location.

It is recommended that the system not be placed in any hazardous type of weather (i.e. heavy rain, snow, etc). Although the system is to a degree "waterproof", it is not recommended for fear of water finding a way into the GPS receiver. Also recommend the unit not be used in conditions where temperatures are within -40°C<X<65°C.

SETTING UP THE GPS RECEIVER

The GPS Receiver, in its default setting, will automatically receive data in a "Static" form. This is the type of data needed for this process. There should be no need to have to set up the receiver in any way for our GPS surveying process. If for some reason you need or want to set up the receiver in a manner that is not of the default variety (i.e. kinematic data transmission, timed surveying, etc), the enclosed GPS 5700 manual will direct and walk you through the process.

SETTING UP THE TRIPOD, GPS RECEIVER, ZEPHYR, AND ASSOCIATED CABLES

This section has two sets of directions: One set will be for setting up the unit in a radome without a TRS or for any random survey point, and another set will be for a unit that has a TRS. If you are taking a GPS survey point for the RSOIS, set up under the temperature sensor.

WITHOUT A TRS OR FOR A GENERAL SURVEY POINT:

1) Clear the radome of all old radiosonde equipment. Mark the TRS mounting points on the floor of the radome. Mark the center point between the TRS mounting points.
2) Set up the GPS antenna tripod over the center point of the TRS footprint. The center pole point should be placed directly on the center point of the TRS footprint. Extend the three legs so that the tripod is approximately level. Using the spring-loaded adjustment levers on two of the legs, level the tripod accordingly. The bubble level mounted on the tripod will give you a fairly approximate level reading.

Figure 1. GPS Antenna Tripod

3) Once the tripod is level, verify the point on the end of the center pole is still setting on the center mark of the TRS footprint. (Even the slightest nudges can knock the tripod out of level, make sure to check it after every step)
4) Mount the GPS antenna on the tripod and orient the north arrow on the GPS antenna (Zephyr) to agree with the compass on the tripod. The north arrow can be found on the underneath side of the Zephyr labeled with a diagram and at position number 1.
5) Measure the height from the indented line that rims the Zephyr down to the radome floor. This measurement should be made in meters, and be measured to an accuracy of 0.001 m. Note this measurement.
6) Hang up the yellow Trimble GPS receiver onto the red knob and associated velcro strip. Make sure to once again check the level bubble. (**Proceed to Powering on and Collecting Data)**

Figure 2. Trimble GPS Receiver on GPS Antenna Tripod

WITH A TRS:

1) Make sure the TRS/UPS is turned off.
2) Gently pull down on the dish of the TRS so that you can reach the NAGS. Make sure the NAGS is facing as close to due North 0° as possible.
3) Unscrew 4 NAGS screws to allow the NAGS flush-mount plate to be placed on the end of the NAGS. Screw on with 4 given screws.

Figure 3. NAGS flush-mount plate on NAGS end

4) You can now place and screw on the Zephyr Antenna on to the threaded end of the bolt. Make sure the number 1 arrow on the bottom of the antenna (also note the Trimble sticker designating the area) is facing straight down. When the dish is in the upright position, this will have the antenna facing due north.
5) Using the yellow GPS cable, connect one end (straight end) to the GPS port on top of the yellow Trimble GPS receive. The other GPS connection (right angle) should screw on to the bottom of the Zephyr.
6) ** This step is only if you are not using the internal batteries given**. Connect the external power cable to the external power port (either port 2 or port 3) by matching up the red dots on the port and the cable end. Do not force them together as this may cause the pins to bend.
7) ** This step is only if you are not using the internal batteries given**. Connect the external power cable to a power cord, and plug the power cord into an associated outlet.
8) You are now ready to power on and collect data.

<u>POWERING ON AND COLLECTING DATA</u>

1) Make sure you have the correct settings (if needed) for the GPS Receiver. The default settings are the correct settings unless otherwise noted.

2) To turn on, press the green power button on the front of the receiver. A green light should light up on either 2 or 3, depending which port you have the power cord plugged in to, or whichever battery is currently running.
3) Once your green light is on, look to the left part of the panel to see if there is a blinking light under the GPS mark (red light). Once this light goes from fast blink to slow blink, you can now press the blue button (data button). An orange light will appear signifying data is now collecting.
4) Allow the receiver to stream data for approximately 4 hours.
5) When the allotted time is up, hold the power button down for two seconds, you should see all of the lights turn off. This will turn the power off. You can now disconnect, and disassemble the GPS unit.

TRANSFERING DATA FROM RECEIVER TO COMPUTER

1) Plug the power cord into an outlet, the cable connection to Port 2 of the receiver, and the comp port into the back of the computer. Now hook up the USB cord from the bottom of the GPS receiver (there is a latch at the bottom of the receiver that opens up) to the computer. The receiver is now hooked up to the computer.
2) Select All Programs, Trimble Data Transfer, Data Transfer (A data transfer window will appear)
3) Make sure the drop down box on the top left under 'Device' says "GPS Recvr-5000 Series: COM 1". You should see on the top right a green check mark stating the device is connected to the computer.

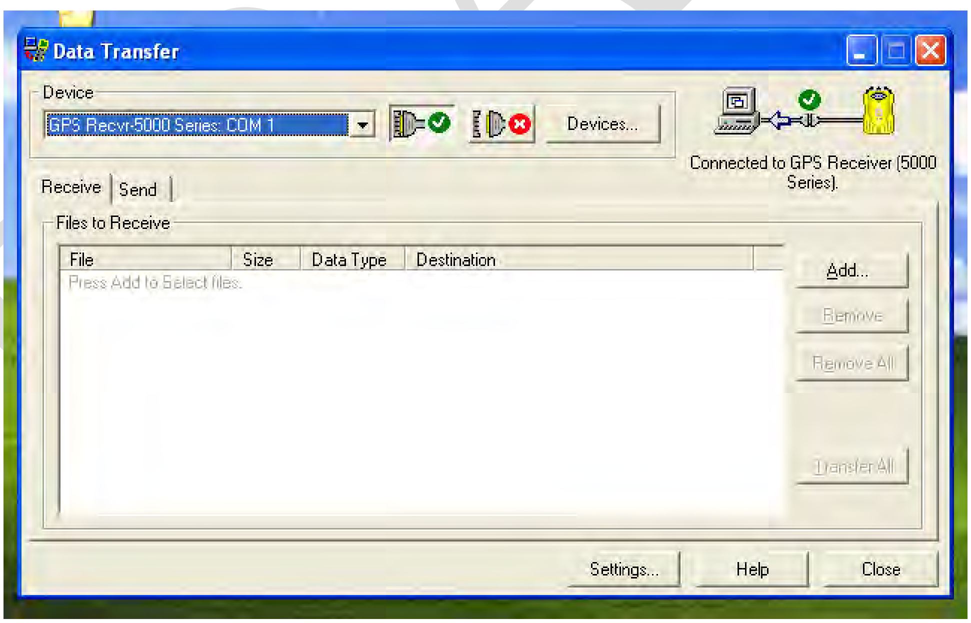


Figure 4. Data Transfer Window

4) Click on the 'Add' button which will bring up an Open Window. In that open window select the Yellow Icon that says 5700-xxxxxxxx
5) You should now be able to select the latest GPS data file. Open this file.

6) After clicking 'open' you should now be back to the Data Transfer Window along with the file attached. You can now click 'Transfer All'. Once the file has transferred you will have a Transferred Completed box appear. Click close.
7) Two files have now been created: a .dat and a .T00 file. They are both placed in the GPS DATA file on the desk top.

SENDING DATA TO OPUS

1) Open up IE and go to the website: http://www.ngs.noaa.gov/OPUS/index.jsp
2) Click on the box on the right that says: NAD 83 (CORS96, MARP00, PACP00) epoch 2002.00 ITRF00
3) Enter your email address.
4) For the data file, enter the .dat file (this file will show up in the GPS folder as the one that's not .T00)
5) The antenna type is: TRM41249.00 SCIT Zephyr 4-Point feed antenna –Stealth Group
6) Enter the distance (in meters) that you measured outside from the base of your point to the line in the Zephyr. ***If you are inside a radome make sure you run opus 2 times. First time you will enter 0 for your height. This will give you an approximate 1 meter difference from the GPS egg to the end of your antenna. Add .9 meters to the meta-data table. The second time you enter the data in OPUS, enter 1.22 as your (m) height. This is a correction factor for launch height. The delta between your two OPUS solutions should be roughly 2m.
7) Click Options and make sure the Geoid Model is Geoid 09
8) Click on "Upload to Static"
9) An email should be sent to you within 15 minutes with an attachment giving you your ortho height and lat/lon's

FINDING HEIGHT/DISTANCE USING LINE OF SIGHT FOR SURFACE EQUIPMENT

This section will allow you to determine an objects height once you determine a base height, for instance the surface release point. Once that height has been determined, you will be able to use this procedure to accurately determine the height of surface instruments (i.e. RSOIS) or any other object for that matter. You will also be able to determine distance away from a reference point, along with the angle at which it is located. For these surveys, we will use the release point as our reference point. This procedure usually takes two people.

1) For this type of survey we will use the release point as our reference point. However, you can certainly use this method to create your own reference point, site dependent. Configure the tripod as you normally would for a GPS survey. However, this time you will only need to screw on the Optical Survey unit. Make sure the unit is level, on the tripod and the Optical unit.

2) Once the entire unit is level, rotate the Optical unit 180º, making sure the entire unit is still level. If it is not, follow the instructions in the handbook which should be located in the Optical unit's box. These directions will show you how you are to readjust the unit to calibrate it.
3) Measure the height from the ground to the middle of the optical lens and write down that value in inches.
4) Have the other person hold the meter extendable ruler on the ground (vertically) of the location you want to survey and use the optical unit to zoom in on the numbers.
5) Once you focus on the numbers, look for the number that falls into the center cross-hairs. If that number is lower than the value of your height that you wrote down earlier, than the position you are measuring (area where ruler is at) is higher than your location, and vice versa.
6) Use the top cross hair and the bottom cross hair to determine the distance in feet you are away from the ruler. Take the top cross hair and minus the bottom cross hair. Take that value and times it by 100. (If top was 30" and bottom was 28": 30"-28"= 2 x 100= 20 feet.
7) If you're attempting to use a reference point from inside, a laser level is available to shoot a laser outside to a point, usually on the ruler. That point can be used to do your measurements.

CATEGORY 12: UTILITY CLEARANCE

Section 12.1

USA North's California Excavation Manual

USA North's

California Excavation Manual

811 / 1-800-227-2600

Know what's below.
Call before you dig.

Disclaimer Notice: The suggested guidelines contained in this booklet are not intended to prevent excavators or operators from providing alternate forms of marking that are in accordance with California Government Code 4216. The suggested guidelines are representative in nature and do not address all delineation or facility markout situations.

NOTE: The Following Two Bullets are California Law.

- **California Business and Professions Code Section 7110:** Page 21.
- **California Government Code (CGC) 4216 requirements:** Page 22-30.
  - Outline your excavation area in white [4216.2 (a)] Page 25.
  - A 2 working day up to 14 calendar day (legal) notice is required before digging [4216.2 (a)] Page 25.
  - USA North will notify its members of your excavation [4216.2 (c)] Page 25.
  - The USA North members will by the legal notice mark or stake the horizontal path of their facilities, provide information about the location of their facility, or advise of clearance [4216.3 (a)] Page 26.
  - Expose the underground facilities by hand before using power equipment [4216.4 (a)] Page 27.
  - The USA North ticket number is valid for 28 calendar days. You must have an active USA North ticket number for the entire duration of your excavation [4216.2 (c)] Page 25.
  - Keep the USA North ticket number to validate your excavation permit [4216.9 (a)] Page 30.
- **CalOSHA Regulation Title 8 Chapter 4 Subchapter 4 Article 6 Section 1541:** Page 30-32

This manual is provided to you as a public service by USA North and is dedicated to the safety of our communities in California, and Nevada.

Know what's below.
Call 2 Working Days To 14 Calendar Days Before You Dig in California or Nevada!

OVERVIEW

USA North provides a free and effective Damage Prevention Service that protects our citizens, our communities, our environment, our essential public services, and our underground facilities in Central / Northern California and all of Nevada. USA North began operation in May of 1975 and incorporated as a Non Profit Mutual Benefit Corporation in 1986. Our purpose is to receive planned excavation reports that will begin within the next 14 calendar days from homeowners, excavators, or professional contractors and transmit those planned excavation reports to all participating members of USA North who may have facilities at that excavation site. Our members will 1) mark or stake the horizontal path of their facility, 2) provide information about the location of their facility, or 3) advise the caller of clearance, for facilities that they own.

USA North's Service Area:

Central & Northern California*:* Alameda, Alpine, Amador, Butte, Calaveras, Colusa, Contra Costa, Del Norte, El Dorado, Fresno, Glenn, Humboldt, Kern, Kings, Lake, Lassen, Madera, Marin, Mariposa, Mendocino, Merced, Modoc, Mono, Monterey, Napa, Nevada, Placer, Plumas, Sacramento, San Benito, San Francisco, San Joaquin, San Luis Obispo, San Mateo, Santa Clara, Santa Cruz, Shasta, Sierra, Siskiyou, Solano, Sonoma, Stanislaus, Sutter, Tehama, Trinity, Tulare, Tuolumne, Yolo and Yuba.

Nevada: Carson City, Churchill, Clark, Douglas, Elko, Esmeralda, Eureka, Humboldt, Lander, Lincoln, Lyon, Mineral, Nye, Pershing, Storey, Washoe, and White Pine.

Common Ground - Study of One-Call Systems and Damage Prevention Best Practices;

The United States Department of Transportation's Office of Pipeline Safety (OPS) initiated the Common Ground report under the authorization of the Transportation Equity Act for the 21st Century (TEA 21), Public Law 105-178, signed into law on June 9, 1998. The purpose of the study was to identify and validate existing best practices performed in connection with preventing damages to underground facilities. The Study ultimately resulted in a quality product that can be used to help in future efforts to improve underground damage prevention. The collected best practices should be shared among stakeholders involved with and dependent upon the safe and reliable operation, maintenance, construction, and protection of underground facilities.

Common Ground Chapters Titles:

1. Introduction Practice Statements
2. Planning & Design Best Practices
3. One-Call Center Best Practices
4. Locating & Marking Best Practices

5. Excavation Best Practices
6. Mapping Best Practices
7. Compliance Best Practices
8. Public Education & Awareness Best Practices
9. Reporting & Evaluation Best Practices
10. Appendix A - Glossary of Terms & Definitions
11. Appendix B - Uniform Color Code & Marking Guideline
12. Appendix C - Sample Form for Reporting Damage Prevention Information
13. Appendix D - Additional References

For a complete version of the Common Ground Alliance Best Practices logon to www.commongroundalliance.com and download this information or order a copy.

Common Ground Alliance Chapter 5 "Excavation Best Practices":

1. One-Call Facility Location Request
2. White Lining (CA & NV requires that you mark in white)
3. Locate Reference Number
4. Pre-excavation meetings
5. Facility Relocations
6. Separate Location Requests
7. One-Call Access (24x7)
8. Positive Response
9. Facility Owner / Operator Failure to Respond
10. Locate Verification
11. Documentation of Marks
12. Work Site Review with Company Personnel
13. One-Call Reference Number at Site
14. Contact Names and Numbers
15. Facility Avoidance
16. Federal and State Regulations
17. Marking Preservation
18. Excavation Observer
19. Excavation Tolerance Zone
20. Excavation within the Tolerance Zone
21. Mis-Marked Facilities
22. Exposed Facility Protection
23. Locate Request Updates
24. Facility Damage Notification
25. Notification of Emergency Personnel
26. Emergency Excavation
27. Backfilling
28. As-Built Documentation
29. Trenchless Excavation
30. Emergency Coordination with Adjacent Facilities

Important Web Sites:

- Common Ground Alliance / One Call Systems Int'l
  www.commongroundalliance.com
- USA North – (Call Before You Dig Center)
  www.usanorth.org

- California Government Code www.leginfo.ca.gov/cgi-bin/calawquery?codesection=gov&codebody=4216&hits=20
- California Code of Regulations (Cal/OSHA) - www.dir.ca.gov/title8/1541.html
- Nevada Revised Statues - www.leg.state.nv.us/NRS/NRS-455.html
- Nevada Administration Code - www.leg.state.nv.us/NAC/NAC-455.html

Be knowledgeable of all Federal, State, County, City, or Local Requirements:

- Construction Code
- Contractor License Code
- Safety Code
- Franchise Code
- OSHA
- County, City or Local Ordinances
- Others that apply

General Excavation Information:

- Prior to starting an excavation, examine the excavation site for physical evidence (manholes, valve covers, water meters, sewer cleanouts, vaults, utility maintenance boxes, pole risers, etc) that would indicate the existence of underground facilities. Always excavate, as cautiously and prudently as possible.
- USA North accepts calls for excavation work on public or private property, on Military Bases, on Indigenous People's Reservations and even on waterways within our coverage area.
- Our members will mark or stake the horizontal path, provide information about the location, or provide clearance for facilities that they own. Excavators should be aware there could be other facilities of the same type at the excavation site owned by the property owner or another company who is not a member of USA North.
- When excavating within 10' of subsurface installations daylight the facility by hand every 25' to make sure the facility is where it is indicated. When excavating in CA or NV within 24" of a facility the law requires you to hand expose and protect the facility (it does not mean daylight or pothole) prior to using power equipment.
- Individuals with first hand knowledge of the excavation site and that can be reached by telephone should call the location description into USA North. This allows us, and our members, to discuss the location with a person who has knowledge of the excavation layout and specific location.
- Limit your excavation location description to a site that can be completed within a 28 calendar day period from

the date of your call to USA North in California or Nevada and that our members can reasonably locate within 2 working days.

- USA North limits excavation work to areas no longer in length than 1½ miles in a metropolitan area and 3 miles in a rural area.
- Dividing larger excavation areas into smaller manageable sites helps our members respond to your excavation site more promptly.
- As work in one excavation site nears completion, call in your next excavation site to USA North and continue this process until your entire excavation area is complete.
- When working on private property the excavator should determine what facilities belong to the property owner; (water, well, sewer, septic tanks, gas, propane lines, electrical, etc.) and what easement(s) may exist on the property, if any. In general, ownership of underground facilities transfers to the property owner behind the curb, behind the sidewalk, clean out, at the meter or point of demarcation.
- USA North notifies only its members of your excavation work, for your safety you should notify any non-member.

<u>Excavation Types:</u>

Special Note - You will need to provide the City or Community that the excavation work is being done in and a verbal description of your excavation site. From your description, your Digsite will be built on the USA North base map to determine which of our members will be notified for that area. If your information is not accurate and correct the wrong members could be notified. It is critical that you provide USA North precise information about the location of the excavation, this is especially true when dealing with; New Streets, New Subdivisions or work off the roadway. If you are using distance or direction measurements, you should be accurate within 10 feet + or - with each measurement. To insure the accuracy of your location, provide the Latitude Longitude positions from a GPS device using NAD 83 CONUS decimal format.

I. <u>Street/Address:</u>

   A. For an address provide:
      1) Address and street name.
      2) Two nearest streets that the address is between (system can take one street).
      3) Where on the property you are digging?
      4) How many feet from the street in front of your address is the work?

   B. For multiple addresses provide:
      1) Addresses and street name.
      2) Two nearest streets that these addresses are between (system can take one street).
      3) Where on the property you are digging?

4) How many feet from the street in front of your address is the work?

C. For a Street provide:

1) Street name and nearest intersecting street
2) Side of street with distance / direction

II. <u>Intersections:</u>

A. For an Intersection provide:

1) Street name and intersecting Street name.
2) Where in the intersection you are working?

B. For work at a single point from the Intersection provide:

1) Street name and intersecting street name.
2) Distance / direction to the point where the work will be.

C. For multiple points from an intersection (you may have to divide your excavation site into multiple locations that fit into four lines of text) provide:

1) Street name and intersecting street name.
2) Distance / direction to the first point where the work will be at;
3) From the first point provide the distance / direction to the second point where the work will be at;
4) From the second point provide the distance / direction to the third point where the work will be at;
5) From the third point provide the distance / direction to the forth point where the work will be at.

D. For continuous work from an intersection provide (you may have to divide your excavation site into multiple locations that fit into four lines of text):

1) Street name and intersecting street name.
2) Distance / direction to the first point where you will be working to;
3) From the first point provide the distance / direction to the second point where you will be working to;
4) From the second point provide the distance / direction to the third point where you will be working to;
5) From the third point provide the distance / direction to the forth point where you will be working to.

III. <u>Between Intersections:</u>

A. For work on a Street between intersections provide:

1) Street name.
2) Two intersecting Street names that the work is between.
3) Description of where on the Street you are working with distance / direction.

B. Multiple points on a Street between intersections provide:
   1) Street name.
   2) Two nearest Street names that the work is between.
   3) Description of where on the Street you are working with distance / direction for each point.

C. For New Streets or New Subdivision (containing no streets on map within the excavation area) provide:
   1) Street and nearest intersection outside the excavation.
   2) Distance / direction to the new Street or Subdivision and a radius they are contained within.

IV. <u>Bounded by Areas</u> (containing no streets on map within the excavation area):

A. For Bounded Areas with Streets provide:
   1) Street names that bound the area (2, 3 or 4 streets).

B. For Bounded Areas with streets and distances provide:
   1) Street names that will be used as boundaries for the area.
   2) Distance / direction from the one or two streets that will create the bounded in area.

<u>USA North Ticket Format:</u>

- ✓ Business Phone Number:
- ✓ Fax Number:
- ✓ Email Address:
- ✓ Your Name:
- ✓ Your Company Name:
- ✓ Type:
- ✓ Industry:
- ✓ Company's Address:
- ✓ City:
- ✓ State:
- ✓ Zip:
- ✓ What County is your work being done in?
- ✓ Start Date: (a 2 working day to 14 calendar day notice is required)
- ✓ Start Time:
- ✓ Working For:
- ✓ As required has site been Premarked?
- ✓ Premarked method used?
- ✓ Permit Type: Permit #:
- ✓ Forman's Name:
- ✓ Cell Telephone: Field Telephone:
- ✓ Does your excavation include boring, if so what type?
- ✓ Type/Nature of Work: (augering, drilling, grading, ripping, trenching, etc.)

- ✓ Will Explosives be used at your work site?
- ✓ Do you intend to use vacuum equipment instead of hand digging to determine the exact location of our member's underground facilities?
- ✓ Digsite Place: (City or Community)
- ✓ Digsite Types: Address(s) between 2 nearest Sts, Street between 2 nearest Sts, Street & nearest St, Intersection or Bounded by Area that contains no Streets; include side of street, footages, other tie in measurements, or lat/long in NAD 83 CONUS decimal format).
- ✓ Will the excavation enter into the street or sidewalk area?
- ✓ Ticket #:
- ✓ Date of Call:
- ✓ Ticket Expiration Date:
- ✓ Update your ticket by:

Calling hours are from 6am-7pm Monday - Friday excluding weekends and the following holidays: New Year's Day, President's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, Day after Thanksgiving, and Christmas. USA North takes excavation notices in Central / Northern California and all of Nevada. Each ticket is active for 28 calendar days in California and Nevada from the date of its issuance. If you excavate and damage facilities prior to our member's response, you may be liable for those damages. After our members have responded to your request, it is your responsibility to notify USA North if you need our member(s) to re-mark their facilities. To minimize graffiti we recommend the use of spray chalk, water base, or UV paint by excavators and operators to identify their excavation site or subsurface installations respectively.

Five Steps to a Safe Excavation:

1. **Survey and Mark:** Survey your proposed excavation site. Make a list of affected operators of underground facilities (operators) at your job site, their needs and requirements. Mark the excavation site on paved surfaces with white spray chalk, water base, UV paint or equivalent less permanent type marking; use flags, stakes, whiskers, etc. on unpaved surfaces, (Homeowners can use flour).

2. **Call Before You Dig:** Call USA North 2 working days to 14 calendar days (legal notice) before you dig in California or Nevada. Only operators who are members of the USA North program will be notified. Compare your list of affected operators determined in Step 1, with the list of operators notified by USA North. For your safety contact any operator at your job site that is not a member of USA North. USA North accepts design inquiry requests through its internet application only, call 925-798-9504 ext 2309 for more information.

3. **Wait the Required Time:** The legal 2 working days to 14 calendar days notice in California and Nevada allows USA North members to examine their underground facility records and respond to you. Our members, who are operators of underground facilities, will mark, or stake the horizontal path of their facility with the appropriate color code, provide you information about the location of their facility, or advise you of clearance. Depending on our member's workload, they may contact you to try to negotiate a new start time for your excavation. This will allow them the opportunity to provide you with greater service.

4. **Respect the Marks:** Preserve facility marks for the duration of the job. If any of the operator markings are not reasonably visible, you must call USA North and request re-marking by the affected operator(s). A re-mark request requires a 2 working day notice. When you request an operator(s) to re-mark their facilities, you will be asked if your excavation site is still outlined in white, so the USA North members can respond to your request.

Note: A USA North ticket is active for 28 calendar days in California and Nevada from the date of its issuance. You must have an active USA North ticket for the entire duration of your excavation.

5. **Dig With Care:** In California and Nevada hand excavate within 24" of the outside diameter of the facility. Facilities that are in conflict with your excavation are to be located with hand tools and protected before power equipment is used. Notify the affected utility of any contact, scrape, dent, nick or damage to their facility.

No Response Follow-Up:

This process starts when the excavator notifies USA North that:

- A 2 working day to 14 calendar day (legal) notice was provided on the original ticket and,
- The start date/time has past and,
- A member(s) failed to respond to the excavation site by the legal start date & time of the ticket.

When a member successfully negotiates a new start date/time with an excavator, the negotiated start date/time becomes the legal start date/time for that excavation notice.

Once the start date/time has past, the excavator should determine if all USA North members have responded. The members will: mark or stake the horizontal path of their facilities, provide information about the location of their facilities, or advise of clearance. If the excavator determines that a member(s) of USA North has failed to respond in one of these manners the following steps are to be taken.

1) First No Response Follow-up: Call USA North after the original or agreed upon legal start date/time, that the work was to begin, and request USA North to send a

"First No Response Follow-up" to the member(s) (name the particular member(s)) that failed to respond to your notice. Request the member(s) to call and respond ASAP or call and provide clearance.

2) Second No Response Follow-up: Wait at least an hour or more, from your last call, to provide our member(s) an opportunity to call and respond to your first request. After this time has past and the member(s) still has not contacted you, call and request USA North to send a "Second No Response Follow-up" to the member(s) (name the particular member(s)) that has failed to respond to your notice. Request the member(s) to call and respond ASAP or call and provide clearance.

3) Third No Response Follow-up: Wait at least an hour or more, from your last call, to provide our member(s) an opportunity to call and respond to your second request. After this time has past and the member(s) still has not contacted you, call and request USA North, to send a "Third No Response Follow-up" to the member(s) (name the particular member(s)) that has failed to respond to your notice. Request the member(s) to call and respond ASAP or call and provide clearance. Note; the Center will attempt to make a call to the member(s) terminal involved and ask the member(s) to respond ASAP once the Third No Response Follow-up message has been transmitted.

Warning: There may be unidentified underground facilities at your job site. The excavator should review the job site for physical evidence of facilities not located, i.e. manholes, valve covers, water meters, sewer cleanouts, vaults, drains, fire hydrant, utility maintenance boxes, pole risers, or other facility indicators such as pavement patches etc.

Damage / Exposed Notification:

- An excavator discovering or causing damage to a subsurface installation shall notify the operator of the installation and USA North.
- USA North accepts damage / exposed notices from the excavator and transmits the notice to our members in the area of the damage. USA North will also provide the excavator with the emergency telephone number for the member whose facility was damaged.

Emergency Notification:

- If the damage results in the escape of any flammable, toxic, or corrosive gas or liquid or endangers life, health or property, the excavator responsible immediately notifies 911 and the facility owner/operator.
- The excavator takes reasonable measures to protect themselves and those in immediate danger, general public, property, and the environment until the facility owner / operator or emergency responders have arrived and completed their assessment.

Suggested Guidelines for Prospective Excavation Site Delineation and Facility Operator Location Markout

General Guidelines

This guide provides for temporary uniform surface marking of both planned excavations and of substructures in potential conflict of planned excavations. White markings are used for excavation delineation. Substructure markings are of a specific color. Appropriate color and common abbreviations are listed herein. Full facility operator and excavator responsibilities are detailed in California Government Code (CGC) 4216 through 4216.9 and California Code of Regulations (Cal/OSHA) Title 8 Section 1541.

<u>Note: Temporary markings should be clearly seen, functional, and considerate to surface aesthetics and the local community. Also, check to see if any local ordinances apply. It is recommended that each operator and excavator use a consistent marking standard.</u>

<u>Marking In Paved Areas</u>

Avoid excessive or oversized marking, especially if marking outside the excavation area. Conditions permitting, use spray chalk paint, water based paint, UV paint, or equivalent less permanent type marking. Limit length, height, and interval of marks to those recommended in this manual. Letters and numbers should not exceed 3" to 6" in height.

<u>Marking in Non-Paved Areas</u>

The use of appropriately colored flags, stakes, whiskers, or chalk lines should be used in non-paved areas. Select marker types that are most compatible to the purpose and marking surface. Adhere to paved area marking suggestions to the extent practical.

> If any marking information is omitted due to site conditions, communicate omitted data by direct contact, signs, phone, fax, etc.
>
> "Offset" markings should clearly indicate the direction, the distance, and the path of facility or excavation.

<u>Marking Removal</u>

We recommend that the permitting agency (Local, City, County, State, or Federal) require the permittee to remove all marking paint or other suitable markings at the conclusion of the excavation. Included are all excavator and utility operator (operator) markings that resulted from the project. This recommendation is based on the fact that the excavator has the knowledge of the specific area and limits of the excavation; they are required under CGC 4216.2. (a) (1) to outline their excavation in white paint or other suitable markings; they requested to have the operators mark the facilities which interface with the excavation; and they have the knowledge of when the excavation is completed. This will help eliminate graffiti on our streets and sidewalks caused by these markings and stop the erroneous use of out-dated operator's markings by other excavators.

Permitting Agencies

We also recommend that permitting agencies (Local, City, County, State, or Federal) make excavators aware when multiple excavation permits are taken out for the same period of time and area. The agencies should advise each excavator that other excavators will be working within the same area and encourage them to communicate with one another so they do not destroy each other's excavation site markings or the markings of the operators responding to the multiple excavation sites.

Excavators

Excavators should be specific when providing the description of the excavation area to USA North and when outlining their excavation area in white chalk paint or other suitable markings. This will help the operators to respond to the exact area of excavation and minimize their markings.

- Excavator's pre-marking (delineation) of the excavation site is a requirement of CGC 4216 and CalOSHA 1541.
- Delineate the area to be excavated before calling USA North. Delineated areas should be identified in white markings with the requester's company identifier (name, abbreviations or initials) within the pre-marked zones (see examples).
- Failure to pre-mark when practical may jeopardize your permit, or result in civil penalties.
- CGC 4216.2 (f) requires: "If pre-marking is not practical, the excavator shall contact" USA North "to advise the operators that the excavator shall identify the area to be excavated in another manner sufficient to enable the operator to determine the exact area of the excavation to be field marked."
- CGC 4216.2 (e) states delineation must not be misleading, duplicative or misinterpreted as traffic or pedestrian control.

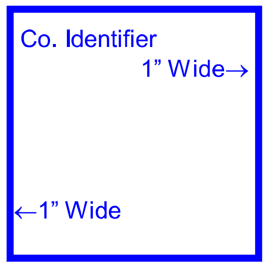
Operators

To increase the accuracy of the locates when the facilities run through utility maintenance boxes, manholes, valve covers, splice boxes etc have your locators pull the lids to determine how many facilities enter and leave the boxes and which direction the facilities run. Operators marking outside the white outlined excavation area should include the USA North ticket number with their marks to identify which excavation site their marks were provided for.

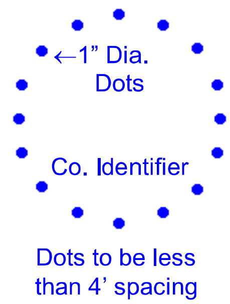
CGA Guidelines For Excavation Delineation

The following marking illustrations are examples of how excavators may choose to mark their area of proposed excavation. The use of white marking products (e.g. paint, flags, stakes, whiskers or a combination of these) may be used to identify the excavation site.

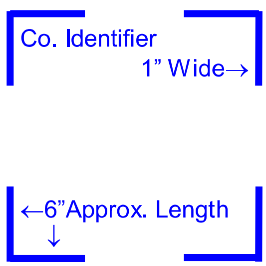
Single Point Excavations Markings



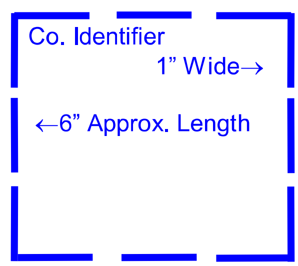
Full Line



Radius or Arc



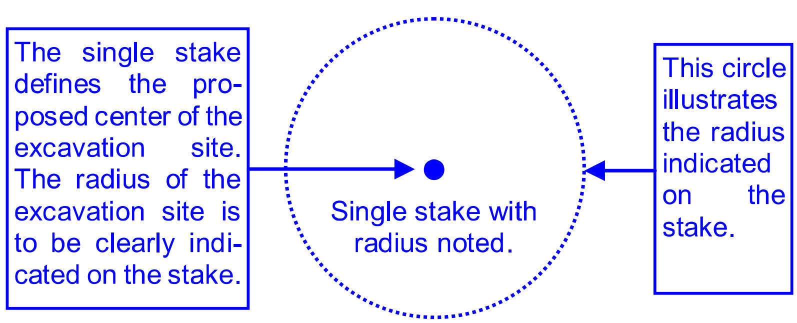
Four Corner



Dash Line

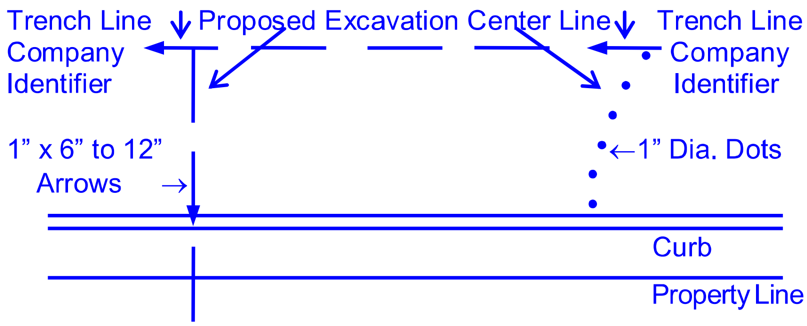
Delineate in white products the proposed area of excavation through the use of: a continuous line, dots marking the radius or arcs, dashes marking the four corners of the project or dashes outlining the excavation project. Limit the size of each dash to approximately 6” to 12” in length and 1” in width with interval spacing approximately 4’ to 50’ apart. The maximum separation of excavation marks is to be reduced to a length that can be reasonably seen by the operator’s locators when the terrain or excavation site conditions warrant it. Dots of approximately 1” diameter are typically used to define arcs or radii and may be placed at closer intervals in lieu of dashes.

Single Stake Marking Center Point of Excavation Site



When an excavation site is contained within a 50' maximum radius, or less, it can be delineated with a single stake that is positioned at the proposed center of the excavation. If the excavator chooses this type of delineation they must convey that they have delineated the excavation site with a single stake at the center of the excavation and include the radius of the site in the notification to the One-Call Center. This single stake is to be white in color with the following information: excavator's company identifier (name, abbreviations, or initials) and the radius of the excavation site in black letters on the stake or with a notice attached to the stake.

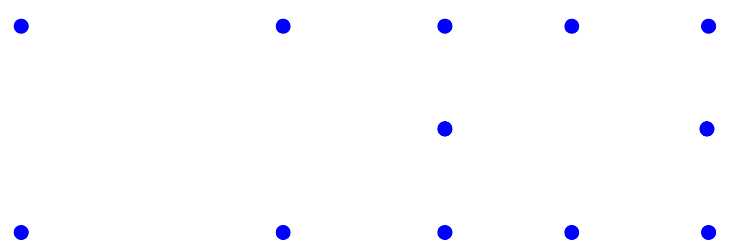
Trenching, Boring, or Other Continuous Types of Excavations



Continuous Excavation Marking

Mark in white paint the proposed centerline of planned excavation 6" to 12" x 1" arrows, approximately 4' to 50' apart to show direction of excavation. The maximum separation of excavation marks is to be reduced to a length that can be reasonably seen by the operator's locators when the terrain at an excavation site warrants it. Mark lateral excavations with occasional arrows showing excavation direction from centerline with marks at curb or property line if crossed. Dots may be used for curves and closer interval marking.

Stakes, Flags or Whiskers Excavation Markers



Stakes, Flags or Whiskers Marking Four Corners

Stakes, Flags or Whiskers Marking Outline of Excavation

Delineate the proposed area of excavation through the use of: stakes, flags or whiskers to mark radius or arcs, the four corners of the project or outlining the excavation project instead of using spray paint. Limit the interval spacing to approximately 4‘ to 50’. The maximum separation of excavation marks is to be reduced to a length that can be reasonably seen by the operator’s locators when the terrain at an excavation site warrants it. Stakes, flags or whiskers provided to illustrate arcs or radii may be placed at closer intervals in order to define the arc or radius. Stakes, flags or whiskers are white in color with the excavator’s company identifier (name, abbreviations, or initials) provided on the stake, flag or whisker.

CGA Guidelines For Operator’s Facility Field Delineation

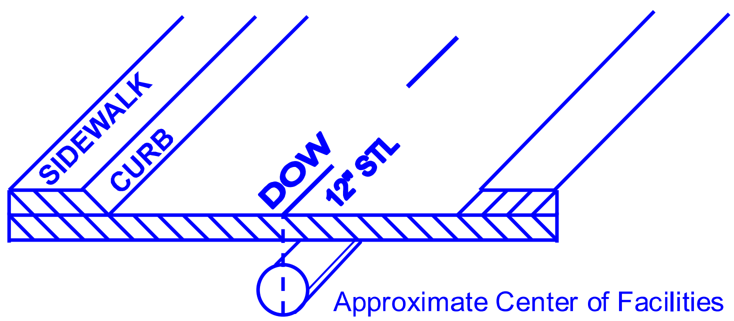
Operator markings of facilities include; the appropriate color for their facility type; their company identifier (name, initials, or abbreviation) when other companies are using the same color, the number and width of their facilities and a description of the facility (HP, FO, STL etc). Use paint, flags, stakes, whiskers or a combination to identify the operator’s facility(s) at or near an excavation site.

1 Marks in the appropriate color are to be approximately 12” to 18” in length and 1” inch in width and separated by approximately 4’ to 50’ in distance as an example. When marking facilities the operator is to consider the type of facility being located, the terrain of the land, the type of excavation being done and the method to adequately mark its facilities for the excavator.

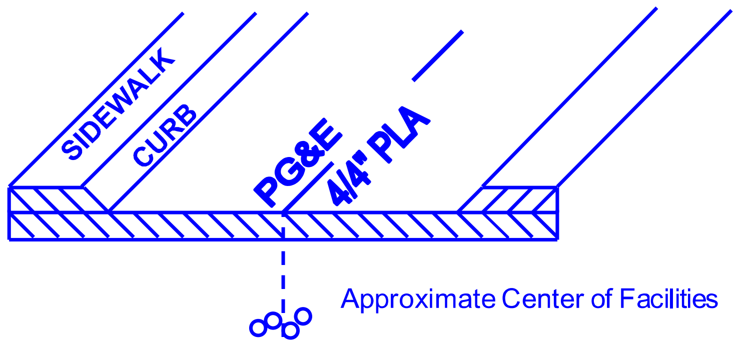
4’ to 50’
|← 12” to 18” →|← in distance →| ↑
between marks 1” Wide

2 The following marking illustrations are examples of how an operator may choose to mark their subsurface installations

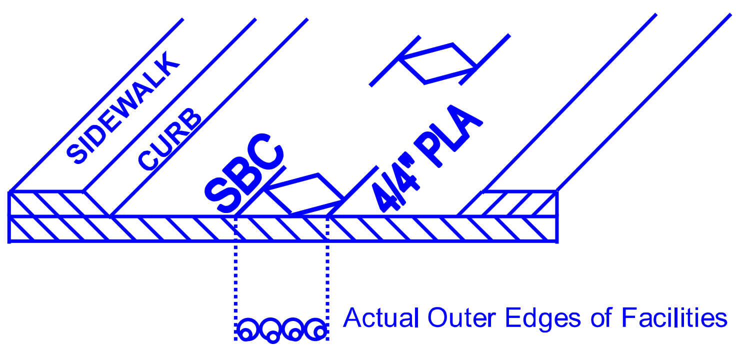
a **Single Facility Marking:** Used to mark a single facility, marks are placed over the approximate center of the facility. This example indicates an operator’s 12” facility. When a facility can be located or toned separately from other facilities of the same type it is marked as a single facility.



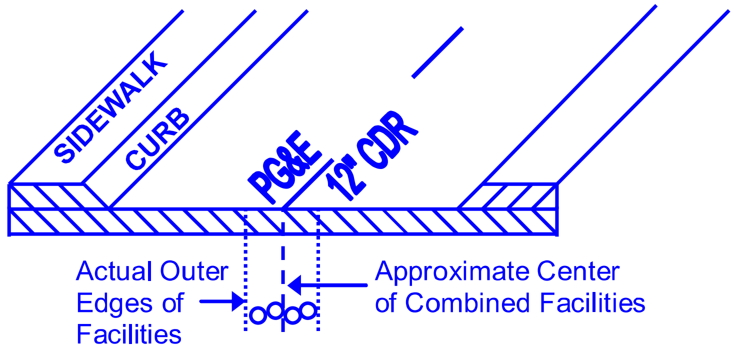
b **Multiple Facility Marking:** Used to mark multiple facilities of the same type (e.g. electric), where the separation does not allow for a separate tone for each facility but the number and width of the facilities is known. Marks are placed over the approximate center of the facilities and indicate the number and width of the facilities. This example indicates 4 plastic facilities that are 4” in diameter (4/4” PLA).



c **Conduit Marking:** Used for any locatable facility being carried inside conduits or ducts. The marks indicating the outer extremities denote the actual located edges of the facilities being represented. An example would be 4 plastic conduits that are 4” in diameter (4/4” PLA), and the marks are 16” apart indicating the actual left and right edges of the facilities.

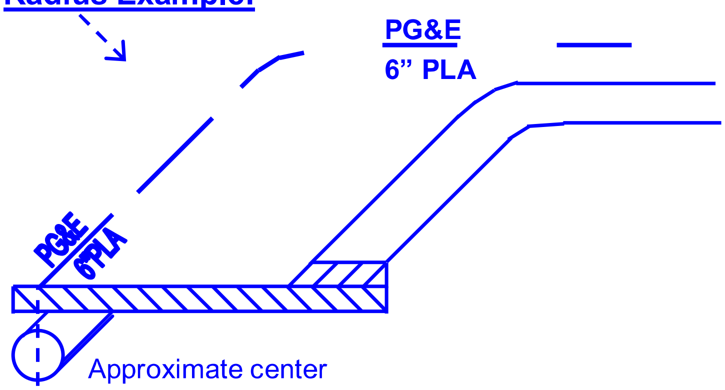


d **Corridor Marking:** Used to mark multiple facilities of the same type (e.g. electric), in the same trench where the total number of facilities is not readily known (operator has no record on file for the number facilities) and that are bundled or intertwined. Marks are placed over the approximate center of the facilities and indicate the width of the corridor. The width of the corridor is the distance between the actual located outside edges of the combined facilities. This example indicates a 12” corridor (12” CDR).

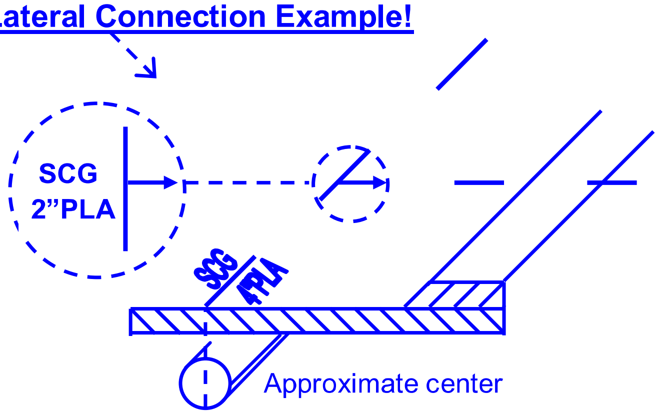


3 Changes in direction, and lateral connections are to be clearly indicated at the point where the change in direction or connection occurs with an arrow indicating the path of the facility. A radius is indicated with marks describing the arc. When providing offset markings, (paint or stakes), show the direction of the facility and distance to the facility from the markings.

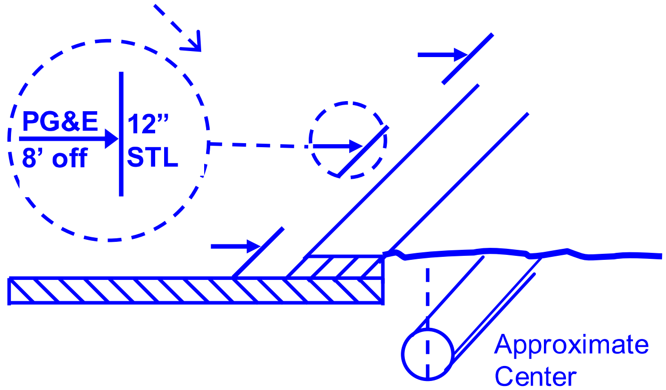
Radius Example!



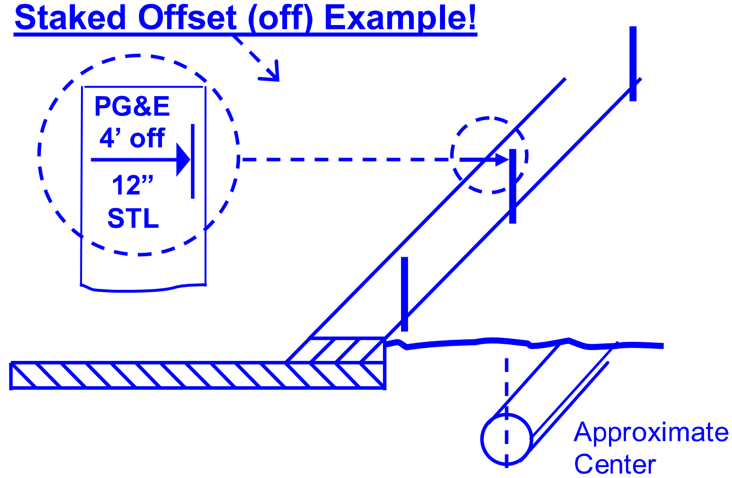
Lateral Connection Example!



Painted Offset (off) Example!



Staked Offset (off) Example!



4 An operator’s identifier (name, abbreviation or initials) is to be placed at the beginning and at the end of the proposed work. In addition to the previous, subsequent operators using the same color, will mark their company identifier at all points where their facility crosses another operator’s facility using the same color. The maximum separation of identifiers is to be reduced to a length that can be reasonably seen by the excavator when the terrain at the excavation site warrants it.

CTYSAC CITIZENS VERIZON

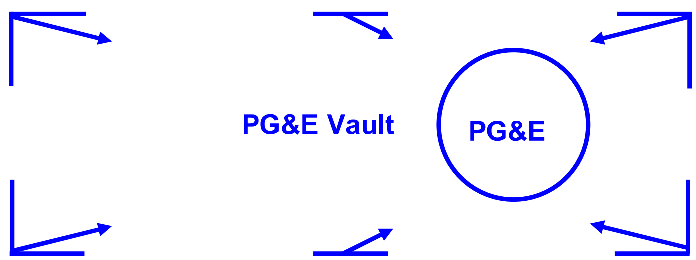
5 Information as to the size and composition of the facility is to be marked at an appropriate frequency. Examples are: the number of ducts in a multi-duct structure, width of a pipeline, and whether it is steel, plastic, cable, etc.

CCWD 4” PLA	RSVTEL 9 PLA	DOW 12” STL

6 Facilities installed in a casing should be identified as such. Two examples are: 6” plastic in 12” steel = 6”PLA/12”STL and fiber optic in 4” steel = FO(4”STL).

<u>ACWD</u>	<u>AT&T</u>
6”PLA/12”STL	FO(4”STL)

7 Structures, such as vaults, inlets, lift stations that are physically larger than obvious surface indications, are to be marked so as to define the parameters of the structure.



8 Termination points or dead ends should be indicated as such.

9 When there is “No Conflict” with the excavation complete one or more of the following:

- Operators of a single type of facility (e.g. AT&T) would mark the area “NO” followed by the appropriate company identifier in the matching APWA color code for that facility (e.g. “NO AT&T”)

- Operators of multiple facilities would mark the area “NO” followed by the appropriate company identifier in the matching APWA color code for that facility with a slash and the abbreviation for the type of facility that there is “No Conflict” (e.g. “NO PG&E/G/D”). The example illustrates that PG&E has no gas distribution facilities at this excavation site. The abbreviation for; gas transmission facilities is “/G/T”, electric distribution is “/E/D” and electric transmission is “/E/T” these should be used when appropriate.

- Place a clear plastic (translucent) flag that states “No Conflict” in lettering matching the APWA color code of the facility that is not in conflict. Include on the flag the operator’s identifier, phone number, a place to write the locate ticket number and date. Operators of multiple facilities would indicate on the flag, which facilities were in "No Conflict" with the excavation as in the previous example.

- If it can be determined through maps or records that the proposed excavation is obviously not in conflict with their facility (s) the locator or operator of the facility may notify the excavator of "No Conflict" by phone, fax, or email, or through the One-Call Center, where electronic positive response is used. Operators of multiple facilities would indicate a "No Conflict" for each facility as in the previous examples.

- Place "No Conflict" markings or flags in a location that can be observed by the excavator and or notify the excavator by phone, fax, or email that there is "No Conflict" with your facilities. When the excavation is delineated by the use of white markings, place "No Conflict" markings or flags in or as near as practicable to the delineated area.

* Caution - Allow adequate space for all facility mark-outs.

"No Conflict" indicates; that the operator providing the "No Conflict" has no facilities within the scope of the delineation, or when there is no delineation, there are no facilities within the work area as described on the locate ticket.

NO CTYSFO/W
NO MCI
NO PG&E/G/T
NO SBC

Work Area Delineation

<u>Color Code Identifiers</u>

White	Proposed Excavation	Pink	Temporary Survey Markings
Red	Electric Power Lines, Cables, Conduit and Lighting Cables	Yellow	Gas, Oil, Steam, Petroleum or Gaseous Materials
Orange	Communication, Alarm or Signal Lines, Cables or Conduit	Blue	Potable Water
Purple	Reclaimed Water, Irrigation and Slurry Lines	Green	Sewers and Drain Lines

Common Abbreviations:

Facility Identifiers

CH	Chemical	SS	Storm Sewer
E	Electric	SL	Street Lighting
FO	Fiber Optic	STM	Steam
G	Gas	SP	Slurry System
LPG	Liquefied Petroleum Gas	TEL	Telephone
PP	Petroleum Products	TS	Traffic Signal
RR	Railroad Signal	TV	Television
S	Sewer	W	Water
SD	Storm Drain	W	Reclaimed Water "Purple"

Underground Construction Descriptions

C	Conduit	HH	Hand Hole
CDR	Corridor	MH	Manhole
D	Distribution Facility	PB	Pull Box
DB	Direct Buried	R	Radius
DE	Dead End	STR	Structure (vaults, junction boxes, inlets, lift stations)
JT	Joint Trench	T	Transmission Facility
HP	High Pressure		

Infrastructure Material

ABS	Acrylonitrile - Butadiene – Styrene	HDPE	High Density Polyethylene
ACP	Asbestos Cement Pipe	MTD	Multiple Tile Duct
CI	Cast Iron	PLA	Plastic (conduit or pipe)
CMC	Cement Mortar Coated	RCB	Reinforced Concrete Box
CML	Cement Mortar Lined	RCP	Reinforced Concrete Pipe
CPP	Corrugated Plastic Pipe	RF	Reinforced Fiberglass
CMP	Corrugated Metal Pipe	SCCP	Steel Cylinder Concrete Pipe
CU	Copper	STL	Steel
CWD	Creosote Wood Duct	VCP	Vertrified Clay Pipe

Guide for Abbreviation Use

This is a guide for placing the above abbreviations in the field. The Company Identifier is to be placed at the top or at the left of the abbreviations. Place the abbreviations in the following order, Company Identifier / Facility Identifier / Underground Construction Descriptions / Infrastructure Material (e.g. SBC/TEL/FO/PLA). This example indicates that SBC has a Telecommunication Fiber Optic line in a single Plastic conduit. The use of the abbreviation /TEL is not necessary, because the orange marking would indicate that the facility was a communication line, but its use is optional. To leave out one or more of the abbreviation types you would continue to follow the order of the abbreviations above leaving out the slash and abbreviation that does not apply (e.g. /TEL), the result would be the following (e.g. SBC/FO/PLA).

CALIFORNIA BUSINESS AND PROFESSIONS CODE 7110

IN ASSEMBLY BILL FORM:

CONTRACTOR STATE LICENSE BOARD ENFORCEMENT Assembly Bill No. 2719

An Act to amend Section 7110 of the Business and Professions Code, relating to contractors.

LEGISLATIVE COUNSEL'S DIGEST

AB2719, as amended, Frazee. Contractors.

Existing law provides that violation of specified laws by a licensed contractor constitutes cause for disciplinary action.

This bill would include within the specified laws provisions dealing with excavations and subsurface installations.

The people of the State of California do enact as follows:

SECTION 1. Section 7110 of the Business and Professions Code is amended to read:

7110. Willful or deliberate disregard and violation of the building laws of the state, or of any political subdivision thereof, or of the minimum painting standards adopted pursuant to Section 37040 of the Health and Safety Code, or of Section 8505 or 8556 of this code, or of Sections 1689.5 to 1689.8, inclusive, or Section 1689.10 to 1689.13, inclusive, of Civil Code, or of the safety laws or labor laws or compensation insurance laws or Unemployment Insurance Code of the state, or violation by any licensee of any provision of the Health and Safety Code or Water Code, relating to the digging, boring, or drilling of water wells, or Article 2 (commencing with Section 4216) of Chapter 3.1 of Division 5 of Title 1 of the Government Code, constitutes a cause for disciplinary action.

CALIFORNIA GOVERNMENT CODE 4216

IN SENATE BILL FORM:

SENATE BILL NO. 1359

CHAPTER 651

An act to amend Sections 4216, 4216.2, 4216.3, 4216.4 and 4216.7 of the Government Code, relating to excavation around subsurface installations.

[Approved by Governor September 29, 2006. Filed with Secretary of State September 29, 2006.]

LEGISLATIVE COUNSEL'S DIGEST

SB 1359, Torlakson. Subsurface installations: excavations.

(1) Existing law requires planned excavations near subsurface installations to be conducted in a specified manner that protects the subsurface installations from damage. Existing law requires an excavator to determine the exact location of subsurface installations using specified tools. If the excavator still cannot locate the exact position of the installation, existing law then requires the excavator to request the operator to provide specified additional information to help determine the exact location of the installation. Existing law provides that an excavator who has failed to comply with regulations, as provided, is liable for any damages unless the owner or operator has not complied with regulations, as provided.

This bill would require the operator, if the excavation is within 10 feet of a high-priority subsurface installation, as defined, to notify the excavator of the installation, as specified, and to hold an onsite meeting with the operator to verify the location of the installation. This bill would allow only a qualified person, as defined, to perform subsurface installation locating activities, require a qualified person performing subsurface installation locating activities to use specified locating activities and devices, and require the operator to maintain plans for the subsurface installations. This bill also would require the regional notification center to provide an excavator with the operator's contact information and require an excavator to immediately notify the operator or 911 emergency services, if the operator cannot be contacted, when an excavator discovers or causes damage to a subsurface installation. This bill would also provide that any operator who fails to provide the position of a subsurface installation will be liable for any resulting costs, as specified, that the excavator may encounter as a result of the discrepancy. This bill would provide that an excavator will be liable for any resulting costs, as specified, for damages to a subsurface installation, for which the operator provided the position of, that are caused by the excavator.

(2) Existing law authorizes an excavator to determine the exact location of subsurface installations that are in conflict with the excavation before using any vacuum excavation devices or power-operated or power-driven excavating or boring equipment within the approximate location of the subsurface installation, provided there is an express written mutual agreement, as specified, and with a specified exception. If there is no express agreement, the excavator is required to use hand tools to determine the location of subsurface installations, as specified.

This bill would instead provide that, if documented notice of the intent to use vacuum excavation devices, or power-operated or power-driven excavating or boring equipment has been provided to the subsurface installation operator or operators and it is mutually agreeable to the operator or operators of the subsurface installation and the excavator, the excavator may use vacuum excavation devices or power-operated or power-driven excavating or boring tools within the approximate location of the subsurface installation.

The people of the State of California do enact as follows:

SECTION 1. Section 4216 of the Government Code is amended to read:

4216. As used in this article the following definitions apply:

(a) "Approximate location of subsurface installations" means a strip of land not more than 24 inches on either side of the exterior surface of the subsurface installation. "Approximate location" does not mean depth.

(b) "Excavation" means any operation in which earth, rock, or other material in the ground is moved, removed, or otherwise displaced by means of tools, equipment, or explosives in any of the following ways: grading, trenching, digging, ditching, drilling, augering, tunneling, scraping, cable or pipe plowing and driving, or any other way.

(c) Except as provided in Section 4216.8, "excavator" means any person, firm, contractor or subcontractor, owner, operator, utility, association, corporation, partnership, business trust, public agency, or other entity which, with their, or his or her, own employees or equipment performs any excavation.

(d) "Emergency" means a sudden, unexpected occurrence, involving a clear and imminent danger, demanding immediate action to prevent or mitigate loss of, or damage to, life, health, property, or essential public services. "Unexpected occurrence" includes, but is not limited to, fires, floods, earthquakes or other soil or geologic movements, riots, accidents, damage to a subsurface installation requiring immediate repair, or sabotage.

(e) "High priority subsurface installation" means high-pressure natural gas pipelines with normal operating pressures greater than 415kPA gauge (60psig), petroleum pipelines, pressurized sewage pipelines, high-voltage electric supply lines, conductors, or cables that have a potential to ground of greater than or equal to 60kv, or hazardous materials pipelines that are potentially hazardous to workers or the public if damaged.

(f) “Inquiry identification number” means the number that is provided by a regional notification center to every person who contacts the center pursuant to Section 4216.2. The inquiry identification number shall remain valid for not more than 28 calendar days from the date of issuance, and after that date shall require regional notification center revalidation.

(g) “Local agency” means a city, county, city and county, school district, or special district.

(h) “Operator” means any person, corporation, partnership, business trust, public agency, or other entity that owns, operates, or maintains a subsurface installation. For purposes of Section 4216.1 an “operator” does not include an owner of real property where subsurface facilities are exclusively located if they are used exclusively to furnish services on that property and the subsurface facilities are under the operation and control of that owner.

(i) "Qualified person" means a person who completes a training program in accordance with the requirements of Title 8, California Code of Regulations, Section 1509, Injury Prevention Program, that meets the minimum training guidelines and practices of Common Ground Alliance current Best Practices.

(j) “Regional notification center” means a nonprofit association or other organization of operators of subsurface installations that provides advance warning of excavations or other work close to existing subsurface installations, for the purpose of protecting those installations from damage, removal, relocation, or repair.

(k) “State agency” means every state agency, department, division, bureau, board, or commission.

(l) “Subsurface installation” means any underground pipeline, conduit, duct, wire, or other structure, except nonpressurized sewerlines, nonpressurized storm drains, or other nonpressurized drain lines.

4216.1. Every operator of a subsurface installation, except the Department of Transportation, shall become a member of, participate in, and share in the costs of, a regional notification center. Operators of subsurface installations who are members of, participate in, and share in, the costs of a regional notification center, including, but not limited to, the South Shore Utility Coordinating Council, the Underground Service Alert–Northern California or the Underground Service Alert–Southern California are in compliance with this section and Section 4216.9.

4216.2. (a) (1) Except in an emergency, any person planning to conduct any excavation shall contact the appropriate regional notification center, at least two working days, but not more than 14 calendar days, prior to commencing that excavation, if the excavation will be conducted in an area that is known, or reasonably should be known, to contain subsurface installations other than the underground facilities owned or operated by the excavator and, if practical, the excavator shall delineate with white paint or other suitable markings the area to be excavated.

(2) When the excavation is proposed within 10 feet of a high priority subsurface installation, the operator of the high priority subsurface installation shall notify the excavator of the existence of the high priority subsurface installation prior to the legal excavation start date and time, as such date and time are authorized pursuant to paragraph (1) of subdivision (a) of Section 4216.2. The excavator and operator or its representative shall conduct an onsite meeting at a mutually-agreed-on time to determine actions or activities required to verify the location of the high priority subsurface installations prior to start time.

(b) Except in an emergency, every excavator covered by Section 4216.8 planning to conduct an excavation on private property may contact the appropriate regional notification center if the private property is known, or reasonably should be known, to contain a subsurface installation other than the underground facility owned or operated by the excavator and, if practical, the excavator shall delineate with white paint or other suitable markings the area to be excavated.

(c) The regional notification center shall provide an inquiry identification number to the person who contacts the center pursuant to this section and shall notify any member, if known, who has a subsurface installation in the area of the proposed excavation. An inquiry identification number may be validated for more than 28 days when mutually agreed between the excavator and any member operator so notified that has a subsurface installation in the area of the proposed excavation; and, it may be revalidated by notification to the regional notification center by the excavator prior to the time of its expiration.

(d) A record of all notifications by excavators and operators to the regional notification center shall be maintained for a period of not less than three years. The record shall be available for inspection by the excavator and any member, or their representative, during normal working hours and according to guidelines for inspection as may be established by the regional notification centers.

(e) As used in this section, the delineation is practical when any of the following conditions exist:

(1) When delineating a prospective excavation site with white paint could not be misleading to those persons using affected streets and highways.

(2) When the delineation could not be misinterpreted as a traffic or pedestrian control.

(3) Where an excavator can determine the exact location of an excavation prior to the time an area has been field marked pursuant to Section 4216.3.

(4) Where delineation could not be construed as duplicative.

(f) Where an excavator makes a determination that it is not practical to delineate the area to be excavated, the excavator shall contact the regional notification center to advise the operators that the excavator shall identify the area to be excavated in another manner sufficient to enable the operator to determine the area of the excavation to be field marked pursuant to Section 4216.3.

4216.3. (a) (1) Any operator of a subsurface installation who receives timely notification of any proposed excavation work in accordance with Section 4216.2 shall, within two working days of that notification, excluding weekends and holidays, or before the start of the excavation work, whichever is later, or at a later time mutually agreeable to the operator and the excavator, locate and field mark the approximate location and, if known, the number of subsurface installations that may be affected by the excavation to the extent and degree of accuracy that the information is available either in the records of the operator or as determined through the use of standard locating techniques other than excavating, otherwise advise the person who contacted the center of the location of the operator's subsurface installations that may be affected by the excavation, or advise the person that the operator does not operate any subsurface installations that would be affected by the proposed excavation.

(2) <u>Only a qualified person shall perform subsurface installation locating activities.</u>

(3) <u>A qualified person performing subsurface installation locating activities on behalf of a subsurface installation operator shall use a minimum of a single-frequency utility locating device and shall have access to alternative sources for verification, if necessary.</u>

(4) <u>Operators of high priority subsurface installations shall maintain and preserve all plans and records for its subsurface installations.</u>

(b) Every operator of a subsurface installation who field marks the location of a subsurface installation shall make a reasonable effort to make field markings in conformance with the uniform color code of the American Public Works Association.

(c) If, at any time during an excavation for which there is a valid inquiry identification number, an operator's field markings are no longer reasonably visible, the excavator shall contact the appropriate regional notification center. The regional notification center shall contact any member, if known, who has a subsurface installation in the area of the excavation. Upon receiving timely notification or renotification pursuant to this subdivision, the operator shall re-locate and re-mark, within two working days, those subsurface installations <u>that</u> may be affected by the excavation to the extent necessary, in conformance with this section.

(d) The excavator shall notify the appropriate regional notification center of the failure of an operator to comply with this section. The notification shall include the inquiry identification number issued by the regional notification center. A record of all notifications received pursuant to this subdivision shall be maintained by the regional notification center for a period of not less than three years. The <u>record</u> shall be available for inspection pursuant to subdivision (d) of Section 4216.2.

4216.4. (a) When the excavation is within the approximate location of subsurface installation, the excavator shall determine the exact location of subsurface installations in conflict with the excavation by excavating with hand tools within the area of the approximate location of subsurface installations as provided by the operators in accordance with Section 4216.3 before using any power-operated or power-driven excavating or boring equipment within the approximate location of the subsurface installation, except that power-operated or power-driven excavating or boring equipment may be used for the removal of any existing pavement if there are no subsurface installations contained in the pavement. <u>If documented notice of the intent to use vacuum excavation devices, or power-operated or power-driven excavating or boring equipment, has been provided to the subsurface installation operator or operators and it is mutually agreeable with the operator or operators and the excavator</u>, the excavator may utilize vacuum excavation devices, or power-operated or power-driven excavating or boring equipment within the approximate location of a subsurface installation and to any depth.

(b) If the exact location of the subsurface installation cannot be determined by hand excavating in accordance with subdivision (a), the excavator shall request the operator to provide additional information to the excavator, to the extent that information is available to the operator, to enable the excavator to determine the exact location of the installation. <u>The regional notification center shall pro-</u>

vide the excavator with the contact phone number of the subsurface installation operator.

(c) An excavator discovering or causing damage to a subsurface installation, including all breaks, leaks, nicks, dents, gouges, grooves, or other damage to subsurface installation lines, conduits, coatings, or cathodic protection, shall immediately notify the subsurface installation operator. The excavator may contact the regional notification center to obtain the contact information of the subsurface installation operator. If high priority subsurface installations are damaged and the operator cannot be contacted, the excavator shall call 911 emergency services.

4216.5. The requirements of this article apply to state agencies and to local agencies which own or operate subsurface installations, except as otherwise provided in Section 4216.1. A local agency which is required to provide the services described in Section 4216.3 may charge a fee in an amount sufficient to cover the cost of providing that service.

4216.6. (a) (1) Any operator or excavator who negligently violates this article is subject to a civil penalty in an amount not to exceed ten thousand dollars ($10,000).

(2) Any operator or excavator who knowingly and willfully violates any of the provisions of this article is subject to a civil penalty in an amount not to exceed fifty thousand dollars ($50,000).

(3) Except as otherwise specifically provided in this article, this section is not intended to affect any civil remedies otherwise provided by law for personal injury or for property damage, including any damage to subsurface installations, nor is this section intended to create any new civil remedies for those injuries or that damage.

(4) This article shall not be construed to limit any other provision of law granting governmental immunity to state or local agencies or to impose any liability or duty of care not otherwise imposed by law upon any state or local agency.

(b) An action may be brought by the Attorney General, the district attorney, or the local or state agency which issued the permit to excavate, for the enforcement of the civil penalty pursuant to this section. If penalties are collected as a result of a civil suit brought by a state or local agency for collection of those civil penalties, the penalties imposed shall be paid to the general fund of the agency. If more than one agency is involved in enforcement, the penalties imposed shall be apportioned among them by the court in a manner that will fairly offset the relative costs incurred by the state or local agencies, or both, in collecting these fees.

4216.7 (a) If a subsurface installation is damaged by an excavator as a result of failing to comply with Section

4216.2 or 4216.4, or as a result of failing to comply with the operator's requests to protect the subsurface installation as specified by the operator prior to the start of excavation, the excavator shall be liable to the operator of the subsurface installation for resulting damages, costs, and expenses to the extent the damages, costs, and expenses were proximately caused by the excavator's failure to comply.

(b) If the operator of a subsurface installation has failed to comply with the regional notification center system requirements of Section 4216.1, that operator shall forfeit his or her claim for damages to his or her subsurface installation, arising from the excavation, against an excavator who has complied with the requirements of Section 4216.2 to the extent damages were proximately caused by the operator's failure to comply.

(c) If an operator of a subsurface installation has failed to comply with the provisions of Section 4216.3, has failed to comply with paragraph (2) of subdivision (a) of Section 4216.2, or has failed to comply with subdivision (b) of Section 4216.4, the operator shall be liable to the excavator who has complied with Sections 4216.2 and 4216.4 for damages, costs, and expenses resulting from the operator's failure to comply with these specified requirements to the extent the damages, costs, and expenses were proximately caused by the operator's failure to comply.

(d) Nothing in this section shall be construed to do any of the following:

(1) Affect claims including, but not limited to, third-party claims brought against the excavator or operator by other parties for damages arising from the excavation.

(2) Exempt the excavator or operator from his or her duty to mitigate any damages as required by common or other applicable law.

(3) Exempt the excavator or operator from liability to each other or third parties based on equitable indemnity or comparative or contributory negligence.

4216.8. This article does not apply to any of the following persons:

(a) An owner of real property who contracts for an excavation project on the property, not requiring a permit issued by a state or local agency, with a contractor or subcontractor licensed pursuant to Article 5 (commencing with Section 7065) of Chapter 9 of Division 3 of the Business and Professions Code.

(b) An owner of residential real property, not engaged as a contractor or subcontractor licensed pursuant to Article 5 (commencing with Section 7065) of Chapter 9 Division 3 of the Business and Professions Code, who as part of improving his or her principal residence or appurtenances thereto is performing or having performed excavation work not requiring a permit issued by a state or local agency.

(c) Any person or private entity that leases or rents power operated or power-driven excavating or boring equipment, regardless of whether an equipment operator is provided for that piece of equipment or not, to a contractor or subcontractor licensed pursuant to Article 5 (commencing with Section 7065) of Chapter 9 of Division 3 of the Business and Professions Code, if the signed rental agreement between the person or private entity and the contractor or subcontractor contains the following provision: "It is the sole responsibility of the lessee or renter to follow the requirements of the regional notification center law pursuant to Article 2 (commencing with Section 4216) of Chapter 3.1 of Division 5 of Title 1 of the Government Code. By signing this contract, the lessee or renter accepts all liabilities and responsibilities contained in the regional notification center law."

4216.9. (a) No permit to excavate issued by any local agency, as defined in Section 4216, or any state agency, shall be valid unless the applicant has been provided an initial inquiry identification number by a regional notification center pursuant to Section 4216.2. For purposes of this section, "state agency" means every state agency, department, division, bureau, board, or commission, including the Department of Transportation.

(b) This article does not exempt any person or corporation from Sections 7951, 7952, and 7953 of the Public Utilities Code.

SEC. 5. Section 4217 of the Government Code is repealed.

CalOSHA Title 8
Construction Safety Orders
Chapter 4, Subchapter 4, Article 6, Section 1541

Effective March 31, 2007

§1541. General Requirements.

(a) Surface encumbrances. All surface encumbrances that are located so as to create a hazard to employees shall be removed or supported, as necessary, to safeguard employees.

(b) Subsurface installations.

(1) The <u>approximate</u> location of <u>subsurface installations</u>, such as sewer, telephone, fuel, electric, water lines, or any other <u>subsurface installations</u> that <u>reasonably</u> may be expected to be encountered during excavation work, shall be determined <u>by the excavator</u> prior to opening an excavation.

<u>(A) Excavation shall not commence until:</u>

1. The excavation area has been marked as specified in Government Code Section 4216.2 by the excavator; and

2. The excavator has received a positive response from all known owner/operators of subsurface installations within the boundaries of the proposed project; those responses confirm that the owner/operators have located their installations, and those responses either advise the excavator of those locations or advise the excavator that the owner/operator does not operate a subsurface installation that would be affected by the proposed excavation.

(B) When the excavation is proposed within 10 feet of a high priority subsurface installation, the excavator shall be notified by the facility owner/operator of the existence of the high priority subsurface installation before the legal excavation start date and time in accordance with Government Code Section 4216.2(a), and an onsite meeting involving the excavator and the subsurface installation owner / operator's representative shall be scheduled by the excavator and the owner / operator at a mutually agreed on time to determine the action or activities required to verify the location of such installations. High priority subsurface installations are high pressure natural gas pipelines with normal operating pressures greater than 415 kPA gauge (60 p.s.i.g.), petroleum pipelines, pressurized sewage pipelines, conductors or cables that have a potential to ground of 60,000 volts or more, or hazardous materials pipelines that are potentially hazardous to employees, or the public, if damaged.

(C) Only qualified persons shall perform subsurface installation locating activities, and all such activities shall be performed in accordance with this section and Government Code Sections 4216 through 4216.9. Persons who complete a training program in accordance with the requirements of Section 1509, Injury and Illness Prevention Program (IIPP), that meets the minimum training guidelines and practices of the Common Ground Alliance (CGA) Best Practices, Version 3.0, published March 2006, or the standards of the National Utility Locating Contractors Association (NULCA), Standard 101: Professional Competence Standards for Locating Technicians, 2001, First Edition, which are incorporated by reference, shall be deemed qualified for the purpose of this section.

(D) Employees who are involved in the excavation operation and exposed to excavation operation hazards shall be trained in the excavator notification and excavation practices required by this section and Government Code Sections 4216 through 4216.9.

(2) All Regional Notification Centers as defined by Government Code Section 4216(j) in the area involved and all known owners of subsurface facilities in the area who are not members of a Notification Center shall be advised of the proposed work at least 2 working days prior to the start of

any digging or excavation work. EXCEPTION: Repair work to subsurface facilities done in response to an emergency as defined in Government Code Section 4216(d).

(3) When excavation or boring operations approach the approximate location of subsurface installations, the exact location of the installations shall be determined by safe and acceptable means that will prevent damage to the subsurface installation, as provided by Government Code Section 4216.4.

(4) While the excavation is open, subsurface installations shall be protected, supported, or removed as necessary to safeguard employees.

(5) An excavator discovering or causing damages to a subsurface installation shall immediately notify the facility owner/operator or contact the Regional Notification Center to obtain subsurface installation operator contact information immediately after which the excavator shall notify the facility operator. All breaks, leaks, nicks, dents, gouges, grooves, or other damages to an installation's lines, conduits, coatings or cathodic protection shall be reported to the subsurface installation operator. If damage to a high priority subsurface installation results in the escape of any flammable, toxic, or corrosive gas or liquid or endangers life, health or property, the excavator responsible shall immediately notify 911, or if 911 is unavailable, the appropriate emergency response personnel having jurisdiction. The facility owner/operator shall also be contacted.

Note: The terms excavator and operator as used in Section 1541(b) shall be as defined in Government Code Section 4216(c) and (h) respectively. The term "owner / operator" means an operator as the term "operator" is defined in Government Code Section 4216(h).

USA North's

California Excavation Manual

811 / 1-800-227-2600

Know what's below. Call before you dig.

USA North (Underground Service Alert)
4090 Nelson Avenue, Suite A, Concord, CA. 94520-1232
Administrative: Phone 925-798-9504; Fax 925-798-9506;
Web Page: www.usanorth.org

This manual is provided to you as a public service by USA North and is dedicated to the safety of our communities in California and Nevada.

Know what's below.
Call 2 Working Days To 14 Calendar Days Before You Dig in California and Nevada!

Revised 01/01/09 ©

CATEGORY 12: UTILITY CLEARANCE

Section 12.2

USA North 811 Ticket Form

USA NORTH 811 TICKET FORM

Whether you enter your ticket online or over the phone, here is the list of questions you will be required to answer.

Business Phone:__________________ **Fax**:_______________ **Email Address:**________________________________

Your Name:______________________________ **Your Company Name** (if applicable):__________________________
Type (Contractor, Homeowner, or USA North Member):____

Company Address (include City/State/Zip Code:)____

What County is your work being done in:____

Will any of your excavation work include Night Work or Weekend Work:__________________________________

Start Date & Time (2 working day notice required):___________________ **Working For**:__________________________

As required has your excavation site been pre-marked:____
Pre-mark method used (What did you use to mark the site):____

Do you have a permit for your work (if yes who issued that permit & what is the permit #):__________________________

Foreman Name:___________________________ **Foreman Cell:** ____

Does your excavation include Boring, if so what type:____

What is the type/nature of work (augering, drilling, grading, trenching, ripping, etc and the reason why you are doing the work):____

Will Explosives be used at the work site:_______ **Do you intend to use vacuum equipment instead of hand digging to determine the exact location of our member's underground facilities:**__________________________________

Digsite Place (City or Community name):____

Where is your work taking place (Address, intersection, side of street, etc. Every location must have a street and cross street. Without an address the location must include side of street & the distance and direction from the cross street. If your work covers an area make sure to include the distances and directions for that as well. More information is available in the USA North Excavation Manual for your state):____
____
____

Will the excavation enter into the street or sidewalk Area:____

The following information will be provided by USA North after you have completed your ticket:

Ticket#:______________ **Date**:_______________ **Expiration Date**:_______________ **Update Date**:_______________

Tickets can be entered online 24/7 at www.usanorth811.org

- To enter **single address digging work** click on the Single Address Ticket Entry Homeowners/Excavators button on our home page.
- To enter **all other types of digging work**, click on the E-Ticket Training Videos link and then follow the instructions.

Call 811 to submit your digging work over the phone

- 6 a.m.—7 p.m. Mon-Fri excluding observed holidays (a list of observed holidays can be found at www.usanorth811.org)

CATEGORY 12: UTILITY CLEARANCE

Section 12.3

USA North Color Brochure

Color Code for:

Marking Excavation Sites & Underground Facilities

	SYMBOL	FACILITY TYPE
	None	Proposed Excavation
	None	Temp. Survey Marking
	SL, E, TS	Street Lighting, Electric, Traffic Signals
	G, Company Name	Gas, Oil, Steam, Chemical
	FA, Tel, R, TV	Fire Alarm, Telephone, Railroad, Television
	W	Water
	W	Reclaimed Water, Irrigation, Slurry
	S, SD	Sewer, Storm Drain

Call Before You Dig

Please, don't wait until the last minute. No matter if your excavation job is large or small, do the safe thing. Call USA North 2 working days to 14 calendar days before you dig in California and Nevada. Your location request number (USA North ticket) is good for 28-calendar days in California and Nevada from the date of issuance of the ticket. If your work will continue past 28-calendar days in California or Nevada, please call USA North and extend your location request ticket. You may extend your USA North ticket the last 6 calendar days of the life of the ticket.

Safety Awareness

Please join USA North and its members and make our community a safe place to live and work! So whatever you do, do it safe, but call before you dig.

USA North Center Holidays

- New Year's Day
- President's Day
- Memorial Day
- Independence Day
- Labor Day
- Thanksgiving Day
- Day After Thanksgiving
- Christmas Day

Call 811 or 1-800-227-2600

Call USA North 2 working days to 14 calendar days before you dig in California or Nevada.

811®

Know what's below. Call before you dig.

4005 Port Chicago Highway Suite 100
Concord, CA 94520-1122
925-798-9504
www.usanorth.org

Hours of Operation
6:00 a.m. to 7:00 p.m.
Monday through Friday
Except Holidays Listed

USA North

Dig Safely.

It's Simple and It's FREE

Call 811 or 1-800-227-2600

Safe digging information for Homeowners, Excavators Professional Contractors or anyone planning to dig.

811®

Know what's below. Call before you dig.

Underground Service Alert - USA North

USA North provides a free and effective Damage Prevention Service that protects our citizens, our communities, our environment, our essential public services, and our underground facilities in Central / Northern California and all of Nevada. Our purpose is to receive planned excavation (disturbing the ground in any way) reports that will begin within the next 2 working days to 14 calendar days in California and Nevada, from homeowners, excavators, or professional contractors, and transmit those planned excavation reports to all participating members of USA North who may have underground facilities at that excavation site. The members notified of your excavation by USA North will mark, or stake the horizontal path of their facility with the appropriate color code, provide you information about the location of their facility, or advise of clearance (please see Step 3 of the "5 Steps to a Safe Excavation" for further details).

Requirements

Legislation: California Government Code 4216, Nevada Revised Statues NRS 455 make it mandatory for those excavating to call the One Call Center (USA North) at least 2 working days but not more than 14 calendar days before you dig. Failure to do so can result in a fine and/or the cost of any damages. In addition there could be liability for third party damages.

Call 811 or 1-800-227-2600

811

Know what's **below.**
Call before you dig.

Five Steps To A Safe Excavation.

Dig Safely.

1 Survey and Mark:

Survey your proposed excavation site. Make a list of affected operators of underground facilities (operators) at your job site, their needs, and requirements. Mark the excavation site on paved surfaces with white spray chalk, water base, UV paint or equivalent less permanent type marking; use flags, stakes, whiskers, etc. on unpaved surfaces, (Homeowners can use flour).

2 Call Before You Dig:

Call USA North 2 working days to 14 calendar days before you dig in California or Nevada. Only operators who are members of the USA North program will be notified. Compare your list of affected operators determined in Step 1, with the list of operators notified by USA North. For your safety contact any operator at your job site that is not a member of USA North. USA North accepts design inquiry requests through its internet application only, call 1-800-640-5137 ext 2309 for more information. In case of a life-threatening situation, call 911 or your local fire department.

3 Wait the Required Time:

The legal 2 working days to 14 calendar days notice in California and Nevada allows USA North members to examine their underground facility records and respond to you. Excavators are required by law to wait until all operator(s) of subsurface installations have provided a positive response to their excavation site. The positive response includes operator's marking, or staking the horizontal path of their facility using the appropriate color code, providing information about the location of their facility, or advising you of clearance. Depending on our member's workload, they may contact you to try to negotiate a new start time for your excavation.

4 Respect the Marks:

Preserve facility marks for the duration of the job. If any of the operator markings are not reasonably visible, you must call USA North and request re-marking by the affected operator(s). A re-mark request requires a 2 working day notice. When you request an operator(s) to re-mark their facilities, you will be asked if your excavation site is still outlined in white, so the USA North members can respond to your request.

Note: *A USA North ticket is active for 28 calendar days in California and Nevada from the date of its issuance. You must have an active USA North ticket for the entire duration of your excavation.*

5 Dig With Care:

In California and Nevada hand excavate within 24" of the outside diameter of the facility. Facilities that are in conflict with your excavation are to be located with hand tools and protected before power equipment is used. Notify the affected utility of any contact, scrape, dent, nick, or damage to their facility.

APPENDIX C

PACE ANALYTICAL SERVICES QUALITY ASSURANCE MANUAL

QUALITY ASSURANCE PLAN

for

Isotech Laboratories, Inc.
1308 Parkland Court
Champaign, IL 61821

Revised March 22, 2012

3/22/2012

General Manager Date

3/22/2012

QC Manager Date

GENERAL QA/QC PROCEDURES

1. SAMPLES

1.1 Sampling Procedures It is the responsibility of the person collecting a sample to follow a sound sampling procedure. This will ensure that the sample collected is representative of the whole. We at Isotech will provide advice on sampling methods, sample storage procedures, and sample size requirements.

1.2 Sample Containers Sample containers should be matched in size, type and condition to the anticipated analysis that will give best representation of the source, while preserving the sample integrity prior to analysis. Unless sample containers are provided by Isotech, the responsibility for adequate containers resides with the client. Again, in addition to being able to provide appropriate sample containers, shipping cartons and shipping instructions, Isotech will provide advice on sample containers/cartons and shipping procedures.

1.3 Sample Custody A completed "Chain of Custody" record is the responsibility of the client and, if required, should be submitted with the samples. Isotech will provide a "Chain of Custody/Request for Analysis" form if needed. Isotech assumes full responsibility for all samples received and stored for analysis at our laboratory. If any samples are removed from Isotech for additional analysis at other laboratories, a "Chain of Custody" form will be completed. All samples received for analysis are assigned a unique, non-duplicated laboratory number which is used as an identifier for each analysis performed.

2. INSTRUCTIONS AND PROCEDURES

2.1 Instrument Operation Procedures Analyses performed with manufactured analysis instruments are carried out by the methods either specified or recommended by the manufacturer of the instrument as identified in the instrument manual or provided by on-site training through the manufacturer's service technicians. Much of the operation of these instruments is controlled by personal computers utilizing software written and licensed by the manufacturers.

2.2 Analytical Procedures The analytical procedures used routinely at Isotech are described in written standard operating procedures (SOP's) for each analysis. Additional procedures may be used, as needed, in the process of satisfying a client's specific analysis requirements. These procedures will either follow published analytical methods, or methods developed at Isotech for a specific analysis. If the Isotech developed procedure becomes routine, then a standard operating procedure is written. All procedures are reviewed and approved by the laboratory supervisors. Various procedural tests and verifications performed are recorded in bound maintenance log books.

3. CALIBRATION AND STANDARDIZATION

3.1 Calibration Procedure and Frequency Depending on the analytical technique, instruments used for quantitative analyses are either calibrated at the beginning of every operating period or the calibration is checked by using a reference sample or a calibration standard. The instrument calibration is also checked at appropriate intervals during analyses. Specific instruments that form components of a sample preparation system are calibrated using duplicate sample analysis as well as analysis of a reference sample at appropriate intervals. Records of calibration results are kept in laboratory notebooks or other secure medium (see Documentation).

3.2 Method Validation Analytical methods are validated by one or more of the following techniques:

3.2.1 check or reference samples are analyzed and the results are compared with the internal documented or external certified (primary and secondary standards) values,

3.2.2 results from the candidate method are compared with those from another method known to be applicable and reliable, or

3.2.2 spiked samples and surrogate samples are analyzed and the method results are compared with the known concentrations.

3.3 Check/Reference Samples A check/reference sample is analyzed approximately every tenth analysis. This, in essence, results in a test of the method. Check/reference samples are chosen which have been analyzed multiple times over an extended period of time with consistent results.

3.4 Standards Primary standards are obtained from the International Atomic Energy Agency, Vienna, Austria, and certified by NIST (National Institute of Standards and Technology, formerly U.S. National Bureau of Standards) or directly from NIST. Secondary standards are obtained from commercially available sources recognized in the industry. Internal Reference standards are prepared by direct calibration against primary and secondary standards.

3.5 Duplicate Samples Duplicate analyses are performed approximately every tenth analysis. This duplicate sample analysis is performed approximately five analyses after the check/reference sample analysis is performed. Therefore, for a particular analysis procedure, a test of the method is performed every five analyses. This assures that at least 20% of all analyses are for maintaining QA/QC.

3.6 Specific Routine Procedures to Assess Performance Standard reference samples, chosen to match the submitted samples as closely as possible, in conjunction with duplicate samples and check samples, provide a matrix for performance evaluation. If a problem is detected with the reference sample, then the problem is first addressed by checking the integrity of the sample itself. Other reference samples are analyzed to determine if the problem persists. If reference sample integrity is verified, further diagnostic testing is carried out until the cause of the discrepancy is identified.

Isotech willingly participates in round-robin testing whenever the opportunity arises and has participated in studies by IAEA and industry. Instrument calibration is carried out whenever analysis of internal standards and check samples suggests a potential problem.

3.7 External Quality Control Checks Blind duplicates, check samples, blanks, and spiked samples may be submitted by the client, and this practice is encouraged.

4. ANALYSES AND ANALYTICAL RESULTS

4.1 Data Reduction and Reporting Calculations made in reducing raw data to reportable form are verified (preferably by a second person) before reporting the results to the client. If a computer program is used to perform calculations, the accuracy of the input data is verified by comparison with the raw data. In all cases where computer programs are used to make the calculations, the person making the calculations verifies that the proper program is used. Data reduction and calculation is performed automatically by the computers which control the instruments. Reported results are verified relative to the computer printouts.

4.2 Hard Copy and Electronic Data Deliverables Normally, final data is emailed to clients as an Excel workbook file, and also a PDF version of the data. Depending on the sample type, hard copy reports can be either a single page per sample, or can be in tabular format with multiple samples per page. Hard copy reports are not mailed to clients, unless clients specifically request them. Upon request, CD’s will be submitted to clients in addition to the hard copy reports. Also, appropriate graphs will be provided upon request. Compositional analyses for natural gas samples are normalized when the Analysis Report is generated. Upon request a QA/QC report containing results for all check samples and duplicates as well as copies of raw data can be provided at additional cost.

4.3 Documentation All laboratory notes, observations, calibrations, manual calculations, and any other pertinent information are kept in bound laboratory notebooks or other secure recording medium. Computer programs used for data storage, retrieval, and calculations, which are developed within Isotech Laboratories, Inc., are documented well enough that someone not intimately familiar with the program development, but who is familiar with the programming language, can understand the operation of the program. Printed and dated copies of the current version and each previous version (insofar as possible) of the program are kept in the developer's files. These copies remain at and are the property of Isotech, should the developer leave employment of Isotech Laboratories, Inc. Electronic backup copies of currently-used computer programs are securely kept by the program's developer or principal user. Backup copies of analyses databases are made periodically. The frequency of making backup copies depends on the frequency of updating the database, but the minimum frequency for making backup copies is weekly. All laboratory notebooks, data, computer programs, computerized databases, and any other means of recording data, observations, calculations, and other pertinent information developed at or on behalf of Isotech, remain the property of Isotech Laboratories, Inc., unless otherwise designated.

4.4 Hard Copy Data Files and Storage All pertinent paperwork associated with each batch of samples is stored in the client files. Typical paperwork can include chain of custody records, client analysis requests, email communication to/from clients regarding samples, final data, and cover letter mailed to client with final data. Data files are kept indefinitely unless clients request that we dispose of them.

5. MAINTENANCE AND REPAIR

5.1 Instruments Each instrument or machine used to produce quantitative analysis results, or leading up to their production, undergoes periodic preventive maintenance according to manufacturer's instructions, or some established preventive maintenance schedule. Preventive maintenance may be done by laboratory personnel, manufacturer's representative, or a qualified third-party contractor, depending on the abilities of the laboratory operator and the complexity of the equipment. Records of repairs and preventive maintenance are kept by the appropriate laboratory personnel in files or notebooks. Records of equipment problems and solutions are kept in files or notebooks. The analyst is the person best qualified to recognize when the instrument or machine they operate is in need of repair, or the method they practice is in need of corrective action. Corrective action is needed when predetermined limits for data acceptability are exceeded. Analysts are also to use their experience and scientific judgment in deciding when corrective action is needed.

5.2 Other Equipment Other laboratory equipment such as vacuum pumps, ovens, test meters and non-instruments such as glassware are maintained by Isotech personnel. In most cases this is performed by the same person who utilizes the equipment for analysis. Visual checks backed by mechanical and electronic gauges provide constant maintenance checks directly to the operators.

6. REVIEW

6.1 Analytical Review At the time of each analysis or sample preparation, the staff chemist performing the analysis reports anomalies to the QC Manager. Staff chemists are all trained on a variety of techniques and work closely together. Constant communication between staff members results in most problems being addressed when they occur. Unusual problems are brought to the attention of the management team. Whenever possible, a sample that is questionable for any reason is re-analyzed to verify results, regardless of when the sample was analyzed initially. This means that more than 10% of samples will be duplicates if the data appears to be unusual in any way.

Before final reports are printed, data is checked to verify that the final data agrees with the raw printouts, and raw percentages for compositional analyses are checked to ensure that all components are identified. Reproducibility of duplicate isotopic samples is compared to stated precision limits. Analytical data is reviewed for anomalies by project coordinators and/or managers.

6.2 Standard Operating Procedures (SOP's): These procedures are developed from specific analytical methods for operating specified equipment to obtain high quality data reflective of each sample analyzed. In addition to revisions due to procedural or equipment changes these SOP's are reviewed by the QC Manager annually.

7. QA/QC PROBLEM REPORTING

7.1 Responsibilities QA/QC is the responsibility of every person who collects or analyzes samples. If any Isotech Laboratories employee observes any QA/QC problem, that employee will discuss the problem with the analyst, QC Manager, Lab Manager or General Manager. No negative action will ever be brought against nor will accrue to any staff member who reports QA/QC problems.

8. SUBCONTRACT POLICY

Samples for analysis of ^{14}C (radiocarbon) are converted to purified carbon dioxide and then submitted to an established radiocarbon dating laboratory for the final analysis. When analyses are requested for which Isotech does not have either the necessary equipment or expertise to provide high quality results, these analyses too may, with the knowledge of the client, be submitted to a subcontract laboratory. Only established, reputable laboratories which maintain strict QA/QC control are utilized. All samples are prepared and packaged using techniques that have been recommended or approved by the subcontract laboratory. Analysis of reference samples and standards is the responsibility of the subcontract laboratory. Duplicate analyses of samples submitted to a subcontract laboratory should be requested by the client and will be charged as regular samples.

APPENDICES: ANALYTICAL PROCEDURES

I. Sample Preparation Procedures for Stable Isotope Analyses

A. Procedures for Stable Isotope Analysis of Water Samples

1. δ^{13}C (Carbon Isotope Analysis) of Dissolved Inorganic Carbon (DIC)

<u>Equipment and Supplies</u>

Thermo GasBench II
Thermo Delta V Plus
12mL Exetainer® with septum cap
Micro spin bar
1mL syringe
23G needle
85% Phosphoric acid
0.1N HCl

<u>Method/Procedure</u> The δ^{13}C of DIC is determined by injecting up to 1 ml of sample water into a helium flushed 12mL Exetainer® containing 0.1mL of 85% phosphoric acid and a magnetic spin bar. Sample size is determined based on alkalinity, which is measured by titration with 0.1N HCl.

The sample is stirred for a minimum of one hour and then allowed to equilibrate for 24 hours. At time of analysis the sample vials are placed in the GasBench tray. The CO_2 generated is flushed out of the vial via a two port needle. Water is removed by two nafion traps, and pure CO_2 is separated using a GC column. The CO_2/helium mixture then enters the mass spectrometer and is compared against a reference standard a total of six times.

<u>Maintenance</u> Vials are recycled and the spin bars are thoroughly cleaned and reused. Gas flow rates through the GasBench system are periodically checked.

<u>QA/QC</u> At a minimum, every tenth analysis is a replicate. A check standard is analyzed every tenth analysis.

<u>Calculation</u> Calculations are performed by the software on the IRMS (Isotope Ratio Mass Spectrometer) at the time of analysis. Data normalization against internal lab standards is performed using Microsoft Excel.

<u>Documentation</u> All procedural tests and verifications performed are recorded in bound maintenance log books. All sample data including the date prepared with analyst identification are recorded on laboratory log sheets and in bound log books.

2. δD (Hydrogen Isotope Analysis) and $\delta^{18}O$ (Oxygen Isotope Analysis) of H_2O

Equipment

3mL syringes
0.2 micron syringe filters
2mL glass vials with septum caps
Picarro CRDS (cavity ringdown spectrometer) model L1102-i fitted with a Leap autosampler

Method/Procedure Water samples are individually filtered into 2mL vials with 0.2 micron syringe filters. If samples are high salinity brines, they should be vacuum distilled prior to loading. The vials are then loaded onto trays which are installed on the autosampler. Samples are analyzed by the CRDS in replicate in accordance with the manufacturer's recommendation.

QA/QC Two reference water samples are used to verify accuracy and reproducibility. These reference waters are analyzed approximately every tenth analysis. The system is calibrated by analysis of primary reference standards obtained from IAEA or NIST. At a minimum, every tenth sample analysis is a replicate.

Calculation Calculations are performed by the software on the CRDS at the time of analysis. Data normalization against internal lab standards is performed using Microsoft Excel.

Documentation All procedural tests, sample preparations and verifications performed are recorded in bound maintenance log books. All final data including the date prepared with analyst identification in bound log books.

3. $\delta^{15}N$ and $\delta^{18}O$ (Nitrogen and Oxygen Isotope Analysis) of Dissolved Nitrate

Equipment and Supplies

0.45 nylon filter paper
Glass filtration apparatus
1N HCl
$BaCl_2$
Cation exchange resin
Anion exchange resin
1N HBr
Ag_2O
Flasks

Stirbars
Freezer
Oven
Freeze-dryer
Teflon beakers
Thermo Delta V Plus
Mettler Toledo MX5 Ultra-Microbalance
Thermo TC/EA
Thermo ConFlo II

Method/Procedure Nitrate is extracted from groundwater samples and converted into $AgNO_3$ using ion-exchange techniques. The nitrate concentration is determined using an Orion AquaFAST ™ colorimeter. The appropriate sample size is filtered and placed on a hot plate to boil. The pH is adjusted to 1-3 using 1N HCl. $BaCl_2$ is added to remove dissolved sulfates, and the sample volume is decreased to 250mL. Precipitated $BaSO_4$ is filtered from the sample and placed into separatory funnels. The sample is allowed to flow through a cation column and then through the anion column, where nitrate is held within the column. 1N HBr is added to the column to strip the nitrate. The eluent is collected and silver oxide is added to create $AgNO_3$. The sample is filtered, frozen in a Teflon beaker, and placed in a freeze drying vacuum oven until only the $AgNO_3$ crystals remain. The crystals are then analyzed using for $\delta^{15}N$ using an EA-IRMS and analyzed for $\delta^{18}O$ using a TC/EA-IRMS system.

Analysis of $\delta^{15}N$ is performed using a Carlo Erba Elemental Analyzer. 1.2 milligrams of $AgNO_3$ is weighed into tin boats and placed in an Autosampler with helium purge. The sample is flash combusted inside the combustion reactor, as shown in this reaction $N + O_2 \rightarrow N_xO_y + N_2$. The products of combustion reaction are then carried to the reduction reactor where excess oxygen is removed, and nitrogen oxides (N_xO_y) are reduced to elemental nitrogen (N_2). The N2 gas is introduced to the IRMS through a ConFlo II interface. Sample values are referenced against international standards.

Analysis of $\delta^{18}O$ is performed using a Thermo TC/EA. 300 micrograms of $AgNO_3$ is weighed into silver boats and placed in a zero blank autosampler. The sample is thermally converted to CO gas in the EA furnace. The CO gas is introduced into the IRMS through a ConFlo II interface. Sample values are referenced against international standards.

Maintenance Glassware is washed and rinsed with deionized water to remove residual sample and residual $AgNO_3$.

QA/QC At a minimum, every tenth sample preparation is a duplicate. Approximately every tenth EA/TCEA analysis a set of standards is analyzed after every ten samples, along with at least one check standard per analysis run.

Calculation Calculations are performed by the software on the IRMS (Isotope Ratio Mass Spectrometer) at the time of analysis. Data normalization against primary international standards is performed using Microsoft Excel.

Documentation All records of sample preparation and notes are hand written in bound log books. All sample data including the date prepared are stored electronically and in print.

Sample Handling Samples should be collected and frozen until analyzed. Samples should be shipped overnight in a cooler on ice. Filtering prior to shipment is preferred but is not required.

4. $\delta^{34}S$ & $\delta^{18}O$ (Sulfur and Oxygen Isotope Analysis) of Dissolved Sulfate

Equipment and Supplies

Thermo Delta V Plus
Mettler Toledo MX5 Ultra-Microbalance
Elementar Vario EL
Thermo TC/EA
Thermo ConFlo II
Thermo AQUAFast II ™ Colorimeter
0.45 micron nylon filter
1N HCl
$BaCl_2$ solution
Filtering apparatus
Various sized beakers
Drying oven
Petri dishes
Tin boats
Silver boats

Method/Procedure The $\delta^{34}S$ & $\delta^{18}O$ of dissolved sulfate is determined by the barium sulfate precipitation technique. Prior to preparation the sulfate concentration must be obtained from the client or determined using a Thermo AQUAFast II ™ colorimeter; a minimum sulfate concentration of 5ppm is required for this analysis. Once the sulfate concentration is known, the amount of sample needed to obtain 25mg of barium sulfate is weighed into a clean beaker. Samples are then filtered to remove particulate matter before being brought to a boiling temperature. Calcium carbonate in the sample is removed by adding 1N hydrochloric acid until the sample reaches a pH of 1-3. An appropriate amount of barium chloride solution is added based on the concentration of sulfate in the sample. The reaction is given sufficient time to complete under heat; a testing solution is used to ensure that all dissolved sulfate has precipitated. The precipitant is then filtered and dried, the final amount is weighed.

The $\delta^{34}S$ of the dried barium sulfate is then determined by combustion to SO_2 gas using an Elementar Vario EL EA. Approximately 1.2mg $BaSO_4$ is weighed into a tin capsule and loaded into an autosampler. The sample is then combusted and passed over a reduction furnace. The resulting SO_2 gas is passed through a ConFlo II interfaced to the IRMS, where it is compared against a reference gas.

Analysis of $\delta^{18}O$ is performed using a Thermo TC/EA. Approximately 300 micrograms of $BaSO_4$ is weighed into silver boats and placed in a zero blank autosampler. The sample is thermally converted to CO gas in the EA furnace. The CO gas is introduced into the IRMS through a ConFlo II interface. Sample values are referenced against international standards.

Maintenance Glassware is washed and rinsed with deionized water to remove residual $BaSO_4$.

QA/QC At a minimum, every tenth sample preparation is a duplicate. Approximately every tenth EA/TCEA analysis a set of standards is analyzed after every ten samples, along with at least one check standard per analysis run.

Calculation Calculations are performed by the software on the IRMS (Isotope Ratio Mass Spectrometer) at the time of analysis. Data normalization against primary international standards is performed using Microsoft Excel.

Documentation All records of sample preparation and notes are hand written in bound log books. All sample data including the date prepared are stored electronically and in print.

Sample Handling Samples should be collected and stored at 4°C until analyzed. Samples should be shipped overnight in a cooler on ice. Filtering prior to shipment is preferred but is not required.

B. Procedures for Stable Isotope Analysis of Gas Samples

1. $\delta^{13}C$ and δD (Carbon and Hydrogen Isotope Analysis) for Hydrocarbon Gases, Offline Prep Systems

Equipment and Supplies

3 SRI 8610C Gas chromatographs
Evacuated transfer system
Copper oxide combustion furnace
Dry ice
Isopropyl alcohol
Liquid nitrogen
Electronic manometer
Electronic vacuum gauge

Helium
Oxygen
Gas-oxygen torch

Method/Procedure The determination of carbon and hydrogen isotopic ratios for hydrocarbons in gas mixtures (e.g. natural gas) requires a sample preparation system capable of first separating the individual hydrocarbons and then quantitatively converting them into carbon dioxide (CO_2) and water for mass-spectrometric analysis. There are 2 systems utilized for processing natural gases. The systems employed are helium purged flow systems consisting of two major units.

The first unit consists of sample injection syringes, SRI 8610C gas chromatographs, a personal computer, and several flow-control valves. This configuration separates the hydrocarbon of interest from the sample and channels it into the combustion-collection unit. The second unit is the combined combustion-collection unit which includes quartz combustion tubes filled with cupric oxide (CuO), and vacuum lines. This system converts the hydrocarbon of interest into CO_2 and water, which are then collected and purified for isotopic analysis.

The water of combustion is transferred into a length of Pyrex tubing that has been sealed at one end and contains a weighed quantity of zinc turnings. The sample tube is sealed off for later mass spectrometric analysis. Similarly, the CO_2 is then transferred into Pyrex tubing and sealed off for later mass spectrometric analysis.

Maintenance The packed columns are baked at manufacturer's recommended temperature when peak separation decreases. At the end of every work day, O_2 is flowed through the copper oxide combustion furnaces to regenerate the CuO. Valve o-ring seals within the evacuated transfer system are replaced as necessary.

Reference Samples The system is tested by analyzing a reference sample every tenth analysis performed.

Replication A duplicate analysis of one of the samples is performed approximately every tenth analysis. This duplicate analysis is performed approximately five analyses after the reference sample analysis is performed. Therefore, a test of the system operation is performed every five analyses.

Calculation The expected yield is calculated form the injection volume and the hydrocarbon concentration

Documentation All procedural tests, sample preparations and verifications performed are recorded in bound maintenance log books. All final data including the date prepared with analyst identification are recorded on laboratory log sheets and/or in bound log books. Digital copies of all chromatograms are stored and backed up regularly.

2. $\delta^{13}C$ (Carbon Isotope Analysis) of CO_2, Offline Prep Method

Method/Procedure Preparation of samples for measurement of the $\delta^{13}C$ of CO_2 is performed on the same system as the hydrocarbons. The procedure is identical to that for the hydrocarbons, with two exceptions. First, CO_2 does not pass through a combustion furnace; gas is channeled directly from the GC outlet to the collection trap. Second, there is no water of combustion.

3. GC-C-IRMS systems, $\delta^{13}C$, δD, and $\delta^{15}N$

Equipment and Supplies

HP6890 GC interfaced to ThermoFinnigan Delta Plus Advantage
HP 6890/7890 interfaced to Thermo Scientific Delta V Plus
Customized autosampler

Method/Procedure The GC-C-IRMS systems, also referred to as "online" or "continuous flow", consist of an Agilent GC combustion unit interfaced with a mass spectrometer (Delta V Plus or Delta Plus Advantage), and are used to analyze the carbon isotopic value of hydrocarbon components in gas samples. Samples are injected into the GC split/splitless injector either manually, or using customized autosamplers. The hydrocarbon components are separated by the GC column, and each individual component slated for isotopic analysis is combusted in a combustion furnace supplied by the instrument manufacturer. The resultant CO_2 is introduced directly into the mass spectrometer, and Finnegan's Isodat software is utilized for peak detection and quantification. Cryogenic focusing of hydrocarbons is achieved using liquid nitrogen, allowing the air to be removed, resulting in enriched concentrations of hydrocarbons.

Hydrogen isotopic values for methane are completed using the same system, but the gas is channeled through a high-temperature pyrolysis furnace instead of through the combustion furnace. The pyrolysis furnace converts methane into H_2 and carbon, and the H_2 gas is introduced directly into the mass spectrometer.

Nitrogen isotopic data for elemental nitrogen (N_2) is generated using the same system.

Maintenance Septa on the GC inlet system are replaced daily when the system is operational. Pyrolysis and combustion tubes are replaced as needed. Combustion tubes are oxidized daily during analysis sequences.

Reference Samples Reference gases are analyzed at the start of each analysis sequence, and then at least 10% of all analyses during a sequence are check samples.

Replication At least 10% of client samples are analyzed in duplicate.

C. Procedures for Stable Isotope Analysis of Solids and Liquids

1. $\delta^{13}C$ & $\delta^{18}O$ (Carbon and Oxygen Isotope Analysis) of Carbonate

Equipment and Supplies

Thermo GasBench II
Thermo Delta V Plus
Mettler Toledo MX5 Ultra-Microbalance
12mL Exetainer® with septum cap
100% Phosphoric acid

Method/Procedure The $\delta^{13}C$ and $\delta^{18}O$ of carbonate is determined by weighing approximately 200 micrograms of sample into an Exetainer® fitted with a septum cap. The vials are placed in a temperature controlled sample block at 70°C and flushed with helium to purge any air from the vial.

The sample is reacted with 100% phosphoric acid for a minimum of one hour and then analyzed. The CO_2 generated is flushed out of the vial via a two port needle. Water is removed by two nafion traps, and pure CO_2 is separated using a GC column. The CO_2/helium mixture then enters the mass spectrometer and is compared against a reference standard a total of six times.

Maintenance Vials are rinsed to remove acid and the glass is recycled.

QA/QC At a minimum, every tenth analysis is a replicate. A set of standards is analyzed after every ten samples, along with at least one check standard per analysis run.

Calculation Calculations are performed by the software on the IRMS (Isotope Ratio Mass Spectrometer) at the time of analysis. Data normalization against internal lab standards is performed using Microsoft Excel.

Documentation All procedural tests and verifications performed are recorded in bound maintenance log books. All sample data including the date prepared are stored electronically and in print.

2. Organic Solids and Liquids $\delta^{13}C$, $\delta^{18}O$, $\delta^{15}N$, $\delta^{2}H$ and $\delta^{34}S$

Equipment and Supplies

Carlo Erba Elemental Analyzer connected to a Finnigan Delta S Mass Spectrometer
ThermoElectron TCEA interfaced to a Thermo Electron Delta V Plus Mass Spectrometer
Elementar EL Vario III interfaced to a Thermo Scientific Delta V Plus Mass Spectrometer

Method/Procedure The determination of carbon, nitrogen, oxygen, hydrogen, and sulfur isotopic ratios for organic solids and liquids is accomplished by combustion or pyrolysis of the materials for mass-spectrometric analysis. The systems employed are standard elemental analyzers with carousel auto samplers, connected to isotope ratio mass spectrometers through an interface supplied by the manufacturer. The combustion products of interest from the elemental analyzers are: carbon dioxide (CO_2) for carbon isotope analysis, N_2 for nitrogen isotope analysis, and sulfur dioxide (SO_2) for sulfur isotope analysis. Oxygen and hydrogen isotopic ratios are analyzed on the TCEA, which converts hydrogen from the organic materials to H_2 gas for hydrogen isotopic measurements, and oxygen within the organic materials is converted to carbon monoxide (CO) for oxygen isotope analysis.

Samples are weighed on a Mettler balance and loaded into a standard EA tin capsule for carbon, nitrogen, or sulfur isotopic analysis, or into a silver capsule for oxygen or hydrogen isotopic analysis. Once the samples are loaded into the EA, a run is started and all instrument control is done by software provided by the MS manufacturer. Samples are combusted as per normal EA operating procedures, and the CO_2 N_2, and SO_2 are separated by the EA. Similarly, the pyrolysis products H2 and CO from the TCEA are separated within the instrument. The vents of the EA and the TCEA are connected to the mass spectrometers via the interface, where a small portion of the EA or TCEA output flows directly into the MS. The MS measures the isotopic value of the component of interest (CO_2, N_2, SO_2, CO, or H_2) and the final isotopic value is generated by software provided by the manufacturer.

Maintenance Ash is removed from the top of the combustion column in the EA or the top of the pyrolysis reactor in the TCEA as directed by the manufacturer, or when peak tailing becomes apparent. Combustion and reduction furnaces in the EA are replaced at appropriate intervals as outlined by the dealer, or when peak shape deteriorates. The TCEA contains glassy carbon, which is periodically replaced.

Reference Samples The systems are tested by analyzing at least one reference at least once per batch of 25 samples loaded into the auto sampler. A blank is also run at the start of each batch.

Replication Approximately 10% of all samples analyzed are replicates.

Documentation All final data including the date analyzed are recorded on laboratory log sheets and/or in bound log books. Digital copies of chromatograms are stored and backed up regularly.

II. Sample Preparation Procedures for Radiogenic Isotope Analyses

A. Procedures for Radiogenic Isotope Analysis of Gases

1. ^{14}C (Radiocarbon) and ^{3}H (Tritium) in CH_4 (Methane) by Radiometric Analysis

Equipment

Peristaltic pump
Flow meters
Gas regulators
Vacuum gauge
Molecular sieve trap
High temperature tube furnaces
Quartz combustion chamber
Vacuum traps and gauges
Vacuum pumps
Mercury manometer

Method/Procedure

1.1 Methane Combustion

The system used for tritium (^{3}H) analysis of methane and for radiocarbon (^{14}C) analysis of methane consists of a peristaltic pump, a CO_2 removal unit, and a sample combustion/collection flow unit. The combustion/collection unit is composed of a tube furnace, a flow control valve, and a series of gas purification and collection traps. The system is attached to a vacuum manifold.

The gas sample enters the system through a flow control valve or is pumped in slowly by a peristaltic pump. The CO_2 associated with the sample is absorbed by the molecular sieve and removed from the sample quantitatively. Methane in the sample is then carried through the combustion tube where it is reacted to CO_2 and H_2O.

The water of combustion is collected in a trap immediately after the combustion furnace by immersing the trap in a dry ice/isopropanol bath. Once the entire sample has been combusted, the frozen water of combustion is melted and transferred to a glass vial to await tritium analysis.

The CO_2 formed by combustion is collected in two liquid nitrogen cooled traps, measured volumetrically, and transferred into a storage cylinder. Storage cylinders are effectively leak-tested during each use by evacuation prior to transferring the sample CO_2. Each cylinder is tagged with sample identification and is forwarded to a subcontractor for ^{14}C analysis along with a chain-of-custody form.

1.2 Tritium Analysis

The water of combustion from methane samples is ready to be analyzed in the liquid scintillation counter (LSC). There is no pre-treatment necessary for the sample, as it is essentially distilled water when it is collected.

The scintillation counting vials are prepared by pipetting 10 ml of commercial scintillation cocktail into a 20 ml plastic vial and then weighing to ±1 mg. The sample is then pipetted or poured into the counting vial and the vial is re-weighed. If the amount of sample is less than 10ml, then tritium-free water is added to bring the total volume of water to about 10ml. Details of the tritium analysis procedure are given later in this document.

Maintenance After each sample, the molecular sieve is baked and evacuated at 350°C. The vacuum system is thoroughly evacuated to remove all residual gas and water vapor after each sample. The water trapping system is disassembled and thoroughly dried and evacuated after each sample.

Calibration/Standardization Gas storage volumes have been calibrated using known quantities of carbon dioxide gas. No further standardization of this system is necessary. Calibration and standardization of the final ^{14}C analysis is performed by the subcontracted laboratory.

Replication and Reference Samples Replicate or reference sample analysis for these analyses are performed only when requested and supported by the client.

Calculation Yields are calculated by comparing the volume of CO_2 generated and the weight of the water collected to the amount expected based on the amount of CO_2 collected. ^{14}C concentrations are determined by the subcontracted laboratory and corrected for isotope fractionation by Isotech's database program.

2. ^{14}C (Radiocarbon) in CH4 and CO_2 by Accelerator Mass Spectrometry (AMS)

Equipment:
Same as for $\delta^{13}C$ of CO_2 and $\delta^{13}C$ of Hydrocarbons.

Method/Procedure:
The same method is employed for sample preparation as for $\delta^{13}C$ of either CH_4 or CO_2. Once the purified CO_2 has been sealed into Pyrex tubing, the tube is tagged with a piece of label tape and sent to the subcontractor along with a chain of custody form for ^{14}C analysis. When there is only enough material available for one sample preparation, the $\delta^{13}C$ is first determined by MS analysis.

B. Procedures for Radiogenic Isotope Analysis of Water

1. ^{14}C (Radiocarbon) in dissolved inorganic carbon (DIC) by Accelerator Mass Spectrometry (AMS)

Equipment and Supplies

Vacuum pumps and gauges
Glass and metal vacuum system
Dry ice
Isopropyl alcohol
Liquid nitrogen
Phosphoric acid
Gas-Oxygen torch

Method/Procedure The ^{14}C of DIC is determined by injecting sample water into an evacuated serum bottle containing 2mL of 85% phosphoric acid and a magnetic spin bar. Sample size is determined based on alkalinity, which is measured by titration with 0.1N HCl. The sample is stirred for a minimum of 15 minutes and then connected to the vacuum system via a needle port. The CO_2 generated is liberated from the water and transferred through a trap cooled in a dry-ice/isopropyl-alcohol mixture (for H_2O removal) to a U-trap which is cooled in liquid nitrogen. The CO_2 is then purified and cryogenically collected in Pyrex tubing. The tube is sealed off and tagged with a piece of labeled and sent to the subcontractor, along with a chain of custody form, for ^{14}C analysis.

Maintenance The system is thoroughly evacuated between samples. Vials are washed and dried.

2. ^{3}H (Tritium) in H_2O

Equipment

Vacuum pumps and gauges
Distillation column
Electrolytic enrichment cells
Electrolysis power source and cooling system
Liquid scintillation counting system
Assorted chemicals and glassware
Dry ice/ isopropyl alcohol
Drying oven

Method/Procedure--Direct Counting of Higher Tritium Content Water (greater than 15 TU). Approximately 15ml of the water sample is treated with 0.1 M $KMnO_4$ at 70°C for about an hour. This sample is then vacuum distilled. Ten ml of the distillate is accurately weighed and mixed with 10ml of an appropriate organic scintillator cocktail in a 20ml plastic vial and counted in a liquid scintillation spectrometer for 1000 minutes. Background and a NIST standard are also similarly counted and the tritium content calculated.

Method/Procedure--Enrichment of Lower Tritium Content Water (less than 15 TU). About 300 ml of the water sample is conventionally distilled to near completion. Exactly 200g is added to an enrichment cell along with 2ml of 9M tritium-free sodium hydroxide and is electrolytically enriched down to about 11-13 ml (final weight is exactly determined), and then neutralized with carbon dioxide for 20 minutes. The enrichment procedure is carried out under conditions of about 2℃ and constant voltage of 4V. Ten ml of the enriched sample is accurately weighed and mixed with an appropriate organic scintillator cocktail in a 20 ml plastic vial and counted in a liquid scintillation spectrometer for 1000 minutes. Background and a NIST standard are also similarly counted and the tritium content calculated.

General QA/QC Procedures Critically reviewing TU/cpm/g of NIST standard versus existing data, critically reviewing background cpm versus existing data, and comparing data from splits of NIST and other samples with outside established laboratories. A criteria of exceeding 1 sigma limits from existing data triggers investigation of possible errors. Electrolytic enrichment cells are calibrated using working standards approximately every 6 months, or whenever duplicates prepared in different cells suggest a possible change in enrichment factor.

Maintenance The vacuum system is thoroughly evacuated between samples. All glassware and electrolytic cells are cleaned with deionized water and baked at about 130° C between samples.

Replication At a minimum, every tenth analysis is a replicate. Periodically a blind split is sent to another established tritium analysis laboratory for check purposes.

Reference Sample A NIST water standard (a dilution of NIST 4361B) is used for each sample set to verify accuracy and reproducibility. A glass-sealed high tritium sample is routinely checked to verify that the counter is operating satisfactorily. QA/QC plots are maintained for both standard and background counts using deviation of 1 sigma as a criteria for a more detailed evaluation of the data.

Calculation Calculations are performed utilizing a spreadsheet to calculate tritium concentration in TU on the date counted.

Documentation All procedural tests, sample preparations and verifications performed are recorded in bound maintenance log books. All final data including the date prepared, with analyst identification, are recorded on laboratory log sheets or in bound log books.

III. Dual Inlet Mass Spectrometric Analysis

A. Measurement of $^{13}C/^{12}C$ and $^{18}O/^{16}O$ in CO_2

Equipment Finnigan MAT Delta S Isotope Ratio Mass Spectrometer

Method/Procedure Because $^{13}C/^{12}C$ and $^{18}O/^{16}O$ analyses are performed simultaneously, the procedure described here generates both measurements. A mass spectrometric analysis involves comparisons of a sample to a reference standard; in this case the comparisons are measurements of mass 44, 45, and 46, giving the both the oxygen and carbon isotopic compositions. This is accomplished by a dual inlet system where the sample and the reference standard are measured alternately. At the beginning of each day, a reference standard is introduced into the standard side of the inlet system, and this gas is generally used for the entire session. There are two different reference standards in aluminum cylinders which are permanently mounted on the MS inlet system. The sample to be analyzed against the standard is introduced into the system via an evacuated inlet system and tube-cracker. With the inlet system fully evacuated, the sample (which is sealed into ¼" Pyrex tubing) is introduced by breaking the glass sample tube and allowing the sample to fill a variable volume bellows. Once the sample has been introduced into the MS, the actual analysis is computer controlled using equipment obtained from the manufacturer. Each analysis is given a specific reference name and/or number, utilizing the lab number as the primary reference. Final results are calculated by the manufacturer's software, and are stored on the hard drive of the computer, recorded in a bound lab notebook, and stored as the computer generated printout.

Maintenance The source region of the MS is periodically disassembled and cleaned. The filament is replaced as needed. Oil levels in mechanical vacuum pumps are checked frequently and maintained at the proper level. Turbomolecular pumps are lubricated according to the manufacturer's recommendations.

Calibration/Standardization The first analysis of each session is a zero enrichment, where the working standard is analyzed against itself to check machine stability. Isotope ratio determination involves multiple direct comparisons of the sample to a reference standard (generally at least 6 comparisons). Stable carbon and oxygen isotope compositions are always reported as the difference between the ratios of the two isotopes of interest in the sample and the ratio in a primary reference standard. That is,

$$\delta X_{(sample)} = [(R_{sample} - R_{standard})/ R_{standard}] \times 1000$$

Where X represents the isotope of interest, ^{13}C or ^{18}O, and R represents the ratio of $^{13}C/^{12}C$, or $^{18}O/^{16}O$. The δ value is expressed in terms of per mil (‰), or parts per thousand.

In practice, the difference between the sample and an internal reference standard is measured and then the value relative to the primary standard is calculated by the instrument manufacturer's software. Two internal reference standards are used at Isotech, both of which have been calibrated multiple times relative to several standards (graphite, oil, carbonates, waters, etc.) available from the International Atomic Energy Agency and the National Institute of Standards and Technology.

Replication Because of replicate sample preparations, at least 10% of all analyses are replicates.

Reference Samples Because 10% of all samples prepared for stable isotope analysis are check samples or reference samples which have been previously analyzed, these samples also serve as check samples for the mass spectrometer.

Calculation All calculations are performed by the software obtained from the manufacturer.

B. Measurement of $^2H/^1H$ (Deuterium/Hydrogen) in H_2

Equipment

Finnigan Delta Plus XL isotope ratio mass spectrometer
Aluminum heating block
Personal computer

Method/Procedure The H_3 factor, which is the portion of the mass 3 signal attributable to ^1H-^1H-^1H (instead of ^2H-^2H), is determined before each run early in the day and periodically throughout the day based on machine performance (if the values start drifting, a new H_3 factor is determined). The reference standard must be replenished at least once during an 8 hour period.

Water samples for deuterium/hydrogen analysis are sealed into ¼" Pyrex tubing as H_2O, along with a measured quantity of zinc. Each sample tube is labeled and reacted in a heating block at 500°C for 35 minutes to generate hydrogen gas. Once the sample has been reacted, it is introduced into the sample side of the MS inlet system and analyzed against the working standard. Each analysis is given a unique label, using the lab number as the primary reference. Once the sample has been introduced into the MS, the analysis is computer controlled. The raw result is calculated by the manufacturer's software and recorded into a bound lab notebook, as well as being stored on computer hard disk and computer generated printout of results.

Maintenance The source region of the MS is periodically disassembled and cleaned. The filament is replaced as needed. Oil levels in mechanical vacuum pumps are checked frequently and maintained at the proper level. Turbomolecular pumps are lubricated according to the manufacturer's recommendations.

Calibration/Standardization The first run each day is a zero-enrichment where the standard is run against itself to check machine stability. Stable hydrogen isotope compositions are always reported as the difference between the ratios of the two isotopes of interest in the sample and the ratio in a primary reference standard. That is,

$$\delta D_{(sample)} = [(^2H/^1H_{\ sample} - {}^2H/^1H_{\ standard}) / {}^2H/^1H_{\ standard}] \times 1000$$

The δ value is expressed in terms of per mil (‰), or parts per thousand.

In practice, the difference between the sample and an internal reference standard is measured and then the value relative to the primary standard is calculated by the instrument manufacturer's software. Two internal reference standards are used at Isotech which have been calibrated relative to several water standards available from the International Atomic Energy Agency and the National Institute of Standards and Technology.

<u>Replication</u> Because of replicate preparation of samples, at least 10% of all analyses are replicates.

<u>Reference Samples</u> Because 10% of all samples prepared for stable isotope analysis are check samples or reference samples which have been previously analyzed, these samples also serve as check samples for the mass spectrometer.

<u>Calculation</u> All calculations are performed by the manufacturer's computer software. The raw data is then converted to final data using a spreadsheet on a personal computer. The spreadsheets are stored on computer hard disk and a copy is attached to the raw printouts for each batch of analyses.

IV. Gas Chromatographic Analysis of Gases

A. Analysis of hydrocarbons

Equipment

Shimadzu 2010 Gas Chromatograph. This (complete) GC system is equipped with two 2010 instruments; one containing a thermal conductivity detector (TCD) and a flame ionization detector (FID), and the other containing dual TCD's. Data processing is done on GC solutions software and a personal computer.

Shimadzu 2014 Gas Chromatograph. This (partial) GC system is equipped with both thermal conductivity (TCD) and flame ionization (FID) detectors. Data processing is done on GC solutions software and a personal computer.

Method/Procedure The sample loop on the GC is evacuated between each sample. Samples are injected into the evacuated sample loop and adjusted to atmospheric pressure. Sample identification is entered into the GC solutions software and the run is initiated.

The Shimadzu 2010 and 2014 utilizes several different packed columns and valve switching to separate the various components. Instrument configuration was designed by Shimadzu specifically to meet the requirements of Isotech. Helium is used as the carrier gas. All valve switching during the analysis is computer-controlled. The resulting component peak areas are then quantified by the software (given raw percent values) by comparing them to previously run standards. The lab technician checks the raw total for each analysis to ensure that all components have been detected. The raw total can vary from day to day depending on atmospheric pressure, with acceptable raw totals of 96% to 104%. The lab technician also checks all baselines for accuracy from the chromatograms shown on the computer screen. This raw computer record is maintained for each sample corresponding to its individual lab number. The raw percentage values for each sample are downloaded into the main sample database, and are normalized to 100% when the Analysis Report is generated.

Maintenance GC columns are periodically baked out according to manufacturer's instructions. Septa in the sampling valves are replaced as needed.

Calibration/Standardization Multiple reference gases are used for standardization of the Shimadzu gas chromatographs. All standards are analyzed on the same day during a new standardization to minimize the effects of barometric pressure variations. The minimum and maximum concentration used for calibration cover the range of the majority of natural gases submitted for analysis. At least four points are used for each component. For each new standardization, the peak area of each concentration for each compound is inserted into a table within the GC Solutions software. This table is then accessed by the software, which uses point-to-point interpolation, to determine component concentrations for gas samples during analysis.

Reference Samples The reference sample used as the 1st run of each day and every tenth sample thereafter is representative of the majority of natural gas samples received for analysis. Data obtained for reference samples and expected results based on previous analyses can be provided as part of a QA/QC report.

Replication Every tenth analysis is a replicate. This replicate analysis is done approximately five samples following the check sample, thus a system check is performed at least every five analyses.

Calculation Each individual component for each sample is manually compared to the computer generated output to insure that the peak was labeled correctly and integrated correctly by the GC Solutions software.

B. Analysis of fixed gases

Equipment

Shimadzu 2010 Gas Chromatograph. This GC system is equipped with two 2010 instruments; one containing a thermal conductivity detector (TCD) and a flame ionization detector (FID), and the other containing dual TCD's but quantification of fixed gases is done using only the TCD's. Data processing is done on GC solutions software and a personal computer.

Shimadzu 2014 Gas Chromatograph. This GC system is equipped with both thermal conductivity (TCD) and flame ionization (FID) detectors but quantification of fixed gases is done using only the TCD. Data processing is done on GC solutions software and a personal computer.

Method/Procedure The procedure for analysis of fixed gases is identical to that for analysis of hydrocarbons, with one exception (for 2010 only). For separation of oxygen and argon, an external column on the Shimadzu 2010 is used. This column operates at -78℃; therefore a dewar of dry ice/isopropyl alcohol is placed on the column before each run. The lab technician checks all baselines to verify peak integration. The Shimadzu 2014 system is not equipped with the external column, thus argon and oxygen values are reported as one value. Also the 2014 system cannot detect helium and can only quantify hydrogen at limited concentrations.

Maintenance GC columns are periodically baked out according to manufacturer's instructions. The septum on the injection valve is periodically replaced.

Calibration/Standardization Multiple reference gases are used for standardization of the Shimadzu gas chromatographs. All standards are analyzed on the same day during a new standardization to minimize the effects of barometric pressure variations. The minimum and maximum concentration used for calibration cover the range of the majority of natural gases submitted for analysis. At least four points are used for each component. For each new standardization, the peak area of each concentration for each compound is inserted into a table within the GC Solutions software. This table is then accessed by the software, which uses point-to-point interpolation, to determine component concentrations for gas samples during analysis.

Check Sample Multiple reference sample are used to verify instrument performance and calibration. Data obtained for reference samples and expected results based on previous analyses can be provided as part of a QA/QC report.

Replication Every tenth analysis is a duplicate. This duplicate analysis is performed approximately five samples following the check sample, thus a system check is performed at least every five analyses.

Calculation Each individual component for each sample is manually compared to the computer generated output to insure that the peak was labeled correctly and integrated correctly by the GC Solutions software.

V. Radiocarbon Analysis of Prepared Samples

Radiocarbon analyses of purified CO2 samples prepared by Isotech are currently being subcontracted to either Beta Analytic Inc., Coral Gables, Florida or to Illinois State Geological Survey, Champaign, Illinois. Beta Analytic is the largest commercial radiocarbon dating laboratory in the world. The attached QA/QC plans have been provided by

BETA ANALYTIC INC
University Branch
4985 S.W. 74 Court
Miami, FL 33155

Illinois State Geological Survey
Natural Resources Building
615 East Peabody Drive
Champaign, IL 61820

APPENDIX D

EXAMPLE FIELD CHECKLIST AND SUMMARY FORMS

QUALITY CONTROL FIELD AUDIT CORRECTIVE ACTION REPORT
Nevada Power Company Reid Gardner Station
Nevada Division of Environmental Protections
AOC No. ____________

Property ID: ____________
Property Name: ____________
Auditor Name: ____________
Signature: ____________

Stanley Consultants, Inc.

Title: ____________
Date/Time: ____________

Activity Audited (Give specific QAPP, SAP, or SOP reference): ____________

Position/Name With Immediate Responsibility for Compliance: ____________

Check As Appropriate

☐ Field Activity ☐ Management Activity ☐ File/Record Activity

☐ Found Compliant ☐ Found Non-Compliant ☐ Corrected Activity

Describe Briefly:

Corrective Action Response (Describe in detail the remedy, including response consistent with Stanley Consultants, Inc. Management Manual for reporting. Use back if needed):

Reported To: ____________
Project Title: ____________

Date/Time: ____________
Response ID: ____________

Check As Appropriate

☐ Critical Measurement ☐ Data Loss or Can Not Be Reported

☐ Qualitative Measurement ☐ Entered Into Logbook

QUALITY CONTROL FIELD AUDIT CORRECTIVE ACTION REPORT
Nevada Power Company Reid Gardner Station
Nevada Division of Environmental Protections
AOC No. ____________

Property ID: ____________
Property Name: ____________
Auditor Name: ____________
Signature: ____________

Stanley Consultants, Inc.

Title: ____________
Date/Time: ____________

System Failure (Describe in detail the departure from prescribed protocols established for this study. Reference section and subsection from the QAPP and the SAP. Use Back If Necessary):

Corrective Action Response (Describe in detail the remedy, including response consistent with Stanley Consultants Inc. Management Manual for reporting. Use Back If Needed):

Project Assessment (Render your opinion as to degree of damage the failure poses to the project and what contingent matters might need to be implemented [e.g. sample loss makes 90% completeness essential, inform drilling supervisor]. Use Back If Needed):

Reported To: ____________ Date/Time: ____________
Project Title: ____________ Response ID: ____________

Check As Appropriate

☐ Critical Measurement ☐ Data Loss or Can Not Be Reported
☐ Qualitative Measurement ☐ Entered Into Logbook

Advanced Technology Laboratories
3151-3153 W. Post Rd.
Las Vegas, NV 89118
Tel: (702) 307-2659 • Fax: (702) 307-2691

P.O. #: ____________
Logged By: ____________ Date: ________

FOR LABORATORY USE ONLY

Method of Transport
- Client ☐
- ATL ☐
- CA OverN ☐
- FedEx ☐
- Other: ________

Sample Condition Upon Receipt

1. CHILLED	Y ☐	N ☐	4. SEALED	Y ☐	N ☐
2. HEADSPACE (VOA)	Y ☐	N ☐	5. # OF SPLS MATCH COC	Y ☐	N ☐
3. CONTAINER INTACT	Y ☐	N ☐	6. PRESERVED	Y ☐	N ☐

Client:
Attention:
Address:
City: State: Zip Code:
Tel:
Fax:
Project Name:
Project #:
Sampler: (Printed Name) (Signature)

Glen Gesmundo Date: Time: Received by: (Signature and Printed Name) Date: Time:

Relinquished by: (Signature and Printed Name) Date: Time: Received by: (Signature and Printed Name) Date: Time:

Relinquished by: (Signature and Printed Name) Date: Time: Received by: (Signature and Printed Name) Date: Time:

I hereby authorize ATL to perform the work indicated below:

Print Name Date

Signature

Send Report To:
Attn:
Co:
Addr:
City: State: Zip:

Bill To:
Attn:
Co:
Addr:
City: State: Zip:

Special Instructions/Comments:

Sample/Records - Archival & Disposal
Unless otherwise requested by client, all samples will be disposed 45 days after receipt and records will be disposed 1 year after submittal of final report.

Storage Fees (applies when storage is requested):
- Sample :$2.00 / sample /mo (after 45 days)
- Records: $1 /ATL workorder /mo (after 1 year)

ITEM	LAB USE ONLY: Batch #: Lab No.	Sample Description: Sample ID / Location	Date	Time	8081A (Pesticides)	8082 (PCB)	8260B (Volatiles)	8270C (BNA)	6010B (Total Metal)	8015B (GRO)	8015B (DRO)	8021 (BTEX)	TITLE 22 / CAM 17 (6010 / 7000)							SOIL	WATER	GROUND WATER	WASTEWATER			TAT	Container(s) #	Container(s) Type	PRESERVATION	QA / QC: RTNE, CT, SWRCB Logcode, OTHER — REMARKS

Circle or Add Analysis(es) Requested
SPECIFY APPROPRIATE MATRIX

- TAT starts 8AM the following day if samples received after 3 PM

TAT: A = Overnight ≤24 hrs; B = mergency ext Workday; C = Critical 2 Workdays; D = nt orkdays; E = Routine 7 Workdays

Container Types: T=Tube V=VOA L=Liter P=Pint J=Jar B=Tedlar G=Glass P=Plastic M=Metal

Preservatives: H=HCl N=HNO_3 S=H_2SO_4 C=4°C Z=$Zn(AC)_2$ O=NaOH T=$Na_2S_2O_3$

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

Stanley Consultants Inc. 319-626-3990	CUSTODY SEAL	Project No.:	
		Date:	
		Time:	
		Sealed By:	

UTILITY LOCATE FORM

Project Name: ____________________

Project Number: ____________________

Site Contact: ____________________

Phone Number: ____________________

Locate Contact Date: ____________________

Locate Meeting Date: ____________________

Field Work Date: ____________________

Work Description: ____

____

____

____

One Call Contacted: Yes No

Utility Type	Phone Number	Contact Name	Date Notified	Confirmation Number
Electric				
Gas				
Telephone				
Cable TV				
Water				
Sewer				
Fiber Options				
Other				
Other				

Utility Locates Required: Yes No

Additional Action Required: ____

____

____

____

FIELD EQUIPMENT AND EXPENDABLES CHECKLIST

Project Name: ______________________ Date Out: ____________
Project Number ______________________ Date In: ____________
Personnel: ____

Quantity Out	Item (circle)	Quantity In
	Project File/Folder	
	Sampling Plan, Health & Safety Plan	
	Field Book & Sharpies	
	Contact Phone Numbers	
	Cell Phone, Charger	
	Camera, Charger	
	Lap Top Computer, Projector	
	First Aid Kit, Fire Extinguisher	
	Personnel Protection Equipment	
	Flame Ionization Detector, Photo Ionization Detector	
	Combustible Gas Indicator	
	Dosimeter/Radiation Meter	
	Conductivity/pH/Temperature/DO/TDS Meter	
	Calibration Gas, Standards, Kit	
	Water Level Indicator, Interface Probe	
	Drager Pump & Tubes	
	Data Logger, Pressure Transducers	
	Turbidity Meter	
	Flow Meter	
	Pumps, Tubing, Foot Values, Batteries	
	Generator, Fuel, Extension Cords	
	Bailers, Rope, Filters, Vacuum Pressure Pump	
	Well Keys, Locks, Wrenches, Hand Tools	
	Sample Containers, Labels, COCs	
	Bowls, Spatulas, Spoons, Trowels, Dipper	
	Packing Tape, Bubble Wrap, Peanuts	
	Coolers, Ice, Custody Seals, Shipping Airbills/Labels	
	Baggies, Aluminum Foil, Trash Bags, Paper Towels	
	Flash Light, Lantern, Batteries, Charger	
	Hand Auger, Shovel, Bolt Cutter	
	Axe, Hammer, Machete, Pick, Pry Bar, Saw	
	Flagging, Stakes, Marking Paint, Tape Measure	
	Survey Equipment, Radios, Binoculars	
	DI Water, DECON Fluids, Buckets, Brushes	
	Traffic Cones, Barricades, Caution Tape	
	Plastic Sheeting, Tarps, Duct Tape	
	Company/Rental Vehicle, Hotel, Plane Tickets	
	Sign Out Board, Voice & E-mail Message	
	Other: ______________________	

EQUIPMENT SIGN-OUT SHEET

Unit Name	Signed Out To	Project Name	Project Number	Date Out	Date In	Cleaned?		Problems? If So, What?
						Yes	No	

CALIBRATION LOG

Unit Name	Date Done	By Whom	Method Used	Repairs Needed

SOIL BORING LOG AND MONITORING WELL CONSTRUCTION DIAGRAM

Boring / Well Number:	Facility Name:	Facility Street Address:
Boring Depth (ft) X Diameter (in):		Drilling Method:
Certified Well Contractor Name: Registration Number:		Logged by:
Ground Surface Elevation (ASL):	Top of Casing Elevation (ASL):	
Date: Start Time:	Date: End Time:	UST Number	LUST Number

Depth (feet)	Well Construction Details	Blow Count if applicable	Sample No.	Type*	Field Screening Results (PID / FID)	Rock Formations, Soil, Color and Classifications, Observations (moisture odor, etc.) First column for USCS

* SS (split spoon) CS (continuous sampler) HSA (hollow stem auger)

Observations	Date:					
Water Levels (BGS)	Level:					
Static Water Level Symbol (v)	Time:					

Q:\20618_NPC_AOC_Implementation\Active\06-Studies\04-Studies\ICLW4_Quality_Assurance_Plan\BORELOG DOC

GROUNDWATER SAMPLING FIELD DATA SHEET

Project Name: ____________________ Well Number: ____________
Project Number: ____________________ Date: ____________
Personnel: ____________________ Time: ____________

Casing Material	Casing Diameter	Casing Stickup
Static Water Level	Well Depth	Saturated Thickness
Casing Volume	Purging Equipment	Sampling Equipment
Casing Headspace Reading	Clear Bailer Result	Sample Depth
Instrumentation Type		Weather Conditions

Time	Casing Volumes	Gallons Purged	Temperature	pH	Conductivity	Comments

Remarks: ____
____
____

Sampled for: Sampled by:

VOCs	SVOCs	Metals	PCBs	Pesticides	TEH		

WELL SPECIFIC FIELD SHEET

Site Name:______________________________Sampled By:____________Date:________________

Weather Conditions:____

Monitoring Well/Piezometer No.								
Protective Casing/Lid? Y/N								
Locked? Y/N								
Well/Piezometer Capped? Y/N								
Concrete Seal? Y/N								
Visual Damage? Y/N								
Standing Water or Litter? Y/N								
*Ground Elevation (M.S.L.)								
*Elevation of Well Top (M.S.L.)								
Inside Casing Diameter (inches)								
Depth to Water (feet)								
Depth of Well (feet)								
Volume of Water in Well (gallon)								
Turbidity Before Purging? Y/N								
Time Begin Purging								
Time Complete Purging								
Volume Purged (gallon)								
**Number of Volumes Purged?								
Depth to Water After Purging (feet)								
Purged Dry? Y/N								
Turbidity After Purging? Y/N								
Date of Sample Withdrawal								
Time of Sample Withdrawal								
Depth to Water Before Sampling								
Time of Field Analysis								
Field Temperature (°F)								
Field Specific Cond. (at 25°)								
Field pH								
Color/Odor								
Turbidity								
Ground Discoloration								
Sample Field Filtered? Y/N								
If stream sample, estimate depth and quantity flowing								

*Filled in prior to going into field
**Filled out after field data collection

Comments: ____

WATER-LEVEL MEASUREMENTS

Site Name | **Job#** | **Task#** | **Date**

Weather Conditions | **By**

Monitoring Well/Piezometer No.	Protective Casing? Y/N	Well/Piezometer Locked? Y/N	Well/Piezometer Capped? Y/N	Concrete Seal Damaged? Y/N	Standing Water or Litter? Y/N	Depth to Water (feet)	Bottom of Well

FORM FOR
DOCUMENTATION OF SURFACE MONITORING POINT

Site Name ______________________________ Permit No. __________

Surface Monitoring Point No. ______________________ Date __________

Name of Person filling out form ______________________________

A. TYPE OF MONITORING POINT

Stream ______ Open Tile ______
Road Ditch ______ Tile with Riser ______
Drainage Ditch ______ Other (describe) ______________________
____

B. PURPOSE OF MONITORING POINT

Upstream ______ Downstream ______
Within Landfill ______ Other (describe) ______________________
____
____

C. SURVEYED LOCATION AND ELEVATION OF POINT
($\pm$ 0.5 ft. Horizontal, $\pm$ 0.01 ft. Vertical, MSL)

Specify corner of site ______________________________
Distance and direction along boundary ______________________________
Distance and direction from boundary to surface monitoring point ______________
____

Benchmark Description ______________________________
Benchmark Elevation ______________________________

Elevation of:
Top of bank of stream or ditch ______________________________
Bottom of stream or ditch ______________________________
Top of open tile ______________________________
Other (describe) ______________________________

Name of Surveyor ______________________ Registration No. __________

D. CONSTRUCTION DETAILS

Tile Diameter ______________________________
Tile Material ______________________________
Riser Length ______________________________
Riser Diameter ____________
Riser Material ____________

Attach scale drawings, cross sectional and plan views, of the sampling point, showing distances and elevations.

NOTE: Attach 8-1/2" x 11" site plan showing locations of all surface and groundwater monitoring points.

RESPIRATOR QUALITATIVE FIT-TEST RECORD

Name of Employee________________________ Employee No

Position________________ Facility

Group__________________ Tested By

Date__________________ Test Location

INFORMATION ON RESPIRATOR ASSIGNED TO EMPLOYEE:

Manufacturer______________ Type_______ Model No.

Anticipated Use

TEST PROCEDURE CHECKOFF:

_____ No facial hair or seal interference.
_____ Respirator worn per manufacturer's instructions, and for a familiarization period.
_____ No leakage under mild face-piece pressure. (Employee exhales and blocks exhalation valve.) or,
_____ No leakage under face-piece vacuum. (Employee inhales and blocks the inhalation passage).
_____ Isoamyl acetate test atmosphere; or
_____ Irritant smoke.
_____ Open air test; or
_____ Chamber test.
_____ Normal breathing and no sensation
_____ Deep breathing and no sensation
_____ Turning head from side to side and no sensation
_____ Nodding head up and down and no sensation.
_____ Talking or jaw action and no sensation.
_____ Normal breathing again and no sensation.
_____ Breathing and exercise performance for two minutes in test atmosphere without sensation of in-leakage

I hereby attest that this qualitative fit-test was conducted according to accepted procedures, and to the best of my knowledge, the information and responses on this form are correct

Signature of Test Conductor

Stanley Consultants INC.

Field Data Record Ground Water

Project:	Project No.:	Date/Time:	Sheet ___ of ___
Contractor Personnel:		SGI Personnel:	

Sample No.: Well Location:

WELL INTEGRITY

	YES	NO
Protect. Casing Secure	☐	☐
Concrete Collar Intact	☐	☐
PVC Stick-up Intact	☐	☐
Well Cap Present	☐	☐
Security Lock Present	☐	☐

Protective Casing Stick-up ______ ft. (from ground)

Riser Stick-up (from ground) ______ ft.

WELL DIAMETER ☐ 2 inch ☐ 4 inch ☐ 6 inch ☐ ______

Well Depth ____ ft. ☐ top of riser ☐ top of casing ☐ ________ ☐ measured ☐ historical

Water Depth ____ ft.

Height of Water Column ____ ft. x ☐ .16 gal/ft (2 in.) ☐ .65 gal/ft (4 in.) ☐ 1.5 gal/ft (6 in.) ☐ __ gal/ft (__ in.)

PID SCREENING MEAS.

Background	
Well Mouth	

WELL MATERIAL ☐ PVC ☐ SS ☐ ___

Volume of Water in Well = ______ gallon(s)

[Vol. = $r^2h(0.163)$] ______ Total gallons to purge

FIELD WATER QUALITY MEASUREMENTS

Purge Volume (gal)							
pH (Std. Units)							
Eh (millivolts)							
Conduct. (μmhos/cm)							
Temp. (C)							
Turb. (NTU)							
DO (mg/l)							

Sample Description

Clear ☐ Turbid ☐

Color ____________

Odor ____________

Other ____________

SAMPLE EQUIP./DECON.

	PURGE	SAMPLE
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Waterra	☐	☐
PVC/Silicon Tubing	☐	☐
Teflon/Silicon Tubing	☐	☐
Air Lift	☐	☐
In-line Filter	☐	☐
Pressure Vacuum Filter	☐	☐
Measuring Tape	☐	☐
________	☐	☐

EQUIPMENT ID

DESCRIPTION OF DECON. PROC.

DECON. FLUID USED

Tap Water	☐
Alconox	☐
Tap Water	☐
HNO_3 (1 or 10%)	☐
Tap Water	☐
Methanol	☐
Hexane	☐
Acetone	☐
Air Dry	☐
DI Water	☐
Air Dry	☐
None	☐

ANALYTICAL PARAMETERS	Filtered (circle)	Preservation Method	Volume Required	Time of Collection	CLP Sample #	CLP Case #
☐ TCL Volatiles	YES NO	4° C	2x40 mL			
☐ BNA Extractables	YES NO	4° C	4x1 L Amb GL			
☐ PCBs/Pesticides	YES NO	4° C				
☐ TAL Metals	YES NO	HNO_3/4° C	1 L PL			
☐ Cyanide	YES NO	NaOH/4° C	1 L PL			
☐ ________	YES NO					

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Signed: ______________

Stanley Consultants INC

Sample Log Sheet

Project:	Project No.:	Date/Time:	Sheet ___ of ___
Contractor Personnel:		SGI Personnel:	

Sample No.: ______________________

Depth/Interval Sampled: _____________

Sample Type: Grab, Composite or Both (circle)

Media: (circle) Surface Soil, Sediment, Subsurface Soil, Surface Water, Other _________, Ground Water

Sketch of Sample Location

Field Screening Information:

Type of Meter:

Other Field Measurements:

Observations:

SAMPLE COLLECTION EQUIPMENT:

Hand Auger	☐	Trowel	☐
Core Sampler	☐	Shelby Tube	☐
Spatula/Spoon	☐	Dredge Sampler	☐
Bowl (stainless)	☐	Kemmerer	☐
Split-spoon (2" or 3")	☐	Extended Arm	☐
OTHER:		Bailer	☐
		Backhoe	☐
		Van Dorn Bottle	☐

DECONTAMINATION PROCEDURE:

DECON. FLUID	USED	DESCRIPTION:
Tap water	☐	
Alconox	☐	
Tap water	☐	
HNO_3 (1 or10%)	☐	
Tap Water	☐	
Methanol	☐	
Hexane	☐	
Acetone	☐	
Air Dry	☐	
DI Water	☐	
Air Dry	☐	
None	☐	

ANALYTICAL PARAMETERS	Filtered (circle)	Preservation Method	Volume Required	Time of Collection	CLP Sample	CLP Case#
☐ TCL Volatiles	YES NO					
☐ BNA Extractables	YES NO					
☐ PCBs/Pesticides	YES NO					
☐ TAL Metals	YES NO					
☐ Cyanide	YES NO					
☐ _________	YES NO					

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Rev: 8 July 1991

Signed: ____________________

Stanley Consultants INC.

Screened-Auger Sampling Data

Project: Project No.:

Date:

Sheet ____ of ____

Area of Contamination:

SGI Personnel:

Weather:

Sample Number	Depth Below Water Table (feet)	Screened Interval (feet bgs)	Amount to be Purged (3 borehole volumes) (gallons)	Water Added During Purging (gallons)	Total Amount of Water Purged (gallon)	Data Sampled	Comments

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Stanley Consultants INC.

Pressure Test Form

Location	Boring no.

Project

Project no.

SGI Personnel

Contractor Personnel

Ground elev.: ______

Total depth: ______

Top of rock

Depth: ______

Flow meter no.: ______

Pressure gauge no.: ______

Water level

Depth: ______

Elev.: ______

Water pipe length: ______

Water pipe ID: ______

Test interval

Depth: ______

Elev.: ______

Sheet __ of __

GAUGE PRESS. ______
PACKER INFL'T'N PRESS. ______

Elapsed Time (min.)	Flow Reading (gal.)	Δ Flow	Elapsed Time (min.)	Flow Reading (gal.)	Δ Flow	Elapsed Time (min.)	Flow Reading (gal.)	Δ Flow	Elapsed Time (min.)	Flow Reading (gal.)	Δ Flow

(Each of the four column groups carries its own "GAUGE PRESS. ______ / PACKER INFL'T'N PRESS. ______" heading.)

Test Configuration - Fill Out Back

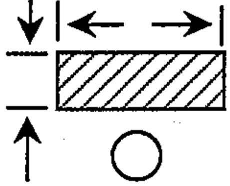
Remarks:

Single ☐
Double ☐

Stanley Consultants INC. **Test Pit Log**	Project: Project No.:	Date/Time:	Sheet ___ of ___
	Contractor Personnel:	SGI Personnel:	
Equipment/Contractor Used:	Location:	Test Pit Number:	
Reach/Capacity:	Total Depth:	Piezometer Installed? Yes No	
Depth to Ground Water:	Weather:	Elevation: Top of Pit ________	

Depth	Sample Number	Stratigraphic Description	REMARKS:

TEST PIT PLAN



North

Vol. = _____ cu. yd.

PROPORTIONS USED

Trace (TR).	0 - 10%
Little (LI.)	10 - 20%
Some (SO.)	20 - 35%
And	35 - 50%

GRAIN SIZE

Boulder	>203 mm	>8 in.
Cobble	76 - 203 mm	3 - 8 in.
C. Gravel	19 - 76 mm	3/4 - 3 in.
F. Gravel	4.75 - 19 mm	3/16 - 3/4 in.
C. Sand	2.0 - 4.75 mm	5/64 - 3/16 in.
M. Sand	0.4 - 2.0 mm	1/64 - 5/64 in.
F. Sand	0.075 - 0.4 mm	
Silt	0.002 - 0.075 mm	
Clay	<0.002 mm	

Stanley Consultants INC
Rock Core Log

Project:	Project No.	Date/Time	Sheet ___ of ___
Contractor Personnel:		SGI Personnel:	
Boring Well Number:	Driller/Equipment:	Elevation: ____ Orientation: ____ Time Start: ____ Time Finish: ____	

Depth	Comments: Tests, Instrumentation, Coring Rate and Smoothness, Coring Fluid Loss	Core Run Length and Recovery (%)	Core Loss Zone	Box Number	Discontinuities: RQD	Discontinuities: Fractures Per Foot	Discontinuities: Description (Tightness, Planarity, Smoothness, Filling, Staining, Orientation)	Lithology: Mineralogy, Classification, Color, Grain Size, Alteration, Cementation, Hardness, Weathered State	Graphic Log

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Stanley Consultants INC.

Field Activity Summary Sheet

Project:	Project No.:	Date:	Sheet ___ of ___
Activity:		SGI Personnel:	
Weather:		Contractor Personnel:	

Summary:

Sketch:

Deviations from Contractor's Work Plan/EPA Procedures:

Photograph #	Roll ID	Description

Rev: 8 July 1991

Signed: ____________________

AF-205

Stanley Consultants INC.

A Stanley Group Company
Engineering, Environmental and Construction Services - Worldwide

Daily Report

Project Name	Project No.	Mon.	Tue.	Wed.	Thu.	Fri.

Day/Date____________________Weather/Temperature________________________

Remarks ____

Crew No. 1
Contractor____________________ Superintendent____________________
Working Hours____________ to ____________ No. of Men ____________
Description of Work____

Crew No. 2
Contractor____________________ Superintendent____________________
Working Hours____________ to ____________ No. of Men ____________
Description of Work____

Crew No. 3
Contractor____________________ Superintendent____________________
Working Hours____________ to ____________ No. of Men ____________
Description of Work____

By____________________________

Stanley Consultants INC.

Soil Gas Survey Data Summary Sheet/PID

Project: Project No.:

Date/Time

Sheet ___ of ___

Contractor Personnel:

SGI Personnel:

Weather Conditions:
Barometric Pressure:
Ambient Temperature:
Precipitation Past 72 Hours (inches):

Instrument Make/Model:

Method Description:

Calibration Procedure:

Sample Description			Instrument #1			Instrument #2		
Sample ID	Sample Depth (ft)	Soil Cover	Initial	Peak	Post 30 Sec.	Initial	Peak	Post 30 Sec.

Stanley Consultants INC.

Pump Test Data Sheet

Project: Project No.: Date/Time: Sheet ___ of ___

Contractor Personnel: SGI Personnel:

Weather:

Well No.: __________ Pumping Well ☐ Observation Well ☐

Distance from Pumping Well: ____________

Well Diameter: _______ Static Water Level: _____

Well Depth: ________________

Screen Size: ________________

Depth Top of Screen: ______ Depth Bottom of Screen: _____

Calculate Volume of Water in Pumping Well:
[VOL = $\Pi r^2 L \times 7.48$ gal/ft.^{3}]

Note: r = Radius (ft)
L = Length of Saturated zone in well (ft)

DISCHARGE INFORMATION:

Well Discharge Rate: ____________________

Discharge Rate Measurement Method: ____________

____

Was rate checked throughout test Y ___ N ___

If yes, note variations:

TEST DATA:

Time Drawdown Test Started: ____________________

Time Recovery Started: ____________________

Time Recovery Completed: ____________________

Elapsed Time: ____________________

Approximate distance and location of discharge outlet from observation/monitoring well: ____________________

____

% Recovery Achieved: ____________________

DRAWDOWN MEASUREMENT INFORMATION:

Recording Method: ____________________

____

Transducer Size (ex. 10 psi): ________________

Transducer Depth: ________________
(Allow Time for water level to equilibrate)

Data Logger Model: ____________________

Data Logger Test Number: ________________

Recording Type: Linear ______ Log ______

Maximum Time Step: ____________________

Obtain Field Print of Data? Y _______ N _______

DIAGRAM OF PUMP TEST SET UP:

Comments:

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Rev: 30 May 1991

Stanley Consultants INC.

Monitoring Well Construction Summary

Well No.

MW-

Project: ____________ No.: ____________

Client: ____________ Date Completed: ____________

Location: ____________

Boring Contractor: ____________ Method: ____________

SGI Personnel: ____________

Reference Elevation: ____________

Elev. Ground Surface: ____________

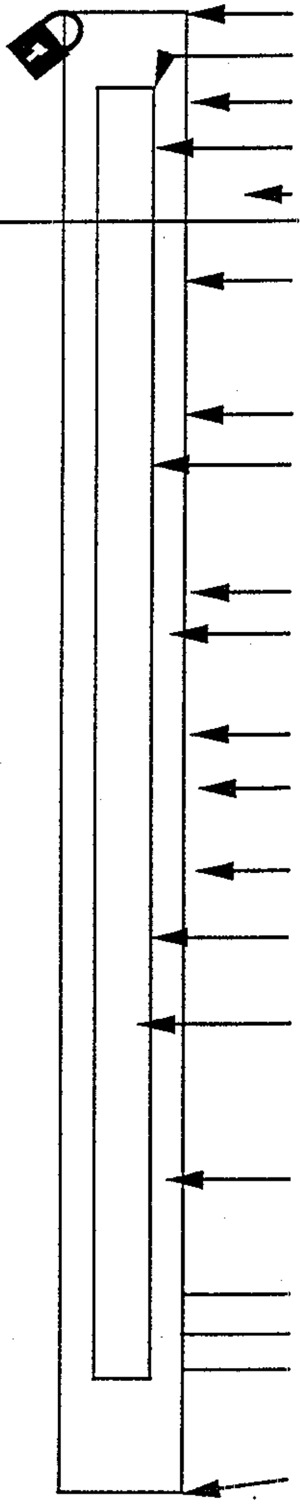
Depth to Ground Water: ____________

Development Date: ____________

Development Method: ____________

Ground Elevation

Generalized Stratigraphy and Water Level



Elevation top of protective casing: ____________

Elevation of top riser pipe: ____________

Stick-up of protective casing: ____________

Stick-up of riser pipe: ____________

Type of surface seal: ____________

I.D. of protective casing: ____________

Type of protective casing: ____________

Depth bottom of protective casing ____________

Riser pipe I.D. ____________

Type of riser pipe: ____________

Borehole diameter: ____________

Type of backfill: ____________

Elevation/depth top of seal: ____________

Type and thickness of seal: ____________

Depth top of filter pack: ____________

Elevation/Depth top of screen: ____________

Type of screen: ____________

Slot size: ____________

I.D. of screen ____________

Type of filter/sand pack: ____________

Elevation/depth bottom of screen: ____________

Elevation/depth bottom of well: ____________

Elevation/depth bottom of filter pack: ____________

Type of backfill below observation well: ____________

Elevation/depth of borehole: ____________

APPENDIX E

DATA VALIDATION STANDARD OPERATING PROCEDURES

TABLE OF CONTENTS

EVALUATION OF METALS DATA FOR SW-846 6010 (ICP-AES) ANALYSIS

1.0 SCOPE

l.l This procedure is applicable to inorganic data obtained from contractor laboratories analyzing metals by SW-846 Method 6010

l.2 The data validation is based upon analytical and quality assurance requirements specified in EPA SW-846, 3rd edition, Method 6010B.

2.0 RESPONSIBILITIES

Data reviewers will complete the following tasks as assigned by the Project Manager or Deputy Project Manager:

2.l. For a full (Tier 3) review :

2.l.l Data Assessment - "Total Review-Inorganics" Checklist Appendix (A.1). The reviewer must answer every question on the checklist.

2.l.2 Data Assessment - Data Assessment Narrative (Appendix A.2). The answer on the checklist must match the action in the narrative (appendix A.2) and on sample analysis result forms.

2.l.3 Data Review Log: It is recommended that each data reviewer maintain a log of the reviews completed to include:

a. date of start of SDG review
b. date of completion of SDG review
c. site name
d. SDG number
e. contract laboratory identifier
f. number of samples
g. matrix
h. hours worked
i. reviewer's initials

2.1.4 Telephone Record Log (telephone log) - the data reviewer should enter the bare facts of inquiry, before initiating any phone conversation with contract laboratory. After the SDG review has been completed, attach a copy of the Telephone Record Log, along with copies of any subsequent associated laboratory submittals, to the completed Data Assessment Narrative (Appendix A.2).

3.0 DATA COMPLETENESS

Each data package is checked by the assigned data reviewer for completeness. A data package is considered to be complete when (a) all deliverables required per project scope are present, and (b) the contents of the electronic data deliverables match the hard-copy contents. If a data package is incomplete, the reviewer shall immediately notify the Project Manager for resolution. If the laboratory does not respond within 48 hours, the laboratory coordinator will be notified.

4.0 REJECTION OF DATA

All values determined to be unacceptable on the sample analysis result forms must be lined over with a red pencil. As soon as review criteria non-compliance causes data to be rejected, that data may be eliminated from any further review or consideration.

5.0 ACCEPTANCE CRITERIA

In order that reviews be consistent among reviewers, acceptance criteria as stated in Appendix A.l (pages 4-13) should be used.

 YES NO N/A

APPENDIX A.1

A.1.1 Cover Page - Present? [___] ___ ___

Is cover page properly filled in, dated and signed by an *authorized signatory* of the laboratory? [___] ___

ACTION: If no, initiate telephone log, and contact laboratory for submittal.

A.1.2 Do sample numbers on cover page agree with sample numbers on:

(a) Analysis Request / Chain-of-Custody? [___] ___ ___
(b) Sample Result Forms? [___] ___ ___

ACTION: If no for any of the above, contact laboratory for clarification / resolution.

A.1.3 Are all data summary forms labeled with:

Laboratory name? [___] ___ ___
Sample and Laboratory ID Nos.? [___] ___ ___
SDG No.? [___] ___ ___
Correct units? [___] ___ ___
Matrix? [___] ___ ___

ACTION: If no for any of the above, note omissions in the data assessment narrative.

A.1.4 Do any computation/transcription errors exceed 10% of reported values on sample result and QC reporting forms for:
(NOTE: Check all forms against raw data.)

(a) all analytes analyzed by ICP? [___] ___ ___

ACTION: If yes, initiate telephone log, contact laboratory for corrected data and correct errors with red pencil and initial.

A.1.5 Raw Data

A.1.5.1 Digestion Log* for ICP present? [___] ___ ___
*Weights, dilutions and volumes used to obtain values.

Are pH values present and < pH 2 for aqueous samples? [___] ___ ___

Percent solids calculation present for soils/sediments? [___] ___ ___

Are preparation dates present on sample preparation logs/bench sheets? [___] ___ ___

A.1.5.2 ICP instrument read out record present? [___] ___ ___

A.1.5.3 Are all raw data to support all sample analyses and QC operations present? [___] ___ ___
Legible? [___] ___ ___
Properly Labeled? [___] ___ ___

ACTION: If no for any of the above questions in sections A.1.5.1 through A.1.5.3, initiate telephone log and contact laboratory for resubmittals.

A.1.6 Holding Times - (aqueous and soil samples)

(Examine sample traffic reports and analysis logs.)

ICP Metals analysis (6 months) exceeded ? ___ [___] ___

NOTE: Prepare a list of all samples and analytes for which holding times have been exceeded. Specify the number of days from date of collection to the date of analysis (from raw data). Attach to checklist.

ACTION: If yes, reject (red-line) values less than Instrument Detection Limit (IDL) and flag as estimated (J) the values above IDL even though sample(s) was preserved properly.

A.1.7 Is pH of any aqueous samples for:

Metals Analysis >2? ___ [___] ___

ACTION: If yes, flag the associated metals data as estimated.

A.1.8 Sample Results Forms

A.1.8.1 Are all sample results forms present and complete? [___] ___ ___

ACTION: If no, initiate telephone log and contact laboratory for submittal.

A.1.8.2 Are correct units (ug/l for waters and mg/kg for soils) indicated on Form I's? [___] ___ ___

Are soil sample results for each parameter corrected for percent solids? [___] ___ ___

Are all "less than IDL" values properly coded with "U"? [___] ___ ___

Are the correct concentration qualifiers used with final data? [___] ___ ___

ACTION: If no for any of the above, initiate telephone log, and contact laboratory for corrected data.

A.1.9 Are field sample ID #s and corresponding laboratory sample ID #s the same as on the Cover Page, sample results forms and in the raw data? [___] ___ ___

Was a brief physical description of samples given on the sample results forms? [___] ___ ___

Was the dilution factor of any sample re-analyzed at dilution noted on sample result form or on Run Log? ___ [___] ___

ACTION: If no for any of the above, note the omissions in the data assessment narrative.

A.1.10 Calibration

A.1.10.1 Is record of at least 2-point calibration present for ICP analysis (blank + at least one standard)? [___] ___ ___

ACTION: If no, initiate telephone log and contact laboratory for submittal. <u>If the 2-point calibration cannot be verified, Reject all associated results</u>.

A.1.11 Initial and Continuing Calibration Verification

A.1.11.1 Present and complete for every metal? [___] ___ ___

ACTION: If no, initiate telephone log and contact laboratory for submittal. <u>If the ICV or CCV cannot be verified, Reject all associated results</u>.

A.1.11.2 Circle on each ICV or CCV summary form all percent recoveries that are outside the acceptable limits of 90% to 110% of true value.

Are all calibration standards (initial and continuing) within control limits:

ICP metals: 90% - 110% recovery? [___] ___ ___

ACTION: Flag as estimated (J) all positive data (not flagged with a "U") analyzed between a calibration standard with %R between 75-89 recovery and nearest acceptable calibration standard. Qualify results <IDL as estimated (UJ) if the ICV or CCV %R is 75-89%. Reject (redline) as unacceptable data if recovery of the ICV or CCV is outside the range 75-125%. Qualify five samples on either side of verification standard out of control limits.

A.1.11.3 Was continuing calibration performed after daily initial calibration, after every 10 samples, and at the end of the analytical run? [___] ___ ___

ACTION: If no for any of the above, qualify the affected data, and note the problem in the "Data Assessment Narrative".

A.1.12 Initial and Continuing Calibration Blanks Summary Forms

A.1.12.1 Present and complete? [___] ___ ___

Was an initial calibration blank analyzed immediately following the daily ICV? [___] ___ ___

Was a continuing calibration blank analyzed after every 10 samples and at the end of the analytical run (following the final CCV)? [___] ___ ___

ACTION: If no, initiate telephone log, contact laboratory for submittal, and note the omission in the "Data Assessment Narrative".

A.1.12.2 Circle on each Blank Summary form all calibration blank positive values that are above 3x IDL or negative responses that are below 3x absolute IDL value.

ACTION: If no for any of the above, flag as estimated (J) positive sample results when raw sample value is less than or equal to calibration blank value analyzed between calibration blank with value above 3x IDL and nearest acceptable calibration blank.
Flag five samples on either side of the calibration blank outside the control limits.

A.1.13 Method (Digestion) Blank

A.1.13.1 Was one method blank analyzed for:

each Sample Delivery Group (SDG)? [___] ___ ___

each batch of digested samples? [___] ___ ___

each matrix type? [___] ___ ___

ACTION: If no for any of the above, flag as estimated (J) all the associated positive data for which prep. blank was not analyzed.

 YES NO N/A

A.1.13.2 Is concentration of any prep. blank value greater than any analyte PQL value? ___ [___] ___

If yes, is the concentration of the sample with the least concentrated analyte less than 10x prep. blank value? ___ [___] ___

ACTION: If yes, reject (redline) all associated data greater than PQL but less than ten times the prep. blank value.

A.1.13.3 Is concentration of prep. blank value less than PQLs ? [___] ___ ___

ACTION: If no, reject (redline) all positive sample results when sample raw data are less than 10 times the prep. blank value.

A.1.13.4 Is concentration of prep. blank below negative PQLs? ___ [___] ___

ACTION: If yes, reject (redline) all associated sample results less than 10x IDL.

A.1.14 ICP Interference Check Sample Results

A.1.14.1 Present and complete? [___] ___ ___

Was ICS analyzed at beginning of each run ? [___] ___ ___

ACTION: If no, flag as estimated (J) all the samples for which Al, Ca, Fe, or Mg is higher than the corresponding value in the ICS.

A.1.14.2 Circle all values on each ICS summary form that exceed ± 20% of true or established mean value.

Are all Interference Check Sample results inside the control limits (± 20%)? [___] ___ ___

If no, is concentration of Al, Ca, Fe, or Mg lower than the corresponding concentration in the ICS? [___] ___ ___

ACTION: (a) If any ICS recoveries are below 80%, qualify (‘UJ’ or ‘J’) all associated results; if ICS recoveries are significantly low (professional judgment), comment on the potential effects on the data in the data assessment narrative. (b) If any recoveries are above 120%, qualify (‘J’) all associated positive results; if ICS recoveries are significantly high (professional judgment), comment on the potential effects on the data in the data assessment narrative.

A.1.15 Matrix Spike Sample Results (Pre-Digestion)

A.1.15.1 Present and complete for: each SDG? [___] ___ ___

each matrix type? [___] ___ ___

ACTION: If no for any of the above, flag as estimated (J) all the positive data less than four times the spiking levels used for which spiked sample was not analyzed.

NOTE: If one spiked sample was analyzed for more than 20 samples, then first 20 samples analyzed do not have to be flagged as estimated (J), if spike recoveries were acceptable (i.e., 75% - 125%).

A.1.15.2 Was field blank used for spiked sample? ___ [___] ___

ACTION: If yes, flag all positive data less than 4x spike added as estimated (J) for which field blank was used as spiked sample.

A.1.15.3 Circle on each Matrix Spike form all spike recoveries that are outside control limits (75% - 125%).

Are all recoveries within control limits? [___] ___ ___

If no, is sample concentration greater than or equal to four times spike concentration? [___] ___ ___

ACTION: If yes, disregard spike recoveries for analytes whose concentrations are greater than or equal to four times spike added. If no, circle those analytes on each Matrix Spike form for which sample concentration is less than four times the spike concentration.

Are results outside the control limits (75-125%) flagged by the laboratory on sample results and spike summary forms? [___] ___ ___

ACTION: If no, note the omissions in the data assessment narrative.

A.1.15.4 Are any spike recoveries:
(a) less than 75%? ___ [___] ___
(b) greater than125%? ___ [___] ___
(c) outside the documented historical acceptance limits for the particular matrix? ___ [___] ___

ACTION: (a) If any recoveries are below 75%, qualify (‘UJ’ or ‘J’) all associated results if the sample result is below 4x the spike concentration; if spike recoveries are significantly low (professional judgment), comment on the potential effects on the data in the data assessment narrative.

(b) If any recoveries are above 125%, qualify ('J') all associated positive results if the sample result is below 4x the spike concentration; if spike recoveries are extremely high, comment on the potential effects on the data in the data assessment narrative.
(c) If any recoveries are outside the documented historical acceptance limits, qualify the data appropriately and indicate potential bias strength and direction in the data assessment narrative.

A.1.16 Matrix Spike Duplicate Sample Results

A.1.16.1 Present and complete for: each SDG? [___] ___ ___

each matrix type? [___] ___ ___

ACTION: If no for any the above, flag as estimated (J) all positive results for which duplicate sample was not analyzed.

Note: (a) If one duplicate sample was analyzed for more than 20 samples, then first 20 samples do not have to be flagged as estimated, if duplicate precision values were acceptable.
(b) If percent solids for soil sample and its duplicate differ significantly (professional judgment), comment on the potential sample heterogeneity in the data assessment narrative.

A.1.16.2 Was field blank used for duplicate analysis? ___ [___] ___

ACTION: If yes, flag all positive data > 10x IDL as estimated (J) for which field blank was used as duplicate.

A.1.16.3 Are all values within control limits (maximum 20% RPD) or within the documented historical acceptance limits for each matrix? [___] ___ ___

Are results outside the control limits or outside documented historical acceptance limits flagged by the laboratory on sample results and duplicate summary forms? [___] ___ ___

ACTION: If no, note the omissions in the data assessment narrative.

NOTE: RPD is not calculable for an analyte of the spike – duplicate pair when both values are less than IDL.

A.1.16.4 Are any duplicate precision (%RPD) values:
(a) greater than 20%? ___ [___] ___
(b) outside the documented historical acceptance limits for the particular matrix? ___ [___] ___

ACTION: (a) If any %RPD are above 20%, qualify ('J') all associated positive results. If RPD values are extremely high (professional judgment), comment on the potential effects on the data in the data assessment narrative.
(b) If any recoveries are outside the documented historical acceptance limits, qualify the data appropriately and indicate potential effects on the data in the data assessment narrative.

A.1.17 Laboratory Control Sample (LCS)

A.1.17.1 Was an LCS prepared and analyzed for:

each SDG? [___] ___ ___

each batch samples digested? [___] ___ ___

each matrix type? [___] ___ ___

ACTION: If no for any of the above, initiate telephone log and contact laboratory for submittal of results of LCS. Flag as estimated (J) all reported results if LCS was not analyzed.

NOTE: If one duplicate sample was analyzed for more than 20 samples, then first 20 samples do not have to be flagged as estimated, if duplicate precision values were acceptable.

A.1.17.2 Are all values within the documented historical acceptance limits for each matrix? [___] ___ ___

A.1.17.3 Are results outside the documented historical acceptance limits flagged by the laboratory on sample results and duplicate summary forms? [___] ___ ___

NOTE: If IDL of an analyte is equal to or greater than true value of LCS, disregard the "Action" below even though LCS is out of control limits.

Is LCS "Found" value higher than the documented historical acceptance limits or greater than certified reference material acceptance limits? ___ [___] ___

ACTION: If yes, qualify all associated positive data as estimated (J).

Is LCS "Found" value lower than the documented historical acceptance limits or less than certified reference material acceptance limits? ___ [___] ___

ACTION: If yes, qualify all associated data as estimated (UJ or J).

 YES NO N/A

A.1.18 Serial Dilution Samples

A.1.18.1 Was Serial Dilution analysis performed for:

each SDG? [___] ___ ___

each matrix type? [___] ___ ___

ACTION: If no for any of the above, flag as estimated all the positive data > 10x IDLs for which Serial Dilution Analysis was not performed.

A.1.18.2 Was field blank(s) used for Serial Dilution Analysis? ___ [___] ___

ACTION: If yes, flag all associated data > 10 x IDLs as estimated (J).

A.1.18.3 Are results outside control limit flagged on sample result forms and serial dilution summary forms when initial concentration is equal to 10 times IDL or greater ? [___] ___ ___

ACTION: If no, note the omissions in the data assessment narrative.

A.1.18.4 Circle on each serial dilution summary form all percent difference that are outside the control limits for initial concentrations equal to or greater than 10 x IDLs only.

Are any percent difference values > 10%? ___ [___] ___

ACTION: Flag as estimated (J) all the associated sample data > 10xIDLs for which percent difference is greater than 10%. If percent difference values are significantly higher than 10% (professional judgment), note the potential effects on the reported data in the data assessment narrative

Note: Flag on sample result forms only the sample results whose associated raw data are > 10xIDL

Note: As an alternate to the serial dilution, the method allows performance of a post-digestion spike addition for evaluation of potential chemical or physical interferences. If this alternate is used, the PSA recovery must be between 75% and 125% to verify the absence of interferences.

A.1.19 Verification of Instrumental Parameters

A.1.19.1 Are bi-annual (every six months) verification reports present for:

Instrument Detection Limits? [___] ___ ___

	YES	**NO**	**N/A**
ICP Interelement Correction Factors?	[___]	___	___
ICP Linear Ranges?	[___]	___	___

ACTION: If no, initiate telephone log and contact lab for submittal.

A.1.19.2 Instrument Detection Limits

	YES	**NO**	**N/A**
A.1.19.2.1 Are IDLs present for: all the analytes?	[___]	___	___
all the instruments used?	[___]	___	___

ACTION: If no for any of the above, initiate telephone log and contact laboratory for submittal.

	YES	**NO**	**N/A**
A.1.19.2.2 Is IDL greater than PQL for any analyte?	___	[___]	___
If yes, is the concentration on sample results form of the sample analyzed on the instrument whose IDL exceeds PQL, greater than 5 x PQL?	[___]	___	___

ACTION: If no, flag as estimated all values less than five times PQL of the instrument whose IDL exceeds PQL.

A.1.19.3 Linear Range Determinations

	YES	**NO**	**N/A**
A.1.19.3.1 Was any sample result higher than high linear range of ICP.	___	[___]	___
Was any sample result higher than the highest calibration standard for non-ICP parameters?	___	[___]	___
If yes for any of the above, was the sample diluted to obtain the result on Form I?	[___]	___	___

ACTION: If no, flag the result reported on sample results form as estimated (J).

A.1.20 Percent Solids of Soils and Sediments

	YES	**NO**	**N/A**
A.1.20.1 Are recalculated percent solids in soil or sediment samples within a reasonable error band, considering rounding error?	[___]	___	___

ACTION: If no, initiate telephone log and contact the laboratory for resolution.

APPENDIX A.2
DATA ASSESSMENT NARRATIVE

Project # ________________ Site __________________ Matrix: Soil _______
SDG# ________________ Lab __________________ Water_______
Contractor ________________ Reviewer __________________ Other_______

A.2.1 Validation Flags- The following flags have been applied in red by the data validator and must be considered by the data user.

J- This flag indicates the result qualified as estimated

Red- Line- A redline drawn through a sample result indicates unusable value. The redlined data are known to contain significant errors based on documented information and should not be used by the data user.

Unqualified Data- The results that do not carry "J" or "red-line" are unqualified for appropriate use.

A.2.2 The data assessment is given below and on the attached sheets.

A.2.2 (continuation)

APPENDIX A.3
INORGANIC DATA ASSESSMENT SUMMARY

SDG NO.___________________________________ SITE____________________

LABORATORY______________________________ MATRIX_______________

REVIEWER'S NAME _________________________ DATE _________________

CHECKED BY _________________________ DATE _________________

DATA ASSESSMENT SUMMARY

	ACCEPTABLE	QUALIFIED	REJECTED
1. HOLDING TIMES			
2. CALIBRATIONS			
3. BLANKS			
4. ICS			
5. LCS			
6. DUPLICATE			
7. MATRIX SPIKE			
8. SERIAL DILUTION			
9. SAMPLE VERIFICATION			
10. OVERALL ASSESSMENT			

ACTION ITEMS:____

AREAS OF CONCERN:____

1.0 PESTICIDE DATA VALIDATION REQUIREMENTS

This section presents data validation requirements for extractable pesticide compounds conducted using SW-846 Method 8081A (EPA 1996).

1.1 DATA PACKAGE COMPLETENESS AND CASE NARRATIVE

A case narrative should be included with each data package and should be reviewed for information specific to the reported data (e.g., missing or substituted documentation, nonconformances, abnormalities encountered with the samples, matrix problems, re-analyses, and deviations from the referenced analytical method).

1.2 INSTRUMENT CALIBRATIONS AND PERFORMANCE

The objective of initial and continuing calibration is to ensure that instrument conditions are adjusted properly to provide acceptable resolution, sensitivity, and accuracy for detecting target compounds prior to and throughout the analysis of samples. The GC must pass specific criteria prior to the analysis of samples to ensure maximum instrument sensitivity and chromatographic resolution specific to pesticide compounds.

1.2.1 Initial Calibrations (Levels D and E)

Initial calibration documents that instrument performance was acceptable prior to sample analysis. Initial calibration may be conducted by external or internal standardization methods. The information below provides guidance on the evaluation of both calibration methods.

Initial calibration criteria include the following:

- A five-point calibration curve must be established, with one concentration at or near the method DL.
- If the percent relative standard deviation (%RSD) is less than 20% over the working range, the average calibration factor can be used. If the %RSD over the working range exceeds 20%, a curve-fitting equation for calculating results must be employed. If curve-fitting is employed, the maximum %RSD shall be ~30%. If the laboratory used an average %RSD that was greater than 20%, qualify all associated positive sample results as estimated (J). For calculation of the calibration factor, see Appendix D.
- If the GC was calibrated using the internal standard technique, then at least one internal standard is analyzed in each calibration standard at the approximate concentration used for sample analysis and is free of matrix interference.
- Calibration standards are injected or purged in the same way as with the samples.
- All target compound peaks across the working range were integrated under the same conditions.

- If toxaphene, chlordane, BHC, or the DDT series were detected, review the calibration and quantitation information described in Section 7.6 of Method 8081A.

- Calibration standards are NIST-traceable (or equivalent).

Necessary documentation includes the following:

- Instrument identification, standard identification, calibration date, and standard analysis raw data

- Traceability certificates for all calibration standards (including a dilution log documenting the preparation), including standard identification, date of preparation, analyte, lot numbers, expiration date, and concentration values.

After evaluation is completed, qualify the sample results as follows:

- If the %RSD of the calibration factors for the initial calibration is >20% (>30% for curve fit calibrations), qualify the associated results for that compound as estimated (J, UJ).

- If the regression coefficients are less than 0.995 qualify any positive results for the associated compounds as estimated (J).

- If the minimum number of standards was not used for calibration (5 for average RRF and linear regression, 6 for second order polynomial, and 7 for third order polynomial) qualify all associated positive results as estimated (J).

- If the instrument was not calibrated before use, qualify all associated sample results as unusable (R, UR).

- If the raw calibration data are unavailable (i.e., cannot be provided by the laboratory) and continuing calibration data are either not available or are out of control, qualify the associated data as unusable (R, UR). If continuing calibration data is available and meets the requirements identified below, qualify all associated sample results as estimated (J, UJ).

- If traceability of calibration standards cannot be established or they were used past their expiration date, qualify all associated sample results as estimated (J, UJ).

- If the calibration data are incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

1.2.2 Continuing Calibration (

Continuing calibration ensures that the instrument conditions are stable and that quantitative results are accurate.

Continuing calibration criteria are as follows:

- All standards were analyzed at the beginning of each analytical run, and a continuing calibration curve has been analyzed daily and after every 20 samples.
- Calibration or RF values or concentrations (regression quantitation models) are within 15%D of the initial calibration values.
- Continuing calibration compounds elute within the retention time windows of the initial calibration values.

Check standards are of known quality.

Necessary documentation includes the following:

- Instrument identification, standard identification, analysis date, and check standard analysis raw data
- For analyses using statistically determined acceptance criteria, derived control limit values
- Standard traceability certificates (including a dilution log documenting the preparation), including source identification, date of preparation, analyte, lot numbers, expiration date, and concentration values

After evaluation is completed, qualify all associated sample results as follows:

- If a continuing calibration check was not analyzed at the minimum frequency, qualify all associated sample results as estimated (J, UJ).
- If the calibration check RFs or concentrations are greater than +15%D of the initial calibration values and an acceptable calibration check has not been reanalyzed or the instrument has not been recalibrated, qualify all associated positive results as estimated (J). Non-detects require no qualification.
- If the calibration check RFs or concentrations are <75%D of the initial calibration values, and an acceptable calibration check has not been reanalyzed or the instrument has not been recalibrated, qualify all associated results as estimated (J, UJ).
- If the calibration checks do not fall within the retention time windows, associated sample results after the last in-control point may be affected. If no peaks are present within the retention time window of the deficient analyte of interest, no qualification is necessary. However, if peaks are present, qualify all affected sample results as unusable (R, UR).
- If the calibration check information is unavailable (i.e., cannot be provided by the laboratory), qualify all associated sample results as unusable (R, UR).

- If the calibration check data are incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

- If traceability of calibration standards cannot be established or they were used past their expiration date, qualify all associated sample results as estimated (J, UJ).

1.2.3 Instrument Performance

Criteria for chromatographic resolution and instrument sensitivity are established to ensure the performance of the overall GC measurement system. These criteria are instrument-specific rather than sample-specific and should be met under all circumstances.

Instrument performance criteria include the following:

- At least three injections of all single-component standard mixtures and multi-response standards have been analyzed within a 72-hour period.

- The DDT and endrin breakdowns (or combined breakdowns) are 120% in all Evaluation B standard analyses.

After evaluation is completed, qualify the sample results as follows:

- If the DDT percent breakdown exceeds 20%, qualify all detected results for DDT as estimated (J) and all non-detects as unusable (UR) if DDD and DDE are detected. In addition, qualify all detected results for DDD or DDE as presumptive and estimated (NJ).

- If the endrin breakdown exceeds 20%, qualify all detected results for endrin as estimated (J) and all non-detects as unusable (UR) if endrin aldehyde or endrin ketone are detected. In addition, qualify all detected results for endrin ketone as presumptive and estimated (NJ).

1.3 BLANKS

Blank sample results are reviewed to assess the extent of contamination introduced through sampling, sample preparation, and analysis. Summarize all blank results in the validation narrative.

1.3.1 Calibration Blanks

Calibration blank results may not involve the same weights, volumes, or dilution factors as the associated samples because non-aqueous samples are reported in pg/kg units and the associated calibration blanks are reported in pg/L units. Therefore, it may be necessary to work from the raw data when reviewing the calibration blank data.

Blank analysis criteria are as follows:

- The calibration blank is performed immediately following a calibration check.

- Calibration blank results are <MDL.

- Calibration blank run after any sample where a target compound was present at levels that saturated the detector.

Necessary documentation includes instrument identification, calibration blank preparation/ analysis date, and calibration blank preparation/analysis raw data.

After evaluation is completed, qualify (applies only to results generated between the out-of-specification calibration blank and the nearest acceptable calibration blank) sample results as follows:

- If calibration blanks were not analyzed at the minimum frequency identified, qualify all associated sample results as estimated (J, UJ).

- If the absolute value of any negative calibration blank result exceeds the MDL, qualify all associated undetected sample results as estimated (UJ) and qualify associated positive sample results within two times the absolute blank value as estimated (J).

- If calibration blank results are >MDL but are less than the RL, qualify associated sample results as undetected (UJ) for any result >RDL but <5 times the highest blank concentration, qualify as estimated (J). Results >5 times the highest blank concentration do not require qualification.

- If the blank data are incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

1.3.2 Laboratory (Preparation) Blanks

Blank analysis criteria include the following:

- Laboratory blanks have been extracted and analyzed for each matrix and have been analyzed on each instrument at a minimum frequency of one per analytical batch. If cleanups are used, e.g. Fluorisil, sulfur cleanup is required, a method blank reflecting the cleanup process must also be analyzed for the batch in the same analytical batch (sulfur blank only if all samples in batch required sulfur cleanup).

- A laboratory blank was prepared at the same time as the samples using the same procedure, including any cleanup steps used.

- Laboratory blank results are <MDL.

Necessary documentation includes the following:

- Instzument identification and laboratory blank preparation/analysis raw data.

- Laboratory blank results, preparation and analysis dates, and MDL/RL values.

After evaluation is completed, qualify the sample results as follows:

- If a laboratory blank was not prepared with the associated samples at the minimum frequency identified, qualify all associated sample results as estimated (J, UJ).

- If calibration blank results are >MDL but are less than the RL, qualify associated sample results as undetected (UJ) for any result >RDL but <5 times the highest blank concentration, qualify as estimated (J). Results >5 times the highest blank concentration do not require qualification.

- If the blank data is incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

1.3.3 Field Blanks

Review the field sampling documentation to identify the field blank samples (usually referred to as equipment blanks) and sample types. If necessary, contact the project coordinator to obtain the required information. Verify that the field blanks were handled in the laboratory as actual samples. Positive results may indicate that decontamination procedures were inadequate or that contamination was inherent to the equipment used. No qualification is to be performed based on field blank results; however, the results should be discussed in the validation narrative to alert data users to uncertainties in the data set during decision-making processes.

1.3.4 Trip Blanks

Review the field sampling documentation, if necessary, to identify the trip blanks. Review the report forms, quantitation reports, and chromatograms. Qualification of sample results is not required based on trip blank results; however, field blank results should be noted in the validation narrative to alert the data user to uncertainties in the data set during decision-making processes.

1.4 BIAS

Compliance with bias requirements is determined by laboratory performance and compliance with project-specific and analytical requirements, as determined by the analysis of MS/MSDs and surrogate compounds.

1.4.1 Surrogate Recovery

Surrogates provide a measure of performance on individual samples. Surrogate recovery criteria are as follows:

- Every sample that is analyzed is spiked with the appropriate surrogate compounds.

- Surrogate recoveries are within the specified laboratory limits or the limits of 50% to 150% if not specified.

- Surrogate materials are of known quality.

Necessary documentation includes the following:

- Surrogate results, preparation and analysis dates, and laboratory-established surrogate recovery limits

- Instrument identification and surrogate preparation/analysis raw data

- Final surrogate concentration, the amount of spike added and associated standard identification

- Traceability certificates (including a dilution log documenting the preparation), including identification, date of preparation, constituent, lot numbers, expiration date, and concentration values.

After evaluation is completed, qualify the sample results as follows:

- If surrogates were not added to the associated samples , qualify all associated sample results as estimated (J, UJ).

- Qualify all associated sample results as estimated (J, UJ) for surrogates out of specification but >l0% recovery. No qualification is required for non-detects associated with high recovery surrogates.

- Qualify all associated detected results as estimated (J) and non-detects as unusable (R) for surrogate recoveries <l0%, unless surrogates were diluted out (i.e., diluted below low-level ICAL standard levels) due to the presence of analyte concentrations requiring dilution to quantitate results. If surrogates are diluted out, qualify all associated results as estimated (J, UJ).

- If the surrogate data are incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

- If traceability of surrogate standards cannot be established or they were used past their expiration date, qualify all associated sample results as estimated (J, UJ).

- If both method blank and sample surrogates are out of specification, note in the validation report narrative.

1.4.2 Matrix Spike Recovery

The MS/MSD results provide matrix-specific information on the accuracy of the method for specific target compound classes. The MS criteria are as follows:

- Matrix spikes were performed on a sample from each matrix present in the analytical batch at a minimum frequency of one per analytical batch.
- Matrix spikes were prepared at the same time as the associated samples in the same analytical batch, using the same procedures, including any cleanup steps used, and spike analytes were added as early in the sample preparation process as practicable.
- Matrix spike materials are NIST-traceable (or equivalent) whenever possible.
- Matrix spike percent recovery is within the laboratory-established limits or the limits of 50% to 150% if not specified.

Necessary documentation includes the following:

- Matrix spike results, preparation and analysis dates, and laboratory-established recovery limits
- Instrument identification and MS preparation/analysis raw data (Levels D and E only)
- Final matrix spike concentration, the amount of spike added, and associated standard identification
- Traceability certificates (including a dilution log documenting the preparation), including identification, date of preparation, constituent, lot numbers, expiration date, and concentration values.

After the evaluation is completed, qualify the sample results of similar matrix as the MWMSD samples according to Table 6-l.

Table 1-1. Pesticide MS/MSD Result Qualification. (2 Pages)

MS/MSD Recovery	Surrogate Recovery	Sample Result	Qualification
<LCL	Within limits	>5 times spike concentration	No qualification
		<5 times spike concentration and detected	J
		Undetected	UJ
<LCL	<LCL	<5 times spike concentration and detected	J

		Undetected	UJ
>UCL	<LCL	<5 times spike concentration limit and detected	U
		Undetected	UJ
>UCL	>UCL	<5 times spike concentration and detected	J
		Undetected	No qualification

- If a MS sample was not prepared with the associated samples at the minimum frequency identified, qualify all associated sample results as estimated (J, UJ).
- If the MS data are incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).
- If traceability of MS standards cannot be established or they were used past their expiration date, qualify all associated sample results as estimated (J, UJ).
- If the field blank has been used for spike analysis, note in the validation narrative.
- If it is determined from validation that only the spiked samples are affected by low recoveries (this may be obtained from the sample preparation sheet or the narrative), qualify only the results for the spiked sample as described above.

1.4.3 Laboratory Control Samples

A LCS or BSS serves as a monitor of the overall performance of all steps in the analysis, including the sample preparation. Typically LCSs are used for non-aqueous sample matrices and should be similar to the matrix composition of the samples to be analyzed. Typically BSSs are used with aqueous samples and are spiked distilled waster.

The LCS/BSS criteria are as follows:

- A LCS/BSS was performed at a minimum frequency of one per analytical batch.
- A LCS/BSS was prepared at the same time as the associated samples in the same analytical batch, using the same procedures, including any cleanup steps used.
- The LCS/BSS standards are NIST-traceable (or equivalent) whenever possible. At a minimum, reagents used must be reagent grade or better.
- Results are within the published control limits or within the limits of 50% to 150% if not specified.

Necessary documentation includes the following:

- The LCS/BSS results and preparation and analysis dates

- Instrument identification and LCS/BSS preparation/analysis raw data

- Final concentration of the LCS/BSS, the amount of spike added to the LCS/BSS, and associated standard identification

- Traceability certificates (including a dilution log documenting the preparation), including identification, date of preparation, constituent, lot numbers, expiration date, and concentration values.

After evaluation is completed, qualify the sample results as follows:

- If the LCS/BSS recoveries are <LCL control limits, qualify all associated sample results as estimated (J for detects, UJ for non-detects).

- If the LCS/BSS recoveries are >UCL, qualify all associated positive sample results as estimated (J).

- If neither a LCS nor BSS sample was prepared with the associated samples at the minimum frequency identified, qualify all associated sample results as estimated (J, UJ).

- If the LCS/BSS data are incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

- If traceability of LCS/BSS standards cannot be established or they were used past their expiration date, qualify all associated sample results as estimated (J, UJ).

1.4.4 Performance Audit Samples

Performance audit samples are introduced to the laboratory as a normal field sample and are primarily used to evaluate the accuracy of the laboratory analytical procedure.

Contact the project coordinator for the identity, source, and control limits for any performance audit sample submitted with the sample group. Note the results of any performance audit sample in the validation narrative and summarize the results in the final data validation report.

1.5 PRECISION

Compliance with precision requirements is determined by the evaluation of MS and MSDs or a laboratory duplicate as described in the following subsections.

1.5.1 Matrix Spike/Matrix Spike Duplicate or Laboratory Duplicate Samples

Laboratory duplicate samples may consist of either a sample/replicate (i.e., the same sample prepared/analyzed twice in the analytical batch) pair or a MS/MSD (i.e., one sample spiked identically, prepared/analyzed in the analytical batch) pair. The frequency and logistics of laboratory replicates and matrix spike replicates are established in the program requirements. In the absence of this at least one precision evaluation sample should be included with every 20 field samples.

Duplicate (laboratory replicate or MS/MSD) sample criteria are as follows:

- The duplicate analysis was prepared at the same time as the associated samples in the same analytical batch, using the same procedures, including any cleanup steps used.

- The RPD must be <30% for aqueous samples (<50% for non-aqueous) for duplicate results >5 times the RL.

- For duplicate results <5 times the RDL, the range between the primary and duplicate results must be less than the RL for aqueous samples (<2 times the RL for non-aqueous).

Necessary documentation includes the following:

- Duplicate results and the preparation and analysis dates
- Instrument identification and preparation/analysis raw data.

After the evaluation is completed, qualify the sample as follows:

- If a duplicate sample was not analyzed with the samples at the minimum frequency identified, qualify all associated sample results as estimated (J, UJ).

- If the measured concentrations are both >5 times the RDL and the RPD is >20% for aqueous samples (>35% for non-aqueous), qualify all associated sample and duplicate results as estimated (J).

- If both sample and duplicate results are non-detects, no .qualification is required.

- If either or both of the measured concentrations are <5 times the RL, the above RPD criteria do not apply and the range between the sample and duplicate concentrations must be evaluated as follows:

  - If the range in concentration between the result(s) or reporting limit(s) is < RL value for aqueous samples (2 times the RL value for non-aqueous matrices), no qualification is required.

- If the range in concentration between the result(s) or reporting limit(s) is >RL value for aqueous samples (2 times the RL value for non-aqueous samples), qualify associated sample results as estimated (J) for detects. Non-detects are not qualified.

- If field blanks were used for laboratory duplicates, note in the validation narrative.

- If the duplicate data are incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

1.5.2 Field Duplicate Samples

The collection of field duplicate (collocated) samples are specified for some sampling events. If a field duplicate sample is sent to the laboratory, the results can aid in the overall evaluation of the data set. The validator shall be provided with the identification of collocated samples or shall obtain identification information where this process is required in the program.

The default RPD limits for the field duplicates (where both results are >5 times the RL) are 30% for water samples and 50% for soils. When one or both the results are <5 times the RL, the default limit should be expressed as the difference between result and RL value or the difference between the RL values, in which the acceptable limits are the range of RDL for water samples and 2 times RL for soils. Data qualification is not required for field duplicate RPD; however, the results of field duplicates should be discussed in the validation narrative to alert data users to uncertainties in the data set during decision-making processes.

1.5.3 Field Split Sample

A field split sample is used primarily to assess precision. A field split sample is a representative sample from a sampling event sent to a third-party (reference) laboratory. If so required by the program, the validator shall contact the project coordinator for the identification of the field duplicate submitted to the laboratory if the information has not already been provided.

The reference laboratory data are used to help formally evaluate the project data quality objectives at the end of the data validation process and are not specifically used to qualify an individual data package. Evaluate the field split sample results by comparing the corresponding sample results to the reference laboratory sample results. Note the results of the split sample duplicate analysis in the validation narrative, and summarize the results in the final data validation report.

1.6 SYSTEM PERFORMANCE

During sample analysis and between instrument performance and internal QC checks, conditions in the measurement system can affect the usability of sample data. Therefore, a review of additional data quality indicators must be performed to identify problems that may affect the interpretation and usability of the subject data. Evaluate system performance by reviewing the following types of information:

- Review the report forms, chromatograms and quantitation reports for evidence of GC/EC baseline anomalies, retention time shifts, extraneous peaks, low resolution, and peak anomalies.

- Check that positive results are not affected by abrupt changes in baseline caused by leaks in the injector system or GC column bleed.

If in the validator's professional judgment quantitative sample results may be biased due to system performance anomalies, such judgment must be addressed in the validation narrative and the affected results shall be qualified accordingly.

1.7 HOLDING TIMES AND SAMPLE PRESERVATION

The analyte-specific holding time and sample preservation criteria are shown in Table 6-2. For any analyte not included in this table, contact the project coordinator for specific criteria.

Table 1-2. Pesticide Analytes, Method Identification, Holding Times,

Analytical Parameters	Method	Holding Time[a]	Preservation
Gas Chromatography			
Pesticides	8081A[b]	Aqueous 7/40[c] Nonaqueous 14/40	All – Cool to 4°C
TCLP Pesticides	1311/8081	Aqueous 7/40 Nonaqueous 14/7/40[d]	All – Cool to 4°C

a. Holding time in days (unless otherwise noted).
b. Four-digit numbers from Test Methods for Evaluating Solid Waste: Physical/Chemical Methods (EPA 1986).
c. First time to initial sample extraction, second time from extraction to analysis.
d. First time to TCLP extraction, second time from TCLP extraction to preparation extraction, and third time from preparation extraction to analysis.

Necessary documentation includes the sampling date and preservation (normally on sample chain-of-custody) and preparation/analysis dates.

After evaluation is completed, qualify results as follows:

- If samples were not preserved and were not analyzed within identified holding times, qualify all affected sample results as unusable (R, UR).

- If samples were not preserved and were analyzed within identified holding times, qualify all affected sample results as estimated (J, UJ).

- If properly preserved samples analyzed past the identified holding times but <2 times past the identified holding times, qualify all affected sample results as estimated (J, UJ).

- If properly preserved samples were analyzed >2 times past the identified holding times qualify all affected detected sample results as estimated (J) and non-detected results as unusable (UR).

1.8 SAMPLE RESULT COMPOUND IDENTIFICATION, QUANTITATION, AND DETECTION LIMITS

Qualitative criteria have been established to minimize false positives and negatives in the reporting of pesticide data. These criteria include compliance with dual, dissimilar column quantitation, retention time window criteria on dissimilar columns and GC/MS confirmation if the sample concentration for any single pesticide is at least 10 parts per million (ppm) in the sample extract.

1.8.1 Compound Identification and Quantitation

Compound identification and quantitation criteria are as follows:

- All positive results are within the retention time windows.
- Positive results were analyzed and reported on dissimilar columns.
- If interference is evident, the lower of the two values are reported.
- If no interference is evident, the higher of the two values are reported.
- The pattern for multi-peak pesticides (e.g., chlordane and toxaphene) matches the standard chromatograms.
- Results are within the linear range of the instrument calibration.
- Proper extraction techniques were used for aqueous and non-aqueous samples and for TCLP samples. Jar extraction was conducted for TCLP, and that the proper extraction fluid was used based on the preliminary evaluation of the waste sample.
- If samples were analyzed using the internal standard technique, internal standard recovery limits are established by the laboratory, or use 50% to 150%.

Required documentation includes the following:

- Laboratory sample results, preparation/analysis dates, and DL values for non-detected analytes
- Instrument identification and sample preparation/analysis raw data (Levels D and E only).

After evaluation is completed, qualify the sample results as follows:

If the qualitative criteria are not met, qualify detected results as non-detect as follows: if the misidentified peak is outside the retention time windows and no interferences are noted, report the RL; if the misidentified peak interferes with a target peak, then the reported value is qualified as estimated and undetected (UJ).

If detected results have not been analyzed on dissimilar columns, qualify the results as unusable (R).

- If quantitation and confirmation are questionable, all affected data should be qualified as presumptive and estimated (NJ).

- If GC/MS confirmation was required but not conducted, note this fact in the validation reports and also note the effect on the sample results.

- Check calculations and correct any sample results as necessary.

- If results are reported from analyses that are outside of the linear calibration range of the instrument, qualify results as estimated (J, UJ).

- If samples were analyzed using the internal standard technique and the recoveries exceed limits, qualify the associated data as estimated (J, UJ). If internal standard recovery limits are not provided by the laboratory, note as such in the validation narrative.

- If sample preparation cannot be verified or if sample preparation was conducted improperly and no other major or minor deficiencies are identified, qualify the associated results as estimated (J, UJ) and note as such in the data validation package and final report (Levels D and E only).

- If the validator determines that incorrect identifications were made as a result of cross-contamination or carryover between analyses, then the affected data should be qualified as unusable (R, UR) and noted as such in the validation narrative.

1.8.2 Reported Detection Limits

Result RL value criterion includes the reported MDL values meeting the RL or client-specific requirements.

Required documentation may include any or all of the following items: preparation/analysis dates, MDL study information, MDL values, and RL values for non-detected analytes.

After evaluation is completed, qualify results as follows:

- Note in the validation report which RL values for non-detects do not meet the method or client-specific values.

- If sample results and RL values cannot be verified, qualify all affected results as estimated (J, UJ).

- If systematic errors are discovered, request clarification from the project coordinator and note the results in the validation reports.

1.9 SAMPLE CLEANUP

Sample cleanup procedures are used to remove matrix interferences. Gel permeation chromatography is frequently used to remove high molecular weight interferents. FluorisilB is frequently used to remove polar compound interferents. Other solid phase absorbants (e.g., alumina, silica gel) used for sample cleanup must meet the criteria defined for Fluorisil except for the criteria that Fluorisil check solutions contain 2,4,5-trichlorophenol.

Sample cleanup criteria includes the following:

- Fluorisil cartridges or bulk material have every lot number checked before use.

- All anlaytes of interest in the check solutions.

- Analyte of interest recoveries 80- 110%.

- Fluorisil check solutions contain 2,4,5-trichlorophenol.

- 2,4,5-tichlorophenol recoveries < 5%.

- GPC columns checked before use.

- All anlaytes of interest in GPC check solutions.

- GPC analyte of interest recoveries should be 80-l 10%.

- GPC column calibrated before use.

- GPC column calibration checked once every 7 days or before use.

- Check materials used are of known quality.

- All associated analytical batch QC samples (e.g., blanks, matrix spikes, LCS/BSS) also received the same cleanup as the samples

Necessary documentation includes the following:

- Lot or batch numbers, check/calibration material identification, analysis dates, check/calibration material analysis results and raw data.

- Analytical batch cleanup logs/raw data

- Check/calibration material traceability certificates including a dilution log documenting the preparation including source identification, date of preparation, analyte, lot numbers, expiration date, and concentration values.

After the evaluation is completed, qualify the samples results as follows:

- If the initial check did not meet the specified recovery, qualify all associated sample results as estimated (J, UJ). If recovery is 0 qualify all associated non-detected results as rejected (UR)

- If the initial check information is unavailable (cannot be provided by the laboratory), qualify all associated sample results as unusable (R, UR).

- If the initial check data is incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

- If a GPC calibration check was not analyzed at the minimum frequency, qualify all associated sample results as estimated (J, UJ).

- If the GPC calibration check internal standards do not fall within the retention time windows, qualify all affected detected sample results as estimated (J) and rejected for non-detects (UR)

- If the GPC calibration check data is unavailable (cannot be provided by the laboratory), qualify all associated sample results as unusable (R, UR).

- If the GPC calibration check data is incomplete or calculations cannot be confirmed, qualify all associated sample results as estimated (J, UJ).

- If traceability of check/calibration materials cannot be established or were used past their expiration date, qualify all associated sample results as estimated (J, UJ).

- If the associated analytical batch QC samples were not given the same cleanup, qualify all associated sample results as estimated (J, UJ).

1.10 OVERALL ASSESSMENT AND SUMMARY

Complete the data validation checklist (Appendix A) and summarize the data validation results according to the requirements of Section 10.0.

PESTICIDE DATA VALIDATION CHECKLIST

Validation Tier	II	III			
Project:			Data Package:		
Validator:		Lab:		Date:	
Case:			SDG:		
Analyses Performed					
SW-846 8081	SW-846 8081 (TCLP)	SW-846 8081 (TCLP)			
Samples/Matrix					

1. Data Package Completeness and Case Narrative

Technical verification documentation present?	Yes	No	N/A

Comments:

2. Instrument Performance and Calibrations

Initial calibration acceptable?	Yes	No	N/A
Continuing calibrations acceptable?	Yes	No	N/A
Standards traceable?	Yes	No	N/A
Standards expired?	Yes	No	N/A
Calculation check aqcceptable?	Yes	No	N/A
DDT and endrin breakdowns acceptable	Yes	No	N/A

Comments:

3. Blanks

Calibration blanks analyzed?	Yes	No	N/A
Calibration blank results acceptable?	Yes	No	N/A
Laboratory blanks analyzed?	Yes	No	N/A
Laboratory blank results acceptable?	Yes	No	N/A
Field/trip blanks analyzed?	Yes	No	N/A
Field/trip blank results acceptable?	Yes	No	N/A

Transcription/calculation errors?	Yes No N/A

Comments:

4. Bias

Surrogates analyzed?	Yes No N/A
Surrogate recoveries acceptable?	Yes No N/A
Surrogates traceable?	Yes No N/A
Surrogates expired?	Yes No N/A
MS/MSD samples analyzed?	Yes No N/A
MS/MSD results acceptable?	Yes No N/A
MS/MSD standards NIST traceable?	Yes No N/A
MS/MSD standards expired?	Yes No N/A
LCS/BSS samples analyzed?	Yes No N/A
LCS/BSS results acceptable?	Yes No N/A
Standards traceable?	Yes No N/A
Standards expired?	Yes No N/A
Transcription/calculation errors?	Yes No N/A
Performance audit sample(s) analyzed?	Yes No N/A
Performance audit sample results acceptable?	Yes No N/A

5. Precision

Duplicate RPD values acceptable?	Yes No N/A
Duplicate results acceptable?	Yes No N/A
MS/MSD standards NIST traceable?	Yes No N/A
MS/MSD standards expired?	Yes No N/A
Field duplicate RPD values acceptable?	Yes No N/A
Field split RPD values acceptable?	Yes No N/A
Transcription/calculation errors?	Yes No N/A

Comments:

6. System Performance

Chromatographic performance acceptable?	Yes No N/A

Positive Results resolved acceptable?	Yes	No	N/A

Comments:

7. Holding Times

Samples properly preserved?	Yes	No	N/A
Sample holding times acceptable?	Yes	No	N/A

Comments:

8. Compound Identification, Quantitation, and Detection Limits

Compound identification acceptable?	Yes	No	N/A
Compound quantitation acceptable?	Yes	No	N/A
Results reported for all requested analyses?	Yes	No	N/A
Results supported in the raw data?	Yes	No	N/A
Samples properly prepared?	Yes	No	N/A
Detection limits meet RDL?	Yes	No	N/A
Transcription/calculation errors?	Yes	No	N/A

Comments:

9. Sample Cleanup

Fluorisil® (or other absorbant) cleanup performed?	Yes	No	N/A
Lot check performed?	Yes	No	N/A
Check recoveries acceptable?	Yes	No	N/A
GPC cleanup performed?	Yes	No	N/A
GPC check performed?	Yes	No	N/A
GPC check recoveries acceptable?	Yes	No	N/A
GPC calibration performed?	Yes	No	N/A
GPC calibration check performed	Yes	No	N/A
GPC calibration check retention times acceptable?	Yes	No	N/A
Check/calibration materials traceable?	Yes	No	N/A
Check/calibration materials expired?	Yes	No	N/A
Analytical batch QC given similar cleanup?	Yes	No	N/A
Transcription/calculation errors?	Yes	No	N/A

Comments:

Comments:

Table . DQO Summary Table

STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7
State the Problem	**Identify the Decisions**	**Identify the Inputs to the Decisions**	**Define Study Boundaries**	**Develop Decision Rules**	**Specify Tolerable Limits on Errors**	**Optimize Sampling Design**

APPENDIX F

ORDWAY AND ASSOCIATES DATA VALIDATION MEMORANDUM OF UNDERSTANDING

1. Introduction

This document describes Ordway and Associates' understanding of the data validation process requested by the Nevada Division of Environmental Protection (NDEP) and has been prepared in accordance with the conference call of December 18, 2009 and the following guidance:

- Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use, OSWER No. 9200.1-85, EPA 540-R-08-005, 13 January 2009;
- Intergovernmental Data Quality Task Force, Uniform Federal Policy for Quality Assurance Project Plans, Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs, Part 1: UFP-QAPP Manual EPA: EPA-505-B-04-900A, DOD: DTIC ADA 427785; and
- NDEP - April 13, 2009 BMI Plant Sites and Common Areas Projects, Henderson, Nevada – *Supplemental Guidance on Data Validation*

The overall data review process consists of three steps as described in Section 2. The first two Data Review Steps are supported by four Stages of verification and validation as described in Section 3.

The initial data package for each analytical method will be verified and validated in accordance with Stage 4. Once it is determined that the data report is acceptable and that no corrective actions will be needed on the part of the laboratory, the data review and validation process may be performed in accordance with Stage 2B.

> Note: For this document, data package or sample delivery group (SDG) are synonymous and are defined as a group of samples which behave similarly with respect to the sampling or the testing procedures being employed and which are processed as a unit. For QC purposes, if the number of samples in a group is greater than 20, then each group of 20 samples or less will all be handled as a separate batch. All required analytical QC samples are performed for each batch of up to 20 samples per matrix per method.

As stated above, once the laboratory has satisfactorily submitted the data package for an analytical method, the next four data packages will be validated in accordance with Stage 2B. Thereafter, at least 10% of the field samples and at least one in every 5 data packages will be validated to Stage 4 with the remainder being validated to Stage 2B. The QA Manager as identified in the QAPP will determine the sample delivery group designated for level 4 validation based on field observations and expected analytical results. An example of the application of this method as it pertains to the November 2009 field sampling efforts including Ponds D and G solids sampling, Waste Management Unit 7 (WMU-7) and the diesel area is demonstrated in a separate attachment. For Stage 2B, any laboratory or matrix QC metrics addressed in the Functional Guidelines with a defined data qualifier (i.e. data flag) would not be considered as needing additional Stage 4 validation.

However, quantitative and qualitative ID errors such as the following could constitute reason for elevating a Stage 2B validation to a Stage 4 validation:

- inability to verify a sample result;
- not reporting an analyte that is present and vice-versa;
- misidentification of compounds (e.g., identifying hexane as MTBE);
- inappropriate manual integrations;
- incorrect number of calibration points;
- exclusion of inside calibration points in calculating acceptance criteria:
- improper regression parameters, (e.g. Forcing zero when it is not allowed); etc.

During the validation process, any recalculations described below will be performed for a single compound in a single sample within the SDG. In the event that a variance is discovered, additional calculations will be performed with appropriate actions to be taken (e.g. contacting the laboratory and requesting a corrected data package, additional data flags, etc.).

As was discussed in the above referenced conference call, this program will be acceptable for meeting the criteria included in NDEP's April 13, 2009 BMI Plant Sites and Common Areas Projects, Henderson, Nevada – *Supplemental Guidance on Data Validation* of all data being validated to Stage 2B and at least 10% of the data being validated to Stage 4.

2. Data Review Process

The Data Review Process consists of three steps as described in Table 1. Within the Data Review Process Step I – Verification and Step II – Validation, may be performed to varying levels or stages as described in Section 3.

Table 1 Data Review Process Summary

Process Term	Objective	Scope	Data Review Step	Output
Verification	Review to see if data required for the project are available	• Sampling • Analysis	I. Completeness Check	Verification Report. • May be a checklist form. • Package includes all documentation
Validation	• Assess and document the performance of the field collection process. • Assess and document the performance of the analytical process.	• Sampling • Analysis	IIa. Check compliance with the method, procedure, and contract requirements. IIb. Compare with measurement performance criteria from the QAPP.	Validation report: • Includes qualified data • May be part of other reports such as RI/FS.
Usability Assessment	Assess and document usability to meet project quality objectives (PQO)s	• Sampling • Analysis	III. Assess usability of data considering project quality objectives and the decision to be made.	Data Validation Summary Report or Usability Report
Notes:				

1. The terms *verification* and *validation* apply to field sampling activities, as well as to the analytical component of data generation.

2. Validation assesses not only compliance with method, procedure, and contract requirements, but also compliance with QAPP-specific requirements.

3. Usability assessments are a minimum requirement for all environmental project phases and data uses. This is the final step of data review: assessing whether the data are suitable as a basis for the decision.

3. Analytical Data Verification and Validation Stages (Data Review Steps I, IIa and IIb.)

3.1. Verification and Validation Stages

There are five levels organized into four stages of data verification and validation as listed below. The minimal requirements for each stage are noted in "( )"s and correspond to the descriptions of each item as listed in Table 2. Each stage of verification and validation includes all items associated with the previous stages. In other words, each higher-level stage builds upon the work performed in the previous stage.

Stage 1: Verification and validation based only on completeness and compliance of sample receipt condition checks (Items 1-9).

Stage 2A: Verification and validation based on completeness and compliance checks of sample receipt conditions and ONLY sample-related QC results (Stage 1 plus items 10-16).

Stage 2B: Verification and validation based on completeness and compliance checks of sample receipt conditions and BOTH sample-related and instrument-related QC results. Stage 2B includes verification with values in the raw data to reported values but not the recalculation of results (Stage 2A plus items 17-23).

Stage 3: A verification and validation based on completeness and compliance checks of sample receipt conditions, both sample-related and instrument-related QC results, and recalculation checks (Stage 2B plus items 24-36).

Stage 4: A verification and validation based on completeness and compliance checks of sample receipt conditions, both sample-related and instrument-related QC results, recalculation checks, AND the review of actual instrument outputs (e.g. chromatograms, mass Spectra, inter-element correction factors, etc.) (Stage 3 plus items 34-39).

Table 2 – Description of Verification and Validation Items	
Item	**Description**
(1)	Documentation identifies the laboratory receiving and conducting analyses, and includes documentation for all samples submitted by the project or requester for analyses.
(2)	Requested analytical methods were performed and the analysis dates are present.
(3)	Requested target analyte results are reported along with the original laboratory data qualifiers and data qualifier definitions for each reported result (and the uncertainty of each result and clear indication of the type of uncertainty reported if required, e.g., for radiochemical analyses).
(4)	Requested target analyte result units are reported (along with their associated uncertainty units if required, e.g., for radiochemical analyses).
(5)	Requested reporting limits for all samples are present and results at and below the requested (required) reporting limits are clearly identified (including sample detection limits or MDA for radiological data, if required).
(6)	Sampling dates (including times if needed), date and time of laboratory receipt of samples, and sample conditions upon receipt at the laboratory (including preservation, pH and temperature) are documented.
(7)	For radiochemical analyses, the sample-specific critical values (sometimes called "critical level," "decision level" or "detection threshold") and sample specific minimum detectable value, activity or concentration for all samples are reported and results at and below the requested (required) critical values are clearly identified.
(8)	For radiochemical analyses, the chemical yield (if applicable to the method) and reference date and time (especially for short lived isotopes) is reported for all samples (as appropriate).
(9)	Sample results are evaluated by comparing sample conditions upon receipt at the laboratory (e.g., preservation checks) and sample characteristics (e.g., percent moisture) to the requirements and guidelines present in national or regional data validation documents, analytical method(s) or contract.
(10)	Requested methods (handling, preparation, cleanup, and analytical) are performed.
(11)	Method dates (including dates, times and duration of analysis for radiation counting measurements and other methods, if needed) for handling (e.g., Toxicity Characteristic Leaching Procedure), preparation, cleanup and analysis are present, as appropriate.
(12)	Sample-related QC data and QC acceptance criteria (e.g., method blanks, surrogate recoveries, deuterated monitoring compounds (DMC) recoveries, laboratory control sample (LCS) recoveries, duplicate analyses, matrix spike and matrix spike duplicate recoveries, serial dilutions, post digestion spikes, standard reference materials) are provided and linked to the reported field samples (including the field

Table 2 – Description of Verification and Validation Items	
Item	**Description**
	quality control samples such as trip and equipment blanks).
(13)	Requested spike analytes or compounds (e.g., surrogate, DMCs, LCS spikes, post digestion spikes, radiological tracers) have been added, as appropriate.
(14)	Sample holding times (from sampling date to preparation and preparation to analysis) are evaluated.
(15)	Frequency of QC samples is checked for appropriateness (e.g., one LCS per twenty samples in a preparation batch).
(16)	Sample results are evaluated by comparing holding times and sample-related QC data to the requirements and guidelines present in national or regional data validation documents, analytical method(s) or contract.
(17)	Initial calibration data (e.g., initial calibration standards, initial calibration verification [ICV] standards, initial calibration blanks [ICBs]) are provided for all requested analytes and linked to field samples reported. For each initial calibration, the calibration type used is present along with the initial calibration equation used including any weighting factor(s) applied and the associated correlation coefficients, as appropriate. Recalculations of the standard concentrations using the initial calibration curve are present, along with their associated percent recoveries, as appropriate (e.g., if required by the project, method, or contract). For the ICV standard, the associated percent recovery (or percent difference, as appropriate) is present.
(18)	Appropriate number and concentration of initial calibration standards are present.
(19)	Continuing calibration data (e.g., continuing calibration verification [CCV] standards and continuing calibration blanks [CCBs]) are provided for all requested analytes and linked to field samples reported, as appropriate. For the CCV standard(s), the associated percent recoveries (or percent differences, as appropriate) are present.
(20)	Reported samples are bracketed by CCV standards and CCBs standards as appropriate.
(21)	Method specific instrument performance checks are present as appropriate (e.g., tunes for mass spectrometry methods, DDT/Endrin breakdown checks for pesticides and arochlors, instrument blanks and interference checks for ICP methods).
(22)	Frequency of instrument QC samples is checked for appropriateness (e.g., gas chromatography-mass spectroscopy [GC-MS] tunes have been run every 12 hours).
(23)	Sample results are evaluated by comparing instrument-related QC data to the requirements and guidelines present in national or regional data validation documents, analytical method(s) or contract.
(24)	Instrument response data (e.g., GC peak areas, ICP corrected intensities) are reported for requested analytes, surrogates, internal standards, and DMCs for all requested field samples, matrix spikes, matrix spike duplicates, LCS, and method blanks as well as calibration data and

Table 2 – Description of Verification and Validation Items	
Item	**Description**
	instrument QC checks (e.g., tunes, DDT/Endrin breakdowns, interelement correction factors, and Florisil cartridge checks).
(25)	Reported target analyte instrument responses are associated with appropriate internal standard analyte(s) for each (or selected) analyte(s) (for methods using internal standard for calibration).
(26)	Fit and appropriateness of the initial calibration curve used or required (e.g., mean calibration factor, regression analysis [linear or non-linear, with or without weighting factors, with or without forcing]) is checked with recalculation of the initial calibration curve for each (or selected) analyte(s) from the instrument response.
(27)	Comparison of instrument response to the minimum response requirements for each (or selected) analyte(s).
(28)	Recalculation of each (or selected) opening and closing CCV (and CCB) response from the peak data reported for each (or selected) analyte(s) from the instrument response, as appropriate.
(29)	Compliance check of recalculated opening and/or closing CCV (and CCB) response to recalculated initial calibration response for each (or selected) analyte(s).
(30)	Recalculation of percent ratios for each (or selected) tune from the instrument response, as appropriate.
(31)	Compliance check of recalculated percent ratio for each (or selected) tune from the instrument response.
(32)	Recalculation of each (or selected) instrument performance check (e.g., DDT/Endrin breakdown for pesticide analysis, instrument blanks, interference checks) from the instrument response.
(33)	Recalculation and compliance check of retention time windows (for chromatographic methods) for each (or selected) analyte(s) from the laboratory reported retention times.
(34)	Recalculation of reported results for each reported (or selected) target analyte(s) from the instrument response.
(35)	Recalculation of each (or selected) reported spike recovery (surrogate recoveries, DMC recoveries, LCS recoveries, duplicate analyses, matrix spike and matrix spike duplicate recoveries, serial dilutions, post digestion spikes, standard reference materials etc.) from the instrument response.
(36)	Each (or selected) sample result(s) and spike recovery(ies) are evaluated by comparing the recalculated numbers to the laboratory reported numbers according to the requirements and guidelines present in national or regional data validation documents, analytical method(s) or contract.
Note:	Selection of analytes, spikes, and performance evaluation checks for the validation checks listed above for a laboratory analytical data package being verified and validated generally will depend on many factors including (but not limited to) the type of verification and validation being performed (manual or electronic), requirements and guidelines

Table 2 – Description of Verification and Validation Items	
Item	**Description**
	present in national or regional data validation documents, analytical method(s) or contract, the number of laboratories reporting the data, the number and type of analytical methods reported, the number of analytes
(37)	All required instrument outputs (e.g., chromatograms, mass spectra, atomic emission spectra, instrument background corrections, and interference corrections) for evaluating sample and instrument performance are present.
(38)	Sample results are evaluated by checking each (or selected) instrument output (e.g., chromatograms, mass spectra, atomic emission spectra data, instrument background corrections, interference corrections) for correct identification and quantitation of analytes (e.g., peak integrations, use of appropriate internal standards for quantitation, elution order of analytes, and interferences).
(39)	Each (or selected) instrument's output(s) is evaluated for confirmation of non-detected or tentatively identified analytes reported in each method, and the number of detected analytes.

3.2. Verification

Verification is a completeness check that is performed to determine whether the required information (the complete data package) is available for further data review.

3.3. Validation

Data validation is comprised of a technical review of the data based on method specifications and laboratory-developed performance criteria by adapting the procedures set forth in the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, USEPA Office of Solid Waste and Emergency Response, EPA-540/R-94-013, February 1994 -update to 2004 version and USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review, USEPA office of Solid Waste and Emergency Response, EPA540/R-94/012, February 1994 -update to 2004 version (Guidelines) for chemical data. Radiological data are technically reviewed based on method specifications, and laboratory-developed performance criteria by adapting the procedures set forth in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, EPA402-R-97-016, Final, December 1997-update to 2000 version and the EPA Functional Guidelines listed previously.