Olympus Technical Services, Inc.

April 15, 2024

Eric Krueger
Department of Environmental Quality
P.O. Box 200901
Helena, MT 59620-0901

Re: Additional Corrective Action Work Plan Required for the Petroleum Release at the Big Hole Petroleum Inc., 218 North Park, Wisdom, Beaverhead County, Montana; Facility ID 99-95062 (TID 17173), Release 4125, Work Plan 34848

Dear Mr. Krueger:

This letter presents a work plan developed by Olympus Technical Services (Olympus), on behalf of Kyle Malkovich and Big Hole Fuel Services, for groundwater monitoring at the Big Hole Petroleum Bulk Facility (Site) located at 218 North Park in Wisdom, Montana. A Site location map is shown on Figure 1 and a Site feature map is shown on Figure 2. The work plan was developed in response to a work plan request issued by the Department of Environmental Quality (DEQ) in a letter dated March 12, 2024, for an Additional Corrective Action Work Plan.

Monitoring wells MW-2R and MW-9R were installed in November 2020 to replace wells destroyed during the 2020 excavation of source area soil beneath the former aboveground storage tank (AST) farm. After excavation activities were completed, Big Hole Fuel Services installed three new ASTs, associated piping, and a pump dock. During this construction activity, it is believed that wells MW-2R and MW-9R were destroyed. The wells have not been located since April 2021. These wells are essential for evaluating the effectiveness of remedial actions at the Site.

This work plan presents a scope of work for two groundwater monitoring wells to be installed to replace presumed-destroyed wells within the excavation area, and two years of semiannual groundwater monitoring after well installation is completed.

Scope of Work

Monitoring Well Installation

Olympus will install two monitoring wells near the former locations of wells MW-2R and MW-9R, represented as proposed wells MW-13 and MW-14 on Figure 3. The actual location of monitoring wells will be determined in the field based on utility clearance and accessibility. Public utility locates will be conducted prior to drilling activities.

The wells will be advanced to a depth of approximately 20 feet below ground surface (bgs) using a direct-push drill rig operated by a licensed groundwater monitoring well contractor. Continuous soil samples will be collected in 5-foot intervals during drilling operations with a macrocore sampler for field screening and possible laboratory analysis. The soil samples will be screened for hydrocarbon vapors using a photoionization detector (PID). Since the replacement wells are being installed within the excavation area, no samples will be collected if no evidence of petroleum impacts in soil are observed. If petroleum impacts are observed (i.e., PID readings above 100 parts per million [ppm]), up to three soil samples will be collected from each soil boring to represent either worst-case impacts, groundwater interface, or bottom of the boring. The actual number and sample interval of soil samples will be determined in the field based on observations made during drilling operations. The samples will be submitted under chain-of-custody procedures to Energy Laboratories, Inc. (Energy) in Helena, Montana. The samples will be analyzed for volatile petroleum hydrocarbons (VPH) and extractable petroleum hydrocarbons (EPH) screen. Samples may be further analyzed for EPH fractions if EPH screen exceeds the 200 mg/kg fractionation limit. One field duplicate soil sample will be collected.

Monitoring wells will be constructed of 2-inch diameter threaded PVC well materials with 15 feet of 0.010-inch slotted prepack screen. The total depth of the well is anticipated to be between 18 and 20 feet bgs, based on the original well installation depth; however, the depth will be determined based on field observations. The annulus will be filled with 10-20 Colorado silica sand from the base of the boring to a depth of approximately two feet above the top of the well screen. Bentonite crumbles will be placed in the annulus above the sand to a depth of approximately one-foot bgs. A 6-inch layer of sand will be placed on top of the bentonite and a traffic-rated flushmount steel monument will be cemented in place. A locking well cap will be used to seal the well casing. A licensed professional surveyor will be subcontracted to survey the horizontal and vertical location of the well. Wells will be developed using a development pump and surge block. Groundwater will be allowed to stabilize for a minimum of 24 hours prior to sampling the monitoring wells.

Soil cuttings from well installation activities will be land applied according to Olympus' SOP. Groundwater collected during well development will be land applied unless sheen or free product is observed during purging, as directed by the DEQ Purge Water Disposal Flowchart.

Groundwater Monitoring

Semiannual groundwater monitoring events will be conducted at the Site during approximate seasonal low and high groundwater conditions for two years following well installation (anticipated October/November and May/June 2024 and 2025). Groundwater monitoring will consist of measuring static water levels (SWLs) and collecting groundwater samples from all twelve Site monitoring wells for the first two events to better evaluate closure status for the Site. The second year of semiannual groundwater monitoring will include SWLs of all Site wells, but a reduced well network to continue evaluating groundwater trends onsite. The anticipated wells to be sampled for the third and fourth events will include MW-3, MW-4R, MW-8, MW-10R, MW-12, MW-13 and MW-14. The wells included for sampling may be adjusted based on results of the first and second events, with approval from the DEQ project manager. The well locations are shown on Figure 3.

Groundwater samples will be collected from all Site wells following Olympus' standard operating procedures for low-flow groundwater sampling (attached). A peristaltic pump operating under low-flow steady state conditions will be utilized to collect groundwater samples. Field parameters will be measured in 3-5 minute intervals during groundwater purge, including depth to water, dissolved oxygen (DO), oxygen-reduction potential (ORP), pH, specific conductivity (SC), temperature, and turbidity will be measured. Upon groundwater parameter stabilization, groundwater samples will be collected into laboratory supplied bottles, preserved, stored on ice, and submitted under chain-of-custody procedures to Energy, for VPH and EPH screen.

One round of intrinsic biodegradation indicators (IBIs) will be collected during one seasonal high groundwater monitoring event to evaluate natural attenuation trends at the Site. IBIs will include sulfates, nitrate/nitrite, dissolved ferrous iron, and methane. An inline 250 micron disposable groundwater filter will be used while collecting groundwater samples for metals analysis.

Based on the age of the petroleum system, DEQ has identified a potential for leaded gasoline to have historically been stored onsite. Lead scavengers of 1,2-dichloroethane (DCA) and 1,2-dibromoethane (EDB) are required to be sampled in groundwater prior to Site closure discussions. Lead scavengers will be analyzed for one round of groundwater samples collected from the source area wells, one upgradient well, and one downgradient well, including wells MW-3, MW-4R, MW-8, MW-10R, MW-12, MW-13 and MW-14. If lead scavengers are detected above the DEQ screening levels, lead scavengers may be required for additional groundwater monitoring events.

Quality assurance/quality control (QA/QC) procedures will be followed to document the provision of reliable, accurate, and defensible data. One field duplicate groundwater sample will be collected per event to test for precision related to sampling methods. One trip blank will be included with each sample cooler containing VPH samples for analysis of unwanted contamination introduced in the field. A review of the laboratory generated data will be performed and the data validated using the Montana Department of Environmental Quality’s Data Validation Summary Form.

Investigation derived waste (IDW) from groundwater will be handled according Olympus’ SOPs (attached). Groundwater collected during purging of monitoring wells will be land applied unless sheen or free product is observed during purging, as directed by the DEQ Purge Water Disposal Flowchart.

Interim Data Submittal

Four interim data submittals (IDS) will be prepared and submitted to DEQ following well installation and the first three groundwater monitoring events. The soil IDS will be submitted following soil boring and well installation and will include monitoring well completion logs, soil data tables, and a figure showing soil analytical results. The groundwater IDS will include a discussion of the results, updated data tables, updated potentiometric and groundwater analytical maps, groundwater field forms, and analytical laboratory reports with accompanying data validation summary forms.

Release Closure Plan Update

The Release Closure Plan (RCP) developed by Olympus in 2021 and updated in 2023 will be updated for the Site based on results of all investigative and remedial activities conducted to date. The RCP will be included with the Corrective Action Report following the fourth groundwater monitoring event, and will include discussion and results of all investigative, post-investigative, and corrective action, as well as evaluation of the conceptual site model, exposure pathways, possible data gaps, and remedial alternatives.

Corrective Action Report

One AR-07 Generic Applications Corrective Action Report will be submitted to DEQ following the fourth monitoring event. The report will include discussion of the soil boring and well installation and groundwater monitoring. Monitoring well completion logs, groundwater monitoring field forms, laboratory analytical reports, data validation summary forms, soil and groundwater data tables, updated potentiometric and groundwater analytical maps, soil analytical maps, an updated RCP will be included in the report. The report will summarize potential data gaps and include recommendations for additional investigation or remedial action needed to facilitate Site closure.

Cost Estimate

Work Plan development, mobilization, monitoring well installation, groundwater monitoring, the interim data submittals, and AR-07 report tasks will be invoiced at unit cost rates approved by the Petroleum Tank Release Compensation Board (PTRCB). Unit cost worksheets for soil boring and well installation and groundwater monitoring are attached to this work plan, which lists PTRCB approved rates for 2024. Work completed beyond 2024 will be invoiced at PTRCB rates updated for that year. Project management and field oversight tasks will be invoiced on a time and materials basis. Total project costs are summarized on the attached cost estimate.

Schedule

Site work will commence following DEQ approval of this work plan. Olympus anticipates conducting the well installation activities in the second quarter of 2024. The first semi-annual groundwater event will be conducted after well installation and development. Please contact me at 406-443-3087 should you have any questions regarding the work plan or the project.

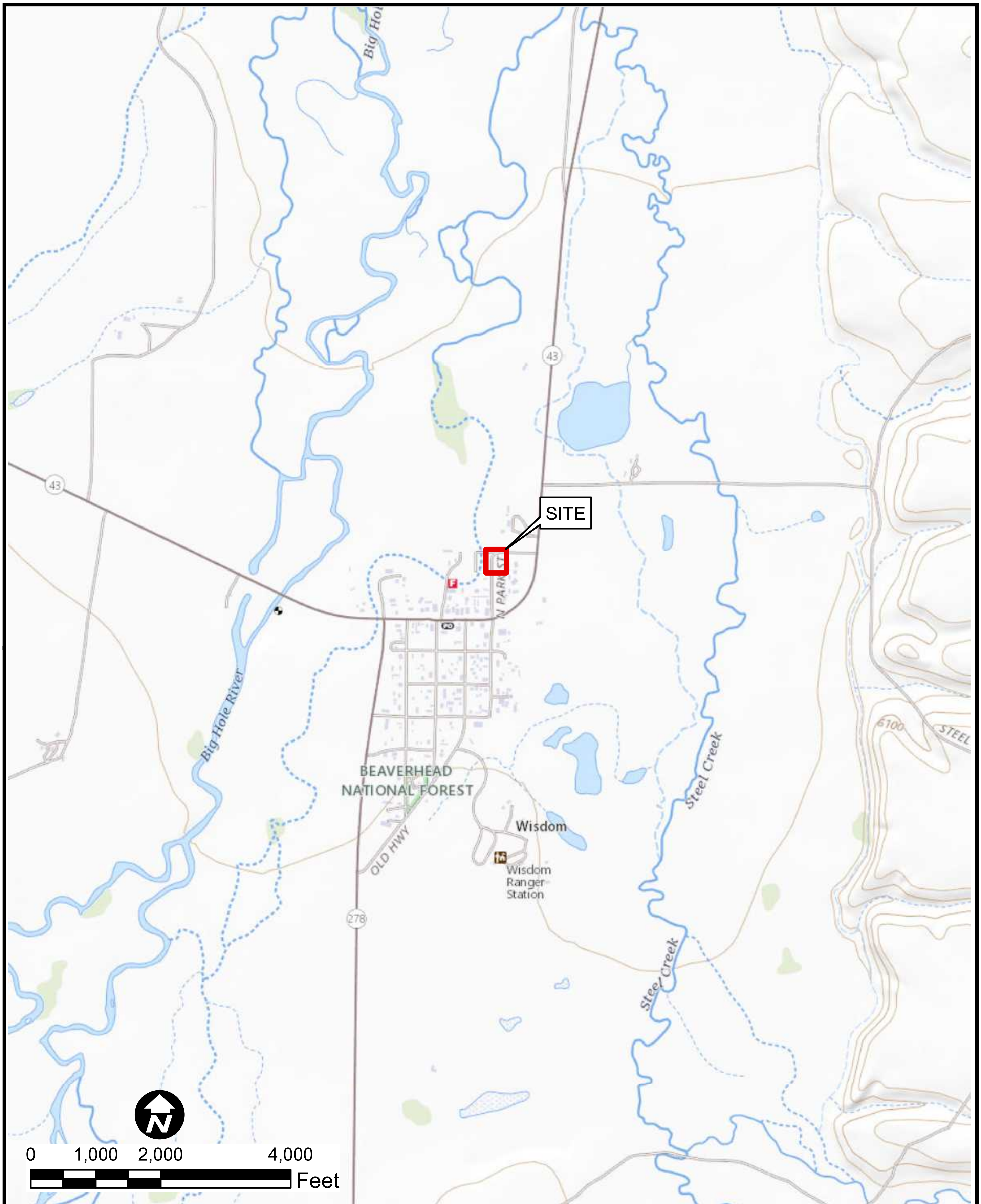
Sincerely,
Olympus Technical Services, Inc.

Diane Tackett

Diane Tackett, PG
Project Geologist

Attachments: Figures 1, 2, and 3; Cost Estimate; Soil Boring and Monitoring Well Installation Unit Cost Worksheet; Groundwater Monitoring Unit Cost Worksheet; and Olympus Standard Operating Procedures

cc: Kyle Malkovich, Big Hole Fuel Services, bigholefuelservices@gmail.com



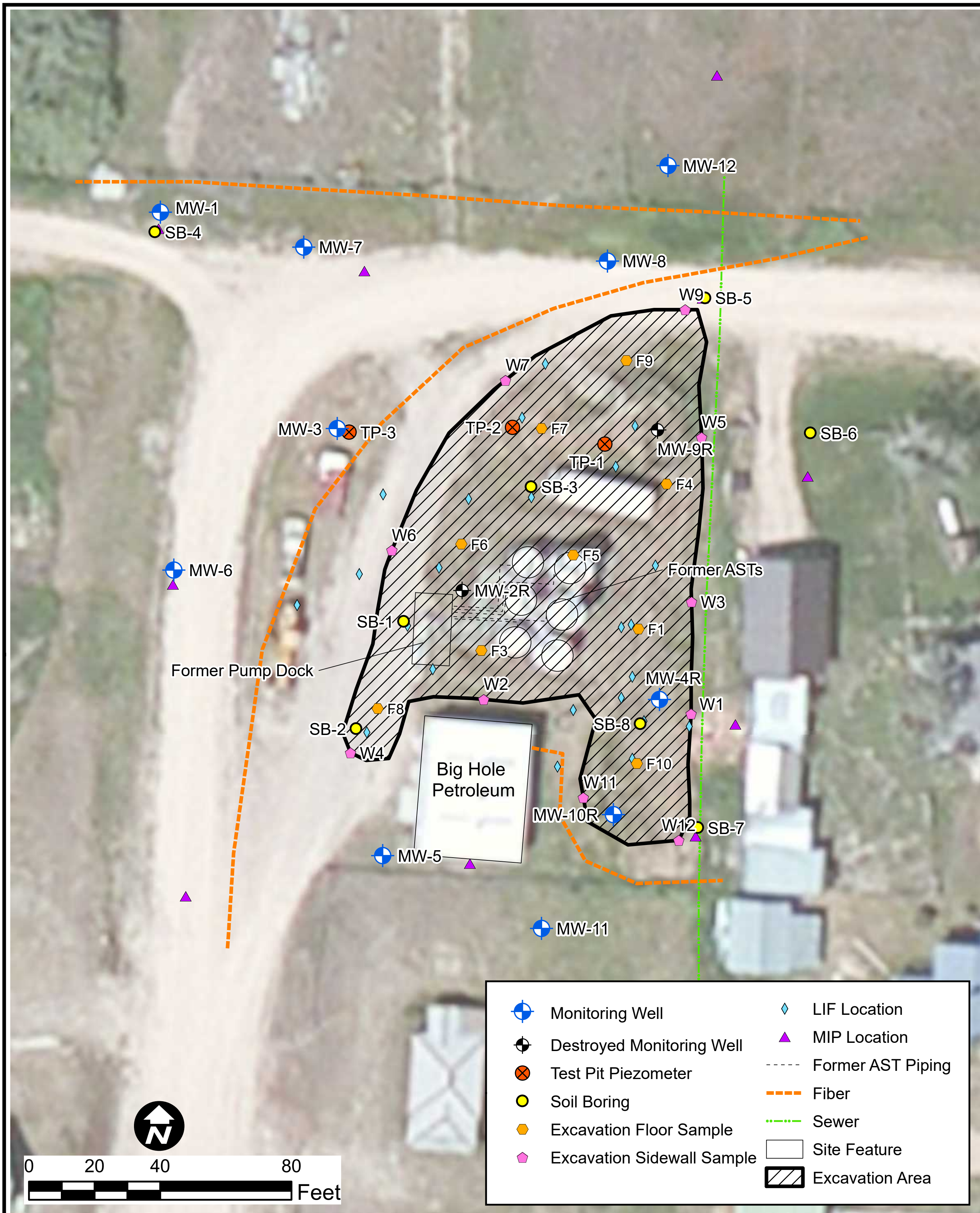
Olympus Technical Services, Inc.

Topographic Map
Big Hole Petroleum
Wisdom, Montana

FIGURE 1

A2302_Topographic Map.mxd

USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed May, 2020.



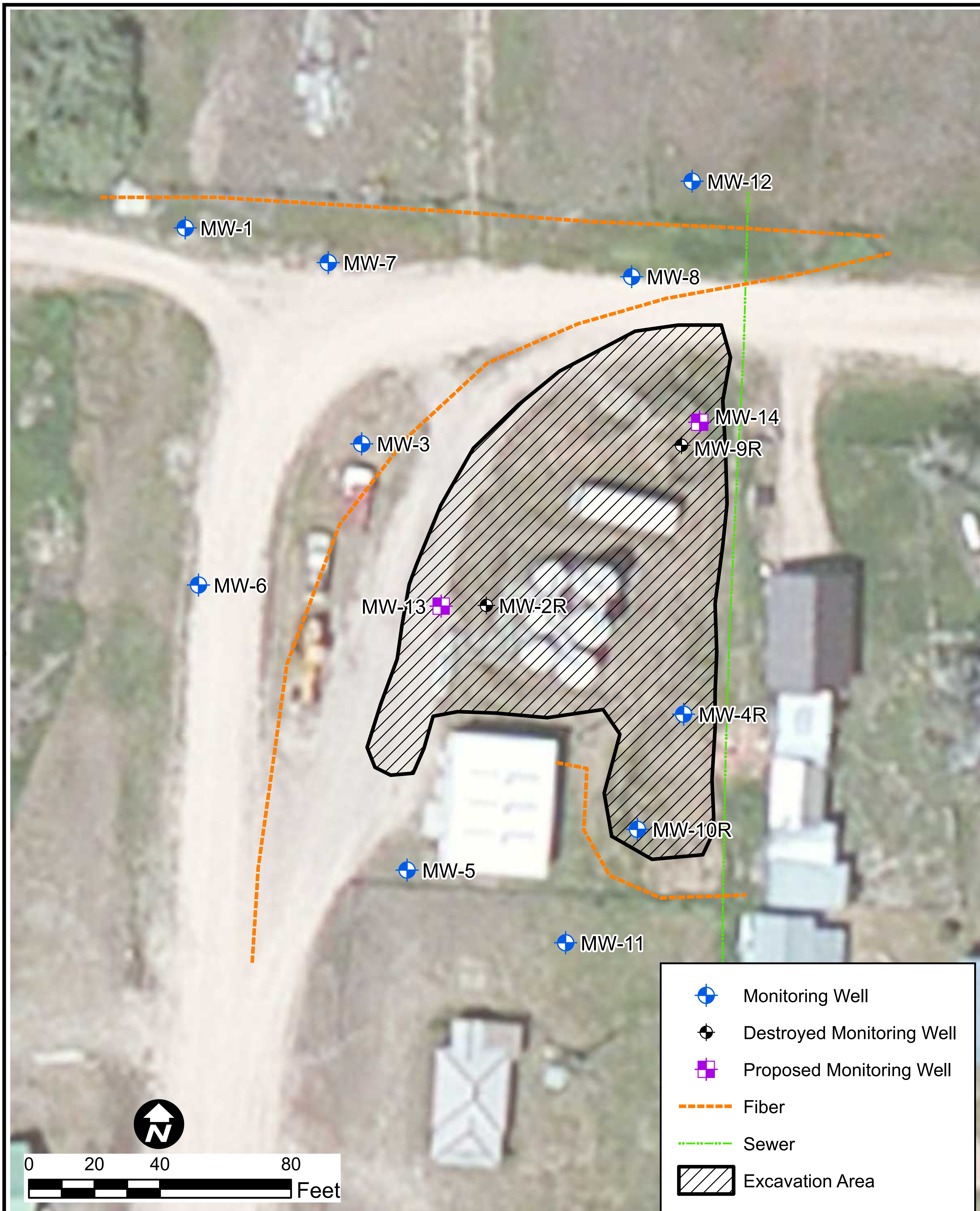
Olympus Technical Services, Inc.

Site Features
Big Hole Petroleum
Wisdom, Montana

FIGURE 2

A2302 Site Layout2021.mxd

Source: Esri, Maxar, Earthstar Geographics, IGN, and the GIS User Community



Olympus Technical Services, Inc.

Proposed Monitoring Wells
Big Hole Petroleum
Wisdom, Montana

FIGURE
3

A2302 Proposed2023.mxd

Source: Esri, Maxar, Earthstar Geographics, IGN, and the GIS User Community

STANDARD OPERATING PROCEDURE SS-1

SAMPLE COLLECTION FROM SOIL BORINGS, EXCAVATIONS AND HAND-DUG PITS

STANDARD OPERATING PROCEDURE SS-1
SAMPLE COLLECTION FROM SOIL BORINGS, EXCAVATIONS, AND HAND DUG PITS

SOIL BORING PROCEDURES

The following procedures are designed to be used during the operation of auger type drill rigs during soil sampling operations. The procedures listed below may be modified in the field by the agreement of the lead site sampler and drill operators based on field and site conditions after appropriate annotations have been made in the appropriate bound field logbook. **Prior to any subsurface work, have utilities (gas and electric, telephone, sewer, etc.) located by a regional one-call service or the utility companies as needed.**

1. Locate the site as directed in the site-specific Sampling and Analysis Plan (SAP).

2. Drillers prepare rig for operation. This includes; but is not limited to, decontamination of the drill rig tools and sampling equipment, leveling the rig, preparing the downhole tool, preparing the auger "flights", and establishing the drill over the location.

3. Mount the split tube to the drive stem.

4. Prior to using the split spoon sampler, sample the surface increment to a depth in accordance with the site-specific SAP.

5. Place split spoon sampler on the ground surface and advance sampler to the desired depth using the rig hammer.

6. After driving the split spoon sampler its entire length or upon refusal of advancement, recover the split spoon sampler. Refusal is defined as 100 blows with the rig hammer and less than 6 inches advancement of the split spoon sampler. Less than 100 blows may be defined as refusal if there is no split spoon advancement. This decision will be made at the discretion of the field sampler.

7. After recovery of the split spoon sampler, open the spoon and place the spoon containing the soil sample into a holding device, maintaining the intervals as sampled.

8. Sampling personnel will then describe the soil sample based on the site-specific SAP instructions, and fill out the appropriate bound file logbooks, field profile sheets, field site sheets, and quality assurance/quality control documentation.

9. Decontaminate the split spoon sampler.

10. Repeat steps 3 to 9 until sampling is completed.

11. The drill rig tools and sampling equipment will be decontaminated prior to moving onto the next site. The drill rig will be left in a safe and secure fashion at the end of each shift.

BACKHOE PIT EXCAVATIONS

The following procedures are designed to be used during the operation of backhoe equipment to excavate sites prior to soil sampling operations. The procedures listed below may be modified in the field by the agreement of the lead site sampler and backhoe operators based on field and site conditions after appropriate annotations have been made in the appropriate bound field logbook.

1. Locate the site as directed in the site-specific SAP. Identify locations of underground utilities.

2. Place the backhoe tractor in a safe position. This will be based on the operators judgment and site conditions.

3. Begin backhoe excavation. Place excavated materials a sufficient distance from the excavation to prevent the return of excavated materials to the pit. Topsoil will be determined by the technical field support, removed, and segregated from the underlying soils.

4. Continue excavation of the pit to the required depth. This depth shall not exceed 5 feet from the ground surface unless the proper pit exit trenches, shoring, and sloping excavations have been excavated to prevent accidental burials of sampling crew and to meet or exceed all OSHA Construction Standards (29 CFR 1926; Appendix A) for entrance by sampling personnel. If OSHA Construction standards for entrance cannot be met, the sample will be obtained from the backhoe bucket.

5. Sampling personnel may enter the pit after all excavation is complete and the excavation is deemed safe to occupy. The site safety officer shall be the oversight authority and will determine what is safe and what is not safe. "Safe" for backhoe pit excavations is defined as meeting or exceeding all OSHA Construction Standards (29 CFR 1926; Appendix A), for entrance by sampling personnel.

6. Soil profile descriptions shall be made from a hand cleaned surface along the pit wall using the Unified Soil Classification System.

7. Soil sampling will follow soil profile description and establishment of sampling intervals based on the site-specific SAP. Soil samples will be collected with decontaminated stainless steel or plastic sampling tools and bowls from the appropriate intervals. A sample collected from a depth increment shall be a representative composite of the entire interval and not biased by sample mass collected largely from the top or bottom of the increment.

8. All pertinent field quality assurance/quality control documentation, bound field logbooks, sample labels, profile sheets, and field site sheets shall be completed prior to refilling the pit.

9. After items 1 through 8 have been completed to the satisfaction of the lead sampler, the site pit shall be refilled with the previously excavated materials. The earthen materials are to be replaced in the same order they were excavated with topsoil placed on top of the filled pit. There will be some unavoidable mixing of soil during the excavation.

10. Decontaminate all sampling equipment, including the backhoe bucket.

11. Move to the next site. If the previous site was the last site of the day, decontaminate the backhoe bucket, secure, and park the backhoe tractor rig for the evening.

HAND DUG PITS

The following procedures are designed to be used during the operation of hand tools to excavate sites prior to soil sampling operations. The procedures listed below may be modified in the field by the agreement of the lead site sampler and field personnel based on field and site conditions after appropriate annotations have been made in the appropriate bound field logbook.

1. Locate the site as directed in the site-specific SAP.

2. Select the appropriate orientation for the excavation. This is be based on the lead field sampler's judgment and site conditions.

3. Begin pit excavation. Place excavated materials a sufficient distance from the excavation to prevent the return of excavated materials to the pit. Topsoil is to be placed separately from the underlying soils. Placement of excavated materials on a sheet of plastic is recommended to facilitate returning excavated material to the pit.

4. Continue excavation of the pit to the required depth. This depth shall not exceed 24 inches from the ground surface.

5. Soil profile descriptions shall be made from a hand cleaned surface along the pit wall using the Unified Soil Classification System.

6. Soil sampling will follow soil profile description and establishment of sampling intervals based on the site-specific SAP. Soil samples will be collected with decontaminated stainless steel or plastic sampling tools and bowls from the appropriate intervals. A sample collected from a depth increment shall be representative composite of the entire interval and not biased by sample mass collected largely from the top or bottom of the increment.

7. All pertinent field quality assurance/quality control documentation, bound field logbooks, sample labels, profile sheets, and field site sheets shall be completed prior to refilling the pit.

8. After items 1 through 7 have been completed to the satisfaction of the lead sampler, the site pit shall be refilled with the previously excavated materials. The earthen materials are to be replaced in the same order they were excavated with

STANDARD OPERATING PROCEDURE

Groundwater Sampling (GW-1)

This Standard Operating Procedure (SOP) covers multiple volume purge and low-flow methods of groundwater sampling from a well.

1.0 Equipment:

Purge Water Containment*
Five Gallon Bucket
Electronic Water Level Probe or
Oil-Water Interface Probe*
Meters: pH, Specific Conductivity, Dissolved Oxygen (DO), Oxidation-Reduction Potential (ORP), Turbidity (low flow)
Pump (Peristaltic, Bladder)
Compressor or Compressed air cylinder for bladder pump
Power Supply (for pump)
Graduated cylinder or other calibrated container for measuring flow rate

Bailers with Line*
Tubing*
Filter(s) and accessories*
Sample Containers
Preservatives*
Decontamination Supplies
Coolers with Ice
Field Sampling Forms
Field Notebook
Chains-of-Custody
Indelible Ink Pen(s)
Personal Protective Equipment
Sampling and analytical plan (SAP)

*As required by site-specific SAP or Site conditions

2.0 Groundwater Sampling Sequence

The sampling sequence within a specific site should begin with the well containing the lowest anticipated analyte concentration. Successive samples will be obtained from wells anticipated to have increasing analyte concentration. If the relative degree of suspected concentrations cannot be reasonably assumed, wells will be sampled in order of increasing proximity to the suspected analyte source area, preferably from the perimeter towards the center of the site, and, if the groundwater flow direction is known, preferably in the order of up-gradient, cross-gradient, down-gradient, then in the vicinity of the suspected analyte source.

3.0 Instrument Calibration

Calibrate instruments at the beginning and end of each day following the appropriate SOP. Document calibration procedures in the field notebook.

4.0 Decontamination

All reusable sample equipment that comes into contact with groundwater shall be decontaminated prior to use at each well following the procedures in the site-specific SAP. This includes but is not limited to the static water level probe/cable and bladder pump barrel.

Decontamination is typically conducted using a phosphate-free soap (e.g. Alconox) water wash, distilled water rinse, isopropyl alcohol wash, nitric acid wash (if metals analysis is to be conducted) and final distilled water rinse procedure.

5.0 Water Level Measurements

Measure static water levels in the wells prior to sample collection and prior to installing the pump and tubing (if a dedicated pump is not already in place). If the well is equipped with a dedicated pump, then measure the static water level prior to purging. Because water levels may fluctuate on a short-term basis, measure the static water levels in all site wells within a relatively short period of time.

If non-aqueous phase liquid (NAPL) is suspected to be present, use an oil-water interface probe to test for its presence. Follow the meter-specific operating instructions for the measurement.

If NAPL is not suspected to be present, utilize an electronic water level probe. Check the operation of the meter by turning on the indicator signal switch and pressing the test button on the side of the reel. The buzzer should sound, and the indicator light should illuminate. If the water-level indicator signal(s) is not functioning properly, replace the batteries and/or use a different meter.

Holding the device atop the casing, lower the cable gradually into the well or piezometer until the indicator contacts the water surface. Contact with the water surface is indicated by a buzzer sound and illumination of the indicator light. Stop lowering the cable. Note the point on the graduated cable that corresponds to the measuring point at the top of the casing when the electronic circuit is first completed. If the measuring point is not designated on the well casing, then use the north side of the casing. Draw the cable at least one foot above the water level, then lower it until the indicator contacts the water surface. If the readings differ by more the 0.02 feet, then repeat until the measured readings stabilize. Record the water level to the nearest 0.01 feet.

6.0 Purging

Sampling can be performed via multiple volume or low flow methods, depending on the SAP requirements. Record all field measurements in a field notebook or field sampling form. Example field sample forms are attached to this SOP.

Multiple Volume Purging Procedure

a) Before purging each well, measure and record the depth to water from the designated measuring point on the well casing to the nearest 0.01 foot using an electronic water level meter.

b) Purge a minimum of three well volumes using a pump or bailer. The following equations can be used to calculate one well volume. The first equation gives the results in cubic feet (V1), and the second equation gives the results in gallons (V2):

V1 = 0.0057 * (d*d) * W   V2 = 0.043 * (d*d) * W

Where:

d = the well casing diameter in inches (in); and

W = the depth of water in the well casing measured in feet, calculated by subtracting the measured depth to water in the well from the total well depth.

Example: Monitoring well diameter = 4-in diameter
Water level = 25.5 ft below ground surface (bgs)
Well depth = 36.0 ft bgs

Therefore, the well has 10.5 ft of water column.

Using equation 1:
V1 = 0.0057 (4in*4in) * 10.5ft
V1 = 0.92 cubic ft

Or using equation 2:
V2 = 0.043 (4in*4in) 10.5ft
V2 = 7.2 gallons

Therefore, 3 well volumes = 3 x 0.96 cubic ft = 2.86 cubic ft

or

3 well volumes = 3 x 10.5 gallons = or 21.5 gallons

would be the minimum three well casing volumes that need to be purged from the well.

c) When using a downhole down-hole DO meter, lower the DO meter into the well to the approximate level of the pump intake and start the meter.

d) The well will be purged and samples will be collected using a disposable hand-bailer, a peristaltic pump, a positive displacement (bladder) pump and/or a disposable polyethylene or Teflon-lined polyethylene tubing. If pump and tubing are not dedicated to the well, the bladder pump will be decontaminated and new tubing or bailers will be used for each subsequent well location. The pump intake should be placed within the well screen and near the middle of the water column. Field parameters (typically DO, pH, temperature, ORP, and specific conductance) should be measured at 1, 2, and 3 well volumes to ensure that all stagnant water has been removed from the well and that water quality parameters have stabilized.

Note: If a well is evacuated during purging, it will be allowed to recharge until the water level has recovered to 80 percent of the static level or for a period not exceeding 24 hours before sampling. If it has not recovered sufficiently to allow sampling after 24 hours, this well will be noted as "dry" during the sampling event.

e) Purge water will be handled in accordance with the site-specific SAP and SOP G-6.

Low Flow Purging Procedure

a) Samples will be collected with a peristaltic (for inorganics only) or bladder (for any analytes) pump. Use new disposable tubing and bladders for collection of each sample.

b) Non-disposable equipment that comes into contact with the sampled water (e.g. bladder pump body) must be decontaminated prior to collection of each sample.

c) Slowly lower the pump or disposable polyethylene tubing into the well until the pump intake is located approximately the midsection of the saturated screened interval. The depth interval of the well screen will be provided in the site-specific SAP. For wells with screens longer than 10 feet, the primary flow zones and target depth for the pump intake should be identified in the site-specific SAP.

d) The well will be pumped at a rate of 100 to 500 milliliters per minute and the water level monitored approximately every five minutes. A steady flow rate will be maintained that results in a stabilized water level, ideally with a drawdown of 0.3 feet or less. Monitor water levels at a minimum of 5-minute intervals and record the measurement on the field sampling form or in the field notebook.

e) Place meters in the flow through cell prior to initiating pumping and record every parameters at a minimum of 5-minute intervals; including, turbidity, pH, oxidation-reduction potential (ORP), temperature, specific conductance (SC), and dissolved oxygen (DO). Record the parameters in a data logger, on the field sampling form, or in the field notebook. The well will be considered stabilized and ready for sample collection when the indicator parameters have stabilized for three consecutive readings as follows:
<10 NTU (turbidity)for three consecutive readings or three consecutive readings within 10% of each other
±0.1 S.U. for pH
±3% for specific conductivity
± 10 millivolts ORP and
± 10% dissolved oxygen or three consecutive values less than 0.5 mg/L

STANDARD OPERATING PROCEDURE G-6

MANAGEMENT OF INVESTIGATIVE-DERIVED WASTE

Standard Operating Procedure
Management of Investigative Derived Waste (G-6)

Prior to the field sampling event, review the Sampling and Analysis Plan to understand how wastes generated during the investigation should be handled. This standard operating procedure is applicable to non-hazardous wastes. If hazardous wastes may be generated, please consult with the project manager and the project specific SAP.

SOIL

Whenever possible, soils excavated from test pits should be placed back in the test pit in the reverse order that it was excavated. To determine appropriate methods for handing of drill cuttings from soil borings or monitoring well installation, soils exhumed from the borehole should be monitored for staining and field screened for VOCs using a PID in accordance with standard operating procedures. Based on the PID screening, cuttings with organic vapor concentrations greater than 100 ppm should be containerized in labeled 55-gallon drums (or roll-off containers if large volumes of cuttings are anticipated) pending further characterization. Alternatively, project personnel may elect to containerize all drill cuttings based on the presence of known contamination and anticipated contaminant concentrations. Containerized soil must be properly labeled, documented and disposed of in accordance with state and federal regulations based on soil analytical results. Soil that does not appear to be contaminated based on observations by field personnel and PID screening may be spread on the ground near the point of origin.

GROUNDWATER

Groundwater purged from a well during development or sampling that has a sheen or contains free product must be containerized in an appropriately labeled 55-gallon drums or tank pending receipt of analytical results. A drum should be dedicated to each well sampled so that the analytical results of the groundwater sample from the well can be used to characterize the water in the drum. If groundwater from several wells is placed in a drum, the water in the drum should be sampled for adequate characterization. The containerized water must be disposed of in accordance with state and federal regulations based on the analytical results. Groundwater that does not have a sheen or contain free product or other know contamination may be discharged to the ground surface in the vicinity of the well location for evaporation and infiltration. All surface discharge areas should not allow for migration of discharge water to a surface water body.

RINSEATE WATER ORIGINATING FROM DECONTAMINATION

All source water for sampling equipment decontamination purposes will be distilled water. For larger equipment when power washing procedures are used for decontamination, potable water will be used. Decontamination will be conducted in a specified area that limits the spread of decontamination water. Decontamination water will be discharged to the ground in the vicinity of the source of dirt and mud to evaporate and infiltrate.

Depending on site conditions, parameters may not stabilize during pumping. If parameters do not stabilize, contact the project manager to select an appropriate course of action. Actions recommended by Montana DEQ include:

- Purge the well for a minimum of four hours prior to sampling if the static water level was stable prior to pumping, or
- Purge three well volumes from the well prior to sampling, or
- Discontinue purging and do not collect a sample.

Lack of stabilization of parameters shall be documented in the field logbook.

7.0 Groundwater Sample Collection

a) Label each sample container with sample identification, date, time collected (military time), and preservative.

b) Don latex or nitrile gloves prior to collecting sample. Without moving or turning off the pump, groundwater samples should be collected in order from most to least volatile analytes directly from the pump discharge tubing into laboratory supplied sample containers (do not collect sample downstream from any inline-flow device/meter). The pump rate may be decreased for sample collection in order to fill sample containers (sometimes necessary to fill volatile organic compound (VOC) sample vials) but the pump rate may not be increased. Samples collected using a bailer will be poured directly from the bailer into the sample jar. Preserve samples according to analytical requirements in attached table or site-specific SAP.

c) Samples collected for volatile organic compounds (VOCs) are typically collected in 40-ml vials. Fill each sample bottle completely so the water forms a convex meniscus at the top to ensure that no air is trapped when sealing the sample container. No air bubbles should pass through the sample as the bottle is filled or be trapped in the sample when the bottle is sealed. Invert the sample container after it is preserved and sealed to verify the absence of air bubbles. If air bubbles are present, uncap the sample bottle, add more sample and repeat procedure. If air bubbles are still present, discard the bottle and re-sample. If air bubbles continue to be present in the sample bottle, it may be caused by the preservative reacting with alkaline water. In that case the sample may be collected without a preservative, but must be analyzed within 7 days of collection. For non-preserved samples, notify the laboratory as soon as possible that the samples will be delivered to them in an unpreserved condition and need to be analyzed within 7 days of collection. The laboratory will indicate when they will need to have the samples delivered by.

d) Collect filtered samples by attaching the in-line filter directly to the sample discharge tubing and pump the sample through the filter directly into the sample container.

e) Store samples on ice and submit for laboratory analysis according to chain of custody procedures specified in SOP G-4.

A list of common analytes and preservative requirements are described below.

Analysis	Number of Containers	Container Type	Preservation	Maximum Holding Time
VOCs	2	40 ml glass	4^0 C & HCL	14 days
SVOCs	2	1 liter glass	4^0 C	7 days
VPH	2	40 ml glass	4^0 C & HCL	14 days
EPH	2	1 liter glass	4^0 C & H_2SO_4	14 days
Metals	1	500 ml Plastic	4^0 C & HNO_3	6 months, 28 days Hg
Nutrients	1	500 Plastic	4^0 C & H_2SO_4	Varies (contact lab)
Common Ions	1	1 liter Plastic	4^0 C	7 days

STANDARD OPERATING PROCEDURE GW-3

MONITORING WELL DESIGN AND CONSTRUCTION

Standard Operating Procedure
Monitoring Well Design and Construction (GW-3)

A universal, set procedure for designing and constructing monitoring wells cannot be listed. Every location within a site may vary depending on contamination encountered, lithology of the subsurface and depth to ground water. A technique that may work at one location may be inappropriate at the next. The following section discusses general guidelines for well design and construction, but actual well designs will depend on site conditions and should be addressed in site-specific SAP and SOP.

Wells drilled for an RI/FS investigation will be designed to specifications suggested by the site being investigated, provided such design presents no conflict with investigation sampling objectives. The policy will permit the site to incorporate any new wells resulting from RI activities into ongoing monitoring programs by ensuring that new wells are constructed in the same manner as existing wells. Conflicts may result when existing well construction is not suitable for the proposed sampling.

The method of well construction and the materials used in the casing and screen may affect the quality of the well, and its utility for ground water monitoring, throughout its lifetime. The elements of proper monitoring well construction presented in this SOP serve as guidelines for wells constructed for the ground water investigation. In addition, these guidelines can be applied to evaluate the adequacy of existing wells when RI sampling will be conducted from available wells. Typical well completion details are shown on Figure GW-3.1.

Well Diameter

The diameter of the well casing will be the minimum that allows the sampling tool to be lowered to the desired depth. The diameter of the borehole, in unconsolidated formations, into which the casing is placed must be at least 4 inches larger than the casing to provide a minimum 2 inches of annular space for placement of sand pack and seal. The diameter of the borehole in consolidated formations shall also be a minimum of 4 inches larger than the casing if installation of the seal is expected.

Well Depth

Wells shall be constructed to be depth discrete, with the well screened in only one aquifer, zone, or layer. This allows the sampling of the area of interest without interference from other layers. This requires provisions for grouting above, and if necessary, below the well screen on the outside of the casing.

Well Casing/Screens

Well casings and screens will be constructed of materials with the least potential for affecting the quality parameters of the sample. Guidance regarding casing and screen materials selection criteria is presented in Table GW-3.1. Well casing and screen shall be steam cleaned and protected from contamination prior to their installation.

Well Drilling

Drilling method selection shall be based on minimizing both the disturbance of the geologic materials penetrated, and the introduction of air, fluids and muds. Organic drilling muds or additives shall be avoided. Advantages and disadvantages of various drilling methods are presented in Table GW-3.2.

Screen Zone Design

The screen zone of the monitor well shall be designed and constructed to: (1) allow sufficient ground water flow to the well for sampling; (2) minimize the passage of formation materials into the well; and (3) ensure sufficient structural integrity to prevent the collapse of the screen structure.

For wells completed in unconsolidated materials, the intake of a monitoring well should consist of a screen or slotted casing with openings sized to ensure that formational material is prohibited from passing through the well during development. The annular space between the face of the formation and the screen or slotted casing should be filled to minimize passage of formation materials into the well. The driller should, therefore, install a sand pack in each monitoring well. It is recommended that aquifer material from the screen zone be analyzed fro grain size in order to determine the correct sand pack and screen slot size.

Screen Size Selection

The screen slot size is determined after the filter pack material has been selected. The screen slot size for a well with a designed filter pack should be selected to retain 90 percent or more of the filter pack material. See the references at the end of the SOP for further detail.

Selecting the Filter Pack

The purpose of selecting the proper filter pack is to 1) stabilize the aquifer material around the well, 2) provide an annular zone with high permeability, and 3) permit the use of the largest possible size of screen openings.

The selection of the filter pack is a vital step in completing a usable well. The design and selection of a proper filter pack is an issue which has many factors to be considered and which cannot be given satisfactory explanation in this SOP. A person designing a well should select and read one of the excellent reference books available on the subject. See the reference list at the end of this SOP.

The following information gives the general guidelines used in selecting the well filter pack. For a detailed explanation of the filter pack selection, refer to the references provided at the end of this SOP.

1. Perform a sieve analysis on the natural aquifer material.
2. Select a filTer pack whose grain size is 4 to 10 times larger than the 30 percent of the finer natural aquifer material.
3. The filter pack grain size should have a uniformity coefficient around 2.5.
4. The filter pack material shall be a siliceous material such as quartz sand, have well-rounded grains, and contain less than 5 percent not-siliceous material.

Placement of the Filter Pack Material

The selected filter pack will be introduced into the annular space adjacent to the screen through a tremie pipe. A minimum 1 1/2-inch diameter tremie pipe is suggested. The end of the tremie pipe should be positioned within 5 feet of the bottom of the borehole before treming in the filter material. As the filter material is tremied into the annular space, the tremie pipe should be raised periodically but kept within 5 feet of the top of the filter pack. This 5-foot interval minimizes bridging and segregation of the filter pack as it is placed. The filter pack placement will continue until the filter pack is 3 feet above the top of the screen.

The top of the sand pack should be measured periodically and recorded in the bound logbook. The total volume of filter material used should also be recorded.

Annular Seal

The materials used to seal the annular space must prevent the migration of contaminants to the sampling zone from the surface to intermediate zones and prevent cross contamination between strata. The materials should be chemically compatible with the anticipated waste to ensure seal integrity during the life of the monitoring well and chemically inert so they do not affect the quality of the ground water samples. The permeability of the sealants should be one to two orders of magnitude less than the surrounding formation. An example of an appropriate use of annular sealant material is using a minimum of two feet of certified sodium bentonite pellets immediately over the silica sand when in a saturated zone. The pellets are most appropriate in a saturated zone because they will swell in the column of water to create an effective seal. A cement and bentonite mixture or antishrink cement mixtures should be used as the annular sealant in the unsaturated zone above the bentonite pellet seal and below the frost line.

Cement-bentonite grout shall also be used to seal the annular space between the casing and borehole wall and between the surface formation and the conductor casing, if such is used. At the surface, the grout shall have positive slope away from the well or piezometer to prevent water from ponding and entering around the casing.

The grout shall be composed of Class B or G Portland cement, fresh water, and 2 to 4 percent bentonite. The grout shall be mixed in the following proportions: 6.5 gallons of water, 94 pounds (1 sack) of cement, and 2 percent (1.88 pounds, dry weight) of bentonite, or 7.8 gallons of water, 94 pounds (1 sack) of cement, and 4 percent (3.76 pounds, dry weight) of bentonite. The bentonite will improve the workability of the grout and reduce shrinkage as the cement sets.

Emplacement of the grout shall be by tremie pipe via gravity feed or pumping. The end of tremie pipe shall be set 5 feet above bottom of filled interval.

After installation of the cement slurry, a minimum of 24 hours of curing time shall elapse prior to resuming any construction operations at the particular borehole.

Well Head Installation

Wells may be constructed in either a "stick-up" or "flush-grade" completion. For a stick-up completion, the well or piezometer casing shall extend approximately 3 feet above ground surface. A vented casing cap with marked well or piezometer designation shall be placed on top of the surface casing. A steel protection casing shall be welded to the conductor casing and shall extend to at least 2 inches above the top of the casing cap. The protective casing shall be fitted with a locking cap and also marked with the well or piezometer designation. A concrete apron, extending at least 1 foot away from the casing and sloping away from the well, shall be constructed around the base of the protective casing. In high-traffic areas, four bumper guards shall be installed around the well. The bumper guards shall be brightly painted posts of 3-inch steel pipe filled with concrete and set in the concrete apron.

For a flush-grade completion, the top of the well or piezometer casing shall terminate at approximately four to six inches below ground surface. A vented casing cap with marked well designation shall be placed on top of the surface casing. A locking, protective steel monument shall be placed above the well casing. The top of the monument shall extend one to two inches above ground surface and the monument shall be cemented in place. A cement apron, extending at least six inches from the monument, and sloping away from the monument, shall be constructed around the monument.

Documentation of Well Design and Construction

Information on well design and completion will be documented when drilling and constructing the well, and will include, but not be limited to:

1. Date/time of construction.
2. Weather conditions.
3. Drilling method and drilling fluid used.
4. Sketch of well location.
5. Borehole diameter and well casing diameter.
6. Well depth (± 0.1 foot).
7. Drilling and lithologic logs.
8. Casing materials.
9. Screen materials and design.
10. Casing and screen joint type.
11. Screen slot size/length.
12. Filter pack material/size, grain analysis.
13. Filter pack volume calculations.
14. Filter pack placement method.
15. Sealant materials (percent bentonite).
16. Sealant placement method.
17. Date/time began grouting well.
18. Date/time of well completion.
19. Surface seal design/construction.
20. Well development procedure.
21. Type of protective well casing.
22. Ground surface elevation (0.01 ft).
23. Top of monitoring well casing elevation (0.01 ft).
24. Detailed drawing of well (include dimensions).

References:

F.G. Driscoll, Groundwater and Wells, Second Edition, St. Paul, Minnesota, Johnson Filtration Systems, Inc., 1986.

U.S. Department of the Interior, Ground Water Manual, Water Resources Technical Publication, 1977.

U.S. Environmental Protection Agency, Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells, National Water Well Association, 1989.

TABLE GW-3.1
WELL CASING AND SCREEN MATERIALS

Type	Advantages	Disadvantages
Polyvinyl chloride (PVC)	Excellent chemical resistance to weak alkalies, alcohols, aliphatic hydrocarbons and oils.	May absorb some constituents from ground water.
	Good chemical resistance to strong mineral acids, concentrated oxidizing acids and strong alkalies.	May react with and leach some constituents into ground water.
Polypropylene	Excellent chemical resistance to mineral acids.	May react with and leach some constituents into ground water.
	Good to excellent chemical resistance to alkalies, alcohols, ketones and esters.	May react with strong oxidizing acids.
	Good chemical resistance to oils.	
	Fair chemical resistance to concentrated oxidizing acids, aliphatic hydrocarbons, and aromatic hydrocarbons.	
Teflon (Teflon is a registered trademark of DuPont, Inc.)	Outstanding resistance to chemical attack; insoluble in all organics except a few exotic fluorinated solvents.	High cost relative to other materials.
Carbon steel	Strong and rigid, temperature sensitivity not a problem.	May react with and leach some constituents into ground water.
		Not as chemically resistant as stainless steel.
Stainless steel	Excellent resistance to corrosion and oxidation.	Heavier than plastics.
		May corrode and leach some chromium in very acidic waters.
		May act as a catalyst in some organic reactions.

TABLE GW-3.2
DRILLING METHODS FOR MONITORING WELLS

Type	Advantages	Disadvantage
Hollow stem auger	No drilling fluid is used, minimizing contamination problems. Formation waters can be sampled during drilling by using a screened lead auger or advancing a well point ahead of the augers. Hole caving can be overcome by emplacing screen and casing before augers are removed.	Can be used only in unconsolidated materials. Limited to depths of 100 to 150 feet, formation samples may not be completely accurate, depending upon how they are taken.
Mud rotary	Can be used in both unconsolidated and consolidated formations. Core samples can be collected. Capable of drilling to any depth. Casing not required during drilling. Flexibility in well construction.	Drilling fluid is required •Contaminants are circulated with the fluid. •The fluid mixed with the formation, water invades the formation, and is sometimes difficult to remove •Bentonite fluids may absorb metals and may interfere with some other parameters •Organic fluids may interfere with bacterial analyses and/or organic-related parameters No information on location of the water table and only limited information on water producing zones, is directly available during drilling. Formation samples may not be accurate.
Air rotary	No drilling fluid is used, minimizing contamination problems. Can be used in both unconsolidated and consolidated formations. Capable of drilling to any depth. Formation sapling ranges from excellent in hard, dry formations to nothing when circulation is lost in formations with cavities. Formation water is blown out of the hole along with cuttings making it possible to determine when the first water-bearing zone is encountered. Collection and field analysis of water blown from the hole can provide enough information regarding changes in water quality for parameters such as chlorides for which only large concentration changes are significant .	Casing is required to keep the hole open when drilling in soft, caving formations below the water table. When more than one water-bearing zone is encountered and hydrostatic pressures are different, flow and possible cross-contamination can occur from one water-bearing zone to another between the time drilling is completed and the hole can be properly cased and grouted off.
Cable tool	Only small amounts for drilling fluid (generally water with no additives) are required. Can be used in both unconsolidated and consolidated formation; well suited when caving, large gravel type formations with large cavities above the water table are encountered. Formation samples can be excellent with a skilled driller. When water is encountered, changes in potentiometric levels are observable. Relative permeabilities and rough water quality data from different zones penetrated can be obtained by skilled operators. Good seal between casing and formation if flush jointed casing is used.	Potential contamination by drilling fluid. Relatively large diameters are required (minimum 4-inch casing). Steel drive pipe must be used.

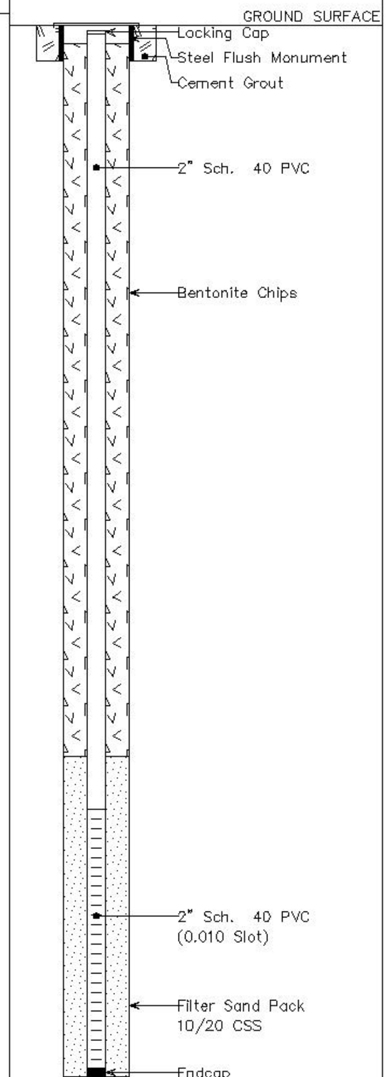
FIGURE GW-3.1
SCHEMATIC OF TYPICAL MONITOR WELL DESIGN

WELL NUMBER: MW2

PROJECT:	WELL LOCATION	DATE:	LOGGED BY:
OWNER NAME:	COUNTY:	HOLE DIA.: 8 in.	DRILL RIG:
ADDRESS:	SECTION:	TOC ELEV.: ft.	SAMPLER TYPE:
	TNSHP/RNG:	GROUND ELEV.: ft.	GW DEPTH: ft.

DESCRIPTION	GRAPHIC LOG	DEPTH (ft.)	SAMPLE RANGE	Headspace OVA	GW DEPTH (ft.)
Black cinder ash.		0		7	
Brown, silty sand and gravel with minor clay from 2 to 2.5 feet. Then sand and gravel.		10 20 30		6 6 6 6 6 9 6 8 8 9 12 4 34 18	
Fine to coarse grained sand.		40		7 11	
Interbedded silt and sand.				7	
No recovery.		50		5	▼
Total boring depth at 60'.		60			

WELL CONSTRUCTION DETAIL



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STANDARD OPERATING PROCEDURE GW-4

WELL DEVELOPMENT

Standard Operating Procedure
Well Development (GW-4)

The monitoring wells, pumping wells, and piezometers shall be developed after construction is completed. The purpose of the development is to remove any remnants of drilling fluid and fine-grained material and to restore the natural permeability of the screened formation. At a minimum, the following development techniques shall be available to develop the wells.

1. Surging with plunger
2. High velocity jetting
3. Airlift pumping
4. Overpumping and backwashing with submersible pump
5. Bailing

The development methods will be selected in the field by the supervising hydrogeologist. This decision will be based primarily on the condition of each well after construction. A description of the methods is provided below.

The duration of the development process will be determined by the supervising hydrogeologist. The amount of turbidity in the discharge water will be used as a guide to determine that development is complete. In addition to turbidity, physical parameters including temperature, pH, and specific conductivity will be measured. Use of the field test equipment will be found in SOP H-3 for conductivity, SOP H-1 for temperature and SOP H-2 for pH. These parameters should be stabilized or changing by less than 10 percent between readings at the end of development. Visual observation may be used to determine that the discharge water is clear. Water produced during development will be discharged in accordance with the site-specific SAP. Personnel will wear protective clothing and use equipment specified in the site-specific Health and Safety Plan.

All procedures used and measurements taken during development will be recorded in the field logbook. This information will include time required, volume of water removed, turbidity readings, pumping rate, and observations made during the development process.

All development equipment must be decontaminated in accordance with SOP G-5.

SURGING WITH PLUNGER

The surging shall be done by solid surge plunger. The belting discs shall be cut to form a free fit in the casing.

Before starting to surge, water should be bailed or pumped from the well to make sure that some water will flow into the well. For operation, the surge plunger shall be lowered into the casing about 15 feet below the water level. The plunger shall be operated up and down in the well casing to exert equal or approximately equal force on the inward and outward movement of the water through the screen. A surge plunger should not be run in a plugged well. In no case shall the surge plunger be operated below the top of the screen. The surging shall be started slowly at first and the speed increased as the work progresses until it reaches the fastest limit at which the tools will drop and rise without excessive slap of the cable. Periodically, the plunger will be removed and the amount of fines accumulated at the bottom of the well will be measured using a weighted steel tape. If fines have been drawn into the well and have blocked 10 percent or more of the total screen length, the well shall be bailed or otherwise cleaned to the bottom between the surge plunger runs. The bottom of the well should be cleaned by bailer or air lift after surge development is completed.

HIGH-VELOCITY JETTING

This method should be used at the beginning of well development, so that any water introduced into the formation during jetting would be removed during later stages of the development. Development of the well shall be accomplished by high-velocity horizontal jetting with potable water of known chemistry. The jetting shall proceed from the bottom of the screen to the top. The outside diameter of the jetting tool shall be one inch less in diameter than the screen inside diameter. The maximum exit velocity of the jetting water at the jet nozzle shall be 150 feet per second. The jetting tool shall be rotated at a speed of less than one revolution per minute. It shall be positioned at one level for not less than two minutes and then shall be moved to the next level, moving more than 6 inches upward from the preceding jetting level.

AIR LIFT PUMPING

Development of the well shall be conducted by utilizing an air line and an air and water eductor pipe. The air line will be placed inside the eductor pipe with the end of the line near, but not extending below, the end of the pipe. Discharge of air from the air line shall always occur within the eductor pipe to prevent clogging of the filter pack and/or formation with air bubbles. Air lift development procedures should begin by determining that ground water can flow freely into the screen. Application of too much air volume in the well when the formation is clogged can result in a collapsed screen. To minimize the initial pumping rate, the air line and eductor pipe should be placed at shallow submergence. Once uninhibited flow to the screen has been established, the air line and eductor pipe should be lowered to approximately 5 feet above the bottom of the screen. Air will then be pumped through the air line causing displacement of the water in the eductor pipe and flow of water into the well. Development will continue by raising the air line/eductor pipe at approximately 5-foot intervals until the entire screen length has been pumped.

For the piezometers, which are not foreseen for sampling ground water, an alternate method of air lift may be used because of the small casing diameter. This method uses only an air line, and the well casing acts as the eductor pipe. The air line shall be placed at least 5 feet above the screen, or at the bottom of the well within the sump. At no time during development should the air line be moved within the screen area. Maintaining the air line above or below the screen prevents charging the filter pack and/or formation with air, which can cause clogging.

The compressors, air lines, hoses, fittings, etc. shall be of adequate size to pump the well by the air lift method. Pressurized air from air compressor(s) needs to be specifically filtered so that oil from the compressor does not contaminate the well.

Air lift pumping development produces best results when the submergence ratio of the air line is about 60 percent for wells 200 feet or less in depth (Ground Water and Wells, Johnson, 1972). The percent pumping submergence can be calculated as follows:

$$\textit{percent pumping submergence} = \frac{\textit{length of airline below pumping water level}}{\textit{total length of well airline}} \times 100$$

The desirable drawdown is from static water level to the top of screen. The pumping rate will be estimated from available drawdown and pumping submergences.

OVERPUMPING AND BACKWASHING WITH SUBMERSIBLE PUMP

The pumping shall be done with a submersible pump capable of pumping at rates up to two times the estimated well capacity (well yield per unit drawdown). The pumping should be carried out in at least five steps including pumping rates of 0.25, 0.5, 1, 1.5, and 2 times the estimated well capacity. Pumping shall be conducted in five-minute cycles and shall continue until acceptable standards as explained at the beginning of SOP are attained.

BAILING

Where the nature of the formation and/or well construction make development of the well infeasible using pumps or air lift, bailers shall be utilized to evacuate water and fine sediments and/or fine formation particles from the well. Bailers should be of diameter allowing free-fall inside the well casing and should be equipped with a check valve at the bottom. The frequency of bailing trips shall depend on the ability of the well to recover.

topsoil placed on top of the filled pit. There will be some unavoidable mixing of the soil during the excavation.

9. Decontaminate all sampling equipment.

10. Move to the next site. If the previous site was the last site of the day, decontaminate the field sampling equipment, secure all equipment, and exit the site.

ATTACHMENT TO SOP SS-1
29 CFR 1926 SUBPART P - EXCAVATION, TRENCHING AND SHORING

Section 2

Labor

29

PART 1926

Revised as of July 1, 1990

CONTAINING
A CODIFICATION OF DOCUMENTS
OF GENERAL APPLICABILITY
AND FUTURE EFFECT

AS OF JULY 1, 1990

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Subpart P—Excavations

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SOURCE: 54 FR 45959, Oct. 31, 1989, unless otherwise noted.

§ 1926.650 Scope, application, and definitions applicable to this subpart.

(a) *Scope and application.* This subpart applies to all open excavations made in the earth's surface. Excavations are defined to include trenches.

(b) *Definitions applicable to this subpart.*

Accepted engineering practices means those requirements which are compatible with standards of practice required by a registered professional engineer.

Aluminum Hydraulic Shoring means a pre-engineered shoring system comprised of aluminum hydraulic cylinders (crossbraces) used in conjunction with vertical rails (uprights) or horizontal rails (walers). Such system is designed, specifically to support the sidewalls of an excavation and prevent cave-ins.

Bell-bottom pier hole means a type of shaft or footing excavation, the bottom of which is made larger than the cross section above to form a belled shape.

Benching (Benching system) means a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Cave-in means the separation of a mass of soil or rock material from the side of an excavation, or the loss of soil from under a trench shield or support system, and its sudden movement into the excavation, either by falling or sliding, in sufficient quantity so that it could entrap, bury, or otherwise injure and immobilize a person.

Competent person means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Cross braces mean the horizontal members of a shoring system installed perpendicular to the sides of the excavation, the ends of which bear against either uprights or wales.

Excavation means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

Faces or *sides* means the vertical or inclined earth surfaces formed as a result of excavation work.

Failure means the breakage, displacement, or permanent deformation of a structural member or connection so as to reduce its structural integrity and its supportive capabilities.

Hazardous atmosphere means an atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

Kickout means the accidental release or failure of a cross brace.

Protective system means a method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

Ramp means an inclined walking or working surface that is used to gain access to one point from another, and is constructed from earth or from structural materials such as steel or wood.

Registered Professional Engineer means a person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer, registered in any state is deemed to be a "registered professional engineer" within the meaning of this standard when approving designs for "manufactured protective systems" or "tabulated data" to be used in interstate commerce.

Sheeting means the members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system.

Shield (Shield system) means a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure. Shields can be permanent structures or can be designed to be portable and moved along as work progresses. Additionally, shields can be either premanufactured or job-built in accordance with § 1926.652 (c)(3) or (c)(4). Shields used in trenches are usually referred to as "trench boxes" or "trench shields."

Shoring (Shoring system) means a structure such as a metal hydraulic, mechanical or timber shoring system that supports the sides of an excavation and which is designed to prevent cave-ins.

Sides. See "Faces."

Sloping (Sloping system) means a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation so as to prevent cave-ins. The angle of incline required to prevent a cave-in varies with differences in such factors as the soil type, environmental conditions of exposure, and application of surcharge loads.

Stable rock means natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed. Unstable rock is considered to be stable when the rock material on the side or sides of the excavation is secured against caving-in or movement by rock bolts or by another protective system that has been designed by a registered professional engineer.

Structural ramp means a ramp built of steel or wood, usually used for vehicle access. Ramps made of soil or rock are not considered structural ramps.

Support system means a structure such as underpinning, bracing, or shoring, which provides support to an adjacent structure, underground installation, or the sides of an excavation.

Tabulated data means tables and charts approved by a registered professional engineer and used to design and construct a protective system.

Trench (Trench excavation) means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

Trench box. See "Shield."

Trench shield. See "Shield."

Uprights means the vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not contact each other. Uprights placed so that individual members are closely spaced, in contact with or interconnected to each other, are often called "sheeting."

Wales means horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

§ 1926.651 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) *Underground installations.* (1) The estimated location of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installations that reasonably may be expected to be encountered during excavation work, shall be determined prior to opening an excavation.

(2) Utility companies or owners shall be contacted within established or customary local response times, advised of the proposed work, and asked to establish the location of the utility underground installations prior to the start of actual excavation. When utility companies or owners cannot respond to a request to locate underground utility installations within 24 hours (unless a longer period is required by state or local law), or cannot establish the exact location of these installations, the employer may proceed, provided the employer does so with caution, and provided detection equipment or other acceptable means to locate utility installations are used.

(3) When excavation operations approach the estimated location of underground installations, the exact location of the installations shall be determined by safe and acceptable means.

(4) While the excavation is open, underground installations shall be protected, supported or removed as necessary to safeguard employees.

(c) *Access and egress*—(1) *Structural ramps.* (i) Structural ramps that are used solely by employees as a means of access or egress from excavations shall be designed by a competent person. Structural ramps used for access or egress of equipment shall be designed by a competent person qualified in structural design, and shall be constructed in accordance with the design.

(ii) Ramps and runways constructed of two or more structural members shall have the structural members connected together to prevent displacement.

(iii) Structural members used for ramps and runways shall be of uniform thickness.

(iv) Cleats or other appropriate means used to connect runway structural members shall be attached to the bottom of the runway or shall be attached in a manner to prevent tripping.

(v) Structural ramps used in lieu of steps shall be provided with cleats or other surface treatments on the top surface to prevent slipping.

(2) *Means of egress from trench excavations.* A stairway, ladder, ramp or other safe means of egress shall be located in trench excavations that are 4 feet (1.22 m) or more in depth so as to require no more than 25 feet (7.62 m) of lateral travel for employees.

(d) *Exposure to vehicular traffic.* Employees exposed to public vehicular traffic shall be provided with, and shall wear, warning vests or other suitable garments marked with or made of reflectorized or high-visibility material.

(e) *Exposure to falling loads.* No employee shall be permitted underneath loads handled by lifting or digging equipment. Employees shall be required to stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials. Operators may remain in the cabs of vehicles being loaded or unloaded when the vehicles are equipped, in accordance with § 1926.601(b)(6), to provide adequate protection for the operator during loading and unloading operations.

(f) *Warning system for mobile equipment.* When mobile equipment is operated adjacent to an excavation, or when such equipment is required to approach the edge of an excavation, and the operator does not have a clear and direct view of the edge of the excavation, a warning system shall be utilized such as barricades, hand or mechanical signals, or stop logs. If possible, the grade should be away from the excavation.

(g) *Hazardous atmospheres*—(1) *Testing and controls.* In addition to the requirements set forth in subparts D and E of this part (29 CFR 1926.50–1926.107) to prevent exposure to harmful levels of atmospheric contaminants and to assure acceptable atmospheric conditions, the following requirements shall apply:

(i) Where oxygen deficiency (atmospheres containing less than 19.5 percent oxygen) or a hazardous atmosphere exists or could reasonably be expected to exist, such as in excavations in landfill areas or excavations in areas where hazardous substances are stored nearby, the atmospheres in the excavation shall be tested before employees enter excavations greater than 4 feet (1.22 m) in depth.

(ii) Adequate precautions shall be taken to prevent employee exposure to atmospheres containing less than 19.5 percent oxygen and other hazardous atmospheres. These precautions include providing proper respiratory protection or ventilation in accordance with subparts D and E of this part respectively.

(iii) Adequate precaution shall be taken such as providing ventilation, to prevent employee exposure to an atmosphere containing a concentration of a flammable gas in excess of 20 percent of the lower flammable limit of the gas.

(iv) When controls are used that are intended to reduce the level of atmospheric contaminants to acceptable levels, testing shall be conducted as often as necessary to ensure that the atmosphere remains safe.

(2) *Emergency rescue equipment.* (i) Emergency rescue equipment, such as breathing apparatus, a safety harness and line, or a basket stretcher, shall be readily available where hazardous atmospheric conditions exist or may reasonably be expected to develop during work in an excavation. This equipment shall be attended when in use.

(ii) Employees entering bell-bottom pier holes, or other similar deep and confined footing excavations, shall wear a harness with a life-line securely attached to it. The lifeline shall be separate from any line used to handle materials, and shall be individually attended at all times while the employee wearing the lifeline is in the excavation.

(h) *Protection from hazards associated with water accumulation.* (1) Employees shall not work in excavations in which there is accumulated water, or in excavations in which water is accumulating, unless adequate precautions have been taken to protect employees against the hazards posed by water accumulation. The precautions necessary to protect employees adequately vary with each situation, but could include special support or shield systems to protect from cave-ins, water removal to control the level of accumulating water, or use of a safety harness and lifeline.

(2) If water is controlled or prevented from accumulating by the use of water removal equipment, the water removal equipment and operations shall be monitored by a competent person to ensure proper operation.

(3) If excavation work interrupts the natural drainage of surface water (such as streams), diversion ditches, dikes, or other suitable means shall be used to prevent surface water from entering the excavation and to provide adequate drainage of the area adjacent to the excavation. Excavations subject to runoff from heavy rains will require an inspection by a competent person and compliance with paragraphs (h)(1) and (h)(2) of this section.

(i) *Stability of adjacent structures.* (1) Where the stability of adjoining buildings, walls, or other structures is endangered by excavation operations, support systems such as shoring, bracing, or underpinning shall be provided to ensure the stability of such structures for the protection of employees.

(2) Excavation below the level of the base or footing of any foundation or retaining wall that could be reasonably expected to pose a hazard to employees shall not be permitted except when:

(i) A support system, such as underpinning, is provided to ensure the safety of employees and the stability of the structure; or

(ii) The excavation is in stable rock; or

(iii) A registered professional engineer has approved the determination that the structure is sufficently removed from the excavation so as to be unaffected by the excavation activity; or

(iv) A registered professional engineer has approved the determination that such excavation work will not pose a hazard to employees.

(3) Sidewalks, pavements, and appurtenant structure shall not be undermined unless a support system or another method of protection is provided to protect employees from the possible collapse of such structures.

(j) *Protection of employees from loose rock or soil.* (1) Adequate protection shall be provided to protect employees from loose rock or soil that could pose a hazard by falling or rolling from an excavation face. Such protection shall consist of scaling to remove loose material; installation of protective barricades at intervals as necessary on the face to stop and contain falling material; or other means that provide equivalent protection.

(2) Employees shall be protected from excavated or other materials or equipment that could pose a hazard by falling or rolling into excavations. Protection shall be provided by placing and keeping such materials or equipment at least 2 feet (.61 m) from the edge of excavations, or by the use of retaining devices that are sufficient to prevent materials or equipment from falling or rolling into excavations, or by a combination of both if necessary.

(k) *Inspections.* (1) Daily inspections of excavations, the adjacent areas, and protective systems shall be made by a competent person for evidence of a situation that could result in possible cave-ins, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions. An inspection shall be conducted by the competent person prior to the start of work and as needed throughout the shift. Inspections shall also be made after every rainstorm or other hazard increasing occurrence. These inspections are only required when employee exposure can be reasonably anticipated.

(2) Where the competent person finds evidence of a situation that could result in a possible cave-in, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions, exposed employees shall be removed from the hazardous area until the necessary precautions have been taken to ensure their safety.

(l) *Fall protection.* (1) Where employees or equipment are required or permitted to cross over excavations, walkways or bridges with standard guardrails shall be provided.

(2) Adequate barrier physical protection shall be provided at all remotely located excavations. All wells, pits, shafts, etc., shall be barricaded or covered. Upon completion of exploration and similar operations, temporary wells, pits, shafts, etc., shall be backfilled.

§ 1926.652 Requirements for protective systems.

(a) *Protection of employees in excavations.* (1) Each employee in an excavation shall be protected from cave-ins by an adequate protective system designed in accordance with paragraph (b) or (c) of this section except when:

(i) Excavations are made entirely in stable rock; or

(ii) Excavations are less than 5 feet (1.52m) in depth and examination of the ground by a competent person provides no indication of a potential cave-in.

(2) Protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied or transmitted to the system.

(b) *Design of sloping and benching systems.* The slopes and configurations of sloping and benching systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (b)(1); or, in the alternative, paragraph (b)(2); or, in the alternative, paragraph (b)(3), or, in the alternative, paragraph (b)(4), as follows:

(1) *Option (1)—Allowable configurations and slopes.* (i) Excavations shall be sloped at an angle not steeper than one and one-half horizontal to one vertical (34 degrees measured from the horizontal), unless the employer uses one of the other options listed below.

(ii) Slopes specified in paragraph (b)(1)(i) of this section, shall be excavated to form configurations that are in accordance with the slopes shown for Type C soil in Appendix B to this subpart.

(2) *Option (2)—Determination of slopes and configurations using Appendices A and B.* Maximum allowable slopes, and allowable configurations for sloping and benching systems, shall be determined in accordance with the conditions and requirements set forth in appendices A and B to this subpart.

(3) *Option (3)—Designs using other tabulated data.* (i) Designs of sloping or benching systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and shall include all of the following:

(A) Identification of the parameters that affect the selection of a sloping or benching system drawn from such data;

(B) Identification of the limits of use of the data, to include the magnitude and configuration of slopes determined to be safe;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) *Option (4)—Design by a registered professional engineer.* (i) Sloping and benching systems not utilizing Option (1) or Option (2) or Option (3) under paragraph (b) of this section shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include at least the following:

(A) The magnitude of the slopes that were determined to be safe for the particular project;

(B) The configurations that were determined to be safe for the particular project; and

(C) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite while the slope is being constructed. After that time the design need not be at the jobsite, but a copy shall be made available to the Secretary upon request.

(c) *Design of support systems, shield systems, and other protective systems.*

Designs of support systems shield systems, and other protective systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (c)(1); or, in the alternative, paragraph (c)(2); or, in the alternative, paragraph (c)(3); or, in the alternative, paragraph (c)(4) as follows:

(1) *Option (1)—Designs using appendices A, C and D.* Designs for timber shoring in trenches shall be determined in accordance with the conditions and requirements set forth in appendices A and C to this subpart. Designs for aluminum hydraulic shoring shall be in accordance with paragraph (c)(2) of this section, but if manufacturer's tabulated data cannot be utilized, designs shall be in accordance with appendix D.

(2) *Option (2)—Designs Using Manufacturer's Tabulated Data.* (i) Design of support systems, shield systems, or other protective systems that are drawn from manufacturer's tabulated data shall be in accordance with all specifications, recommendations, and limitations issued or made by the manufacturer.

(ii) Deviation from the specifications, recommendations, and limitations issued or made by the manufacturer shall only be allowed after the manufacturer issues specific written approval.

(iii) Manufacturer's specifications, recommendations, and limitations, and manufacturer's approval to deviate from the specifications, recommendations, and limitations shall be in written form at the jobsite during construction of the protective system. After that time this data may be stored off the jobsite, but a copy shall be made available to the Secretary upon request.

(3) *Option (3)—Designs using other tabulated data.* (i) Designs of support systems, shield systems, or other protective systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and include all of the following:

(A) Identification of the parameters that affect the selection of a protective system drawn from such data;

(B) Identification of the limits of use of the data;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data, which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) *Option (4)—Design by a registered professional engineer.* (i) Support systems, shield systems, and other protective systems not utilizing Option 1, Option 2 or Option 3, above, shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include the following:

(A) A plan indicating the sizes, types, and configurations of the materials to be used in the protective system; and

(B) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite during construction of the protective system. After that time, the design may be stored off the jobsite, but a copy of the design shall be made available to the Secretary upon request.

(d) *Materials and equipment.* (1) Materials and equipment used for protective systems shall be free from damage or defects that might impair their proper function.

(2) Manufactured materials and equipment used for protective systems shall be used and maintained in a manner that is consistent with the recommendations of the manufacturer, and in a manner that will prevent employee exposure to hazards.

(3) When material or equipment that is used for protective systems is damaged, a competent person shall examine the material or equipment and evaluate its suitability for continued

use. If the competent person cannot assure the material or equipment is able to support the intended loads or is otherwise suitable for safe use, then such material or equipment shall be removed from service, and shall be evaluated and approved by a registered professional engineer before being returned to service.

(e) *Installation and removal of support*—(1) *General.* (i) Members of support systems shall be securely connected together to prevent sliding, falling, kickouts, or other predictable failure.

(ii) Support systems shall be installed and removed in a manner that protects employees from cave-ins, structural collapses, or from being struck by members of the support system.

(iii) Individual members of support systems shall not be subjected to loads exceeding those which those members were designed to withstand.

(iv) Before temporary removal of individual members begins, additional precautions shall be taken to ensure the safety of employees, such as installing other structural members to carry the loads imposed on the support system.

(v) Removal shall begin at, and progress from, the bottom of the excavation. Members shall be released slowly so as to note any indication of possible failure of the remaining members of the structure or possible cave-in of the sides of the excavation.

(vi) Backfilling shall progress together with the removal of support systems from excavations.

(2) *Additional requirements for support systems for trench excavations.* (i) Excavation of material to a level no greater than 2 feet (.61 m) below the bottom of the members of a support system shall be permitted, but only if the system is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the support system.

(ii) Installation of a support system shall be closely coordinated with the excavation of trenches.

(f) *Sloping and benching systems.* Employees shall not be permitted to work on the faces of sloped or benched excavations at levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling, or sliding material or equipment.

(g) *Shield systems*—(1) *General.* (i) Shield systems shall not be subjected to loads exceeding those which the system was designed to withstand.

(ii) Shields shall be installed in a manner to restrict lateral or other hazardous movement of the shield in the event of the application of sudden lateral loads.

(iii) Employees shall be protected from the hazard of cave-ins when entering or exiting the areas protected by shields.

(iv) Employees shall not be allowed in shields when shields are being installed, removed, or moved vertically.

(2) *Additional requirement for shield systems used in trench excavations.* Excavations of earth material to a level not greater than 2 feet (.61 m) below the bottom of a shield shall be permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the shield.

Appendix A to Subpart P

Soil Classification

(a) *Scope and application*—(1) *Scope.* This appendix describes a method of classifying soil and rock deposits based on site and environmental conditions, and on the structure and composition of the earth deposits. The appendix contains definitions, sets forth requirements, and describes acceptable visual and manual tests for use in classifying soils.

(2) *Application.* This appendix applies when a sloping or benching system is designed in accordance with the requirements set forth in § 1926.652(b)(2) as a method of protection for employees from cave-ins. This appendix also applies when timber shoring for excavations is designed as a method of protection from cave-ins in accordance with appendix C to subpart P of part 1926, and when aluminum hydraulic shoring is designed in accordance with appendix D. This Appendix also applies if other protective systems are designed and selected for use from data prepared in accordance with the requirements set forth in

§ 1926.652(c), and the use of the data is predicated on the use of the soil classification system set forth in this appendix.

(b) *Definitions.* The definitions and examples given below are based on, in whole or in part, the following: American Society for Testing Materials (ASTM) Standards D653-85 and D2488: The Unified Soils Classification System, The U.S. Department of Agriculture (USDA) Textural Classification Scheme; and The National Bureau of Standards Report BSS-121.

Cemented soil means a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

Cohesive soil means clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay and organic clay.

Dry soil means soil that does not exhibit visible signs of moisture content.

Fissured means a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.

Granular soil means gravel, sand, or silt, (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

Layered system means two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.

Moist soil means a condition in which a soil looks and feels damp. Moist cohesive soil can easily be shaped into a ball and rolled into small diameter threads before crumbling. Moist granular soil that contains some cohesive material will exhibit signs of cohesion between particles.

Plastic means a property of a soil which allows the soil to be deformed or molded without cracking, or appreciable volume change.

Saturated soil means a soil in which the voids are filled with water. Saturation does not require flow. Saturation, or near saturation, is necessary for the proper use of instruments such as a pocket penetrometer or sheer vane.

Soil classification system means, for the purpose of this subpart, a method of categorizing soil and rock deposits in a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing order of stability. The categories are determined based on an analysis of the properties and performance characteristics of the deposits and the environmental conditions of exposure.

Stable rock means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Submerged soil means soil which is underwater or is free seeping.

Type A means cohesive soils with an unconfined compressive strength of 1.5 ton per square foot (tsf) (144 kPa) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam. Cemented soils such as caliche and hardpan are also considered Type A. However, no soil is Type A if:

(i) The soil is fissured; or

(ii) The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or

(iii) The soil has been previously disturbed; or

(iv) The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater; or

(v) The material is subject to other factors that would require it to be classified as a less stable material.

Type B means:

(i) Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa); or

(ii) Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silt loam, sandy loam and, in some cases, silty clay loam and sandy clay loam.

(iii) Previously disturbed soils except those which would otherwise be classed as Type C soil.

(iv) Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

(v) Dry rock that is not stable; or

(vi) Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

Type C means:

(i) Cohesive soil with an unconfined compressive strength of 0.5 tsf (48 kPa) or less; or

(ii) Granular soils including gravel, sand, and loamy sand; or

(iii) Submerged soil or soil from which water is freely seeping; or

(iv) Submerged rock that is not stable, or

(v) Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical (4H:1V) or steeper.

Unconfined compressive strength means the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

Wet soil means soil that contains significantly more moisture than moist soil, but in such a range of values that cohesive material will slump or begin to flow when vibrated. Granular material that would exhibit cohesive properties when moist will lose those cohesive properties when wet.

(c) *Requirements*—(1) *Classification of soil and rock deposits.* Each soil and rock deposit shall be classified by a competent person as Stable Rock, Type A, Type B, or Type C in accordance with the definitions set forth in paragraph (b) of this appendix.

(2) *Basis of classification.* The classification of the deposits shall be made based on the results of at least one visual and at least one manual analysis. Such analyses shall be conducted by a competent person using tests described in paragraph (d) below, or in other recognized methods of soil classification and testing such as those adopted by the America Society for Testing Materials, or the U.S. Department of Agriculture textural classification system.

(3) *Visual and manual analyses.* The visual and manual analyses, such as those noted as being acceptable in paragraph (d) of this appendix, shall be designed and conducted to provide sufficient quantitative and qualitative information as may be necessary to identify properly the properties, factors, and conditions affecting the classification of the deposits.

(4) *Layered systems.* In a layered system, the system shall be classified in accordance with its weakest layer. However, each layer may be classified individually where a more stable layer lies under a less stable layer.

(5) *Reclassification.* If, after classifying a deposit, the properties, factors, or conditions affecting its classification change in any way, the changes shall be evaluated by a competent person. The deposit shall be reclassified as necessary to reflect the changed circumstances.

(d) *Acceptable visual and manual tests*—(1) *Visual tests.* Visual analysis is conducted to determine qualitative information regarding the excavation site in general, the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated material.

(i) Observe samples of soil that are excavated and soil in the sides of the excavation. Estimate the range of particle sizes and the relative amounts of the particle sizes. Soil that is primarily composed of fine-grained material is cohesive material. Soil composed primarily of coarse-grained sand or gravel is granular material.

(ii) Observe soil as it is excavated. Soil that remains in clumps when excavated is cohesive. Soil that breaks up easily and does not stay in clumps is granular.

(iii) Observe the side of the opened excavation and the surface area adjacent to the excavation. Crack-like openings such as tension cracks could indicate fissured material. If chunks of soil spall off a vertical side, the soil could be fissured. Small spalls are evidence of moving ground and are indications of potentially hazardous situations.

(iv) Observe the area adjacent to the excavation and the excavation itself for evidence of existing utility and other underground structures, and to identify previously disturbed soil.

(v) Observe the opened side of the excavation to identify layered systems. Examine layered systems to identify if the layers slope toward the excavation. Estimate the degree of slope of the layers.

(vi) Observe the area adjacent to the excavation and the sides of the opened excavation for evidence of surface water, water seeping from the sides of the excavation, or the location of the level of the water table.

(vii) Observe the area adjacent to the excavation and the area within the excavation for sources of vibration that may affect the stability of the excavation face.

(2) *Manual tests.* Manual analysis of soil samples is conducted to determine quantitative as well as qualitative properties of soil and to provide more information in order to classify soil properly.

(i) *Plasticity.* Mold a moist or wet sample of soil into a ball and attempt to roll it into threads as thin as ⅛-inch in diameter. Cohesive material can be successfully rolled into threads without crumbling. For example, if at least a two inch (50 mm) length of ⅛-inch thread can be held on one end without tearing, the soil is cohesive.

(ii) *Dry strength.* If the soil is dry and crumbles on its own or with moderate pressure into individual grains or fine powder, it is granular (any combination of gravel, sand, or silt). If the soil is dry and falls into clumps which break up into smaller clumps, but the smaller clumps can only be broken up with difficulty, it may be clay in any combination with gravel, sand or silt. If the dry soil breaks into clumps which do not break up into small clumps and which can only be broken with difficulty, and there is no visual indication the soil is fissured, the soil may be considered unfissured.

(iii) *Thumb penetration.* The thumb penetration test can be used to estimate the unconfined compressive strength of cohesive soils. (This test is based on the thumb penetration test described in American Society for Testing and Materials (ASTM) Standard designation D2488—"Standard Recommended Practice for Description of Soils (Visual—Manual Procedure).") Type A soils with an unconfined compressive strength of 1.5 tsf can be readily indented by the thumb; however, they can be penetrated by the thumb only with very great effort. Type C soils with an unconfined compressive strength of 0.5 tsf can be easily penetrated several inches by the thumb, and can be molded by light finger pressure. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences. If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

(iv) *Other strength tests.* Estimates of unconfined compressive strength of soils can also be obtained by use of a pocket penetrometer or by using a hand-operated shearvane.

(v) *Drying test.* The basic purpose of the drying test is to differentiate between cohesive material with fissures, unfissured cohesive material, and granular material. The procedure for the drying test involves drying a sample of soil that is approximately one inch thick (2.54 cm) and six inches (15.24 cm) in diameter until it is thoroughly dry:

(A) If the sample develops cracks as it dries, significant fissures are indicated.

(B) Samples that dry without cracking are to be broken by hand. If considerable force is necessary to break a sample, the soil has significant cohesive material content. The soil can be classified as a unfissured cohesive material and the unconfined compressive strength should be determined.

(C) If a sample breaks easily by hand, it is either a fissured cohesive material or a granular material. To distinguish between the two, pulverize the dried clumps of the sample by hand or by stepping on them. If the clumps do not pulverize easily, the material is cohesive with fissures. If they pulverize easily into very small fragments, the material is granular.

Appendix B to Subpart P

Sloping and Benching

(a) *Scope and application.* This appendix contains specifications for sloping and benching when used as methods of protecting employees working in excavations from cave-ins. The requirements of this appendix apply when the design of sloping and benching protective systems is to be performed in accordance with the requirements set forth in § 1926.652(b)(2).

(b) *Definitions.*

Actual slope means the slope to which an excavation face is excavated.

Distress means that the soil is in a condition where a cave-in is imminent or is likely to occur. Distress is evidenced by such phenomena as the development of fissures in the face of or adjacent to an open excavation; the subsidence of the edge of an excavation; the slumping of material from the face or the bulging or heaving of material from the bottom of an excavation; the spalling of material from the face of an excavation; and ravelling, i.e., small amounts of material such as pebbles or little clumps of material suddenly separating from the face of an excavation and trickling or rolling down into the excavation.

Maximum allowable slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Short term exposure means a period of time less than or equal to 24 hours that an excavation is open.

(c) *Requirements*—(1) *Soil classification.* Soil and rock deposits shall be classified in accordance with appendix A to subpart P of part 1926.

(2) *Maximum allowable slope.* The maximum allowable slope for a soil or rock deposit shall be determined from Table B-1 of this appendix.

(3) *Actual slope.* (i) The actual slope shall not be steeper than the maximum allowable slope.

(ii) The actual slope shall be less steep than the maximum allowable slope, when there are signs of distress. If that situation occurs, the slope shall be cut back to an actual slope which is at least ½ horizontal to one vertical (½H:1V) less steep than the maximum allowable slope.

(iii) When surcharge loads from stored material or equipment, operating equipment, or traffic are present, a competent person shall determine the degree to which the actual slope must be reduced below the maximum allowable slope, and shall assure that such reduction is achieved. Surcharge loads from adjacent structures shall be evaluated in accordance with § 1926.651(i).

(4) *Configurations.* Configurations of sloping and benching systems shall be in accordance with Figure B-1.

TABLE B-1

MAXIMUM ALLOWABLE SLOPES

SOIL OR ROCK TYPE	MAXIMUM ALLOWABLE SLOPES (H:V)[1] FOR EXCAVATIONS LESS THAN 20 FEET DEEP [3]
STABLE ROCK TYPE A [2] TYPE B TYPE C	VERTICAL (90°) 3/4 : 1 (53°) 1:1 (45°) 1½: 1 (34°)

NOTES:

1. Numbers shown in parentheses next to maximum allowable slopes are angles expressed in degrees from the horizontal. Angles have been rounded off.
2. A short-term maximum allowable slope of 1/2H:1V (63°) is allowed in excavations in Type A soil that are 12 feet (3.67 m) or less in depth. Short-term maximum allowable slopes for excavations greater than 12 feet (3.67 m) in depth shall be 3/4H:1V (53°)
3. Sloping or benching for excavations greater than 20 feet deep shall be designed by a registered professional engineer.

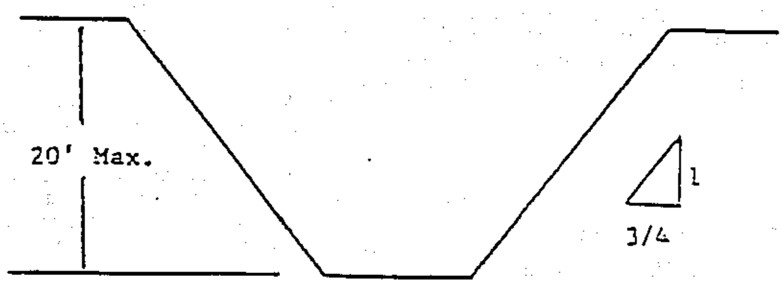
Figure B-1

Slope Configurations

(All slopes stated below are in the horizontal to vertical ratio)

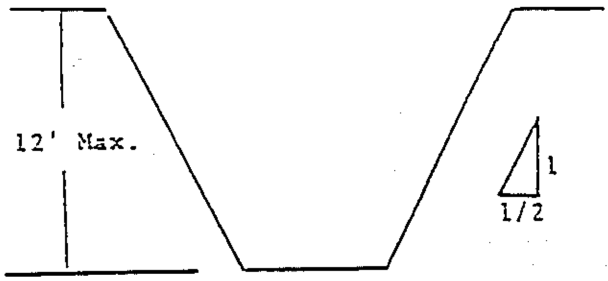
B-1.1 Excavations made in Type A soil

1. All simple slope excavation 20 feet or less in depth shall have a maximum allowable slope of ¾:1.



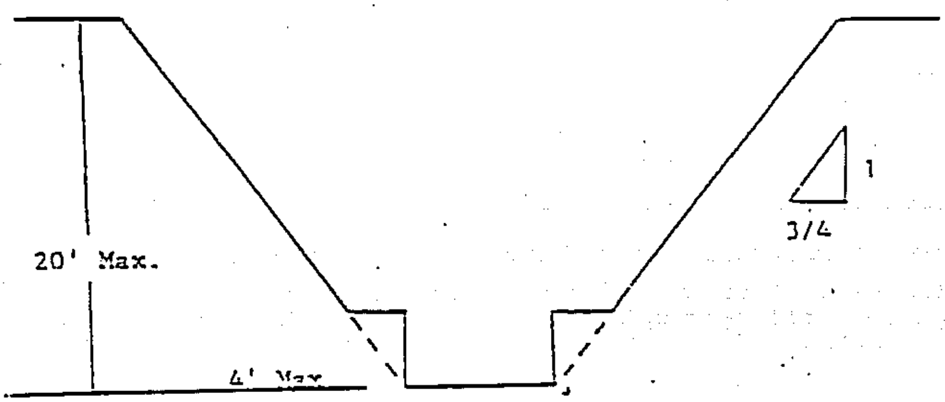
SIMPLE SLOPE—GENERAL

Exception: Simple slope excavations which are open 24 hours or less (short term) and which are 12 feet or less in depth shall have a maximum allowable slope of ½:1.

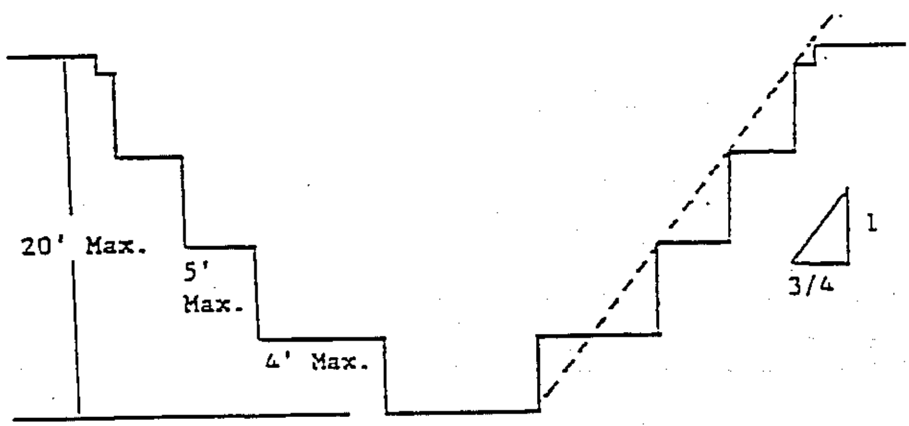


SIMPLE SLOPE—SHORT TERM

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of ¾ to 1 and maximum bench dimensions as follows:

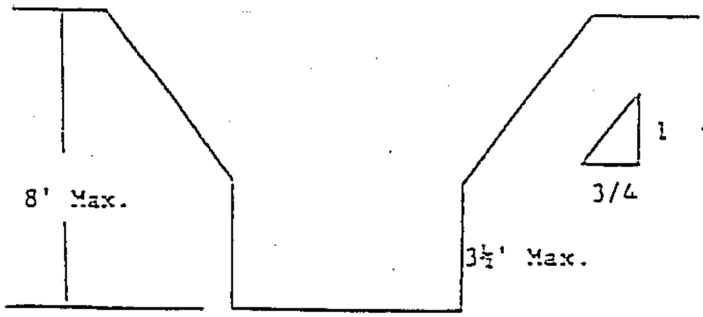


SIMPLE BENCH



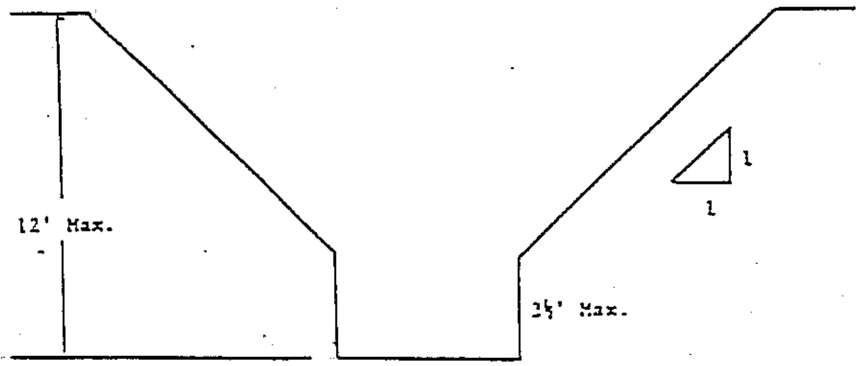
MULTIPLE BENCH

3. All excavations 8 feet or less in depth which have unsupported vertically sided lower portions shall have a maximum vertical side of 3½ feet.



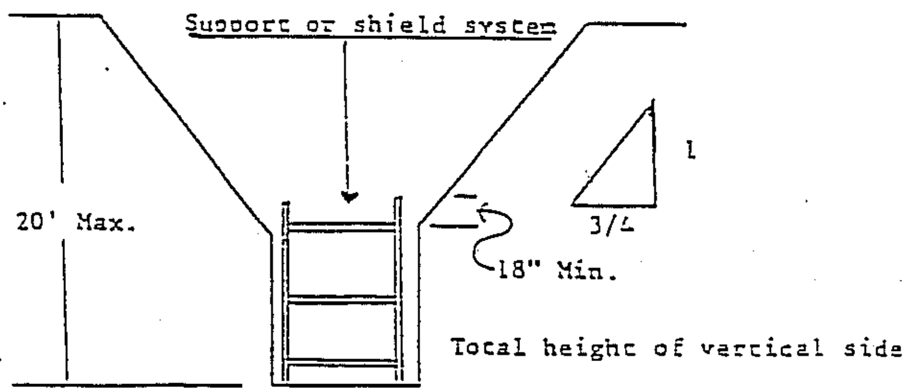
UNSUPPORTED VERTICALLY SIDED LOWER PORTION—MAXIMUM 8 FEET IN DEPTH

All excavations more than 8 feet but not more than 12 feet in depth which unsupported vertically sided lower portions shall have a maximum allowable slope of 1:1 and a maximum vertical side of 3½ feet.



UNSUPPORTED VERTICALLY SIDED LOWER PORTION—MAXIMUM 12 FEET IN DEPTH

All excavations 20 feet or less in depth which have vertically sided lower portions that are supported or shielded shall have a maximum allowable slope of ¾:1. The support or shield system must extend at least 18 inches above the top of the vertical side.

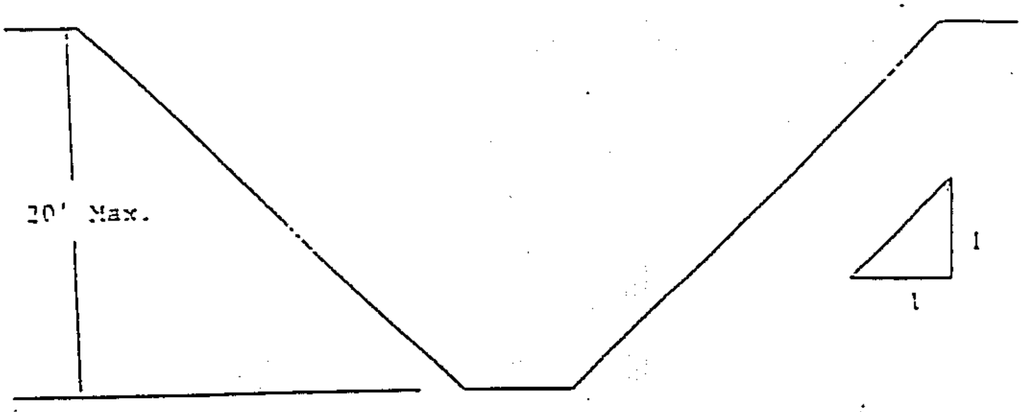


SUPORTED OR SHIELDED VERTICALLY SIDED LOWER PORTION

4. All other simple slope, compound slope, and vertically sided lower portion excavations shall be in accordance with the other options permitted under § 1926.652(b).

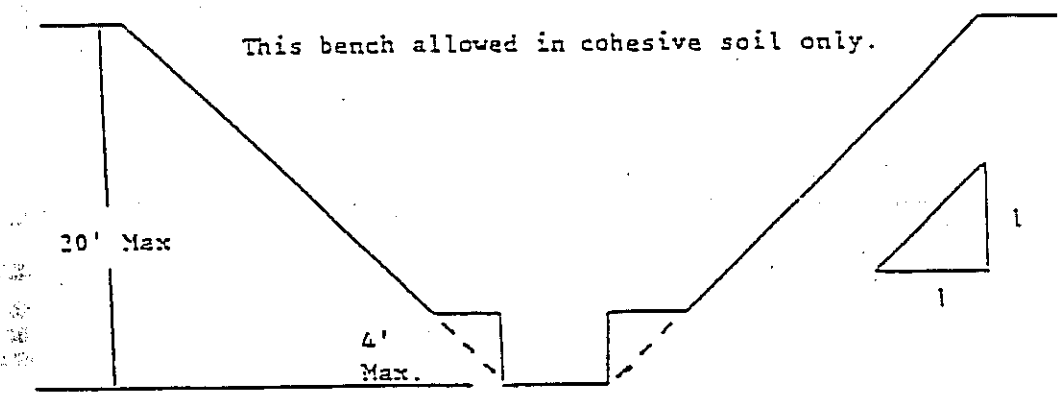
B-1.2 Excavations Made in Type B Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1.

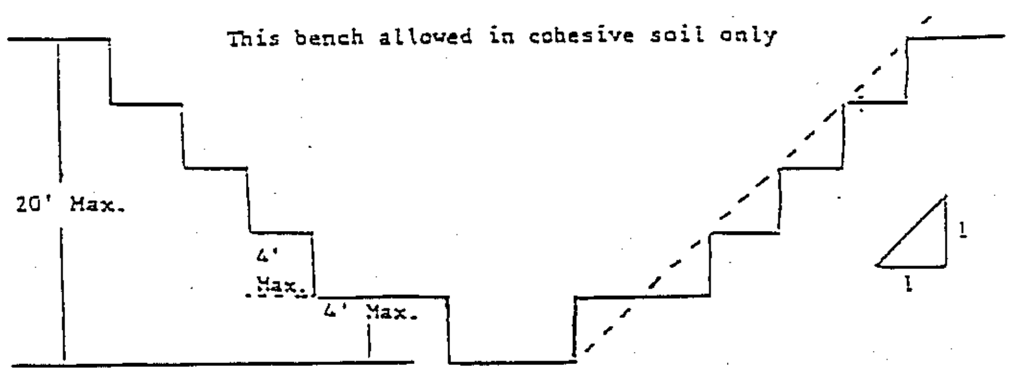


SIMPLE SLOPE

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1 and maximum bench dimensions as follows:

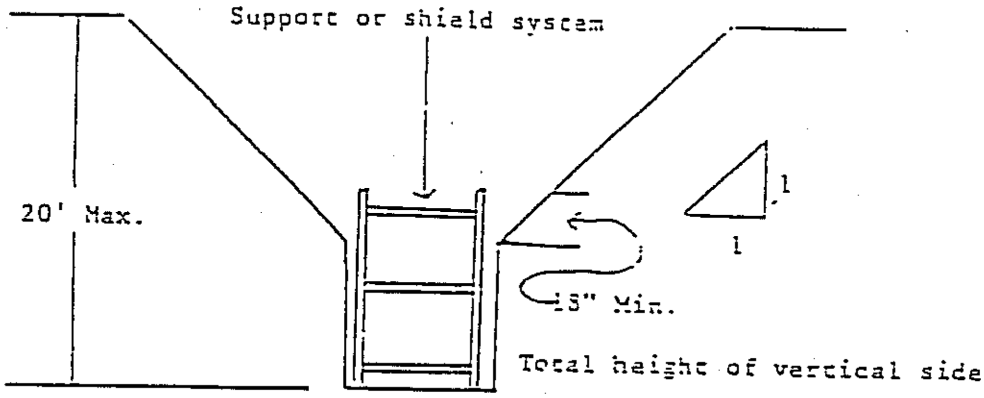


SINGLE BENCH



MULTIPLE BENCH

3. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1:1.

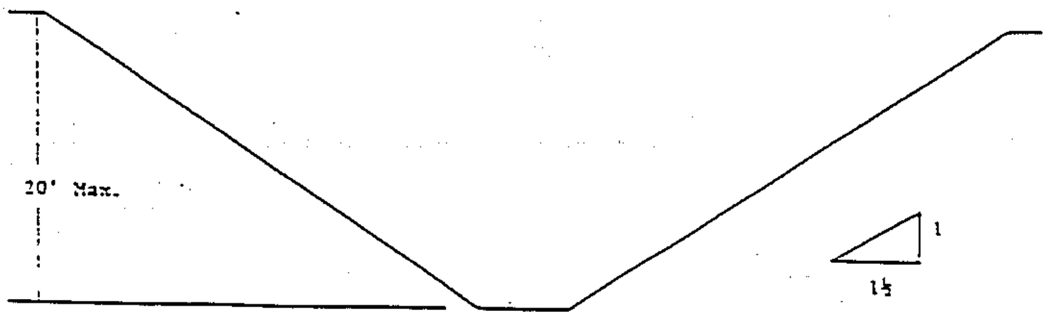


VERTICALLY SIDED LOWER PORTION

4. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

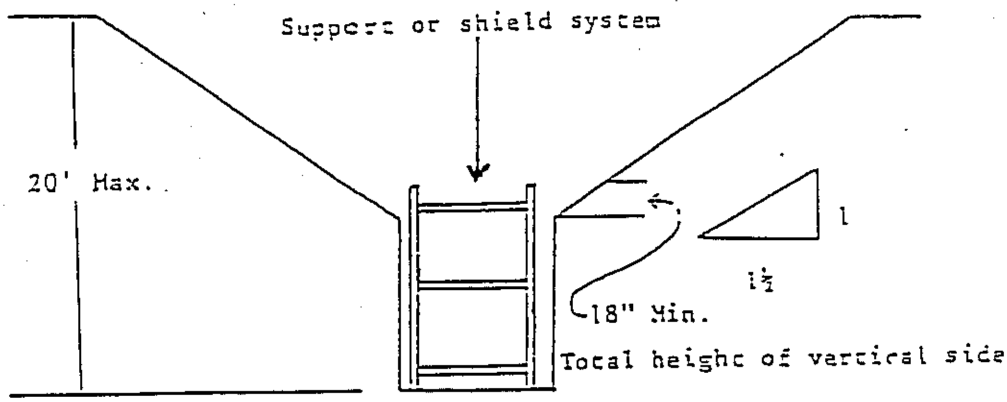
B-1.3 Excavations Made in Type C Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1½:1.



SIMPLE SLOPE

2. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1½:1.

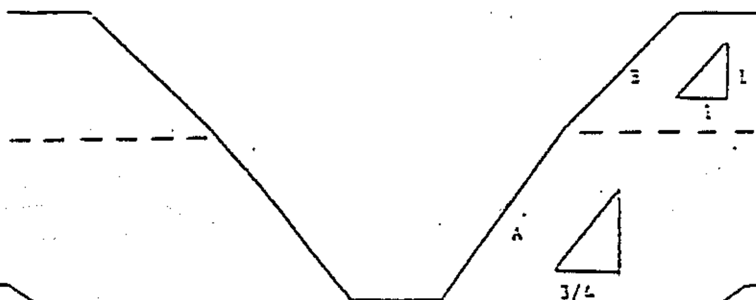


VERTICAL SIDED LOWER PORTION

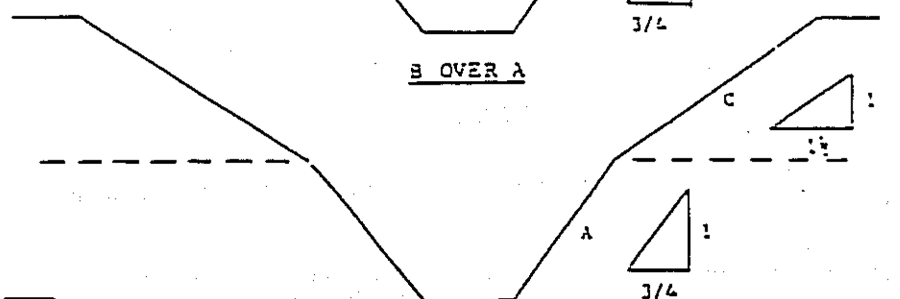
3. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

B-1.4 Excavations Made in Layered Soils

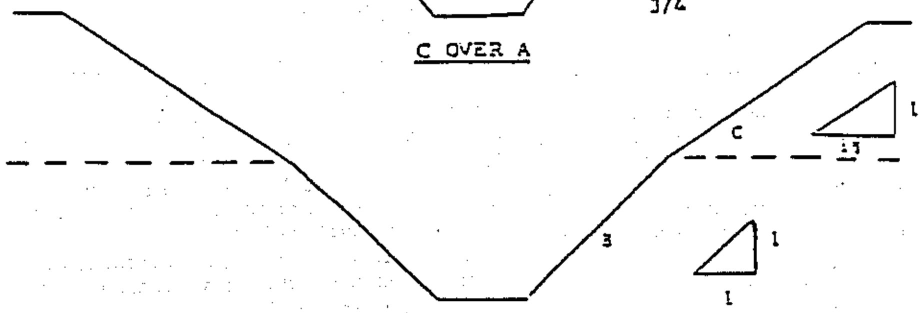
1. All excavations 20 feet or less in depth made in layered soils shall have a maximum allowable slope for each layer as set forth below.



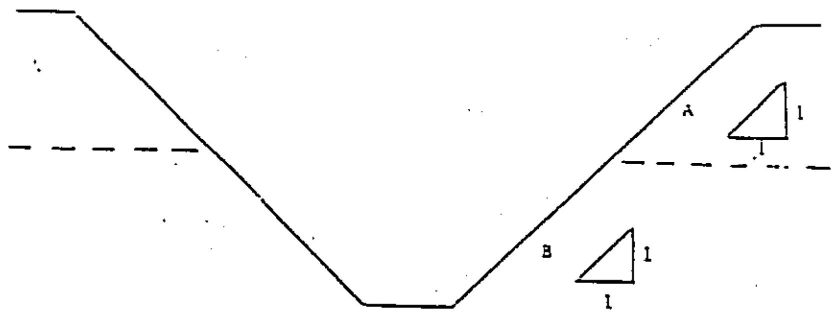
B OVER A



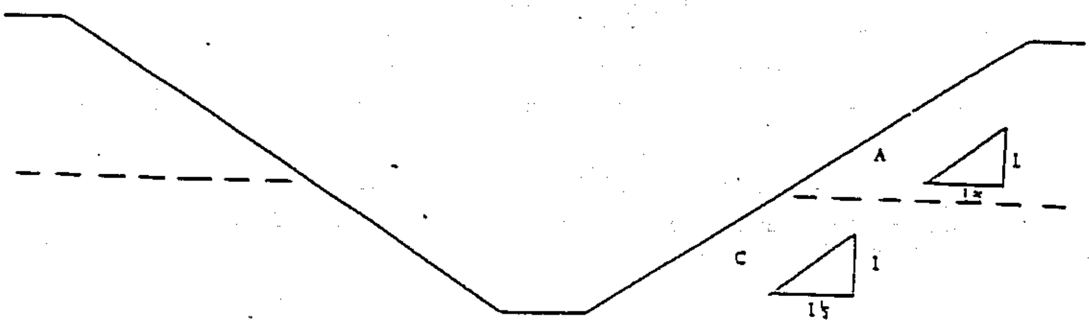
C OVER A



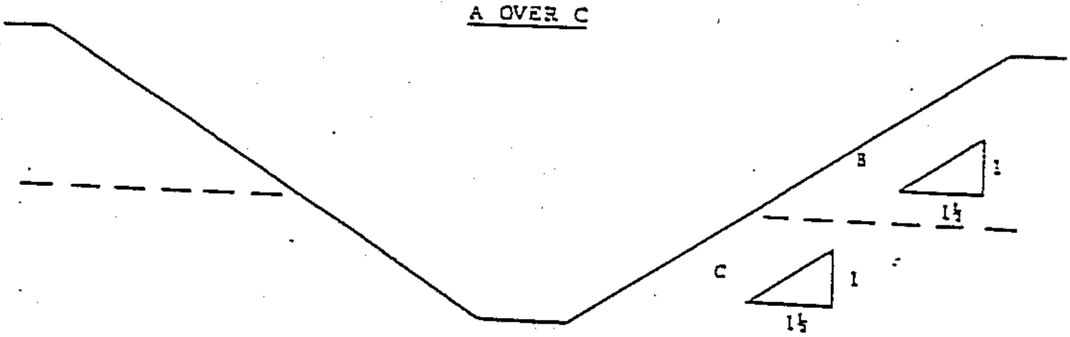
C OVER B



A OVER B



A OVER C



B OVER C

2. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

Appendix C to Subpart P

Timber Shoring for Trenches

(a) *Scope.* This appendix contains information that can be used timber shoring is provided as a method of protection from cave-ins in trenches that do not exceed 20 feet (6.1 m) in depth. This appendix must be used when design of timber shoring protective systems is to be performed in accordance with § 1926.652(c)(1). Other timber shoring configurations; other systems of support such as hydraulic and pneumatic systems; and other protective systems such as sloping, benching, shielding, and freezing systems must be designed in accordance with the requirements set forth in § 1926.652(b) and § 1926.652(c).

(b) *Soil Classification.* In order to use the data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of this part.

(c) *Presentation of Information.* Information is presented in several forms as follows:

(1) Information is presented in tabular form in Tables C-1.1, C-1.2, and C-1.3, and

Tables C-2.1, C-2.2 and C-2.3 following paragraph (g) of the appendix. Each table presents the minimum sizes of timber members to use in a shoring system, and each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. The data are arranged to allow the user the flexibility to select from among several acceptable configurations of members based on varying the horizontal spacing of the crossbraces. Stable rock is exempt from shoring requirements and therefore, no data are presented for this condition.

(2) Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix, and on the tables themselves.

(3) Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.

(4) Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.

(5) Miscellaneous notations regarding Tables C-1.1 through C-1.3 and Tables C-2.1 through C-2.3 are presented in paragraph (g) of this Appendix.

(d) *Basis and limitations of the data.*—(1) *Dimensions of timber members.* (i) The sizes of the timber members listed in Tables C-1.1 through C-1.3 are taken from the National Bureau of Standards (NBS) report, "Recommended Technical Provisions for Construction Practice in Shoring and Sloping of Trenches and Excavations." In addition, where NBS did not recommend specific sizes of members, member sizes are based on an analysis of the sizes required for use by existing codes and on empirical practice.

(ii) The required dimensions of the members listed in Tables C-1.1 through C-1.3 refer to actual dimensions and not nominal dimensions of the timber. Employers wanting to use nominal size shoring are directed to Tables C-2.1 through C-2.3, or have this choice under § 1926.652(c)(3), and are referred to The Corps of Engineers, The Bureau of Reclamation or data from other acceptable sources.

(2) *Limitation of application.* (i) It is not intended that the timber shoring specification apply to every situation that may be experienced in the field. These data were developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be designed as specified in § 1926.652(c).

(ii) When any of the following conditions are present, the members specified in the tables are not considered adequate. Either an alternate timber shoring system must be designed or another type of protective system designed in accordance with § 1926.652.

(A) When loads imposed by structures or by stored material adjacent to the trench weigh in excess of the load imposed by a two-foot soil surcharge. The term "adjacent" as used here means the area within a horizontal distance from the edge of the trench equal to the depth of the trench.

(B) When vertical loads imposed on cross braces exceed a 240-pound gravity load distributed on a one-foot section of the center of the crossbrace.

(C) When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

(D) When only the lower portion of a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

(e) *Use of Tables.* The members of the shoring system that are to be selected using this information are the cross braces, the uprights, and the wales, where wales are required. Minimum sizes of members are specified for use in different types of soil. There are six tables of information, two for each soil type. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is then made. The selection is based on the depth and width of the trench where the members are to be installed and, in most instances, the selection is also based on the horizontal spacing of the crossbraces. Instances where a choice of horizontal spacing of crossbracing is available, the horizontal spacing of the crossbraces must be chosen by the user before the size of any member can be determined. When the soil type, the width and depth of the trench, and the horizontal spacing of the crossbraces are known, the size and vertical spacing of the crossbraces, the size and vertical spacing of the wales, and the size and horizontal spacing of the uprights can be read from the appropriate table.

(f) *Examples to Illustrate the Use of Tables C-1.1 through C-1.3.*

(1) *Example 1.*

A trench dug in Type A soil is 13 feet deep and five feet wide.

From *Table C-1.1*, for acceptable arrangements of timber can be used.

Arrangement #1

Space 4×4 crossbraces at six feet horizontally and four feet vertically.

Wales are not required.

Space 3×8 uprights at six feet horizontally. This arrangement is commonly called "skip shoring."

Arrangement #2

Space 4×6 crossbraces at eight feet horizontally and four feet vertically.

Space 8×8 wales at four feet vertically.

Space 2×6 uprights at four feet horizontally.

Arrangement #3

Space 6×6 crossbraces at 10 feet horizontally and four feet vertically.

Space 8×10 wales at four feet vertically.

Space 2×6 uprights at five feet horizontally.

Arrangement #4

Space 6×6 crossbraces at 12 feet horizontally and four feet vertically.

Space 10×10 wales at four feet vertically.

Spaces 3×8 uprights at six feet horizontally.

(2) *Example 2.*

A trench dug in Type B soil in 13 feet deep and five feet wide. From Table C-1.2 three acceptable arrangements of members are listed.

Arrangement #1

Space 6×6 crossbraces at six feet horizontally and five feet vertically.

Space 8×8 wales at five feet vertically.

Space 2×6 uprights at two feet horizontally.

Arrangement #2

Space 6×8 crossbraces at eight feet horizontally and five feet vertically.

Space 10×10 wales at five feet vertically.

Space 2×6 uprights at two feet horizontally.

Arrangement #3

Space 8×8 crossbraces at 10 feet horizontally and five feet vertically.

Space 10×12 wales at five feet vertically.

Space 2×6 uprights at two feet vertically.

(3) *Example 3.*

A trench dug in Type C soil is 13 feet deep and five feet wide.

From Table C-1.3 two acceptable arrangements of members can be used.

Arrangement #1

Space 8×8 crossbraces at six feet horizontally and five feet vertically.

Space 10×12 wales at five feet vertically.

Position 2×6 uprights as closely together as possible.

If water must be retained use special tongue and groove uprights to form tight sheeting.

Arrangement #2

Space 8×10 crossbraces at eight feet horizontally and five feet vertically.

Space 12×12 wales at five feet vertically.

Position 2×6 uprights in a close sheeting configuration unless water pressure must be resisted. Tight sheeting must be used where water must be retained.

(4) *Example 4.*

A trench dug in Type C soil is 20 feet deep and 11 feet wide. The size and spacing of members for the section of trench that is over 15 feet in depth is determined using Table C-1.3. Only one arrangement of members is provided.

Space 8×10 crossbraces at six feet horizontally and five feet vertically.

Space 12×12 wales at five feet vertically.

Use 3×6 tight sheeting.

Use of Tables C-2.1 through C-2.3 would follow the same procedures.

(g) *Notes for all Tables.*

1. Member sizes at spacings other than indicated are to be determined as specified in § 1926.652(c), "Design of Protective Systems."

2. When conditions are saturated or submerged use Tight Sheeting. Tight Sheeting refers to the use of specially-edged timber planks (e.g., tongue and groove) at least three inches thick, steel sheet piling, or similar construction that when driven or placed in position provide a tight wall to resist the lateral pressure of water and to prevent the loss of backfill material. Close Sheeting refers to the placement of planks side-by-side allowing as little space as possible between them.

3. All spacing indicated is measured center to center.

4. Wales to be installed with greater dimension horizontal.

5. If the vertical distance from the center of the lowest crossbrace to the bottom of the trench exceeds two and one-half feet, uprights shall be firmly embedded or a mudsill shall be used. Where uprights are embedded, the vertical distance from the center of the lowest crossbrace to the bottom of the trench shall not exceed 36 inches. When mudsills are used, the vertical distance shall not exceed 42 inches. Mudsills are wales that are installed at the toe of the trench side.

6. Trench jacks may be used in lieu of or in combination with timber crossbraces.

7. Placement of crossbraces. When the vertical spacing of crossbraces is four feet, place the top crossbrace no more than two feet below the top of the trench. When the vertical spacing of crossbraces is five feet, place the top crossbrace no more than 2.5 feet below the top of the trench.

TABLE C-1.1

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE A P_a = 25 X H + 72 psf (2 ft Surcharge)

PTH OF ENCH ET)	SIZE (ACTUAL) AND SPACING OF MEMBERS **													
	CROSS BRACES							WALES		UPRIGHTS				
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	4	5	6	8
5	UP TO 6	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---				2X6	
0	UP TO 8	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---					2X8
10	UP TO 10	4X6	4X6	4X6	6X6	6X6	4	8X8	4			2X6		
	UP TO 12	4X6	4X6	6X6	6X6	6X6	4	8X8	4				2X6	
10	UP TO 6	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---				3X8	
0	UP TO 8	4X6	4X6	6X6	6X6	6X6	4	8X8	4		2X6			
15	UP TO 10	6X6	6X5	6X6	6X8	6X8	4	8X10	4			2X6		
	UP TO 12	6X6	6X6	6X6	6X8	6X8	4	10X10	4				3X8	
5	UP TO 6	6X6	6X6	6X6	6X8	6X8	4	6X8	4	3X6				
)	UP TO 8	6X6	6X6	6X6	6X8	6X8	4	8X8	4	3X6				
)	UP TO 10	8X8	8X8	8X8	8X8	8X10	4	8X10	4	3X6				
	UP TO 12	8X8	8X8	8X8	8X8	8X10	4	10X10	4	3X6				
OVER 20	SEE NOTE 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may by substituted for wood.

TABLE C-1.2

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE B $P_a = 45 \times H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (ACTUAL) AND SPACING OF MEMBERS**													
	CROSS BRACES							WALES		UPRIGHTS				
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET) UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15	VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET) CLOSE	2	3		
5 TO 10	UP TO 6	4X6	4X6	6X6	6X6	6X6	5	6X8	5			2X6		
	UP TO 8	6X6	6X6	6X6	6X8	6X8	5	8X10	5			2X6		
	UP TO 10	6X6	6X6	6X6	6X8	6X8	5	10X10	5			2X6		
	See Note 1													
10 TO 15	UP TO 6	6X6	6X6	6X6	6X8	6X8	5	8X8	5		2X6			
	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X10	5		2X6			
	UP TO 10	8X8	8X8	8X8	8X8	8X10	5	10X12	5		2X6			
	See Note 1													
15 TO 20	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	8X10	5	3X6				
	UP TO 8	8X8	8X8	8X8	8X8	8X10	5	10X12	5	3X6				
	UP TO 10	8X10	8X10	8X10	8X10	10X10	5	12X12	5	3X6				
	See Note 1													
OVER 20	SEE NOTE 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may by substituted for wood.

TABLE C-1.3

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE C P_a = 80 X H + 72 psf (2 ft. Surcharge)

DEPTH OF [illegible]NCH ([illegible]ET)	SIZE (ACTUAL) AND SPACING OF MEMBERS**													
	CROSS BRACES									UPRIGHTS				
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN.)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET) (See Note 2)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE				
5 TO 0	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	8X10	5	2X6				
	UP TO 8	8X8	8X8	8X8	8X8	8X10	5	10X12	5	2X6				
	UP TO 10	8X10	8X10	8X10	8X10	10X10	5	12X12	5	2X6				
	See Note 1													
0 0 5	UP TO 6	8X8	8X8	8X8	8X8	8X10	5	10X12	5	2X6				
	UP TO 8	8X10	8X10	8X10	8X10	10X10	5	12X12	5	2X6				
	See Note 1													
	See Note 1													
5 0 20	UP TO 6	8X10	8X10	8X10	8X10	10X10	5	12X12	5	3X6				
	See Note 1													
	See Note 1													
	See Note 1													
[illegible]R	SEE NOTE 1													

* Mixed Oak or equivalent with a bending strength not less than 850 psi.
** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.1

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *
SOIL TYPE A P_a = 25 X H + 72 psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (S4S) AND SPACING OF MEMBERS **													
	CROSS BRACES							WALES		UPRIGHTS				
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	4	5	6	8
5 TO 10	UP TO 6	4X4	4X4	4X4	4X4	4X6	4	Not Req'd	Not Req'd				4X6	
	UP TO 8	4X4	4X4	4X4	4X6	4X6	4	Not Req'd	Not Req'd					4X8
	UP TO 10	4X6	4X6	4X6	6X6	6X6	4	8X8	4			4X6		
	UP TO 12	4X6	4X6	4X6	6X6	6X6	4	8X8	4				4X6	
10 TO 15	UP TO 6	4X4	4X4	4X4	6X6	6X6	4	Not Req'd	Not Req'd				4X10	
	UP TO 8	4X6	4X6	4X6	6X6	6X6	4	6X8	4		4X6			
	UP TO 10	6X6	6X6	6X6	6X6	6X6	4	8X8	4			4X8		
	UP TO 12	6X6	6X6	6X6	6X6	6X6	4	8X10	4		4X6		4X10	
15 TO 20	UP TO 6	6X6	6X6	6X6	6X6	6X6	4	6X8	4	3X6				
	UP TO 8	6X6	6X6	6X6	6X6	6X6	4	8X8	4	3X6	4X12			
	UP TO 10	6X6	6X6	6X6	6X6	6X8	4	8X10	4	3X6				
	UP TO 12	6X6	6X6	6X6	6X8	6X8	4	8X12	4	3X6	4X12			
OVER 20	SEE NOTE 1.													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.
** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.2

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE B P_a = 45 X H + 72 psf (2 ft. Surcharge)

DEPTH OF (ENCH 'EET)	SIZE (S4S) AND SPACING OF MEMBERS **													
	CROSS BRACES							WALES		UPRIGHTS				
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	2	3	4	6
5	UP TO 6	4X6	4X6	4X6	6X6	6X6	5	6X8	5			3X12 4X8		4X12
TO	UP TO 8	4X6	4X6	6X6	6X6	6X6	5	8X8	5		3X8		4X8	
0	UP TO 10	4X6	4X6	6X6	6X6	6X8	5	8X10	5			4X8		
	See Note 1													
0	UP TO 6	6X6	6X6	6X6	6X8	6X8	5	8X8	5	3X6	4X10			
TO	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X10	5	3X6	4X10			
5	UP TO 10	6X8	6X8	8X8	8X8	8X8	5	10X12	5	3X6	4X10			
	See Note 1													
5	UP TO 6	6X8	6X8	6X8	6X8	8X8	5	8X10	5	4X6				
TO	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X12	5	4X6				
0	UP TO 10	8X8	8X8	8X8	8X8	8X8	5	12X12	5	4X6				
	See Note 1													
/ER 20	SEE NOTE 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.
** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.3

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE C $P_a = 80 \times H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (S4S) AND SPACING OF MEMBERS **														
	CROSS BRACES							WALES		UPRIGHTS					
	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET) UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15	VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET) CLOSE					
5 TO 10	UP TO 6	6X6	6X6	6X6	6X6	8X8	5	8X8	5	3X6					
	UP TO 8	6X6	6X6	6X6	8X8	8X8	5	10X10	5	3X6					
	UP TO 10	6X6	6X6	8X8	8X8	8X8	5	10X12	5	3X6					
	See Note 1														
10 TO 15	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	10X10	5	4X6					
	UP TO 8	8X8	8X8	8X8	8X8	8X8	5	12X12	5	4X6					
	See Note 1														
	See Note 1														
15 TO 20	UP TO 6	8X8	8X8	8X8	8X10	8X10	5	10X12	5	4X6					
	See Note 1														
	See Note 1														
	See Note 1														
OVER 20	SEE NOTE 1														

* Douglas fir or equivalent with a bending strength not less than 1500 psi.
** Manufactured members of equivalent strength may be substituted for wood.

Appendix D to Subpart P

Aluminum Hydraulic Shoring for Trenches

(a) *Scope.* This appendix contains information that can be used when aluminum hydraulic shoring is provided as a method of protection against cave-ins in trenches that do not exceed 20 feet (6.1m) in depth. This appendix must be used when design of the aluminum hydraulic protective system cannot be performed in accordance with § 1926.652(c)(2).

(b) *Soil Classification.* In order to use data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of part 1926.

(c) *Presentation of Information.* Information is presented in several forms as follows:

(1) Information is presented in tabular form in Tables D-1.1, D-1.2, D-1.3 and E-1.4. Each table presents the maximum vertical and horizontal spacings that may be used with various aluminum member sizes and various hydraulic cylinder sizes. Each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. Tables D-1.1 and D-1.2 are for vertical shores in Types A and B soil. Tables D-1.3 and D1.4 are for horizontal waler systems in Types B and C soil.

(2) Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix.

(3) Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.

(4) Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.

(5) Miscellaneous notations (footnotes) regarding Table D-1.1 through D-1.4 are presented in paragraph (g) of this appendix.

(6) Figures, illustrating typical installations of hydraulic shoring, are included just prior to the Tables. The illustrations page is entitled "Aluminum Hydraulic Shoring: Typical Installations."

(d) *Basis and limitations of the data.*

(1) Vertical shore rails and horizontal wales are those that meet the Section Modulus requirements in the D-1 Tables. Aluminum material is 6061-T6 or material of equivalent strength and properties.

(2) Hydraulic cylinders specifications. (i) 2-inch cylinders shall be a minimum 2-inch inside diameter with a minimum safe working capacity of no less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufaturer.

(ii) 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe working capacity of not less than 30,000 pounds axial compressive load at extensions as recommended by product manufacturer.

(3) Limitation of application.

(i) It is not intended that the aluminum hydraulic specification apply to every situation that may be experienced in the field. These data were developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be otherwise designed as specified in § 1926.652(c).

(ii) When any of the following conditions are present, the members specified in the Tables are not considered adequate. In this case, an alternative aluminum hydraulic shoring system or other type of protective system must be designed in accordance with § 1926.652.

(A) When vertical loads imposed on cross braces exceed a 100 Pound gravity load distributed on a one foot section of the center of the hydraulic cylinder.

(B) When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

(C) When only the lower portion or a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

(e) *Use of Tables D-1.1, D-1.2, D-1.3 and D-1.4.* The members of the shoring system that are to be selected using this information are the hydraulic cylinders, and either the vertical shores or the horizontal wales. When a waler system is used the vertical timber sheeting to be used is also selected from these tables. The Tables D-1.1 and D-1.2 for vertical shores are used in Type A and B soils that do not require sheeting. Type B soils that may require sheeting, and Type C soils that always require sheeting are found in the horizontal wale Tables D-1.3 and D-1.4. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is made. The selection is based on the depth and width of the trench where the members are to be installed. In these tables the vertical spacing is held constant at four feet on center. The tables show the maximum horizontal spacing of cylinders allowed for each size of wale in the waler system tables, and in the vertical shore tables, the hydraulic cylinder horizontal spacing is the same as the vertical shore spacing.

(f) *Example to Illustrate the Use of the Tables:*

(1) Example 1:

A trench dug in Type A soil is 6 feet deep and 3 feet wide. From Table D-1.1: Find vertical shores and 2 inch diameter cylinders spaced 8 feet on center (o.c.) horizontally and 4 feet on center (o.c.) vertically. (See Figures 1 & 3 for typical installations.)

(2) Example 2:

A trench is dug in Type B soil that does not require sheeting, 13 feet deep and 5 feet wide. From Table D-1.2: Find vertical shores and 2 inch diameter cylinders spaced 6.5 feet o.c. horizontally and 4 feet o.c. vertically. (See Figures 1 & 3 for typical installations.)

(3) A trench is dug in Type B soil that does not require sheeting, but does experience some minor raveling of the trench face. The trench is 16 feet deep and 9 feet wide. From Table D-1.2: Find vertical shores and 2 inch diameter cylinder (with special oversleeves as designated by footnote #2) spaced 5.5 feet o.c. horizontally and 4 feet o.c. vertically, plywood (per footnote (g)(7) to the D-1 Table) should be used behind the shores. (See Figures 2 & 3 for typical installations.)

(4) Example 4: A trench is dug in previously disturbed Type B soil, with characteristics of a Type C soil, and will require sheeting. The trench is 18 feet deep and 12 feet wide. 8 foot horizontal spacing between cylinders is desired for working space. From Table D-1.3: Find horizontal wale with a section modulus of 14.0 spaced at 4 feet o.c. vertically and 3 inch diameter cylinder spaced at 9 feet maximum o.c. horizontally. 3×12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

(5) Example 5: A trench is dug in Type C soil, 9 feet deep and 4 feet wide. Horizontal cylinder spacing in excess of 6 feet is desired for working space. From Table D-1.4: Find horizontal wale with a section modulus of 7.0 and 2 inch diameter cylinders spaced at 6.5 feet o.c. horizontally. Or, find horizontal wale with a 14.0 section modulus and 3 inch diameter cylinder spaced at 10 feet o.c. horizontally. Both wales are spaced 4 feet o.c. vertically. 3×12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

(g) *Footnotes, and general notes, for Tables D-1.1, D-1.2, D-1.3, and D-1.4.*

(1) For applications other than those listed in the tables, refer to § 1926.652(c)(2) for use of manufacturer's tabulated data. For trench depths in excess of 20 feet, refer to § 1926.652(c)(2) and § 1926.652(c)(3).

(2) 2 inch diameter cylinders, at this width, shall have structural steel tube (3.5×3.5×0.1875) oversleeves, or structural oversleeves of manufacturer's specification, extending the full, collapsed length.

(3) Hydraulic cylinders capacities. (i) 2 inch cylinders shall be a minimum 2-inch inside diameter with a safe working capacity of not less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(ii) 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe work capacity of not less than 30,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(4) All spacing indicated is measured center to center.

(5) Vertical shoring rails shall have a minimum section modulus of 0.40 inch.

(6) When vertical shores are used, there must be a minimum of three shores spaced equally, horizontally, in a group.

(7) Plywood shall be 1.125 in. thick softwood or 0.75 inch. thick, 14 ply, arctic white birch (Finland form). Please note that plywood is not intended as a structural member, but only for prevention of local raveling (sloughing of the trench face) between shores.

(8) See appendix C for timber specifications.

(9) Wales are calculated for simple span conditions.

(10) See appendix D, item (d), for basis and limitations of the data.

ALUMINUM HYDRAULIC SHORING
TYPICAL INSTALLATIONS

FIGURE NO. 1

VERTICAL ALUMINUM HYDRAULIC SHORING (SPOT BRACING)

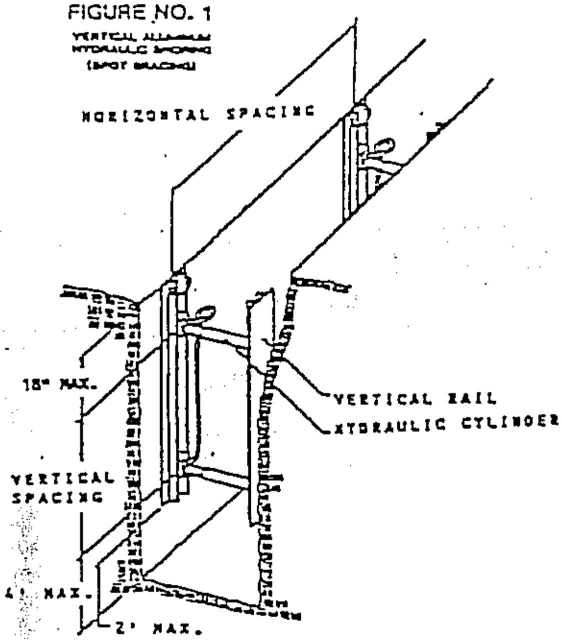


FIGURE NO. 2

VERTICAL ALUMINUM HYDRAULIC SHORING (WITH PLYWOOD)

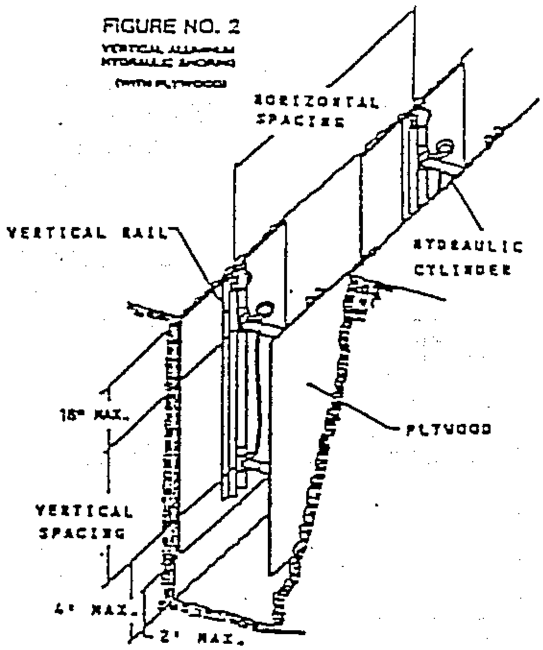


FIGURE NO. 3

VERTICAL ALUMINUM HYDRAULIC SHORING (STACKED)

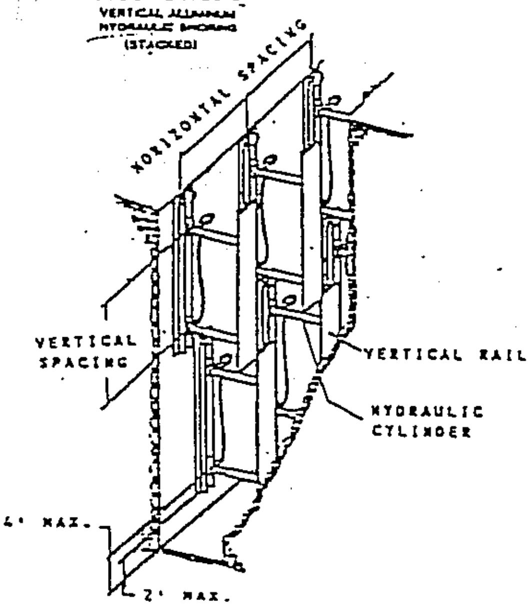


FIGURE NO. 4

ALUMINUM HYDRAULIC SHORING WALER SYSTEM (TYPICAL)

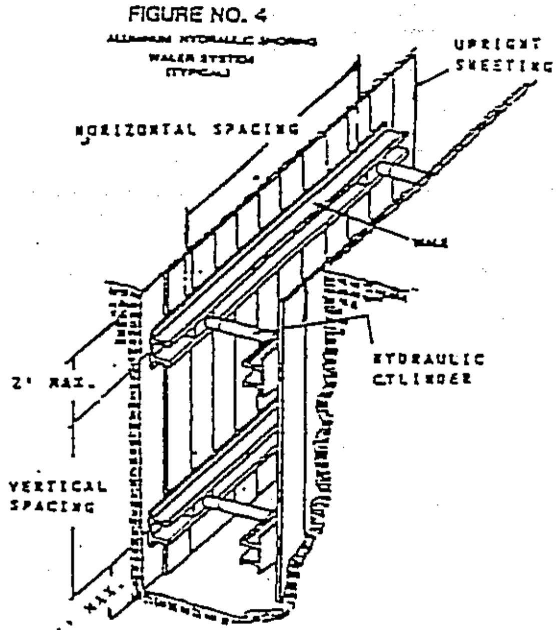


TABLE D - 1.1
ALUMINUM HYDRAULIC SHORING
VERTICAL SHORES
FOR SOIL TYPE A

DEPTH OF TRENCH (FEET)	HYDRAULIC CYLINDERS				
	MAXIMUM HORIZONTAL SPACING (FEET)	MAXIMUM VERTICAL SPACING (FEET)	WIDTH OF TRENCH (FEET)		
			UP TO 8	OVER 8 UP TO 12	OVER 12 UP TO 15
OVER 5 UP TO 10	8	4	2 INCH DIAMETER	2 INCH DIAMETER NOTE (2)	3 INCH DIAMETER
OVER 10 UP TO 15	8				
OVER 15 UP TO 20	7				
OVER 20	NOTE (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Note (1): See Appendix D, Item (g) (1)
Note (2): See Appendix D, Item (g) (2)

TABLE D - 1.2
ALUMINUM HYDRAULIC SHORING
VERTICAL SHORES
FOR SOIL TYPE B

‾EPTH OF TRENCH (‾EET)	HYDRAULIC CYLINDERS				
	MAXIMUM HORIZONTAL SPACING (FEET)	MAXIMUM VERTICAL SPACING (FEET)	WIDTH OF TRENCH (FEET)		
			UP TO 8	OVER 8 UP TO 12	OVER 12 UP TO 15
OVER 5 ꞋP TO 10	8	4	2 INCH DIAMETER	2 INCH DIAMETER NOTE (2)	3 INCH DIAMETER
)VER 10 UP TO 15	6.5				
OVER 15 P TO 20	5.5				
ꞋER 20	NOTE (1)				

ꞋES to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
): See Appendix D, Item (g) (1)
(2): See Appendix D, Item (g) (2)

TABLE D - 1.3
ALUMINUM HYDRAULIC SHORING
WALER SYSTEMS
FOR SOIL TYPE B

DEPTH OF TRENCH (FEET)	WALES		HYDRAULIC CYLINDERS						TIMBER UPRIGHTS		
			WIDTH OF TRENCH (FEET)						MAX.HORIZ.SPACING (ON CENTER)		
	VERTICAL SPACING (FEET)	SECTION MODULUS (IN^3)	UP TO 8		OVER 8 UP TO 12		OVER 12 UP TO15		SOLID SHEET	2 FT.	3 FT.
			HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER			
OVER 5 UP TO 10	4	3.5	8.0	2 IN	8.0	2 IN NOTE(2)	8.0	3 IN	—	—	3x12
		7.0	9.0	2 IN	9.0	2 IN NOTE(2)	9.0	3 IN			
		14.0	12.0	3 IN	12.0	3 IN	12.0	3 IN			
OVER 10 UP TO 15	4	3.5	6.0	2 IN	6.0	2 IN NOTE(2)	6.0	3 IN	—	3x12	—
		7.0	8.0	3 IN	8.0	3 IN	8.0	3 IN			
		14.0	10.0	3 IN	10.0	3 IN	10.0	3 IN			
OVER 15 UP TO 20	4	3.5	5.5	2 IN	5.5	2 IN NOTE(2)	5.5	3 IN	3x12	—	—
		7.0	6.0	3 IN	6.0	3 IN	6.0	3 IN			
		14.0	9.0	3 IN	9.0	3 IN	9.0	3 IN			
OVER 20	NOTE (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Notes (1): See Appendix D, item (g) (1)
Notes (2): See Appendix D, Item (g) (2)
* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

TABLE D - 1.4
ALUMINUM HYDRAULIC SHORING
WALER SYSTEMS
FOR SOIL TYPE C

DEPTH OF TRENCH	WALES		HYDRAULIC CYLINDERS						TIMBER UPRIGHTS		
			WIDTH OF TRENCH (FEET)						MAX.HORIZ SPACING (ON CENTER)		
	VERTICAL SPACING	SECTION MODULUS*	UP TO 8		OVER 8 UP TO 12		OVER 12 UP TO 15		SOLID SHEET	2 FT.	3 FT.
(FEET)	(FEET)	(IN^3)	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER			
OVER 5 UP TO 10	4	3.5	6.0	2 IN	6.0	2 IN NOTE(2)	6.0	3 IN	3x12	—	—
		7.0	6.5	2 IN	6.5	2 IN NOTE(2)	6.5	3 IN			
		14.0	10.0	3 IN	10.0	3 IN	10.0	3 IN			
OVER 10 UP TO 15	4	3.5	4.0	2 IN	4.0	2 IN NOTE(2)	4.0	3 IN	3x12	—	—
		7.0	5.5	3 IN	5.5	3 IN	5.5	3 IN			
		14.0	8.0	3 IN	8.0	3 IN	8.0	3 IN			
OVER 15 UP TO 20	4	3.5	3.5	2 IN	3.5	2 IN NOTE(2)	3.5	3 IN	3x12	—	—
		7.0	5.0	3 IN	5.0	3 IN	5.0	3 IN			
		14.0	6.0	3 IN	6.0	3 IN	6.0	3 IN			
OVER 20	NOTE (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Notes (1): See Appendix D, item (g) (1)
Notes (2): See Appendix D, Item (g) (2)
* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

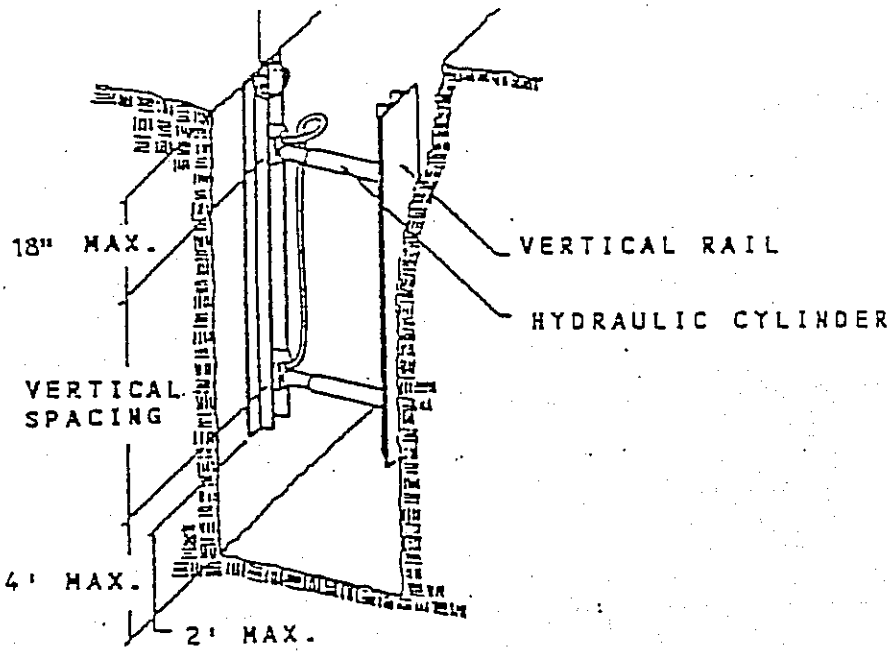


FIGURE 1. ALUMINUM HYDRAULIC SHORING

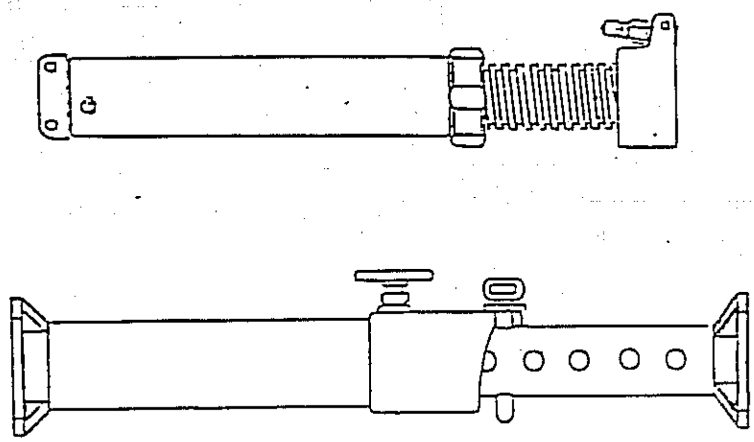


FIGURE 2. PNEUMATIC/HYDRAULIC SHORING

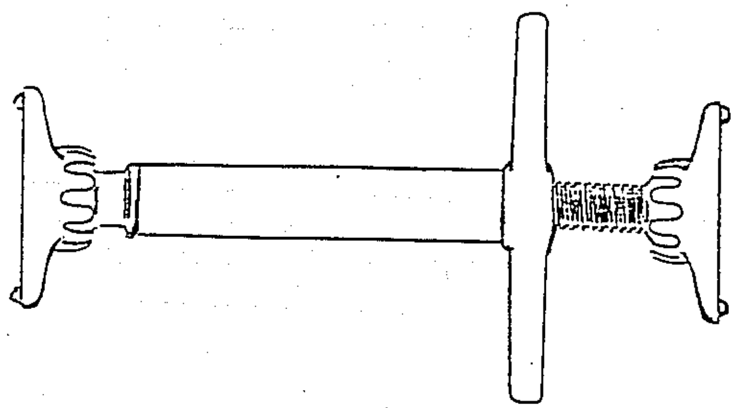


FIGURE 3. TRENCH JACK (SCREW JACK)

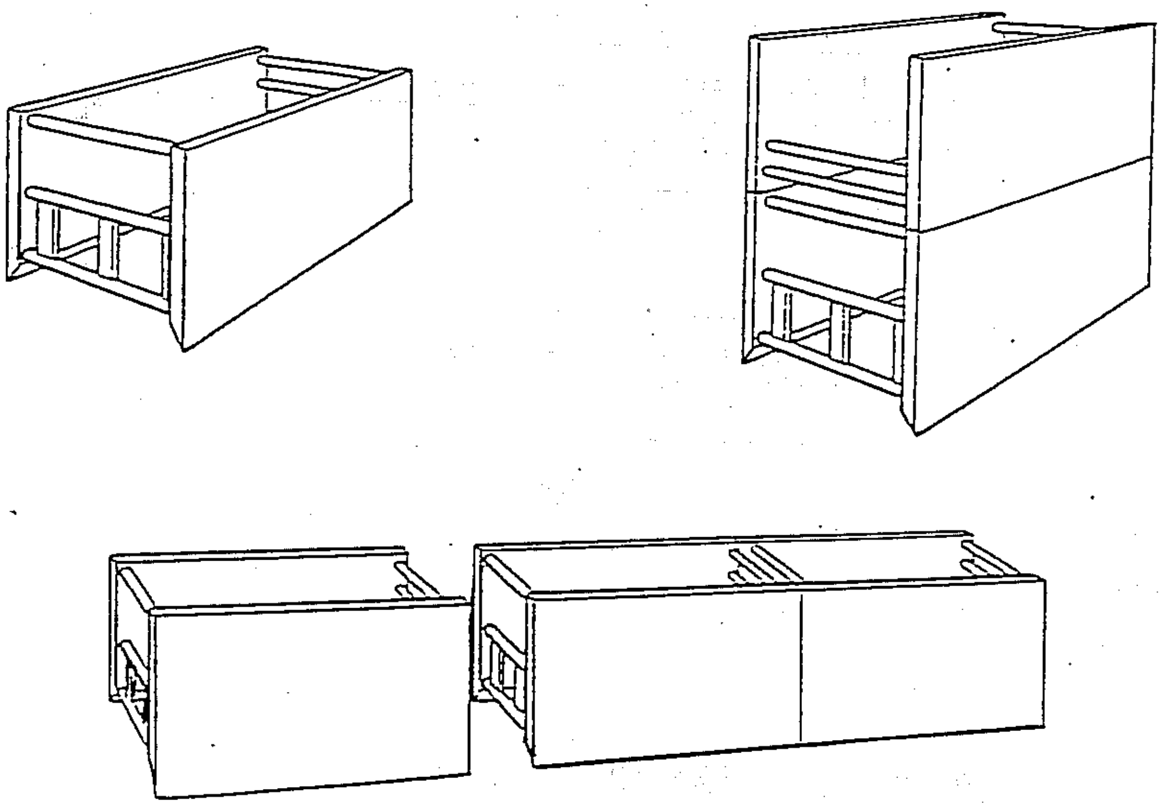


FIGURE 4. TRENCH SHIELDS

Appendix F to Subpart P—Selection of Protective Systems

The following figures are a graphic summary of the requirements contained in subpart P for excavations 20 feet or less in depth. Protective systems for use in excavations more than 20 feet in depth must be designed by a registered professional engineer in accordance with § 1926.652 (b) and (c).

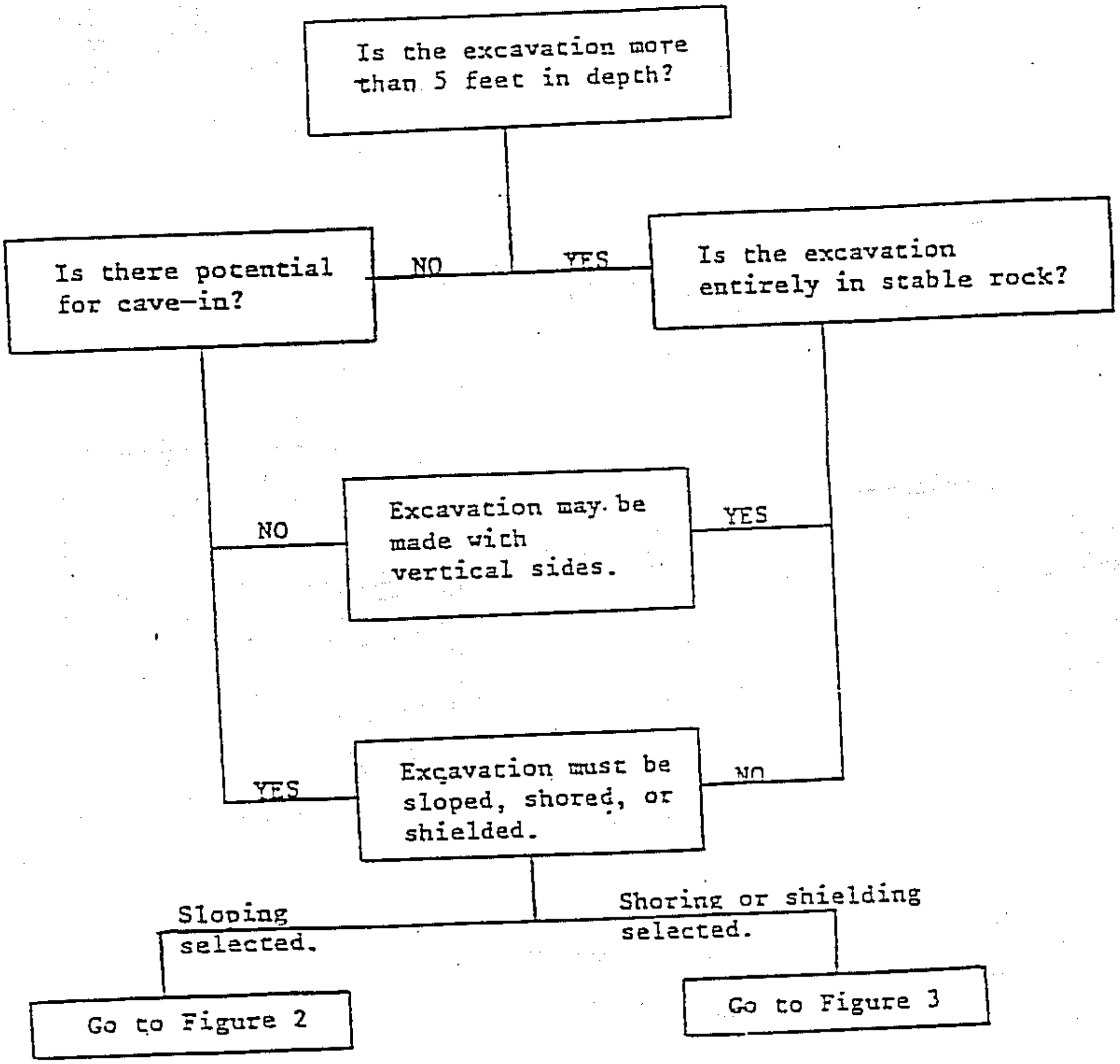


FIGURE 1 - PRELIMINARY DECISIONS

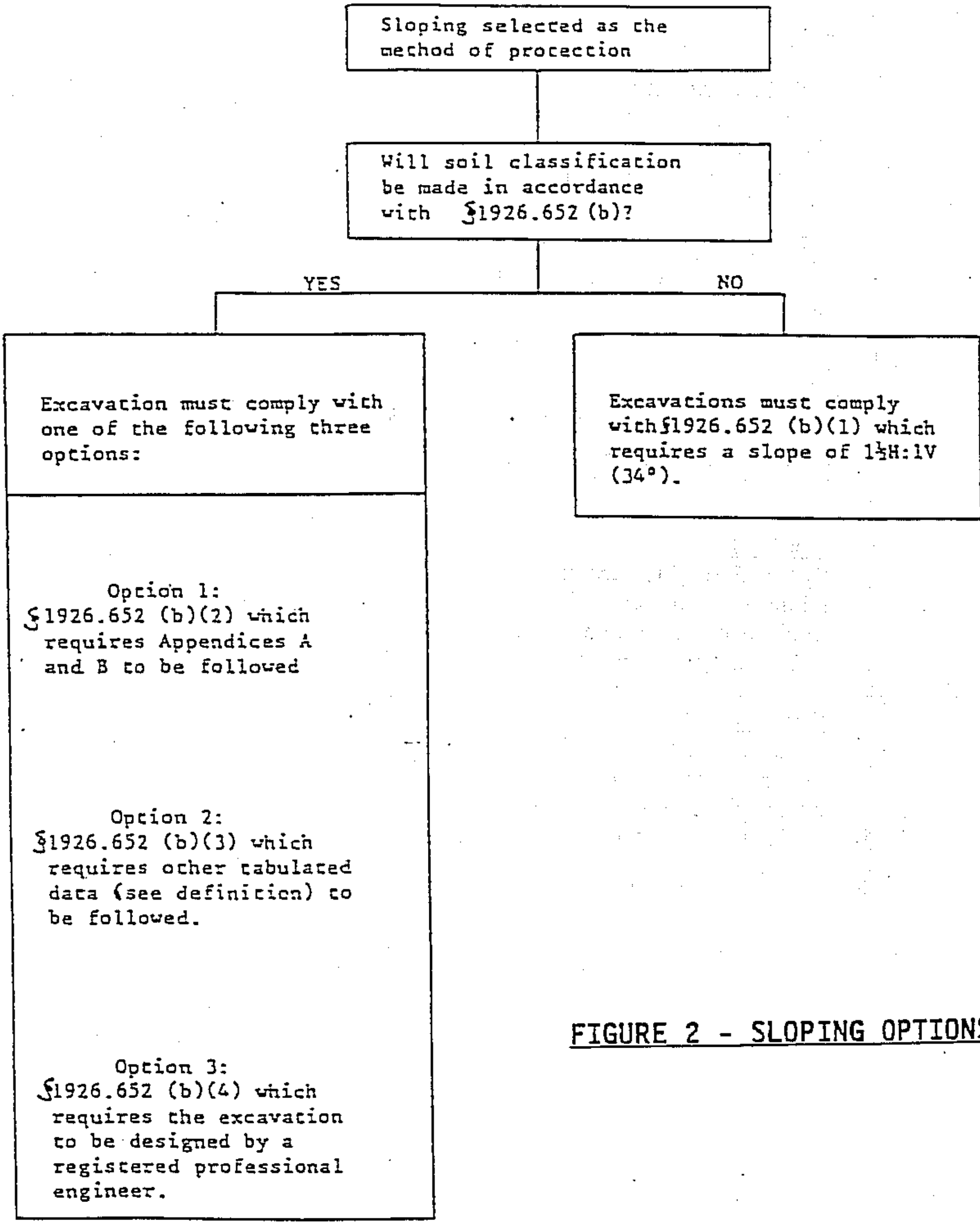


FIGURE 2 - SLOPING OPTIONS

Shoring or shielding selected
Soil classification is required when shoring or shielding is used. The excavation must comply with one of the following four options:
Option 1 §1926.652(c)(1) which required Appendices A and C to be followed (e.g. timber shoring). Option 2 §1926.652(c)(2) which requires manufacturers data to be followed (e.g. hydraulic shoring, trench jacks, air shores, shields). Option 3 §1926.652(c)(3) which requires tabulated data (see definition) to be followed (e.g. any system as per the tabulated data). Option 4 §1926.652(c)(4) which requires the excavation to be designed by a registered professional engineer (e.g. any designed system).

FIGURE 3 - SHORING AND SHIELDING OPTIONS

STANDARD OPERATING PROCEDURE SS-10

FIELD SCREENING SOIL

STANDARD OPERATING PROCEDURES
FIELD SCREENING SOIL PROCEDURE

FIELD SCREENING

The following procedures are designed to be used to field screen petroleum impacted soil using a photoionization detector (PID) for Volatile Organic Compounds (VOCs). This methodology was developed for field soil screening to generate consistency and reliability of results when using PID instruments. **Soil samples collected for field soil screening may not be used for laboratory analysis. Separate soil samples must be collected according to the soil sampling protocols outlined in this handbook.** This process will likely be used during drilling operations or excavations of petroleum impacted soils for determining if petroleum contamination is present in soils at the work Site.

1. PID instrument shall be operated and calibrated to yield "total organic vapors" in parts per million (PPM). PID instrument should be operated with a 10.2 eV lamp source. Calibration must be checked/adjusted daily. See SOPG-7 for MultiRAE and AutoRAE calibration procedures.

2. Using new nitrile gloves, half fill a plastic whirl pack or Ziplock® baggie with sample material. Whirl and zip-tie or zip to close the baggie.

3. Vigorously shake the sample bags for at least thirty (30) seconds once or twice in a 10-15 minute period to allow for headspace development.

4. If ambient temperatures are below 32^{O} Fahrenheit headspace development should be conducted in a heated vehicle or building.

4. Open a small portion of the zip lock bag and insert the PID tubing, record the maximum meter reading (should be within the first 2-5 seconds). Erratic responses should be discounted as a results of high organic vapor concentrations or conditions of elevated headspace moisture.

5. Record appropriate information about the sample collection in the bound field logbook. Any deviations from this method should be noted in the field logbook.