FREEPORT-MCMORAN

Copper Queen Branch
36 W Hwy 92
Bisbee, AZ 85603

William Hart
Senior Environmental Scientist
Telephone: 520-432-6206
Fax: 520-432-1395
e-mail: William_Hart@fmi.com

March 23, 2015

Ms. Mindi Cross
Water Quality Compliance Section
Arizona Department of Environmental Quality
1110 West Washington Street
Phoenix, Arizona 85007

Re: Mitigation Plan For Sulfate With Respect To Drinking Water Supplies and Field Work Plan For Monitoring Well Installation For Expanded Groundwater Monitoring. Mitigation Order on Consent No. P-121-07

Dear Ms. Cross:

Freeport Minerals Corporation, Copper Queen Branch (CQB) submits the following documents to the Arizona Department of Environmental Quality (ADEQ).

- Mitigation Plan For Sulfate With Respect To Drinking Water Supplies Mitigation Order On Consent, Docket No. P-121-07, dated March 6, 2015.
- Field Work Plan For Monitoring Well Installation For Expanded Groundwater Monitoring, Mitigation Order On Consent, Docket No. P-121-07, dated March 6, 2015.

The draft Mitigation Plan submitted to ADEQ on May 28, 2014 was revised to incorporate the recommendations made by ADEQ in their Review of the Mitigation Plan letter dated December 19, 2014:

- Recommendation 1 asked for CQB to provide a work plan to ADEQ for the installation of monitoring wells as part of the expanded groundwater monitoring program. The requested field work plan is included. The monitoring well locations identified in the work plan were previously approved on March 19, 2014 during a meeting with ADEQ and CQB.
- Recommendation 2 was to revise the Mitigation Performance Review Report period. ADEQ recommended that if a trigger level is exceeded during the timeframe when Mitigation Performance Review Reports are being submitted every five years, the performance report submittals would revert back to an annual frequency until the contingency actions are taken or until the sulfate concentration drops below the trigger level. CQB has revised Section 4.2 to reflect this recommendation.

Based on these revisions and submittals, CQB anticipates obtaining formal approval of the Mitigation Plan For Sulfate With Respect To Drinking Water Supplies, Mitigation Order On

Consent, Docket No. P-121-07. Currently CQB is proceeding with the mitigation plan under conditional approval from ADEQ. Until formal approval is granted CQB will provide the following submittals per the mitigation plan:

- Bi-Annual Groundwater Sampling – 1st quarter complete, next sampling event in 3d quarter 2015
- Annual Groundwater Monitoring Reports – March 31, 2015
- Annual Mitigation Performance Review Report – April 30, 2015
- Annual CAG Meeting – Approximately June 2015

This conditional approval was discussed and granted in emails between ADEQ, CQB, and CAG members between March 2 and March 12, 2015.

If you have any questions regarding this letter or either of the documents listed above, please contact me at (520) 432-6206.

Sincerely,

William Hart
Sr. Environmental Scientist
Freeport Minerals Corporation

Enclosures

cc: Robert Quintanar/Freeport Minerals Corporation, Copper Queen Branch
Stu Brown/Freeport-McMoRan Corporation
Sheila Deely/Freeport-McMoRan Corporation
Madeline Keller/ADEQ
Julian Stewart/ADEQ
Jim Norris/Clear Creek Associates

Proof of Delivery

Close Window

Dear Customer,

This notice serves as proof of delivery for the shipment listed below.

Tracking Number:	1Z8711260195648615
Service:	UPS Next Day Air®
Weight:	2.00 lbs
Shipped/Billed On:	03/24/2015
Delivered On:	03/25/2015 9:55 A.M.
Delivered To:	PHOENIX, AZ, US
Signed By:	SERBAN
Left At:	Front Desk

Thank you for giving us this opportunity to serve you.

Sincerely,

UPS

Tracking results provided by UPS: 05/21/2015 11:56 A.M. ET

Print This Page Close Window

FIELD WORK PLAN FOR MONITOR WELL INSTALLATION FOR EXPANDED GROUNDWATER MONITORING

MITIGATION ORDER ON CONSENT DOCKET NO. P-121-07

Prepared for:

FREEPORT MINERALS CORPORATION
COPPER QUEEN BRANCH
36 West Highway 92
Bisbee, Arizona 85603

Prepared by:

CLEAR CREEK ASSOCIATES, P.L.C.
221 North Court Avenue Suite 101
Tucson, Arizona 85701

March 6, 2015

FIELD WORK PLAN FOR MONITOR WELL INSTALLATION FOR EXPANDED GROUNDWATER MONITORING

MITIGATION ORDER ON CONSENT DOCKET NO. P-121-07

Prepared for:

FREEPORT MINERALS CORPORATION
COPPER QUEEN BRANCH
36 West Highway 92
Bisbee, Arizona 85603

Prepared by:

REGISTERED GEOLOGIST
CERTIFICATE NO.
57975
BENJAMIN
DAIGNEAU
DATE SIGNED
ARIZONA U.S.A.
Expires: 6/30/2017

Ben Daigneau
Arizona Registered Geologist No. 57975

March 6, 2015

TABLE OF CONTENTS

TABLE

FIGURES

APPENDICES

1.0 INTRODUCTION

This field work plan describes the data objectives and field methods that will be used for the installation of twelve monitor wells for expanded groundwater monitoring under the Mitigation Plan (Clear Creek Associates [Clear Creek], 2014a). The Mitigation Plan was submitted to Arizona Department of Environmental Quality (ADEQ) in May 2014 pursuant to the Mitigation Order on Consent Docket No. P-121-07 (ADEQ, 2007). The Mitigation Plan provides the methodology for implementation of the recommended alternative of the Feasibility Study (Clear Creek, 2014b)

The field procedures described in this work plan are consistent with those in the Quality Assurance Project Plan (QAPP) contained in Appendix F of the *Work Plan to Characterize and Mitigate Sulfate with Respect to Drinking Water Supplies in the Vicinity of the Concentrator Tailing Storage Area* (Hydro Geo Chem, 2008).

Expanded groundwater monitoring activities focus on detailing the position of the sulfate plume with respect to the Arizona Water Company (AWC) and Naco Water Company (NWC) public water supplies near Naco, Arizona. The sulfate plume is defined as groundwater with dissolved sulfate concentrations exceeding 250 milligrams per liter (mg/L) attributable to the Concentrator Tailing Storage Area (Figure 1). The project objective is to install new wells outside the plume to monitor sulfate concentrations upgradient of the Naco area public drinking water supplies, track plume movement, detect sulfate concentration trends, and determine the potential for sulfate to increase above 250 mg/L at a public water supply. The proposed well sites are shown on Figure 2.

2.0 SCOPE OF WORK

Up to twelve new monitor wells may be installed at six well sites. A shallow and a deep well may be installed in the basin fill aquifer at each site, depending on the depth of the basin fill. The wells will be placed laterally between the plume and the public drinking water supplies and arrayed in a manner to allow direct measurement of plume velocity (i.e., the time for the plume front to migrate between monitoring wells) and the rate of change of sulfate concentrations at the plume front (i.e., how long it take for concentrations to increase from low levels to greater than 250 mg/L).

The new monitoring wells will be installed in the basin fill aquifer, the primary aquifer from which the public supplies draw water. The shallower well will be screened from the water table to the approximate elevation of the depth of the AWC-03 public supply well. If the basin fill is significantly deeper than the depth of AWC-03, a deeper well will be screened over the remainder of the saturated basin fill from below the shallow well to the bedrock-basin fill contact.. Hydraulic testing will be conducted at the new monitoring wells to determine hydraulic properties for the basin fill near the public water supplies. An initial water quality sample will be collected from each well at the end of hydraulic testing.

The well sites are located in Sections 7 and 18 of Township 24 South, Range 24 East of the Gila and Salt River Baseline and Meridian (Figure 2). Three well sites are located on property owned by Rosemead Properties, Inc. (RPI), and three well sites are on the Turquoise Valley Golf Course (TVGC).

3.0 HYDROGEOLOGIC SETTING

This section provides an overview of the hydrogeologic setting in the area of the new wells. A detailed discussion of the hydrogeology and water quality in the work area is in Revision 1 of the Aquifer Characterization Report (Clear Creek, 2010), which should be reviewed by field staff prior to initiating field activities. Field personnel should also be familiar with the hydrogeologic discussions in Section 5.1 and Appendices A and B of the Feasibility Study (Clear Creek, 2014b).

The geologic materials in the Bisbee-Naco area and surrounding mountains can be divided into three generalized units: Recent alluvium, Quaternary and Tertiary basin fill deposits, and the bedrock complex. Recent alluvium consists of unconsolidated alluvial material. Basin fill consists of poorly to moderately cemented clastic material (Littin, 1987). The bedrock complex comprises older, indurated units including sedimentary rocks of the Cretaceous Bisbee Group, Jurassic to Tertiary igneous rocks, Paleozoic sedimentary formations, and Precambrian metamorphic rocks. Figure 3 is a generalized geologic map of the area by Hayes and Landis (1964).

Basin Fill is the primary unit to be drilled and sampled under this work plan. Bedrock will not be penetrated more than is needed to establish the contact with basin fill.

3.1 Recent Alluvium

Recent alluvium includes stream channel sediments, pediment and terrace gravel, sheet wash deposits and alluvial fans (Hayes and Landis, 1964). Recent alluvium occurs primarily along Greenbush Draw and is not a significant aquifer because it typically is unsaturated.

3.2 Basin Fill

The Tertiary to Quaternary basin fill deposits are primarily poorly to moderately cemented sand and gravel lying unconformably on Cretaceous or older sedimentary bedrock. The basin fill consists of interbedded boulder to pebble conglomerate, gravel, sand, silt and clay (Littin, 1987). Caliche cementation is commonly present within the upper 40 to 130 feet of the basin fill penetrated by monitoring wells. Near the sulfate plume, the basin fill ranges in thickness from zero at its contact with surface outcrops of bedrock to approximately 640 feet near Naco.

The basin fill is the primary drinking water aquifer in the expanded groundwater monitoring area and provided about 95 percent of all water for domestic purposes in the Bisbee area in the 1980s (Littin, 1987). Most drinking water supply wells monitored under the Mitigation Order are installed with screened intervals in the shallow basin fill. All of the AWC and NWC public supply wells are screened in the basin fill except AWC-05, which is screened in both basin fill and bedrock.

There are five existing BMO monitor wells in the area of the proposed wells (Figure 4). The thickness of the basin fill at those wells ranges from 290 feet to 636 feet at BMO-2008-5M and BMO-2008-4B, respectively. The lithologic logs at those and other nearby monitor wells show that the basin fill around the proposed wells is dominated by sand and gravel. Silty sediments are concentrated in the top 80 feet of the boreholes except at BMO-2008-5M where silt dominated sediments were observed down to 160 feet below land surface (bls). Caliche is noted in the top 70 feet of the BMO-2008-5B borehole. Based on the BMO wells, grain size variations in the basin fill are gradational with no thick or through-going interbeds.

3.3 Bedrock Complex

Bedrock in the expanded groundwater monitoring area consists of the Lower Cretaceous Bisbee Group formations. The Bisbee Group consists of four sedimentary formations, which are, in descending order, Cintura Formation, Mural Limestone, Morita Formation, and the Glance Conglomerate. The formations have gradational contacts and are conformable with one another where they are exposed in the Mule Mountains to the east. Section 5.4.3 discusses identification of bedrock during drilling, which is a critical determination for this work.

The Cintura Formation is comprised of grayish red siltstone and mudstone, feldspathic sandstone, and minor amounts of green-gray calcareous claystone, with thin beds of fossiliferous limestone in its basal 100 feet. Hayes (1970) notes that the lithology of the Cintura Formation is so similar to that of the underlying Morita Formation that distinguishing between the two formations would be difficult except for their relative stratigraphic positions with respect to the intervening Mural Limestone. Maximum preserved thickness of Cintura Formation in the Mule Mountains is 1,850 feet (Hayes and Landis, 1965).

The Mural Limestone is composed of an upper member of dark gray limestone that is up to 275 feet thick with subordinate sandstone in the upper 50 feet, and a lower member up to 453 feet thick consisting of interbedded calcareous sandstone, siltstone and impure fossiliferous limestone (Hayes and Landis, 1965).

The Morita Formation is generally composed of grayish red siltstone and mudstone, pale red feldspathic sandstone, minor amounts of greenish gray calcareous claystone, thin beds of impure limestone in the upper part of the formation, and a small amount of pebble conglomerate in the lower part of the formation. The Morita formation is approximately 2,600 feet thick (Hayes, 1970) where it outcrops in the Mule Mountains.

The Glance Conglomerate is the basal unit of the Bisbee Group and lies unconformably on a variety of older lithologic units. The Glance Conglomerate is an alluvial fan deposit made up of locally derived material with variable ratios of schist, limestone, and granitic clasts (Hayes, 1970); and consists of poorly sorted, poorly rounded, cobble- to pebble-sized clasts in a sandy and silty grayish-red to reddish brown mudstone matrix. Boulder-sized clasts are also locally present.

The bedrock complex generally has low permeability compared to basin fill unless the intrinsic permeability is enhanced by secondary structures such as faults, fractures, and/or dissolution in the case of limestone. For this reason, the bedrock units typically do not yield as much water to wells as the basin fill (Litten, 1987).

3.4 Hydraulic Properties

Groundwater flow in the vicinity of the proposed monitoring wells is generally westward. Prior to starting work, the most current groundwater monitoring report should be reviewed for recent water level and sulfate concentration data.

The groundwater flow is influenced by the hydraulic properties of the hydrostratigraphic units and the geologic structure prevailing in different subregions of the area. Hydraulic testing in 2008 and 2010 found the hydraulic conductivity of the basin fill to range from 2.3 to 127.8 ft/day with a geometric mean of 37.7 ft/day and an arithmetic mean of 29.7 ft/day. Hydraulic conductivity estimates for BMO-2008-4B, BMO-2008-5B, BMO-2008-6B, and BMO-2010-3B at the leading edge of the sulfate plume are 39.5, 55, 2.3, and 15.5 ft/day, respectively.

3.5 Distribution of Sulfate at the Leading Edge of the Plume

The estimated location of the leading edge of the sulfate plume in the work area in the first quarter 2014 is shown by the 250 mg/L sulfate concentration contour on Figure 4. The figure also shows the sulfate concentrations at wells sampled under the Mitigation Order. The highest concentrations along the leading edge of the plume are at BMO-2008-5B (230 mg/L) and TVI 875 (300 mg/L). The southwestern edge of the plume is bounded by lower concentrations at SCHWARTZ (125 mg/L) and COB MW-2 (40.5 mg/L).

Based on depth specific sampling and water samples from monitor wells installed for the Mitigation Order (Clear Creek, 2010), the plume is vertically zoned at the leading edge and does not extend to the bottom of the basin fill. Figure 5 is a cross-section through BMO-2008-4B, BMO-2010-3B, BMO-2010-3M, and the AWC wellfield. The thickness of the sulfate plume is approximately 300 feet at BMO-2008-4B and the basin fill is 636 feet thick. Figure 4 shows that the sulfate plume extends south and west of BMO-2008-4B, but the sulfate concentration of the well is less than 250 mg/L because it is below the plume. The sulfate concentration of ROGERS 803 is also below 250 mg/L. ROGERS 803 is 140 feet deep and it is believed that the well sits above the elevated sulfate zone. This shows that there may also be unimpacted groundwater above the plume in some areas. Depth-specific water quality sampling under this work plan will be conducted to describe the vertical distribution of sulfate at the front of the plume.

4.0 DATA OBJECTIVES

Data to be collected for installation of the monitor wells will include lithologic logs, depth-specific reconnaissance water quality, hydraulic testing results, water levels, and an initial water quality sample from the new wells. The data will be used to characterize the hydrogeology and water quality between the leading edge of the plume and the public supply wells. The field procedures (Section 5.0) are designed to collect data that are scientifically valid and legally defensible in accordance to the data quality indicators discussed in Section 3.3 of the QAPP

Up to two wells are planned for each site to investigate the water quality and hydraulic properties of the upper and lower portions of the basin fill aquifer separately. The shallow wells will be screened across the upper portion of the aquifer from the water table down to an elevation equivalent to the screened depth of AWC-03[1], which is approximately 4,270 feet above mean sea level (amsl). The deeper wells will be installed with a screened interval spanning from 20 feet below the shallow well to the basin fill-bedrock contact. Data from the installation of monitoring wells in 2008 and 2010 show that sulfate concentrations can be different in the upper and lower portions of the basin fill as discussed in Section 3.5. In the event that shallow bedrock is encountered, it may not be possible to construct a deeper well as described above. Site-specific conditions will be considered when designing wells with shallow bedrock intercepts.

Geologic and depth specific reconnaissance water quality data will only be collected during installation of the deeper borings. This data will not be collected from the shallow wells because they would be redundant due to the close proximity of the shallow and deeper wells.

---

[1] The depth of AWC-03 encompasses the depths of AWC-02 and AWC-04, but is less than the depth of AWC-05.

Groundwater quality and hydraulic characteristics will be determined at the shallow wells after installation.

4.1 Data Types

Field data will be collected by Clear Creek field staff, CQB, and the drilling contractor during and after well installation. This section describes the types of data that will be collected, when the data will be collected, and how the data types will meet the project objectives.

Lithologic logs of the boreholes will be created during installation of each of the deep wells to document the stratigraphy at each well site. The lithologic data will be used to examine the basin fill sediment characteristics at each of the borehole locations. The lithologic data combined with results from the hydraulic testing will be used to characterize the relative geology and hydraulic properties at the front of the plume.

Groundwater quality samples will be collected from each well during reconnaissance depth-specific sampling and after well development and testing. The reconnaissance depth-specific sampling will be conducted at 40-foot intervals during installation of the deep wells. The reconnaissance depth specific samples will be used to determine if there is a vertical sulfate gradient in the boring. The initial well sample collected after hydraulic testing, and the subsequent quarterly samples specified by the Mitigation Plan, will be used to monitor changes in the sulfate concentration over time. These periodic sulfate measurements will be used to determine the rate of increase, if any, between low and high sulfate concentrations.

Water levels at the newly installed wells will be measured during depth specific sampling and after well construction. Water levels from several wells will be used to determine the hydraulic gradient at the front of the plume to calculate the groundwater velocity. Water levels collected during depth-specific sampling will be used to verify the hydraulic connection during sampling.

Hydraulic testing will include a three-hour step rate test, an eight-hour constant rate pumping test and a recovery period. The test data will be used calculate the hydraulic conductivity at each well. Comparison of the measured hydraulic conductivities from several wells will be used to evaluate the distribution of hydraulic conductivity at the leading edge of the plume.

5.0 FIELD ACTIVITES

This section describes the field activities and the field methods for well installation and construction. The drilling contractor will be required to perform all work in accordance with the *Technical Specifications Monitor Well Installation Services for Freeport-McMoRan Corporation, Copper Queen Branch* (Clear Creek, 2014c). Clear Creek field staff will be onsite to observe the drilling contractor and verify that the work is conducted safely and in accordance with the specifications. Clear Creek will record field measurements and field notes in a logbook or on the field sheets included in Appendix A.

5.1 Certification and Preliminary Activities

All field staff shall have Occupational Safety and Health Administration (OSHA) 40-hour training and certification as described in the Code of Federal Regulations (CFR), Title 29, Section 1910.120. Staff working within the CQB property boundaries shall also have site-specific hazard awareness training and Mining Safety and Health Administration (MSHA) training as prescribed in 30 CFR Subchapter H. All certified field operations personnel must annually complete OSHA and MSHA refresher courses to maintain their certifications. All personnel and subcontractors will have appropriate licensure and certification as required by law to perform their specific field operation. In particular, drillers will have a current well driller's license issued by the Arizona Department of Water Resources (ADWR).

Prior to starting field activities, the Clear Creek Project Manager will obtain necessary permits, and notify property owners of scheduled field activities. Required permits may include an Arizona Pollutant Discharge Elimination System (AZPDES) or De Minimis General Permit (DGP). CQB will submit the ADWR notice of intent to drill forms for each well.

5.2 Site-Specific Requirements

All of the monitor wells will be installed on private property. The RPI property is unoccupied. The TVGC property is an operating golf course and restaurant. There may be site-specific requirements to limit access and maintain public safety on both sites, and to reduce the impact on patrons of the TVGC at those sites. The requirements may include restricted work times, noise control, site access controls, or notification of the property owner for specific tasks. Clear Creek, CQB, the drilling contractor, and the respective property owner will meet prior to mobilization to discuss any restrictions.

5.3 Site Preparation

Each well site will be prepared by developing an access road, if needed, checking for underground utilities, clearing a well pad, and installing fencing for security prior to mobilization of the drill rig to the site. CQB will install roads and clear the well pad. The drilling contractor will be responsible for fencing and site security. The Clear Creek Project Manager will ensure that the drilling contractor requests a blue stake survey at least 72 hours, but not more than 2 weeks ahead of drilling. A private utility locator may be used, if there is concern that underground utilities were not identified by the Arizona Blue Stake. Clear Creek will coordinate the private utility locator and document the results at the discretion of CQB.

5.4 Drilling and Well Installation

The drilling and well installation will be conducted pursuant to the Technical Specifications.

5.4.1 Drill Methods

The deep monitor wells and shallow monitor wells on TVGC property will be drilled with the rotosonic method to recover minimally disturbed soil samples. The air rotary method may be used to ream the hole to the final diameter prior to well installation depending on whether or not a large diameter casing can be advanced to depth by a rotosonic drill rig. At the RPI sites, the shallow wells will be installed using the more economical of available methods after the installation of the deep well.

If the rotosonic method cannot be used to install the borehole to final depth due to subsurface conditions, which inhibit progress or strain the equipment beyond best-practice use, then an air rotary casing-advance method will be used instead. No drilling fluid will be used to install any of the deep wells.

Clear Creek will be on site to oversee the drilling. Drilling oversight will consist of documenting drill equipment, site conditions, time spent on specific tasks, safety meetings, drilling conditions, and enforcement of the technical specifications.

5.4.2 IDW Control

Investigation derived waste (IDW) will be contained during drilling, construction and development activities. Water produced during drilling and development can be used for dust control or discharged to the ground after containment, but no water will be allowed to run off the drill pad and the water must not create a safety hazard or nuisance. All remaining IDW will be transported and disposed of at a location designated by CQB or the property owner. Water generated during hydraulic testing may be discharged at the TVGC and RPI sites in accordance with a DGP, if the generated water does not cause damage to the property, contaminate other wells or waterways, or create a nuisance. Clear Creek will monitor the drilling contractor to determine that the IDW control is conducted as described here and in the technical specifications.

5.4.3 Lithologic Logging

Lithologic logging of boreholes for wells will be conducted by Clear Creek's site geologist. The lithology will be logged at 5-foot intervals for rotosonic core samples and at 10-foot intervals for rotary methods. Logging will be conducted visually according to the specifications of American Society for Testing and Materials (ASTM) D2488-00 for comparability between lithologic descriptions between different locations. A copy of this ASTM standard is provided in Appendix B. The site geologist will note the following on the logs:

- Sample description
- Color (using a Munsell color chart)
- Unified Soil Classification System (USCS) classification symbol or lithologic name
- Grading (for coarse grained soils)
- Estimated percentages of gravel, sand, and fines
- Consistency of dominant size fraction
- Local or geologic name, if applicable
- Degree of rounding/angularity
- Lithology of larger grains
- Reaction with hydrochloric acid

It will be important to identify the basin fill-bedrock contact for this project, as the wells will be installed in the basin fill down to the contact. Bedrock composition is described in Section 3.3. Bedrock should be easy to identify when using the rotosonic or air rotary casing advance method because the casing will generally not advance into competent bedrock using those methods. If a rotary method is used, determination of the bedrock contact will be based on multiple lines of evidence. The bedrock can be identified by noting drilling conditions and examination of the lithologic cuttings as described below:

- Drill rate may decrease significantly.
- Color change (Cintura and Morita formations are usually pink and the Mural Limestone is uniform gray).

- Cuttings are monolithic, lithified, and angular.

5.4.4 Reconnaissance Depth-Specific Sampling

The project objective is to install wells outside of the plume. Depth-specific sampling will be used to help achieve that goal. Reconnaissance depth-specific water samples will be collected in the deeper borings at approximately 40-foot intervals throughout the saturated portion of the basin fill, starting at 10 feet below the water table. The exact depths and sampling interval may change based on site-specific conditions. For example, more frequent sampling may be conducted if elevated sulfate is encountered and less frequent sampling may be conducted if low sulfate conditions are found.

Depth-specific sampling will be conducted using a Push-Ahead sampler, Hydropunch, or similar product in the rotosonic borings and by airlifting, if the casing advance method is required. Clear Creek will record pH, electrical conductivity, and temperature using a calibrated handheld meter during purging. A field-filtered, unpreserved sample will be collected from each depth-specific sampling interval. A calibrated colorimeter will be used to measure dissolved sulfate concentration in a portion of the sample. Another portion of the sample will be sent to an Arizona-certified laboratory for confirmation of the field results. See Section 5.8 for sample collection procedures and Section 7.0 for sampling handling.

A well would be considered inside the plume if the depth-averaged sulfate concentration in the completed well is over 250 mg/L. This means that a single depth-specific sample with a concentration over 250 mg/L does not necessarily indicate that the completed well will be considered to be within the plume based on the anticipated screen lengths. If a depth-specific sample with a sulfate concentration over 250 mg/L is encountered, the field staff will do the following:

- Confirm the sulfate analysis by re-analyzing the sample.
- Confirm the analysis using a new aliquot of water from the same filtered sample.

- Notify the Clear Creek Project Manager.
- Calculate average of sulfate concentrations from all of the depth-specific samples collected from the anticipated screened interval of the deep or shallow well assuming a proportional inflow for each vertical interval sample.

If the depth-specific sample data indicate there is a high potential for the sulfate concentration in the final well to be over 250 mg/L, the borehole may not be completed as a well. The decision to abandon the borehole will be at the discretion of CQB.

5.4.4.1 Depth-Specific Sampling When Using Rotosonic Drilling Method

Hydropunch and Push-Ahead samplers work by installing a sealed sampler ahead of the drive casing into an undisturbed portion of the borehole. The sampler is opened to allow groundwater to collect in the sampler and the core pipe that is used to advance the sampler. The sample can then be collected from inside the core pipe. Ideally, the sample is representative of the groundwater conditions at the specified depth at which the sampler is driven because that portion of the basin fill is not disturbed by drilling.

Procedures for sampling are as follows:

- Drilling will be stopped 5 to 10 feet above the interval where the sample will be collected and the core barrel will be removed from the borehole.
- A decontaminated and sealed sampling tool will be inserted through the casing to the bottom of the boring. The sampler will be driven approximately 5 to 10 feet beyond the bottom of the borehole.
- An electric sounder will be lowered within the sampler to ensure it maintained its seal during installation, and remains sealed until sampling begins. If water is measured inside the sampler then it is not sealed and the sample will be considered not to be representative of the sample depth.
- The sampler will be opened to allow formation water to enter. The samplers are opened by rotating the drill string or pulling back on the sampler depending on the type.
- A disposable bailer will be lowered to the bottom of the sampler in order to collect the formation water. Clear Creek will collect water for the measurement of field

parameters and field sulfate concentration. Additional water will be collected for a laboratory sample at some intervals.

- Field measurements will be recorded on the field sheets in Appendix A, along with the name of the boring, the depth of the casing and sampling tool at the time of sample collection, and the date and time of the measurements.
- The sampling tool may be left in the borehole to allow the groundwater level to attain equilibrium. In this case, an electric sounder will be used to measure the water at 1 to 5 minute intervals until the water level is stable.

The reconnaissance sulfate sample and samples for laboratory analysis will be filtered using a 0.45 micrometer (µm) filter, collected in an unpreserved 250 mL bottle. Sample handling is discussed in more detail in Section 7.0.

In the event that a sample cannot be collected using the Hydropunch or Push-Ahead samplers, a sample may be bailed from the drill casing. The bailed samples will be collected using a metal bailer lowered on a winch cable. The sample may be collected by bailing out one wetted volume of water from the drill casing. Because rotosonic and casing advance drill methods install casing as the borehole is advanced, inflow to the casing consists of groundwater at the bottom of the casing. The depth-specific representativeness of the bailed sample depends on whether bailing induces significant vertical flow along the outside of the casing. Thus, site-specific conditions such as the degree of open space between the drill casing and the aquifer formation and the vertical conductivity of the aquifer can influence the depth specific representativeness of the sample. Open borehole sampling is less preferable than Hydropunch or Push-Ahead sampling, which are assumed to have better depth-specific representativeness.

5.4.4.2 Depth Specific Sampling for Casing Advance Methods

Depth-specific samples will be collected by airlifting if a casing advance method is used. The casing advance methods provide temporary casing that is advanced with the bit. The casing prevents formation water from entering the borehole except at the drill face. To collect the depth specific sample, water will be blown out of the borehole with compressed air. After the hole is cleared of water, it will be allowed to recharge with groundwater and a water sample and field parameters will be collected by airlifting the hole again. The sample will be collected as described in Section 5.7.3.

5.4.5 Well Construction

The final well design will be determined in the field by CQB and Clear Creek based on the geologic conditions and project objectives. The deep borehole will be installed first. The well design for both wells will be determined using the data from the deep borehole.

The wells will be constructed as described in the technical specification using flush threaded nominal 5-inch polyvinyl chloride (PVC) well casing. The well screen will be factory-slotted nominal 5-inch PVC with 0.125-inch slots. A 21-foot joint of low carbon steel casing will be installed at the surface to meet minimum well construction standards for the surface seal.

The screened interval for the shallow well will be from the top of the water table to an elevation of approximately 4,270 ft amsl. The ground surface elevation will be determined by CQB prior to well construction. The deeper well will be constructed with a screened interval 20 feet below the planned bottom of the shallow well screen and down to the basin fill-bedrock contact. Because there will be 20 feet of filter pack above the screen of the deeper well, the shallow and deep wells together will sample the fully saturated thickness of the basin fill. Example well designs are shown on Figures 6 and 7, assuming a basin fill depth of 600 feet. The minimum screen length for the deep well will be 60 feet. If the basin fill thickness below the shallow well is less than 80 feet, CQB may decide to construct a single well. Similarly, if the bedrock is shallower than 4,270 ft amsl, CQB may decide to construct a single well spanning the saturated basin fill.

The field technician will perform the following activities for well construction:

- Prior to well construction, estimate the amount of materials (e.g., well casing, packing material, and grout) needed to construct the well.
- Prior to and during well construction, prepare and use a well-construction diagram to monitor the progress of the well construction. Record the progress in the field notebook or on a well construction form.
- During well construction, periodically have the driller measure the depth of the filter pack and check to make sure that "bridging" of the packing material does not occur. A tightly fitting rubber surge block may be used in wetted portions of the well screen to compact the filter pack.
- During well construction, immediately notify the driller of a potential problem if the materials used for well construction are significantly more or less than estimated.

An as-built diagram for the well and annular materials used in well construction will be recorded on field sheets in Appendix A.

5.5 Well Development

Each new well will be developed by bailing, swabbing, airlifting, and pumping to remove sediment from drilling and installation activities, and to maximize well efficiency. The water extracted from the well during development will be contained or discharged as discussed in Section 5.4.2. CQB will obtain any permits required to discharge water generated during development.

Clear Creek will measure field parameters using a handheld multimeter during development. Additionally, the sediment and sand load in the well discharge will be monitored using an Imhoff cone. The well will be considered developed when the water has stable field parameters, and is clear with less than 0.5 milligrams/liter sand content, as measured by the Imhoff cone.

Initial development will be completed by bailing, swabbing and airlifting. The exact method will be determined based on equipment available and the well construction. The general development methods are:

- The depth to the bottom of the well (total depth) will be measured to determine whether any sediment has accumulated in the well. Clear Creek will record changes in depth over time.
- The wetted portion of the well screen will be swabbed with a tightly fitting rubber surge block to dislodge any material finer than the screen slot size. Clear Creek will record the time spent swabbing at each interval of the well casing
- Air lifting or bailing will be used to remove sediments from the well. The sediment removed from the well will be examined to determine the sediment size and overall quantity of the material.
- The material removed will be examined to determine if filter pack is being removed from the well, which would indicate a break in the casing or well screen.
- A temporary submersible pump and sounding tube will be installed in the well for pumping development. Well development will be considered complete as described above.

5.6 Hydraulic Testing

After well development, a three-hour step rate test and an eight-hour constant rate test will be conducted. A recovery period will be conducted following the constant rate test. The step test will be conducted with three one-hour steps, increasing the discharge rate at each successive step. The discharge rate will be based on the screened interval of the completed well and development pumping rates. Discharge rates will be measured by an in-line flow meter installed by the drilling contractor. Discharge rates used for step-rate testing at existing BMO wells in basin fill usually ranged from 15 to 60 gallons per minute during the step test. The well will be allowed to recover to 100% of the static water level between the step-test and the constant-rate test. In the past, this has meant letting the well recover overnight.

The constant rate test will be conducted based on the drawdown during the step rate test. The recovery period will be conducted until the well recovers to 90% of the water level measured prior to the test or for the same duration as the pumping.

Drawdown and recharge will be recorded using a pressure transducer with a vented cable and manual depth to water measurements will be collected for verification. Manual measurements will be made with an electric sounder that is decontaminated between each well (Section 6.3). Clear Creek will collect field parameters measurements of the discharge at regular intervals to monitor changes over time. At the conclusion of the pumping test, a water quality sample will be collected for analysis of sulfate and other general chemistry. CQB will obtain any permits required to discharge water generated during testing.

Consistent with the QAPP (Hydro Geo Chem, 2008), the pumping tests will be conducted using the general guidelines provided below:

1. Prior to beginning the test, measure the static water level using a well sounder. Install a pressure transducer below the anticipated drawdown level. Be certain that the transducer has a sufficient pressure range to accurately measure the anticipated drawdown. Measure the static water level with the pressure transducer and verify the transducer water level measurement by using an electric sounder.

2. Select pumping rate(s) for the test to provide the necessary drawdown data and to avoid lowering the water level below the transducer or pump intake. Use a constant pumping rate throughout the step, if a step test or the entire test if a constant rate test.

3. Measure depth to water levels during the test with a pressure transducer/data logger assembly and periodically verify it with a electric sounder. Record the measuring point for manual water level measurements and the stickup of the measuring point above land surface. At a minimum, take measurements according to the following schedule:

4. <u>Time of Pumping Step</u> <u>Measurement Interval</u>

Time of Pumping Step	Measurement Interval
0 to 15 minutes	1 minute
15 to 50 minutes	5 minutes
50 to 100 minutes	10 minutes
100 to 500 minutes	30 minutes

5. Ensure that water discharged during the pumping test is directed down gradient of the well so that re-infiltration of the discharge water does not affect the test results.

6. Continue pumping long enough to collect sufficient drawdown data. Ideally, pumping will be continued for 480 minutes or longer; although, the work location or other constraints may dictate a shorter pumping period.

7. After pumping is discontinued, measure the recovery of water levels in the well at frequency intervals similar to those used for the active pumping period. Continue measurements until the water level in the well has recovered to within 90 percent of its pre-pumping level or for a period equal to the duration of pumping.

During or near the end of each pumping test, a groundwater sample will be collected from the test well using the sample collection and handling procedures in Section 7.0. Pumping test results will be interpreted using analytical software such as AQTESOLV (HydroSOLVE, Inc., 2007).

5.7 Initial Well Sample

At the end of the constant rate pumping test an initial groundwater sample will be collected from each completed well and analyzed for sulfate and major element ions. Table 1 contains the analyte list for the initial well sample. Because the initial well sample is collected at the end of aquifer testing, it is assumed that well purging will have been accomplished by the pumping test.

5.8 Sample Collection and Labelling

Depth-specific samples will be analyzed for dissolved sulfate only by both field and laboratory analyses. Depth-specific samples for laboratory analysis will consist of filtered water collected in an unpreserved 250 mL bottle. Samples will be filtered using a 0.45 µm filter. Bottles for samples sent for laboratory analysis will be obtained from the laboratory. Depth-specific samples for field analysis of sulfate will be collected in a bucket because of the need to let sediment settle from the sample. The bucket will be washed with alconox between uses.

Initial well samples will shipped to a laboratory for analysis of the constituents on Table 1. Initial well samples will include an unfiltered portion collected in a 250 mL, unpreserved bottle, as well as a filtered portion collected in both an unpreserved 250 mL bottle and a 250 mL bottle preserved with nitric acid (HNO_3). Initial well samples will be collected in pre-preserved bottles obtained from the laboratory.

Samples collected during depth-specific sampling will be filtered using a hand vacuum pump and beaker. Initial well samples will be collected using a hose and in-line filter connected directly to a sampling spigot installed at the wellhead.

The vacuum pump procedure is as follows:

- Sampling personnel will decontaminate all equipment that will used for sampling, except the hand pump as described in Section 6.3.
- At least 500 mL of water will be collected in a decontaminated container (bucket or beaker) directly from the discharge point.
- A new, 0.45 µm filter will be used for each sample. The filter will be connected to the sampling equipment using polyethylene tubing.
- The hand vacuum pump will be used to draw the sample through the filter and into a decontaminated 500 mL beaker. The hand pump will not touch the sample water at any point.
- The sample will be transferred from the beaker to an unpreserved 250 mL polyethylene bottle for laboratory analysis or directly into the measuring vessel for field analysis.

The sampling procedure using a sampling spigot is as follows:

- Sampling personnel will decontaminate the sampling spigot adaptor and tubing as described in Section 6.3.
- The sampling adaptor and hose will be installed on the sampling spigot and water will be allowed to run through the adaptor for at least 10 seconds.
- An unfiltered sample will be collected for alkalinity determination.
- A new, 0.45µm filter will be pushed onto the end of the hose and a filtered sample will be collected into an unpreserved 250 mL polyethylene bottle for analysis of anions. A 250 mL polyethylene bottle preserved with nitric acid will be filled for analysis of cations.

Sampling personnel will wear a new pair of nitrile gloves when collecting each sample. All samples will be labelled in ink with the sample date and time, sample name, well name, location, preservative, filtered/unfiltered, and the initials of the sampling personnel.

6.0 FIELD EQUIPMENT

The field geologist will be responsible for properly maintaining and calibrating all field equipment. Operation, calibration, and maintenance procedures for all equipment will be kept accessible when equipment is being used, calibrated, or serviced. Measurement equipment will be calibrated when it is first used and recalibrated periodically based on the recommendations in the instrument's operations manual. Maintenance practices also will follow the manufacturers' recommendations. The time and results of calibration and maintenance will be recorded for each piece of equipment.

6.1 Field Meters

A handheld Myron Ultrameter II meter will be used to measure electrical conductivity, temperature, and pH in the field. The meter will have automatic temperature correction of electrical conductivity. A colorimeter will be used to measure sulfate concentration in the field

The meter will be calibrated every day that it is used. The pH probe will be calibrated with at least two standards that have pH values that bracket the anticipated pH values for the samples to be tested. Standards with pH of 7 and 10 will be used for calibration. The calibration shall be checked at least twice every 24 hours with the pH 7 standard, and the probe will be recalibrated if the reading is out of the range of 6.7 to 7.3. The conductivity probe will be calibrated using a 7,000 microSiemens per centimeter (µS/cm) standard.

The colorimeter will be rented from an equipment supplier. Clear Creek will request that the meter be calibrated by the supplier prior to being shipped to the site for use. Clear Creek will calibrate the meter in the field and store the meter in accordance with the manufacturer's recommendations.

6.2 Pressure Transducers

The pressure transducer should be capable of measuring water levels with a sensitivity of 0.01 ft, although the transducer accuracy may differ depending on pressure rating. The accuracy of the pressure transducer will be periodically verified using the sounder probe. Data collected by the pressure transducer will be downloaded after each use or every day if it is installed for longer than 24 hours. Maintenance for the pressure transducer will follow the guidelines of the operations manual. The transducer assembly will be stored in a clean, secure location when not in use.

6.3 Equipment Decontamination

Properly decontaminated sampling equipment will help prevent errors due to cross-contamination. Prior to work that will include sampling, all reusable equipment will be decontaminated. This includes non-dedicated groundwater pumps, electric sounders, and any other equipment brought onsite. Cleaned equipment should not lie on the ground or any unclean surfaces. Disposable, single-use equipment such as filters, bailers, sampling spigots, and nylon string will be used at a single sample collection location and then discarded.

Groundwater sampling focuses on sulfate and other major element ions (e.g., calcium, magnesium, chloride, bicarbonate). Because the major element ions are nonsorbing and exist at relatively high concentrations in the groundwater, equipment decontamination is not subject to the rigorous protocols that are needed for decontamination when sampling for trace organic and metal compounds. Nevertheless, proper equipment decontamination is important to preserve sample integrity and maintain quality control. The following procedures should be used to decontaminate any reusable equipment involved in sampling.

1) Decontamination of reusable sampling equipment (e.g., buckets, beakers)

a) Use proper personal protective equipment. This includes safety glasses and chemical resistant gloves. Use care while handling detergents.

b) Scrub exterior of equipment with a non-phosphate detergent/potable water mixture.

c) Flush interior of equipment with a non-phosphate detergent/potable water mixture.

d) Rinse interior and exterior of equipment with potable water.

e) Rinse interior and exterior of equipment with deionized water.

f) Allow the equipment to air dry.

g) Properly dispose of all disposable sampling and cleaning equipment.

2) Decontamination of mobile monitoring well pumps and pump riser pipe

a) Use proper personal protective equipment. This includes safety glasses and chemical resistant gloves. Use care while handling detergents.

b) Pressure wash interior and exterior portions of riser pipe with a non-phosphate detergent /potable water mixture.

c) Repeat step "b" using potable water.

d) Pump a non-phosphate detergent /potable water mixture through the submersible pump.

e) Repeat step "d" using potable water.

f) Allow the exterior of pump and riser pipe to air dry with the exception of probes that must remain moist (e.g. pH probe).

g) Properly dispose of all disposable sampling and cleaning equipment.

3) Decontamination of probes

a) Use proper personal protective equipment. This includes safety glasses and chemical resistant gloves. Use care while handling detergents.

b) Rinse probes with deionized water for several seconds between each reading.

c) Rinse containers used for field measurements with deionized water between each reading. If there is residual residue on containers, use a non-phosphate/potable water mixture to manually remove residue. Afterward rinse containers with potable water then deionized water.

d) Allow the probes and containers to air dry.

e) Properly dispose of all disposable sampling and cleaning equipment.

7.0 SAMPLE HANDLING

Groundwater samples for laboratory analysis will be stored on ice from the time they are collected until they arrive at the laboratory. Field analyzed samples will be analyzed immediately. Chain of Custody (COC) documentation for samples submitted for laboratory analysis will be maintained from the time of collection until the samples are analyzed.

7.1 Sample Custody and COC Documentation

Samples are in the sampling personnel's custody upon collection. The custody of the samples will be the responsibility of the sampling personnel until the samples are shipped to the laboratory. A sample is considered to be under a person's custody if one or more of the following conditions are met:

- The sample is in the person's physical possession.
- The sample is in the view of the person after that person has taken possession.
- The sample is secured by that person so that no one can tamper with the sample.
- The sample is secured by that person in an area that is restricted from unauthorized personnel.

Custody of samples will be documented from the time of sample collection through the receipt of the sample by the laboratory. COC forms will be filled out completely and will accompany the samples when shipped to the laboratory. The COC form will identify the contents of each shipment. The COC form will remain in the sampling personnel's possession until the samples have been hand delivered or shipped to the laboratory. The sampling team leader or designee will sign the COC form in the "relinquished by" box and note the date and time the samples were relinquished. A properly completed COC form will specify:

- The project name, required signatures, dates, and times that samples were relinquished and accepted.

- Analyses requested, time and date of sampling, and sample matrix.
- Unique field identification of each sample.
- Number of containers submitted.
- Temperatures upon receipt by the analytical laboratory.

7.2 Sample Transport

Water samples will be transported to an Arizona-certified laboratory by field staff, courier, or commercial shipper. The samples will be transported to the lab in time to allow for the analysis of the samples within the hold times shown on Table 1. The following procedures will be followed for sample transport:

- Ice will be placed in a sturdy plastic bag to prevent leaking. Glass sample containers will be protected by bubble wrap, foam, or some other packing material. Sufficient packing material will be used to prevent sample containers from making contact during shipment. Enough ice will be added to maintain the cooler temperature at 4°C +/− 2°, until receipt by the laboratory. The plastic bag will be zip-locked or closed with a twist or cable tie.

- The COC records will be signed by the person relinquishing possession of the samples and will be placed inside a plastic bag. The bag will be sealed and taped to the inside of the cooler lid. The shipping address will be verified before the samples are relinquished to the courier.

- The cooler will be closed and taped shut with packing tape around both ends.

- If a courier or shipping agent is used, the cooler will be transferred with a completed shipping bill.

8.0 DATA MANAGEMENT

A field logbook of all project activities will be maintained by Clear Creek field staff in addition to the use of the field forms included in Appendix A. The logbook will be check periodically by the Clear Creek Project Manager to determine if there are missing or erroneous data. The field forms and logbook will be scanned at the end of each field shift and stored digitally. Laboratory data will be reviewed within 7 days of receipt from the laboratory to determine completeness. Digital files of the original laboratory reports will be kept by Clear Creek and transmitted to CQB.

9.0 REFERENCES

Arizona Department of Environmental Quality (ADEQ). 2007. Mitigation Order on Consent Docket No. P-121-07, In the Matter of: Phelps Dodge Corporation, Copper Queen Branch, located at 36 West Highway 92, Bisbee, Arizona, ADEQ Identification Number 100531. November 14, 2007.

Clear Creek Associates. 2010. Revision I Aquifer Characterization Report, Task 4.0 of Aquifer Characterization Plan, Mitigation Order on Consent Docket No. P-121-07, Cochise County, Arizona, Volumes I and II. December 15, 2010.

Clear Creek Associates. 2014a. Mitigation Plan for Sulfate with Respect to Drinking Water Supplies, Mitigation Order on Consent Docket No. P-121-07, May 28, 2014.

Clear Creek Associates. 2014b. Feasibility Study for Drinking Water Supplies that may be Affected by Sulfate in the Future, Mitigation Order on Consent Docket No. P-121-07. May 28, 2014.

Clear Creek Associates. 2014c. Technical Specifications Monitor Well Installation Services for Freeport-McMoRan Corporation, Copper Queen Branch. June XX, 2014.

Hayes, P.T. 1970. Mesozoic Stratigraphy of the Mule and Huachuca Mountains, Arizona. United States Geological Survey Professional Paper 658-A.

Hayes, P.T. and E.R. Landis. 1964. Geologic Map of the Southern Part of the Mule Mountains, Arizona. United States Geological Survey Miscellaneous Geologic Investigations Map-418.

Hydro Geo Chem, Inc. (HGC). 2008. Revision 1, Work Plan to Characterize and Mitigate Sulfate with Respect to Drinking Water Supplies in the Vicinity of the Concentrator Tailing Storage Area, Cochise County, Arizona. July 3, 2008.

HydroSOLVE, Inc. 2007. AQTESOLV Aquifer Test Analysis Software version 4.50.002. Licensed by HydroSOLVE, Inc.

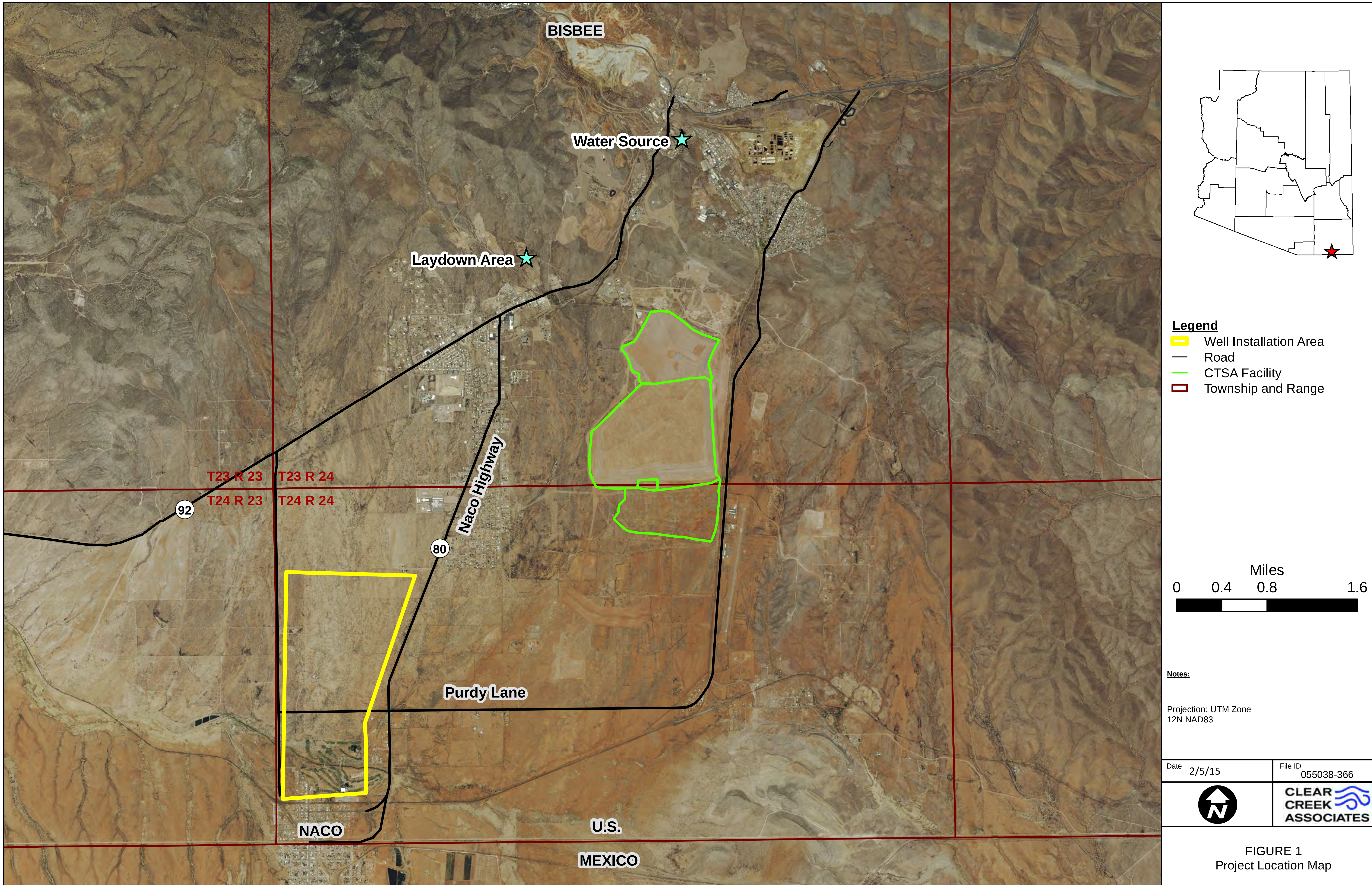
Littin, G.R. 1987. Ground-Water Resources of the Bisbee-Naco Area, Cochise County, Arizona. United States Geological Survey Water-Resources Investigations Report 87-4103.

TABLE

TABLE 1
Groundwater Sampling Analyte List

Analyte	Method	Target MDL (mg/L)	Container	Preservation	Holding Time	Filtered (F), Unfiltered (U)
pH	EPA 150	N/A	500 mL plastic or glass	N/A	analyze immediately	U
Temperature (Co)	Thermometric	N/A	500 mL plastic or glass	N/A	analyze immediately	U
Conductivity	Conductance	N/A	500 mL plastic or glass	N/A	analyze immediately	U
TDS	SM 2540C/160.1	10	250 mL HDPE	4º C	7 days	F
Total Alkalinity (as CaCO3)	SM 2320B	2	500 mL HDPE	4º C	14 days	U
Chloride	EPA 300.0	1	250 mL HDPE	4º C	28 days	F
Fluoride	EPA 300.0	0.1	250 mL HDPE	4º C	28 days	F
Nitrate	EPA 300.0	0.02	250 mL HDPE	4º C	48 hours	F
Nitrite	EPA 300.0	0.02	250 mL HDPE	4º C	48 hours	F
Sulfate	EPA 300.0	10	250 mL HDPE	4º C	28 days	F
Calcium	EPA 200.7	0.2	250 mL HDPE	4º C; HNO3 to pH < 2	6 months	F
Magnesium	EPA 200.7	0.2	250 mL HDPE	4º C; HNO3 to pH < 2	6 months	F
Potassium	EPA 200.7	0.3	250 mL HDPE	4º C; HNO3 to pH < 2	6 months	F
Sodium	EPA 200.7	0.3	250 mL HDPE	4º C; HNO3 to pH < 2	6 months	F

FIGURES



Notes:

Projection: UTM Zone 12N NAD83

Date 2/5/15	File ID 055038-366
	CLEAR CREEK ASSOCIATES

FIGURE 1
Project Location Map

Legend

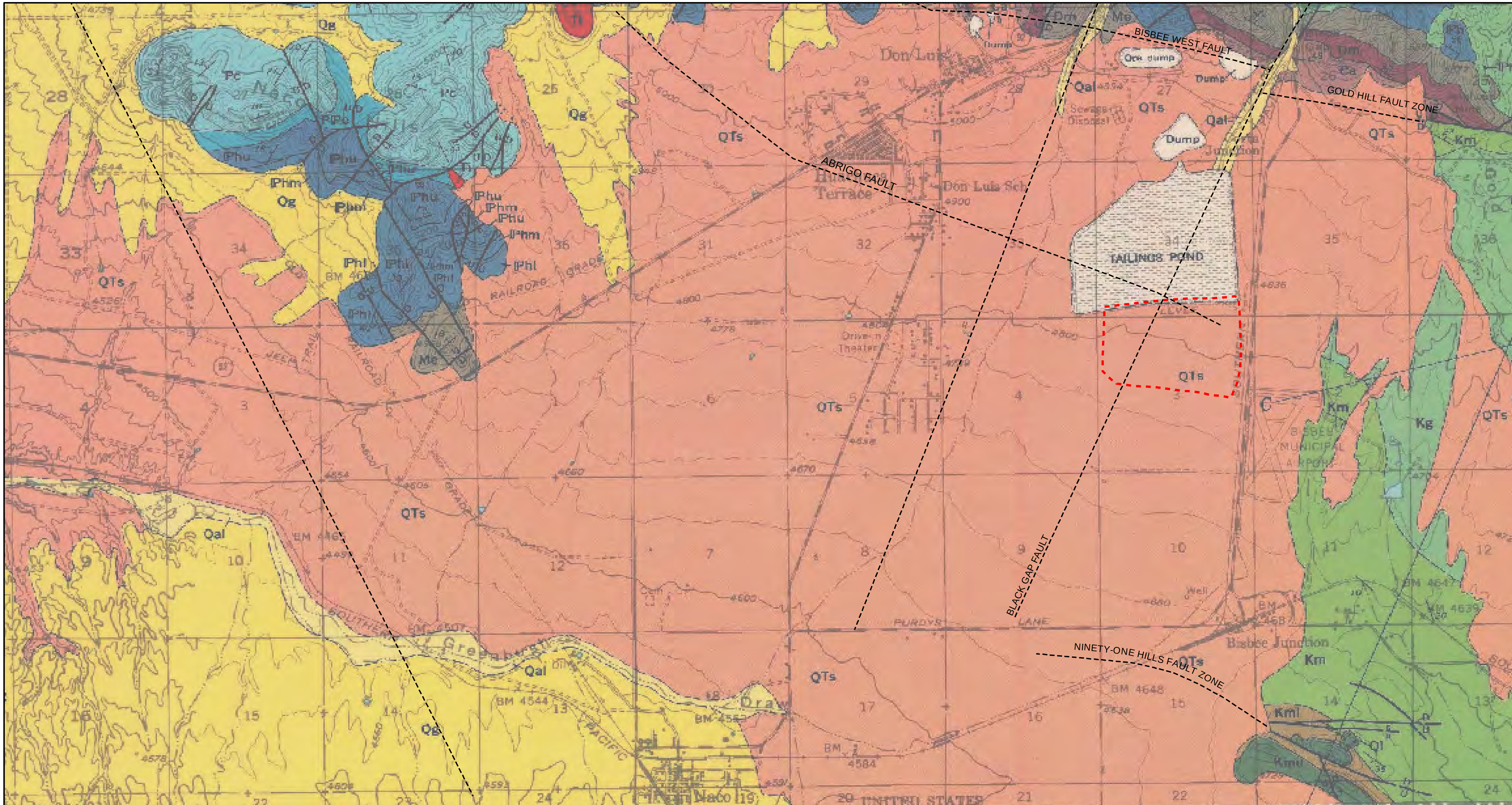
▲ Monitoring Well Site

0 500 1,000
Feet

File ID 055038-365

Date 2/5/15

FIGURE 2
Site Locations



Legend

Former Evaporation Ponds
Faults (dashed where inferred)

Geologic Unit - Hayes and Landis (1964)

Basin Fill
- Qal - Quaternary Alluvium
- Qg - Quaternary Gravel
- QTs - Quaternary Tertiary sediment
- Ti - Tertiary Intrusive

Bisbee Group
- Kc - Cintura Formation (not shown)
- Kmu - Upper Mural Limestone
- Kml - Lower Mural Limestone
- Km - Morita Formation
- Kg - Glance Conglomerate

Paleozoic Sedimentary Formations
- Pc - Colina Limestone
- PPe - Earp Formation
- Phu, Phm, Phl - Horquilla Limestone
- Me - Escabrosa Limestone
- Dm - Martin Limestone
- Ca - Abrigo Limestone

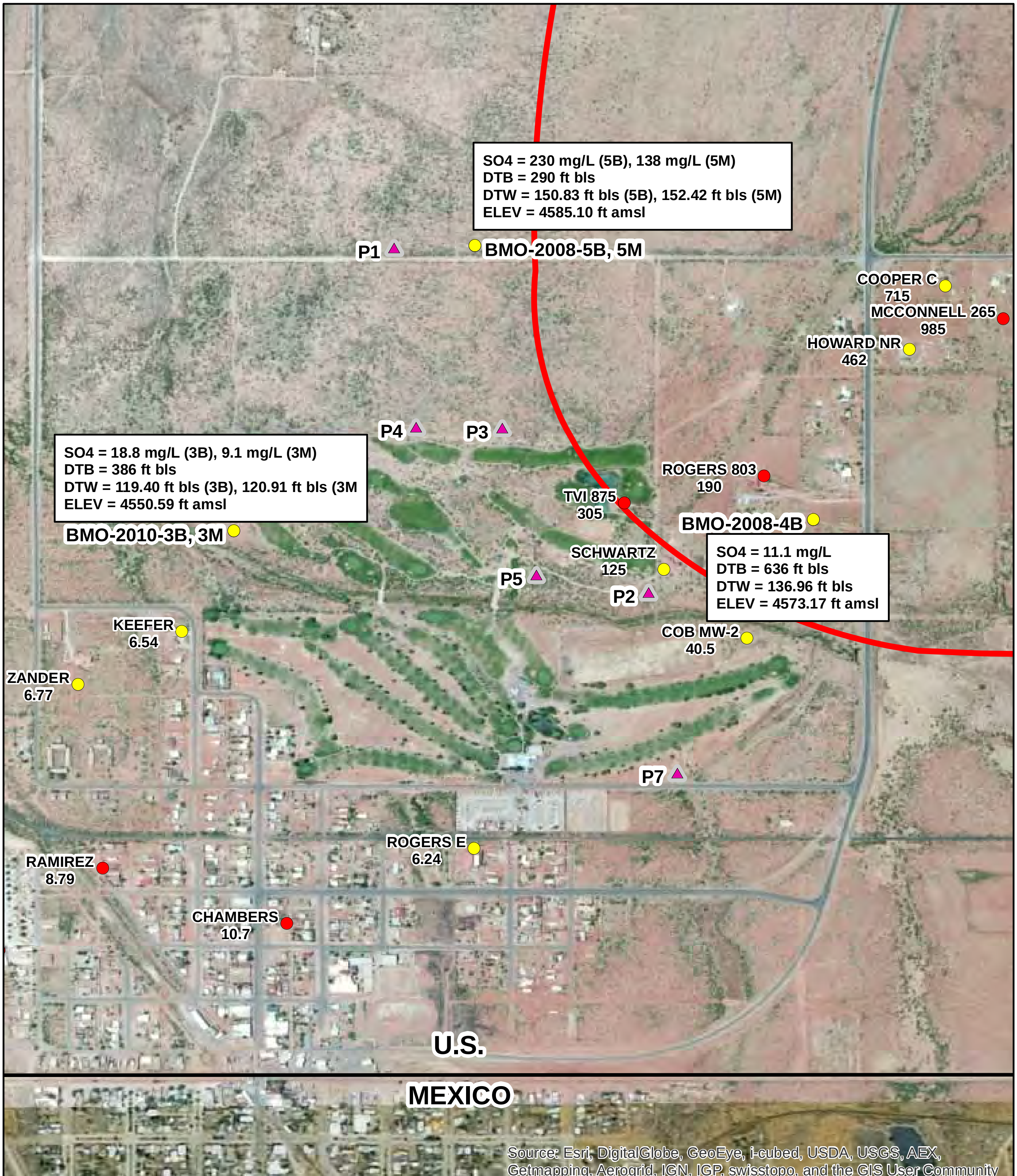
Scale (Feet)
0 3,000 6,000

Projection: UTM Zone 12N NAD83
Geology reprinted from Hayes and Landis (1964) USGS Miscellaneous Geologic Investigations I-418

Date 2/5/15
File ID 055038-358A

CLEAR CREEK ASSOCIATES

FIGURE 3
Geologic Map



Legend

Proposed Well Sites (2 wells each)

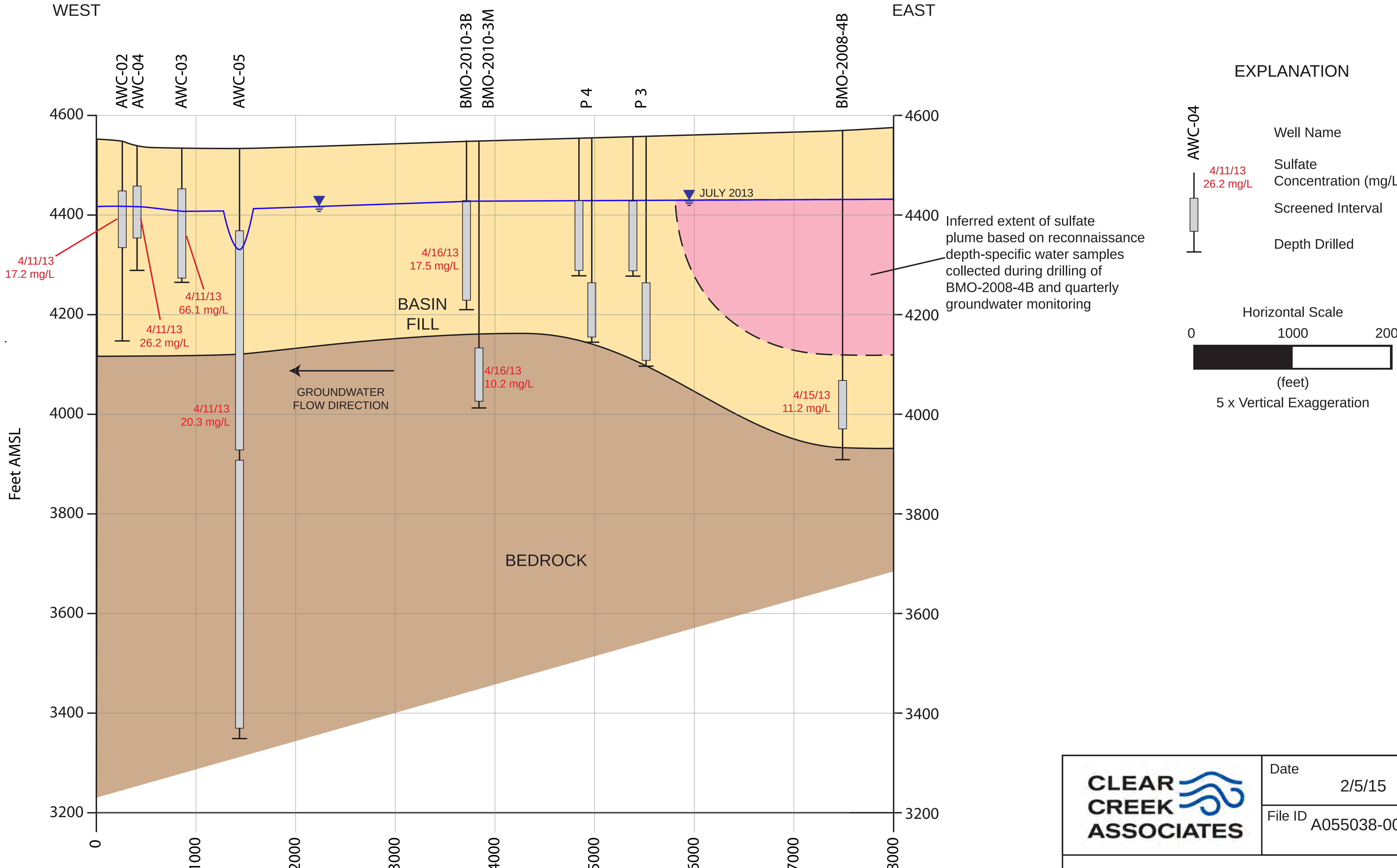
Existing Monitor Well

SO4 = Most recent sulfate concentration for basin fill well - milligrams per Liter
DTB = Depth to bedrock - feet below land surface
DTW = Depth to water - feet below land surface
ELEV = Site elevation above mean sea level

File ID 055038-367

Date 2/5/15

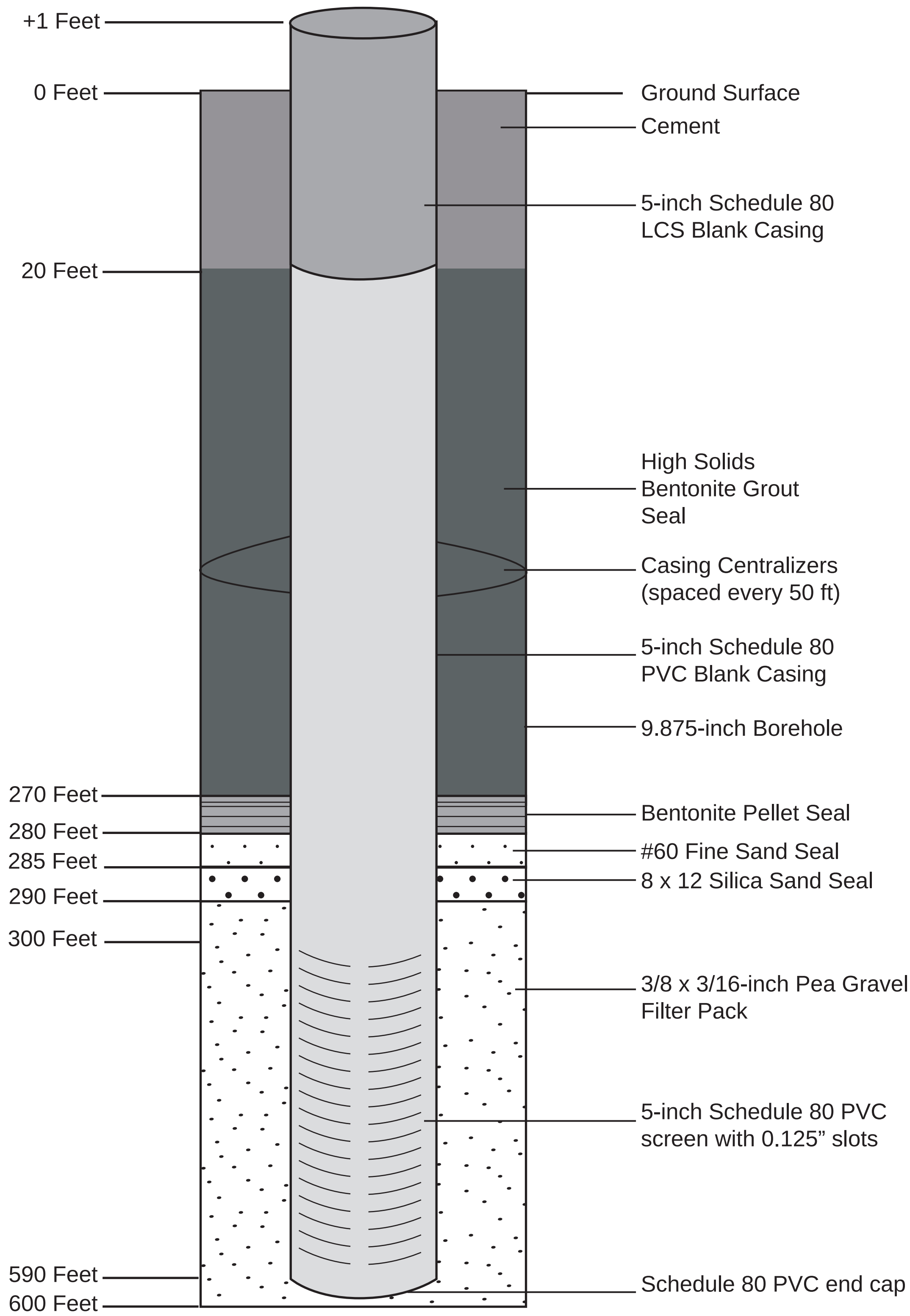
FIGURE 4
Existing Wells in the
Well Installation Area



CLEAR CREEK ASSOCIATES

Date	2/5/15
File ID	A055038-001

FIGURE 5
Geologic Cross Section

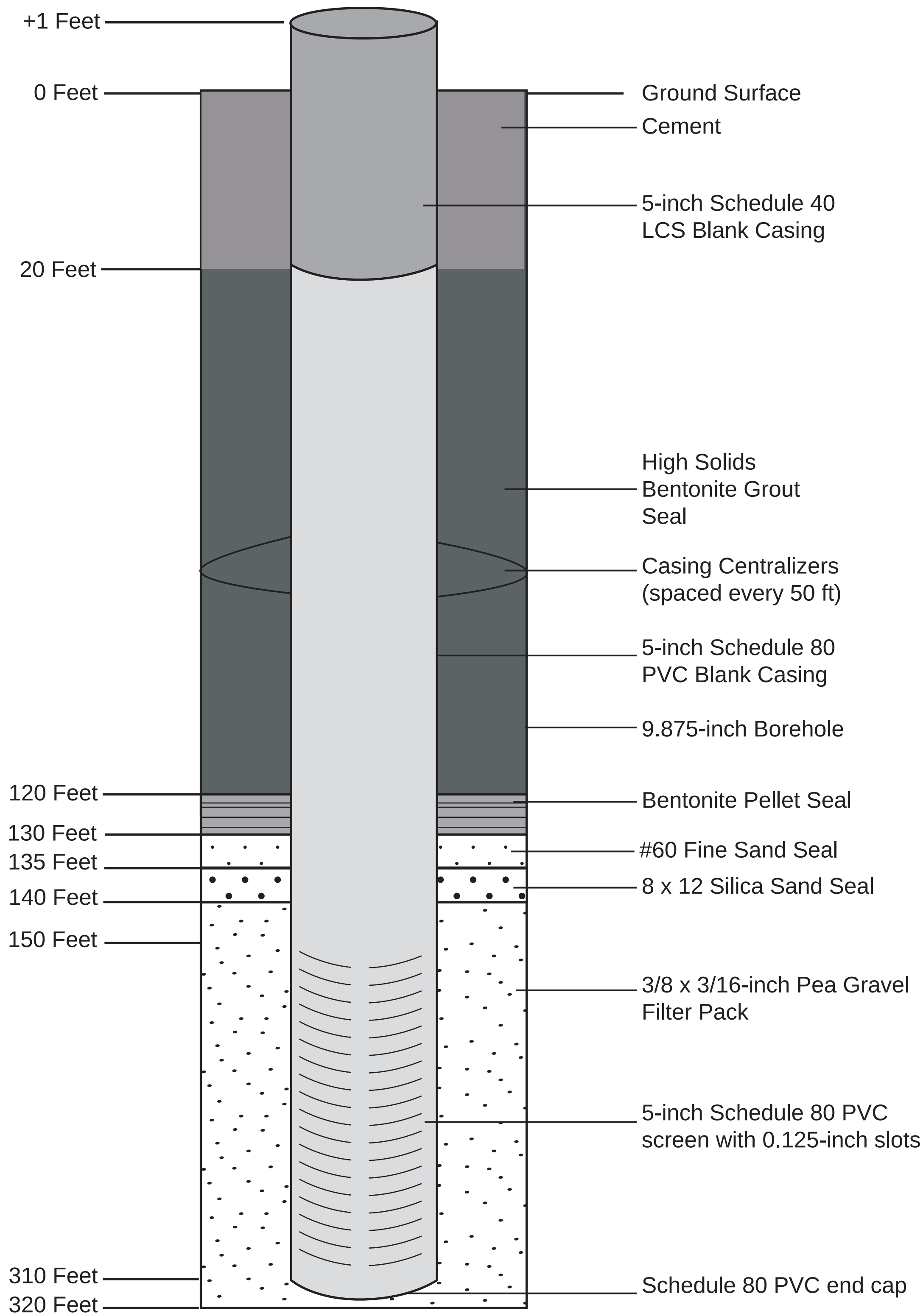


CLEAR CREEK ASSOCIATES

Notes:
NOT TO SCALE
LCS: Low Carbon Steel
PVC: Polyvinyl Chloride
All casing diameters are nominal

File ID	Date
055038-057A	2/5/15

FIGURE 6
Preliminary Deep
Monitor Well Design



CLEAR CREEK ASSOCIATES

Notes:
NOT TO SCALE
LCS: Low Carbon Steel
PVC: Polyvinyl Chloride
All casing diameters are nominal

File ID	Date
	2/5/15

FIGURE 7
Preliminary Shallow
Monitor Well Design

APPENDIX A

Field Forms

WATER SAMPLE DATA LOG

Project No.:	Project
Well ID:	Date:
Location:	Weather:
Purpose of Sampling Event:	

WELL DATA

Total Depth of Well (ft bls):	Static Water Level (ft bls):
Sample Interval (ft bls):	Date/Time:
Casing Diameter (in):	3 Casing Volumes:

FIELD SAMPLING DATA

Time	Discharge Rate (gpm)	Total Discharge (gallons)	pH	Temp. (°C)	Specific Conduct. (µs/cm)	Color	Odor	Comments

Sample Name:____________________________________

Time Pumping Started: ____________________ Time of Sample Collection: ____________________

Type of Samples Collected:____________________________________

Total Discharge (gal): ____________________ EC-T-pH Meter Type: ____________________

Sample Collected by: ____________________________________

How Sample Collected: ____________________________________

Additional Comments: ____________________________________

CLEAR CREEK ASSOCIATES

CLEAR CREEK ASSOCIATES

WATER SAMPLE DATA LOG
Zonal Sampling

Project No.:	Project:
Well No.:	Date:
Location:	Weather:

WELL DATA

Total Depth of Well (ft bls):	Static Water Level (ft bls):
Sample Interval (ft bls):	Date/Time:
Tubing Diameter (in):	Pt. of Measurement:
Borehole Diameter (in):	

FIELD SAMPLING DATA

Time	Discharge Rate (gpm)	Total Discharge (gallons)	pH (SU)	Temp. (°C)	Specific Conduct. (µs/cm)	Field Sulfate (mg/L)	Sand Content (mL/L)	TDS (ppm)	Color	Odor	Comments

Time Pumping Started: ________________________

Airline depth: ________________________

psi / cfm of air package: ________________________

Total Discharge (gallons): ________________________

Sample ID: ________________________

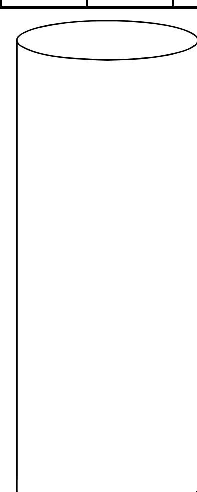
Sample Collected by: ________________________

How Sample Collected: ________________________

Date/Time of Sample Collection: ________________________

EC-T-pH Meter Type: ________________________

Additional Comments: ________________________



Sketch depth-specific method here

WELL DEVELOPMENT
FIELD DATA LOG

Project No.:	Client:	ADWR Registration No.:
Well ID/Name:	Date:	
Location:	Weather:	
Geologist:		
Total Depth of Well (ft bls):	Measuring Point (M. P.):	
Screen Interval(s) (ft bls):	Distance from ground level to M. P.(ft):	

Time	Activity (Bail, Swab, Pump)	Q (gpm)	Totalizer Reading (g)	Q_T (gal)	Sand Content (ml/l)	pH	Conductivity (us/cm)	Temp (F / C)	Pumping Water Level (ft.bls)	Comments

Additional Comments:

CLEAR CREEK ASSOCIATES

Well ID/Name:

Project No.:

ADWR Registration No.:

WELL DEVELOPMENT
FIELD DATA LOG (CONTINUED)

Page ____ of ____

Date: __________

Time	Activity (Bail, Swab, Pump)	Q (gpm)	Totalizer Reading (g)	Q_T (gal)	Sand Content (ml/l)	pH	Conductivity (us/cm)	Temp (F / C)	Pumping Water Level (ft. bls)	Comments

Additional Comments:

CLEAR CREEK ASSOCIATES

Well ID:_______
ADWR Reg. No:_______
Page ____ of ____

PIPE TALLY

Project Name:	Project No.:	Site Address:	ADWR Registry No.:
Drilling Co.:		Date Started:	Date Finished:
Well Blank Description(s):		Well Screen Description(s):	
Total Drilled Depth (ft bls):		Total Cased Depth (ft bls):	

Type of Connections: ❑ **Welded** ❑ **T+C** ❑ **Flush Thread** ❑ **Other**

Pipe No.	✓	**Length** (ft)	**Length Σ** (ft)	**Pipe Type**	**Pipe No.**	✓	**Length** (ft)	**Length Σ** (ft)	**Pipe Type**

Notes:

CLEAR CREEK ASSOCIATES

Project No. ____________

Well/Boring____________
Page _____ of_____

Project/Client Name	Location (Cadastral)		Elevation (ft amsl)	Project No.
Drilling Co.	Location (NAD 83 GPS Latitude Longitude)		Date Started	Date Finished
Lithology Described By	Drilling Equipment	Drilling Method	ADWR Well Registration No.	
Total Depth	Drilling Fluid		* Indicates (based on visual estimates of volume):	
Bit Diameter	Conductor Casing (type; diameter; depth)		■ Relative % fines (F < 0.074mm)	
Comments			□ Relative % sand (S>.074<4.8mm)	
* Clasification System:	**Unified Soil Classification System (ASTM)**		▨ Relative % gravel (G > 4.8mm)	

Description	Depth (feet)	Drill Rate (feet/hour)	* F S G (%)	Remarks

CLEAR CREEK ASSOCIATES

Project No. ____________

Well/Boring____________
Page _____ of_____

Description	Depth (feet)	Drill Rate (feet/hour)	* F S G (%)	Remarks

CLEAR CREEK ASSOCIATES

AQUIFER TEST DATA

Project:	Project No.:		Static Water Level:
Well Location:	Well No.:		Measuring Point:
Well Diameter:	Measured By:		Elevation Measuring Point:
Pump Setting:	Pump On: Date	Time:	Available Drawdown:
Screen Interval(s):	Pump Off: Date	Time:	Distance From Pumping Well:
How Q Measured:	Duration of Aquifer Test:		Initial Totalizer Reading:

Time of Measurement	**Time Since Pumping Started (t) (minutes)**	**Air line Pressure Reading (psi)**	**Total Length of Air line (feet)**	**Correction (feet)**	**Calculated Water level (feet)**	**Drawdown (feet)**	**Discharge (gpm)**	**Specific Capacity (gpm/ft)**	**Totalizer Reading (gallons)**	**Remarks**

No. ________
Date ________

Time of Measurement	Time Since Pumping Started (t) (minutes)	Sounder Reading (feet)	Correction (feet)	Water Level (feet)	Drawdown (feet)	Discharge (gpm)	Specific Capacity (gpm/ft)	Totalizer Reading (gallons)	Remarks

ESTIMATED ANNULAR MATERIAL RECORD

Project No.:	Client:	ADWR Registration No.:
Well ID:	Date:	
Location:	Weather:	
Geologist:		

ANNULAR VOLUME CALCULATIONS

Total Depth of Borehole [T]: __________ feet   Total Cased Depth: __________ feet

Length of Interval to be filled [L]: __________ feet   Rat Hole Volume [R]: __________ Ft^3

Borehole Diameter [D]: __________ inches   Casing Diameter [d]: __________ inches

Annular Volume (A): $(D^2-d^2)\ 0.005454 =$ ____________________ Ft^3/Lin. Ft

Expected Calculated Volume = (AxL)+R= ____________________ Ft^3

ANNULAR MATERIALS TALLY

Type of Annular Material: ____________________

Type/Size of Container: ____________________

Measurement Method: ____________________

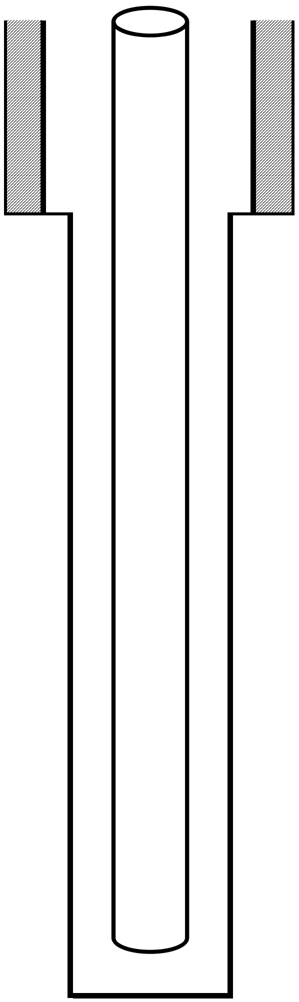
EQUATIONS

2,700 lbs. Silica Sand = 1 cubic yard = 27 cubic feet

[1] Volume of bag (Ft^3) = bag weight/100

[2] Calculated depth = Previous Calculated depth - (v/A)

No.	✓	Weight of Bag (lbs.)	Volume of Bag (v) (ft^3)	Total Vol. of Bags (ft^3)	Calculated Depth (ft bls)	Tagged Depth (ft bls)	Comments



CLEAR CREEK ASSOCIATES

Well ID: ___________________________
Project No.: ________________________
ADWR Registration No.: ______________
Page ___ of ____

ESTIMATED ANNUAL MATERIAL RECORD (CONTINUED)

No.	**✓**	**Weight of Bag** (lbs.)	**Volume of Bag (v)** (ft^3)	**Total Vol. of Bags** (ft^3)	**Calculated Depth** (ft bls)	**Tagged Depth** (ft bls)	**Comments**

Notes: ____
____
____

CLEAR CREEK ASSOCIATES

APPENDIX B

ASTM D2488-00

Designation: D 2488 – 00

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

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

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

1. Scope *

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

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

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

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

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

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

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

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

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

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 2113 Practice for Diamond Core Drilling for Site Investigation[2]

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)[2]

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and rock as Used in Engineering Design and Construction[3]

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)[2]

3. Terminology

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

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

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

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

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

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Feb. 10, 2000. Published May 2000. Originally published as D 2488 – 66 T. Last previous edition D 2488 – 93$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

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

limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

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

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

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

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

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

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

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

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

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

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

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

4. Summary of Practice

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

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

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

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

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

5. Significance and Use

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

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

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

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

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

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

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

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

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

6. Apparatus

6.1 *Required Apparatus*:

6.1.1 *Pocket Knife or Small Spatula*.

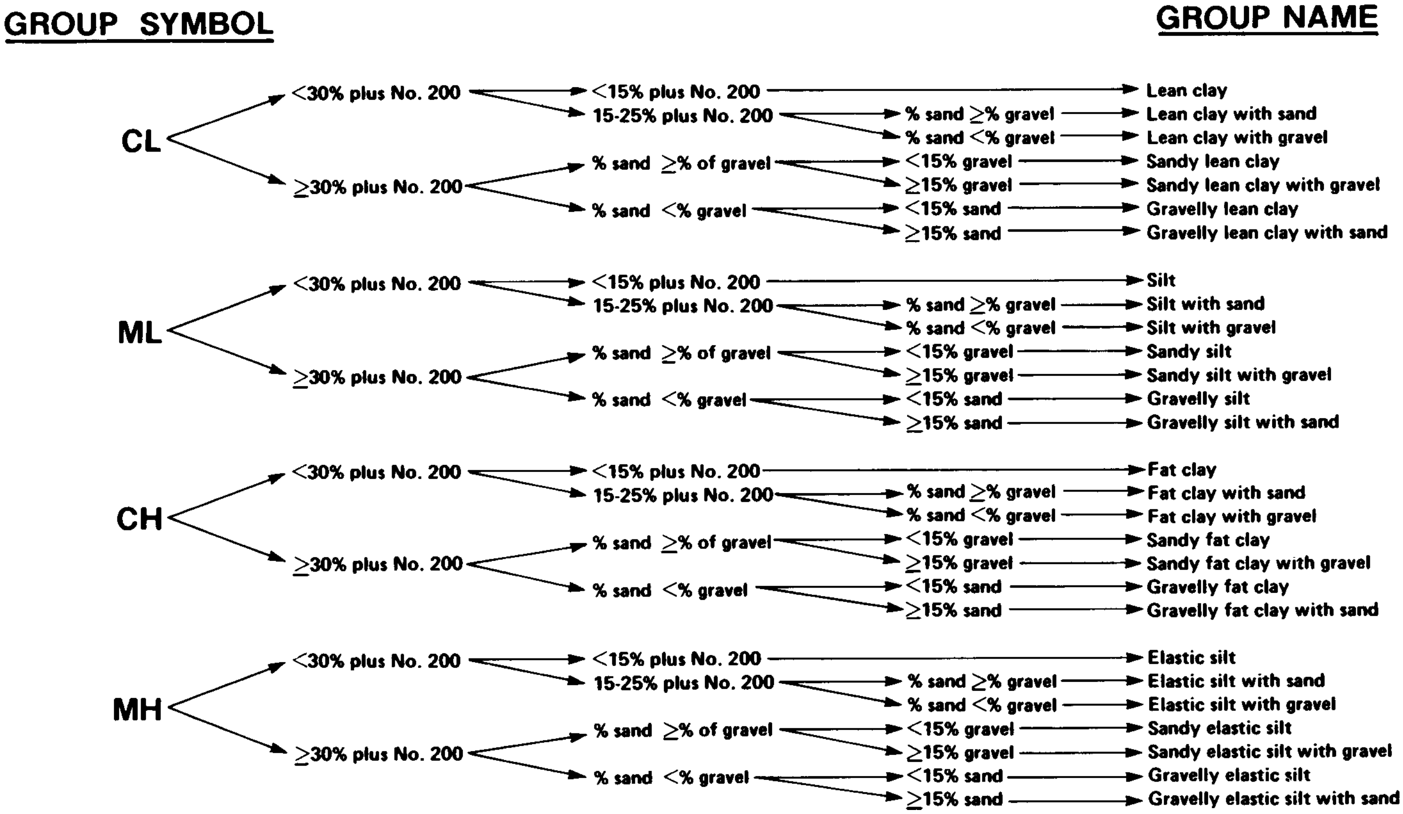
6.2 *Useful Auxiliary Apparatus*:

6.2.1 *Small Test Tube and Stopper* (or jar with a lid).

6.2.2 *Small Hand Lens*.

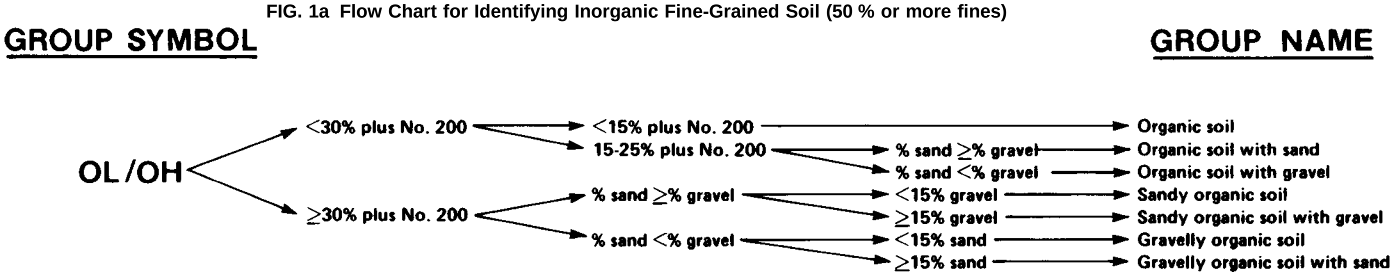
7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water



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

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



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

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

supply or natural source, including non-potable water.

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

8. Safety Precautions

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

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

9. Sampling

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

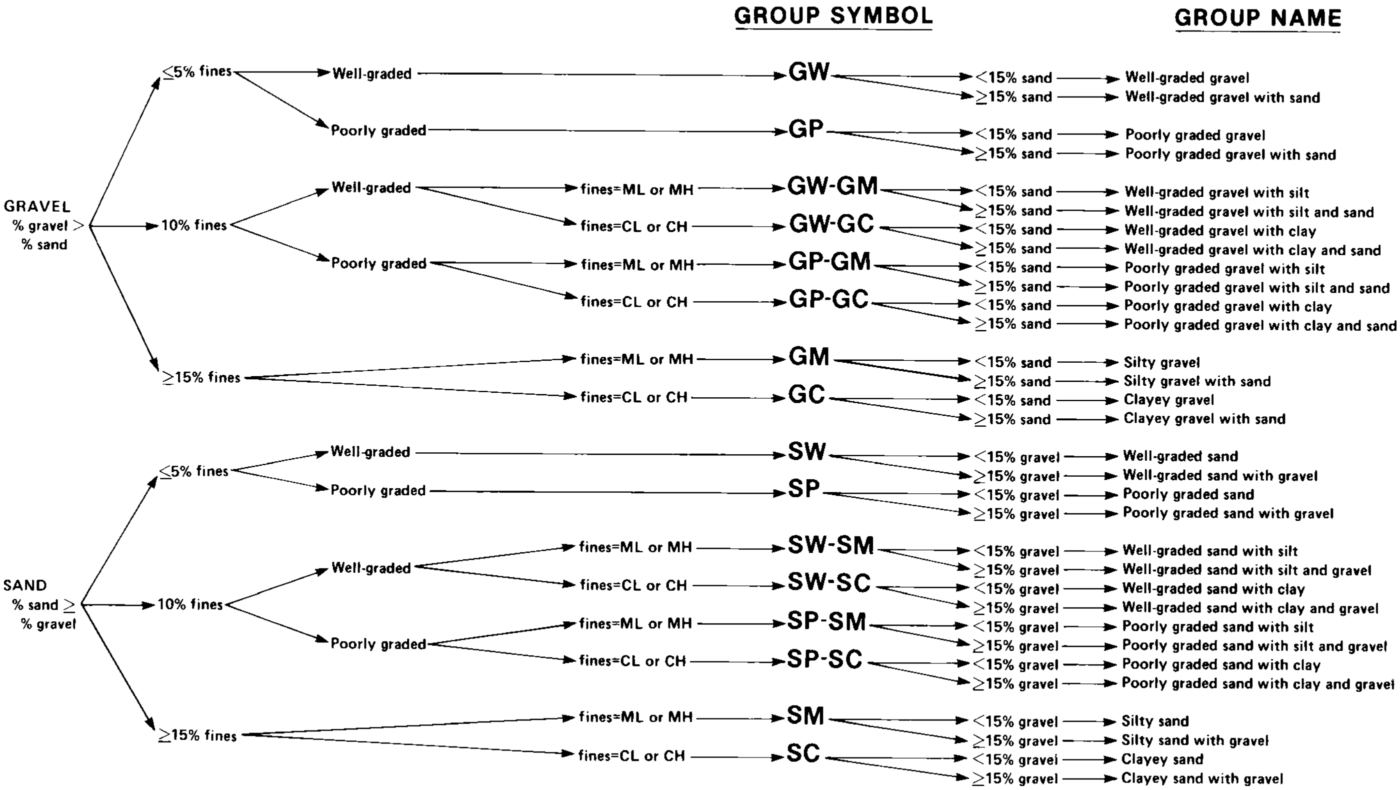
NOTE 6—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Test Method D 1586.

9.2 The sample shall be carefully identified as to origin.

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

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

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (⅜ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)



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

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

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

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

10. Descriptive Information for Soils

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

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

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

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

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

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

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

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

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

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

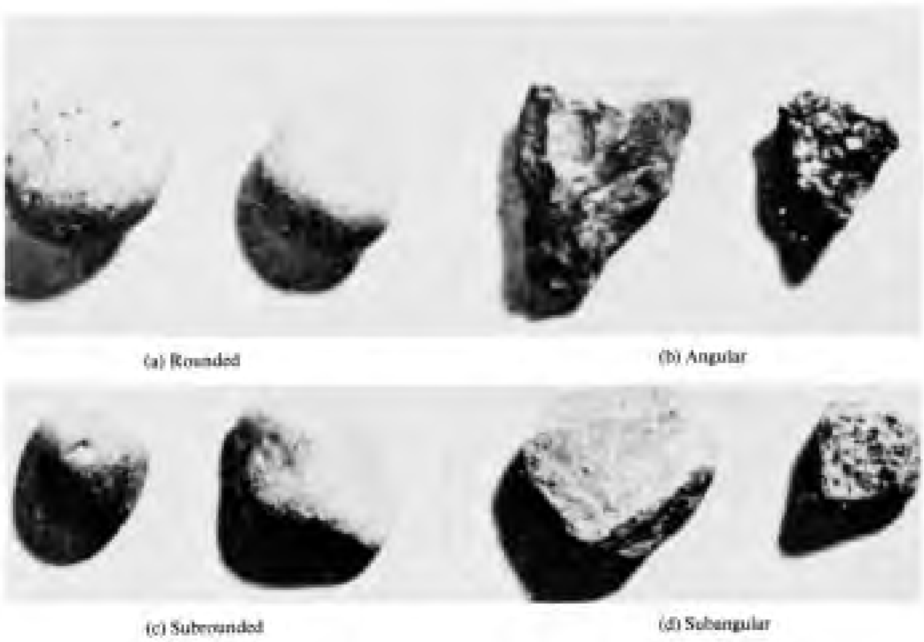


FIG. 3 Typical Angularity of Bulky Grains

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

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

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

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

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

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

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

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

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

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

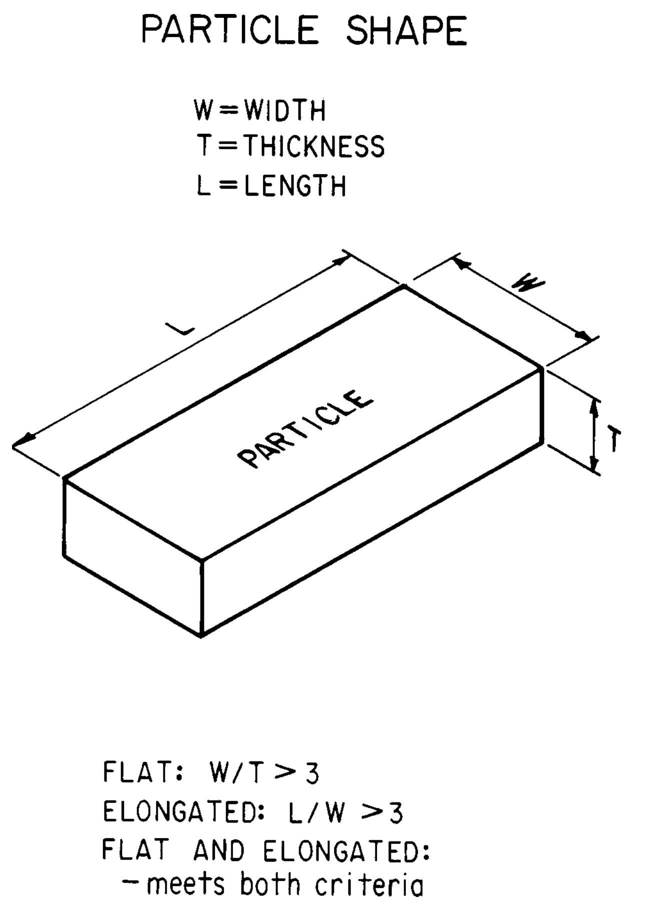


FIG. 4 Criteria for Particle Shape

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

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Dilatancy

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

TABLE 6 Criteria for Describing Toughness

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

TABLE 7 Criteria for Describing Dilatancy

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

hole, caving of trench or hole, or the presence of mica.

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

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

11. Identification of Peat

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

12. Preparation for Identification

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

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

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

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

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

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

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

13. Preliminary Identification

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

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

14. Procedure for Identifying Fine-Grained Soils

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

14.2 *Dry Strength*:

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

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

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

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

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

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

14.3 *Dilatancy*:

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

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

14.4 *Toughness*:

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

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

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

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

TABLE 8 Criteria for Describing Toughness

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

TABLE 9 Criteria for Describing Dilatancy

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

TABLE 10 Criteria for Describing Toughness

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

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A ⅛-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

14.7 *Identification of Inorganic Fine-Grained Soils*:

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

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

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

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

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

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

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

14.8 *Identification of Organic Fine-Grained Soils*:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

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

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

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

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

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

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

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

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

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

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

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

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

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

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

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

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

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

16. Report

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

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

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

Geologic Interpretation—Alluvial fan

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

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

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

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

TABLE 13 Checklist for Description of Soils

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

For intact samples:

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

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

17. Precision and Bias

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

18. Keywords

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

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

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

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

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

Prefix:	Suffix:

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

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

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

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (1993$^{\epsilon1}$) that may impact the use of this standard.

(1) Added Practice D 3740 to Section 2.

(2) Added Note 5 under 5.7 and renumbered subsequent notes.