3R - 425

WORKPLAN

11/28/2011

CONESTOGA-ROVERS
& ASSOCIATES

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Albuquerque, NM, USA 87110
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December 2, 2011

Reference No. 075034

Mr. Glenn von Gonten
New Mexico Oil Conservation Division
1220 South Saint Francis Dr.
Santa Fe, NM 87505

RECEIVED OCD
2011 DEC -5 A 11: 31

Dear Mr. von Gonten:

Re: ConocoPhillips San Juan 29-7 Unit 37 Subsurface Remediation Work Plan
Replacement Pages with NMOCD-Requested Modifications
API No. 30-039-07643
NMOCD No. 3R-425
CRA Project No. 075034

Enclosed please find a copy of the replacement pages for the ConocoPhillips San Juan 29-7 Unit 37 Subsurface Remediation Work Plan as compiled by Conestoga-Rovers and Associates, Inc. (CRA) in response to the December 1, 2011 letter issued by the New Mexico Oil Conservation Division (NMOCD) conditionally approving the San Juan 29-7 Unit 37 Site Characterization Report and Subsurface Remediation Work Plan, which were submitted to the NMOCD on November 28, 2011 on behalf of ConocoPhillips by Conestoga-Rovers and Associates (CRA).

Changes have been made to the following sections of the referenced work plan as follows:

1. On Page 9, Section 3.4, Second Paragraph: "Approximately 90 to 93 injection points (IPs), depending on Site surface and subsurface structures, will be used to inject an estimated 60,000 gallons of *Cool-Ox*™ solution over an approximate area of 5,950 ft^2 (70 ft x 85 ft) to treat approximately 8,815 yd^3 of impacted soil (Figures 6 and 7)."

2. On Page 11, Section 3.6: "Groundwater samples from all Site monitoring wells will be analyzed for BTEX by EPA Method 8260B, HPC by Method 9215, dissolved manganese and selenium by Method 6010B, nitrate and sulfate by Method 300.0, and total dissolved solids (TDS) by Method SM2540C. Groundwater samples will be collected quarterly for at least one year from MW-4 and a nearby water supply well and analyzed for nitrate, sulfate, and TDS in order to attempt to demonstrate those constituents are at background levels at the Site. Confirmation soil samples will be analyzed for TPH-GRO and TPH-DRO by Method SW8015B or 8260B and BTEX by EPA Method 8260B."

If you have any questions or require additional information, please contact me at (505) 884-0672 or keblanchard@craworld.com.

Yours truly,

CONESTOGA-ROVERS & ASSOCIATES

Kelly E. Blanchard

Kelly E. Blanchard
Project Manager

KB/cd/1
Encl.

cc: Richard Hodgson, Referenced Property Owner
Terry Lauck, ConocoPhillips (Electronic Only)
Brandon Powell, NMOCD

3R425

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November 28, 2011 Reference No. 075034

Mr. Glenn von Gonten
New Mexico Oil Conservation Division
1220 South Saint Francis Dr.
Santa Fe, NM 87505

Dear Mr. von Gonten:

Re: ConocoPhillips San Juan 29-7 Unit 37 Subsurface Remediation Work Plan
and Site Characterization Report
API No. 30-039-07643
CRA Project No. 075034

Enclosed please find a copy of the above-referenced documents as compiled by Conestoga-Rovers and Associates, Inc. This work plan details proposed remediation at the site scheduled to begin on December 7, 2011 pending New Mexico Oil Conservation Division (NMOCD) approval.

If you have any questions or require additional information, please contact me at (505) 884-0672 or keblanchard@craworld.com.

Yours truly,

CONESTOGA-ROVERS & ASSOCIATES

Kelly E. Blanchard

Kelly E. Blanchard
Project Manager

KB/cd/1
Encl.

cc: Brandon Powell, NMOCD
Terry Lauck, ConocoPhillips (Electronic Only)
Richard Hodgson, Referenced Property Owner

SUBSURFACE REMEDIATION WORK PLAN

SAN JUAN 29-7 UNIT 37
RIO ARRIBA COUNTY, NEW MEXICO

Prepared For:
ConocoPhillips Company
Risk Management and Remediation
420 South Keeler Avenue
Bartlesville, Oklahoma 74004

NOVEMBER 2011
REF. NO. 075034 (2)

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1.0 INTRODUCTION

ConocoPhillips Company (ConocoPhillips) retained Conestoga-Rovers & Associates (CRA) to conduct site remediation of impacted subsurface soil and groundwater in the area of the San Juan 29-7 Unit 37 gas well production facility (Site). The Site is located within Unit Letter N, Section 12, Township 29N, Range 7W, Rio Arriba County, New Mexico (Latitude: 36.73552° N; Longitude: -107.52488° W) (Figure 1).

The results of recent site characterization activities indicated that groundwater and soil are impacted in the area where the release of condensate from an above ground storage tank occurred on the Site (Figure 2). The hydrocarbon impacts from the release that exceeded state standards included benzene, toluene and total xylenes in groundwater and Total benzene, toluene, ethylbenzene and xylenes (BTEX), total petroleum hydrocarbons-gasoline range organics (TPH-GRO) and total petroleum hydrocarbons-diesel range organics (TPH-DRO) in the vadose zone soil. Soil impacts were delineated in the area of the release to a maximum depth of 110 feet-below ground surface (ft-bgs). Groundwater impacts in the immediate area of the release appear to extend to approximately 60 feet downgradient from the release.

This document contains the work plan for the remediation of the subsurface soil and groundwater that was impacted from the release. The plan includes the technical approach for the injection of the *Cool-Ox*™ Technology that will be used for remediation of the impacted soil and groundwater, confirmation sampling, and a groundwater monitoring plan.

1.1 SITE HISTORY

The surface of the Site is currently owned by Mr. Richard Hodgson and is leased by ConocoPhillips. The San Juan 29-7 Unit 37 natural gas production well was spudded in October 1955 by El Paso Natural Gas Company. Meridian Oil, Inc., a subsidiary of Burlington Resources, Inc. (Burlington), took over the operation of the well on November 1, 1986. ConocoPhillips acquired Burlington on March 31, 2006. The well is currently operated by ConocoPhillips. A Site detail map with the current site features is included as Figure 2.

ConocoPhillips discovered a leaking inspection plate gasket on an above ground condensate tank on August 26, 2010 (Figure 2). Approximately 23 barrels (bbls) of condensate were released and fully contained within the berm; however, no liquids were recovered. The release was immediately reported to the New Mexico Oil

Conservation Division (NMOCD) with a C-141 Release Notification and Corrective Action form filed by ConocoPhillips on September 16, 2010.

2.0 PREVIOUS INVESTIGATIONS

The release from the above ground storage tank was addressed in the area of the release by excavating impacted soil, subsurface soil sampling and groundwater monitoring and sampling from September 2010 to October 2011.

2.1 PRELIMINARY SITE INVESTIGATION AND REMEDIATION, SEPTEMBER 2010 - JANUARY 2011

Following the discovery of the release of condensate from the above ground tank at the site, Envirotech , Inc. (Envirotech) of Farmington, New Mexico excavated soil from the area below the former tank location that was removed. Between September 24, 2010 and January 3, 2011, Envirotech excavated approximately 5,100 cubic yards (yd^3) of soil. The excavation measured approximately 70 ft by 120 ft by 30 ft deep (Figure 2). The horizontal extent of the hydrocarbon-impacted area was not completed and the vertical delineation of the impacted area was not achieved to the regulatory levels. For practical and safety reasons and due to limitations posed by surface structures, the vertical extent of the excavation was halted at approximately 30 ft-bgs. The excavation was subsequently backfilled with clean soil. The excavated soil was hauled to **XXXX** for treatment.

To further delineate impacts vertically, Tetra Tech sampled subsurface soil and groundwater in the impacted area (soil boring B-1) between January 12 and 14, 2011 (Figure 2). Organic vapors were detected in the soil above the NMOCDs recommended field screening level of 100 ppm of the borehole to the total depth of 129.5 ft-bgs. At this depth, a dry shale layer was encountered with a PID reading of 0.5 ppm. Groundwater was encountered at approximately 111 ft-bgs in the boring.

Laboratory results for the samples collected from the borehole are summarized and presented in Tables 1 and 2, respectively. All analytical results for soil samples collected from B-1 were below the recommended NMOCD remediation action levels with the exception of the sample collected from 30 to 32 ft-bgs (Table 1). This sample had a total BTEX concentration of 433.25 milligrams per kilogram (mg/kg) and total TPH at a concentration of 5680 mg/kg. The NMOCD action limits for BTEX, TPH and benzene are 100 mg/kg, 50 mg/kg, and 10 mg/kg, respectively. Analytical results from the groundwater sample collected from the open borehole indicated hydrocarbon concentration in groundwater above the New Mexico Water Quality Control Commission (NMWQCC) standards (Table 2) with a benzene concentration of 0.930 milligrams per liter (mg/L) (NMWQCC standard of 0.01 mg/L), toluene concentration of 15.0 mg/L (NMWQCC standard of 0.75 mg/L) ethylbenzene concentration of 1.4

mg/L (NMWQCC standard of 0.75 mg/L) and total xylenes concentration of 18.8 mg/L (NMWQCC standard of 0.62 mg/L).

2.2 SITE CHARACTERIZATION, FEBRUARY 2011 - MARCH 2011

To further evaluate Site conditions, four groundwater monitoring wells were installed and two additional soil borings were advanced at the Site by Tetra Tech between February 28 and March 4, 2011 (Figure 2). Soil borings were advanced in or near the center of the excavation conducted at the site between September 2010 and January 2011.

Boring B-2 (Figure 3) was located approximately 20 ft north of MW-1 and was advanced to a depth of 120 ft-bgs. Field screening of soil samples indicated soil impacts above the NMOCD field screening action level (100 ppm) from a depth of 102 to 104 ft-bgs (222.9 ppm). The highest organic vapors in B-2 were recorded at a depth of 45 to 47 ft-bgs (6190 ppm)..

Boring B-3 was advanced to a total depth of 57 ft-bgs. Field screening of soil samples collected from B-3 showed no signs of hydrocarbon impacts to a total depth of 57 ft-bgs with all PID readings at 20 ppm or lower. This boring was called "North Boring" in early field data records.

Soil samples were collected for laboratory analysis from the soil boring of all four monitoring wells and B-2 (Table 1 and Figure 3). No samples were collected for laboratory analysis from B-3 since no hydrocarbon impacts were observed and groundwater was not encountered. Soil samples that were detected above the regulatory levels for this phase of the site characterization were found at the following locations and depths:

- B-2 at depths of 45 to 47 ft-bgs; and
- MW-1 at a depth of 50 to 52 ft-bgs.

Due to the elevated vapors encountered in B-2, monitoring well MW-1 was installed approximately 20 ft south of B-2. Three afdditional monitoring wells (MW-2, MW-3, and MW-4) were installed at the Site (Figure 2). Groundwater was encountered in these wells at approximately 110 ft-bgs. The analytical results for these wells from the March 2011 groundwater sampling event indicated that only benzene was detected above the NMWQCC standard in one well (MW-1) at a concentration of 0.066 mg/L (Table 2 and Figure 4). No other monitoring wells showed any hydrocarbon constituents above the NMWQCC groundwater quality standards.

2.3 SITE CHARACTERIZATION, SEPTEMBER 2011 - OCTOBER 2011

To further evaluate Site conditions and to delineate the area of additional remediation, 11 borings were advanced and four monitoring wells were installed at the Site from September 2011 to October 2011 (Figure 2). Soil borings were advanced in the area of the excavation and outside the area of excavation. One monitoring well was installed upgradient of the release and three monitoring wells were installed downgradient of the release.

Field screening of soil samples and laboratory results indicated impacts (organic vapors > 100 ppm) in the immediate area of the release to depths ranging from 40 ft-bgs to 110 ft-bgs. Soil analytical results indicated Total BTEX and TPH above the NMOCD action levels in four of the borings (B-4, B-5/MW-8, B-6/MW-6 and B-8), which are located within the excavation area (Table 1 and Figure 3). In addition, soil boring B-6/MW-6 located approximately 60 feet southeast of the excavation indicated TPH above the NMOCD action limit (Table 1 and Figure 3). Boring B-10, located approximately 10 feet south of the excavation, showed BTEX and TPH above the NMOCD action limits (Table 1 and Figure 3).

Groundwater analytical results are summarized in Table 2 and Figure 4. During this portion of the Site characterization, groundwater was encountered at approximately 110 ft-bgs, which is consistent with groundwater levels encountered during previous phases of the site characterization. The groundwater flow direction was determined to be towards the south (Figure 5). During this phase, groundwater analytical data were collected from borings that showed water and from all monitoring wells. The analytical results indicated benzene exceeded the NMWQCC standard at five locations (MW-1, MW-6/B-6, B-4, B-5/MW-8, and B-8). Toluene exceeded the standard at one location (B-5/MW-8). Total xylenes concentrations exceeded the standard at two locations (B-5/MW-8 and B-8).

2.4 SITE CONCEPTUAL MODEL

The Site has been used as a natural gas production well for approximately 55 years and has contained condensate and produced water storage tanks, as well as, separators and other ancillary equipment. ConocoPhillips discovered a leaking inspection plate gasket on a condensate tank on August 26, 2010 (Figure 2). Approximately 23 bbls of condensate were released and fully contained within the berm; however, no liquids were recovered. The primary chemicals of concern are hydrocarbon constituents that originated from the condensate spill.

Impacted soil was excavated from an area covering approximately 70 ft by 120 ft below the former above-ground storage tank location and the area of the condensate release at the Site (Figure 2). For safety reasons and due to limitations posed by surface structures, the vertical extent of the excavation was halted at approximately 30 ft-bgs. Subsurface conditions at the Site were delineated from March 2011 to October 2011, using 11 soil borings and 8 monitoring wells (Figure 2).

The NMOCD recommended remediation action levels for soil are dependent upon site-specific ranking criteria of:

- depth to groundwater;
- proximity of the wellhead to water sources or private domestic wells; and
- distance to surface water bodies including but not limited to perennial rivers, streams, creeks, irrigation canals, lakes, ponds and playas.

Based on these ranking criteria, the NMOCD action levels for hydrocarbons in soil for the Site are:

- 10 milligrams per kilogram (mg/kg) for benzene;
- 50 mg/kg for total BTEX; and
- 100 mg/kg for TPH.

The NMWQCC standards for hydrocarbons in groundwater are as follows:

- 0.01 milligrams per liter (mg/L) for benzene;
- 0.75 mg/L for toluene;
- 0.75 mg/L for ethylbenzene; and
- 0.62 mg/L for total xylenes.

From the Site characterization, the vadose zone soil that showed impacts above NMOCD action levels covered an approximate area of 5,950 ft^2 or an area covering approximately 70 ft by 85 ft to a depth of 40 ft-bgs to 110 ft-bgs. In general, in this area, the upper 30 feet of impacted soil was removed and the remaining impacted soil warranting remediation includes approximately 8,800 yd^3 (Figures 6 and 7).

Groundwater was encountered in the monitoring wells at the Site at approximately 110 ft-bgs. Analytical results for groundwater samples collected from the monitoring wells indicate hydrocarbon concentrations above the NMWQCC standards at monitoring wells MW-1, MW-6/B-6, MW-8/B-5 and soil boring locations B-4, B-8 and B-10 (Figure 4). No other monitoring wells showed hydrocarbon constituents above the NMWQCC groundwater quality standards. In general, groundwater impacts above the NMWQCC groundwater quality standards were delineated in the area near the release area and extending to approximately 60 feet downgradient and southeast of the point of release.

3.0 SITE REMEDIATION TECHNICAL APPROACH AND PROCEDURES

This section presents the technical approach and procedures that will be used for the remediation of soil and groundwater at the site. The technical approach is based on the current understanding of the site conceptual model and is intended to remediate the site using the *Cool-Ox*™ Technology. The scope of the use of this technology includes treatment in the area covering approximately 5,950 ft^2 (Figure 6).

3.1 DOCUMENTATION

All information collected during the injection of the *Cool-Ox*™ will be documented in such a manner that it can be easily transferred and interpreted by those not familiar with the field activities. In accordance with this goal, bound field logbooks will be maintained throughout the *Cool-Ox*™ injection process, confirmation sampling and quarterly groundwater monitoring. Each page will be legible when copied and written using an indelible-ink pen for all records. The pages in the logbook will be dated, numbered and initialed by the recorder. In addition to the field data, general information will also be recorded, such as equipment used, equipment calibration records, daily weather conditions, personnel onsite, site safety meeting and any anomalies that may occur during field activities.

3.2 UTILITY LOCATION

Prior to initiation of field activities, CRA will call ConocoPhillips and New Mexico One Call and arrange for buried pipelines and utilities to be located and marked in the area of the Site.

3.3 HEALTH AND SAFETY PLAN AND JOB SAFETY ANALYSIS

The project health and safety plan includes a discussion of the field activities and a map to the nearest medical facility. A copy of the health and safety plan will be kept onsite during all field activities. CRA will conduct daily health and safety "tailgate" meetings prior to initiation of field activities, to evaluate the potential safety risks associated with the drilling activities. A daily Job Hazard Analysis (JHA) will be completed to evaluate potential safety risks associated with the field activities.

3.4 COOL-OX™ IN-SITU TREATMENT

For site remediation, DeepEarth Technologies, Inc. (DTI) will use the *Cool-Ox*™ Technology which is a patented in-situ and ex-situ remediation process that uses a patented solution of calcium peroxide that generates hydrogen peroxide slowly and facilitates the oxidation of petroleum hydrocarbons. A simple stoichiometric diagram for the reaction is included as Appendix A. The Material Safety Data Sheet (MSDS) for *Cool-Ox*™ is included as Appendix B. The *Cool-Ox*™ treatment facilitates an accelerated biodegradation of petroleum hydrocarbons following the oxidation phase by releasing nutrients without any exothermic reaction and reduces the mobility, toxicity and volume of the hydrocarbon impacts. The process is based on using hydrogen peroxide as the generator of the oxidizing radicals; however, unlike the traditional Fenton Reaction, or Fenton-like processes that use liquid hydrogen peroxide, the *Cool-Ox*™ process generates hydrogen peroxide from solid, food-grade, peroxygens that are injected into the soil and/or groundwater in an aqueous suspension. Once in place, the peroxygens react to produce hydrogen peroxide without an exothermic reaction as would occur with a Fenton-like process. The *Cool-Ox*™ process eliminates Fenton-like problems because the peroxygens employed are only sparingly soluble in aqueous solutions, and thus, the dissolution rate is quite slow. Once injected, they remain in the impacted media for an extended period of time before undergoing hydrolysis. The low solubility coupled with the buffered solution and the process taking place at a slightly basic pH eliminates the need to inject iron salts and results in greater control over the process. The *Cool-Ox*™ process treats a wide range of chemicals due to the controlled nature of the process and the slightly alkaline pH of 8 and also works well in calcareous soils.

The *Cool-Ox*™ process to treat the subsurface soil and groundwater impacts at the site will utilize a small probe, direct push technology (DPT) drill rig supported by DTI's mixing and injection trailer (the Deep-Shot-Rig™) to advance temporary 1.5-inch diameter injection points on 8-foot spacings in the area shown in Figure 8. Approximately 90 to 93 injection points (IPs), depending on Site surface and subsurface structures, will be used to inject an estimated 60,000 gallons of *Cool-Ox*™ solution over an approximate area of 5,950 ft^2 (70 ft x 85 ft) to treat approximately 8,815 yd^3 of impacted soil (Figures 6 and 7). In the area that was excavated, the injection process will begin at 30 ft-bgs and continue to the depth that was assessed during the investigative phase (Figures 6 and 7). The depth of vadose zone soil impacts that were delineated during the investigative phase varied from 40 ft-bgs to top of groundwater, which was encountered at approximately 110 ft-bgs. Therefore, on the edges of the soil impacts the injection will be from near surface to 40 ft-bgs and near the center of the impacts or near the release point from 30 ft-bgs to a depth of 110 ft-bgs. In addition, Monitoring Wells MW-1, MW-6, MW-7 and MW-8 will be used to inject *Cool-Ox*™ into groundwater.

The reaction of the injected *Cool-Ox*™. with the hydrocarbons will be expressed if impacts are encountered and noted in the site logbook. A characteristic of the *Cool-Ox*™

technology is the production of a lather (resembling dirty shaving cream), when the reagent reacts with hydrocarbon impacts. However, at depths greater than 30 feet, the reaction may not be observed on the surface. If impacts are present at the IPs and visible on the surface, the evolution of foam reveals impacts. During the treatment process it is quite normal to adjust the injection technique and IP spacing to compensate for varying site conditions or impacts. Each temporary injection point will be sealed using hydrated bentonite.

3.5 CONFIRMATION SAMPLING

To evaluate the effectiveness of the *Cool-Ox*™ treatment of soil and groundwater at the site, groundwater will be monitored on a quarterly basis following the completion of the injection of the *Cool-Ox*™ for one year. After one year, the monitoring program and the analytical program will be revaluated and appropriately amended, if necessary.

Groundwater samples will be collected for analysis of BTEX and heterotrophic plate count (HPC) analysis, as well as dissolved manganese and dissolved selenium, the only NMWQCC regulated metals that were discovered above their respective standards during the initial baseline sampling event in March 2011. The HPC data will be collected to verify biodegradation (i.e. increased hydrocarbon-degrading microbe populations) after the *Cool-Ox*™ treatment. In addition, field parameters to include dissolved oxygen (DO), pH, temperature, oxidation reduction potential (ORP) and specific conductance will be measured and recorded. Groundwater samples will be collected using a disposable bailer and placed into the appropriate laboratory-provided containers following field parameter measurements.

Approximately four months after the completion of the *Cool-Ox*™ treatment, subsurface soil samples will be acquired at the site from five (5) borings that will be located within the treatment area. Subsurface soil samples in the affected areas will be collected either continuously or at a minimum of every five (5) feet depending on subsurface conditions, such as staining, using a hollow-stem auger (HSA) drill rig in conjunction with a split-spoon sampler. The split-spoon samples will be screened using the PID, which will be calibrated daily and samples selected for analyses by the site geologist will be placed into an appropriate sample container for submission to the laboratory. The samples selected for laboratory analyses will be determined based on the olfactory, visual evidence and head space analysis using the PID. At a minimum, the soil sample with either the highest head space concentration per boring and at the total depth of the boring will be submitted for laboratory analysis. For head space analysis, a portion of the soil sample interval will be placed into a clean Ziploc bag, allowed to warm for 30 minutes and then screened using the PID. The data will be recorded in the site logbook and on the lithologic log form.

Each sample for laboratory analysis will be identified by the soil boring number, depth of the sample, date and time of the sample collection, requested analyses and initials of the sampler. The samples will be placed in an ice-chilled cooler immediately for transport under chain-of-custody protocol to the laboratory.

The split spoon sampler will be decontaminated prior to the collection of each sample. Drilling and sampling equipment will be thoroughly cleaned prior to initiation of drilling activities and in between each boring location at the site. Decontamination procedures for the split-spoon sampler will include a wash with an Alconox (or similar) detergent solution, a fresh water rinse, and air-drying if possible. The drilling equipment will be cleaned between each boring with a high-pressure steam cleaner. All soil borings will be sealed and plugged with hydrated bentonite chips upon completion of each boring. CRA Standard Operating Procedures will be followed as in Appendix C.

3.6 ANALYTICAL PROGRAM

Groundwater samples from all Site monitoring wells will be analyzed for BTEX by EPA Method 8260B, HPC by Method 9215, dissolved manganese and selenium by Method 6010B, nitrate and sulfate by Method 300.0, and total dissolved solids (TDS) by Method SM2540C. Groundwater samples will be collected quarterly for at least one year from MW-4 and a nearby water supply well and analyzed for nitrate, sulfate, and TDS in order to attempt to demonstrate those constituents are at background levels at the Site. Confirmation soil samples will be analyzed for TPH-GRO and TPH-DRO by Method SW8015B or 8260B and BTEX by EPA Method 8260B.

3.7 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control measures will be followed according to industry accepted standards. One duplicate groundwater sample will be collected for each sampling event and one duplicate soil sample will be collected during the confirmation soil sampling. A trip blank will be included in each cooler shipped to the laboratory. The trip blanks will be analyzed for BTEX. A temperature trip blank will be included with each submitted cooler and used to determine temperature at the time of submission to the lab.

patented solution of calcium peroxide that generates hydrogen peroxide slowly and facilitates the oxidation of petroleum hydrocarbons. A simple stoichiometric diagram for the reaction is included as Appendix A. The Material Safety Data Sheet (MSDS) for *Cool-Ox*™ is included as Appendix B. The *Cool-Ox*™ treatment facilitates an accelerated biodegradation of petroleum hydrocarbons following the oxidation phase by releasing nutrients without any exothermic reaction and reduces the mobility, toxicity and volume of the hydrocarbon impacts. The process is based on using hydrogen peroxide as the generator of the oxidizing radicals; however, unlike the traditional Fenton Reaction, or Fenton-like processes that use liquid hydrogen peroxide, the *Cool-Ox*™ process generates hydrogen peroxide from solid, food-grade, peroxygens that are injected into the soil and/or groundwater in an aqueous suspension. Once in place, the peroxygens react to produce hydrogen peroxide without an exothermic reaction as would occur with a Fenton-like process. The *Cool-Ox*™ process eliminates Fenton-like problems because the peroxygens employed are only sparingly soluble in aqueous solutions, and thus, the dissolution rate is quite slow. Once injected, they remain in the impacted media for an extended period of time before undergoing hydrolysis. The low solubility coupled with the buffered solution and the process taking place at a slightly basic pH eliminates the need to inject iron salts and results in greater control over the process. The *Cool-Ox*™ process treats a wide range of chemicals due to the controlled nature of the process and the slightly alkaline pH of 8 and also works well in calcareous soils.

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The reaction of the injected *Cool-Ox*™ with the hydrocarbons will be expressed if impacts are encountered and noted in the site logbook. A characteristic of the *Cool-Ox*™ technology is the production of a lather (resembling dirty shaving cream), when the reagent reacts with hydrocarbon impacts. However, at depths greater than 30 feet, the reaction may not be observed on the surface. If impacts are present at the IPs and visible on the surface, the evolution of foam reveals impacts. During the treatment process it is quite normal to adjust the injection technique and IP spacing to compensate for varying site conditions or impacts. Each temporary injection point will be sealed using hydrated bentonite.

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Each sample for laboratory analysis will be identified by the soil boring number, depth of the sample, date and time of the sample collection, requested analyses and initials of the sampler. The samples will be placed in an ice-chilled cooler immediately for transport under chain-of-custody protocol to the laboratory.

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Quality assurance/quality control measures will be followed according to industry accepted standards. One duplicate groundwater sample will be collected for each sampling event and one duplicate soil sample will be collected during the confirmation soil sampling. A trip blank will be included in each cooler shipped to the laboratory. The trip blanks will be analyzed for BTEX. A temperature trip blank will be included with each submitted cooler and used to determine temperature at the time of submission to the lab.

4.0 REPORTING

Upon completion of the groundwater monitoring for one year, CRA will evaluate the data collected and prepare a report presenting the results and summarizing the use *Cool-Ox*™ for the Site. The report will contain the soil and groundwater analytical results, groundwater levels, potentiometric surface maps for each monitoring period, and the locations of the *Cool-Ox*™ injections.

FIGURES

SOURCE: USGS 7.5 MINUTE QUAD
"DELGADITA MESA, NEW MEXICO"

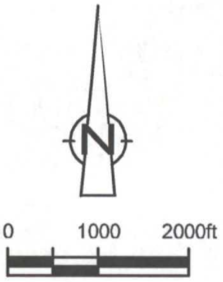

figure 1

SITE LOCATION MAP
SAN JUAN 29-7 UNIT 37
UNIT LETTER N. SEC 12. T29N, R07W
RIO ARRIBA COUNTY, NEW MEXICO
ConocoPhillips Company

FIGURE 2

Soil Boring Location Map

CONOCOPHILLIPS COMPANY
SAN JUAN 29-7 UNIT 37
GAS PRODUCTION WELL SITE
Unit Letter N, Sec 12, T29N, R07W
Rio Arriba County, New Mexico

LEGEND

- ☼ ConocoPhillips San Juan 29-7 Unit 37 Wellhead
- ● Boring Location
- ▲ Monitoring Well
- – – Approximate 2010 Excavation Location
- – – – Approximate Location of Current San Juan 29-7 Unit 37 Tank Placement (aerial image shows prior tank placement)

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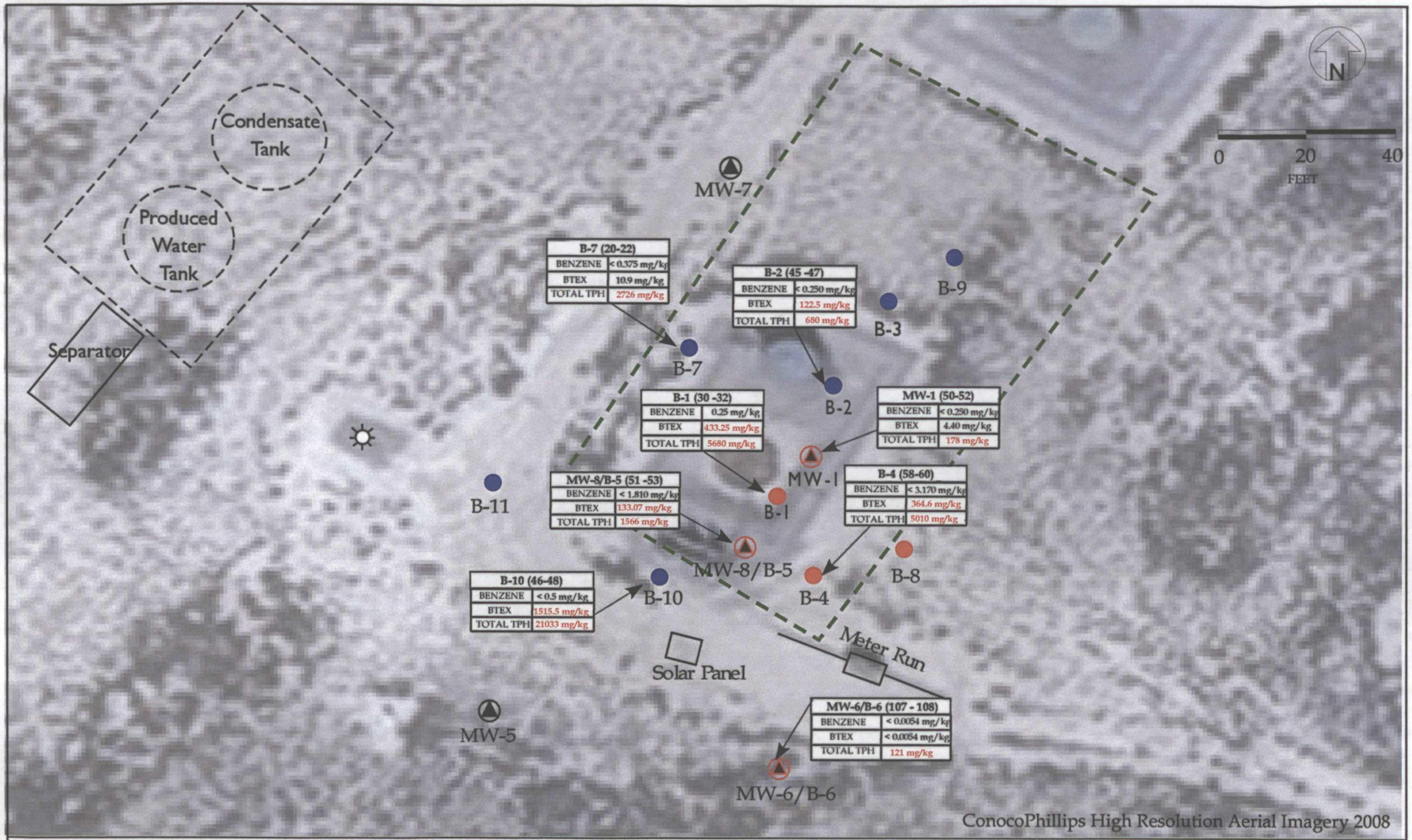
CONESTOGA-ROVERS & ASSOCIATES



ConocoPhillips High Resolution Aerial Imagery 2008

FIGURE 3

Soil Boring Analytical Results Map

CONOCOPHILLIPS COMPANY
SAN JUAN 29-7 UNIT 37
GAS PRODUCTION WELL SITE
Unit Letter N, Sec 12, T29N, R07W
Rio Arriba County, New Mexico

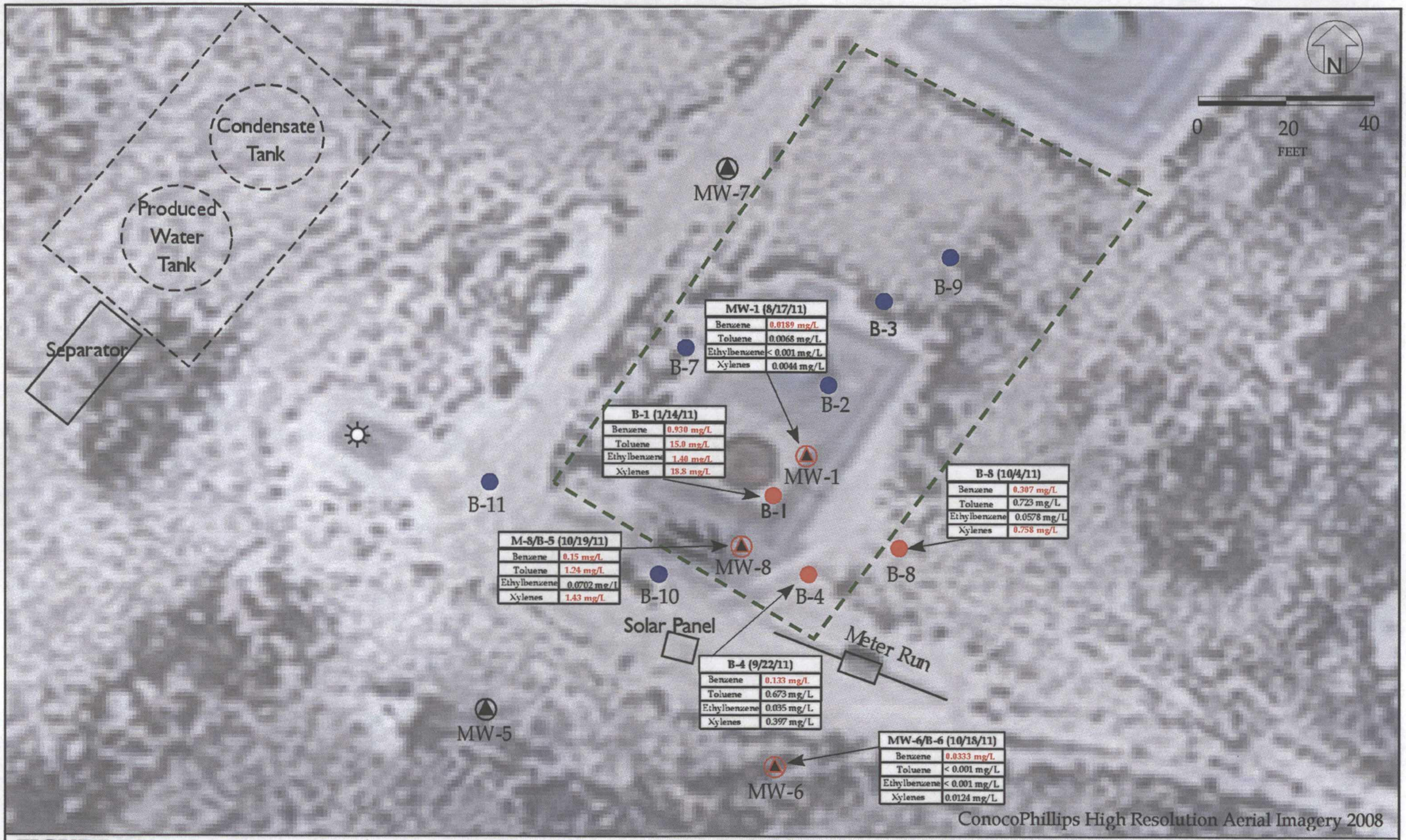
LEGEND

- ☼ ConocoPhillips San Juan 29-7 Unit 37 Wellhead
- ● Boring Location
- ▲ Monitoring Well
- - - Approximate 2010 Excavation Location
- ▲ Monitoring Well with Groundwater Impacts
- ● Boring with Groundwater Impacts
- - - - Approximate Location of Current San Juan 29-7 Unit 37 Tank Placement (aerial image shows prior tank placement)
- **BOLD** Exceeds New Mexico Oil Conservation Division (NMOCD) Recommended Remediation Action Levels

BENZENE	10 mg/kg
BTEX	50 mg/kg
TOTAL TPH	100 mg/kg

NMOCD Recommended Remediation Action Levels
Note* TPH standard considers combined concentrations of DRO and GRO

CONESTOGA-ROVERS & ASSOCIATES



MW-1 (8/17/11)	
Benzene	**0.0189 mg/L**
Toluene	0.0068 mg/L
Ethylbenzene	< 0.001 mg/L
Xylenes	0.0044 mg/L

B-1 (1/14/11)	
Benzene	**0.930 mg/L**
Toluene	**15.0 mg/L**
Ethylbenzene	**1.40 mg/L**
Xylenes	**18.8 mg/L**

B-8 (10/4/11)	
Benzene	**0.307 mg/L**
Toluene	0.723 mg/L
Ethylbenzene	0.0578 mg/L
Xylenes	**0.758 mg/L**

M-8/B-5 (10/19/11)	
Benzene	**0.15 mg/L**
Toluene	**1.24 mg/L**
Ethylbenzene	0.0702 mg/L
Xylenes	**1.43 mg/L**

B-4 (9/22/11)	
Benzene	**0.133 mg/L**
Toluene	0.673 mg/L
Ethylbenzene	0.035 mg/L
Xylenes	0.397 mg/L

MW-6/B-6 (10/18/11)	
Benzene	**0.0333 mg/L**
Toluene	< 0.001 mg/L
Ethylbenzene	< 0.001 mg/L
Xylenes	0.0124 mg/L

FIGURE 4
Groundwater Analytical Results Map

CONOCOPHILLIPS COMPANY
SAN JUAN 29-7 UNIT 37
GAS PRODUCTION WELL SITE
Unit Letter N, Sec 12, T29N, R07W
Rio Arriba County, New Mexico

LEGEND

- ☼ ConocoPhillips San Juan 29-7 Unit 37 Wellhead
- ● Boring Location
- ▲ Monitoring Well
- - - Approximate 2010 Excavation Location
- ▲ Monitoring Well with Groundwater Impacts
- ● Boring with Groundwater Impacts
- - - - Approximate Location of Current San Juan 29-7 Unit 37 Tank Placement (aerial image shows prior tank placement)
- **BOLD** Exceeds New Mexico Water Quality Control Commission (NMWQCC) Standards

NMWQCC Standards

Benzene	0.01 mg/L
Toluene	0.750 mg/L
Ethylbenzene	0.750 mg/L
Xylenes	0.620 mg/L

CONESTOGA-ROVERS & ASSOCIATES

ConocoPhillips High Resolution Aerial Imagery 2008

FIGURE 5

GROUNDWATER POTENTIOMETRIC
MAP OCTOBER 2011

CONOCOPHILLIPS COMPANY
SAN JUAN 29-7 UNIT 37
GAS PRODUCTION WELL SITE
Unit Letter N, Sec 12, T29N, R07W
Rio Arriba County, New Mexico

LEGEND

- ☼ ConocoPhillips San Juan 29-7 Unit 37 Wellhead
- – – Approximate 2010 Excavation Location
- – – Location of Current San Juan 29-7 Unit 37 Tank Placement (aerial image shows prior tank placement)
- – – Groundwater Elevation Contour Lines (Dashed where inferred)
- ● Boring Location
- ▲ Monitoring Well

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CONESTOGA-ROVERS & ASSOCIATES

ConocoPhillips High Resolution Aerial Imagery 2008

FIGURE 6

Soil Impacts Map

CONOCOPHILLIPS COMPANY
SAN JUAN 29-7 UNIT 37
GAS PRODUCTION WELL SITE
Unit Letter N, Sec 12, T29N, R07W
Rio Arriba County, New Mexico

LEGEND

☼ ConocoPhillips San Juan 29-7 Unit 37 Wellhead
● Boring Location
▲ Monitoring Well
- - Approximate 2010 Excavation Location
- - - Approximate Location of Current San Juan 29-7 Unit 37 Tank Placement (aerial image shows prior tank placement)

93 Total Depth of Soil Impacts (feet below ground surface) Based on Photoionization Detector Readings over 100 parts per million, If any

— Soil Impact Contour Line

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CONESTOGA-ROVERS & ASSOCIATES

M:\clients\CRA\COP_San-Juan\3-D_Rendering-fig7.dwg, Created 11/22/2011,Plotted 11/22/2011

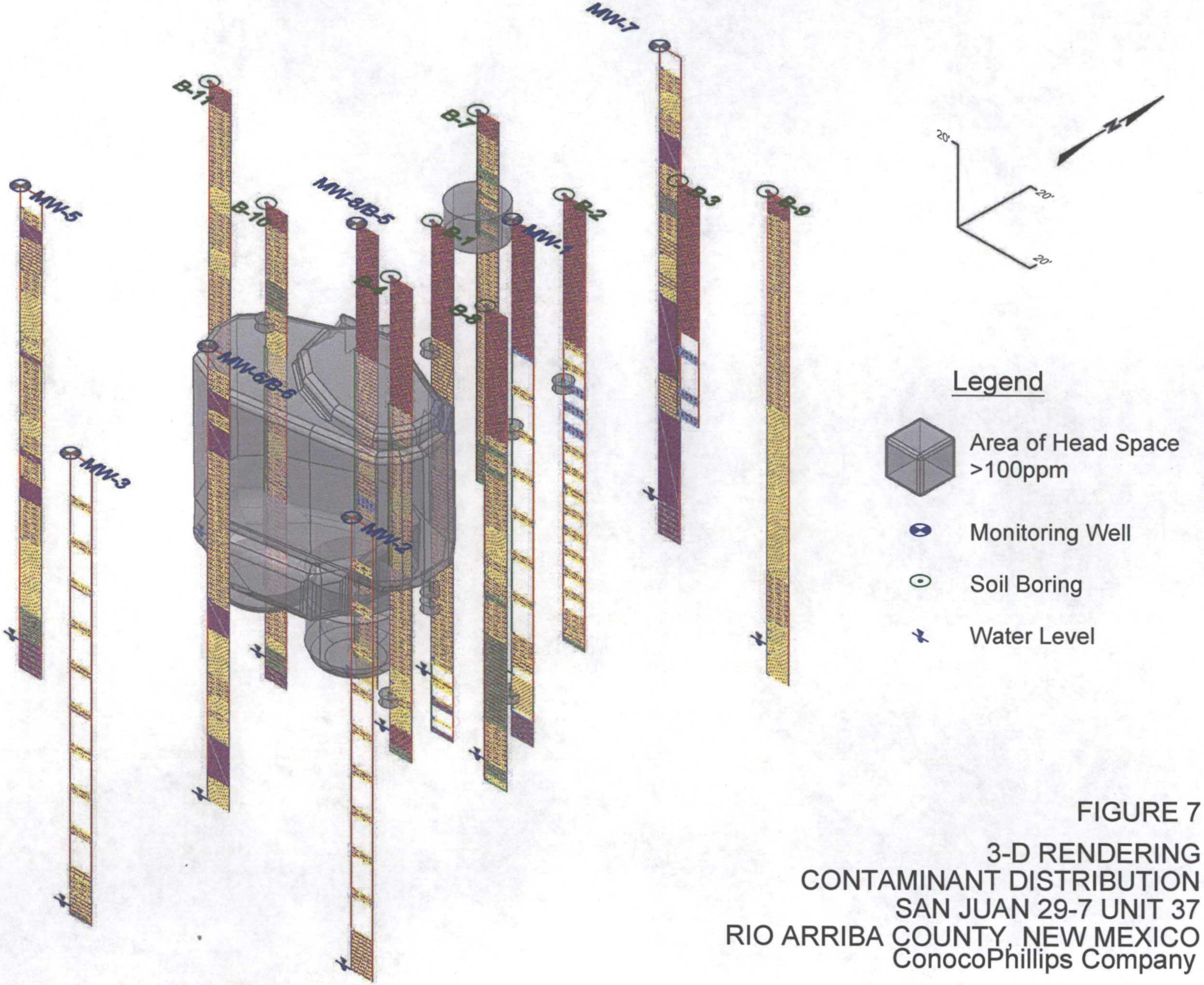
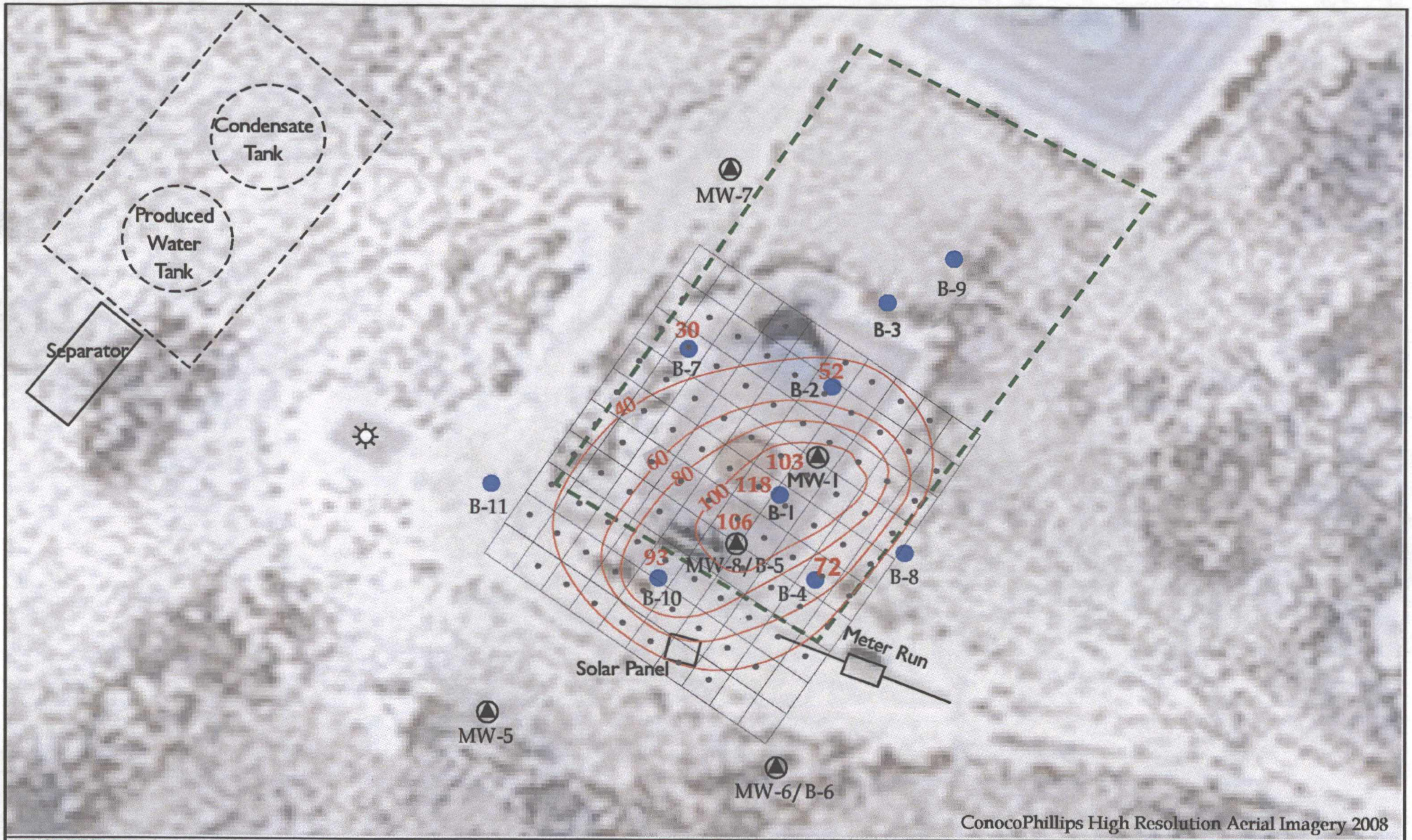


FIGURE 7

3-D RENDERING
CONTAMINANT DISTRIBUTION
SAN JUAN 29-7 UNIT 37
RIO ARRIBA COUNTY, NEW MEXICO
ConocoPhillips Company



ConocoPhillips High Resolution Aerial Imagery 2008

FIGURE 8
Example of Potential
Cool Ox™ Injection
Point Grid*
CONOCOPHILLIPS COMPANY
SAN JUAN 29-7 UNIT 37
GAS PRODUCTION WELL SITE
Unit Letter N, Sec 12, T29N, R07W
Rio Arriba County, New Mexico

LEGEND

- ☼ ConocoPhillips San Juan 29-7 Unit 37 Wellhead
- ● Boring Location
- ▲ Monitoring Well
- – – Approximate 2010 Excavation Location
- - - - Approximate Location of Current San Juan 29-7 Unit 37 Tank Placement (aerial image shows prior tank placement)
- **93** Total Depth of Soil Impacts (feet below ground surface) Based on Photoionization Detector Readings over 100 parts per million, If any
- — Soil Impact Contour Line

*Cool Ox™ Injection Grid is Approximate; Actual grid will be determined in the field

CONESTOGA-ROVERS & ASSOCIATES

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TABLES

TABLE 1
Laboratory Soil Analytical Results Summary
ConocoPhillips Company San Juan 29-7 Unit 37

Sample Name	Date	Headspace (ppm)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX	TPH DRO (mg/kg)	TPH GRO (mg/kg)	Total TPH (mg/kg)
B-1 (30-32)	1/14/2011	2686	0.25	48	11	374	**433.25**	380	5300	**5680**
B-1 (66-68)	1/14/2011	467	< 0.0064	0.11	0.082	1.88	2.072	11	14	25
B-1 (68-70)	1/14/2011	346	< 0.0058	0.014	< .0058	0.089	0.103	12	0.38	12.38
B-1 (86-88)	1/14/2011	103	< 0.0054	< 0.0054	< .0054	< .0054	--	< 5.0	< 0.1	--
B-1 (88-90)	1/14/2011	485	< 0.0051	< 0.0051	< .0051	0.017	0.017	< 5.0	< 0.1	--
B-1 (92-94)	1/14/2011	722	< 0.0056	0.006	< .0056	0.017	0.023	< 5.0	0.14	0.14
B-1 (122.5-123.5)	1/14/2011	0.5	< 0.005	0.096	0.022	0.347	0.465	< 5.0	0.11	0.11
B-2 (45-47)	3/1/2011	6190	< 0.25	6.6	4.9	111.0	**122.5**	50	630	**680**
B-2 (106-108)	3/1/2011	50.7	< 0.005	0.012	< .005	0.0343	0.0463	< 5.0	0.13	0.13
B-4 (58-60)	9/22/211	2077	< 3.17	53.6	13.0	298.0	**364.60**	1,150	3,860	**5010**
B-4 (106-108)	9/22/2011	7.1	< 0.006	0.0181	<0 .006	0.0364	0.0545	< 10.2	< 14.7	--
B-5 (51-53)	9/22/2011	2546	< 1.810	50.8	5.47	76.8	**133.07**	366	1,200	**1566**
B-5 (103-105)	9/23/2011	210.1	< 0.0054	0.0286	< 0.0054	0.026	0.0546	< 10.2	< 13.4	--
B-6 (107-108)	9/26/2011	6.4	< 0.0054	< 0.0054	< 0.0054	< 0.0107	--	121	< 11.7	**121**
B-7 (20-22)	9/27/2011	2482	< 0.375	< 0.375	< 0.375	10.9	10.9	2,440	286	**2726**
B-8 (108-110)	10/3/2011	0.4	< .0057	< .0057	< .0057	< 0.0057	--	< 10.3	< 16.2	--
B-9 (100-102)	10/13/2011	0.9	< 0.0056	< 0.0056	< 0.0056	< 0.0056	--	< 10.6	< 20.2	--
B-10 (46-48)	10/18/2011	2595	< 5.0	333	62.5	1120	**1515.5**	933	20100	**21033**
B-10 (105-107)*	10/18/2011	27.6	< .0055	0.0552	0.01	0.162	0.2272	< 10.5	17.6	17.6
B-11 (100-102.5)	10/20/2011	0.3	< 0.0064	< 0.0064	< 0.0064	< 0.0064	--	< 0.0102	< 0.0167	--
MW-1 (50-52)	3/3/2011	2118	< 0.25	< 0.25	< 0.25	4.4	4.4	110	68	**178**
MW-1 (114-116)	3/3/2011	106.4	< 0.005	< 0.005	< 0.005	< 0.005	--	< 5.0	0.73	0.73
MW-2 (106-108)	3/2/2011	5.9	< 0.005	< 0.005	< 0.005	< 0.005	--	< 5.0	< 0.1	--
MW-3 (106-108)	3/2/2011	4.4	< 0.005	< 0.005	< 0.005	< 0.005	--	< 5.0	< 0.1	--
MW-4 (102-104)	2/28/2011	30.2	< 0.005	< 0.005	< 0.005	< 0.005	--	91	1.5	92.5
MW-4 (111-113)	2/28/2011	2.2	< 0.005	< 0.005	< 0.005	< 0.005	--	0.1	< 5.0	0.1
MW-5 (107-108.5)	9/24/2011	144.0	< .0.0054	< 0.0054	< 0.0054	< 0.0108	--	< 10	< 11.6	--
MW-6	9/26/2011	See Results for B-6								
MW-7 (105-107.5)	10/12/2011	8.4	< 0.0059	< 0.0059	< 0.0059	< 0.0059	--	< 11.1	< 20.3	--
MW-8	9/22/2011	See Results for B-5								
NMOCD Action Limits		**100**	**10 mg/kg**	**NE**	**NE**	**NE**	**50 mg/kg**	**NE**	**NE**	**Total TPH = 100 mg/kg**

Notes:
MW = monitoring well
B = Soil Boring
NMOCD = New Mexico Oil Conservation Division
BOLD = Exceeds NMWQCC Action Limits
mg/kg = milligrams per kilogramliter (parts per million)
< 0.005 = below laboratory detection limit
NE = Not Established

TABLE 2
GROUNDWATER ELEVATIONS AND ANALYTICAL SUMMARY
CONOCOPHILLIPS SAN JUAN 29-7 UNIT 37

Well ID	**Measuring Point Elevation (ft)*	*Date*	*Depth to Groundwater (ft-TOC)*	*Groundwater Elevation (ft-TOC)*	*Benzene (mg/L)*	*Toluene (mg/L)*	*Ethylbenzene (mg/L)*	*Xylenes (total) (mg/L)*	*TPH-DRO (mg/L)*	*TPH-GRO (mg/L)*	*Manganese (dissolved) (mg/L)*	*Selenium (dissolved) (mg/L)*	*Nitrate (as N) (mg/L)*	*Sulfate (mg/L)*	*Total dissolved solids (TDS) (mg/L)*	*Heterotrophic Plate Count (CFU/mL)*
MW-1	189.86	3/17/2011	108.91	80.95	**0.066**	0.39	0.011	0.084	0.28	1.5	**2.77**	<0.01	<0.500	**1610**	**2730**	--
		8/17/2011	108.81	81.05	**0.0189**	0.0068	<0.001	0.0044	<0.50	<0.50	**0.318**	<0.015	0.25	**1500**	**2480**	180,000
		10/18/2011	108.87	80.99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	300,000
MW-2	188.94	3/17/2011	109.20	79.74	<0.001	<0.001	<0.001	<0.001	< 0.11	< 0.1	**0.334**	**0.0664**	**55.8**	**1000**	**2950**	NA
		8/17/2011	109.10	79.84	<0.001	<0.001	<0.001	<0.003	<0.50	<0.50	0.179	**0.0726**	**71.9 E / 54.1**	**1040**	**2110**	61,000
		10/18/2011	109.13	79.81	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	124,000
MW-3	188.35	3/17/2011	109.42	78.93	<0.001	0.013	<0.001	0.0042	< 0.1	< 0.1	**1.79**	0.0316	**29.7**	**857**	**2360**	NA
		8/17/2011	109.35	79.00	<0.001	<0.001	<0.001	<0.003	<0.50	<0.50	**1.42**	**0.0524**	**33.0**	**972**	**1960**	18,000
		10/18/2011	109.37	78.98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	230,000
MW-4	198.16	3/17/2011	111.11	87.05	<0.001	<0.001	<0.001	<0.001	0.14	< 0.1	0.0215	0.042	**10.4**	**1290**	**2650**	NA
		8/17/2011	111.10	87.06	<0.001	<0.001	<0.001	<0.003	<0.50	<0.50	0.0062	0.0402	9.4	**1240**	**2000**	9800
		10/18/2011	111.16	87.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	90,000
MW-5	--	10/18/2011	118.05**	--	< 0.0010	< 0.0010	< 0.0010	< 0.0030	< 0.5	< 0.5	NA	NA	NA	NA	NA	970,000
MW-6	--	10/18/2011	109.55**	--	**0.0333**	< 0.0010	< 0.0010	0.0124	< 0.5	< 0.5	NA	NA	NA	NA	NA	720,000
MW-7	--	10/18/2011	119.7**	--	< 0.0010	< 0.0010	< 0.0010	< 0.003	< 0.5	< 0.5	NA	NA	NA	NA	NA	2,000,000
MW-8	--	10/19/2011	--	--	**0.15**	**1.24**	0.0702	**1.43**	< 0.5	7.1	NA	NA	NA	NA	NA	2,300,000
B-1	--	1/14/2011	--	--	**0.930**	**15.0**	**1.40**	**18.80**	1.4	73	NA	NA	NA	NA	NA	NA
B-4	--	9/22/211	--	--	**0.133**	0.673	0.035	0.397	0.57	3.2	NA	NA	NA	NA	NA	NA
B-5	--	9/23/2011	--	--	**0.297**	**0.954**	0.109	**1.450**	NA	NA	NA	NA	NA	NA	NA	NA
B-6	--	--	--	--	No Sample Obtained, too much mud in hole to bail											
B-7	--	--	--	--	No Sample Obtained (augers stuck at 95 feet bgs)											
B-8	--	10/4/2011	--	--	**0.307**	0.723	0.0578	**0.758**	< 0.61	6.8	NA	NA	NA	NA	NA	NA
B-9	--	10/14/2011	--	--	< 0.001	< 0.001	< 0.001	< 0.003	< 1.6	< 0.5	NA	NA	NA	NA	NA	NA
B-10	--	--	--	--	No Sample Obtained, dry hole											
B-11	--	--	--	--	No Sample Obtained, dry hole											
NMWQCC Standards					**0.01**	**0.75**	**0.75**	**0.62**	NE	NE	**0.2**	**0.05**	**10**	**600**	**1000**	NE

Notes:
MW = Monitoring Well
B = Soil Boring
NMWQCC = New Mexico Water Quality Control Commission
BOLD/Red = Exceeds NMWQCC Groundwater Quality Standard
mg/L = milligrams per liter (parts per million)
'<' = Analyte not detected above set laboratory detection limit
E = Analyte concentration exceeded the calibration range
ft = Feet
TOC = below top of casing
* = Elevation relative to an arbitrary 200 feet
** = Wells not surveyed.
NE = Not Established
NA = Not analyzed
TPH DRO = total petroleum hydrocarbons diesel range organics
TPH GRO = total petroleum hydrocarbons gasoline range organics

APPENDIX A

COOL OX™ STOICHIOMETRIC DIAGRAM

DeepEarth Technologies, Inc.

How Does it Work?

(Produce Hydrogen Peroxide In-Situ)

$$CaO_2 + H_20 \rightarrow Ca(OH)_2 + H_2O_2 + O_2$$

(Chelates Activate Intrinsic Catalysts – Produces Radicals)

$$H_2O_2 + Fe^{+2} \rightarrow (OH)^- + [OH]^\bullet + Fe^{+3}$$

$$H_2O_2 + Fe^{+3} \rightarrow (OH)^- + [OOH]^\bullet + Fe^{+2}$$

(Radicals React with Contaminants – Oxidation By-products)

$$[OH]^\bullet \;\&\; [OOH]^\bullet + C_x \rightarrow C_x(OH)_y$$

(Biodegradable By-products Used by Microbes)

$C_x(OH)_y + O_2 \rightarrow CO_2$ **Totally Green**

Cool-Ox™

APPENDIX B

COOL OX™ MATERIAL SAFETY DATA SHEET

Cool-Ox™

Material Safety Data Sheet

1. Chemical Product and Supplier Identification

Product Name: *Cool-Ox*™ — Cool-Ox is a registered trademark of DeepEarth Technologies, Inc., all rights reserved.
Chemical Name: Oxidizer
Chemical Family: Peroxygens
Trade Names: Cool-Ox ™
Formulator: DeepEarth Technologies, Inc.
12635 South Kroll Drive
Alsip, IL 60803

Toll free: 1-877-Cool-Ox-1
Emergency: 1-312-909-3667
1-850-206-3260

MSDS Number: PB-01
Issue Date: July 1, 2011
Patented Product: Formulation and use of this product is protected under USPTO Patent # 6,843,618.

2. Composition/Information on Ingredients

Components:

Compound	CAS Number
Calcium Peroxide	1305-79-9
EDTA	60-00-4
DTPA	67-43-6
EDDHA	1170-02-1
Potassium Phosphate	7778-77-0
Ammonium Phosphate	7783-28-0

3. Hazards Identification

Emergency Overview: Oxidizer - Contact with combustibles may under extreme circumstances, cause fire. In fire, material decomposes, releasing oxygen that may intensify the fire.

Potential Health Effects: Irritating to the mucous membrane and eyes. If product contacts eyes and face, treat eyes first. Submerge contaminated clothing in water prior to drying. Do not dry near open flame or heat source.

Inhalation: At high concentrations, slight nose and throat irritation with cough. In case of repeated or prolonged exposure, there is a risk of sore throat and nose bleeds.

Eye contact: Severe eye irritation with watering and redness. Risk of serious or permanent eye lesions.

Skin contact: In case of prolonged contact; irritation.

Ingestion: Irritation of the mouth and throat with nausea and vomiting.

4. First-Aid Measures

Inhalation: Remove the subject from dusty environment. Consult with a physician in case of respiratory symptoms.

Eye contact: Flush eyes with running water for 15 minutes, while keeping the eyelids wide open. Consult with ophthalmologist in all cases.

Skin contact: Wash the affected skin with running water. Remove and clean clothing. Consult with a physician in case of persistent pain or redness.

Ingestion: If the victim is conscious, rinse mouth and administer fresh water. **DO NOT induce vomiting**. Consult a physician in all cases.

5. Fire-Fighting Measures

Flash point:	Not applicable
Flammability:	Not applicable
Auto-flammability:	Not applicable
Danger of explosion:	Non-explosive
Common extinguishing methods:	Large quantities of water, water spray. In case of fire in close proximity, all means of extinguishing are acceptable.
Inappropriate extinguishing methods:	No restriction.
Special precautions:	Evacuate all non-essential personnel. Intervention only by capable personnel who are trained and aware of the hazards of the product. If safe to do so, remove unaffected product to a safe area.
Specific hazards:	Oxidizing substance. Oxygen released on exothermic decomposition may support combustion in case of surrounding fire. Pressure burst may occur due to decomposition in confined spaces/containers. Contact with flammables may cause fire or explosion.
Fire fighting instructions:	Personnel should wear full bunker gear and positive-pressure, self-contained breathing apparatus. Apply cooling water to sides of transport or storage vessels that are exposed to flames until fire is out. Do not approach hot vessels containing product.

6. Accidental Release Measures

Precautions:	Observe the protection measures given in Sections 5 and 8. Avoid materials and products which are incompatible with the product (see Section 10). Avoid direct contact of the product with water. Immediately notify the appropriate authorities in case of reportable discharge.
Cleanup methods:	Collect the product with a means suitable to avoid dust formation. All the receiving equipment should be clean, vented, dry, labeled and made of material that is compatible with the product. Because of the contamination risk, the collected material should be isolated in a safe place. Clean the area with large quantities of water. For disposal methods, refer to Section 13.

7. Handling and Storage

Handling:	Clean and dry process piping and equipment before any operation. Never return unused product to storage container. Keep away from incompatible products. Containers and equipment used to handle this product should be used exclusively for this material. Avoid any contact with water or humidity.
Storage:	Store in a dry area, protected from heat sources and direct sunlight.
Other precautions:	Warn personnel about the dangers of the product.

8. Exposure Controls/Personal Protection

Engineering controls: Provide ventilation in work areas to keep dust below the following applicable limits:

ACGIH™ TLV™ (1996)	OSHA PEL	NIOSH REL (1994)
5 mg/m^3 TWA	Total dust - 15 mg/m^3 TWA	5 mg/m^3 TWA
	Respirable fraction - 5 mg/m^3 TWA	

ACGIH™ and TLV™ are registered trademarks of the American Conference of Governmental Industrial Hygienists.

Eye/face protection: Dust proof chemical goggles.

Hand protection: Impervious protective gloves made of nitrile, natural rubber, or neoprene.

Skin protection: For brief contact, few precautions other than clean body-covering, clothing should be needed. When prolonged or frequently repeated contact could occur, use protective, full body clothing impervious to this material.

Respiratory protection: For many conditions, no respiratory protection may be needed; however, in dusty or unknown atmospheres use a NIOSH approved dust respirator.

Other precautions: Safety shower and eyewash stations. Consult your industrial hygienist or safety manager for the selection of personal protective equipment suitable for the working conditions.

9. Physical and Chemical Properties

Appearance: White to pale amber powder
Odor: Odorless
pH: 7 - 9 (saturated solution)
Melting Point: 527 °F (275 °C) - Decomposes
Vapor Pressure: Not applicable
Vapor Density: Not applicable
Boiling point: Not applicable
Bulk Density: 0.5 - 0.65 g/mL (Loose Method)
Solubility in Water: Moderate

10. Stability and Reactivity

Chemical Stability: Stable under certain conditions (see below).

Conditions to avoid: Heat and moisture

Materials to avoid: Water, Acids, Bases, Salts of heavy metals, Reducing agents, Organic materials, Flammable substances

Hazardous decomposition products: Oxygen, hydrogen peroxide, steam and heat.

Hazardous polymerization: Does not occur.

11. Toxicological Information

Acute toxicity:	Oral route, LD_{50}, rat, 7340 mg/kg
Chronic toxicity:	No data
Irritation:	Rabbit (eyes), severe irritant
Sensitization:	No data
Target Organ Effects:	Eyes and respiratory passages.

12. Ecological Information

Acute ecotoxicity:	Fish, Cyprinus carpio, 48 hours, LC_{50}, 25.6 mg/L
Chronic ecotoxicity:	No data
Mobility:	Low solubility and mobility.
Abiotic degradation:	Air - Not applicable Water - Slow hydrolysis Water/Soil - Complexation/precipitation Carbonates/phosphates present at environmental concentrations. Degradation products: carbonates/phosphates sparingly soluble.
Biotic degradation:	Not applicable
Potential for bioaccumulation:	Not applicable
Comments:	Observed effects are related to alkaline properties of the product. Hazard to the environment is limited due to the product properties a) No bioaccumulation. b) Weak solubility and precipitation as carbonate or phosphate in aquatic environment. c) rapid neutralization at environmental pH.

13. Disposal Considerations

Waste Disposal Method:	Consult current federal, state and local regulations regarding the proper disposal of this material and its emptied containers.

14. Transport Information

D.O.T. Proper Shipping Name:	Oxidizing substances, solid, n.o.s.
UN Number:	UN 1479
Hazard Class:	5.1
Label(s):	5.1 (Oxidizer)
Packing Group:	III
STCC Number:	4918717
Emergency Response Guide #:	140

15. Regulatory Information

TSCA Inventory List: Not Listed

CERCLA Hazardous Substance (40 CFR Part 302)

Listed substance: No
Unlisted substance: Yes
Reportable Quantity (RQ): Not Listed
Characteristic(s): Ignitability
RCRA Waste Number: D001

Sara, Title III, Sections 302/303 (40 CFR Part 355- Emergency Planning and Notification)

Hazard category: Eye and skin irritant
Threshold planning quantity: Not Listed

Sara, Title III, Sections 311/312 (40 CFR Part 370- Hazardous Chemical Reporting: Community Right-To-Know)

Extremely hazardous substance: No
WHMIS Classification: C Oxidizing Material
Material Causing Other Toxic Effects - Eye and skin irritant

Canadian Domestic Substances List: Listed, DSL/NDSL Record number - 3929
This product has been classified in accordance with the hazard criteria of the CPR and the MSDS contains all of the information required by the CPR.

16. Other Information

HMIS™ Rating:

Health - 2 Flammability - 0 Reactivity - 1 PPE - Required

HMIS™ is a registered trademark of the National Paint and Coating Association.

NFPA™ Rating:

Health - 2 Flammability - 0 Reactivity - 1 OX

NFPA™ is a registered trademark of the National Fire Protection Association.

Disclaimer

The information contained in this document is believed to be true and correct. However, the formulator makes no warranty, either expressed or implied, as to its authenticity, accuracy or to the use of this product and this document is subject to change or revision without prior notice.

APPENDIX C

STANDARD OPERATING PROCEDURES (SOPs)

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1.0 STANDARD OPERATING PROCEDURES FOR MONITORING WELL DESIGN AND CONSTRUCTION

1.1 INTRODUCTION

Monitoring well design and construction is conducted to characterize the hydraulic and groundwater quality at the site. Standard Operating Procedures (SOPs) are presented herein for obtaining a variety of hydraulic and groundwater quality results, including:

- groundwater elevation data;
- performance of aquifer testing; and
- collection of groundwater samples for groundwater quality analysis.

This guideline is not intended to provide the basis for designing a groundwater monitoring network, but instead assumes that a groundwater monitoring network has been designed, a site-specific Work Plan has been established, and that a CRA representative is preparing to mobilize to the site.

Monitoring well design and construction procedures vary from project to project due to different chemicals of concern, different guidance provided by the state/province where the site is located, and the specific objectives of the project (i.e., hydraulic monitoring, groundwater sampling, aquifer testing). It is essential that all monitoring well design and construction activities conform to local, provincial/state, and federal regulations. Therefore, it is essential that the CRA representative carefully review the Work Plan requirements. The primary goal of monitoring well design and construction is the appropriate placement of monitoring wells in various geologic and groundwater environments. It is imperative appropriate monitoring well installation and construction techniques are chosen.

1.2 BACKGROUND

The design and installation of monitoring and remediation wells involves drilling boreholes into various types of geologic formations. Designing and installing monitoring wells may require several different drilling methods and installation procedures.

It is important that the drilling method used minimizes the disturbance of subsurface materials.

The drilling method should not contaminate the subsurface soils and groundwater. It is extremely important that drilling does not create a hydraulic link or conduit between different hydrostratigraphic units. Groundwater in monitoring and extraction wells must not be contaminated by drilling fluids or the borehole advancement process. Drilling equipment is decontaminated before use and between well locations to prevent cross contamination between well locations and sites. Drilling equipment is decontaminated between all well locations regardless of whether or not contaminants are suspected. The Work Plan will specify the required decontamination procedures for the site. The only time decontamination is not required is when boreholes are advanced on known clean sites for the purpose of collecting geologic information.

Finally, precleaned monitoring well construction materials are used in order to prevent the potential introduction of contaminants into a hydrostratigraphic unit.

1.3 PLANNING AND PREPARATION

Prior to undertaking monitoring well design and construction:

1. Review the Work Plan and Site-Specific Health and Safety Plan (HASP), project documents, all available geologic and hydrogeologic mapping and reports, water well records, and historic site reports to become familiar with the geologic and hydrogeologic framework of the site and surrounding area. Review and become familiar with the health and safety requirements, and discuss the work activities with the Project Coordinator.
2. Obtain a site plan and previous stratigraphic logs. Determine the exact number, location, and depth of wells to be installed.
3. If not performed as part of borehole advancement, complete a Property Access/Utility Clearance Data Sheet (QSF-019). In most instances, the utility clearances and property access will have been completed as part of the well drilling and advancements.
4. Determine notification requirements with the Project Coordinator. Have all regulatory groups, the client, landowner, drilling contractor, and CRA personnel been informed of the well design and installation program?
5. Determine the methods for handling and disposal of well installation and decontamination fluids. Generally, this is dealt with as part of the well advancement activities.

In addition to the above, the following may be required when conducting monitoring well design and installation activities:

1. Establish a water source for well installation and decontamination. Pre-plan the methods of handling and disposal of well installation and decontamination fluids.

2. Arrange with the drilling contractor/client to provide a means of containment and disposal of fluids.

1.4 EQUIPMENT DECONTAMINATION

Borehole Installation and Sampling

Prior to use and between each borehole location, drilling and sampling equipment must be decontaminated in accordance with the Work Plan, the QAPP, or the methods presented in the following section.

The minimum wash procedures for decontamination of drilling or excavating equipment are:

1. High pressure hot water wash (brushing and detergent as necessary to remove particulate matter).
2. Potable, hot water, high pressure rinse.

On environmental sites, soil sampling equipment (e.g., split spoons, trowel, spoons, shovels, bowls) is typically cleaned as follows:

1. Wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates.
2. Rinse with tap water.
3. Rinse again with tap water.
4. Air dry for as long as possible.

1.5 LOCATION AND MARKING OF WELL INSTALLATION SITES/FINAL VISUAL CHECK

The proposed well locations marked on the site plan are located and staked in the field. On most sites, this should be completed several days prior to the drill rig arriving on site. Well locations are required for the completion of utility locates. Generally, well locations are strategically placed to assess site hydrogeologic conditions.

When possible, it is prudent to use a hand auger or post-hole digging equipment to a sufficient depth to confirm that there are no buried utilities or pipelines. This is particularly important in limited space sites where wells are being installed close to buried utilities. Alternatively, a Hydrovac truck can vacuum a large diameter hole to check for utilities, although soils collected this way may require containment on site. This procedure generally clears the area to the full diameter of the drilling equipment which will follow.

Once the final well location has been selected and utility clearances are complete, one last visual check of the immediate area should be performed before drilling proceeds to confirm the locations of adjacent utilities (subsurface or overhead) and verify adequate clearance. If gravity sewers or conduits exist in the area, access manholes or chambers should be opened and the conduit/sewer alignments confirmed. Do not enter manholes unless confined space procedures are followed.

Well locations are selected primarily to provide a good geographical distribution across the site. Most often, the well locations specified in the Work Plan are not pre-verified to confirm clearance from underground or overhead utilities, nor to consider the site's specific characteristics (e.g., traffic patterns, drainage patterns). Consequently, it is the Site Geologist's responsibility to perform the following:

1. Select the exact location of each well consistent with the site and project requirements.
2. If a well must be relocated more than 20 feet from the initially identified location, confirm the new location's suitability with the Project Coordinator.
3. Ensure all utilities have been cleared prior to initiating borehole advancement activities.

To the extent practical, wells should be located adjacent to permanent structures (e.g., fences, buildings) that offer some form of protection and a reference point for future identification. Wells located in high traffic areas or road allowances or low lying wet areas are undesirable, but may be unavoidable.

1.6 DRILLING METHODS

The following drilling methods are listed in order of preference. However, final selection will be based on site geologic and hydrogeologic conditions.

Hollow Stem Augering and Solid-Stem Augering

Continuous flight hollow stem augering (HSA) or solid-stem augering (SSA) are the most frequently used methods of borehole advancement. Its primary advantages are:

1. Generally, no additional drilling fluids are introduced into the formation.
2. Representative geologic samples can be obtained easily using split-spoon samplers in conjunction with the standard penetration test (SPT) and HSA.
3. A monitoring well can be installed through the auger, eliminating the need for a temporary borehole casing.

Information regarding split-spoon sampling is discussed in the SOP for soil sampling.

HSAs are available with an inside diameter of 2.5, 3.25, 4.25, 6.25, 8.25, and 10.25 inches. Some drilling contractors have inside diameter HSAs as large as 16.25 inches. The most commonly used inside diameter is 4.25 inch for the installation of a 2-inch diameter monitoring well. Larger diameter HSAs, including 6.25, 8.25, and 10.25 inch, are used for large diameter monitoring or extraction wells ranging in size from 4 to 8 inches. SSA's generally have outside diameters of 2, 4 and 6 inches. Boreholes can usually be advanced to depths of about 100 feet with an HSA in unconsolidated clays, silts, and sands.

Installation of a well through a HSA is a simple process, but precautions need to be taken to ensure that well construction, particular sealing, is properly completed. Installation of well in a SSA boring is completed in an open borehole. Precaution should be taken in the open hole installation for SSA borings that the boring does not cave during the installation process and is dependent on the competency of the borehole.

Removing a HSA from flowing sand may be difficult since the auger has to be removed without rotation, if at all possible. A bottom plug or pilot bit assembly should be used to keep out soils and water that have a tendency to fill the bottom of the HSA during drilling. If flowing sands are encountered, potable water (analyzed for contaminants of concern) may be poured into the HSA to equalize the hydrostatic pressure, which will keep the formation materials and water from flowing into the HSA once the plug or pilot bit is removed.

1.7 WELL DESIGN CONSIDERATIONS

Well design must be completed prior to initiating well installation activities.

The compatibility of the well construction materials with the groundwater environment should be verified. Certain materials are not compatible in a corrosive environment or where groundwater has high solvent concentrations. In deeper well applications, well material strength should be considered. Finally, the overall cost of the well materials should be considered.

1.7.1 WELL MATERIALS

The following well materials are commonly used:

- PVC well screen and riser pipe;
- stainless steel well screen and riser pipe;

- stainless steel screen and black iron (low carbon steel) riser pipe; and
- stainless steel screen and PVC riser pipe.

1.7.1.1 PVC WELL MATERIALS

PVC is generally either Schedule 40 or Schedule 80. Schedule 80 PVC is thicker and provides more strength than Schedule 40. Schedule 80 PVC is more resistant to heat caused by the placement and setting of grout. Because of the higher strength and greater heat resistance, Schedule 80 is preferred for well applications greater than 100 feet.

PVC is available in a variety of diameters, from 0.5 inch to 8 inch. PVC is relatively inexpensive and readily supplied by drilling contractors well material suppliers. PVC is light and generally comes pre-cleaned and bagged.

PVC is resistant to corrosion, most acids, oxidizing agents, salt, alkaline, and oils and fuels. However, it may break down in environments with high solvent concentrations. PVC can become brittle over time and is not as strong as metal.

PVC installations may be difficult in deep applications through a large water column because of its buoyancy.

PVC wells should not be constructed using solvent cement.

Threaded PVC well materials should be used where possible.

PVC well materials should meet the National Sanitation Foundation (NSF) Standard 14.

1.7.2 WELL DIAMETER

The diameter of a well is primarily dictated by the purpose of the well. Generally, wells installed for groundwater and hydraulic monitoring should be between 1 and 2 inches (2.5 and 5 cm) in diameter. The diameter is also dependent on the drilling method being used.

Small diameter wells allow for the installation of bladder pumps as well as small diameter tubing and bailers. Wells smaller than 1 inch (2.5 cm) should only be used for hydraulic monitoring. Due to the small diameter, sampling equipment cannot be used in wells smaller than 1 inch (2.5 cm) in diameter. The cost saving for wells smaller than 1 inch (2.5 cm) is negligible.

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For groundwater remediation, 4- to 6-inch (10 to 15 cm) diameter wells are sufficient. Wells greater than 6 inches (15 cm) in diameter are generally installed for water supply and are project specific.

1.7.3 SCREEN LENGTH AND PLACEMENT

Screen lengths for wells can vary depending on a variety of factors including:

- formation thickness;
- seasonal groundwater fluctuations; and
- extraction/water supply.

Screen length should be consistent with the hydrogeologic conditions and the desired monitored interval. A 10-foot (3.0 m) long screen is suitable for groundwater table wells where the screen is positioned 2 feet above the groundwater level to observe top of groundwater for anticipated groundwater fluctuation.

If monitoring for light non-aqueous phase liquids (LNAPL), the screen length is generally 10 feet. A longer screen length can be installed to accommodate seasonal groundwater fluctuations. A 5- to 10-foot screen length is adequate where the hydrostratigraphic formation is low and allows for the water level to be drawn down during sampling through the filter pack into the screened interval.

1.7.4 WELL SLOT SIZE

Well slot sizes are described in thousandths of an inch. For most monitoring wells, a No. 10 slot [0.01-inch] well screen is adequate in most hydrostratigraphic units. PVC wells screens are typically available in No. 10 (0.01-inch) or No. 20 (0.02-inch) slot sizes. Stainless steel screens are available in a wider range of slot sizes. Typically, stainless steel screens must be specially ordered and require additional delivery time. Wells screens can be slotted, continuous slot, or louvered. Well points come in very limited slot sizes.

Some state/provincial and federal regulators require design of monitoring well screen slot sizing. The design of the slot size is based upon grain size results from the desired monitored interval.

1.7.5 SAND PACK SIZING

The silica sand pack placed around the well screen should be no finer than the slot size of the screen. Some companies supply different sieve size ranges for the same sand size number. Grain size curves should be obtained from the driller or well materials supplier to ensure proper sand size prior to placement.

In some instances, generally in situations with flowing sands, a natural sand pack may be required. A natural sand pack is not desired because of the increase in development time.

1.7.6 WELL SEALING

All wells must be properly sealed. A seal is placed over the silica sand pack. Cuttings must never be used to seal a well.

Certain well applications require specific well seals including:
- bentonite gravel or chips;
- bentonite grout;
- cement/bentonite grout; and
- cement grout.

Prior to initiating well installation activities, confirm sealing requirements with local, state/provincial, or federal regulations.

1.8 FIELD PROCEDURES FOR WELL INSTALLATIONS

The following presents the field procedure and techniques for installing a well in overburden and bedrock.

1.8.1 INSTALLATION REQUIREMENTS

Well installation requires the following components:
1. Annular space.
2. Instrumentation details.
3. Filter pack placement.
4. Bentonite seal.
5. Grouting.
6. Protective casings and well caps.
7. Surface seal.

8. Protective posts (if required).

1.8.2 ANNULAR SPACE

The annular space is the space between the outside of the riser pipe or casing and the inside of the HSA, casing, or borehole wall.

The borehole diameter must be sufficient to allow well construction to proceed without difficulty. Check with local, state/provincial, or federal regulations to insure that the borehole annular space meets regulations. To assure adequate size, a minimum 2-inch annular space is required to allow a minimum filter pack, seal, and grout at the specific intervals. An annular space of less than 2 inches is not acceptable.

1.8.3 INSTRUMENTATION DETAILS

Prior to installation through the auger or into the borehole, the well assembly (i.e., well screen and riser components) and the length of each component must be measured and recorded. The borehole must be measured to ensure installation at the desired interval to be monitored.

Once the depth of the borehole has been confirmed and the length of the well assembly is known, well construction can proceed. Placement problems are easily identified by measuring the amount of riser stickup during installation and comparing to the measured depth of the borehole.

1.8.4 FILTER PACK PLACEMENT

The primary filter pack is composed of graded washed silica sand. The silica sand size should be no finer than the screen size opening. The primary sand pack size may have to be designed based on the well screen slot size and the grain size of the hydrostratigraphic formation.

The primary filter pack is placed as follows:

1. The filter pack is placed using the tremie line method.
2. A minimum 6 inches (15 cm) of the filter pack material is placed under the bottom of the well screen. This interval of filter pack provides a firm footing for the well.
3. The top of the filter pack is determined in the field based on the geologic and hydrogeologic conditions encountered during borehole advancement.

4. The filter pack should extend a minimum of 2 feet, if possible, above the top of the well screen.
5. For shallow overburden wells it is common to extend the filter pack to about 2 feet above the top of screen to account for anticipated seasonal groundwater fluctuations.
6. In shallow overburden wells the sand pack should not be extended across a native and fill unit. For deeper overburden wells, it is common to select a specific hydrogeologic unit to monitor.
7. The filter pack should never extend through a confining unit causing two or more permeable units to become connected.

Placing the filter pack by pouring may be acceptable if measurements are taken to ensure that the filter pack is reaching the assigned depth.

The filter pack must be carefully placed concurrent with the removal of the HSA or temporary casing when collapsing borehole conditions exists. The filter pack must be maintained in the HSA or temporary casing to ensure proper filter pack placement around the well screen.

Placement of the filter pack is typically a delicate and time consuming operation. It requires a balance between placement of too much sand and "locking" the well components in the auger or temporary casing, or placing too little sand, which allows the formation materials to collapse around the well screen. A good well installation will involve constantly checking the filter pack level as the auger or temporary casing is extracted from the borehole. Constant measurement of the filter pack will allow for adjustment of the rate and amount of filter pack placement.

In certain situations it may be necessary to add potable water within the HSA or temporary casing to maintain a positive hydrostatic pressure on the formation materials. This will help stop the flow of formation materials into the HSA or temporary casing. This generally occurs in sandy/silty soils below the water table. If potable water is added, the volume of water added must be recorded and additional purging volumes will be required to remove the volume of potable water added.

1.8.5 BENTONITE SEAL

A bentonite seal is placed on top of the filter pack. This seal consists of high solids, pure bentonite material. Bentonite in either pellet or granular or chip form is acceptable. Check with local, state/provincial, and federal regulations concerning bentonite seal material requirements.

Generally, 3/8-inch (1 cm) bentonite chips are used, but larger 3/4-inch (1.9 cm) bentonite chips may be used in larger annular spaces. Bentonite pellets have a machined surface and are good for deep well applications, or for adding bentonite seals through a long water column.

When placing a bentonite seal:

1. Pouring the bentonite seal is acceptable in shallow applications [less than 50 feet (15 m)] where the annular space is large enough to prevent bridging.
2. Take continuous measurements to ensure that the bentonite seal is being placed in the proper interval, and that bridging is not occurring.
3. Place the bentonite seal above the filter pack to a minimum of 2 feet (0.6 m) thick.
4. Allow the bentonite to hydrate before grouting.
5. If the water table is temporarily below the bentonite seal interval, use potable water to hydrate the bentonite.

1.8.6 GROUTING

The annular space between the well casing and borehole wall must be filled with neat cement grout, cement/bentonite grout, or bentonite grout. Check required local, state/provincial, and federal regulations regarding well sealing requirements.

Bentonite grout does not crack or harden and is generally self healing. Cement/bentonite grout may crack, but bentonite will typically seal any cracks. Cement/bentonite grout must contain at least 5 percent bentonite volume by weight. Neat cement will crack and may pull away from riser pipe or borehole wall.

When placing grout:

1. Prepare the grout in accordance with the manufacturer's specifications.
2. Place the grout into the borehole, over the bentonite seal.
3. Place the grout from the top of the bentonite seal to within 2 feet of the ground surface or, if possible, below the frost line.
4. Allow the grout to set for a minimum of 24 hours before installing a concrete surface seal. Grout will generally settle due to infiltration into medium- and coarse grained soils. Check grout levels and, if required, add additional grout to the borehole to bring the grout level to the required depth.
5. When grouting on contaminated sites, collect and contain displaced fluids for future disposal.

When a concrete surface seal is not required, the grout is brought to within 0.5 to 1 foot below ground surface. The remaining annular space is backfilled to match the surrounding ground surface conditions (e.g., asphalt, topsoil). This method will reduce surface water infiltration and well lifting due to frost.

1.8.7 PROTECTIVE CASINGS

A protective casing is installed over the completed well and sealed in place. Once installed and grouted, the casing should extend about 2.5 feet above ground surface, if applicable. The outer protective casing is made of steel and has a locking cap that is hinged, waterproof, and resistant to vandalism. The protective casing should have sufficient clearance around the inner well casing so that no contact is made with the outer protective casing. A concrete surface seal is installed flush to promote drainage away from the outer protective casing at a depth below the frost line to deter frost heaving. Check local, state/provincial, and federal regulations pertaining to requirements for concrete surface seals.

Typically, a concrete form (sonatube) is used to provide a collar for the concrete around the protective casing. The concrete surface seal is placed as follows:

1. The concrete surface seal is sloped to promote surface drainage away from the well.
2. The protective casing is installed with two weep holes for drainage. The weep holes should be 1/4 inch (0.6 cm) in diameter and drilled into the protective casing slightly above the top of the concrete surface seal. The weep holes will prevent standing water from accumulating inside the protective casing and allow internal air pressure to be in equilibrium with atmospheric conditions.
3. Bentonite chips or pellets are placed in the annular space below ground level in the protective casing.
4. Silica sand is placed in the annular space above the bentonite chips or pellets and above the weep hole to prevent insect infestation.

Sometimes a well must be completed in a high traffic area. In this situation, the well is completed as a flush-mount installation. A waterproof protective casing is essential to ensure the integrity of the screened hydrostratigraphic unit. The protective casing is grouted in place and is fitted with bolts and a rubber gasket to deter surface water infiltration. For a flush-mount installation, the well top is generally fitted with a locking expandable cap with watertight screw-on connections (as referenced in ASTM F480). For a flush-mount installation, the well cap must have a lock to deter vandalism. For above-grade installations, the well cap or well casing must be properly vented to allow air pressure to be in equilibrium with atmospheric conditions.

Flush-mount installations are typically more problematic and maintenance intensive. If possible, avoid the use of flush-mount installations.

Once all well installation activities are complete, wells are labeled with the appropriate well identification in at least two locations.

1.9 WELL CONSTRUCTION TECHNIQUES

1.9.1 WELL INSTALLATION

Boreholes for well installations should be drilled as close to vertical as possible. Slanted boreholes are not acceptable unless specified in the well design or Work Plan. Well casings and screens should be installed plumb in the boreholes. Where critical, especially on installations deeper than 50 feet (15 m), centralizers may be used to help keep the screen as close as possible to the center of the borehole. An alternative method to setting a well casing and well assembly is to suspend the casing or assembly from the wireline on the drill rig.

Petroleum-based lubricating oils or grease should not be used on casing threads. Teflon tape can be used to ensure a watertight seal. No glue of any kind should be used to secure casing joints. For some steel casings, welded joint construction is acceptable.

The well is installed as follows:

1. Before placing the well assembly at the bottom of the borehole, place at least 6 inches (0.15 m) of filter pack at the bottom of the borehole to serve as a footing.
2. On a well installed to a depth greater than 50 feet, centralizers are required. Place the centralizers on the well casing or well assembly above the proposed bentonite seal interval. Place the centralizers so as not to interfere with the placement of the filter pack, bentonite seal, and annular grout. (Generally, wells less than 50 feet deep will not require centralizers unless required by local, state/provincial, or federal regulations, or the Work Plan.)
3. During well installation through a HSA, slowly pull back the auger as the filter pack, bentonite seal, and annular grout are tremied or poured in place.
4. When the well has been lowered into the borehole, place the filter pack around and above the top of the screen, as required.
5. When the filter pack has been installed, place a minimum 2-foot thick bentonite seal directly on top of the filter pack.
6. Allow the bentonite seal to hydrate for a reasonable amount of time (generally, 30 minutes is sufficient).

7. When the bentonite seal has hydrated sufficiently, seal the remaining borehole annular space grout placed with a tremie line using positive displacement methods. Generally, the grout will be brought to 2 feet below ground surface or below the frost line, whichever is greater. In situations where no concrete seal is being placed, the grout can be brought to 0.5 to 1 foot below ground surface.
8. During grout placement, ensure the end of the tremie line is always submerged in the grout to ensure positive displacement.
9. During grout placement on contaminated sites, containerize all fluids for future disposal.
10. Allow the grout to set for about 24 hours before installing the concrete surface seal. If the grout level has subsided, top off the borehole annular space with grout or bentonite pellets to the required depth.
11. Install protective casings in a minimum 2-foot thick concrete surface seal graded to divert surface water away from the monitoring well. Check local, state/provincial, and federal regulations for concrete surface seal requirements. Some agencies require that concrete pads be constructed around the wells.
12. When installation is complete, label the well in at least two locations for future identification.

For well installation in a high traffic area (i.e., parking lot, residential yard, road allowances) it may be necessary to install a flush-mount protective casing. It is important that the flush-mount protective casing be watertight to protect the screened hydrostratigraphic unit. Flush-mount protective casings are designed to extend from ground surface down into the concrete surface seal. Elevate the areas in the immediate vicinity of a flush-mount well to the extent possible to promote surface water drainage away from the flush-mount protective casing. Be aware of possible trip hazards associated with a flush-mount protective casing in areas of pedestrian traffic need. It is also important to avoid installing a well in a low-lying area that is susceptible to surface water accumulation and ponding.

1.10 WELL INSTALLATION DOCUMENTATION

Details of each overburden well installation are recorded on a Stratigraphic Log and also in the field book. Well installation details, comprised of the following, are recorded on a Well Log and in the log book:

1. Drilling method.
2. Borehole diameter.
3. Borehole depth.
4. Well screen length.
5. Well screen depth.

6. Well screen and riser diameter.
7. Outer casing diameter if present.
8. Filter pack interval.
9. Filter pack material.
10. Seal/plug interval.
11. Seal material.
12. Grout interval.
13. Grout material.
14. Stickup/flush-mount detail.
15. Surface seal detail.
16. Protective type detail.
17. Date installed.

Overburden stratigraphic details are recorded in detail, in accordance with the soil classification methods detailed in the SOP for soil sampling, on a Stratigraphic Log.

1.11 WELL INSTALLATION FOLLOW-UP ACTIVITIES

Upon completion of monitoring well installation activities:

1. Submit all stratigraphic and instrumentation logs to CRA's hydrogeology department for input of data and generation of final stratigraphic and instrumentation logs.
2. Plot well locations on site plan, since well locations may have changed in the field due to underground/overhead utilities or field conditions.
3. Arrange for a surveyor to obtain horizontal and vertical control for well locations.
4. Tabulate well construction details.
5. Measure groundwater levels in accordance with the SOP for Water Sampling to confirm hydraulic stabilization and groundwater flow direction.
6. Prepare a summary report describing the field activities including, but not necessarily limited to, drilling method(s), well design and construction details, site geology, and site hydrogeology.
7. File the field book at the appropriate CRA office.

1.12 WELL DEVELOPMENT

Monitoring well development is the process of obtaining hydraulic stabilization of a monitoring well. To ensure hydraulic stabilization of a well, it is recommended to remove five to ten well volumes. The removal of well volumes will aid in achieving a sand free condition with the lowest possible turbidity.

The most suitable methods of well development are:

1. Waterra™ (surge block).
2. Surge block.
3. Pumping/over pumping/backwashing.
4. Bailing.
5. Airlifting.
6. A combination of the above five methods.

1.12.1 BAILING

In a relatively clean permeable formation, bailing is an effective development technique. The bailer is allowed to freefall down the well until it strikes the water surface. That contact creates a strong outward surge of water through the screen into the formation. This action tends to break bridging that has occurred in the formation from the borehole advancement process. As the bailer fills and is rapidly removed from the water column, particulate matter outside the well intake flows through the well screen. Subsequent bailing will remove all accumulated particulate from inside the well. Bailing is continued until the water is free from suspended particulate matter.

1.13 WELL DEVELOPMENT DOCUMENTATION

A well is developed after installation to ensure hydraulic stabilization.

Details of well development are recorded in a standard CRA field book, and must include:

1. Well identification number.
2. Date of development.
3. Development method.
4. Well type including diameter and construction.
5. Measuring point location and elevation (if known).
6. Measured water level.
7. Measured bottom depth.
8. Water column length.
9. Screened interval.
10. Well volume.
11. Volumes purged.
12. All field parameter measurements.

1.14 FOLLOW-UP ACTIVITIES

Once well construction and development is completed:

1. Submit and complete stratigraphic logs.
2. Tabulate well installation and development details.
3. Summarize the development activities including development method, development duration, volumes removed, and field parameters.
4. File the field stratigraphic log forms and field book at the appropriate CRA office.
5. Document the water level in the well.
6. Arrange for surveys of wells for horizontal and vertical control.

1.15 REFERENCES

Numerous publications are available describing current monitoring well design and construction procedures. Four excellent references are:

1. Driscoll, F.G., 1986. Groundwater and Wells, 2nd Edition. Johnson Division.
2. Freeze, R.A. and Cherry, J.A., 1979. Groundwater. Prentice Hall, Inc.
3. ASTM D5092. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifer.
4. Nielsen, David M., 1991. Practical Handbook of Ground-Water Monitoring

In addition, the following ASTM publications apply:

ASTM D5474	Guide for Selection of Data Elements for Ground-Water Investigations
ASTM D5787	Practice for Monitoring Well Protection
ASTM D5521	Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers
ASTM D5978	Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells
ASTM D5299	Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities

2.0 STANDARD OPERATING PROCEDURES FOR GROUNDWATER SAMPLING

2.1 INTRODUCTION

Groundwater sampling is conducted in order to characterize the groundwater quality at the site. Standard Operating Procedures (SOPs) are presented herein for groundwater monitoring of the site groundwater monitoring wells.

This guideline is not intended to provide the basis for designing a groundwater monitoring program, but instead assumes that a groundwater monitoring program has already been designed. It is also assumed that a site-specific Work Plan has been established and that a CRA representative is preparing to mobilize to the site.

Groundwater sampling procedures vary from project to project due to:

- Different chemicals of concern;
- Different guidance provided by local, provincial/state, and/or federal regulatory agencies with jurisdiction at the site; and
- The specific objectives of the project.

It is essential that all groundwater sampling activities conform to local, state/provincial, and federal regulations. Therefore, it is essential that the CRA representative carefully reviews the Work Plan requirements. The primary goal of groundwater sampling is the collection of samples and fluid levels representative of the hydrostratigraphic unit. It is necessary to use appropriate sampling techniques to collect representative samples and fluid levels that provide reliable and reproducible results in accordance with the Work Plan and all relevant regulations.

2.2 PLANNING AND PREPARATION

Prior to groundwater sampling:

1. Review the Work Plan, project documents, and Site-Specific Health and Safety Plan (HASP) with the Project Manager/Coordinator.
2. Assemble the site plan, well logs, and previous sampling/purging data required for the sampling event. Determine the exact number and locations of wells to be sampled.
3. Confirm with the Project Manager/Coordinator that a Property Access/Utility Clearance Data Sheet (QSF-019) has been completed.
4. Arrange access to the site. Obtain all well and site keys. Consider site access conditions (e.g., snow).
5. Contact the laboratory to arrange:

- Sample containers delivery;
- Preservatives if required;
- Coolers;
- Shipping details;
- Sample starting date; and
- Expected duration of sampling program.

6. Evaluate sample notification needs with the Project Coordinator. Have the regulatory groups, client, landowner, CRA personnel, and laboratory been notified of the sampling activities?
7. Evaluate containment and disposal requirements for purge waters.
8. Plan sampling activities to ensure that wells that historically go dry or have poor recharge fit into the sampling program. This will reduce the time required for sample collection.
9. Plan the sequence of sampling activities to reduce the potential for cross contamination. For groundwater sampling, start with clean wells and progress to impacted wells.

2.3 FIELD PROCEDURES FOR GROUNDWATER SAMPLING

The typical series of events that takes place for a groundwater sampling program is:

1. Well identification and inspection.
2. Fluid level monitoring.
3. Well depth sounding.
4. Well volume calculation.
5. Measure dissolved oxygen (DO) downhole if required.
6. Purging and sampling equipment installation.
7. Well purging and stabilization monitoring.
8. Record final water quality parameters per the Work Plan.
9. Sample collection, sample preparation, completion of chain-of-custody (COC), sample packaging.
10. Final water level monitoring (if required), purging, sampling equipment removal, secure the well.
11. Equipment decontamination.
12. Field note completion and review.
13. Sample shipment and COC distribution.
14. Purged groundwater and decontamination fluid disposal

2.3.1 WELL IDENTIFICATION AND INSPECTION

At sites with numerous wells or nested wells, misidentification of wells has occurred. The CRA representative must be alert to the possibility of potential cap switching, mislabeled wells, or unlabeled well locations.

Determine proper well location and identification by comparing the well log details to the measured well depths (i.e., total well depth, casing diameter, casing stick-up, or stick-down distances), field tie-ins, and site plan.

Once well identification has been established, complete a thorough well inspection:

1. Determine if the well cap and lock are secure, and check for vandalism.
2. If no lock is present, dedicate a new lock to the well location.
3. Examine the integrity of the surface seal.
4. Check for cracks, evidence of frost heave, or subsidence in the vicinity of the well.
5. Examine the integrity of the protective casing. Ensure that the casing can be closed and locked.
6. If required, re-label the well to assist in future identification.
7. If the well is installed with dedicated sampling equipment, check for cracks or leaks in tubing, and worn or frayed rope.
8. Record all the well inspection details in the field book to document well conditions and suitability for groundwater sampling activities.
9. Forward the well inspection results to the Project Coordinator, especially if repairs are required.

2.3.2 WATER LEVEL MONITORING/WELL DEPTH SOUNDING

Fluid level measurements are made relative to a surveyed reference point. For groundwater level measurements, the reference point is usually marked on the top of the well riser or casing. (The protective casing should not be used as a reference point.) The top of the well riser/casing is usually not level and/or square; therefore, the reference point must be clearly marked on the riser and noted in the field book. Clearly marking the reference point will eliminate future measurement errors. The elevation of the reference point should be determined to the nearest 0.01 foot (1 mm). Typically, the reference point is marked on the north side of the well casing.

Prior to commencing well purging and groundwater sampling, the water level is measured for hydraulic monitoring and to determine the well volume. Typically, a complete round of water level measurements is taken at a site to establish groundwater conditions prior to initiating well purging or groundwater sampling activities.

A number of instruments are available to measure groundwater levels. CRA typically uses:

- Battery operated water level indicators (i.e., audible and/or visual identification of water level); and
- Battery operated oil/water interface probes (i.e., audible and/or visual identification of water levels and presence of NAPL).

Well depth sounding is often required to confirm well identification, evaluate the accumulation of sediment in the well bottom, or assist in determining the standing well volume. Sounding is performed using a water level indicator or an oil/water interface probe. The fluid level indicator or weighted tape is lowered to the bottom of the well and a comparison is made of the installed well depth versus the measured well depth. The presence of excessive sediment or drill cuttings may warrant redevelopment of the well prior to well purging and groundwater sampling activities.

The total well depth is compared to the original installed total well depth. If the well screen is more than 50 percent blocked by accumulated sediment, the well is redeveloped prior to the next groundwater sampling event. Report all wells requiring redevelopment to the Project Coordinator.

2.3.2.1 ELECTRICAL WATER LEVEL INDICATORS

The most common method of obtaining water level measurements is the electronic water level indicator (e.g., Solinst). These meters consist of calibrated cable or tape with a weighted sensing tip at the end. When the tip contacts the water, an electric circuit is completed and the light and/or buzzer signals the contact. The following procedures shall be used with electrical water level meters:

1. Check the proper operation of the meter by inserting the tip into water and noting if the contact is registered clearly (on some meters, the sensor is in the midpoint of the metal tips). Deionized water cannot be used for this check, as it will not conduct an electrical current. Always check to see if the tape has been previously repaired and if a correction of the measurement is required.
2. Dry the tip and then slowly lower the tip into the well until contact with the water is indicated.
3. Slowly raise the tip until the light and/or buzzer just begins to deactivate. This indicates the static water level.

4. Using the thumb and index finger, grasp the tape at the reference point and note the reading to the nearest 0.01 foot (1 mm).
5. Record the water level measurement in the field book. Compare to previous measurements to see if significant changes [i.e., greater than 2 feet (0.6 m)] have occurred. Recheck the water level if a significant difference is measured.
6. Decontaminate the submerged end of the tape.

2.3.2.2 INTERFACE PROBE

Electrical water level indicators are not reliable when light non-aqueous phase liquids (LNAPL) are floating on the water surface; therefore another method to determine fluid levels is required.

Phase separated liquids may consist of lighter than water materials (i.e., petroleum hydrocarbons) which float on the groundwater surface are categorically referred to as LNAPL; or heavier than water materials (dense organic chemicals) which are denser than water and will sink until a confining layer or less permeable layer is encountered, and are categorically referred to as dense non-aqueous phase liquids (DNAPL). Interface probes will detect the surface of LNAPL layers and the interface between LNAPL and groundwater or groundwater and DNAPL.

The interface probe uses an optical liquid sensor in conjunction with an electric circuit to detect the top of a phase separated liquid and the interface between the phase layer and water (water level). The procedure for use of this probe is:

1. Lower the probe tip into the well until an alarm is heard. (The alarm associated with NAPL detection varies depending on the brand of probe.) The appropriate alarm sounds when the top of the phase layer has been detected. Grasp the calibrated tape at the reference point and note the reading. Confirm the reading by slowly raising and lowering the probe to the level of the phase layer.
2. Once the top of the phase layer is confirmed, slowly lower the probe until the appropriate alarm is heard. This indicates that the water level has been encountered. Grasp the tape at the reference point and note the reading. Confirm this water level measurement.
3. Decontaminate the submerged end of the tape and probe prior to the next use.

2.4 WELL VOLUME CALCULATION

Prior to commencing well purging, the volume of water in the well must be known to determine the volume of groundwater to be removed prior to sampling. A well volume is defined as the volume of water contained in the well screen and casing (and in the case of an open bedrock hole, the volume of water in the open borehole and possibly in the well casing). To determine the standing water volume in a well:

1. Calculate the distance from the bottom of the well to the static water level.
2. Measure the inside diameter of the well or casing. Obtain the volume of standing water in the well using the following formula:

$$V = \pi r^2 h \text{ (7.48 U.S gallons/cubic feet) (1 liter/1,000 cubic centimeters)}$$

where:

V = volume of water in gallons or liters
π = 3.142
r = radius of well casing (feet or meters)
h = depth of water column in the well (feet or meters)

Typical 1-Foot Casing Volumes	
Diameter (inches)	*Gallons (U.S.) of Water Per Foot of Casing*
1.5	0.09
2	0.16
3	0.37
4	0.65
6	1.47

2.5 WELL PURGING AND STABILIZATION MONITORING

Prior to initiating groundwater sample collection, the wells are purged of the standing stagnant groundwater volume. Purging is performed until the water in the well is representative of the actual conditions in the hydrostratigraphic unit. Purging is considered complete once purged groundwater is free of sediment and field parameters including specific conductance and pH are stable. Stabilization is achieved when field measurements for specific conductance and pH are within a range of plus or minus 10 percent of the average for the last three readings. Once the number of well volumes required to achieve stabilization is established, the volume required to reach stabilization for future sampling events is reduced or eliminated. Extended purging of a well will generally result in achieving sediment free groundwater conditions.

During purging, if stabilization has not occurred after removal of five well volumes, purging is continued until ten well volumes have been removed. If stabilization still has not been achieved, stabilization may be dropped as a pre-condition to groundwater sampling. The Project Coordinator should be notified that stabilization has not occurred after the removal of ten well volumes.

For low yield wells (i.e., wells that are dry after one well volume) it is necessary to purge the well dry and sample as soon as the well has sufficient volume for sampling or to a level that is sufficient to collect the necessary groundwater sample volume.

The purging equipment is lowered into the top of the standing water column. Well purging is completed from as close to the top of the water column as possible, not from the well bottom, unless poor well recovery occurs. Purging from the top of the water column moves water from the formation through the well screen of the well and into the well casing. This allows for the entire static volume to be removed.

Meter calibration fluids should be available for meter recalibration in the field. Spare meters should also be available for meter replacement if necessary.

2.6 SAMPLING TECHNIQUES

Samples are collected directly from the bailer, when possible, or an alternate device (i.e., pump) may be installed or used. If new sampling equipment is installed, the first few bails or discharge volumes should be discarded to allow acclimation of the sampling equipment with the groundwater.

Samples are typically collected from the pump or bailer with the discharged groundwater collected directly in the appropriate sample containers. The interior of the bottle or cap must not be touched or handled in anyway. New gloves (i.e., disposable nitrile gloves or equivalent) should be worn for the collection of each sample. Caps from sample bottles must not be placed on the ground or in pockets to eliminate the possibility of cross contamination.

Once sample collection is complete, samples are placed in a cooler on ice to maintain a sample temperature no more than 4°C.

2.7 SAMPLE LABELS/SAMPLE IDENTIFICATION

Label all groundwater samples with the following, written in indelible ink

1. A unique sample number (monitoring well number).
2. Date and time.
3. Parameters to be analyzed.
4. Job number.

5. Sampler's initial.

Secure the label to the bottle. It is recommended that bottle labels be covered with wide clear tape to protect the label during sample packing and shipment. Pack glassware in appropriate packing material to deter breakage during sample packing and shipment.

2.8 EQUIPMENT DECONTAMINATION

Non-disposable equipment is decontaminated between sampling locations and prior to leaving the site. Upon completion of the sampling program, all equipment is decontaminated at the site and then returned clean.

For most groundwater sampling programs, sampling equipment (e.g., pumps, bailers, water level indicators) is typically cleaned as follows:

1. Wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates.
2. Rinse with tap water and\or distilled water.
3. Air dry for as long as possible.

2.9 PURGE WATER AND DECONTAMINATION FLUID DISPOSAL

Project specific disposal methods for purged groundwater and decontamination fluids are determined by the Project Manager during the sampling program's planning and preparation stage and may include:

1. Off-site treatment at private treatment/disposal facility or publicly owned treatment facilities (sanitary sewer).
2. On-site treatment at a client operated facility.
3. Direct discharge to the surrounding ground surface, allowing for evaporation.

2.10 FOLLOW-UP ACTIVITIES

The following should be performed once groundwater sampling is completed:

1. Double check the Work Plan and QAPP to ensure all samples and QA/QC samples have been collected and confirm with the Project Coordinator.
2. Decontaminate all equipment at the site then return clean to the appropriate office equipment manager.
3. Dispose of purge water and cleaning fluid as specified in the Work Plan.
4. Notify the contract laboratory when the samples should arrive. Enclose a completed chain-of-custody in each cooler.
5. Complete and file the appropriate forms. Also complete the field notes.

6. Return site and well keys.

2.11 REFERENCES

For additional information pertaining to groundwater sampling activities the user of this manual may reference the following:

ASTM D5474	Guide for Selection of Data Elements for Groundwater Investigations
ASTM D4696	Guide for Pore-Liquid Sampling from the Vadose Zone
ASTM D5979	Guide for Conceptualization and Characterization of Groundwater Systems
ASTM D5903	Guide for Planning and Preparing for a Groundwater Sampling Event
ASTM D4448	Standard Guide for Sampling Groundwater Wells
ASTM 4750	Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
ASTM D6000	Guide for Presentation of Water-Level Information at Ground-Water Sites

3.0 STANDARD OPERATING PROCEDURES FOR SOIL SAMPLING

3.1 INTRODUCTION

Soil sampling is conducted to characterize the physical and/or chemical conditions of soil at the site. Standard Operating Procedures (SOPs) are presented herein for obtaining a variety of soil samples for physical and chemical analyses, including:

- Surficial soil samples (soil between ground surface and 6 to 18 inches below ground surface);
- Subsurface samples that require borehole installation; and
- Pit excavations.

This guideline is not intended to provide the basis for designing a soil sampling program, but instead assumes that a soil sampling program has been designed, a Work Plan has been established, and the sampling team is preparing to mobilize to the field.

Soil sampling procedures vary from project to project due to different parameters of concern, different guidance provided by the state/province where the site is located, or the specific objectives for the project. Therefore, it is essential that the sampling team members carefully review the Work Plan. The primary goal of soil sampling is to collect representative samples for examination and chemical analysis (if required).

3.2 PLANNING AND PREPARATION

The following activities are required prior to undertaking a soil sampling program:

1. Review the Work Plan, project documents, and health and safety requirements with the Project Coordinator.
2. Obtain a site plan and any previous stratigraphic logs. Determine the exact number, location, and depths of samples to be collected.
3. Contact the laboratory to arrange/determine:
    - Glassware/sample jars;
    - Cooler;
    - Shipping details;
    - Start date; and
    - Expected sampling duration.
4. Initiate a Property Access/Utility Clearance Data Sheet, if necessary. In most instances, surface sampling activities do not require utility clearances.
5. Determine notification needs with the Project Coordinator. Have the regulatory groups, client, landowner, CRA personnel, and laboratory been informed of the sampling event?

6. Determine the methods for handling and disposal of wash waters and spent decontamination fluids.
7. Establish a water source for drilling and decontamination activities. Pre-plan the methods for handling and disposal of drill cuttings, wash waters, and spent decontamination fluids.

3.3 SAMPLING METHODS

3.3.1 BOREHOLE INSTALLATION AND SAMPLING

Several manual methods are available for the collection of shallow subsurface soil samples (e.g., hand augers, hollow and solid stem augers). However, the most common methods used by CRA to advance boreholes are a drill rig equipped with continuous flight hollow stem augers (HSAs) or solid stem augers (SSAs) and split-spoon samplers, or a direct-push drilling unit equipped with solid tube soil samplers.

3.4 EQUIPMENT DECONTAMINATION

<u>Borehole Installation and Sampling</u>

Prior to use and between each borehole location at an environmental site, the drilling and sampling equipment must be decontaminated in accordance with the Work Plan or the methods presented in this section.

The minimum wash procedures for decontamination of drilling or excavating equipment are:

1. High pressure hot water wash (brushing and detergent as necessary to remove particulate matter).
2. Potable, hot water, high pressure rinse.

On environmental sites, the soil sampler equipment (split spoons, trowel, spoons, shovels, bowls) are typically cleaned as follows:

1. Wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates.
2. Rinse with tap water.
3. Air dry for as long as possible.

3.5 PROCEDURES FOR BOREHOLE INSTALLATION AND SAMPLING

Once the prior planning and preparation activities are completed, the drilling program can proceed. The typical series of events that takes place is:

1. Locating and marking boring locations.
2. Initiation of a Property Access/Utility Clearance Data Sheet (QSF-019), including obtaining appropriate signoffs by the client representative and drilling subcontractor representative.
3. Contractor mobilization; equipment and material check.
4. Site selection of decontamination pad and drum staging area (if applicable); final visual examination of proposed drilling area for utility conflicts.
5. Decontamination of sampling and drilling equipment prior to use.
6. Borehole advancement utilizing the approved method as outlined in the Work Plan.
7. Soil sample collection; descriptions of the soil samples in accordance with the Work Plan.
8. Monitoring well installation (if applicable).
9. Sample preparation and packaging.
10. Abandonment of boreholes or installation of monitoring wells.
11. Collection of groundwater samples (if monitoring wells are installed).
12. Surveying of borehole location and elevations.
13. Field note completion and review.

3.5.1 LOCATION AND MARKING OF DRILL SITES/FINAL VISUAL CHECK

The proposed borehole locations marked on the site plan are located in the field and staked or flagged. On most sites, this will likely be done several days in advance of the drill rig arriving on site. Unless boreholes are to be installed on a fixed grid, the proposed locations are usually strategically placed to assess site conditions.

Once the final location for the proposed boring has been selected and utility clearances are complete, one last visual check of the immediate area should be performed before drilling proceeds. This should confirm the locations of any adjacent utilities (subsurface or overhead) and verification of adequate clearance. If gravity sewers or conduits exist in the area, any access manholes or chambers should be opened and the conduit/sewer alignments confirmed. Do not enter manholes unless confined space procedures are followed.

If possible, it is prudent to use a hand auger or post-hole digging equipment to a sufficient depth to confirm that there are no buried utilities or pipelines. Alternatively, a

Hydrovac truck can vacuum a large diameter hole to check for utilities, although soils collected this way may require containment on site. This procedure generally clears the area to the full diameter of the drilling equipment which will follow.

If it is necessary to relocate a proposed borehole due to terrain, utilities, access, etc., the Project Coordinator must be notified and an alternate location will be selected.

3.5.2 SAMPLE COLLECTION

A boring is advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the Project Coordinator or Work Plan. Typically, the depth interval for sampling is 2.5 to 5 feet, or less in homogeneous strata, with at least one test and sampling location at every change of stratum. In some cases samples are taken continuously (i.e., 2-foot long samples at 2-foot intervals).

Collected soil samples are described in the field using the USCS (visual manual procedure). The soil description is recorded on a Stratigraphic Log or field book in the following order:

1. USCS Soil Symbol of major component.
2. Native or fill.
3. Secondary and minor soil components.
4. Relative densities/consistency.
5. Grain size/plasticity.
6. Gradation/structure.
7. Color.
8. Moisture content.
9. Observations of odor or visual chemical presence (i.e., non-aqueous phase liquid [NAPL]).
10. Additional descriptions.

For environmental sampling, always change gloves between collecting subsequent soil samples to prevent cross contamination. Decontaminate all tools (e.g., samplers, spatulas) prior to use on each sample to prevent cross contamination in accordance with the Work Plan.

Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler, and assures that the standard penetration test (SPT) or other sampling technique is performed on essentially undisturbed soil, is acceptable. The drilling method is selected based on the subsurface conditions. Each of the following methods has proven to be acceptable for specific subsurface conditions:

- HSA with inside diameter between 2.5 and 6.25 inches (5.7 to 15.9 cm);
- Solid stem auger (SSA) with auger diameter between 2.5 and 6.25 inches (5.7 to 15.9 cm); and
- Direct-push (dual tube systems, discrete soil sample systems).

Discrete Grab Sampling Methodology for Boreholes

When borehole drilling, the split-spoon sample retrieved from the borehole is considered a discrete grab sample that has been taken from one sampling location, as long as both the stratigraphy of the entire sample and the level of contamination are consistent over the length of the split-spoon sample. If a single split-spoon sample contains soils from two different stratigraphic units, the soils from each of these stratigraphic units are considered separate discrete grab samples.

If a single split-spoon sample contains soils from a single stratigraphic unit, but visual observation indicated that some of the soil was heavily impacted with contaminants, while the rest of the soil was only lightly impacted, then the soils representing each of the two levels of contamination are considered two separate discrete grab samples.

3.5.2.1 SPLIT-SPOON SAMPLERS

This method is used to obtain representative samples of subsurface soil materials and to determine a measure of the in situ relative density of the subsurface soils. The test methods described below must be followed to obtain representative samples.

SPT involves the use of split-barrel samplers (also known as split spoons). Split-spoon sampling is performed in accordance with ASTM D1586. The split-spoon sampler consists of an 18- or 24-inch long, 1.5 to 2-inch outside diameter tube, which comes apart lengthwise into two halves.

Once the borehole is advanced to the target depth and cleared of cuttings, representative soil samples are collected in the following manner:

1. The split-spoon sampler is inspected to ensure it is properly cleaned and decontaminated. The driving shoe (tip) should be relatively sharp and free of severe dents and distortions.
2. The cleaned split-spoon sampler is attached to the drill rods and lowered into the borehole.
3. After the sampler has been lowered to the bottom of the hole, it is given a single blow to seat it and make sure that it is in undisturbed soil. If there still appears

to be excessive cuttings in the bottom of the borehole, remove the sampler from the borehole and remove the cuttings.

4. Mark the drill rods in three or four successive 6-inch (15 cm) increments, depending on sampler length, so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-inch (15 cm) increment.

The sampler is then driven continuously for either 18 or 24 inches by use of a 140-pound (63.5 kg) hammer. The hammer may be lifted and dropped by either the cathead and rope method, or by using a trip, automatic, or semi-automatic drop system. The hammer should free-fall a distance of 30 inches (±1 inch) per blow. Measure the drop at least daily to ensure that the drop is correct. To ensure a free-falling hammer, no more than 2 1/4 turns of the rope may be wound around the cathead (see ASTM D1586). The number of blows applied in each 6-inch (15 cm) increment is counted until one of the following occurs:

1. A total of 50 blows have been applied during any one of the 6-inch (15 cm) increments described above.
2. A total of 100 blows have been applied.
3. There is no advancement of the sampler during the application of ten successive blows of the hammer (i.e., the spoon is 'bouncing' on a stone or bedrock).
4. The sampler has advanced the complete 18 or 24 inches without the limiting blow counts occurring as described above.

In some cases where the limiting number of blow counts has been exceeded, CRA may direct the driller to attempt to drive the sampler more if collection of a greater sample length is essential, as long as the sampler is still being advanced.

On the field form or in the logbook, record the number of blows required to drive each 6-inch increment of penetration. The first 6 inches is considered to be a seating drive. The sum of the number of blows required for the second and third 6 inches of penetration is termed the "standard penetration resistance" or the "N-value".

The sampler is then removed from the borehole and unthreaded from the drill rods. The open shoe (cutting end) and head of the sampler are partially unthreaded by the drill crew and the sampler is transferred to the geologist/engineer work surface.

The open shoe and head are removed by hand by the drill crew or CRA representative, and the sampler is tapped so that the tube separates.

Measure and record the length of sample recovered making sure to discount any sloughed material that is present on top of the sample core.

Caution must be used when conducting split-spoon sampling below the groundwater table, particularly in sand or silt. These soils tend to heave or "blow back" into the HSA due to the difference in hydraulic pressures between the inside of the HSA and the undisturbed soil. To equalize the hydraulic pressure, it may be necessary to fill the inside of the HSA with potable water from a reliable and pre-tested source. Drilling mud is uncommonly used and presents problems for sample collection and well development. The water level within the boring or HSA needs to be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling. Since heave or blow back is not always obvious to the driller, it is essential that the water level in the borehole always be maintained at or above the groundwater level. Split-spoon sampling below the water table in sands and silt occasionally results in non-representative samples being collected due to the heaving effect disturbing the soil. This is particularly important if the water level in the hole has not been maintained at the in situ water level.

Heaving conditions and the volume of potable water used should be noted on a Stratigraphic Log. The volume of water added must be removed during well development prior to groundwater sampling. This practice may not be acceptable if environmental samples are to be collected.

Suspected low N-values should be noted on the field logs. If it is critical to have accurate N-values below the water table, other methods can be employed, such as conducting a dynamic cone penetration test. This quick and easy test involves attaching a cone shaped tip to the end of the drill rods, and driving the tip into the ground similar to the split-spoon method, except that the borehole is not pre-augered. Cones may be driven 20 to 40 feet through a formation without augering. Blow counts are recorded for each 1 foot of advancement. Consult the Project Manager if such conditions are unexpectedly encountered.

Sampling in SSA borings are similar to the HAS methodology except all sampling is conducted in an open hole. Care must be taken in this case to assure that the boring remains open throughout the process.

3.5.3 FIELD SAMPLE SCREENING

When soil sampling at sites with known or suspected VOC impact, it is often required to measure the soil for the presence of undifferentiated organic vapors. This field screening can be performed using a photoionization detector (PID). Immediately upon the opening of the split-spoon or discrete soil sampler, the soil is screened with a PID

(HNu, Microtip, or equivalent) for the presence of undifferentiated organic vapors. This is accomplished by running the PID along the length of the soil sample. Record the highest reading.

Another method of field screening is head space measurement. This consists of placing a portion of the soil sample in a sealable glass jar, placing aluminum foil over the jar top, and tightening the lid. The jar is only partially filled. The jar is shaken and set aside for at least 30 minutes. After the sample has equilibrated, the lid of the jar is opened, the foil is punctured with the PID probe, and the air (headspace) above the soil sample is monitored. Record this headspace reading on the field form or in the field book. As an alternative, the soil can be placed in a sealable Ziploc® bag.

Representative portions of the soil sample may be retained for geologic record following description. Place the soil portions into labeled, sealable sample containers (usually mason jars or Ziploc® bags) without destroying any apparent stratification. If a stratigraphic change is observed within the split-spoon sampler, a separate geologic record sample is kept.

3.6 PROCEDURES FOR SOIL CLASSIFICATION

This SOP for Soil Classification is not intended to provide complete training in soil classification. Soil Classification will require additional training and experience.

Criteria and procedures for soil classification and description include:

1. A standard method of describing the soil by name and group symbol.
2. Standard field identification methods based on visual examination and manual tests on representative soil samples by a qualified CRA representative for interpretation of subsurface conditions at the site.
3. Verifying field description descriptions through the inspection.
4. Confirming descriptive information by laboratory determination of selected soil characteristics if required in the Work Plan.
5. Factual overburden stratigraphic logs completed by CRA personnel responsible for interpreting the subsurface conditions at the site and review/confirmation of soil descriptions by the Project Coordinator.

The overburden stratigraphic log is the factual description of the soil at each borehole location and will be relied on to interpret soil characteristics at the site. The overburden stratigraphic log will also be used to interpret the soil characteristics' influence and significance on the subsurface environment. CRA personnel responsible for interpreting the subsurface conditions at the site will also verify overburden stratigraphic log accuracy. If practical, the Project Coordinator, Geologist, or Geotechnical Engineer should confirm the soil descriptions and examine representative soil samples.

Describing and classifying soils is a skill that is learned through experience and by systematic training using laboratory results of soil composition in comparison to field descriptions.

Descriptions for natural undisturbed soils are recorded on a Stratigraphic Log.

Soil descriptions are completed in the following order:

1. Unified Soil Classification System (USCS) group symbol(s) (e.g., SM) of primary soil components or dual or borderline symbols.
2. Name and adjective description of primary, secondary, and minor grain size components.
3. Relative density for non-cohesive soils or consistency for cohesive soils.
4. Gradation and soil structure for non-cohesive soils or structure and plasticity for cohesive soils.
5. Color.
6. Moisture content.
7. Other physical observations including presence of staining and or odors.

When describing vegetative matter presence in soils, do not use the term organic. The use of the term organic often leads to confusion regarding the presence of organic chemicals [i.e., VOCs, semi-volatile organic compounds (SVOCs)]. Similarly, as noted above, use more specific terms for odors than organic.

The description of fill soils is similar to those used to describe native undisturbed soils. Fill soils will be identified as fill [i.e., SP/GP-Sand and Gravel (Fill)]. To determine if soils are fill, look for evidence that the soil has been artificially placed (e.g., brick fragments, slag, glass, wood fragments). Relative or inconsistent soil density can also assist in determining if soils are fill, along with irregular soil structure.

Soils are identified and grouped consistently to determine subsurface pattern or changes and non-conformities in the soil stratigraphy. The stratigraphy of each soil boring or test pit is compared to ensure that patterns or changes in soil stratigraphy are noted and that consistent terminology is used.

Visual examination, physical observation, and manual tests [based on ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)] are used to aid in classifying and grouping soil samples in the field. These procedures are described in the following subsection. ASTM D2488 should be reviewed for detailed explanations of the procedures. [Note that the related ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) uses slightly different percentages of soil components.) Visual-manual procedures used to aid in soil identification and classification include:

1. Visual determination of grain size, soil gradation, and percentage of various soil components to the nearest 5 percent (i.e., gravel, sand, silt, and clay).
2. Dry strength, dilatancy, toughness, and plasticity tests (i.e., thread or ribbon test) for identification of inorganic fine grained soils (e.g., CL or CH [clays], and ML or MH [silts]).
3. Soil compressive strength and consistency estimates based on thumb indent and or pocket penetrometer (preferred) methods.

The three main soil divisions are:

1. Coarse grained soils (e.g., sand and gravel).
2. Fine grained soils (e.g., silts and clays).
3. Soils with high natural organic and vegetative matter content (e.g., peat, marl).

These soil divisions are presented in the table of USCS classifications below.

Major Divisions			Group Symbol	Typical Description
Coarse grained soils more than 50% retained on No. 200 sieve	Gravel more than 50% of coarse fraction retained on No. 4 sieve	clean gravel <5% fines	GW	well graded gravel, gravel-sand mixtures
			GP	poorly graded gravel, gravel-sand mixtures
		gravel with >15% fines	GM	silty gravel, gravel-sand-silt mixtures
			GC	clayey gravel, gravel-sand-clay mixtures
	Sand more than 50% of coarse fraction passes No. 4 sieve	clean sand <5% fines	SW	well graded sand, fine to coarse sand, gravelly sand
			SP	poorly graded sand
		sand with >15% fines	SM	silty sand, sand-silt mixtures
			SC	clayey sand, sand-clay mixtures
Fine grained soils more than 50% passes No. 200 sieve	Silt and Clay liquid limit <50, low plasticity	inorganic	ML	Inorganic silt
			CL	Inorganic clay
		organic	OL	organic silt, organic clay
	Silt and Clay liquid limit ≥50, high plasticity	inorganic	MH	silt of high plasticity, elastic silt
			CH	clay of high plasticity, fat clay
		organic	OL	organic clay, organic silt, low plasticity
			OH	organic clay, organic silt, high plasticity
Highly organic soils			Pt	peat

3.6.1 COARSE GRAINED SOILS

The USCS symbols for coarse grained soil are primarily based on grain size, grain size distribution (gradation), and percent of fines (silt and clay content).

Grain size classification used for describing soils is in terms of particle size and sieve size (e.g., gravelly sand, trace silt). Coarse grained soil is composed of more than 50 percent by weight, sand size, or larger (75 µm diameter, No. 200 sieve size). Note that there are other definitions for coarse grained or coarse textured soil and for sand and for sand size as soil having greater than 70 percent particles equal to or greater than 50 µm diameter (after "Guidelines for Contaminated Sites in Ontario") or 60 µm diameter ("Canadian Foundation Manual").

The percentage descriptors for soil components are different for coarse grained versus fine grained soils. The following are the percentage component descriptors for coarse grained soils:

• Noun (e.g., sand, gravel)	Major Component;
• Adjective (e.g., silty, clayey, sandy, gravelly)	Greater than 15%;
• With (e.g., with silt, with clay, with sand, with gravel)	5% to 15%; and
• Trace (e.g., trace silt, trace clay, trace sand, trace gravel)	<5%.

Grain size distribution of coarse grained soils includes:

- Poorly graded (i.e., soil having a uniform or predominantly one grain size, SP and GP);
- Well graded (i.e., poorly sorted soils with a wide range of particle sizes with substantial percentage of intermediate sizes, SW and GW); and
- Dirty (i.e., soil having greater than 15 percent fines, SM, SC, GM, and GC).

Coarse grained soils are further classified based on the percentage of fine grained soils (e.g., silts and clays) they contain. Coarse grained soils containing greater than 15 percent fine grained soils are described with an adjective (e.g., silty [SM, GM], clayey [SC, GC]). This description is attributed to soil particles that adhere when the soil sample is rubbed between the hands or adhere to the sides of sample jars after shaking, or rolling in the jar. The jar shake test will also result in the segregation of sand and gravel particles and can be used as a visual aid in determining sand and gravel content percentages.

Examples of the group symbol, name, and adjectives used to describe the primary, secondary, and minor components of soil are:

- GW - Sandy Gravel (e.g., 70 percent gravel and 30 percent sand, well graded);

- GW - Sandy Gravel-trace silt (less than 5 percent silt, well graded);
- SP - Sand (a uniform sand, predominantly one sand grain size); and
- SM - Silty Sand, with clay (sand with greater than 15 percent silt, and 5 to 15 percent clay).

Relative density is important in establishing the engineering properties and behavior of coarse grained soils. Relative density of non-cohesive (coarse grained) soils is determined using the standard penetration test (SPT) blow counts (N-values) in accordance with ASTM D1586. A detailed discussion of the SPT and N values can be found in Section 5.9.2.1.

The SPT provides reliable indications of the relative density of sand and fine gravel. N-values in coarse grained soil are influenced by a number of factors that result in overestimated relative densities. For example, in coarse grained gravel, dilatent silty fine sands, sand below the water table and uniform coarse sand, N-values tend to be conservative and under estimate the relative density. The Project Geotechnical Engineer will assess these effects, if required.

Other methods, such as modified SPT and cone penetration tests, are used on occasion to supplement or replace the SPT method for certain site-specific conditions. All modifications to the SPT or substitute methods must be recorded as required to interpret test results and correlate relative density.

3.6.2 FINE GRAINED SOILS

A fine grained soil is made up of more than 50 percent silt and clay (i.e., fines greater than 50 percent by weight passing the 75 μm (No. 200) sieve size). Description of visual-manual field methods and criteria to further characterize and group fine grained soil (e.g., CL, CH, ML, and MH) are discussed in ASTM D2488.

The percentage descriptors for components is different for fine grained versus coarse grained soils. The following are the percentage component descriptors for fine grained soils:

• Noun (e.g., silt, clay)	Major Component;
• Adjective (e.g., sandy, gravelly, silty, clayey)	Greater than 30%;
• With (e.g., with sand, with gravel, with silt, with clay)	15% to 30%;
• Few (e.g., few sand, few gravel, few silt, few clay)	5% to 15%; and
• Trace (e.g., trace silt, trace clay, trace sand, trace gravel)	<5%.

Further soil characterization tests include dry strength, dilatency, toughness, and plasticity (thread or ribbon test).

Criteria for Describing Dry Strength

Description	*Criteria*
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen crumbles into powder 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

Criteria for Describing Dilatancy

Description	*Criteria*
None	No visible change in small wetted specimen when rapidly shaken in palm of hand
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 or stretching

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

Criteria for Describing Plasticity

Description	*Criteria*
Nonplastic	1/8-inch (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 re-rolled 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 re-rolled several times after reaching the plastic limit; the lump can be formed without crumbling when drier than the plastic limit

Examples of group symbol identification based on visual-manual procedures and criteria for describing fine grained soil are:

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

Positive classification by USCS group symbols as described in ASTM D2487, is through laboratory determination of particle size characteristics, liquid limit, and plasticity index. The need for laboratory testing will be determined by the Project Hydrogeologist, Geologist, or Geotechnical Engineer and will be detailed in the Work Plan. If no laboratory testing is performed to confirm soil classification, a statement of qualification (method used) is required for group symbols.

Examples of terminology that accompany the group symbols are:

- ML - Sandy Silt (e.g., 30 percent sand); and
- CL - Clay (lean) with sand (e.g., 15 to 29 percent sand)

The USCS group symbols require the use of lean clay (CL) and fat clay (CH). The use of these symbols is dependent on the plasticity of the soil. Classification such as silty clay can only be used for a very narrow set of conditions, and will only be used if Atterberg Limit results are available. The lean and fat clay designations are not universally used, but adherence to the USCS requires that these symbols be used.

Correlation of N-values and consistency for clays is unreliable. Consistency determinations will be performed using more appropriate static test methods, especially for very soft to stiff clays. N-values are more reliable in hard clays.

Estimates of unconfined compressive strength (Su) can be obtained by a pocket penetrometer test. To estimate consistency and compressive strength with a pocket penetrometer, cut a minimum 4-inch (10 cm) soil core perpendicular to the soil core length. Hold the core with moderate confining pressure so as not to deform the soil core. Slowly insert the pocket penetrometer tip into the perpendicular face of the soil core until the pocket penetrometer indents the soil core to the mark indicated on the piston of the penetrometer. The pocket penetrometer estimate of the soil compressive strength (Su) is the direct reading of the value mark on the graduated shaft indicated by the shaft ring marker, or by the graduated piston reading at the shaft body. For average estimates, complete this procedure several times on the ends and middle of the soil core. For Shelby tube samples (or thin wall samplers), perform the pocket penetrometer test at several locations on the exposed ends of the sample.

In situ shear vane tests or other test methods provide better compressive strength estimates for very soft to stiff consistency clay soil.

Describing soil consistency is an important component in evaluating the engineering properties and strength characteristics of fine grained cohesive soil. Consistency terms like soft and hard are based on the unconfined compressive strength (Su) and shear strength or cohesion (cu) of the soil.

Patterns of soil gas and groundwater movement in fine grained soil are influenced by natural soil structure. Soil structure is dependent on the depositional method and to a lesser extent climate. The identification of fill soil is equally important in determining soil characteristics in fine grained soils.

3.6.3 CHEMICAL DESCRIPTION

During soil examination and logging, carefully check for the presence of light or dense NAPL. NAPL may be present in gross amounts or present in small/minute quantities. The adjectives and corresponding quantities used when describing NAPL within a soil matrix are as follows:

Visual Description	*Fraction of Soil Pore Volume Containing NAPL*
Saturated	>0.5
Some	0.5 - 0.25
Trace	<0.25

A complete description of NAPL must describe the following:

- Color;
- Quantity;
- Density (compared to water) (i.e., light/floats or heavy/sinks);
- Odor (if observed); and
- Viscosity (i.e., mobile/flowable, non-mobile/highly viscous-tar like).

The presence of an "iridescent sheen" by itself does not constitute "NAPL presence", but may be an indicator that NAPL is close to the area.

NAPL presence within a soil matrix may be confirmed by placing a small soil sample within water, shaking, and observing for NAPL separation (i.e., light or dense) from the soil matrix.

Trace amounts of NAPL are identified/confirmed by a close visual examination of the soil matrix, (i.e., separate soil by hand, wearing disposable gloves) and performing a careful inspection of the soil separation planes/soil grains for NAPL presence.

Often during sample examination with a knife, an iridescent sheen will be noted on the soil surface (i.e., clay/silts) if the knife has passed through an area of NAPL.

There are a number of more complicated tests available to confirm/identify NAPL presence, these are:

- Ultraviolet (UV) fluorescent analysis;
- Hydrophobic dyes (use with care, consult the health and safety SOPs as some hydrophobic dyes are potential human carcinogens);
- Centrifugation; and
- Chemical analysis.

CRA typically utilizes organic vapor detection results, visual examination, soil/water shake testing, and chemical analysis, to confirm NAPL presence. The more complex techniques described may be incorporated on sites where clear colorless NAPL is present and its field identification is critical to the program.

3.6.4 CHEMICAL SAMPLE PREPARATION AND PACKAGING

Subsurface soil samples are usually grab samples, used to characterize the soil at a specific depth or depth interval (e.g., 2 to 4 feet). On occasion, composite samples are collected from a borehole over a greater depth interval (e.g., 5 to 15 feet).

The following describes the collection of grab samples for chemical analysis (all soil from one split spoon).

Clayey Soils

1. Discard upper and lower ends of sample core (3 inches [7.5 cm]).
2. Use a precleaned stainless steel knife.
3. Cut the remaining core longitudinally.
4. With a sample spoon, remove soil from the center portion of the core and place in a precleaned stainless steel bowl.
5. Remove large stones and natural vegetative debris.
6. Homogenize the soil and place directly into sample jars.

Sandy Soils

As sandy soils have less cohesion than clayey soils, it is not easy to cut the core longitudinally to remove the center of the sample. Therefore, with a stainless steel spoon, scrape away surface soils which have likely contacted the sampler and then sample the center portion of the soil core.

Record all soil samples in the log book.

3.7 COMMUNICATION OF FIELD FINDINGS

Field findings should be communicated frequently with the office technical staff responsible for the program. This communication allows the office staff to: confirm that the investigation meets the intent of the Work Plan; alter procedures and sampling protocol if soil conditions are markedly different from those assumed; and assist in determining screening intervals for piezometers or monitoring wells.

Call office staff no later than the completion of the first borehole, and sooner if possible. Be prepared to discuss the results by faxing the field logs beforehand (wherever possible) and by having a copy of the field log in hand when on the telephone. Call after each borehole and call before leaving the site.

3.8 BOREHOLE ABANDOMENT

Following completion of the borehole it must be properly abandoned in accordance with the project documents. Some jurisdictions have requirements or standards of practice that require filling the borehole with bentonite or cement grout.

Whenever possible, the cuttings are returned to the borehole to within 1 foot of the ground surface. The remainder of the borehole is topped off with material consistent with the surrounding ground surface. Excess cuttings are usually collected in drums or a lugger box or spread on the surrounding ground surface consistent with the protocols specified in the Work Plan and as required by federal, state, provincial, and local regulations.

Check with the Project Coordinator to determine the method for handling drill cuttings.

3.9 BOREHOLE TIE-IN/SURVEYING

Recording the locations of boreholes on the site plan is extremely important, and may be accomplished by manual measurement (i.e., swing ties) and surveying. Manual measurements for each borehole must be tied into three permanent features (e.g., buildings, utility poles, hydrants). Include diagrams with measurements in the field book.

In addition to manual measurements, surveying with respect to a geodetic benchmark and a site coordinate system is often completed at larger sites for horizontal and vertical control.

3.10 FIELD NOTES

Field notes must document all the events, date and time of activities, weather, site personnel, equipment used, calibration activities, and measurements collected during the sampling activities. The field notes must be legible and concise such that the entire borehole installation and soil sampling event can be reconstructed for future reference.

Field notes documenting events, equipment used, and related items are typically recorded in a standard CRA field book, while soil descriptions and PID readings are recorded on a Stratigraphic Log. Field book/form entries are made in black ink and any changes/corrections are stroked out with a single line, initialed, and dated to indicate when and by whom the correction was made.

The field notes should document the following for each borehole completed:

1. Identification of borehole.
2. Depth.
3. Static water level depth and measurement technique.
4. Time started and completed.
5. Measured field parameters.
6. Sample appearance.
7. Sample odors (if respiratory protection is not required).
8. Types of sample containers and sample identification numbers.
9. Parameters requested for analysis.
10. Field analysis data and method(s).
11. Sample distribution and transporter.
12. Laboratory shipped to.
13. Chain-of-custody number for shipment to laboratory.
14. Field observations on sampling event.
15. Name of collector(s).
16. Climatic conditions including air temperature.
17. Problems encountered and any deviations made from the established sampling protocol.

3.11 FOLLOW-UP ACTIVITIES

Complete the following activities at the conclusion of the field work:

1. Double check the Work Plan to ensure all samples have been collected and confirm this with the Project Coordinator.
2. Ensure that all sample locations are surveyed such that the sample location could be readily re-established.
3. Clean equipment and return to the equipment administrator with the appropriate form dated and signed. Complete water disposal (if required), and cleaning fluid disposal requirements as specified in the Work Plan.
4. Notify the contract laboratory as to when to expect the samples.
5. Submit a memo to the Project Coordinator indicating sampling procedures and observations (such as surface staining), grid layout, and all QA/QC documentation.

3.12 REFERENCES

For additional information pertaining to this topic, the user of this manual may reference the following:

Subsurface Soil Sampling

ASTM D420	Guide for Site Characterization for Engineering, Design, and Construction Purposes
ASTM PS 89	Guide for Expedited Site Characterization of Hazardous Waste Contaminated Sites
ASTM D5434	Guide for Field Logging of Subsurface Explorations of Soil and Rock
ASTM D2487	Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D2488	Practice for Description and Identification of Soils (Visual-Manual Procedure)
ASTM D5784	Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
ASTM D5872	Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
ASTM D4700	Guide for Soil Sampling from the Vadose Zone
ASTM D1586	Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils
ASTM D4220	Practices for Preserving and Transporting Soil Samples