Kennedy Jenks

4 May 2026

Mr. Christopher Herman
Environmental Project Officer
Petroleum Tank Cleanup Section
Montana Department of Environmental Quality
P.O. Box 200901
Helena, Montana 59620

Subject: Corrective Action Work Plan (DEQ Work Plan ID 35163)
Former Bulk Petroleum Facility Site (Carter BNSF Lease Property)
Third Street & RR Tracks, Mountain View Road, Carter, Chouteau County, Montana
for General Mills Operations LLC
Facility ID #60-15031 (TID 30814), DEQ Release #4469

Dear Mr. Herman:

On behalf of General Mills Operations LLC (GMOL), Kennedy/Jenks Consultants, Inc. (Kennedy Jenks) submits this revised Corrective Action Work Plan (CAWP) for the former Bulk Petroleum Facility (Carter BNSF Lease Property) located in Carter, Montana (the Site). Site location and Site layout maps are provided as Figures 1 and 2, respectively.

This CAWP, prepared in response to a Work Plan Request (WPR) issued by the Montana Department of Environmental Quality (DEQ) on 13 March 2026, presents a scope of work for assessing and remediating the source area at the Site. The scope includes high-resolution site characterization (HRSC), in-situ chemical oxidation (ISCO) injection, post-injection confirmation soil sampling, and four semiannual groundwater monitoring events beginning in spring/summer 2026 and concluding in winter 2027/2028.

Kennedy Jenks originally submitted the CAWP to DEQ on 16 April 2026 and DEQ provided comments on 24 April 2026. This revised CAWP is responsive to DEQ's comments on the original submittal, with changes summarized in the response to comment matrix provided in Appendix A.

Site Ownership and Operation History

The Site has been owned by Burlington Northern Santa Fe Railway Company (BNSF) and its predecessor company (Great Northern Railway Company) since 1921. Prior to 1933, the Site was leased to Mutual Oil Company and then leased to Continental Oil Company until 1933. GMOL has leased the Site from BNSF since 10 January 1949 with primary Site operations related to grain-handling activities. GMOL ceased all grain handling operations in 2002.

212 Carnegie Center, Suite 200 | Princeton, NJ 08540
609.285.2637 | JenniferKriczky@kennedyjenks.com

Site Conditions

The Site, located in Carter, Chouteau County, Montana[1], consists of a former bulk petroleum facility located adjacent to the BNSF railroad tracks. The town of Carter is located across the BNSF railroad tracks to the northwest, upgradient of the Site, and is served by a municipal water supply.

Historical documentation shows that the Site held two 1,100-gallon steel aboveground storage tanks (ASTs), one of which held diesel fuel, while the other contained gasoline. A building presumably used for fuel handling was located northeast of the ASTs. According to aerial imagery, the ASTs were removed prior to 1995. The Site is not currently operated or occupied, though grain handling structures and equipment still exist.

Based on previous investigations, native subsurface soil consists of clay with interbedded sand and gravel layers. Soil impacts having concentrations of volatile petroleum hydrocarbons (VPH) and benzene above Risk-Based Screening Levels (RBSLs) exist at the Site. These soil impacts are generally located around GMW-7 at approximately 6 to 12 feet (ft) belowground surface (bgs) and extending approximately 35 ft to the south-southeast, and around the former ASTs.

The depth to groundwater at the Site is approximately 5 to 15 ft bgs, although groundwater is often not observed in borings until approximately 15 to 20 ft bgs. The aquifer within the unconsolidated sediments is semi-confined, with groundwater depths typically rising in wells after installation. The general groundwater flow direction in the vicinity of the Site is to the southeast.

A dissolved-phase petroleum impact zone occurs onsite with concentrations of VPH, lead scavengers, 1-methylnaphthalene, and benzene that are above the DEQ-7 Human Health Standards (HHS), with impacts limited to the former AST and filling station area and a narrow band extending south from GMW-7. Dissolved-phase impacts appear relatively stable based on historical monitoring data.

Extractable petroleum hydrocarbon (EPH) screen results were high enough to warrant further fractionation for both soil and groundwater, however, individual EPH fractions have not been reported above RBSLs or HHS.

Release History

In June 2003, BNSF conducted a Phase II Environmental Site Assessment (ESA) which revealed that a petroleum release had occurred near the location of the former ASTs. BNSF filed a 24-Hour Release Report on 3 October 2003, and the Site was assigned Facility ID #60-15031 and DEQ Release #4469. Historical soil borings, including those installed beginning in 2003, are shown on Figure 3.

In January 2006, GMOL retained Atlatl, Inc. (Atlatl, now JBR Environmental Consultants, Inc. [JBR]) to conduct a Phase I ESA and remedial investigation (RI). The Phase I identified the former petroleum-related uses at the Site, as well as results of the previous BNSF investigation. In March 2006, DEQ,

[1] The approximate coordinates of the Site are latitude 47.7989 North and longitude -110.3533 West.

BNSF, and GMOL representatives discussed responsibility for investigation and remediation of the Site, and GMOL submitted a 30-Day Release Report on 22 March 2006.

In addition to the petroleum release(s) identified at the Site, the neighboring Mountain View Co-Op (MVCO) property also reported a release (DEQ Facility ID #08-09911, Release #3893). Release #3893, now closed using a Petroleum Mixing Zone (PMZ), has a PMZ boundary adjacent to the GMOL site and dissolved-phase petroleum impacts from the MVCO site appear to be outside of the PMZ boundary and extending onto the GMOL Site based on figures provided in the MVCO site PMZ Report (JBR 2013).

Post-Release Site Investigation History

In response to the March 2006 Release Report, DEQ issued a request to GMOL on 23 March 2006 for an RI Work Plan. GMOL submitted a *Work Plan for Initial Remedial Investigation* (Atlatl 2006) to DEQ in May 2006 and JBR completed a Site investigation that included installation of 10 soil borings. Groundwater was collected from the 10 borings, and five of the borings were converted to GWM wells GMW-1 through GMW-5. The investigation effectively delineated the contaminant plume to the north and southeast, identified soil and groundwater petroleum impacts associated with the former ASTs, and recommended further investigation. Results of the initial RI activities were summarized in a *Remedial Investigation for Petroleum Contamination at General Mills, Carter Montana* report submitted to DEQ in January 2008 (Atlatl 2008).

In response to the Atlatl 2008 report, DEQ issued a request for additional corrective action at the Site and in response, GMOL submitted a *Work Plan for Remedial Investigation* in February 2009 (JBR [formerly Atlatl] 2009). JBL completed additional Site investigation activities from March 2010 through January 2011 to determine whether upgradient petroleum hydrocarbon impacts were present, and whether a utility corridor on the southeastern side of the Site was impacted by the hydrocarbon plume. JBR installed three soil borings that were finished as GWM wells GMW-6 through GMW-8. Groundwater sampling was also conducted in March, July, September, and December 2010. GMOL submitted a *Phase II Remedial Investigation and Monitoring Event* report (JBR 2010) and a *Groundwater Monitoring Report* (JBR 2011) to DEQ that identified two “source areas” containing petroleum-impacted soils contributing to groundwater impacts. The first area was located immediately surrounding GMW-3 in the location of the former ASTs, and the second area was located near the grain elevators in the vicinity of GMW-7, where a former pipeline ran from the railroad tracks to the former ASTs.

In 2016, Kennedy Jenks conducted a groundwater investigation to assess the nature and extent of constituents in Site groundwater since the last sampling event completed in 2011. Monitoring wells GMW-1 through GMW-8 were sampled and analytical results indicated two upgradient wells (GMW-1 and GMW-7), one source well (GMW-3), and one downgradient well (GMW-5) exceeded RBSLs. Kennedy Jenks also conducted a file review to assess the current status of the MVCO site petroleum release.

In 2018, Kennedy Jenks installed four additional monitoring wells to assess groundwater impacts near the grain elevators. Sampling of the existing eight monitoring wells (GMW-1 through GMW-8) and the four new wells (GMW-9 through GMW-12) was completed and analytical results indicated that groundwater in source area well GMW-3 and upgradient well GMW-7 contained benzene concentrations exceeding RBSLs. Analytical results also indicated that contaminant concentrations and plume size were decreasing. The conclusions of this investigation determined that the Site could be approached similarly to the adjacent MVCO site by seeking closure through the establishment of a PMZ.

In 2020, Kennedy Jenks completed a nitrate investigation and concluded that while groundwater analytical results indicate nitrate is present at levels above the DEQ Maximum Contaminant Level (MCL), concentrations are higher in the southwest portion of the Site, indicating that the source of nitrates in groundwater is away from where GMOL historically operated. The Site is in an agricultural area with the potential for nitrate to be from several different sources surrounding the property. Following this nitrate investigation, BNSF approved moving forward with closing the Site using a PMZ approach with DEQ.

In 2021, Kennedy Jenks worked with the DEQ Petroleum Tank Cleanup Section to move the Site towards closure. In October 2021, DEQ requested an RI Work Plan to address data gaps necessary prior to obtaining a PMZ Closure. A *Remedial Investigation Work Plan* was submitted to DEQ in November 2021 (Kennedy Jenks 2021) with the following objectives:

- Assess the current groundwater plume
- Determine whether the soil adjacent to GMW-7 and southeast of GMW-7 is impacted by petroleum constituents
- Determine the vapor risk of the two grain handling buildings

Kennedy Jenks installed two soil borings and three sets of nested soil vapor wells, and collected soil, groundwater, and soil vapor samples between December 2021 and April 2022 to meet RI Work Plan objectives. All data objectives were met, and the Conceptual Site Model (CSM) of the Release Closure Plan (RCP) demonstrated that all receptor pathways would be eliminated by use of institutional controls to restrict use of groundwater and future excavation of soils on the Site and the north adjoining property. RI activities were summarized in a *Remedial Investigation Report* submitted to DEQ in June 2022 (Kennedy Jenks 2022) with PMZ closure as the recommended path forward for the Site.

In 2024, per conversations with DEQ, two additional data gaps were identified that needed to be addressed in order to continue working towards closure of the Site with the goal of complying with Montana PMZ statute §75-11-503 Montana Code Annotated (MCA): defining source areas and defining the PMZ boundary in accordance with ARM 17.56.604 and the DEQ PMZ Technical Guidance document.

Kennedy Jenks completed additional soil and groundwater investigations in 2024 and 2025 to further define the source area and extent of dissolved-phase impacts, as well as the PMZ boundary. GMOL submitted a *Work Plan for Groundwater Investigation* to DEQ in July 2024 (Kennedy Jenks 2024), which included advancing five additional soil borings to evaluate the saturated zone encountered during drilling, completing the borings as GWM wells, and subsequent GWM. In August 2024, five additional GWM wells (GMW-1D, GMW-3D, GMW-7D, GMW-13, GMW-14) were installed with 5-foot-long screens to determine representative concentrations of petroleum constituents in groundwater without interference from petroleum-impacted vadose zone soils that may be present in existing GWM wells.

The screened interval of the new wells targeted the saturated zone encountered during well installation (approximately 15 to 19 ft bgs).

The soil and groundwater investigation activities completed in 2024 and 2025 were summarized in a *Supplemental Groundwater Investigation Report* (Kennedy Jenks 2025a), as well as a *Supplemental Groundwater Monitoring Report* (Kennedy Jenks 2025b) submitted to DEQ in February and August 2025, respectively. Soil analytical results indicate that petroleum impacts are limited to the former AST and filling station area, and to a narrow band beginning at GMW-7 heading south towards this area (Kennedy Jenks 2025a).

Groundwater analytical results indicate that there are two areas of petroleum impacts (Kennedy Jenks 2025a, Kennedy Jenks 2025b). One area of petroleum impacts is located along the boundary of the MVCO site and downgradient of the MVCO site. This area is addressed in the existing PMZ for the MVCO site. The second area of petroleum impacts, and primary source area for the GMOL Site, is located near the elevators (GMW-7 and GMW-7D). This primary source area for the GMOL Site is the focus of this CAWP.

The most recent potentiometric surface of the groundwater and its apparent flow direction are shown on Figure 4. Historical potentiometric surfaces and apparent flow directions have remained generally consistent, with groundwater flowing gradually to the south-southeast at the Site.

The extent of the existing dissolved phase benzene impacts above DEQ-7 Human Health Standards (HHS) in groundwater is shown on Figures 5A (2025 benzene isoconcentrations) and 5B (trend of dissolved-phase impacts since 2010). Dissolved phase concentrations above DEQ-7 HHS have reduced in size since 2010, and benzene concentrations above the DEQ-7 HHS only remain around Site wells GMW-3, GMW-5, GMW-07, GMW-7D, GMW-13, and GMW-14. Monitoring wells GMW-13 and GMW-14 were installed during the 2024 investigation and are adjacent to the MVCO PMZ boundary. Soil and groundwater impacts are also depicted in cross-sections shown on Figures 6A and 6B.

Corrective Action Work Plan

Following completion of the 2024 and 2025 soil and groundwater investigations, as well as submittal of the *Supplemental Groundwater Investigation Report* (Kennedy Jenks 2025a) and *Supplemental Groundwater Monitoring Report* (Kennedy Jenks 2025b), DEQ requested a CAWP to fulfill closure requirements under Montana PMZ statute §75-11-503 MCA, ARM 17.56.604, and the DEQ PMZ Technical Guidance document. Previously identified data gaps have been resolved, including: (1) defining the source area; (2) defining the PMZ boundary; (3) ensuring conditions at the Site provide present and long-term protection of human health, safety, and the environment; and (4) demonstrating that natural breakdown or attenuation is actively occurring within the plume.

Cleanup Objectives

The CAWP is designed to address the final two requirements under the DEQ PMZ Technical Guidance document: (1) remove source material to the maximum extent practicable; and (2) advance the Site to a condition that calls for no further corrective action.

Scope of Work

This CAWP describes the following tasks:

- Task 1 – Project Management
- Task 2 – Utility Clearance
- Task 3 – High Resolution Site Characterization
- Task 4 – In Situ Chemical Oxidation Injection
- Task 5 – Post-Injection Confirmation Sampling
- Task 6 – Semiannual Groundwater Monitoring
- Task 7 – Data Validation Review
- Task 8 – Reporting

The activities associated with each task are described below.

Task 1 – Project Management

Project management for this CAWP will include coordination with DEQ, GMOL, and BNSF, scheduling of personnel, preparing bottle orders from the analytical laboratory, ordering sampling materials and equipment, development and/or update of a Site-specific Health and Safety Plan (HASP), progress reporting, and other miscellaneous tasks. Throughout the project, continued coordination with DEQ is expected to occur through virtual meetings (DEQ's preferred method), which are assumed to be conducted on an as needed basis. It is also assumed that a 15-day comment period for local government offices, as required by MCA Title 75, Chapter 11, Part 309(1)(e)(i), will be required prior to beginning tasks under this CAWP.

Task 2 – Utility Clearance

Underground utilities in the vicinity of the Site may include those installed by GMOL or others for grain handling operations. Kennedy Jenks will notify the Montana Utility Notification Center (811) for utility clearance prior to any intrusive activities. In addition, Kennedy Jenks will subcontract a private utility locating company to clear the work area for utilities installed by GMOL or others. The private utility locator will use both conductive and nonconductive utility locating equipment, as well as ground penetrating radar (GPR). Kennedy Jenks will mark the work areas that require utility clearance and will provide oversight of the utility locating activities. Known Site utilities are shown on Figure 2.

Task 3 – High-Resolution Site Characterization

Kennedy Jenks will subcontract a qualified HRSC provider to advance borings to provide subsurface imaging in the area of remaining source mass identified in previous investigations. The imaging will use a membrane interface probe (MIP) coupled with an electrical conductivity dipole (EC) and a hydraulic profiling tool (HPT) system, collectively known as the MIHPT. The MIHPT will be advanced using direct push technology (DPT) to log volatile hydrocarbon impacts in addition to soil electrical conductance and indicators of formation permeability. The goal of this imaging is to obtain an understanding of lithological and hydrogeological data, along with information regarding potential constituents of concern, to better focus subsequent ISCO injections.

MIHPT borings are proposed to be advanced at the approximate locations shown on Figure 7 and to an approximate depth of 15 ft bgs. As applicable, discrete confirmatory soil and/or groundwater samples will be collected by Kennedy Jenks and submitted to a DEQ-accredited laboratory via chain-of-custody protocol for analysis of Montana methods for VPH, EPH screen, and EPH fractions, if necessary. If EPH screen results are above 200 milligrams per kilogram (mg/kg), EPH screen samples will be further fractionated without polynuclear aromatic hydrocarbons (PAHs).

Prior to advancing each boring, non-disposable drill tooling and equipment will be cleaned using a hot water pressure washer and phosphate-free detergent and rinsed with distilled water. Following completion of each boring, the bore holes will be abandoned per DEQ requirements, and the ground surface will be restored to match preexisting conditions.

After completion of the field work component of this task, the subcontractor will provide a report summarizing the results of the HRSC. Following receipt of this report, a meeting will be scheduled with DEQ to discuss the HRSC results and proposed locations of the ICSO injection borings.

Task 4 – In Situ Chemical Oxidation Injection

Using results of the HRSC, Kennedy Jenks will conduct a focused ISCO injection to address the remaining source mass in the subsurface. Kennedy Jenks will coordinate with a chemical oxidation product vendor to verify the selected reagent is the appropriate solution for Site application based on HRSC results.

A qualified drilling subcontractor will conduct the ISCO injection using a DPT drill rig. The subcontractor will provide the equipment necessary for mixing and injecting the selected reagent. The reagent will be mixed with water onsite and injected into the subsurface at depths corresponding to the potential zone of impacts identified during the HRSC. Three ISCO injection events are planned, with the number of injection points, treatment area, and mass of reagent adjusted based on Site conditions and treatment effectiveness. It is anticipated that the treatment area and number of borings will decrease with each injection event.

Prior to advancing each injection boring, non-disposable drill tooling and equipment will be cleaned using a hot water pressure washer and phosphate-free detergent and rinsed with distilled water. Following completion of each injection point, the bore holes will be abandoned per DEQ requirements, and the ground surface will be restored to match preexisting conditions. Kennedy Jenks will mark each completed injection point and record GPS coordinates to document injection locations.

During the injection phase, Kennedy Jenks will have routine coordination with the reagent vendor and drilling subcontractor to verify field application of the treatment is working as intended. ISCO injections can be susceptible to issues arising from subsurface lithology, soil type, and groundwater and atmospheric conditions. Kennedy Jenks and subcontractors will remain flexible in the field to adjust the amount injected, spacing of injection points, or timing between treatment events as necessary.

Task 5 – Post-Injection Confirmation Soil Sampling

To achieve a successful PMZ, the source mass must be removed to the maximum extent practicable, and any remaining source area impacts must be demonstrated to not pose unacceptable present or future risk to human health, safety, or the environment (ARM 17.56.607 [10][h]). To meet both requirements, Kennedy Jenks will collect confirmation soil samples from the locations previously shown to have remaining source area impacts.

Following the first semiannual seasonal high GWM event, Kennedy Jenks will provide oversight while a licensed driller advances two soil borings to approximately 20 ft bgs using a DPT drill rig. Soil cores will be collected using a macrocore soil sampling system. Kennedy Jenks will field screen the soil cores with visual observations and with the use of a photoionization detector (PID). Samples showing the highest PID readings will be collected for laboratory analysis for petroleum hydrocarbons using Montana methods for VPH, EPH screen, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). Samples with concentrations above the EPH screen threshold (200 mg/kg) will be fractionated without PAHs. Samples will be collected in laboratory-supplied bottles and placed in a cooler on ice. Coolers will be shipped to the laboratory via chain-of-custody procedures. Laboratory analytical results will be compared to the DEQ RBSLs.

If field screening does not indicate the presence of constituents of concern in the field, at least one sample will be collected from a suspected depth of impact based on previous results (i.e., from the results of the HRSC or earlier investigations). Borings will be advanced in the approximate areas previously drilled that showed residual source mass continued to exist in the subsurface.

Prior to advancing each boring, non-disposable drill tooling and equipment will be cleaned using a hot water pressure washer and phosphate-free detergent and rinsed with distilled water. Following completion of each soil boring, the bore holes will be abandoned per DEQ requirements, and the ground surface will be restored to match preexisting conditions. If field screening does not indicate the presence of constituents of concern (i.e., PID readings greater than 100 parts per million [ppm]), soil cuttings will be returned to the bore hole to be used as backfill, with bentonite pellets used as backfill from approximately 3 ft bgs to the ground surface. Any remaining soil cuttings, or soil cuttings indicated to have the presence of constituents of concern, will be placed in 55-gallon drums stored on secondary containment in a locked enclosure to be disposed of at a later date.

Task 6 – Semiannual Groundwater Monitoring

Four rounds of semiannual groundwater monitoring events will be conducted at the Site during approximate seasonal high and low groundwater conditions, starting approximately two weeks after the conclusion of the final ISCO injection event and continuing through winter 2027/2028. The first groundwater monitoring event will be conducted to evaluate groundwater conditions following the corrective action.

Groundwater samples will be collected from the existing Facility monitoring wells (GMW-01 through GMW-14) by a low-flow sampling method according to DEQ's *Groundwater Sampling Guidance*. Prior to sampling, static water levels (SWLs) will be measured using an electronic water level probe. The SWL data will be used to develop a potentiometric map of the groundwater table.

During purging, groundwater field parameters (pH, dissolved oxygen, specific conductivity, temperature, turbidity, and oxidation-reduction potential) will be collected and recorded until field parameters have stabilized. Upon groundwater parameter stabilization, groundwater samples will be collected into laboratory-supplied containers, preserved, stored on ice, and submitted under chain-of-custody procedures to a DEQ-accredited laboratory.

Groundwater samples will be analyzed for VPH and EPH screen using the Montana-modified Massachusetts Method. Samples with concentrations above the EPH screen threshold (1,000 micrograms per liter [µg/L]) will be fractionated without PAHs. Groundwater samples will also be analyzed for lead scavengers 1,2 Dichloroethane (1,2-DCA) and ethylene dibromide (EDB) via U.S. Environmental Protection Agency (EPA) Method 8260B and EPA Method 8011, respectively. Groundwater results will be compared to HHS in DEQ Circular DEQ-7 *Montana Numeric Water Quality Standards*.

To avoid cross-contamination between wells, dedicated, disposable equipment will be used whenever possible, or the sampling equipment will be cleaned between wells using a detergent and water solution wash followed by a minimum of two distilled water rinses.

Purge water will be disposed of according to DEQ's *Disposal of Untreated Purge Water from Monitoring Wells* flowchart. Investigation-derived waste (IDW) will be stored onsite in 55-gallon steel drums on a secondary containment unit and within an enclosed shed, for disposal by a licensed waste disposal contractor. Existing analytical data will be used for waste stream characterization.

Task 7 – Data Validation Review

Each laboratory analytical report will be reviewed for quality assurance/quality control (QA/QC) purposes to verify the data is usable and valid. Data validation review will include preparation of DEQ Data Validation Summary Forms (DVSFs) found online under the Guidance dropdown at the Petroleum Tank Cleanup Section webpage. The DVSFs will be appended to the applicable reports.

Task 8 – Reporting

Kennedy Jenks will prepare the following deliverables:

- Corrective Action Report: The Corrective Action Report will present the results of the field activities conducted during the first year of CAWP implementation activities, including HRSC, ISCO injections, and the first two seasonal GWM events. The report will be submitted to DEQ approximately eight weeks following receipt of validated laboratory analytical results from the first seasonally low GWM event. If requested by DEQ, the RCP will be updated and appended to the Corrective Action Report.

- Two Interim Data Submittals (IDSs): Each IDS will include updated tables and figures submitted to DEQ approximately three (3) weeks following receipt of validated laboratory analytical results from each seasonally high GWM event. The first IDS will include results of the post-injection confirmation soil sampling.

- Groundwater Monitoring Report: The GWM Report will present the results of the second year of GWM and will include historical GWM data. If requested by DEQ, the RCP will be updated and appended to the GWM Report. The GWM Report will be submitted to DEQ approximately five weeks following receipt of validated laboratory analytical results from the second seasonally low GWM event.

- PMZ Report: The PMZ Report will incorporate details from historical Site work, as well as the previous PMZ Report, and will summarize CAWP implementation activities and results. The PMZ Report will be prepared in support of requesting release closure through establishment of a PMZ, with expected boundaries shown on Figure 9. This report is estimated to be submitted approximately eight weeks following written notification from DEQ that closure through establishment of a PMZ is approved.

Reports will be prepared using standardized DEQ report formats found online under the Forms dropdown at the Petroleum Tank Cleanup Section webpage. Reports will be submitted electronically following the PTCS submittal requirements found under the Guidance dropdown at the Petroleum Tank Cleanup Section webpage.

Quality Assurance/Quality Control

Field QA/QC will include the collection of duplicate samples during each sampling event. One duplicate sample per 20 samples (soil and groundwater) will be collected. The results of the duplicate sample will be compared to the primary sample for consistency. An equipment blank will be collected any day that downhole equipment will be reused to assess proper cleaning techniques. Additionally, a field blank will be collected each day that groundwater samples are collected.

A Quality Assurance Project Plan (QAPP) was provided in Appendix A of the *Remedial Investigation Work Plan* (Kennedy Jenks 2021) and will be used for the implementation of this CAWP. The laboratory will follow its standard internal QA/QC procedures during sample analysis (provided in the QAPP). Standard Operating Procedures (SOPs) to be followed in the field are provided in Appendix B of this CAWP.

Investigation-Derived Waste

Soil and groundwater obtained from investigation and/or cleaning procedures will be containerized and held onsite pending characterization and disposal. The 55-gallon drums used to containerize IDW will be stored on a secondary containment unit within an enclosed shed that will be locked.

Health and Safety Plan

Field work will follow the health and safety protocols outlined in the site-specific Health and Safety Plan. Site work will not take place within 25 feet of the BNSF railroad tracks.

Estimated Schedule

Kennedy Jenks anticipates that Site work will commence in late spring 2026, weather permitting. Kennedy Jenks will provide at least one-week advance notice to DEQ. The estimated schedule is shown on Figure 10 and summarized below:

- 15-day Local government comment period: May 2026
- HRSC and ISCO Injection Events: Late spring through early summer 2026
- First Semiannual High GWM Event: July 2026
- Post-Injection Confirmation Soil Sampling: Following first GWM event, July 2026
- First IDS: August 2026
- First Semiannual Low GWM Event: October 2026
- Corrective Action Report: December 2026
- Second Semiannual High GWM Event: May 2027
- Second IDS: June 2027
- Second Semiannual Low GWM Event: October 2027
- GWM Report: November 2027
- PMZ Report: Within eight weeks after DEQ approval of a PMZ request

Please contact Jennifer Kriczky at (609) 285-2637 or JenniferKriczky@kennedyjenks.com should you have any questions regarding the CAWP or the project.

Very truly yours,

KENNEDY/JENKS CONSULTANTS, INC.

Jennifer Kriczky
Senior Project Manager

Spenser O.E. Kuhn, L.G., P.G.
Senior Associate Scientist

<u>Figures</u>

- Figure 1: Site Location
- Figure 2: Site Map & Utilities
- Figure 3: Soil Boring Locations

- Figure 4: Potentiometric Surface Map 2025
- Figure 5A: Groundwater Isoconcentration – Benzene May 2025
- Figure 5B: Benzene Plume Area – 2010, 2016, 2022, 2025
- Figure 6A: Cross Section Segments A-A’
- Figure 6B: Cross Section Segments B-B’
- Figure 7: HRSC Proposed Locations
- Figure 8: Proposed Injection Areas
- Figure 9: PMZ Boundary and Buffer Zones
- Figure 10: Proposed Project Schedule

Appendices

- Appendix A: Response to Comments Matrix
- Appendix B: Standard Operating Procedures

References

Atlatl, Inc. 2006. Work Plan for Initial Remedial Investigation at General Mills, Carter, Montana.

Atlatl, Inc. 2008. Report of Remedial Investigation for Petroleum Contamination at General Mills, Carter, Montana.

JBR Environmental Consultants, Inc. 2009. Work Plan for Remedial Investigation, Former Bulk Petroleum Facility, Third Street and RR Tracks Mountain View Road, Carter, Montana.

JBR Environmental Consultants, Inc. 2010. Phase II Remedial Investigation and Monitoring Event, Former Bulk Petroleum Facility, Third Street and RR Tracks Mountain View Road, Carter, Montana.

JBR Environmental Consultants, Inc. 2011. Groundwater Sampling Report, General Mills Elevators Carter, Montana, 20 January 20 2011.

JBR Environmental Consultants, Inc. 2013. Petroleum Mixing Zone Closure Summary Report for Release # 3893, Work Plan #6958, General Mills Elevators Carter, Montana, 3 December 2013.

Kennedy/Jenks Consultants, Inc. 2021. Remedial Action Work Plan, Former Bulk Petroleum Facility, Carter, MT. Facility ID: 60-15031. Release ID: 4469. Work Plan: 34420.

Kennedy/Jenks Consultants, Inc. 2022. Remedial Investigation Report, Former Bulk Petroleum Facility, Carter, MT. Facility ID: 60-15031. Release ID: 4469. Work Plan: 34420.

Kennedy/Jenks Consultants, Inc. 2024. Work Plan for Groundwater Investigation, Former Bulk Petroleum Facility, Carter, MT. Facility ID: 60-15031. Release ID: 4469. Work Plan: 34420.

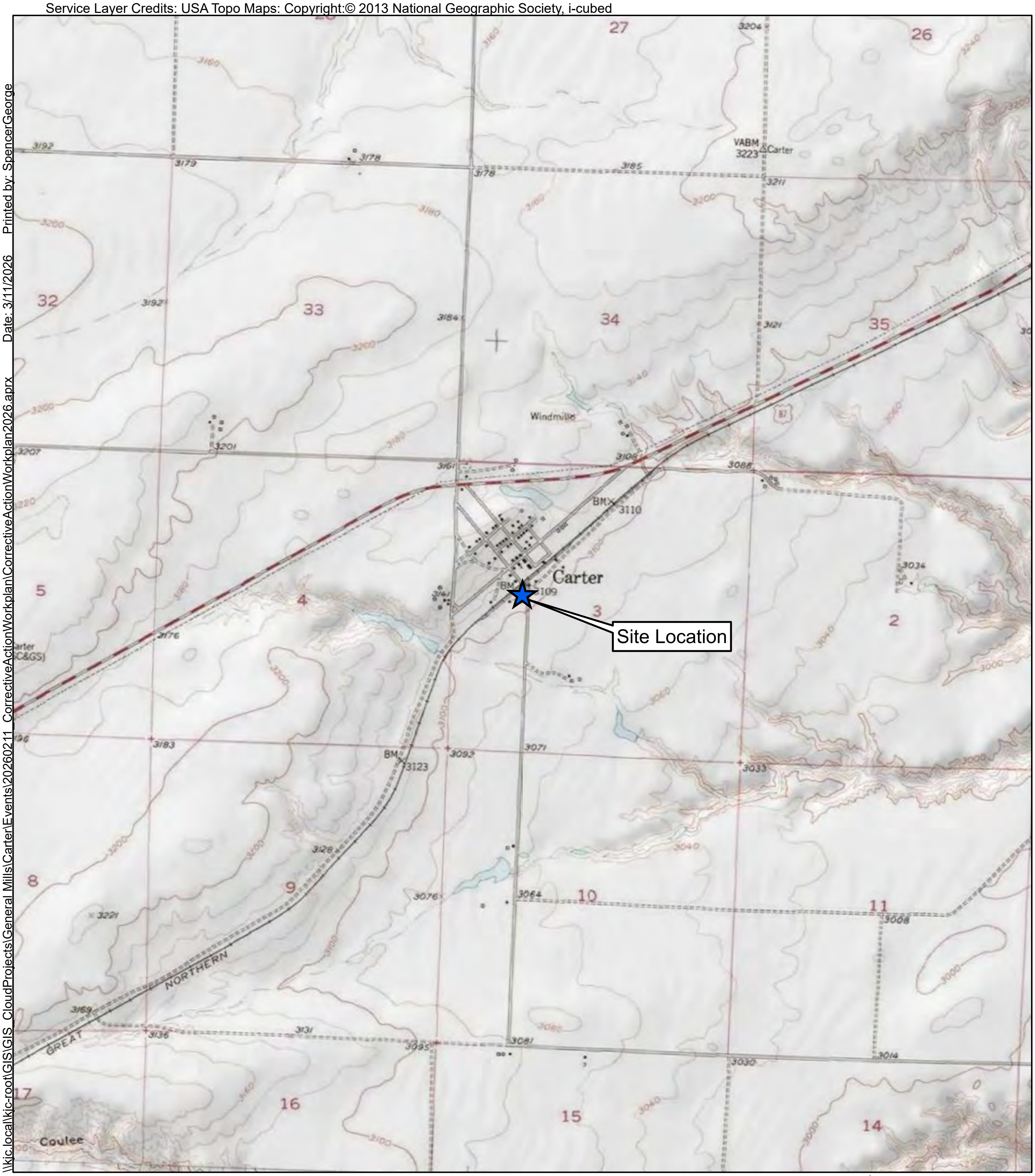
Kennedy/Jenks Consultants, Inc. 2025a. Supplemental Groundwater Investigation Report. GMOL Carter Elevator Site. 3rd Ave & Railroad Tracks, Carter, Montana. MDEQ Facility 60-15031, MDEQ Release 4469.

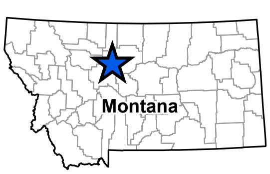
Kennedy/Jenks Consultants, Inc. 2025b. Supplemental Groundwater Monitoring Report. GMOL Carter Elevator Site. 3rd Ave & Railroad Tracks, Carter, Montana. MDEQ Facility 60-15031, MDEQ Release 4469.

Figures

Service Layer Credits: USA Topo Maps: Copyright:© 2013 National Geographic Society, i-cubed

\\kic.local\kic-root\GIS\GIS_CloudProjects\General Mills\Carter\Events\20260211_CorrectiveActionWorkplan\CorrectiveActionWorkplan2026.aprx Date: 3/11/2026 Printed by: SpencerGeorge





Map Location

N

0 1,250 2,500

Scale: Feet

Kennedy Jenks

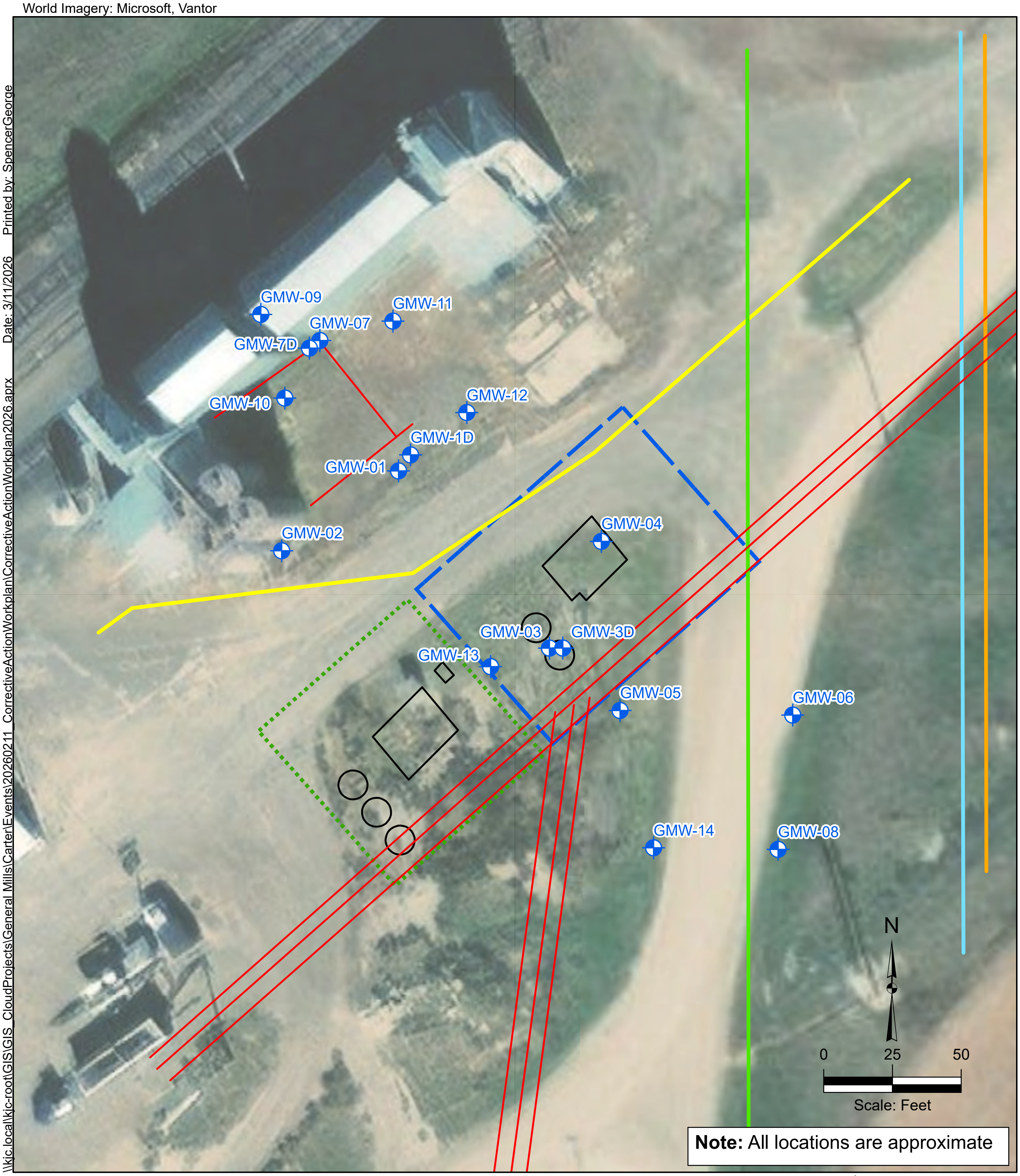
General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Site Location

2549063*00

Figure 1

World Imagery: Microsoft, Vantor



\\kjc.local\kjc-root\GIS\GIS_CloudProjects\General Mills\Carter\Events\20260211_CorrectiveActionWorkplan\CorrectiveActionWorkplan2026.aprx Date: 3/11/2026 Printed by: SpencerGeorge

Legend

- Monitoring Well
- General Mills Bulk Site
- Mountain View Co-Op Original Lease Site
- Gas Line
- Approximate Sewer Line
- Approximate Water Line
- Approximate Fiber Optics Line
- Overhead Power Line

Kennedy Jenks

General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Site Map & Utilities

2549063*00

Figure 2

World Imagery: Microsoft, Vantor

Printed by: SpencerGeorge Date: 3/11/2026 \\kjc.local\kjc-root\GIS\GIS_Cloud\Projects\General Mills\Carter\Events\20260211_CorrectiveActionWorkplan\CorrectiveActionWorkplan2026.aprx

Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Projection: Lambert Conformal Conic

Legend

- Soil Boring (2003)
- Soil Boring (2007)
- Soil Boring (2010)
- Soil Boring (2021)
- Soil Boring (2026)
- Monitoring Well
- Mountain View Co-Op Groundwater Monitoring Well
- Mountain View Co-Op Original Lease Site
- General Mills Bulk Site

Notes:

1. Locations are approximate.

N

0 20 40

Scale: Feet

Kennedy Jenks

General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Soil Boring Locations

2549063*00

Figure 3

World Imagery: Microsoft, Vantor

Printed by: SpencerGeorge Date: 3/12/2026 \\kjc.local\kjc-root\GIS\GIS_CloudProjects\General Mills\Carter\Events\20260211_CorrectiveActionWorkplan\CorrectiveActionWorkplan2026.aprx

Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Projection: Lambert Conformal Conic

Legend

- Monitoring Well and Groundwater Elevation (feet)
- Mountain View Co-Op Groundwater Monitoring Well (Not Measured)
- Approximate Potentiometric Surface Elevation Contours
- Approximate Groundwater Flow Direction
- General Mills Bulk Site
- Mountain View Co-Op Original Lease Site

Notes:

1. Locations are approximate.
2. Groundwater elevations are displayed in feet.
3. Groundwater elevations were measured on 14 March 2025.
4. NM = Not Measured.
5. Well GMW-04 not used in contouring.

N

0 20 40

Scale: Feet

Kennedy Jenks

General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Potentiometric Surface Map 2025

2549063*00

Figure 4

World Imagery (Clarity): Source: Esri, Vantor, Earthstar Geographics, IGN, and the GIS User Community

Benzene Screening Level		
	Units	MT DEQ-7 HHS
Benzene	µg/L	5

\\KJC.local\KJC-Root\GIS\GIS_CloudProjects\General Mills\Carter\Events\20260211_CorrectiveActionWorkplan\CorrectiveActionWorkplan2026.aprx Date: 3/17/2026 Printed by: JenniferJoern

Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Projection: Lambert Conformal Conic

Legend

- Monitoring Well and Benzene Concentration (µg/L)
- Mountain View Co-Op Groundwater Monitoring Well (Not Measured)
- MT DEQ 7 HHS - 5 µg/L
- Approixmate Benzene Isoconcentration Contour - 100 µg/L
- Mountain View PMZ
- General Mills Bulk Site
- Mountain View Co-Op Original Lease Site

Notes:

1. Locations are approximate.
2. Data presented in micrograms per liter (µg/L).
3. J indicates an estimated concentration based on either being less than the laboratory reporting limit or data validation findings.
4. < indicates concentrations were not detected at or above the laboratory reporting limit.

N

0 20 40

Scale: Feet

Kennedy Jenks

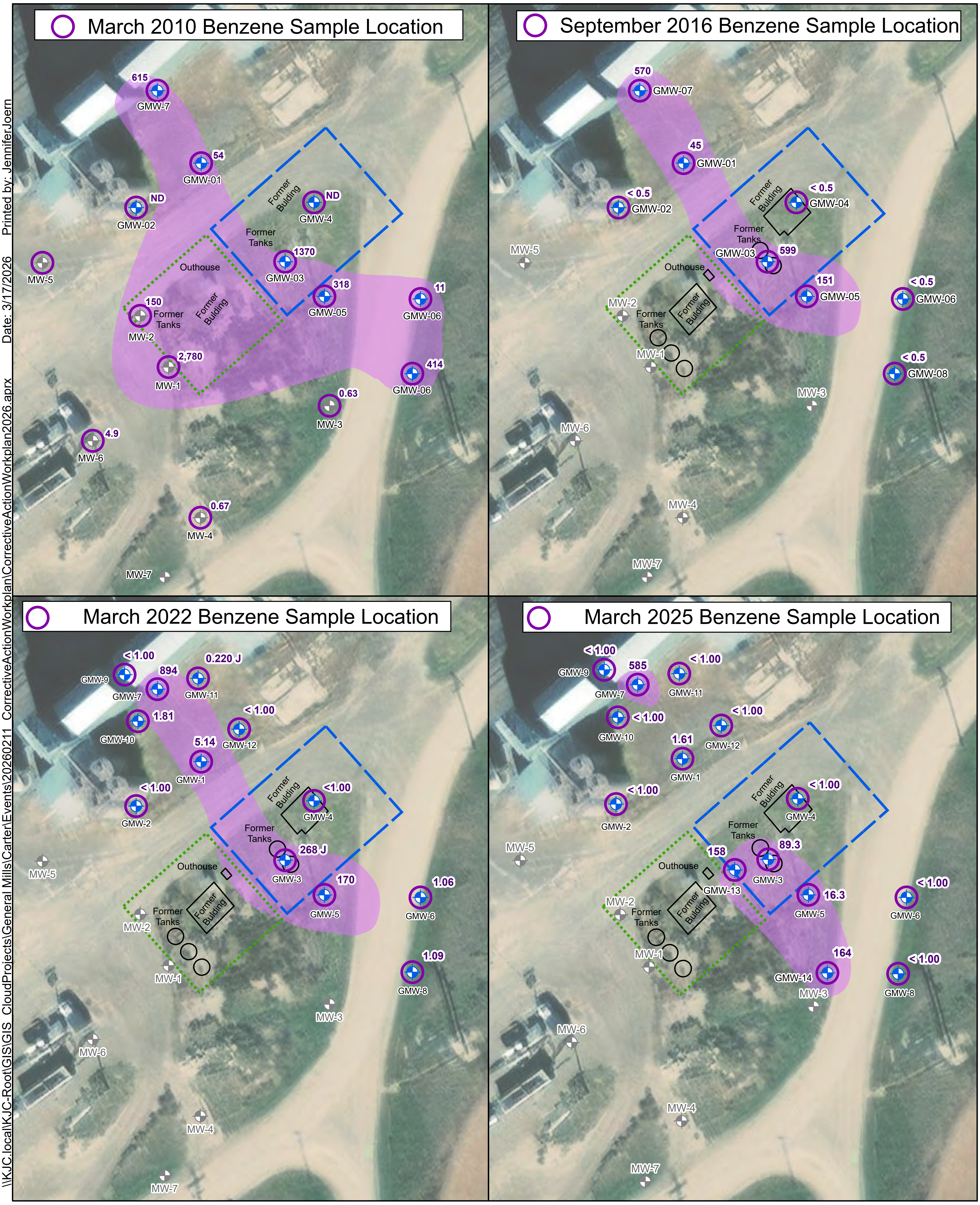
General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Groundwater Isoconcentration – Benzene
May 2025

2549063*00

Figure 5A

World Imagery: Microsoft, Vantor



\\KJC.local\KJC-Root\GIS\GIS_CloudProjects\General Mills\Carter\Events\20260211_CorrectiveActionWorkplan\CorrectiveActionWorkplan2026.aprx Date: 3/17/2026 Printed by: JenniferJoern

Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Projection: Lambert Conformal Conic

Legend

- Monitoring Well
- Mountain View Co-Op Groundwater Monitoring Well
- Benzene Plume
- General Mills Bulk Site
- Mountain View Co-Op Original Lease Site

Notes:

1. All locations are approximate.
2. Only constituents that were detected are displayed.
3. All data presented in micrograms per liter (µg/L)
4. Samples were collected in December 2021 from GMW-4, GMW-11 and GMW-12.

N

0 25 50

Scale: Feet

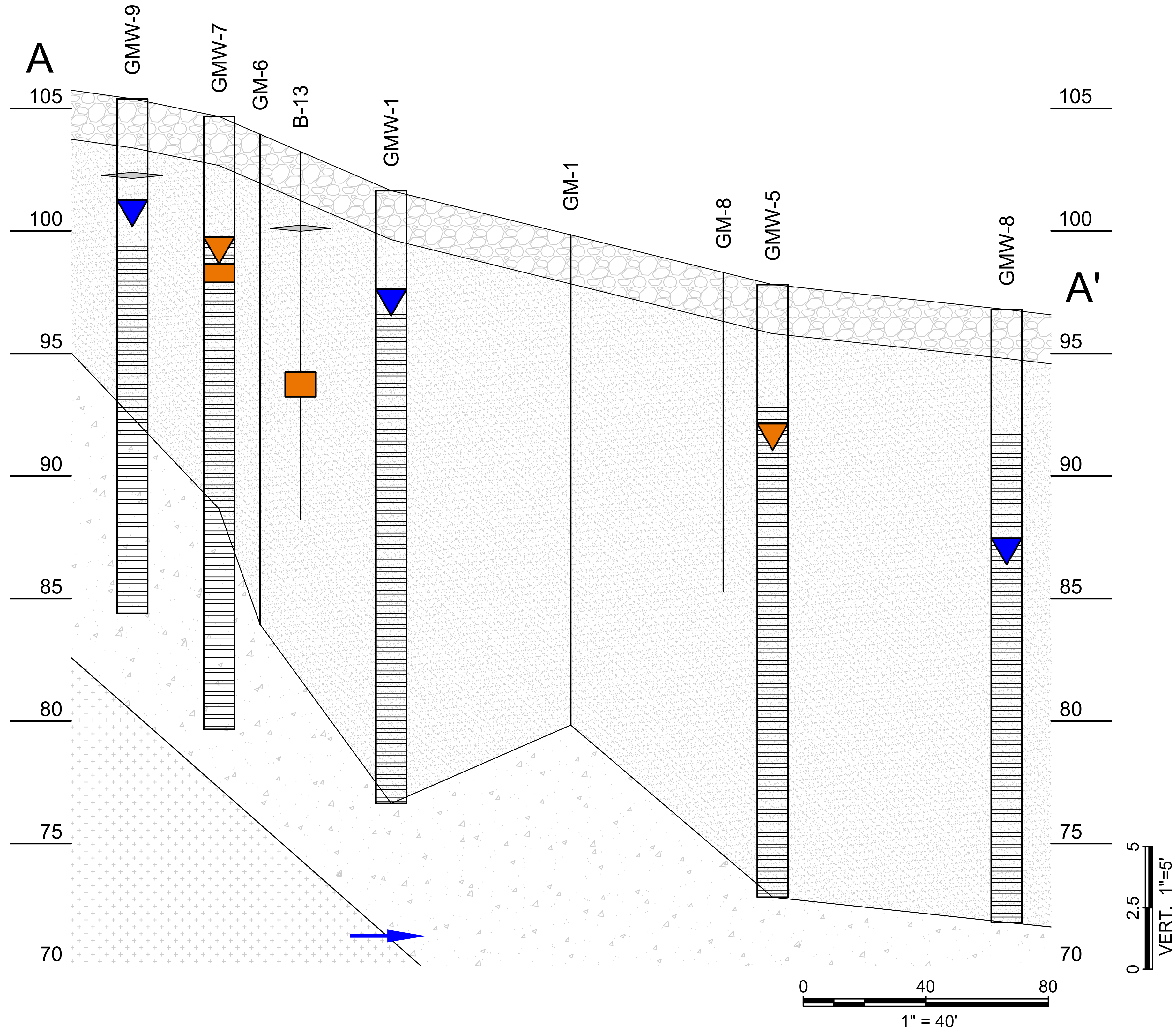
Kennedy Jenks

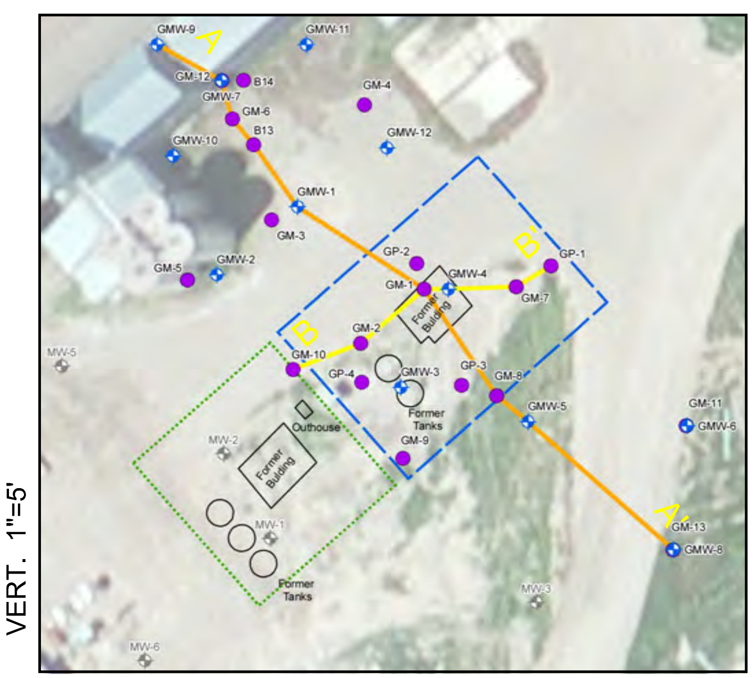
General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Benzene Plume Area - 2010, 2016, 2022, 2025

2549063*00

Figure 5B





LEGEND

- IMPACTED GROUNDWATER
- NON-IMPACTED GROUNDWATER
- IMPACTED SOIL
  GMW-7 (last sampled 2007)
  B-13 (last sampled 2021)
- APPROXIMATE GROUNDWATER FLOW
- TOP SOIL
- SILTY CLAY
- SANDY SILT W/CLAY
- MIX OF SILTY CLAY AND SANDY LAYERS
- CINDER

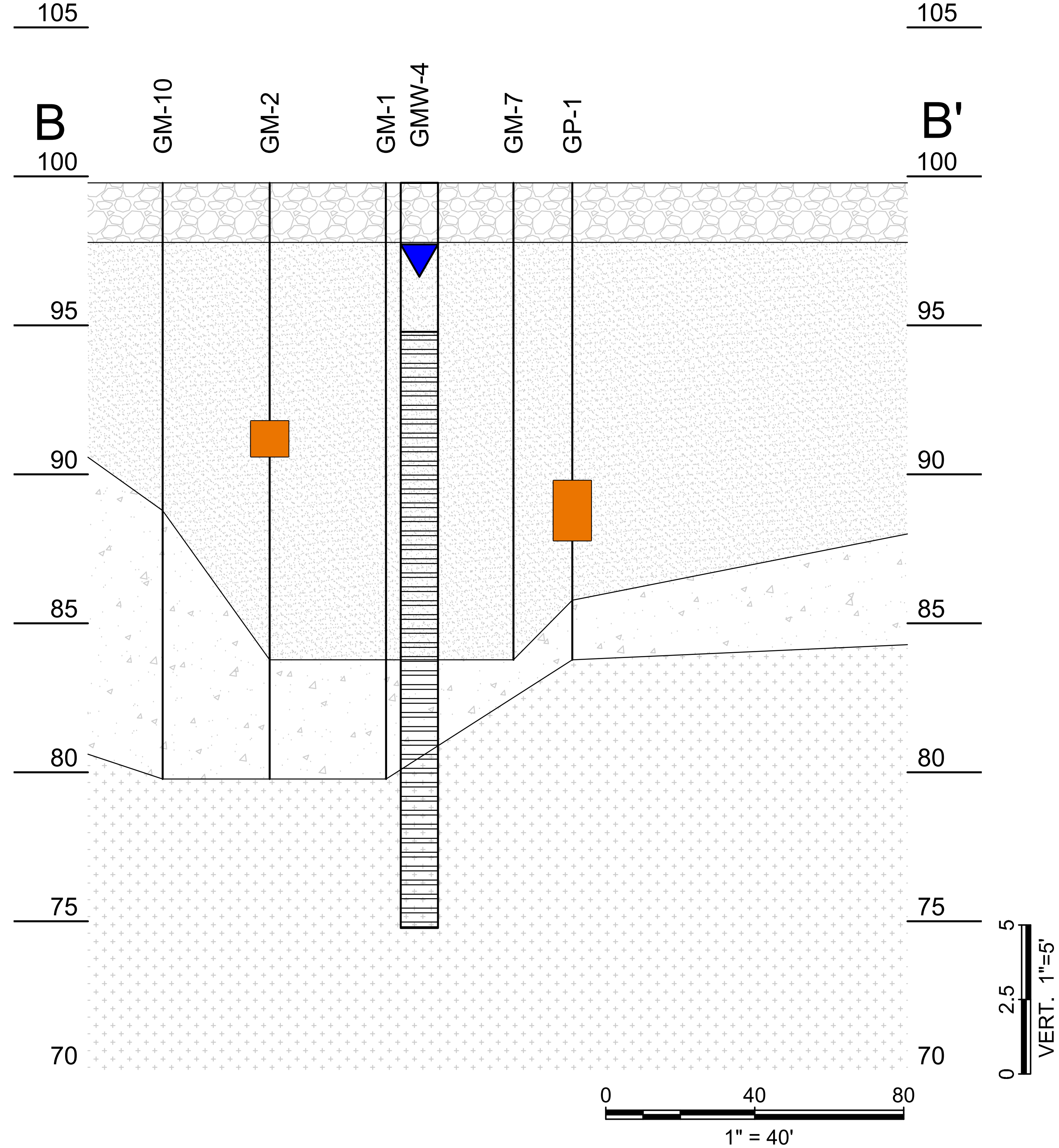
Kennedy Jenks

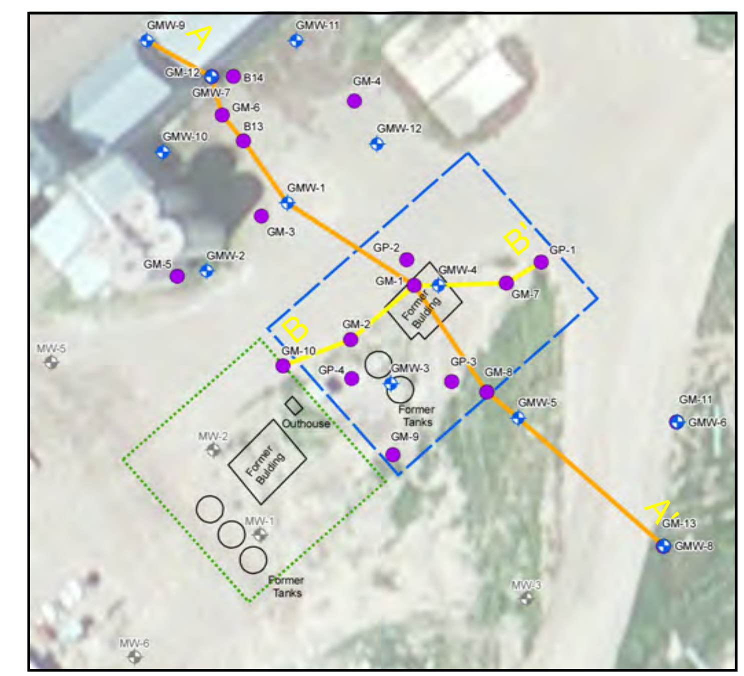
General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Cross Section Segments A-A'

2549063*00

Figure 6A





LEGEND

NON-IMPACTED GROUNDWATER

IMPACTED SOIL
GM-2 (last sampled 2007)
GP-1 (last sampled 2003)

TOP SOIL

SILTY CLAY

SANDY SILT W/CLAY

MIX OF SILTY CLAY AND SANDY LAYERS

Kennedy Jenks

General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Cross Section Segments B-B'

2549063*00

Figure 6B

World Imagery: Microsoft, Vantor

Legend

- Soil Boring (2003)
- Soil Boring (2007)
- Soil Boring (2010)
- Soil Boring (2021)
- Soil Boring (2026)
- Monitoring Well
- HRSC Proposed Locations
- Mountain View Co-Op Original Lease Site
- General Mills Bulk Site

Notes:

1. Locations are approximate.
2. HRSC locations can be adjusted based on results.

N

0 7.5 15

Scale: Feet

Kennedy Jenks

General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

HRSC Proposed Locations

2549063*00

Figure 7

\\KJC.local\KJC-Root\GIS\GIS_CloudProjects\General Mills\Carter\Events\20260211_CorrectiveActionWorkplan\CorrectiveActionWorkplan\CorrectiveActionWorkplan2026.aprx Date: 3/17/2026 Printed by: JenniferJoern

Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Projection: Lambert Conformal Conic

World Imagery: Microsoft, Vantor

\\KJC.local\KJC-Root\GIS\GIS_CloudProjects\General Mills\Carter\Events\20260211_CorrectiveActionWorkplan\CorrectiveActionWorkplan2026.aprx Date: 3/17/2026 Printed by: JenniferJoern

Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Projection: Lambert Conformal Conic

Legend

- Soil Boring (2003)
- Soil Boring (2007)
- Soil Boring (2010)
- Soil Boring (2021)
- Soil Boring (2026)
- Monitoring Well
- HRSC Proposed Locations

Proposed Injection Areas

- Area 1
- Area 2
- Area 3
- General Mills Bulk Site

Notes:

1. Locations are approximate.

N

0 7.5 15

Scale: Feet

Kennedy Jenks

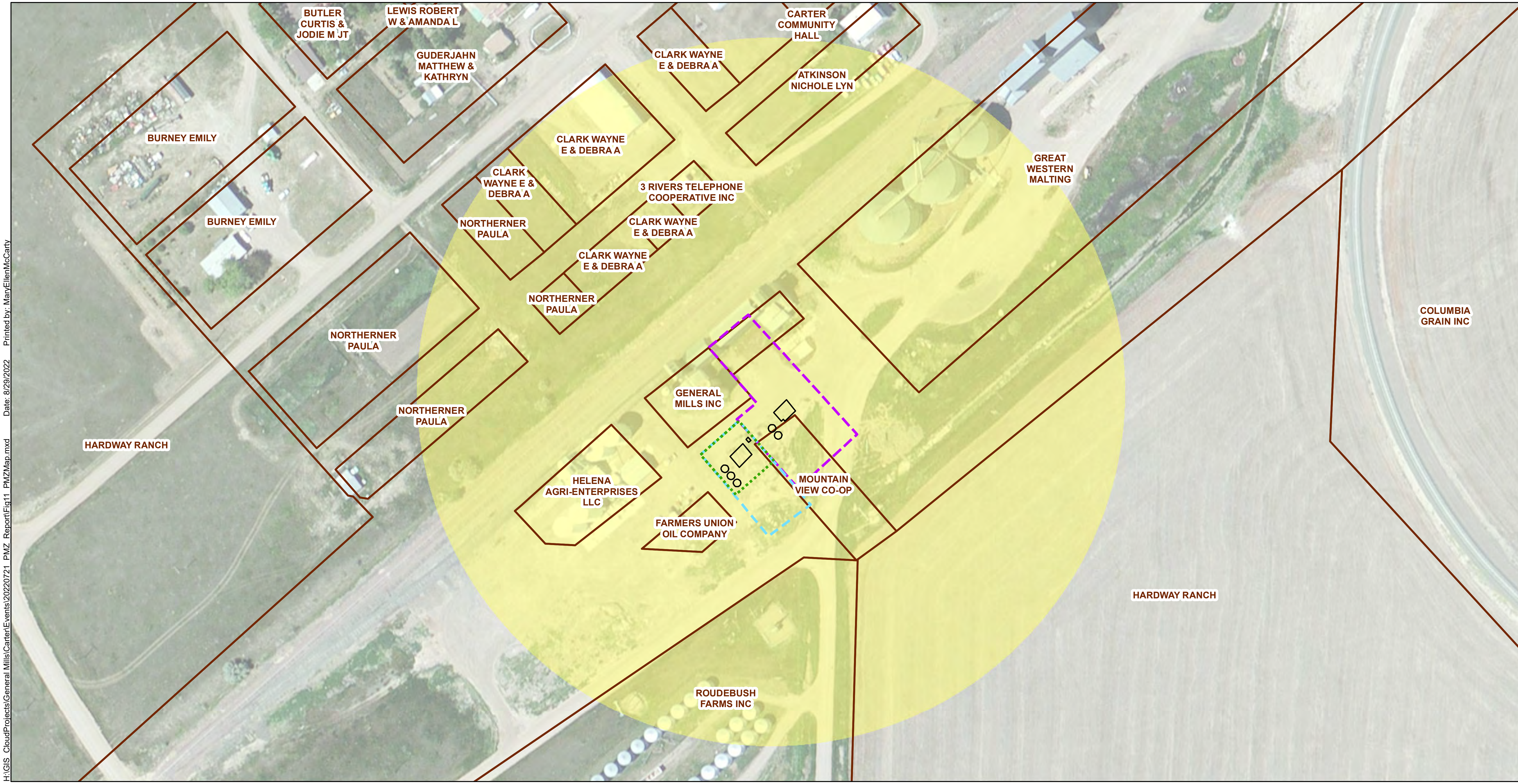
General Mills Operations LLC
Corrective Action Work Plan
Carter, Montana

Proposed Injection Areas

2549063*00

Figure 8

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Projection: Lambert Conformal Conic Datum: North American 1983

H:\GIS_CloudProjects\General Mills\Carter\Events\20220721_PMZ_Report\Fig11_PMZMap.mxd Date: 8/29/2022 Printed by: MaryEllenMcCarty

Legend

PARCELID

- PMZ Boundary
- Mountain View Co-Op PMZ Boundary
- PMZ Buffer
- Mountain View Co-Op Original Lease Site
- Property Boundaries

Notes:

1. All locations are approximate.

N

0 50 100

Scale: Feet

Kennedy Jenks

Petroleum Mixing Zone
Corrective Action Work Plan
Carter, Montana

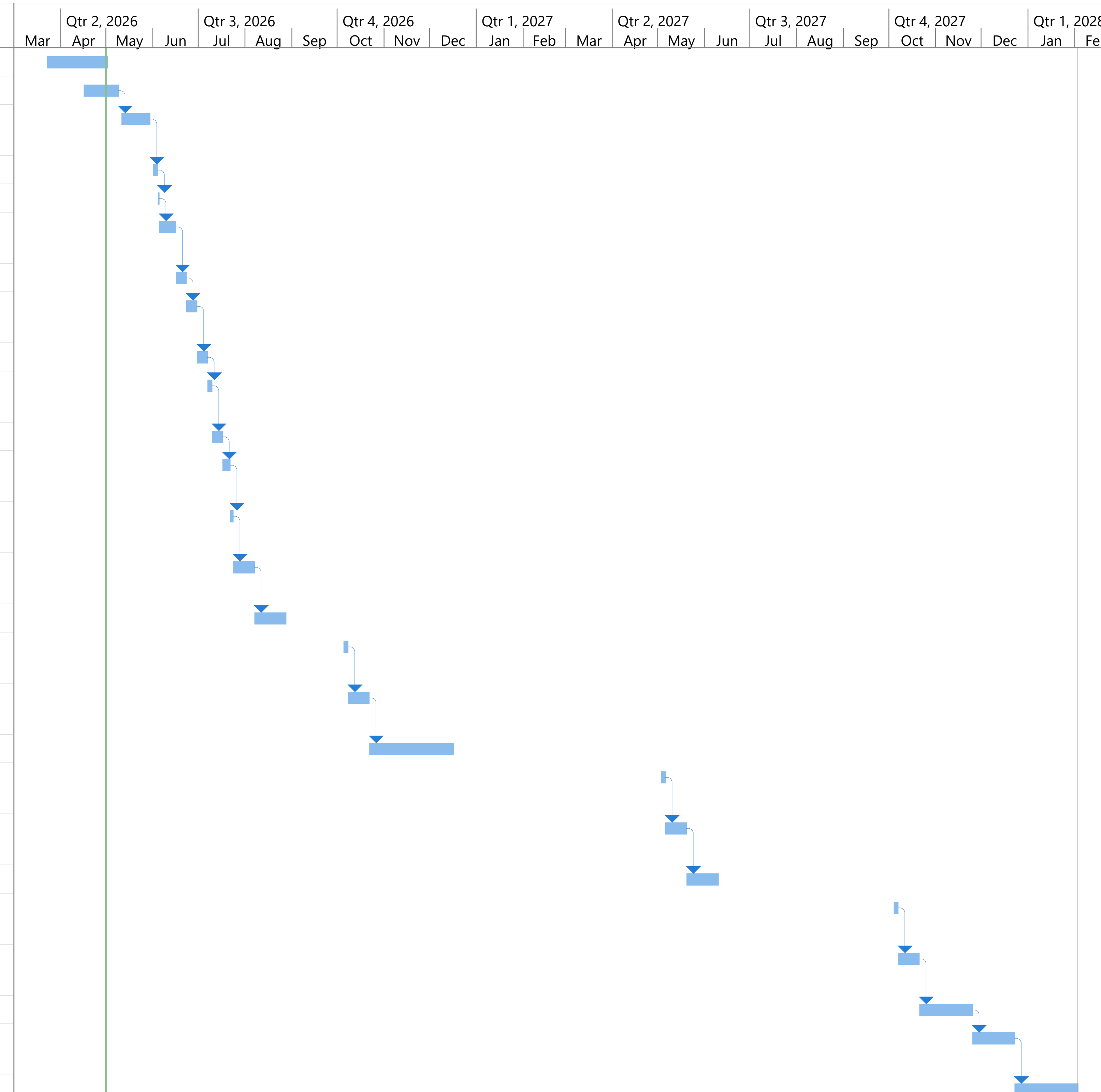
PMZ Boundary and Buffer Zones

2149063*00

Figure 9

Figure 10. Proposed Project Schedule

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1			Project Setup	6 wks	Mon 3/23/26	Fri 5/1/26		
2			DEQ WP Approval	3.4 wks?	Thu 4/16/26	Fri 5/8/26		
3			15-day Comment Period	15 days	Mon 5/11/26	Fri 5/29/26	2	
4			HRSC	3 days	Mon 6/1/26	Wed 6/3/26	3	
5			Discuss HRSC results	1 day	Thu 6/4/26	Thu 6/4/26	4	
6			ISCO Injection (1st Event)	7 days	Fri 6/5/26	Mon 6/15/26	5	
7			Waiting period	1 wk	Tue 6/16/26	Mon 6/22/26	6	
8			ISCO Injection (2nd Event)	5 days	Tue 6/23/26	Mon 6/29/26	7	
9			Waiting period	1 wk	Tue 6/30/26	Mon 7/6/26	8	
10			ISCO Injection (3rd Event)	3 days	Tue 7/7/26	Thu 7/9/26	9	
11			Waiting period	1 wk	Fri 7/10/26	Thu 7/16/26	10	
12			Semiannual GWM (1st High)	3 days	Fri 7/17/26	Tue 7/21/26	11	
13			Post-Injection Soil Sampling	2 days	Wed 7/22/26	Thu 7/23/26	12	
14			Analytical Processing	10 days	Fri 7/24/26	Thu 8/6/26	13	
15			First IDS	3 wks	Fri 8/7/26	Thu 8/27/26	14	
16			Semiannual GWM (1st Low)	3 days	Mon 10/5/26	Wed 10/7/26		
17			Analytical Processing	10 days	Thu 10/8/26	Wed 10/21/26	16	
18			CA Report	8 wks	Thu 10/22/2(	Wed 12/16/2	17	
19			Semiannual GWM (2nd High)	3 days	Mon 5/3/27	Wed 5/5/27		
20			Analytical Processing	10 days	Thu 5/6/27	Wed 5/19/27	19	
21			Second IDS	3 wks	Thu 5/20/27	Wed 6/9/27	20	
22			Semiannual GWM (2nd Low)	3 days	Mon 10/4/27	Wed 10/6/27		
23			Analytical Processing	10 days	Thu 10/7/27	Wed 10/20/27	22	
24			GWM Report	5 wks	Thu 10/21/2	Wed 11/24/2	23	
25			DEQ Approval for PMZ	4 wks	Thu 11/25/27	Wed 12/22/27	24	
26			PMZ Report	6 wks	Thu 12/23/2	Wed 2/2/28	25	



Project: Project Schedule 20260
Date: Fri 5/1/26

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

Appendices

Appendix A

Response to Comment Matrix

Document: Contract:	**Corrective Action Work Plan for Petroleum Release** **Fomer Bulk Petroleum Facility Site (Carter BNSF Lease Property)**					
Review Comments from:	Christopher Herman					
Review Comments from:	William Bergum					
Review Comments from:						
Review Comments from:						

Reviewer/ Comment #	Page	Section/ Paragraph/ Line No.	Comments	A, D, E, FD or X[1]	Response	A or D[2]
1	NA	NA	Need to provide SOP as an attachment or Appendix.	A	Please see Appendix B of the revised Corrective Action Work Plan (CAWP)	
			END of COMMENTS			

A= agree D=disagree E = explanation FD = needs further discussion X = take exception to

Appendix B

Standard Operating Procedures

SOG: In-Situ Chemical Oxidation (ISCO) Injections

C.1 Introduction

This guideline describes the equipment and procedures typically used by Kennedy/Jenks Consultants (Kennedy/Jenks) personnel for conducting in-situ chemical oxidation injections (ISCO).

ISCO is a form of advanced oxidation processes and advanced oxidation technology, is an environmental remediation technique used for soil and/or groundwater remediation to reduce the concentrations of targeted environmental contaminants to acceptable levels. ISCO is accomplished by injecting chemical oxidizers directly into the contaminated medium (soil or groundwater) to destroy chemical contaminants in place. It can be used to remediate a variety of organic compounds, including some that are resistant to natural degradation. Reagent breakthrough is the point at which the selected reagent is monitored to arrive at the observation well(s). Breakthrough can be continuously monitored either directly with use of ion-specific data logging transducers, or indirectly by monitoring proxy data, with use of data logging transducers.

In general, water levels in the injection and observation well(s) are continuously recorded during injection and breakthrough phases.

C.2 Project Planning

The Kennedy/Jenks project manager or other qualified personnel will select the appropriate injection method and procedures, method of field data interpretation, and reporting requirements and will instruct field personnel in specific project requirements and procedures.

These requirements and procedures are selected on the basis of local hydrogeologic conditions, project specifications, and other factors. Typical planning requirements include staging of field equipment, health and safety considerations, site access, permitting, and other relevant factors.

Required permits, if any, should be acquired during the project planning phase.

Field Equipment

Field equipment typically required for ISCO injections include the following items:

- Submersible pump
- Injection solution/potable water
- Appropriately sized water tanks/containers
- Generator and fuel or reliable indoor power supply
- Field water quality instruments
- Appropriate water sampling equipment and containers
- Steel surveyors tape with “popper” (a sounding device)

- Electric contact or acoustic water level sounder
- Totalizing flow meter with adjustable valve or flow restrictor
- Decontamination equipment (buckets, soap, and DI water)
- Personal Protective Equipment
- Data logger and pressure transducers
- Stop watch
- Aquifer-test record sheets and water tight clip board/notebook
- Daily field log book
- Calculator
- Lap-top computer with data transfer program.

C.3 Typical Procedures

1. Initially, equipment and well(s) will be made ready for the ISCO injection through performance of the following activities:

    a. Decontaminate down-hole equipment which will come in contact with groundwater.

    b. Install pressure transducers in the injection and observation well(s) to the desired depth and secure transducer cable firmly to well head.

    c. Calibrate transducers. Water levels are calibrated by measuring the depth to water by hand. pH transducers will be calibrated prior to placement down-well.

    d. Install submersible pump in in the injection solutions tank(s) and secure pump to the bottom.

    e. Measure the static water level in injection and observation wells. Note measurement points, they should correspond to surface elevation (survey) data.

    f. Program transducers to collect data at frequencies adequate for project objectives.

2. The flow rate used to inject the ISCO solution during the injection will be based on the results of previous hydraulic data. The solution volume and concentration will be based on site hydrogeology and the calibrated range of instrumentation used to monitor breakthrough.

    The following activities will be performed prior to and during performance of the ISCO injection test:

    a. Prior to injection, the water levels of injection and observation wells will be measured to identify static water level conditions.

b. Program and initialize transducers prior to the test. Make sure each works properly. One way to test pressure transducers is to have the instrument read a water level, raise the cable one foot, have the instrument read the water level again and verify that the new water level is one foot “lower” than the previous water level.

c. Mix the selected volume of solution to the desired concentration in a tank nearby the injection site.

d. At the start of solution injection, water levels will be continuously recorded using pressure transducers and data loggers and/or by manual measurement. Solution concentration in injection and observation wells will be continuously recorded using pH transducers. The frequency of measurements using data loggers will be variable throughout the test. Data will be collected electronically at short time intervals (seconds) during the first stages of the test as longer time intervals (minutes) may be used during the later stages of the test. Some data loggers can be programmed to acquire data on a logarithmic time basis.

e. The injections rate will be held constant to the extent possible and will be calibrated throughout the duration of the test. A totalizing flow meter with a ball valve may be used to regulate the flow rate. The pre-adjusted flow rate and the total discharge will also be recorded throughout the duration of the test. If the flow allows, check the flow rate by measuring the drop in water level in the batch solution tank (volume) over time (assuming the tank is of known dimensions).

f. During the course of the ISCO injection, pH measurements will be made to monitor breakthrough.

3. At the termination of the ISCO test, the data loggers' sampling time base is reset and the injecting pump is shut off. Post-injection monitoring of the ISCO solution in the subsurface should occur over longer durations.

C.4 Data Evaluation Techniques

The data evaluation procedures used will be dependent on the specific data needs of each injection. Analyses of ISCO profiles and/or breakthrough curves, and post-injection groundwater monitoring will be used to estimate the effectiveness of the ISCO injection.

C.5 References

Driscoll, F.G. 1986. Groundwater and Wells. Second Edition.

Freeze, R.A. and Cherry, J. A. Groundwater. Prentice-Hall.

U.S. Geological Survey Professional Paper 708. 1979. Ground-Water Hydraulics.

U.S. Bureau of Reclamation. 1977. Groundwater Manual. First Edition.

SOG: Typical Hydraulic Push/Drive Sampling

C.1 Introduction

This guideline describes the equipment and procedures typically used by Kennedy/Jenks Consultants personnel for collecting soil and reconnaissance groundwater samples with a hydraulic push/drive system.

C.2 Equipment

- Portable, hydraulic push/drive sampling system
- 6-inch long, 1.75-inch O.D. stainless steel or brass liners and liner sealing materials (Teflon sheets, plastic end caps, Ziploc plastic bags)
- Type II Portland cement or granular bentonite
- Screen Point 16 Groundwater Sampler (or equivalent)
- Mechanical bladder pump
- FID or PID organic vapor analyzer
- Water level indicator
- Temperature, specific conductivity, and pH meters
- Equipment cleaning materials
    1. Steam cleaner
    2. Generator
    3. Stiff-bristle brushes
    4. Buckets
    5. High-purity phosphate-free liquid soap
    6. Deionized water
    7. Rinsate collection system
- Personal protective equipment
- Appropriate groundwater sample containers
- Chain-of-custody forms
- Insulated sample storage container and ice substitute

C.3 Typical Procedures

1. Obtain applicable drilling and well construction permits prior to mobilization.

2. Clear drilling locations for underground utilities and structures by a One Call notification, private utility locating services to identify and mark underground utilities, and air knife services to vacuum extract soil or hand auger to a depth of 6 feet below ground surface (bgs).

3. All downhole equipment will be decontaminated prior to use at each location.

4. Soil borings will be advanced using a portable, hydraulic push/drive sampling system that simultaneously drives steel sampling rods (single or nested) into the ground to collect continuous soil cores.

5. As the sampling rods are advanced, the soil core will be collected in a 1 sample barrel, which is attached to the end of the inner rods. After being advanced to the next targeted depth interval, the inner rods will be removed from the borehole with a hydraulic winch. The sampler

(containing new acetate liners) and inner rods will then be lowered back into the borehole to the previous depth and the rods are driven another few feet. This process will be repeated until the desired depth is reached.

6. The soil samples will be retained for lithologic logging and chemical analyses, if appropriate.

7. The soils will be classified in the field in approximate accordance with the visual-manual procedure of the Unified Soil Classification System (ASTM D-2488-93), and the Munsell Color Classification.

8. As a field screening procedure, at each sampling interval put the soil from the split spoon into an airtight container and allow it to equilibrate. After this, use a PID to monitor the headspace in the container.

9. If required, soil samples will be collected at selected intervals for laboratory analysis. Collect soil samples in order of decreasing volatility (i.e., volatile organic compounds, low molecular weight alcohols, volatile petroleum hydrocarbons, semivolatile organic compounds, organochlorine pesticides, 1,4-dioxane, naphthalene, and extractable petroleum hydrocarbons) as necessary to conduct the bench scale ISCO test.

10. If groundwater samples will not be collected, the soil borings will be backfilled with hydrated granular bentonite and patched at the surface with native material.

11. Upon encountering the desired groundwater sampling depth, the sample barrel and inner rods will be removed, and a Screen Point 16 groundwater sampler will be driven to depth. The drive casing will be pulled up approximately 3 feet to expose the slotted PVC casing. Groundwater samples will then be collected from the screen sheath via mechanical bladder pump.

12. The depth to groundwater will be measured prior to groundwater sampling.

13. The sample will be drained directly into sample containers. The containers will be labeled to document the sample designation, type, date and time of collection, collector(s), location, and any additional information.

14. After collecting the reconnaissance groundwater sample, decant groundwater into a clean container and record the following field parameters/observations:

    1. Temperature (°C)
    2. pH
    3. Specific conductivity (μmhos/cm)
    4. Depth to water
    5. Color
    6. Other observations (odors, free-phase product)

15. After sample collection, the boring will be backfilled with hydrated granular bentonite and patched at the surface with native material.

16. Complete chain-of-custody forms in the field and transport the samples in insulated containers, at an internal temperature of approximately 4 °C, to the selected laboratory.

C.4 Equipment Cleaning

1. Downhole equipment (rods, sampler) will be decontaminated prior to each borehole.

2. Sampling equipment (sampler) will be steam cleaned or washed with a brush in a solution of high-purity phosphate-free soap and potable water, then rinsed with potable water followed by double rinsing with deionized water prior to each sampling run.

3. Downhole equipment and vehicles which warrant it, will be steam cleaned prior to leaving site at completion of sampling.

C.5 Investigation-Derived Residuals

Soil cuttings will be placed in labeled 55-gallon DOT-approved drums with bolt-on covers. Decontamination water and groundwater residuals will be contained in labeled 55-gallon DOT-approved drums with bolt-on covers. All residuals generated during sampling activities will be stored at the site.

SOG: Procedures for Using a PID Vapor Analyzer

C.1 Introduction

This guideline identifies the procedures that will be used by Kennedy/Jenks Consultants personnel during operation of a photo ionizing detector (PID) vapor analyzer or Organic Vapor Monitor (OVM).

C.2 Equipment

- PID Organic Vapor Analyzer (MiniRAE or equivalent)
- Calibration gas with regulator, tubing
- Pint plastic jars
- Aluminum foil
- Small screw driver

C.3 Procedures

1. Check battery charge level. If in doubt, charge battery as described in manual. Battery should typically be recharged daily after use.

2. Turn unit on. DO NOT look into sensor (ultraviolet radiation hazard).

3. The probe or pump should make an audible sound (vacuum) confirming operation.

4. Perform zero and calibration procedures as described in operating manual. Calibration for specific compounds can be performed so instrument response is proportional to the calibration gas concentration. Isobutylene calibrant is available and response factors for other compounds are provided in the instrument manual.

5. The PID does not detect methane and many compounds with an ionization potential greater than the lamp energy (typically about 10 eV). Consult the operation manual reference for ionization potentials and response factors for common compounds. The standard 10.6 eV lamp is appropriate for 1,4-dioxane; however, a site constituent of potential concern includes methylene chloride which responds to an 11.7 eV lamp. Accordingly, soil cores will be screened with PIDs equipped with both types of lamps.

6. If so equipped, set alarm at desired level.

7. Once calibrated, unit is ready for use.

8. Position intake assembly should be in close proximity to area in question as sampling rate only allows for localized readings.

9. A slow, sweeping motion of the intake assembly will help prevent the bypassing of problem areas.

10. For screening soil samples in the field refer to the headspace method described in SOG-13: Boring and Subsurface Soil Sampling.

11. Be prepared to evacuate the area if preset alarm sounds.

12. Static voltage sources; such as power lines, radio transmissions, or transformers; may interfere with measurements. See operating manual for discussion of necessary considerations.

13. Regular cleaning and maintenance of instrument and accessories will ensure representative readings.

14. As with any field instrument, accurate results depend on the operator being completely familiar with the operator's manual for unit use.

15. Moisture may affect readings.

16. The PID is capable of recording readings at a determined rate which are logged and downloaded to a computer. Refer to manual for instructions on how to use this feature.

C.4 References

RAE Systems by Honeywell, Rev. D April 2014. *MiniRAE 3000 User's Guide. P/N 059-4020-000*.

OVM - SM 580 Instruction Manual, Thermo-Analytical.

SOG: Boring and Subsurface Soil Sampling

D.1 Introduction

This guideline describes the equipment and procedures that are used by Kennedy/Jenks Consultants personnel for drilling and collecting soil samples.

D.2 Equipment

- Drill rigs and associated drilling and sampling equipment as specified in work plan:
  Hollow stem auger (anticipate using)
  Air-rotary casing hammer (if necessary for scheduling)

- CME, 5 ft x 94 mm continuous-core barrels (hollow-stem auger)

- 2.5-inch or 2.0-inch I.D. split-spoon drive sampler

- 2.5-inch or 2.0-inch brass liners and sealing materials (plastic end caps, Teflon seals, silicon tape, zip-lock plastic bags)

- Large capacity stainless steel borehole bailer

- PID-Organic Vapor Analyzer (MiniRAE or equivalent)

- Sampler cleaning equipment
  Steamcleaner
  Generator
  Stiff-bristle brushes
  Buckets
  High purity phosphate-free liquid soap, such as Liquinox
  Methanol (if necessary)
  0.1N nitric acid (if necessary)
  Deionized water
  Potable water

- Insulated sample storage and shipping containers

- Personal protective equipment (refer to project site safety plan)

D.3 Typical Procedure

1. Obtain applicable drilling and well construction permits prior to mobilization.

2. Clear drilling locations for underground utilities and structures by One Call notification, private utility locating services to identify and mark underground utilities, and air knife services to vacuum extract soil to a depth of 6 feet below ground surface (bgs).

3. Have all downhole equipment steamcleaned prior to drilling each boring.

4. Ensure that borings made to construct shallow monitoring wells are drilled with an auger drill rig that uses hollow stem augers of appropriate size to provide an annular space of a minimum of 2 inches between borehole wall and well casing.

5. Collect soil samples for stratigraphic logging purposes with continuous coring system in 5-foot increments.

6. Collect soil samples for stratigraphic logging and chemical and physical analyses by driving a split-spoon drive sampler, in 2.5- to 5-foot increments, below the depth of the auger bit with a rig-mounted hammer. Record the standard penetration resistance. If the sample is pushed rather than driven, be sure to record the push force.

7. When drilling with air-driven drill rigs, collect soil samples for stratigraphic logging purposes from the cyclone separator discharge on the dual tube percussion hammer, which separates air from formation cuttings as the drive casing is advanced.

8. Have the soils classified in the field in approximate accordance with the visual-manual procedure of the Unified Soil Classification System (ASTM D-2488-90) and the Munsell Color Classification.

9. Prior to each sampling event, wash the split-spoon drive sampler and brass liners with high purity phosphate-free soap, and double-rinse them with deionized water and methanol and/or 0.1N nitric acid, as appropriate.

10. As a field screening procedure, at each sampling interval put the soil from the split spoon into an airtight container and allow it to equilibrate. After this, use a PID to monitor the headspace in the container.

11. Collected soil samples in order of decreasing volatility (i.e., volatile organic compounds, low molecular weight alcohols, volatile petroleum hydrocarbons, semivolatile organic compounds, organochlorine pesticides, 1,4-dioxane, naphthalene, and extractable petroleum hydrocarbons) as necessary to conduct the bench scale ISCO test.

12. Complete chain-of-custody forms in the field and transport the samples in insulated containers, at an internal temperature of approximately 4 °C, to the selected laboratory.

13. If applicable, as described in the site safety plan, use a PID to analyze in situ air samples from the breathing zone, the inside of the augers or casing, and other locations as necessary.

D.4 Equipment Cleaning

1. Prior to drilling each boring, steamclean downhole equipment (augers, well casing, sampler).

2. Before collection of each drilling sample, steamclean or wash sampling equipment (sampler and brass liners) with a brush, in a solution of high purity phosphate-free soap and potable water. Rinse the equipment with potable water and methanol and/or 0.1N nitric acid, as appropriate. Follow this with double-rinsing using distilled water.

3. Before leaving the site at completion of drilling, steamclean downhole equipment and vehicles that require cleaning.

D.5 Investigation-Derived Residuals

Place soil cuttings and other residuals in appropriately labeled containers for disposition by the client. All soil samples transported to the laboratory must be returned to the client for disposition. Kennedy/Jenks Consultants is available to assist the client with options for disposition of residuals.

SOG: Borehole Logging

Version: 4/27/2026
Approved: 4/30/2026

C.1 Introduction

This Standard Operating Guideline (SOG) provides procedures typically followed by Kennedy/Jenks Consultants (Kennedy/Jenks) personnel for classifying soils and preparing boring logs and other types of soil reports. The purpose of this SOG is to facilitate acquisition of uniform descriptions of soils encountered during borehole programs and to promote consistency in logging practices used by Kennedy/Jenks personnel. This SOG provides guidance on procedures that are generally consistent with standard practices used to classify soils. Deviations from, and additions to, procedures described herein may be appropriate based on project-specific objectives, site-specific conditions, and/or regulatory requirements. The user of this SOG should modify the sampling procedures used, as appropriate, to conform to the project-specific requirements and then document such deviations from this SOG in the project-specific documentation of subsurface exploration activities.

Borehole logging is the systematic observation and recording of geologic and hydrogeologic information from subsurface borings and excavations. The Unified Soil Classification System (USCS) (ASTM D2487-17[2025]) is used to identify, classify, and describe soils principally for engineering purposes, and is based on laboratory tests.

For field applications, ASTM D2488-26 (Visual-Manual Procedure) is used as the general guide adopted under this SOG.

Both ASTM D2487 and ASTM D2488 utilize the same group names and symbols. However, soil reports should state that boring logs are not formal USCS laboratory determinations but are based on the visual-manual procedures described in ASTM D2488.

This SOG contains the following sections:

- Field Equipment/Materials
- Typical Procedures
  - Soil Classification
  - Classification of Coarse-Grained Soil
  - Classification of Fine-Grained Soil including Organic Soils
- Other Logging Parameters
- Logging Refuse
- References.

C.2 Field Equipment/Materials

Material/equipment typically required for classifying soils and preparing boring logs may include:

- Pens, pencils, waterproof pens, and field logbook or other appropriate field forms (e.g., boring log forms), water-tight field case

- Daily inspection report forms

- USCS (ASTM D2488) table and classification chart
- Soil color chart (i.e., Munsell). If used, the edition of the Munsell chart should be specified on each borehole log as the color descriptions and hue, color values and chromas have changed between editions. Also, whenever possible, the newest version of Munsell's color charts should be used due to fading of color chips over time.
- American Geological Institute (AGI) Data Sheets
- Graph paper
- Engineer's scale
- Previous project reports and boring logs (if available)
- Pocket knife or putty knife
- Hand lens
- Supply of clean water
- Dilute hydrochloric acid (HCl) (make sure and MSDS for HCl is included in the project HASP)
- Oil-red-o hydrophobic dye
- Aluminum foil, Teflon® sheets, and paper towels
- Sample containers (brass, stainless steel or aluminum liners, plastic or glass jars)
- Clean rags or paper towels
- Sample shipping and packaging supplies
- Personnel and equipment decontamination supplies
- Personal protective equipment as described in the Health and Safety Plan (HASP).

C.3 Typical Procedures

Soil classification and borehole logging should be conducted by a qualified geologist, engineer or other personnel trained and experienced in the classification of soils.

Soils are typically logged in conjunction with advancing boreholes and sampling subsurface soils.

The USCS as described in ASTM D2488 categorizes soils into 15 basic group names, each with distinct geologic and engineering properties. The following steps are required to classify a soil sample:

1. Observe basic properties and characteristics of the soil. These include grain-size grading and distribution and influence of moisture on fine-grained soil.

2. Assign the soil a USCS classification and denote it by the standard group name and symbol.

3. Provide a written description to differentiate between soils in the same group, if necessary.

Many soils have characteristics that are not clearly associated with a specific soil group. These soils might be near the borderline between groups, based on either grain-size grading and distribution, or plasticity characteristics. In this case, assigning dual group names and symbols might be appropriate (e.g., GW-GC or ML-CL).

The two basic soil groups are:

1. **Coarse-Grained Soils –** For soils in this group, more than half of the material is larger than No. 200 sieve (0.074 mm).

2. **Fine-Grained Soils (including Organic Soils) –** For soils in this group, one half or more of the material is smaller than No. 200 sieve (0.074 mm).

Note: No. 200 sieve is the smallest size that can be seen with the naked eye.

C.4 Classification of Coarse-Grained Soils

Coarse-grained soils are classified on the basis of:

4. Grain size and distribution

5. Quantity of fine-grained material (i.e., silt and clay)

6. Character of fine-grained material

Classification uses the following symbols:

Basic Symbols	**Modifying Symbols**
G - gravel	W - well graded
S - sand	P - poorly graded
	M - with silt fines
	C - with clay fines

The following are basic facts about coarse-grained soil classification:

- The basic symbol G is used if the estimated volume percentage of gravel is greater than that for sand. In contrast, the symbol S is used when the estimated volume percentage of sand is greater than the percentage of gravel.

- Gravels include material in the size range from 3 inches to 0.2 inches (i.e., retained on No. 4 sieve). Sand includes material in the size range from 0.2 inches to 0.003 inches. Use the grain size scale used by engineers (ASTM Standards D422-63[2007] and D643-97) to further classify grain size as specified by the USCS.

- Although not specifically treated in ASTM D2488, cobbles range in size from 3 inches to 10 inches and boulders refer to particles with a single dimension greater than 10 inches. They are included here for the purpose of completeness and for their hydrogeologic significance.

Note: The ASTM grain size scale differs from the Modified Wentworth Scale used in teaching most geologists. Also, it introduces a distinction between sorting and grading (i.e., well graded equals poorly sorted and poorly graded equals well sorted.)

- The modifying symbol W indicates good representation of a range of particle sizes in a soil.
- The modifying symbol P indicates that there is a predominant excess or absence of particle sizes.
- The symbol W or P is only used when a sample contains less than 15 percent fines.
- Modifying symbol M is used if fines have little or no plasticity.
- Modifying symbol C is used if fines have low to high plasticity (clayey)

The following rules apply for the written description of the soil group name:

Types of Soil	**Rule**
Sands and gravels (clean)	Less than 5 percent fines
Sands (or gravels) with fines	5 to 15 percent fines
Silty (or clayey) sands or gravels	Greater than 15 percent fines

- Other descriptive information may include:
  - Color (e.g., Munsell Soil Color chart, specify edition). Soil color is named and coded using the Munsell Soil Color chart if required for the project. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded. For example, “dk brn (7.5 YR, 3/4).”
  - Relative Density/Penetration Resistance. For cohesionless materials use very loose, loose, medium, dense, or very dense estimated from drive sample hammer blows or other field tests. Blow counts may be used, if reliable.
  - Maximum grain size (fine, medium, coarse, as described in AGI data sheets or USCS). Note the largest cross-sectional dimension measured in tenths of an inch for grains larger than sand size.
  - Composition of grains (mineralogy)
  - Approximate percentage of gravel, sand, and fines (use a percentage estimation chart as provided in the AGI data sheets)

Modifiers	**Description**
Trace	Less than 5 percent
Few	5 to 10 percent
Little	15 to 25 percent
Some	30 to 45 percent
Mostly	50 to 100 percent

  - Angularity (round, subround, angular, subangular)
  - Shape (flat or elongated)
  - Moisture Condition (dry, moist, wet)

  - o Dry - Absence of moisture to the touch.
  - o Damp - Contains enough water to keep the sample from being brittle, dusty or cohesionless; is darker in color than the same material in the dry state.
  - o Moist - Leaves moisture on your hand, but displays no visible free water.
  - o Wet - Displays visible free water.
- HCl Reaction (none, weak, strong)
- Cementation (Crumbles under finger pressure: weak, moderate, or strong)
- Range of Particle Sizes (sand, gravel, cobble, boulder)
- Maximum Particle Size (fine, medium, coarse)
- Cementation (weak, moderate, or strong)
- Hardness (breaks with hammer blow)
- Structure (stratified, laminated, fissured, slickensided, blocky, lensed, homogeneous)
- Organic material
- Odor
- Iridescent sheen (based on sheen test)
- Debris (e.g., paper, wood, plastic, cloth, concrete, construction materials, etc.).
- o Additional Comments (e.g. roots or rootholes, difficult drilling, borehole caving, presence of mica, contact and/or bedding dip, bedding features, sorting, structures, fossils, cementation, geologic origin, formation name, minerals, oxidation, etc.

C.5 Classification of Fine-Grained Soils

Fine-grained soils are classified on the basis of:

1. Liquid limit
2. Plasticity

Classification uses the following symbols:

Basic Symbols	**Modifying Symbols**
M - silt	L - low liquid limit
C - clay	H - high liquid limit
O - organic	
Pt - peat	

The following rules apply for the written description of the soil group name:

Types of Soil	**Rule**
Silts and clays with sand and/or gravel	5 to 15 percent sand and/or gravel
Sandy or gravelly silts or clays	Greater than 15 percent sand and/or gravel

The following are basic facts about fine-grained soil classification:

- The basic symbol M is used if the soil is mostly silt, while symbol C applies if it consists mostly of clay. Use of symbol O indicates that organic matter is present in an amount sufficient to influence soil properties. The symbol Pt indicates soil that consists mostly of organic material.
- Modifying symbols are based on the following hand tests conducted on a soil sample:
  - Dry strength (crushing resistance: none, low, medium, high, very high)
  - Dilatancy (molded ball reaction to shaking: none, slow, rapid)
  - Toughness (resistance to rolling or kneading near plastic limit: low, medium, high)
  - Plasticity (nonplastic, low, medium, high).
- Soil designated ML has little or no plasticity and can be recognized by none to low dry strength, slow to rapid dilatency, and low toughness.
- CL (lean clay) indicates soil with medium plasticity, which can be recognized by medium to high dry strength, no or slow dilatency, and medium toughness.
- OL is used to describe an organic, fine-grained soil that is less plastic than CL soil and can be recognized by low to medium dry strength, medium to slow dilatency, and low toughness. In some cases, it may be possible to differentiate organic silts (OL) from organic clays (OH), based on correlations between dilatancy, dry strength, toughness, or laboratory tests.
- MH soil has low to medium plasticity and can be recognized by low to medium dry strength, no to slow dilatency, and low to medium toughness.
- Soil designated CH (fat clay) has high plasticity and is recognizable by its high to very high dry strength, no dilatency, and high toughness.
- OH is used to describe an organic fine-grained soil that is less plastic than CH soil and can be recognized by medium to high dry strength, slow dilatency, and low to medium toughness. In some cases, it may be possible to differentiate organic silts (OL) from organic clays (OH), based on correlations between dilatancy, dry strength, toughness, or laboratory tests.

  Note: PT (peat) is used to describe a highly organic soil composed primarily of vegetable tissue with a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor.
- Other descriptive information includes:
  - Color (e.g., Munsell). Soil color is named and coded using the Munsell Soil Color chart if required for the project. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded. For example, “reddish brn (5YR, 4/4).”
    - Moisture condition,
  - Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.
  - Consistency (thumb penetration test: very soft, soft, firm, hard, very hard. For fine sediments use very soft, soft, medium, stiff, very stiff, and hard.) These are estimated from drive sample hammer blows or other field tests. Blow counts may also be used, if reliable.

    - Structure (same descriptors as coarse grain)
    - Compactness (loose, dense) for silts
    - Odor
    - Iridescent sheen (based on sheen test)
    - Debris (e.g., paper, wood, plastic, cloth, concrete, construction materials, etc.).
    - HCl Reaction (none, weak, strong).
  - Additional Comments (e.g. roots or rootholes, difficult drilling, borehole caving, presence of mica, contact and/or bedding dip, bedding features, cementation, structures, fractures, fracture fillings, fossils, formation name, minerals, oxidation).

Fine-Grained Rock Description:

- Textural Classification
- Color. Rock color is named and coded using the Geological Society of America rock color chart. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded. For example, "gry grn (5G, 5/2)."
- Hardness. Very hard, hard, medium, soft, very soft.
- Moisture Content. Dry, damp, moist, wet (saturated).
- Size Distribution. Approximate percentage of gravel, sand, and fines (silt and clay).
- Estimated Permeability. Very low, low, moderate, or high. This is based primarily on grain size, sorting, and cementation. Estimate secondary permeability due to natural rock fractures when applicable.
- Miscellaneous. Odor, contact and/or bedding dip, cementation, bedding, inclusions, secondary mineralization, fossils, structures, formation name, and fractures.
- Fractures are identified by depth, angle, width, and associated mineralization if applicable. The interpretation of the fracture type (i.e., as natural [N], coring induced [CI], or handling induced [HI]) should be stated. For example, "NF @90.8', 25 deg to axis, 0.1" wide, minor calcite."

Coarse-Grained Rock Description:

- Textural Classification.
- Color. Rock color is named and coded using the Geological Society of America rock color chart. The code should be in parentheses immediately following the written description. Presence of mottling and banding also is recorded. For example, "gry olive grn (5GY, 3/2)."Hardness. Very hard, hard, medium, soft, very soft.
- Moisture Content. Dry, damp, moist, and wet (saturated).
- Size Distribution. Approximate percentage of gravel, sand, and fines (silt and clay).

- Grain Shape. Angular, subangular, subrounded, rounded, or well-rounded, for grains larger than sand size.
- Grain Size. The largest cross-sectional dimension measured in tenths of an inch for grains larger than sand size.
- Miscellaneous. Odor, contact and/or bedding dip, cementation, bedding, inclusions, secondary mineralization, fossils, structures, formation name, and fractures.
- Fractures are identified by depth, angle, width, and associated mineralization, if applicable. The interpretation of the fracture type (i.e., as natural [N], coring induced [CI], or handling induced [HI]), should be stated. For example, "NF @126.1', 35 deg to axis, 0.1" wide, minor calcite."

C.6 Other Logging Parameters

Rock Quality Designation

This designation generally follows ASTM D6032/D6032M-17 Standard Test Method for Determining Rock (RQD) of Rock Core.

The RQD denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. This method is generally applied to core barrel samples.

Standard Penetration Tests

This method generally follows ASTM D1586/D1586M-18e1 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils. This method provides a means of assigning a relative density to the soil by counting the number of hammer blows (blow counts) required to advance a split-barrel sampler a specified distance into the undisturbed soil ahead of the lead auger. This method is not applicable to boreholes advanced with direct-push sampling equipment. It is used primarily in conjunction with hollow stem auger drilling apparatus as the test can be performed through the auger string without removal of the augers thereby allowing the borehole to remain open to the bottom of the drill string without risk of caving. As the sampler is advanced by the repeated drop of a hammer of known weight, the blow counts are recorded on the log and used to provide a relative density descriptor to the soil penetrated during the test.

The number of blows required to drive the sampler 6 in. by a 140-lb hammer falling 30 in. Fifty blow counts per 6-in drive is considered "refusal," and sampling at this depth is usually terminated. In addition, a total of 100 blow counts per 18-in. drive, or no observed advance of the sampler during ten successive hammer blows, is also considered "refusal." During coring, leave this section blank. Normally, the second and third 6-in. intervals are recorded and added as the number of blows per feet.

Sampler Type/Depth. Give sampler type by the letter code listed below and identify the depth at the top of the sampling interval in feet below ground surface (bgs).

Sampler type	Inside diameter(in.)	Code
Standard penetrometer	1.38	SP

Split-barrel (small)	2.0	SBS
Split-barrel (large)	2.5	SBL
HQ wireline core	2.3	PC

Those descriptors are as follows for coarse grained soils:

Very Loose	0 to 3 SPT Sampler	0 to 4 Mod CA Sampler
Loose	4 to 7 SPT Sampler	5 to 10 Mod CA Sampler
Medium Dense	8 to 23 SPT Sampler	11 to 30 Mod CA Sampler
Dense	24 to 38 SPT Sampler	31 to 50 Mod CA Sampler
Very Dense	> 38 SPT Sampler	>50 Mod CA Sampler

Relative Density Descriptors for fine grained soils are as follows:

Very Soft	<1 SPT Sampler	0 to 1 Mod CA Sampler
Soft	1 to 3 SPT Sampler	2 to 4 Mod CA Sampler
Firm	4 to 6 SPT Sampler	4 to 8 Mod CA Sampler
Stiff	7 to 12 SPT Sampler	8 to 15 Mod CA Sampler
Very Stiff	13 to 23 SPT Sampler	15 to 30 Mod CA Sampler
Hard	> 23 SPT Sampler	>30 Mod CA Sampler

Regardless of the degree of adherence to the ASTM Standard Method, split barrel samplers are used as the preferred method of undisturbed sample acquisition in a hollow stem auger drilling. Upon retrieval of the sampler from the borehole, the sampler should be opened without making contact with its interior contents and the logging personnel should record the percent recovery or length of the sample recovered. Sample containers should be removed with a clean gloved (gloves may not be needed, depending upon requirements of HASP) hand and placed in a clean, dry area for examination and logging. The sample will be described per the above. Any lithologic changes that may be observable in the exposed ends of the intact core over the sampled interval should be recorded on the log before any disturbance thereof. The depth of the lithologic changes should be estimated and recorded on the boring log. The least disturbed sample container of the two deeper six-inch sample increments should be secured with Teflon® or aluminum end sheets and snug fitting plastic end caps, sealed with silicon tape, depending upon testing, sampler may be filled with one-inch rings instead of 6 inch. Sealing material should also be compatible with subsequent testing requirements.

<u>Ambient Temperature Head-Space:</u>

Organic vapor analyzers such as photoionization detectors (PIDs) or flame ionization detectors (FIDs) are generally used to assess the relative concentration of volatile hydrocarbons in the soil as the borehole is advanced and recorded as a value in parts per million on the boring log. This can be done by placing a uniform amount of soil in a Ziploc® bag, glass jar or other clean container, allowing the soil in the container to equilibrate to the ambient temperature, then inserting the probe of the PID or FID into the sealed container and recording the maximum PID or FID reading.

Non-Aqueous Phase Liquid (NAPL) Containing Soil

Appropriate observations of NAPL containing soil should include the following:

Hydrophobic Dye Test: Many NAPLs may be clear and/or odorless or present in low enough concentrations rendering difficulty in detection without the aid of a dye test. The use of oil-red-o (a hydrophobic dye) can assist in the field to determine NAPL presence. The dye test includes adding NAPL-suspect soil to a sterilized glass jar containing water and mixing the soil/water by shaking or other methods. Once the soil and water have been mixed the oil-red-o is added to the jar and mixed by shaking or other methods. Oil-red-o is insoluble in water, and if no NAPL is present, will remain in the solid powder form. If NAPL is present, the dye will dissolve and stain the NAPL a bright red color. After completion of the test it should be noted whether or not NAPL is present, along with the relative presence of NAPL (low, moderate, high).

Appearance: If a separate phase liquid appears to be present, it might be described as “dark brown viscous fluid or liquid observed in the soil matrix.” This remark should follow the lithologic description in the borehole log. Observations of color should be made such as “black streaks” or “mottled gray to “olive brown”, however, it should not be inferred or remarked that the color is a necessary consequence of petroleum staining.

Odor: If the soil smells like petroleum it might be remarked that it has a “petroleum like” or “solvent like” odor. The use of terms like “strong” or “slight” should be avoided because there is no way to ensure that these terms can be applied uniformly in the field between various persons performing the logging (i.e., each person’s olfactory sense is different). The use of terms like “chemical odor” should also be avoided as there is no common reference point. Notations regarding the type of petroleum distillate present (e.g., “diesel-like odor” or “gasoline odor”) are inappropriate as these are determinations that can only be accurately made by laboratory analysis.

C.7 Logging Refuse

This procedure applies to the logging of subsurface samples collected from a landfill or other waste disposal sites:

1. Observe refuse as it is brought up by the hollow stem auger, bucket auger, or backhoe.

2. If necessary, place the refuse in a plastic bag to examine the sample.

3. Record observations according to the following:

    a. Composition (by relative volume), e.g., paper, wood, plastic, cloth, cement, construction debris. Use such terms as "mostly" or "at least half." Do not use percentages.

    b. Moisture content: dry, damp, moist, wet.

    c. State of decomposition: highly decomposed, moderately decomposed, slightly decomposed, etc.

    d. Color: obvious mottling included.

e. Texture: spongy, plastic (cohesive), friable.

f. Odor.

g. Combustible gas indicator readings (measure downhole).

h. Miscellaneous: dates of periodicals and newspapers, degree of drilling effort (easy, difficult, very difficult).

C.8 References

Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils. ASTM D1586/D1586M-18e1

Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). ASTM D2488-26.

Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System. ASTM D2487-17(2025)

Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core. ASTM D6032/D6032M-17.

Grain Size Scale Used by Engineers. ASTM D422-63(2007) and ASTM D643-97.

Compton, R. R. 1962. *Manual of Field Geology*. New York: John Wiley & Sons, Inc.

U.S. Department of the Interior. 1989. *Earth Manual*. Washington, D.C.: Water and Power Resources Service.

International Society for Rock Mechanics. Commission on Classification of Rocks and Rock Masses. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr. 1981, Vol. 18, pp. 85-110, Great Britain.

SOG: Well Construction and Development

C.1 Introduction

This guideline describes procedures used by Kennedy/Jenks Consultants (Kennedy/Jenks) personnel for well construction and development following completion of boring and soil sampling procedures (described in Standard Operating Guideline, Boring and Subsurface Soil Sampling).

C.2 Well Construction Materials

- 2-inch or 4-inch Schedule 40 PVC blank casing
- 2-inch or 4-inch Schedule 40 PVC slotted casing, of appropriate slot size
- 2-inch or 4-inch Schedule 40 PVC threaded and slip caps
- Stainless steel well centralizers
- Ground-level traffic-rated watertight well housing enclosure
- Locking expansion plugs
- Combination or key lock
- Filter pack sand (refer to Standard Operating Guideline, Design of Filter Packs and Selection of Well Screens for Monitoring Wells)
- Type I or II Portland cement
- Concrete
- Bentonite powder
- 0.25-inch bentonite pellets or chips.

C.3 Well Development Equipment

- 2-inch or 4-inch-diameter vented surge block
- 1-inch dedicated PVC hose for well development and purging
- Centrifugal surface pump
- Submersible pump (4-inch-diameter wells or larger)
- 55-gallon DOT-approved drums
- Teflon, stainless steel or PVC bailer
- Teflon-coated bailer retrieval wire
- Airlift pump with foot valve and compressor
- Bladder pump (2-inch diameter wells only)

C.4 Typical Procedure

1. Following completion of selected borings, install the well casing through the center of the hollow stem auger, drive casing, or open boring. The well consists of a PVC Schedule 40 slotted well

casing of appropriate diameter and a blank casing with a threaded bottom cap and a slip or threaded top cap or watertight expansion plug. The casing string must be held in tension during initial installation.

2. Place clean, well graded sand around the slotted section of the well to serve as the filter pack. The grade of sand is chosen on the basis of aquifer units encountered (refer to Standard Operating Guideline, Design of Filter Packs and Selection of Well Screens for Monitoring Wells). The filter pack is emplaced as the auger or temporary casing is removed from the boring.

3. Ensure that filter pack sand for the well extends to approximately 3 feet above the top of the screened interval.

4. If required in the well construction permit, notify the appropriate inspector prior to placing the well seal.

5. Place a 2- to 3-foot thick bentonite pellet seal above the sand pack, as the auger and/or casing is removed from the boring. If the seal is placed above the water table, the bentonite pellets must be hydrated with potable water prior to placement of the annular seal.

6. Fill the remainder of the annulus between the well casing and the borehole wall with cement/bentonite grout (with approximately 5 percent bentonite), or a high-solids bentonite slurry (11 to 13 pounds per gallon), to a depth of approximately 1 foot below ground surface. If the water level is higher than the seal, use a tremie pipe to place the grout.

7. Install either a threaded cap or a locking watertight expansion plug on the well. Place a steel hasp-locking well housing over the top of the well and cement it into the annulus of the boring.

8. Place a traffic-rated precast concrete or steel well enclosure approximately 1 to 2 inches above grade, and cement it into place with concrete. Have a concrete apron constructed around the well housing enclosure to facilitate runoff.

9. Repeat Steps 1 through 9 for all wells at site.

10. Following the curing of the grout (approximately 24 hours), each well is developed. Prior to development activities, measure the depth in each well to static water level and total casing depth.

11. Also prior to well development, if applicable, check the water interface of each well for the presence of floating product (NAPL). Use a clear bailer or color indicator paste for the inspection.

12. If a well has a water level of less than 25 feet, it may be developed by using a centrifugal surface pump with dedicated 1-inch I.D. clear flex suction hose, placed with the hose intake placed temporarily at all levels of the screened interval. If the well is greater than 25 feet deep, a submersible pump or airlift pump with air filter is used for development. In either case, a surge block of appropriate size can be moved up and down inside the screened section of the well casing to create a surging action that hydraulically stresses the filter pack.

13. During development of each well, ensure that field parameters and observations are recorded on a Kennedy/Jenks purge and sample form (attached). Information to be recorded includes, but is not limited to, the following items:

- Depth to water
- Development time and volume
- Development (flow) rate
- pH, temperature, specific conductivity, and turbidity
- Other observations, as appropriate (e.g., color, presence of odors, or sheen)
- Develop each well until water of relatively low turbidity is removed from the casing.
- When development of each well is discontinued, record the following field parameters/observations:
- Depth to water
- Temperature
- pH
- Specific conductance
- Turbidity
- Color

C.5 Investigation-Derived Wastes

Place groundwater produced by well development in appropriately labeled containers for disposition by the client, following the IDW Management SOG.

SOG: Design of Well Screen Filter Packs and Selection of Well Screens

C.1 Introduction

This guideline describes the procedures used by Kennedy/Jenks Consultants personnel for designing filter packs for monitoring wells and selecting a screen of appropriate size. The user of this SOG should modify the procedures used, as appropriate, to conform to the project-specific requirements and conditions.

C.2 General Information

A filter pack is an engineered structure usually consisting of a uniformly graded mixture of sand or gravel surrounding the intake interval of a piezometer, monitoring well, or extraction well. Its major function is to stabilize water-bearing formation by preventing erosion of the soils/formation from the borehole wall into the well. Associated benefits are that a properly designed filter pack reduces turbidity in water samples and prevents clogging of the intake structure.

If a well is to be used for pumping (extraction and/or supply), the filter pack also increases the effective radius of the well and minimizes abrupt head losses between the well casing and the water-bearing zone. The latter feature is important when a pumping well is used during aquifer pumping tests.

C.3 Filter Pack Structure

As mentioned earlier, the principal function of a filter pack is to prevent movement of soil particles into the well during pumping or bailing. The filter medium should be sufficiently coarse to minimize seepage forces that resist the movement of fluid to the well and consequently increase turbulence and head loss. Therefore, the filter pack must be constructed of the coarsest material possible that is also fine enough to effectively prevent erosion and movement of the formation from the borehole wall to the well screen.

A uniform granular material, spheroid in shape, naturally packs in cubic-close packing. The maximum diameter of the smallest pore space in such an arrangement is approximately 15 percent of the grain diameter of the filter medium. The significance of this is that effective filter size of a granular medium is only 15 percent of the diameter of the mean grain size. Therefore, the filter material is significantly coarser than the material it is intended to filter.

C.4 Filter Pack Design Considerations

There are a number of methods for designing a filter pack (see references at the end of this section). The choice of method to use and the way to select appropriate parameters for the method depend on a number of variables, including:

1. Purposes of the well:
   - Production
     - Domestic

    - Agricultural
- Use in pumping tests
- Use as monitoring well to sample groundwater for:
    - Metals, PCBs, and other readily sorbed chemicals
    - VOCs
    - MEK, acetone, and relatively nonsorbing chemicals
- Use an extraction well
- Use as soil vapor extraction well
- Use as a piezometer

2. Nature of the natural soil/formation:
   - Coarse-grained
   - Clay or silt
   - Gradation:
     - Well graded
     - Poorly graded
     - Uniform
     - Gap-graded
3. Regulatory environment: state or federal agency-promulgated design standards
4. Anticipated cost of well

For the purposes of this guideline, the anticipated uses of a well are groundwater quality monitoring, pumping tests, and groundwater or soil vapor extraction (e.g., for remediation) at discharge rates generally less than those associated with full-scale production wells. Because the general objective of well installation is to monitor or extract from water-bearing zones, fine to coarse-grained granular material is assumed to comprise the screened zone. However, as discussed below, the filter pack should be designed on the basis of the finest-grained portion of the zone to be screened.

Finally, although there are a number of techniques described in the literature (see references at end of this section), three design protocols are presented in this document: protocol described in the California Department of Health Services (DHS) Decision Tree, Chapter 3 (California DHS 1986), and two composite "expedited" protocols based on review of a number of references that might be applicable for more typical drilling and well installation projects. These methods are presented in Figure 1 and described in the Expedited Methods section of this guideline. Two examples of the DHS method are presented in Figure 2 (a and b) and Figure 3 (a and b).

C.5 Sieve Analysis and Preparation of the Grading Curve

1. For sieve analysis and preparation of the grading curve, collect a sample (>500 grams) of soil representative of the material to be screened. If the interval to be screened is laminated or otherwise bedded, use a sample of the finest-grained lamination or bed for design of the filter pack.

2. Air-dry the sample and perform sieve analysis in approximate accordance with ASTM Method D422. In most circumstances, determination of the distribution of grain sizes smaller than No. 200 mesh (0.075 mm) is not necessary.

3. Plot grain size distribution on semi-logarithmic paper, with the cumulative percent passing as the ordinate (linear) and the sieve size (measured in millimeters) as the abscissa (logarithmic). By convention, in the use of percent passing, sieve sizes increase from right to left (Figures 2 and 3). A smooth curved line is drawn to fit the data points.

   Note: Some methods discuss grain sizes in terms of percent retained (100 percent minus percent passing). For consistency, percent passing is used throughout this guideline.

C.6 California DHS Decision Tree Method

The California Decision Tree Method (California DHS 1986) is one of the most specific and detailed methods available. For many situations, this method is too cumbersome and requires more detailed (and costly) design specifications than necessary. However, it does provide a standard to which other methods can be compared.

C.6.1 Step One: Selection of Design Parameters

After plotting data points and drawing a "best-fit" grading curve through them, select the design parameters of the soil, as follows:

1. Choose the following indicator of grain sizes:
   a. $D_{10(s)}$: diameter of sieve through which 10 percent (cumulative) of the soil sample passes.
   b. $D_{30(s)}$: diameter of sieve through which 30 percent (cumulative) of the soil sample passes.
   c. $D_{60(s)}$: diameter of sieve through which 60 percent (cumulative) of the soil sample passes.
2. Calculate coefficient of uniformity (Cu) of soil sample, according to the following equation:

$$Cu_{soil} = \frac{D_{60(s)}}{D_{10(s)}}$$

3. On the basis of coefficient of uniformity and size of smallest soil fraction, select a filter multiplication factor, F_{30}, in accordance with the flowcharts presented in Figure 1 and the examples shown in Figures 2 and 3.
4. After selecting the appropriate filter multiplication factor, calculate D_{30} sieve diameter of the proposed filter pack by multiplying $D_{30(s)}$ by F_{30}. Plot the D_{30} diameter of the proposed filter pack on the grading curve. This point is designated $D_{30(fp)}$.
5. Draw a smooth curve approximately parallel to the soil grading curve, which passes through $D_{30(fp)}$. If the original soil gradation curve is nonuniform ($Cu_{(soil)} > 2.5$), construct the filter pack curve so that it does not exceed a $Cu_{(fp)}$ of 2.5.
6. Grading curves with identical coefficients of uniformity have identical slopes on the cumulative percent passing graph (Figures 2 and 3). Therefore, to establish a particular $Cu_{(fp)}$ that contains the designated $D_{30(fp)}$ point, construct a line through any D_{10} point that passes through and D_{60} point so that the ratio D_{60}/D_{10} equals the desired coefficient of uniformity (Cu). Then plot a new line parallel to the line through the D_{10} and D_{60} points discussed above and

passing through $D_{30(fp)}$. This line is the filter pack curve used to select appropriate grading of the final filter material.

C.6.2 Step Two: Selection of Design Specifications for Filter Pack

Each supplier has a specific brand designation for its most commonly used sand grades (e.g., Monterey 1C- or Lonestar #3). However, to properly designate a graded sand, the D_{90} and D_{10} diameters (or occasionally the D_{95} and D_5 or the D_{80} and D_{20} diameters, depending on supplier) of the sand must be specified. For example, a graded sand that is designated 12x20 (or "twelve by twenty") generally refers to a uniformly graded sand of which 90 percent passes through a No. 12 sieve (1.4 mm) and 10 percent passes through a No. 20 sieve (0.85 mm).

- **Option 1: Selecting a Pregraded Sand –** After plotting the filter pack curve as described in Step One, locate $D_{0(fp)}$, $D_{10(fp)}$, $D_{30(fp)}$, $D_{50(fp)}$, and $D_{70(fp)}$ on the curve and draw a grading curve through these points. Based on grading specifications provided by the sand supplier, select the pregraded sand that most closely mimics the filter pack design curve. Both ASTM practice (ASTM draft, 1988) and the DHS method (California DHS, 1986) suggest a maximum departure of 8 percent of the selected curve from the filter pack design curve. Therefore, the D_{30}, D_{50}, and D_{70} points of the selected pregraded sand curve should be within an envelope of tolerance of ±8 percent of each of these points on the grading curve of the filter pack. For example, if the $D_{70(fp)}$ value is 1.5 mm, the D_{70} point on the selected curve should be between approximately 1.4 mm and 1.6 mm.

- **Option 2: Specifying a Custom-Graded Curve –** If a premixed graded sand that meets the specifications described above is not available, a custom filter pack sand might be required. To provide specifications to the supplier, a different approach is generally required because of the mechanics of blending sands.

Select three or four convenient sieve sizes to adequately represent the filter pack curve. They should be close to the $D_{10(fp)}$, $D_{30(fp)}$, and $D_{60(fp)}$ values. Estimate the percent of sand passing on the curve through these sieve diameters and provide the estimates as specifications to the supplier. Johnson Division's Information on Groundwater (Johnson Division, 1986) recommends a tolerance of ±8 percent in these specifications. For example, if 65 percent of the proposed pack (based on the filter pack curve) passes though the No. 12 sieve (1.4 mm), the specification should call for between 57 and 73 percent of the actual filter material to pass through the No. 12 sieve.

C.7 Expedited Methods

The protocols described below, Methods E-1 and E-2, are intended for use on more typical one-well, two-well, or three-well projects where there is little or no previous knowledge of the site soil. These methods are intended to provide a more rational procedure for selecting a filter pack than "guesstimating," without incurring the cost and time involved with the California DHS method described above.

C.7.1 Method E-1

When planning to install the first well in an area where prior knowledge of the subsurface is nonexistent or very general, based on available literature, yet supplies and equipment must be ordered, follow Method E-1 protocol, presented in Table 1. This information is derived from ASTM protocol (Gass, 1988).

Table 1: Expedited Method for Selecting a Filter Pack

Anticipated Strata	Well Screen Slot Size (inches)	Filter Pack Material (Approximate Range of Standard U.S. Sieve Sizes)
Sand and gravel	0.030	4 x 20
Silt and sand	0.020	8 x 30
Clay and silt	0.010	16 50

C.7.2 Method E-2

The draft ASTM protocol (Gass, 1988) is less specific than the DHS protocol (California DHS, 1986) concerning the design of the filter pack, although it does require a sieve analysis. Design criteria for Method E-2 are presented in Table 2.

Table 2: Suggested ASTM (Draft) Filter Pack Design Criteria

Soil Character	F_{30}
Fine-grained, uniformly graded	4 to 6
Very fine-grained (silt), nonuniform	6 to 10

The ASTM protocol further proposes a $Cu_{(fp)} \leq 2.5$. It provides the data shown in Table 3 to aid in selection of the appropriate screen opening after completion of the filter pack grading curve.

Table 3: Proposed Astm (Draft) Slot Sizes For Selected Filter Pack Grades

Size of Screen Opening mm (inches)	Well Screen Slot Number	Sand Pack Mesh Size Name
0.25 (0.010)	10	20 x 40
0.50 (0.020)	20	10 x 20
0.75 (0.030)	30	10 x 20
1.0 (0.040)	40	8 x 12
1.5 (0.060)	60	6 x 9
2.0 (0.080)	80	4 x 8

C.8 General Filter Pack Specifications

To minimize later consolidation of the filter pack and potential chemical impact to water, do not use minerals or cementing agents that are not inert (e.g., calcium carbonate) in filter packs. The filter should contain more than 95 percent silica, in the form of quartz, chert, chalcedony, etc. The filter material should also be rounded to facilitate packing and minimize problems.

C.9 Design of the Well Intake (Screen)

The selection of the appropriate well screen or slotted section is based on two criteria: maximum allowable entrance velocity of water to the well and grading of the filter pack. The entrance velocity should be minimal, except during development of the well. A number of sources (e.g., California DHS 1986; Johnson Division, 1986) cite a maximum allowable entrance velocity (V) of 0.1 ft/sec.

The design parameters involved are diameter of the well (D, measured in inches); discharge of the well (Q, measured in gpm); amount of open area of the intake section, which is dependent on length (L, measured in feet) of the screened section; and amount of open area (A, dimensionless, as a percentage of the total area of the well over the screened interval).

If V ≤ 0.1 ft/sec, then the following relationship applies:

$$\frac{Q}{450\left(\frac{gpm}{cfs}\right)} \; x \; \frac{1}{\frac{L \; x \; D\pi}{12 \; x \; A}}$$

Generally, the length of the screened interval (L) is estimated from the thickness of the water-bearing interval. The well discharge (Q) is estimated based on anticipated yield of the zone and/or supply requirements. Therefore, the diameter of the well (D) and the percentage of open area (A) are the two independent design parameters.

The total open area (L x D x A) of the well screens is generally depicted in terms of square inches per foot of length for a given slot size (aperture width), density of apertures (number of slots) per inch of length per row of slots, and number of rows of slots (usually based on the diameter of the well). Most suppliers present these parameters in their catalogs, or the parameters can be calculated for field-slotted screens. The minimum allowable open area, based on maximum entrance velocities, should be estimated during design of the well to establish a minimum slot size.

The second criterion for design of the screen is grading of the filter pack, which usually establishes the maximum slot size. The screen should be selected to allow some filter material to pass through during development to grade the filter pack and stabilize it. A general consensus in associated literature (California DHS, 1986; Johnson Division, 1986; Gass, 1988; ASTM draft, 1988) favors the idea that the screen should allow less than 10 percent of the filter pack to flow into the well during development. Therefore, the maximum slot size (aperture width) should be $D_{10(fp)}$. For example, if $D_{10(fp)}$ is 0.5 mm, the appropriate maximum slot size should be 0.02 inch (0.51 mm).

There might be some cases where a smaller or larger slot size is advantageous. For example, if the filter pack is nonuniform ($Cu_{(fp)} > 2.5$), a slot size of $D_{10(fp)}$ might not allow for proper settlement and stabilization of the filter pack. In such cases, the DHS (California DHS, 1986) recommends a maximum slot size of $D_{20(fp)}$. When the native soil has a very skewed distribution, toward fine-grained sizes, and suspended soil (turbidity) in water samples is of concern, a smaller slot size might be appropriate.

C.10 References

American Society for Testing Materials. 2024. D5092/D5092M-16. *Standard Practice for Design and Installation of Groundwater Monitoring Wells*. ASTM, Philadelphia, PA.

American Society for Testing Materials. 1988. *Draft - Recommended Practice for Design and Installation of Groundwater Monitoring Wells*. ASTM, Philadelphia, PA.

California DHS. 1986. California Site Mitigation Decision Tree, Chapter 3, Section 3.4.3. California, DHS.

Gass, T. E. 1988. *Monitoring Well Filter Pack and Screen Slot Selection*. Water Well Journal: (6):30-32

Johnson Division. 1986. *Groundwater And Wells*. Second Edition.

Johnson Division, St. Paul, MN.

Johnson Division. 1987. *Monitoring Well Specifications*. Johnson Division, St. Paul, MN.

Roscoe Moss Company. 1985. *The Engineer's Manual For Water Well Design*. pp. 148-153.

Sowers, F. 1979. *Soil Mechanics and Foundations*: Geotechnical Engineering. Fourth Edition: pp. 119-120. McMillan Publishing Co., New York, NY.

U.S. Environmental Protection Agency. 1987. *Groundwater*. EPA 1625/6-87/016. U.S. EPA, Washington D.C.

Water and Power Resources Service (WPRS). 1981. *Water and Power Resources Service Groundwater Manual*. First Edition, Reprinted 1981. pp. 330-333. John Wiley and Sons, New York, NY.

SOG: Well Abandonment

C.1 Introduction

This guideline describes the equipment and procedures used by Kennedy/Jenks Consultants personnel for monitoring well abandonment activities.

C.2 Equipment

- **Drill Rigs:** high torque hollow-stem auger or mud rotary rig.
- **Hollow-Stem Augers or Drill String:** I.D. greater than the well casing and O.D. equal to or greater than the diameter of the original boring drilled to install the well.
- Foxboro FID-Organic Vapor Analyzer or HNU PID-Organic Vapor Analyzer
- **Personal Protective Equipment:** Described in the site safety plan
- **Sealing Material:** cement/bentonite grout

C.3 Typical Procedures

Monitoring wells may be destroyed by either of the two methods: Procedure A - removing all well construction materials within the original borehole by overdrilling or pulling the well materials and completely filling the created hole with an appropriate sealing material, or Procedure B - filling the well filter pack, casing and any other significant voids with an appropriate sealing material under pressure. Both procedures are described below. The choice of which procedure may depend on site's conditions (local lithology, site activities, adjacent site activities, local regulations, etc.) and the well's conditions (depth, multi-screened intervals, collapsed casing, etc.). In most cases, Procedure A allows for more accurate documentation and greater assurance of proper well abandonment, and is therefore, usually the recommended procedure.

C.3.1 For Either Procedure

- Applicable well abandonment permits shall be obtained prior to mobilization.
- The monitoring well to be destroyed shall be investigated to determine its condition and the details of its construction prior to abandonment. The depth, casing diameter, and construction and sealing design of the well shall be ascertained. The well will be sounded immediately before it is destroyed to determine whether there are obstructions that will interfere with the abandonment. Such obstructions shall be removed, if necessary, prior to the well abandonment operations.

C.3.2 Procedure A - Removal of All Well Materials and Sealing

- All downhole equipment will be steam cleaned prior to drilling each boring.
- The monitoring well shall be destroyed by removing all material within the original borehole (including the well casing, screen, filter pack, and annular seal), and the created hole filled completely with appropriate sealing material, described below. Material to be extracted from the original borehole shall be removed by means of overdrilling the borehole with hollow-stem augers or drill string with an I.D. greater than the well casing, and an O.D. equal to or greater than the diameter of the boring drilled to install the well. Well materials will be removed from the interior of the augers as they are advanced. An alternative to overdrilling includes the use of a PVC extraction tool and an excavator or similar piece of heavy machinery used to pull and remove the well casing from below the ground surface. Should the well materials break or be unable to be fully removed, the operator shall dig down to a minimum of 3 feet below ground surface, cut the well casing flush, and begin backfilling as described below.
- Upon completion of the overdrilling to the depth of the original boring, all well material will be removed.
- The reamed boring will be backfilled with a neat cement grout containing 5% bentonite by weight, as the augers are removed from the boring. The grout will be injected into the boring from the bottom through the hollow-stem augers or with a tremie pipe.
- If necessary, for purposes of ascertaining residual disposal requirements, "grab" samples should be collected from the drilling residuals as the boring is advanced. Samples of the residuals will be collected from depths most likely to contain chemicals of concern, based on previous sample analysis. If adequate sample analysis can be documented from previous investigations, no additional residual sample analysis may be necessary.

C.3.3 Procedure B - Filling all Well Voids with Sealing Material

- Based on the pre-abandonment well inspection described above, the well may require removal of obstructions in the casing.
- The filter pack, casing and any other significant voids within the well shall be filled with sealing material. In some cases, the casing may have to be perforated or punctured, to allow for the proper placement of the sealing material. Sealing material may have to be applied under pressure to ensure proper distribution.
- The sealing material shall be a neat cement grout containing 5% bentonite by weight.

C.4 Equipment Cleaning

1. Downhole equipment (augers, well casing, sampler) will be steam cleaned prior to each boring.
2. Downhole equipment, and vehicles which warrant it, will be steam cleaned prior to leaving the site at completion of drilling.

C.5 Investigation-Derived Residuals

Soil cuttings and other residuals will be contained in labeled DOT-approved 55-gallon drums or roll-off bins for disposition by the client. Kennedy/Jenks Consultants is available to assist the client with options for disposition of residuals, following the IDW Management SOG.

SOG: Equipment Decontamination

Version: 4/27/2026
Approved:

C.1 Introduction

This guideline describes field procedures typically followed by Kennedy/Jenks Consultants personnel during the decontamination of sampling and monitoring equipment. Proper decontamination procedures minimize the potential for cross-contamination among sampling points on a single site or between separate sites.

C.2 Equipment

- Two or three containers (e.g., 5-gallon buckets, or 5- or 10-gallon plastic tubs) for dip rinsing, washing, and collection of rinse water.
- Two or three utility brushes or test tube brushes for removal of visible contamination. A test tube brush (or similar) can be stapled to the end of a dowel and used to clean the inside of a bailer.
- Non-phosphate Alconox, Liquinox, or trisodiumphosphate (TSP) to be mixed with potable or distilled water.
- Rinse solutions, such as methyl alcohol (methanol), dilute nitric acid (0.1 molar), deionized or distilled water, and/or tap water. Deionized water is preferable to distilled water because the deionization process typically results in greater removal of organic compounds as discussed below:

  Acid rinse (inorganic desorption) 10% nitric or hydrochloric acid solution reagent grade nitric or hydrochloric acid and deionized water (1% to be used for low carbon steel equipment)[1].

  Solvent rinse (organic desorption isopropanol, acetone, or methanol; pesticide grade).

  Deionized water is preferable to distilled water because the deionization process typically results in greater removal of organic compounds.

- Multi-gallon storage containers filled with potable water to be used for rinsing or washing.
- Spray bottles, squirt bottles, or garden sprayers to apply rinse liquid. A separate bottle should be used for each liquid.
- Solvex or neoprene gloves that extend, as a minimum, halfway up the forearm. In cooler weather, it is advisable to use different resistant chemicals neoprene gloves that provide better insulation against cold temperatures.
- Paper towels to wipe off gross contamination.

[1] Nitric acid will be used if available and if metals are identified as an analytical parameter.

- Garbage bags, or other plastic bags, and aluminum foil to wrap clean sampling equipment after decontamination, to store sampling equipment or and to dispose of decontamination debris.
- Sample bottles for rinsate blanks. For these blanks, Laboratory Type II (millipore) water should be used. Purified water from the selected analytical laboratory is recommended. This water is often filtered and boiled to remove impurities.
- DOT-approved container (e.g., 55-gallon drum) to store contaminated wash and rinse water. Contained decontamination should be labeled appropriately.
- Steamcleaner with power source and water supply.

C.3 Procedures

In most cases, the following procedures are adequate to remove contamination.

1. Preclean sampling equipment. If there is gross contamination on equipment, wipe it off with paper towels and/or rinse it off with water. Additional internal decontamination may be possible by circulation of water or cleaning solutions.
2. Wash all parts of equipment with detergent water and scrub with brushes. Take equipment apart when appropriate to remove visible contamination.
3. Steamclean sampling equipment, if warranted. The steamcleaner is effective in removing contamination, especially volatile hydrocarbons. Steamcleaning is generally used for larger sampling equipment.
4. Rinse equipment by dipping in rinse solution, spraying, or pouring solution over it. Dip rinsing can introduce contaminants into solution. Spraying might not allow a thorough rinsing of the equipment, but it is a more efficient rinsing method because less rinse solution is used. Appropriate rinsing solutions are specified in the project sampling and analysis plan. Some typical solutions are indicated in the equipment section of this SOG.

   Dilute acids (used to remove metals and other cations)

   Methanol (used to remove organic compounds)

   Tap water

   Deionized/distilled water.
5. Rinse sampler with generous amounts of deionized water. Pouring water over the sampler is best, although spraying or using a squirt bottle to apply rinse water might be adequate if you are trying to minimize waste.
6. Wipe sampling equipment with a paper towel or allow it to air dry.
7. Place samplers in clean plastic bags or sealed containers, or wrap them in aluminum foil, for storage in an undisturbed location that is free of contamination.

C.4 Investigation-Derived Residuals

For details of handling investigation-derived residuals refer to the project sampling and analysis plan.

C.5 Special Notes

- To reduce the potential for cross-contamination, samples should be collected so that the least contaminated stations areas are sampled first. Subsequent sampling should be completed in the order of increasing contamination. Areas that typically have lower levels of contamination include those upgradient of source, background areas, and the periphery of the contaminated area.

- Monitoring instruments that come into contact with sampled materials must be decontaminated, along with sampling devices. They should be washed, or at least rinsed before monitoring other sampling sites.

C.6 References

U.S. Environmental Protection Agency. 1987. *Handbook: Groundwater*. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio.

Washington Department of Ecology. 1982. *Methods for Obtaining Waste Samples*. Ch. 173-303 WAC. Washington State Department of Ecology, Olympia, Washington.

SOG: Handling and Disposal of Investigation-Derived Waste

C.1 Introduction

Environmental site investigations usually result in generation of some regulated waste, particularly if the project involves drilling and construction of monitoring wells. Any potentially hazardous or dangerous material that is generated during a site investigation must be handled and disposed of in accordance with applicable regulations (e.g., EPA 903/B-93-004, EPA 903/B-99-001, 40 CFR 260-265, 49 CFR 100-177, etc.). This guideline provides a procedure to be used for dealing with investigation-derived wastes that have the potential of being classified as hazardous or dangerous, including soil cuttings, well development water, and decontamination water.

The user of this SOG should modify the procedures used, as appropriate, to conform to the project-specific requirements.

C.2 Equipment

- DOT-approved packaging (typically DOT 17E or 17H drums)
- Funnel
- Bushing wrench
- 15/16-inch socket wrench
- Shovel
- Appropriate markers (spray paint, paint pen)
- Plastic sheeting
- Drip pans
- Pallets

C.3 Typical Procedures

C.3.1 Preparing Containers

1. Place each container on a pallet if it is to be moved with a fork lift after it is full.

2. Place plastic sheeting under containers for soil and drip pans under containers used to hold water.

3. Ensure that packaging materials are compatible with the wastes to be stored in them. Bung-type drums should be used to contain liquids. If a liquid is corrosive, a plastic or polymer drum should be used.

4. Solids should be placed in open-top drums. Liners are placed in the drums if the solid material is corrosive or contains free liquids. Gaskets are also used on open-top drums.

C.3.2 Storing Wastes

1. As waste materials are generated, place them directly into storage containers.

2. Do not fill storage drums completely. Provide sufficient outage so that the containers will not be overfull if their contents expand.

3. After filling a storage drum, seal it securely, using a bung wrench or socket wrench, for a bung-type or open-top drum, respectively.

4. Label drums or other packages containing hazardous or dangerous materials and mark them for storage or shipment. To comply with marking and labeling requirements, affix a properly filled out yellow hazardous waste marker and a DOT hazard class label to each waste container. Do not mark drums with Kennedy/Jenks Consultants' name. All waste belongs to the client. Mark accumulation start date.

5. During an ongoing investigation, use a paint marker to mark the contents, station number, date, and quantity of material on each drum or other container. Do not mix investigation-derived wastes with one another or with other materials. Do not place items such as Tyvek, gloves, equipment, or trash into drums containing soils or liquids, and do not mix water and soil. Disposable protective clothing, trash, soil, and water materials should be disposed of in separate containers.

6. Upon completion of field work, or the portion of the project that generates wastes, notify the client as to the location, number, contents, and waste type of waste containers. Remind the client of the obligation to dispose of wastes in a timely manner and in accordance with applicable regulations.

C.4 Regulations

40 CFR, Chapter I, Subchapter I (261-265). *Solid Waste*.

49 CFR 100-177, *Federal Transportation of Hazardous Materials Regulations*.

EPA Region III, Superfund Removal Branch. 1993. *A Guide to Evaluating Hazardous Wastes at a Superfund Site for Disposal*. September.

EPA Region III, Superfund Removal Branch. 1998. *A Guide to Managing Classification and Disposal of Hazardous Waste at Superfund Sites*. December.

SOG: Environmental Data Collection

C.1 Introduction

This guideline describes recommended procedures to be followed by Kennedy/Jenks Consultants when collecting environmental data. The guideline is divided into Pre-field Procedures and Field Procedures for ease of use.

C.2 Pre-Field Procedures

The following procedures represent the minimal effort appropriate for most environmental data collection projects. Refer to project-specific plans for additional data collection procedures.

1. Review the work plan or sampling plan prior to initiating fieldwork and discuss any questions with project manager or field leader.
2. Review the Health and Safety Plan.
3. Set up subcontract with analytical laboratory for type and quantity of analyses, documentation and delivery format, both hard copy and electronic data deliverables (EDDs) and turnaround time requirements. Establish contacts at the laboratory, field and home office (Project Manager or person responsible) for all communications.
4. Notify the analytical laboratory of the upcoming fieldwork and advise about the following:
    a. Number of samples per medium
    b. Analyses needed
    c. Dates of sample delivery, coordinate for Saturday pick-up if necessary
    d. Means of delivery (e.g., courier, FedEx)
    e. Turnaround time required
    f. Level of quality control (QC) reporting required
    g. Delivery format, for both hard copy and EDDs. (If EDDs will be uploaded into a database, refer to the Database Use Data Quality SOG.)
5. Order the sample containers from the laboratory. Determine whether field personnel will preserve the samples in the field or if pre-preserved sample containers will be provided. It is preferable to order containers with appropriate preservatives.
6. Arrange for delivery or pickup of sample containers.
7. Request the laboratory fax or email you chain-of-custody forms and laboratory receipt documents immediately after receiving the samples.

8. Check the chain-of-custody form to verify the correct samples were collected and correct analyses were requested. Double check the laboratory receipt documents to verify there are no typographical errors for samples.

   If changes are required, request change in writing, via email, do not request over the phone. Request the laboratory to include all change request documentation in the laboratory summary report.

C.3 Field Procedures

1. At the beginning of each field day, identify planned work and document field conditions in the field notes.

2. Hold Tailgate Safety Meeting and have all present sign the form.

3. Complete sample identification labels for each sampling container using an indelible pen. Use the sample identification protocol described in the work plan or sampling plan. It is recommended that pre-printed labels be created at the office prior to going to the field site, if possible.

4. Complete the chain-of-custody form, accounting for each sample. Verify that sample identifications, sampling times, and requested analyses on the chain-of-custody form match the sample identifications, sampling times, and requested analyses on the sample labels.

5. Verify that the appropriate QC samples (field duplicate samples, trip blanks samples, etc.) required in the work plan or sampling plan were collected. If applicable, document blind duplicate parents in field notes, and if using a database, supply a summary table of your parent and duplicate samples to your database coordinator.

6. Verify, where applicable, that the appropriate sample volume was collected to enable the analytical laboratory to perform QC analyses (e.g., matrix spike and matrix spike duplicate analysis). (For example, if a water sample is being analyzed for polynuclear aromatic hydrocarbons, 1 liter of sample is required for the analysis, and another 2 liters are required for the matrix spike and matrix spike duplicate analyses.)

7. Collect, preserve, and transport samples to the analytical laboratory in accordance with the work plan or sampling plan including performance evaluation samples provided by the United States Environmental Protection Agency.

8. Provide adequate ice in coolers so that the coolers arrive at the laboratory at a temperature of 4 degrees C ± 2 degrees C.

9. Keep in contact with the project manager or other team member to report any problems, unusual observations, etc.

10. Verify that samples were received by the analytical laboratory and that the laboratory understands the chain-of-custody and requested analyses prior to beginning analyses.

11. If samples are sent by overnight delivery, be sure to include the tracking number and time released to the delivery service on the chain-of-custody form.

SOG: GPS and Field Tablet Use

C.1 Introduction

This guideline describes the field procedure typically followed by Kennedy Jenks Consultants for environmental data collection using the field tablet and GPS unit. The field tablet and GPS unit are used during field events when GPS is required to locate a new or previous sample location, or when the location coordinates of a sample need to be recorded in the field. The field tablet can also be used to record field notes, sample parameters, and photographs, depending on what is required for the data collection event.

C.2 Equipment

- Field Tablet (iPad or other similar device)
- Arrow 100 GPS Unit
- Portable WIFI unit (if field tablet is not WIFI enabled)
- Chargers for units

C.3 Typical Procedure

1. Before any field work begins, have a GIS user set up the ArcGIS online map. Field staff will view/use this map through the Collector app on the field tablet. The ArcGIS online map can be set up to include any features that may be helpful in the field, including but not limited to; historical sample locations, buildings, roads, wells, topography, water features, and/or preselected sample locations. The field team should also specify to the GIS user any information that will be collected using the field tablet. The GIS user can set up fields to collect this information using the Collector app. Additionally, notify the GIS user to set up the map to collect metadata in the background during field collection. **This must all be completed prior to the start of the field event.**

2. Ensure all equipment is charged and in good working order prior to the start of field work. Check that the Collector app and the EosToolsPro app (GPS unit) are downloaded to the field tablet.

3. When in the field, turn on the tablet, the GPS unit, and the WIFI unit (if needed). Connect the antennae to the Arrow 100 GPS unit if not yet connected. Connect the GPS unit to the tablet using Bluetooth. The blue light next to the Bluetooth icon on the Arrow 100 unit will turn on when the device is connected.

4. Open the Collector app. Open Settings and check that the location provider is set to use the Arrow 100 GPS device, and not the internal GPS of the field tablet. In the Settings, ensure that the accuracy is set to <1m.

5. Open the map that was created for this field project. Check that all layers have downloaded onto the map. Layers can be turned on and off using the center icon along the top menu bar.

6. Check that the GPS unit is collecting location information. On the Arrow 100 unit, the GPS, DGPS, and DIFF lights should all be on. When the device is collecting location information, a

box will appear in the bottom left corner of the field tablet screen. The number in this box presents the current location accuracy of the Arrow 100 unit. Location accuracy can vary depending on overhead cover, the location of the antennae, and if the user is moving at the time. If location accuracy is poor, stand in one location and ensure that the antennae is open to the sky. Accuracy should improve.

7. When the GPS unit is connected, the map will automatically center itself on the user's location. This location is identified by a small blue arrow. Field staff can reset the map to their location at any time using the target icon on the left of the top menu bar. This tool can be used to locate features in the field. Field staff only need to walk toward the desired feature until their location on the map overlaps with the feature they want to reach. Field staff should make sure that they are always fully aware of their surroundings while using the tablet, and especially while navigating.

8. If the map has been set up with preselected sample locations with information fields, the field staff can use the tablet to navigate to a sample, then select that sample location icon on the tablet. A window will open to the right providing any information previously input for that location. If any new information needs to be recorded, the field staff can select to edit the feature using the icon on the right of the window. Once editing mode is turned on, the fields can be filled in or edited as required. The sample location can also be moved during editing mode, simply by selecting a new location on the map. Preselected sample locations can be moved in the field if the field staff encounter a utility or obstruction that prevents the collection of the sample at the original location. Once all information has been correctly recorded, select "Update" in the top right corner of the screen. Changes can also be discarded by selecting "Cancel" on the top left of the screen.

9. New features can also be collected using the Collector app. Navigate to the location of the new feature. Select the plus icon on the right of the screen to collect a new feature. Select the feature that is being collected. The feature will automatically be placed on the user's current location but can be moved by selecting another location on the map. Fill in any required information into the available fields. Select "Submit" in the top left corner to save the new feature.

10. When using WIFI, the tablet will automatically sync to ArcGIS Online. The map can be viewed online as it is updated in real time. If no WIFI is available, information can be collected in the field and synced to ArcGIS Online later when the field team has WIFI access.

11. Troubleshooting: Most technical problems with the tablet can be fixed by disconnecting and reconnecting the GPS unit via Bluetooth, by restarting the Collector app, or by restarting the tablet. Try these solutions first if the unit loses GPS connection, if layers wont load, or if the tablet will not collect new information. Reach out with questions to the contacts below:

    - Jennifer O'Brien – GIS lead. JenniferJoern@kennedyjenks.com
    - EOS (GPS Unit) Support - (450) 824-3325 (International [Canadian] charge rates apply)

SOG: Measuring Groundwater Levels

C.1 Introduction

This guideline describes the field procedure typically followed by Kennedy/Jenks Consultants when measuring groundwater levels. Groundwater levels in wells will be measured prior to commencing developing, purging, sampling, and pumping tests.

C.2 Equipment

- Electronic water level monitoring probe or other measuring device
- Decontamination supplies (e.g., buckets, Alconox, distilled water, squirt bottle)
- Field notebook
- Groundwater purge-and-sample form(s) if in conjunction with groundwater sampling
- Keys for locks (if necessary)
- Tools to open well covers (e.g., socket wrench, spanner wrench)
- Disposable gloves (as a minimum), and other protective clothing (as necessary).

C.3 Typical Procedure

1. If more than one well will be measured, begin depth measurement in the order in terms of lowest to highest chemical concentrations in the monitoring wells.

2. Remove well caps from all wells prior to initiation of water level measurement activities. This will allow wells to equilibrate, if necessary.

3. If the potential exists for floating product (LNAPL) to be present, use an electric oil-water interface probe or oil-sensitive paper to measure depth of the floating product and the electronic depth probe to measure the depth-to-water. Record both depths in field notebook and note the water depth as the "depth with oil layer present." Unless otherwise instructed, always measure depths to floating product layer and groundwater from the top of the north side of the well casing.

4. When floating product is not present, measure depth-to-water using a pre-cleaned water level probe from the top of the north side of the well casing, unless otherwise instructed.

5. Repeat measurements a minimum of three times or have field partner confirm measurement.

6. Record time of day the measurement was taken using military time (e.g., 16:00).

7. Decontaminate water level and/or oil-water interface probe and line prior to reuse.

SOG: Groundwater Sampling

D.1 Introduction

This Standard Operating Guideline (SOG) provides procedures typically followed by Kennedy/Jenks Consultants personnel during the collection of groundwater samples from monitoring wells. Groundwater sampling from temporary boreholes (e.g., grab groundwater samples collected from direct push borings) is not addressed by this SOG. This SOG provides guidance on procedures that are generally consistent with standard practices used in environmental sampling. Federal, state and/or local regulatory agencies may require groundwater sampling procedures that differ from those described in this SOG and/or may require additional procedures. As guidance, this SOG does not constitute a specification of requirements for groundwater sampling. Deviations from, and additions to, the procedures described herein may be appropriate based on project-specific sampling objectives, site-specific conditions, and/or regulatory requirements. The user of this SOG should modify sampling procedures used, as appropriate, to conform to project-specific requirements and document such deviations from this SOG in project-specific documentation of groundwater sampling activities.

This SOG does not address Quality Assurance/Quality Control (QA/QC) procedures for groundwater sampling in detail. While some general QA/QC procedures are addressed, project-specific QA/QC procedures should be developed and presented in a Quality Assurance Project Plan (QAPP), field sampling and analysis work plan, or other project- or activity-specific document.

This SOG contains the following sections:

- Field Equipment/Material
- Typical Procedures for Monitoring Well purging and Groundwater Sampling
- Stabilization Criteria for Adequacy of Monitoring Well Purging
- Typical Procedures for Groundwater Sampling using Passive Diffusion Bags (PDBs)
- Quality Control Guidance
- Investigation-Derived Waste (IDW) Management
- References

D.2 Field Equipment/Materials

Material/equipment typically required for the collection of groundwater samples from monitoring wells may include:

- Electric water-level monitoring probe
- Multi-phase interface monitoring probe

- Bladder pump, peristaltic pump, pre-cleaned, disposable, 2- or 4-inch bailers with disposable cord, inertial pump, submersible pump, passive diffusion bags or other suitable apparatus for purging the well and sampling
- Flexible discharge tubing [polyethylene (PE), Teflon™, or similar]
- Purge water collection container
- Multi-parameter water quality meter (e.g., temperature, pH, specific conductance, redox potential)
- Turbidity meter
- Flow-through cell
- Nitrocellulose filters (if conducting field filtering)
- Sample containers (laboratory-supplied) with appropriate preservatives
- Additional chemical preservatives (if necessary)
- Watch or stopwatch, and bucket
- Sample labels, pens, field logbook, or other appropriate field forms (e.g., groundwater purge and sample forms, chain-of-custody forms), and access agreements and third-party sample receipts (if warranted)
- Previous purging and sampling data for monitoring wells to be sampled, including water levels, purging parameters, and laboratory analysis results.
- Monitoring well boring and construction log (including wellhead elevation survey and reference point information)
- Personnel and equipment decontamination supplies
- Sample shipping and packaging supplies
- Personal protective equipment as specified in the Health and Safety Plan (HASP).

D.3 Typical Procedures for Monitoring Well Purging and Groundwater Sampling

1. **Pre-Purging Data Collection and Purging Equipment Placement.** Record data and information collected during this procedure on a groundwater purge and sample form. Perform the following prior to groundwater sampling:

a. Calibrate the multi-parameter water quality meter, prior to beginning sampling and as necessary based on field conditions, in accordance with the instructions in the manufacturer's operation manual. Note that it may be appropriate to keep a written log of the calibration procedures and instrument maintenance with the instrument.

b. Examine the monitoring well to be sampled and associated protective surface enclosure for any structural damage, poorly fitting caps, and leaks into the inner casing. If notable conditions exist, they should be recorded on the sampling log for the well so that any necessary follow-up corrective actions can be planned and implemented.

c. Record an initial measurement of the depth to water. Calculate the volume of water in the well casing if wetted-casing-volume-based purging is to be used to remove the so-called "stagnant water" from the well prior to sampling. The volume of water in the wetted well casing should be calculated using the formula: $V = (\pi r^2) \times L$ where r is one half of the inner diameter of the well casing/screen and L is the length of wetted casing/screen (calculated by subtracting the depth to water from the total well depth). Total well depth should not be measured at the start of a sampling event (due to the potential to cause turbidity). Measure the total well depth after sample collection. Note that some regulatory agencies require that the calculated "stagnant water" volume include the water contained in the pores space of the wetted portion of the monitoring well filter pack in addition to the casing/screen. If this is a requirement, it should be defined in the project-specific sampling requirements.

d. If light non-aqueous phase liquid (LNAPL) is potentially present, measure the depth and thickness of the LNAPL and the static water level using a multiphase interface monitoring probe.

e. Use one of the following devices for purging:

   (1) Bladder pump: adjust the pump intake at a depth approximately equal to the middle or just slightly below the middle of the well screen interval or water column unless another position is justified based on site-specific conditions.

   (2) Peristaltic pump: place the pump intake at a depth equal to the approximate middle or just slightly above the middle of the well screen interval or water column unless another position is justified based on site-specific conditions. Note: If degassing of water is occurring when sampling with a peristaltic pump, alternative types of sampling equipment should be used for volatile organic compound (VOC) or volatile petroleum hydrocarbon (VPH) sample collection.

   (3) Inertial pump: place the pump intake at a depth approximate to the middle or just slightly below the middle of the well screen interval or water column unless another position is justified based on site-specific conditions. Note: Some studies suggest that the use of inertial pumps for purging and/or sampling may produce a low bias when collecting samples for VOC and VPH

analyses. This should be considered along with regulatory requirements when selecting an inertial pump for purging and/or sampling.

(4) Submersible pump: place the pump intake at a depth approximate to the middle or just slightly below the middle of the well screen interval unless another position is justified based on site-specific conditions.

(5) Pre-cleaned or disposable bailers. Note: The use of bailers for low-flow purging/sampling is not appropriate.

(6) Another suitable purging/sampling device may be selected for use depending upon project requirements.

2. **Monitoring Well Purging and Sampling.** When purging of a monitoring well prior to sampling is appropriate and/or required, purge the well using either (a) wetted-casing-volume-based purging or (b) low-flow purging as described in the following sections. If a well exhibits evidence of slow recharge, or produces excessively silty water, etc., the well may need to be redeveloped.

a. Wetted-casing-volume-based purging.

(1) Establish a purging rate to pump or bail approximately three wetted-casing volumes of groundwater without dewatering the well.

(2) If using a pump, set-up the discharge tubing, flow-through cell, water quality meter, and purge water collection container. If turbidity is measured, collect the sample for turbidity measurement after groundwater passes through the flow-through cell in the vial provided with the turbidity meter. If using a bailer, maintain a clean plastic container next to the well for collecting observation samples. Begin purging the well.

(3) At the beginning of purging and periodically thereafter, record the following information and water quality parameters/observations on the groundwater purge and sample form: As guidance, field parameters may be measured after one purge volume is removed and every ½ purge volume thereafter.

- Date and time
- Purge volume and/or flow rate
- Water depth
- Temperature
- pH
- Specific conductance
- Dissolved oxygen
- Oxidation-reduction potential (ORP)

- Other observations as appropriate (turbidity, color, presence of odors, sheen, etc).

(4) Continue purging until water quality parameters have stabilized (refer to "Stabilization Criteria for Adequacy of Monitoring Well Purging" below) and/or a minimum of three wetted-casing volumes of water have been removed from the well. If a well purges dry, let it recover to 80 percent of original water column, then sample. If the well takes a very long time to recover (i.e., longer than 2 hours), try to sample the well at the end of day or first thing the next day.

(5) Collect the sample in pre-cleaned sample containers suitable for the laboratory analyses to be performed.

(6) If sampling using a bailer, use a bottom-emptying device or other technique to avoid sample agitation. If the collected water is very turbid, or a bottom-emptying bailer is not used, properly transfer the water from the bailer into the appropriate sample containers. Be careful to avoid agitating the sample. When sampling for VOCs, turn the bottle upside down after filling the container to identify possible headspace. If bubbles are present, top off the sample container or resample.

b. Low-flow purging and sampling.

(1) Place the pump intake at a depth equal to the approximate middle or just slightly above the middle of the well screen interval or water column or otherwise as dictated by well-specific soil stratigraphy and project-specific requirements. For example, it may be appropriate that the pump intake be set opposite to any preferential flow pathways (i.e., zones of higher permeability).

(2) Place an electronic water-level indicator probe in the well, approximately 0.5 to 3 inches below the piezometric surface. If available, a transducer of sufficient accuracy can also be used to measure depth to water when purging.

(3) Connect the pump discharge tube to a flow-through cell housing a water quality parameter probe.

(4) Activate the pump for purging at a flow rate ranging from approximately 0.1 to 0.5 liters per minute (L/min) or other flow rate as dictated by project-specific and/or site-specific requirements. (Note: Some regulatory agencies may require specific flow rates). Determine the flow rate by timing the rate at which the flow-through cell is filled.

(5) During purging, monitor the water level in the well to evaluate potential drawdown. The goal is to minimize drawdown to less than approximately 4 inches. If drawdown is observed (especially rapid drawdown at the beginning of purging), decrease the pumping rate.

(6) Measure water quality parameters at approximately 3- to 5-minute intervals (i.e., time required for one flow-through cell volume) during purging.

Continue purging until water quality parameters have stabilized (refer to "Stabilization Criteria for Adequacy of Monitoring Well Purging" below)

(7) Immediately after purging, collect the sample in pre-cleaned sampled containers suitable for the laboratory analyses to be performed using the same flow rate that was used during purging unless it is necessary to decrease the rate to minimize aeration or turbulent filling of sample containers. If sampling for VOCs or VPH reduce the flow rate to 0.1 L/min or less.

3. **Sampling with LNAPL Present in a Monitoring Well.** Wells containing LNAPL are typically not sampled for dissolved phase constituents in groundwater due to the potential for entrainment of LNAPL in the aqueous sample matrix. If such sampling is required, and purging is not required, make sure the pump intake is placed in the upper 2 feet of water column and collect the samples without purging in a manner that reduces the potential for mixing of the groundwater sample with air or LNAPL. If groundwater sampling is required from wells containing LNAPL for the purposes of characterizing VOCs, and purging is required, purge the well prior to sampling unless or until LNAPL becomes entrained in the sampling apparatus. If LNAPL will likely become entrained in the groundwater, the sample should be collected without purging. If LNAPL becomes entrained in the sampling apparatus then the sampling effort for VOCs should be aborted.

4. **Field Filtering Groundwater Samples.** Groundwater sample filtering and/or preservation should be performed in accordance with the requirements of the analytical method being specified and any other project-specific requirements. For example, samples collected for dissolved metals are typically filtered using a 0.45 µm filter.

5. **Sample Collection Considerations.** When multiple analyses will be performed, collect the samples in order of decreasing sensitivity to volatilization (i.e., VOC samples first and metals last). When sampling for VOCs, turn the sample container upside down after filling to identify possible headspace. If bubbles are present, top off the sample bottle or resample (do not reuse bottles, especially if they have been pre-preserved by the vendor or laboratory). If possible, the pump should not be moved or turned off between purging and sampling; however, the pump may need to be turned off for a very brief period (as a practical matter) so field personnel can handle samples and minimize the potential for water to splash on the ground surface. The ground surface should be protected from incidental splashing, especially if water from the well would be considered a hazardous waste for disposal purposes.

6. **Monitoring Wells with Slow Recharge.** If a well purges dry, let it recover to 80 percent of original water column, then sample. If the well takes a very long time to recover (i.e., longer than 2 hours), try to sample the well at the end of day or first thing the next day.

7. **Sample Container Filling and Shipping.** Fill the appropriate containers for the analyses to be requested and ensure that the required label information is completely and accurately filled in. Follow sampling packaging, shipping, and chain-of-custody procedures (see applicable SOG).

8. **Decontamination.** Follow personnel and equipment decontamination procedures (see applicable SOG).

D.4 Stabilization Criteria for Adequacy of Monitoring Well Purging

Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EPA 2001) states that "with respect to groundwater chemistry, an adequate purge is achieved when pH, specific conductance, and temperature of groundwater have stabilized and the turbidity has either stabilized or is below 10 Nephelometric Turbidity Units (NTUs). Wells should be considered stable when the criteria listed in the following table have been met for pH, specific conductance, temperature, and turbidity. Attempts should also be made to stabilize ORP and dissolved oxygen.

Field Parameters	Stabilization Criteria for Three or More Consecutive Readings	Notes
pH	Difference between three or more consecutive readings is within ±0.1 units	–
Temperature	Difference between three or more consecutive readings is within ±3%	–
Specific Conductance	Difference between three or more consecutive readings is within ±3%	–
Turbidity	Difference between three or more consecutive readings is within ±10% or three consecutive readings below 10 NTUs	Generally, turbidity is the last parameter to stabilize. Attempts should be made to achieve stabilization; however, this may not be possible. It should be noted that natural turbidity in groundwater may exceed 10 NTUs. If turbidity is greater than 50 NTU, redevelopment of the well may be warranted.
ORP	Difference between three or more consecutive readings is within ±10mV	Very sensitive. Attempts should be made to achieve stabilization; however, due to parameter sensitivity this may not be possible.
Dissolved Oxygen	Difference between three or more consecutive readings is within ±0.3 milligrams per liter (mg/L)	Very sensitive. Attempts should be made to achieve stabilization, especially when collecting samples of VOC analysis; however, due to parameter sensitivity this may not be possible.

Attempts should be made to achieve the stabilization criteria. Because of geochemical heterogeneities in the subsurface environment, stabilization of field parameters during purging may not always be achievable. If field parameter measurements do not indicate stabilization, continued conventional purging may be required until a minimum of three wetted-casing volumes have been removed. During low-flow purging of a well containing a large volume of casing water, it may be practical to discontinue low-flow purging and proceed with sampling if field parameters have not stabilized within a reasonable period. This judgment must be made on a site-specific/project-specific basis.

D.5 Typical Procedures for Groundwater Sampling Using Passive Diffusion Bags (PDBs)

Groundwater sampling using water-filled passive diffusion bag (PDB) samplers may be suitable for obtaining samples for VOC analysis. The suggested application of the method is for long-term monitoring of VOCs in groundwater wells at well characterized sites. (Note: The use of PDBs may not be suitable for the assessment of Tertiary Amyl Methyl Ether, methyl tert-butly ether, methyl-isobutyl ketone, styrene, and acetone).The effectiveness of the use of a single PDB sampler in a well is dependent on the assumption that there is horizontal flow through the well screen and that the quality of the water in the well screen is representative of the groundwater in the aquifer directly adjacent to the screen. If there are vertical components of intrabore-hole flow, multiple intervals of the formation contributing to flow, or varying concentrations of VOCs vertically within the screened or open interval, then a multiple deployment of PDB samplers within a well may be more appropriate for sampling the well.

Typically PDB samplers should not be used in wells having screened or open intervals longer than10 feet. If PDB samplers are to be used in wells with screened intervals of greater than 10 feet, then they are generally used in conjunction with borehole flow meters or other techniques to characterize vertical variability in hydraulic conductivity and contaminant distribution or used strictly for qualitative reconnaissance purposes. In larger well screens or in wells that may have vertical flow, the use of baffles should be considered.

Following are the procedures for deploying a PDB sampler.

1. **Acquire PDBs.** Obtain the pre-filled PDB samplers from the analytical laboratory. (The PDB samplers are prefilled at the laboratory with laboratory-grade deionized water. Unfilled PDB samplers can be obtained and filled in the field but this is not recommended.)
2. **Deploy PDBs in Monitoring Wells.** To deploy the PDB sampler in the well:
    a. Measure the well depth and compare the measured depth with the reported depth to the bottom of the well screen from well-construction records. This is to check whether sediment has accumulated in the bottom of the well, whether there is a non-screened section of pipe (sediment sump) below the well screen, and the accuracy of well-construction records.

    b. Attach the PDB sampler to a weighted line. (Sufficient weight should be added to counterbalance the buoyancy of the PDB sampler.) (Note: Stainless-steel or Teflon-coated stainless-steel wire is preferable, but rope can be used if it is of sufficient strength, non-buoyant, and subject to minimal stretching. However, the rope should not be reused due to the potential for cross contamination.) Additionally, to prevent cross-contamination, the weighted lines should not be reused in different wells.

    c. To prevent cross-contamination, he PDB samplers should not contact non-aqueous phase liquid (NAPL) during deployment or retrieval.

d. Calculate the distance from the bottom of the well, or top of the sediment in the well, up to the point where the PDB sampler is to be placed.

e. Attach the PDB sampler to the weight or weighted line at the target depth.

   1) For the field-fillable type of PDB sampler, the sampler is equipped with a hanger assembly and weight that can be slid over the sampler body until it rests securely near the bottom of the sampler.

   2) If using a coated stainless-steel wire as a weighted line, make loops at appropriate points to attach the upper and lower ends of PDB sampler.

   3) Where the PDB sampler position varies between sampling events, movable clamps with rings can be used.

   4) When using rope as a weighted line, tie knots or attach clasps at the appropriate depths. Nylon cable ties or stainless-steel clips inserted through the knots can be used to attach the PDB samplers.

f. Lower the weight and weighted line down the well until the weight rests on the bottom of the well and the line above the weight is taut. The PDB samplers should now be positioned at the expected depth. (The depth can be checked by placing a knot or mark on the line at the correct distance from the top knot/loop of the PDB sampler to the top of the well casing and checking to make sure that the mark aligns with the lip of the casing after deployment.)

g. Secure the assembly. (A suggested method is to attach the weighted line to a hook on the inside of the well cap.)

h. Reattach the well cap. The well should be sealed in such a way as to prevent surface-water in-flow into the well.

i. Allow the system to remain undisturbed until the PDB sampler equilibrates. Laboratory and field data suggest that a 2-week equilibration time is probably adequate for most applications. Note: In less-permeable formations, longer equilibration times may be required.

3. **<u>Recovering the PDBs.</u>** Following the equilibration time, recover the PDB sampler from the monitoring well.

   a. Remove the PDB samplers from the well by using the attached line. The PDB samplers should not be exposed to heat or agitated.

   b. Examine the surface of the PDB sampler for evidence of algae, iron or other coatings, and for tears in the membrane. Note the observations in a sampling field book. If there are tears in the membrane, the sample should be rejected. If there is evidence that the PDB sampler exhibits a coating, then this should be noted in the report.

   c. Detach and remove the PDB sampler from the weighted line. Remove the excess liquid from the exterior of the bag to minimize the potential for cross contamination.

4. **Sample Container Filling and Shipping.** Transfer the water from the PDB sampler to sample container. This is typically accomplished by carefully cutting a small hole in the bag and directing the flow into the sample container. Some commercially available PDB samplers provide a discharge device that can be inserted into the sampler. When transferring the sample to the sample container, minimize agitation. Ensure that the required label information is completely and accurately filled in. Follow sampling packaging, shipping, and chain-of-custody procedures (see applicable SOG).

5. **Decontamination.** Follow personnel and equipment decontamination procedures (see applicable SOG).

D.6 Quality Control Guidance

Follow the quality control requirements specified in the Quality Assurance Project Plan (QAPP), project-specific field sampling and analysis work plan, and/or project-specific regulatory requirements, as applicable. The following may be used as guidelines.

1. Approximately one duplicate sample should be obtained for each sampling event or for each batch of samples (a batch is typically defined as 20 samples). Collect duplicate samples immediately after the original samples are collected. Purging is not performed between original sample collection and collection of duplicate samples. Original and duplicate samples are collected sequentially, without appreciable delay between collection cycles. Duplicate samples are to be submitted to the laboratory blind (i.e., not identified as a duplicate sample).

2. Typically, at least one type of field blank sample (rinsate or transfer) should be collected per day of water sampling. All field blank samples are to be collected, preserved, labeled, and treated like any other sample. Field blank samples are to be sent blind to the laboratory (i.e., not identified as a field blank). Record in the field notebook the collection of any blank sample (rinsate, transfer, trip). The types of field blank samples are discussed below.

    a. Rinsate blank samples. If rinsate field blank samples are required, prepare the sample by pouring deionized water over, around, and through the various reusable sampling implements contacting a natural sample. Rinsate blanks need not be collected when dedicated sampling equipment is used for purging and sampling the well. Rinsate blank samples are to be analyzed for the same parameters as the environmental samples.

    b. Transfer blank samples. Transfer blank samples are routinely prepared when no rinsate blank samples are collected. (The purpose of a transfer blank sample is to monitor for entrainment of contaminants into the sample from existing atmospheric conditions at the sampling location during the sample collection process.) A transfer blank sample is prepared by filling a sample container(s) with distilled or deionized water at a given sampling location. Transfer blank samples are to be analyzed for the same parameters as the environmental samples.

c. Trip blank samples. Trip blank samples are submitted for VOC analysis to monitor for possible sampling contamination during shipment as volatile organic samples are susceptible to contamination by diffusion of organic contaminants through the Teflon-faced silicone rubber septum of the sample vial. Trip blank samples are prepared by the laboratory by filling VOA vials from organic-free water and shipped with field sample containers. Trip blank samples accompany the sample bottles through collection and shipment to the laboratory and are stored with the samples. It is suggested that a trip blank sample be included in each cooler of samples submitted for VOC analysis.

D.7 Investigation-Derived Waste (IDW) Management

Purge water is to be contained onsite in an appropriate labeled container for disposition by the client unless other project-specific procedures are defined. Other investigation-derived wastes, such as personal protective equipment, are to be properly handled and disposed. Preferably, PPE IDW should also be containerized and left onsite for disposal by the client. As a matter of practice, any waste, or potential waste, generated onsite, should remain onsite. Refer to the IDW SOG.

D.8 REFERENCES

ASTM. 2023. Designation: D 6452-18. Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations. Copyright ASTM, West Conshocken, PA.

ASTM International. 2021. Designation D 6771-21. Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations. Copyright ASTM International, West Conshocken, PA.

U.S. Environmental Protection Agency. 2001. *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM)*. Dated November 2001. U.S. EPA Region 4.

U.S. Environmental Protection Agency. 2010. *Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells, Procedures. Revision 3. Janua*ry 19.

Vroblesky, Dan A. 2001. U.S. Geological Survey, User's Guide for Polyethylene Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells. Part 1: Deployment, Recovery, Data Interpretation, and Quality Control and Assurance. Water-Resources Investigations Report 01-4060. Columbia, South Carolina.

SOG: Sample Packaging and Shipping

C.1 Introduction

This guideline presents methods for shipping non-hazardous materials, including most environmental samples via United Parcel Service (UPS) and Federal Express. Many local laboratories offer courier service as well.

C.2 Equipment

- Coolers or ice chests
- Blue ice or equivalent
- Sorbent material
- Bubble-wrap
- Strapping tape
- Labels and pens
- Chain-of-Custody forms
- Chain-of-Custody seals
- Manifests

C.3 Procedure

Samples shipped to each analytical laboratory can be sent by UPS or Federal Express on a next-day basis unless other arrangements are made. Ice chests, used to refrigerate perishable items, can be used to convey non-hazardous samples to the analytical laboratory.

- A large trash bag (e.g., drum liner) should be used as a liner inside the shipping container (i.e., cooler) and sealed with a custody seal when finished packing the cooler.

- Absorbent pads should be placed in the bottom of the shipping container to absorb liquids in the event of sample container breakage. Transportation regulations require absorbent capacity of the material to equal the amount of liquid being shipped; each pad absorbs approximately 1 quart of liquid.

- Sample jars (liquid and solid) should be sealed with tape and placed into a sealable plastic bag to minimize the potential for spills.

- Liquid samples in glass jars or bottles should also be wrapped in plastic bubble wrap. A small amount of air space is desirable in filled plastic containers. This often prevents the cap of the container from coming off should the container undergo compression.

- Volatile organics analysis (VOA) vials should be packed in sponge holders. Additionally, exposure of filled VOA vials to other types of sample containers, by placement in the same shipping container, is not recommended. Various non-VOA sample containers are solvent-rinsed which may contaminate the VOA vials before or after sample collection. Therefore, a separate shipping container for VOA vials is recommended.

- An equal weight of ice substitute should be used to keep the samples below 4 degrees Centigrade for the duration of the shipment (up to 48 hours). Care in choosing a method of sample chilling should be observed so that the collected samples are not physically or chemically damaged. Re-usable blue ice blocks, block ice, ice cubes, or dry-ice are suitable for keeping samples chilled.

- Labels of samples may get wet. Use of waterproof pens and labels is desirable for identification of sample containers. Use of clear tape to cover each affixed sample label is helpful in ensuring sample identification.

- Strong adhesive tape should be used to band the coolers closed. Additionally, it is recommended that the drain plug be covered with adhesive tape to prevent any liquid from escaping.

- Chain-of-custody documentation should accompany shipments of samples to the analytical laboratory. Often, the chain-of-custody document contains an analytical request section which may be completed following sample collection. Chronological listing of collected samples is desirable. A copy of the completed chain-of-custody form should be retained in the event that the original form is lost or destroyed.

Specific requirements for packaging materials may apply if the samples being shipped are known to be hazardous materials as defined in 49 CFR 171.8 (samples are not considered hazardous waste and therefore manifest requirements do not apply). UPS holds shippers responsible for damage occurring in the event of accidents when a hazardous material is shipped as a non-hazardous material. Samples which obviously are hazardous materials should therefore be shipped as such, and samples which most likely are not hazardous materials should be shipped in coolers. Guidelines for shipping hazardous materials by UPS are provided in the *Guide for Shipping Hazardous Materials* available from UPS. Specific labels for shipping of hazardous materials are available.

SOG: Field Measurement of Dissolved Oxygen

C.1 Introduction

This guideline describes the procedures that will typically be followed by Kennedy/Jenks Consultants personnel during field measurement of dissolved oxygen (DO).

C.2 Equipment

- Yellow Springs Instruments' or Horiba dissolved oxygen meter, or equivalent
- Spare membranes
- Electrolyte solution
- Deionized water
- Sodium sulfite solution (zero O_2 solution)
- DO bottle (BOD bottle)

C.3 Procedure

1. Inspect dissolved oxygen meter for damage. Inspect probe for sufficient electrolyte and to determine if oxygen sensor membrane is in good condition. Field Services will replace the membrane if torn or wrinkled. Inspect for air bubbles beneath the membrane. If bubbles are present, remove membrane and add electrolyte solution. Replace membrane so no air bubbles are entrapped.

2. Rinse probe with deionized water.

3. Calibrate probe and meter according to manufacturer's instruction.

4. Take a grab sample, using a DO bottle so it is filled without headspace, flush water by inserting tube into bottle or fill bottle while submerged. Insert probe into bottle, allow time for stabilization.

5. Read and record dissolved oxygen concentration.

SOG: Field Measurement of Turbidity

C.1 Introduction

This guideline describes the procedures that will typically be used by Kennedy/Jenks Consultants personnel during field measurement of turbidity.

C.2 Equipment

- Portable turbidity probe/meter
- Turbidity calibration solution (100 NTU solution)
- Deionized water
- Calibration cup

C.3 Procedure

1. Calibrate instrument in accordance with manufacturer's recommendations immediately prior to making measurements.
2. Rinse decontaminated glass beaker with approximately 50 ml of sample water three times.
3. Rinse turbidity probe with deionized water.
4. Fill sample cup with sample water, minimize aeration.
5. Turn on meter. Immerse electrode in sample and allow several minutes for the probe to equilibrate with the water. Obtain reading. Use a consistent amount of time for reading to stabilize.
6. Record reading on standardized field forms or in the field book. Note any problems (e.g., erratic readings).
7. Rinse probe with deionized water and store according to manufacturer's directions.

C.4 References

USEPA. (2013). *Field Branches Quality Systems and Technical Procedures: Field Turbidity Measurement.* United States Environmental Protection Agency, Region 4. January 29.

SOG: Field Measurement of pH

C.1 Introduction

This guideline describes the procedure that will be used by Kennedy/Jenks Consultants personnel during performance of field pH measurements.

C.2 Equipment

- Portable pH meter with potassium chloride (KCl) probe and temperature probe
- Extra KCl filling solution
- 50 ml plastic jar or other suitable container
- Squirt bottle and supply of deionized (DI) water
- pH 7, 10, and 4 buffer solutions

C.3 Typical Procedures

1. Calibrate meter according to manufacturer's instructions. Prior to first measurement, check calibration against pH 7 buffer and again periodically over the course of the day and recalibrate if the reading is more than 0.1 units from 7.
2. Use 50 ml plastic jar or other suitable containers for measurement readings. Rinse sample test container with sample water three times prior to measurement.
3. Immerse pH probe and temperature electrode in sample water. Gently stir sample for thorough mixing. Read and record pH to nearest 0.1 unit once pH reading has stabilized. Many pH meters possess an automatic feature which indicates final stabilized measurement.
4. Rinse or bathe pH and temperature probes with DI water or soak in DI water between measurements. Changing DI water bath between measurement stations increases accuracy of measurements.

C.4 Instrument Calibration - General Procedure

1. Calibrate pH meter in the field at the beginning of each day of field work and when the standard check is out of calibration.
2. Rinse pH and temperature probes in DI water.
3. Turn on meter and immerse pH and temperature probe in a pH 7 buffer solution. Calibrate meter to pH 7, allowing enough time for meter to stabilize.
4. Rinse pH and temperature probe with DI water.

5. Immerse pH and temperature probe in either a pH 4 or a pH 10 buffer solution, depending on whether expected pH of samples is above or below pH 7. If expected sample pH is above pH 7, use pH 10 solution for the second calibration. If expected sample pH is below pH 7, use pH 4 for the second calibration. Calibrate meter to second pH solution, allowing enough time for meter to stabilize.

6. Rinse pH and temperature probe with DI water.

7. Perform occasional rechecking of meter calibration to pH 7 calibration solution during usage. Repeat the calibration process (Steps 2-4) if value for final pH check is more than 0.1 units from pH 7.0.

C.5 Maintenance

1. Store meter in case with pH electrode immersed in a pH 7 buffer solution.

2. Inspect pH and temperature probes for cracks and scratches.

3. Inspect pH probe for containing adequate amount of KCl solution. If amount is low, refill as needed.

4. Carry spare batteries and screwdriver in the meter case.

5. Carry a copy of the instruction manual with meter.

SOG: Field Measurement of Redox Potential (EH)

C.1 Introduction

This guideline describes the procedures that will typically be used by Kennedy/Jenks Consultants personnel during field measurement of redox potential (eH).

C.2 Equipment

- Portable pH meter capable of output in millivolts
- eH and KCl reference probe
- Quinhydrone
- 125 ml plastic jars
- Deionized water

C.3 Procedure

1. Calibrate instrument in accordance with manufacturer's recommendations immediately prior to making measurements.

2. Rinse decontaminated glass beaker with approximately 50 ml of sample water three times.

3. Rinse eH electrode with deionized water.

4. Fill beaker with sample water, minimize aeration.

5. Turn on meter. Immerse electrode in sample and allow several minutes for the probe to equilibrate with the water. Obtain reading to nearest 10 mv. Use a consistent amount of time for reading to stabilize.

6. Record reading on standardized field forms or in the field book. Note any problems (e.g., erratic readings).

7. Rinse probe with deionized water and store according to manufacturer's directions.

C.4 References

Standard Method 2580*, Standard Methods for the Examination of Water and Wastewater*, 18th ed., APHA/AWWA/WEF 1992.

SOG: Field Measurement of Temperature and Specific Conductance

C.1 Introduction

This guideline provides procedures for measuring specific conductance and temperature using a Yellow Springs Instruments (YSI) conductivity meter, Horiba U52 Water quality meter, or similar.

C.2 Equipment

- YSI conductivity meter or Horiba U52 water quality meter
- Standard conductivity solutions
- Deionized water in squirt bottle
- Pint plastic jar
- Small brush

C.3 Field Procedures

This guideline describes the procedures that will typically be used by Kennedy/Jenks Consultants personnel during performance of field temperature and specific conductance measurements.

1. Calibrate conductivity and temperature functions of instrument in accordance with manufacturer's specifications.
2. Rinse sample cup with sample water three times.
3. Fill sample cup with water sample.
4. Rinse conductivity probe with deionized water then with sample water and place probe in sample cup.
5. Submerge conductivity probe in sample so that flow cell holes are immersed. Pump probe up and down a few times to dislodge bubbles. Do not submerge to bottom, for this causes false high readings. Read sample temperature to the nearest 0.1 degrees C after temperature has stabilized.
6. Remove probe from sample and rinse with deionized water.
7. Record conductivity and temperature so temperature correction can be applied if necessary.

C.4 Maintenance

1. Store meter in case during transport. Immerse probe in deionized water for storage.
2. Check batteries before taking meter into the field. Carry spare batteries and deionized water for rinsing probe.
3. If meter readings are erratic, use a bottle brush and mild acid to clean holes in probe, otherwise, return meter and probe to factory for repair.

SOG: Environmental Data Review

C.1 Introduction

This guideline describes recommended procedures to be followed by Kennedy/Jenks Consultants when reviewing environmental data to determine whether data are of acceptable quality.

C.2 Procedures

At a minimum, all environmental data should be reviewed according to the following procedures prior to any data use or reporting.

1. As soon as the results are received from the analytical laboratory, review the results immediately for obvious problems (e.g., missing or non-requested analyses/analytes, appropriate reporting limits etc.). Communicate any concerns or questions to the project manager and to the laboratory immediately. If communication is done via a phone conversation, follow-up with an email to document the incident

2. Do a thorough quality review of the data as soon as possible after receiving the data using the Data Quality Checklist.

3. If historic data are available, compare the new results to the historical data to see if the data make “sense.” For example, if the data indicate a detection of a chemical of interest not previously detected in a groundwater sample from a select well, consult with the laboratory to verify the results.

4. If the laboratory also provided electronic data deliverables (EDD), check the hard copy report against the EDD for accuracy.

5. If errors are encountered in the report, have the laboratory reissue the report or portions of it. If the laboratory also provided an EDD, make sure the laboratory reissues the EDD as well.

6. Add data validation qualifiers as needed after completion of the data review. Only someone qualified to conduct data validation should add qualifiers to analytical data. Also enter the data validation qualifiers into the database if an EDD was provided.