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Environment

Subject:

Bedrock Monitoring Well Work Plan

RACER Trust, Lansing Industrial Land, Lansing, Michigan

Date:
March 1, 2019

Contact:
Patrick Curry

Phone:
810-225-1926

Email:
Patrick.curry@arcadis.com

Our ref:
B0064479.2019

Dear Ms. Matlock:

This work plan has been prepared by Arcadis on behalf of the Revitalizing Auto Communities Environmental Response (RACER) Trust for its Lansing Industrial Land located in Lansing Township and the City of Lansing, Michigan (Site). This work plan describes the proposed installation of two deep bedrock monitoring well pairs (four wells total). The additional wells will be installed to monitor deeper portions of the bedrock aquifer between Lansing Township water supply wells located west of Plants 2 and 3 and known 1,4-dioxane source areas at the Site.

BACKGROUND

The lower 1,4-dioxane plume is located within a layer of weathered bedrock located approximately 65-80 feet below ground surface (ft bgs). At Plant 3 and the northern portion of Plant 2, the zone consists of the higher permeability weathered sandstone of the Grand River Formation and transitions in the north-central portion of Plant 2 to the interbedded shale and fine sandstone of the Saginaw Formation. The weathered zone is gradational, varies in thickness, and transitions vertically to more consolidated bedrock. Groundwater is encountered at approximately 65 to 70 feet below grade. At Plant 3 the weathered bedrock surface is deeper and is overlain by a saturated deep overburden consisting primarily of dense interbedded silt and fine sand. The lower 1,4-dioxane plume migrates from the Plant 3 source area to the south-southeast within the deep overburden and weathered bedrock. As bedrock becomes shallower to the south the lower 1,4-dioxane plume transitions into the weathered bedrock on the northern portion of Plant 2 and migrates to the southern portion of Plant 2 solely within the weathered bedrock zone. The permeability of the weathered bedrock zone is typically an order of magnitude higher than the deeper consolidated bedrock (Arcadis, 2013). This, coupled with the heavily interbedded shales encountered within the Saginaw Formation at Plant 2, limit vertical migration of 1,4-dioxane and confine the bulk of the 1,4-dioxane mass to the relatively thin weathered zone.

Previous investigations have delineated the lower 1,4-dioxane plume to the MDEQ Part 201 Residential Drinking Water (DW) criteria of 7.2 micrograms (µg/L), both vertically, and horizontally (Arcadis 2013, 2014, 2016a, 2016b, 2017). A network of sentinel wells in the weathered bedrock around the lower 1,4-dioxane plume, as well as consolidated bedrock wells along the axis of the plume and around the perimeter of the Site, are used for sentinel monitoring of the lower 1,4-dioxane plume. To date, low-level 1,4-dioxane analysis (United States Environmental Protection Agency [USEPA] Drinking Water Method 522) at bedrock monitoring wells installed along the core of the lower 1,4-dioxane plume have demonstrated a two to three order of magnitude reduction in concentration between the more permeable weathered bedrock zone and the shallow competent bedrock (Arcadis 2018). Concentration of 1,4-dioxane in bedrock wells at the Site have ranged from non-detect to 2.3 µg/L. Low-level results for the Lansing Township Municipal wells located west of the Site have noted concentrations of 1,4-dioxane up to 0.36 µg/L. The location and open borehole depth intervals of the Lansing Township wells as well as existing bedrock monitoring wells are shown on **Figure 1**.

The results of the 2016 Lower 1,4-Dioxane Plume Toe Investigation (Arcadis 2016a) suggest that the Former Adam's Plating Company (APC) site located directly to the west of Plant 2 may also contribute 1,4-dioxane to the weathered bedrock zone with a plume that migrates parallel to the lower 1,4-dioxane plume, and between the Site and municipal well (TWP-90-3) located west of Plant 2.

PROPOSED INVESTIGATION

The lower 1,4-dioxane plume is located partially within or along the fringe of the Lansing Township wellhead protection area (WHPA). The Lansing Township WHPA is based on a 10-year travel time predicted by a large-scale groundwater flow model prepared by the United Stated Geologic Survey (USGS 1997, 2009, 2018). In response to concerns, two bedrock monitoring well nested pairs are proposed along the western property boundary to monitor the deeper bedrock adjacent to the Site. The nearest Lansing Township municipal wells are TWP-90-3 located to the west of APC and the RACER lower 1,4-dioxane plume, and TWP-90-4 located west of the Plant 3 1,4-dioxane source area (**Figure 1**). Well TWP-90-3 is cased to 102 ft bgs and is constructed with open borehole to a depth of 399 ft and Well TWP-90-4 is cased to 122 ft bgs and is constructed with open borehole to a depth of 404 ft bgs.

The goal of the bedrock monitoring wells will be to monitor select intervals within the first 100 to 125 feet of bedrock below the weathered zone along the western boundary of the Site. The two locations shown on **Figure 1** located between the 1,4-dioxane source areas and the two closest municipal wells were chosen to represent locations where 1,4-dioxane might be detected if migration toward the municipal wells occurs or is occurring. The current bedrock monitoring well network effectively monitors the first 20-30 feet of bedrock. The target zone for the proposed wells will be below this depth with well screen intervals placed within open boreholes extending 125 to 200 feet below grade.

Scope of Work

The proposed monitoring well locations are shown on **Figure 1**. The scope of work will include:

Utility Clearance

Prior to advancing borings at the Site, utility clearance will be completed for all proposed locations. Reliable lines of evidence that may be utilized in accordance with the site-specific utility clearance plan include: Miss Dig call, client provided maps of utilities, visual site inspection, and/or hand clearing to a depth of 5 feet below grade.

Drilling, Geophysics and Well Construction

Construction of the proposed bedrock monitoring wells will be completed in stages. A 10-inch borehole will be advanced to consolidated rock to approximately 80 feet below ground surface (bgs) at each location using rotary-sonic drilling methods. Drilling will then switch over to air rotary and an 8-inch borehole will be advanced in the competent rock to a depth of approximately 125 feet bgs. Steel casing (7-inch) will be cemented in place to a depth of 125 feet bgs. Once the cement has cured (e.g. 24 to 48 hours), a 6-inch borehole will be opened below the casing using air-rotary to a depth of 200 feet bgs. The borehole will then be developed using air-lift techniques to remove any remaining debris.

Once the borehole is completed, downhole geophysics (optical and acoustic televiewer; fluid temperature, resistivity, conductivity, and natural gamma) will be used to characterize the geology within the borehole and determine appropriate monitoring intervals. Intervals will be chosen to coincide with the more permeable sandstone with monitoring wells constructed with 2-inch, 15-foot stainless steel wire wrap screens followed by schedule 40 polyvinyl chloride (PVC) riser. Centralizers will be installed on the PVC casing at 20-foot intervals to prevent the casing from sagging in the borehole. The borehole around the well screens will be filled with an appropriate filter pack around the screens with the intervals between screened intervals and the borehole above the screens filled with bentonite grout, in the form of weighted bentonite pellets. A diagram of the proposed well construction is included as **Figure 2**. Once the bentonite has had enough time to hydrate and create a seal between the boreholes, the PVC wells will be developed with a submersible pump using a purge and surge technique.

Arcadis personnel will log and describe the overburden and bedrock cores recovered during sonic drilling in accordance with the Arcadis Soil Description Technical Guidance Instruction (TGI) based on the standard operating procedures included in the Field Sampling Plan (FSP, Arcadis 2011). Boring logs will be generated based on the field descriptions. Bedrock descriptions to 80 feet bgs will be completed consistent with the Bedrock Description TGI included as **Attachment 1**. Arcadis personnel will record basic descriptions of the air rotary cuttings and drilling conditions, however, borehole geophysics will be relied on for the descriptions of the open borehole.

Following well installation and development, the wells will be allowed to equilibrate with the bedrock aquifer for a period of at least one week, after which the new wells will be sampled using low-flow sampling procedures (FSP, Arcadis 2011). Samples will be submitted to Test America Laboratory in Burlington, Vermont for low-level 1,4-dioxane analysis using USEPA Method 522.

Because these wells extend into the drinking water aquifer, Arcadis will obtain well permits from the Ingham County Health department for each location, prior to commencement of drilling.

Investigation Derived Waste (IDW) Handling

Soil and rock cuttings will be placed in labeled and sealed 55-gallon steel drums and stored in a secured area. Water from decontamination of drilling tooling, water generated during drilling, and purge water from sampling and monitoring well development will be stored in frac tanks for characterization and disposal. If possible, an existing waste profile will be used for waste profiling, otherwise composite samples will be collected from IDW for permitting purposes.

Reporting

Following completion of the fieldwork, Arcadis will prepare a summary memo outlining the results of the bedrock monitoring work. It is anticipated this memo can be completed within 4 to 6 weeks after receipt of the final analytical results from Test America. The memo will include a brief discussion of the field activities, analytical summary tables, results of the borehole geophysical surveys, and attachments including laboratory analytical reports and any other relevant information.

Routine monitoring of the new bedrock wells will be incorporated into the Interim Groundwater Monitoring Plan (IGMP).

SCHEDULE

The tentative scheduled start date for the bedrock monitoring well installations is May 2019 but is dependent upon the availability of the drilling rig. The duration of the scope of work is assumed to be approximately sixteen days for well installation, geophysics, and well development activities.

If you have any questions regarding the scope of work described above, please contact Patrick Curry (Arcadis) at 810-225-1926 or Dave Favero (RACER Trust) at 734-879-9525.

Sincerely,

ARCADIS of Michigan, LLC

Patrick Curry, PG, CPG

Principal Geologist

Copies:

Cheryl Louden, LBWL

Dave Favero, RACER Trust

Enclosures:

Figures

Figure 1. Proposed Bedrock Monitoring Wells

Figure 2. Bedrock Monitoring Well Construction Details

Attachment

Attachment 1. Bedrock Core Collection and Description Technical Guidance Instruction

References

Arcadis 2011. Field Sampling Plan. RACER Trust, Lansing Plants 2, 3, and 6 Industrial Land, Lansing, Michigan. August 26.

Arcadis 2013. Resource Conservation and Recovery Act Facility Investigation (RFI) Supplemental Phase 2 Activities Summary Report. RACER Trust, Lansing Plants 2, 3, and 6 Industrial Land, Lansing, Michigan. February 26.

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Arcadis 2016a. Lower 1,4-Dioxane Plume Toe Investigation Report. RACER Trust, Plant 2, Lansing, Michigan. March 11.

Arcadis 2016b. Supplemental Lower 1,4-Dioxane Plume Toe Investigation Report. RACER Trust, Plant 2, Lansing, Michigan. March 11.

Arcadis 2017. Lower 1,4-Dioxane Plume Northeast Lobe Investigation. RACER Trust, Plant 2, Lansing, Michigan. February 2017.

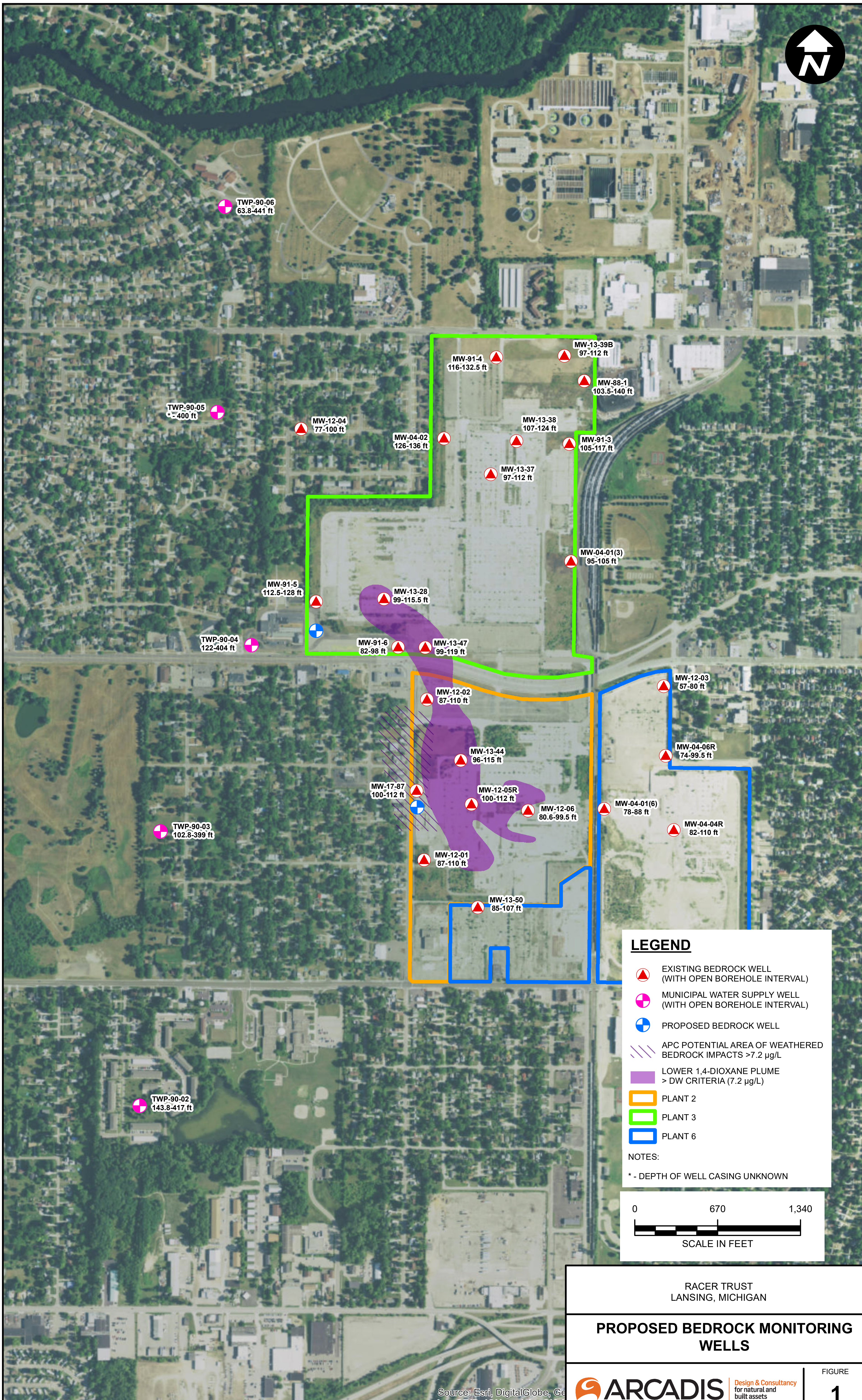
Arcadis 2018. 2017 Annual Groundwater Monitoring Report. RACER Trust, Plants 2, 3, and 6 Lansing, Michigan. May 7.

USGS 1997. Ground-Water Flow in the Saginaw Aquifer in the Vicinity of the North Lansing Well Field, Lansing, Michigan-Part 1, Simulations with a Regional Model. Open-File Report 97-569.

USGS 2009. Model Refinement and Simulation of Groundwater Flow in Clinton, Eaton, and Ingham Counties, Michigan. Scientific Investigations Report 2009-5244.

USGS 2018. Delineation of Contributing Areas for 2017 Pumping Conditions to Selected Wells in Ingham County, Michigan. Open-File Report 2018-113.

FIGURES



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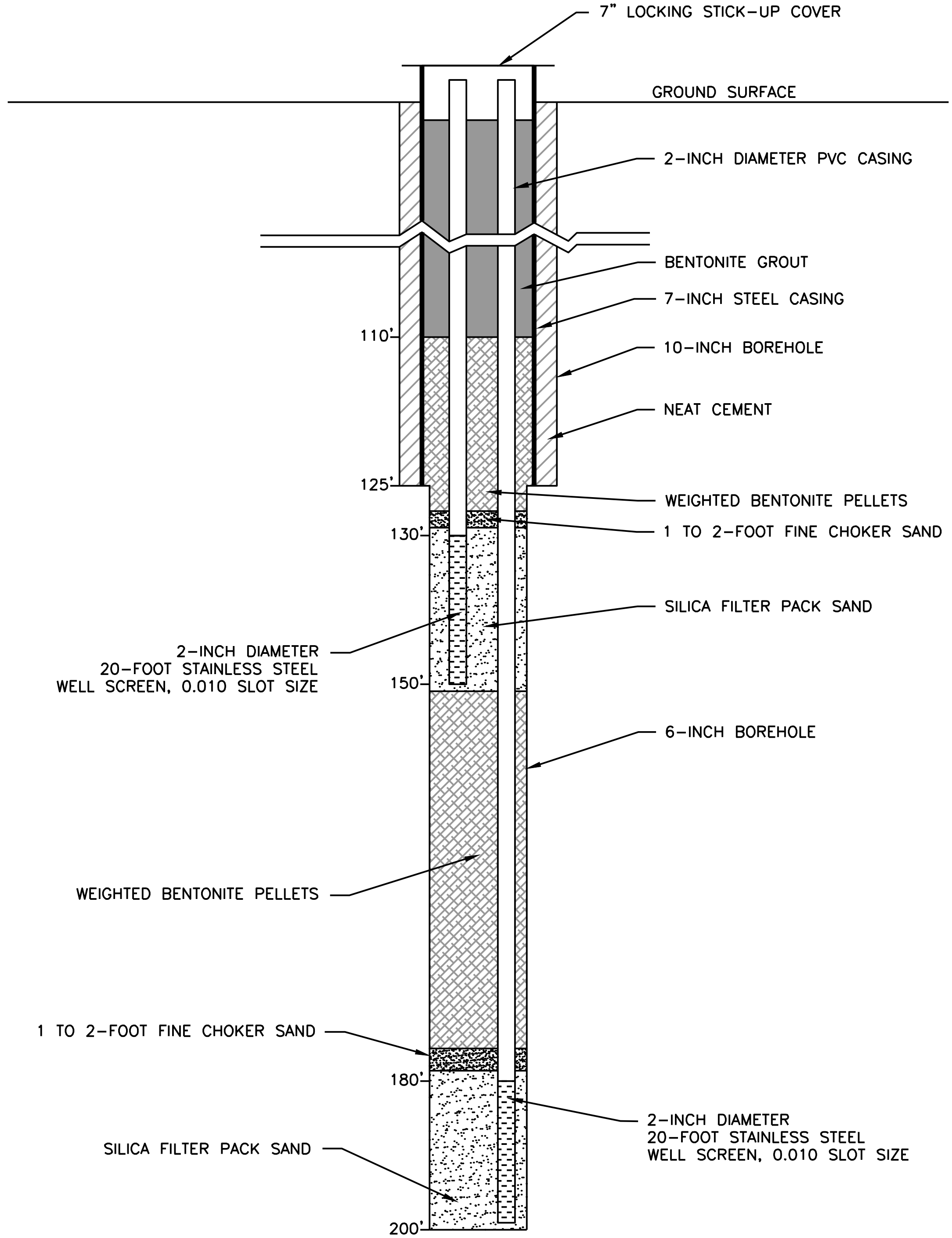

TYPICAL MONITORING WELL DETAIL

NOTES
1. SCREEN DEPTH WILL BE DETERMINED IN THE FIELD BASED ON FINDINGS FROM GEOPHYSICS AND OBSERVATIONS. TWO 20' SCREENS WILL BE INSTALLED AT EACH BORING.

LEGEND

CM	CENTIMETER
FT	FOOT
PVC	POLYVINYL CHLORIDE
SCH	SCHEDULE
SS	STAINLESS STEEL
VF	VERY FINE

RACER TRUST
LANSING, MICHIGAN

BEDROCK MONITORING WELL CONSTRUCTION DETAILS

ARCADIS Design & Consultancy for natural and built assets

FIGURE
2

ATTACHMENT 1

Bedrock Core Collection and Description Technical Guidance Instruction

TGI - BEDROCK CORE COLLECTION AND DESCRIPTION

Rev: 0

Rev Date: October 15, 2018

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	October 15, 2018	All	Updated and re-written as TGI	Marc Killingstad

APPROVAL SIGNATURES

Prepared by:		10/15/2018
	Michael Cobb	Date:
Technical Expert Reviewed by:		10/15/2018
	Marc Killingstad (Technical Expert)	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what are described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Technical Guidance Instruction (TGI) describes the procedures to be used to collect and describe bedrock core samples. The approach described here is applicable for subsurface investigations employing a standard wire-line or conventional diamond-bit coring approach, where the project objectives may include:

- Describing bedrock lithology, degree of weathering, fracturing, and other field-observable rock characteristics
- Evaluating relative groundwater yield of fractures or intervals to assist in well design decisions

The methodology described here is in general accordance with *ASTM Method D 2113-99, Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation*. Additional terminology standards are based on the New York Department of Transportation's *Rock Core Evaluation Manual* (NYSDOT, 2015). This approach and level of detail is appropriate for most environmental-site subsurface investigations. Given the diverse nature of bedrock, and variety of potential project objectives, the project team will review site-specific data needs prior to starting work and, if needed, adapt the field procedures.

The scope of this TGI is specific to core collection and description; it does not encompass the broader suite of tasks associated with bedrock drilling or well construction (see relevant SOP and TGIs, as needed). Note that coring work is often combined with related bedrock characterization techniques, including packer-testing, geophysical logging, FLUTe™ profiling and whole-core rock sampling. These tasks are outside of the scope of this TGI; however, if such additional work is part of the project scope, the planning and sequencing of coring will consider the requirements of those tasks.

3 PERSONNEL QUALIFICATIONS

Arcadis field personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed.

In addition, Arcadis field personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The HASP and other documents will identify other training requirements or access control requirements.

Bedrock core logging will only be performed by Arcadis personnel or authorized subcontractors with a bachelor's degree in geology or a geology-related discipline. Field personnel will complete training on this TGI in the office and/or in the field under the guidance of an experienced field geologist with at least 2 years of prior experience with bedrock core description.

Note that this TGI is written specifically for site characterization and remediation projects. When bedrock core samples are to be used for engineering purposes (e.g., foundation design, rock mechanics, design of excavation support), field staff will work under the direction of a geotechnical engineer.

4 EQUIPMENT LIST

Typically Provided by Geologist	Typically Provided by Driller
• Approved site-specific Health and Safety Plan (HASP) • Approved site-specific FIP/work plan which will include boring location map and drilling plan • Required PPE (see site-specific HASP) • Field logbook and/or rock coring logs • Permanent marking pen for labeling boxes and cores (indelible ink) • 6-foot wooden folding ruler (or similar) graduated in tenths-of-feet (not inches) • Distilled water and spray bottle for wetting and washing core • Camera and/or smart device (phone or tablet) • Pen knife (to test rock hardness) • Munsell rock color chart • Rock hammer • Plastic sheeting (e.g., Weatherall Visqueen) • Stopwatch • Carpenter's protractor • Photoionization detector (PID) or Flame ionization detector (FID) (as appropriate, depending on site-specific constituents of concern) • Air monitoring equipment (as required) • Hand lens (optional) • 10% Hydrochloric acid solution (appropriately labeled eye-dropper for carbonate identification [optional]) • Sturdy saw horses to support core box at working height (optional)	• Core boxes • Wood blocks to separate core runs in core boxes • Rubber hammer (for tapping rock core out of core barrel)

5 CAUTIONS

- **Review relevant guidance**: Utility avoidance, drilling, decontamination, management of investigation derived waste and related tasks will be completed in accordance with a project-specific field implementation plan (FIP)/work plan and/or applicable SOPs or TGIs.
- **Use a trusted, experienced driller:** The quality of bedrock core samples often depends on the skill of the driller (e.g., at selecting the correct tooling, down-pressure and spin-rate for the type of rock and depth). An inexperienced driller will often drill more slowly and cause unnecessary mechanical breaks in the core. It is also important to use a rig equipped with a high-speed coring head. Many rotary or auger rigs are not capable of the speeds required for coring, unless modified for coring.

- **Choose a clean water supply for drilling fluid:** Water is the preferred drilling fluid when coring. The water used for drilling will be of sufficient quality to meet project objectives. Testing of water supply will be considered. Drilling muds are to be avoided, except in special cases where circulation cannot be maintained.
- **Understand your driller's plans for recirculation of drilling water:** Recirculation is common practice in coring, to limit generation of large quantities of investigation-derived waste (IDW). Water is pumped down the inside of the core barrel to cool the bit and carry rock cuttings back to the surface through the annular space outside the barrel. The return water spills into a mud tub, often designed with several baffles to help cuttings fall out of suspension. This water is then pumped back down the core barrel, or recirculated, until the sediment load is too great, then water must be replaced. Recirculation can increase the risk of cross-contamination, so caution is needed. However, coring without recirculation can quickly generate very large quantities of IDW and is often not practicable.
- **Avoid cross-contamination**: Core drilling often involves creating long open boreholes that may, at least temporarily, penetrate confining beds or create artificial connections between fracture zones at different depths. If cross-contamination is a concern at a site, work will be planned to limit the length of open sections (e.g., by telescoping casing), and limit the duration that a borehole stands open. Field crews will stop-work if dense-non-aqueous phase liquid (DNAPL) is encountered (e.g., if sheens are observed on drilling return water).

6 HEALTH AND SAFETY CONSIDERATIONS

Conduct drilling and related tasks in in accordance with a site-specific Health and Safety Plan (HASP). Review all site-specific and procedural hazards as they are provided in the HASP, and review Job Safety Analysis (JSA) documents in the field each day prior to beginning work. Appropriate personal protective equipment (PPE) will be worn at all times in line with the task and the site-specific HASP.

Note that full core boxes can be heavy and awkward to lift, depending on core-diameter and box size. Be sure to use proper bending and lifting techniques to avoid muscle strain and other potential injuries. Use two people to lift heavy core boxes whenever feasible.

Use appropriate hand protection when conducting carbonate-rock test (using dilute acid) and hardness tests (using a penknife). If site- or client-specific health and safety requirements prohibit use of fixed/folding-blade knives, an alternative steel object (e.g., nail) may be substituted.

7 PLANNING CONSIDERATIONS

Bedrock coring is the primary method available for collecting representative, minimally disturbed field samples from bedrock boreholes. The most common approach involves a cylindrical diamond-impregnated core bit attached to an outer string of drill pipe. The entire pipe is spun at a high velocity, cutting a donut-shaped hole, leaving an intact core of rock that passes through the bit into the core barrel as drilling continues deeper. At the end of a core run (typically 5 or 10-feet long), the core is snapped off by backing the tools slightly.

What coring method is appropriate for the job? There are two common bedrock coring methods that use different approaches to retrieve cores:

- **Wireline Coring**: Core samples are brought to the surface between runs using a retriever on a wire that connects to the top of the inner core-barrel and lifts it to the surface, leaving the outer barrel in place. This is the most common method and is preferred in most cases.
- **Conventional Coring**: Core is retrieved by removing the entire coring tool string from the borehole. This approach is less common, but it occasionally used for shallow boreholes where only one or two runs are required (e.g., to confirm rock at the base of overburden borehole).

What core size is appropriate? Coring tools exist in several common sizes, generally referred to by a two-letter code. The most-common dual-tube wire-line core-sizes are listed in the table below.

	Common Wireline Core Bit Sizes (inches)		
	NQ	**HQ**	**PQ**
Core Diameter	**1.88**	**2.50**	**3.34**
Hole Diameter	**2.98**	**3.78**	**4.83**

Note: conventional core sizes are denoted NX, HX or similar, and have slightly different sizing.

NQ cores are most often used in shallow geotechnical applications, while HQ core are the most common used for environmental well drilling. HQ's size is suitable for most geophysical logging techniques, and some small-diameter packer assemblies, but subsequent reaming is often (though not always) required to enlarge the borehole before a well can be set. PQ is used less frequently because the larger size adds considerable weight, but a PQ core hole can more often be used to build a monitoring well without additional reaming.

What type of rock is expected? It is critical to have a good idea of what conditions will be encountered before starting.

- Review previously completed logs.
- Check available geologic maps or water-resources reports.
- Consult other knowledgeable geologists who have experience in the area.
- Learn what bedrock units might be present, how they are commonly described, and whether they have useful diagnostic characteristics.
- Learn whether there are any key marker beds, or whether there any key confining beds that should not be penetrated.
- If needed, the field geologist will review lithologic characterization techniques specific to the types of rock expected.

What level of logging detail is required? Core description can be time-consuming; therefore, consider the project data needs and establish priorities for what aspects of the rock will be classified. For most environmental projects, highly detailed logging of lithology and petrology are unnecessary, while fractures are of paramount concern. Sometimes identifying a particular contact is critical, but minor lithologic variability is not. Establishing priorities in advance will allow the field geologist to prepare and perform efficiently in the field. *When planning, note that a single geologist often cannot keep up with the requirements of core-collection and description in real-time (e.g., as the hole is being drilled). Additional "catch-up" time is often necessary and will be considered in project planning.*

8 PROCEDURE

Core description is a multi-step process. The general sequence of work can be summarized as follows:

Stage	Activity
Rig set-up	Establish measuring points, measure tooling, establish roles and procedures with driller.
Active coring	Track drilling progress. Track water use. Watch return water for signs of impact. Conduct air monitoring. Setup and label core boxes.
Core extraction	Arrange core in box. Screen core for contaminant impacts. Mark and label core and fractures. Measure recovery. Calculate rock quality designation (RQD).
Core logging	Describe rock lithology, structure, weathering, fracturing, and other characteristics.
End of hole	Photograph core boxes. Store or dispose of core.

8.1 Before Coring Starts

<u>Prepare for accurately tracking depths</u>

1. Discuss with driller what reference point will be used for ground surface (e.g., the base of the mud tub) and mark it, if needed. All depths will be recorded relative to this datum.
2. Measure and mark (if needed), a fixed reference point above the ground surface that will serve as the starting/stopping point for core runs (e.g., the top of an outer casing or a vice)
3. Measure out core tooling lengths, including barrels, bits and subs, so that the depth of the barrel will be known to the nearest tenth of a foot.

<u>Prepare for tracking water usage</u>

1. Confirm whether the driller will be recirculating drilling water or using a continuous clean source. [NOTE: *Recirculation is a common practice in coring; however, it is not permissible for all projects and jurisdictions*].
2. Discuss with driller how water usage will be tracked. Water lost in each run will be estimated, either via a change in level of a mud tub and/or drop in level of a separate water tank.
3. Measure dimensions of mud tub and/or water tank to estimate volume. Mark graduations, if needed, so that volume changes can be estimated.

8.2 Active Coring

1. Request that the driller tag borehole with a weighted line before start of coring and periodically between runs to confirm depth.
2. Use a stopwatch (or equivalent) to time the length of each run (e.g., 40 min for 10 feet)
3. Note starting and ending water volume in tanks and/or mud tub.
4. Note the starting and ending core-run depth by noting the position of joints in the drilling string relative to the fixed reference point.
5. To the extent feasible, the driller should maintain a consistent bit pressure, water pressure, and rotational rate throughout a run, and avoid stopping or backing the tools, until the run is complete.
6. Request that driller alert you to changes in drilling condition during a run, including:
   a. Significant change in drilling rate that may indicate a change in lithology or weathering.
   b. A change in water recirculation rate that may indicate a major fracture
   c. Bit drop, which may indicate a void or highly-weathered zone.
   d. Any odors or sheens that may occur from the return water. [NOTE: *Under most drilling programs, the appearance of sheens or NAPL in the drilling water is cause to exercise stop-work authority. Drilling through a zone known to contain NAPL must be done only with CPM approval*.]
   e. Change in sediment load in return water, which may indicate a highly-weathered zone.
7. If air monitoring is required at the borehole (based on HASP and nature of contaminants present), periodically screen the driller breathing zone and return water splash zone.

8.3 Core Extraction

8.3.1 Core Handling and Labelling

In most instances, core samples will be placed directly into core-boxes by the driller. Core samples will be placed with increasing depths aligned left to right and top to bottom. If core is covered in sediment or mud, it is helpful to rinse the core with clean water before placing it in the box.

The drillers will take care not to unnecessarily break the core as they are extracting from the barrel; however, they will have to break long sections of core that overlap the box-edges, typically using a hammer.

Core and core boxes will be labeled using a heavy indelible marker (e.g., Sharpie) as follows:

What to Label	How to Label
Start and end of core runs	Label box edges or insert wooden blocks to separate runs. Label run number at top of run; e.g., “Run 2”, at the start of Run 2.

What to Label	How to Label
Vertical alignment of core	Draw short arrows on each major section of core pointing toward ground surface. (An alternate method using two parallel colored stripes is common but is challenging on wet core.)
Mechanical breaks (also called driller breaks)	Two parallel lines crossing the break at a right angle and labeled with the letter "M" (see Section 8.3.2)
Fractures (natural breaks)	A single line crossing the fracture at a right angle
Intervals with no core recovery	Insert a wooden spacer marked "No recovery" and with corresponding depth for any interval where no rock was recovered (e.g., a weathered zone that washed out, or karst void)
Sections of core removed from box	Insert a wooden spacer marked "Removed" with corresponding depth.
Core box lid (outside)	Site or project name, well or borehole ID, date drilled, box number (e.g., "1 of 5") and start and end depth of core contained in the box. (Additional information such as site address and project number can be included, if needed.)
Core box lid (inside)	Label the same as the box exterior. If core is expected to be archived, it is common practice to also include the depths, recovery and rock quality designation (RQD) for each run contained in the box.
Core box left end	Site or project name, well or borehole ID, box number, and start and end depth of core contained in the box.

8.3.2 Assessing Natural or Mechanical Breaks

When evaluating a core, it is necessary to determine whether the observed fractures are natural or mechanical. The primary indicators to look for include:

Signs of a Natural Fracture	• Weathering on face • Oxidation of minerals adjacent to face • Clay on face (if distinct from sediment in drilling fluid) • Linear striations on face
Signs of Mechanical Break	• Absence of weathering or oxidation • Crisp edges

Other considerations when evaluating the nature of break include:

- Weak, friable rock (such as shale), will often have numerous mechanical breaks that that are indistinguishable from real ones. Judgement is required, but for the sake of RQDs, such fractures are generally considered natural.

- If the core spins on itself inside the barrel A rounded or “ground” fracture faces can sometimes occur. This can happen to either a natural or mechanical break, so other evidence is required.

Assessing the nature of fractures can be challenging and subjective. In general, where the case is uncertain, assume the fracture is natural.

8.3.3 Core Run Description

Several descriptors are made on the basis of the core-run, typically 5 or 10 feet in nominal length. Lengths and depths are best recorded to the nearest 0.1 foot.

What to Record	How to Determine
Start and end depth	Determine by tracking advancement of the core tooling, referenced to ground surface. Note that cores occasionally snap off above the drilled depth on retrieval, leaving a cored “stub” in the hole, which is typically retrieved in the next run. When this happens, the run depths and retrieved core depths will differ. Both values will be recorded. Periodic soundings are helpful to verify depth.
Recovery length and percentage	Measure the total length of recovered core. The recovery percentage is based on start and end depths of the retrieved core (i.e., do not count a stub of core left in the hole).
Rock Quality Designation (RQD)	Add up the length of unfractured core-pieces greater than 4-inches in length (where fractures are dipping, measure between the points where fractures intersect the center-line of the core). Divide by the total length of the core run (bottom minus top depth of core recovered) and record the result as a percentage. Note that most common practice is to exclude obvious mechanical breaks when assessing RQD sections. However, where it is unclear whether a break is natural or mechanic, assume it is natural for the RQD assessment.
Water Loss	Determine based on changed level in mud tub, water tank, or other method (determined in consultation with the driller before coring starts). If a sudden change in water loss is observed during the run, record the approximate depth where it occurred.
Run-Time (optional)	Stopwatch recording of the total time to core a run. This can be useful in showing transition between rock types, or that the core bit has dulled. In some cases, foot-by-foot times can be recorded by chalk-marking increments on the barrel.

8.3.4 Contaminant Screening of Core

Methods for screening for contamination while coring depend on the nature of impacts suspected. As noted above, air-monitoring at the ground surface of the borehole, and continuous visual observation of the return water while drilling generally provide the first indication of an impact.

Specific procedures for screening cores will be identified in the project FIP/work plan. Common approaches include the following:

- If NAPL may be present, fracture surfaces will be visually inspected for sheens or NAPL.
- Though field staff will NOT intentionally sniff the core, obvious odors are sometimes useful indicators. Field descriptions of odors will be general, and not attempt to specify what contaminant it smells like.
- If screening core for volatile organic compounds (VOCs) with a photo-ionization detector (PID), focus attention on fractures. With the core lying in the core-box, separate the fracture slightly, cover the opening with a gloved hand, and then insert the PID tip into the fracture aperture.
- If NAPL is suspected (e.g., based on high PID hits, or sheens in the return water), but not visible on the core, one of several commercially available NAPL-detection kits (using hydrophobic dye) may be applied to the core as a supplemental test.

As noted above, when NAPL is observed in a borehole, drilling will almost always stop to avoid dragging the impacts down—drilling deeper will occur ONLY when necessitated by the project objectives, and ONLY after consulting project leadership.

8.4 Procedures for Core Logging

Logging core includes two parts: (1) describing the nature of the rock (e.g., lithology, structure, bedding) and (2) logging observed discontinues (e.g., fractures or weathered zones).

8.4.1 Logging Rock Characteristics

The field geologist will log the following characteristics of the rock core:

What to Record	How to Describe
Depth	Note top of an interval being described, relative to ground surface. Avoid referencing depths relative to the position in the core run.
Rock type	Describe based on observation. Use terminology consistent with local mapping, if available. If the specific type cannot be determined in the field, use a more general descriptor (e.g., metamorphic).
Grain size	See chart in **Attachment 1**. For crystalline rocks, note applicable texture.
Color	Reference Munsell rock color chart. Describe matrix color and major clast color separately, if applicable.

What to Record	How to Describe
Weathering state	See terminology chart (**Attachment 1**).
Hardness	See terminology chart (**Attachment 1**).
Degree of Fracturing	See terminology chart (**Attachment 1**). Also note general characteristics of fractures (e.g., if oxidized, filled, rough or smooth, dominantly aligned with bedding/foliation, etc.). Call out depths of major fractures. (See also, Section 8.4.2)

Other observations may also be made, if appropriate to the rock type. Common supplemental observations include:

- Diagnostic minerals present
- Presence and abundance of fossils
- Particle angularity/shape, e.g., for conglomerates or breccias
- Effervesce, e.g., if testing for limestone or dolomite using a hydrochloric acid solution
- Presence of healed fractures.
- Observations of porosity, pitting, vugs, or cavities (see terminology chart in **Attachment 1**)

8.4.2 Logging Discontinuities

In addition to characterizing the rock mass (as described above), core descriptions will often identify the depth and characteristics of specific fractures and other discontinuities. In general, the following will be noted:

- Fractures (excluding mechanical breaks), including descriptors for orientation, filling, oxidation or mineralization
- Zones of notable porosity (e.g., pitting, vugs)
- Zones of intense weathering (e.g., greater than surrounding rock mass)

Discontinuities are logged either in list-form, or on a scaled-graphical log, using standard abbreviations to identify important characteristics (see **Attachment 1**).

Note that in moderately or intensely fractured rock, logging every observed fracture may not be practical, or especially useful. Generalizations such as “intensely fractured zone” are often appropriate.

8.5 Procedures to Complete after Completion of Core Hole

8.5.1 Photographing Core

All core boxes will be photographed in a systematic manner. Best practice includes the following steps:

- Place the core box in a well-lit space

- Lay a tape measure or marking stick for scale along the length of the core box
- Wet the core with a spray bottle
- Take a high-resolution photograph showing the entire core box and labeled lid from directly above or at slight angle.
- If close-ups of particular features are needed, include a visible scale and labeled notecard in the photo.
- If a color is a key diagnostic aspect, a standard color reference chart may be included in the photos.

It is generally easiest to obtain consistent, high quality photographs by taking the photos in batches (e.g., after a borehole is completed), rather than attempting to take photographs immediately after each core run.

8.5.2 Core Storage or Disposal

If core will be stored for potential future use, boxes will be moved to a central location. In general:

- Core boxes will be stored under cover, ideally indoors and somewhere where they will not need to be moved often
- Boxes will be places on pallets (or similar) to keep off the ground
- Boxes will be stacked so that the labeled ends are visible and facing the same direction
- Boxes will be stacked no more than about 3 feet high (to avoid lifting above waist level)

If core is to be discarded, do so only after reviewing notes and confirming that all important details have been recorded. Core will be disposed-of consistent with project IDW requirements. Core boxes will not be removed from a site without appropriate planning and approval.

9 WASTE MANAGEMENT

Coring may generate several types of IDW in addition to the cores themselves:

- Coring typically generates substantial quantities of drilling fluid. It is typically a mixture of water and suspended fine sediment. In most cases, this is drummed. For large jobs, roll-off or “sludge” boxes may be more economical.
- Solid rock cuttings also accumulate in the mud tub. These are typically shoveled into drums.
- Other waste streams include decontamination liquids, and disposable materials (well material packages, personal protective equipment [PPE], etc.).

Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage,* the procedures identified in the FIP or QAPP as well as state-, federal- or client-specific requirements. Be certain that all IDW will be placed in clearly labeled, appropriate containers and documented in the field log book.

10 DATA RECORDING AND MANAGEMENT

Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements as outlined in the FIP/work plan and/or QAPP.

Core descriptions and related activities will be recorded in a field book and/or on appropriate field forms. In addition to the core description information detailed above, field notes will record personnel present on site, including driller names, drilling equipment used, significant weather conditions, and the timing of all activities.

Field forms, logs/notes (including daily field and relevant calibration logs), and digital records will be maintained by the field team lead.

Records will be transmitted to the Arcadis Project Manager and/or Task Manager, as appropriate, at the end of each day or as specified in the FIP/work plan.

Electronic data files will be sent to the project team and uploaded to the electronic project folder daily or as specified in the FIP/work plan.

Management of the original documents from the field will be completed in accordance with the site-specific QAPP.

11 REFERENCES

ASTM, 1999. Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation, D 2113-99.

New York State Department of Transportation (NYSDOT), 2015. Geotechnical Engineering Manual, Rock Core Evaluation Manual, GEM-23, Rev. 2.

12 ATTACHMENTS

Attachment 1. Bedrock Core Description Terminology

Attachment 1
Bedrock Core Description Terminology

Bedding Thickness*

Term	Average Thickness
Massive	No visible bedding
Very Thick-Bedded	Greater than 4 ft. (> 1.2 m)
Thick-Bedded	1 ft. to 4 ft. (0.3 m to 1.2 m)
Medium-Bedded	4 in. to 12 in. (100 mm to 300 mm)
Thin-Bedded	1.2 in. to 4 in. (30 mm to 100 mm)
Very Thin-Bedded	0.5 in. to 1.2 in. (13 mm to 30 mm)
Laminated	< 0.1 in.

*For igneous and metamorphic rocks, planar features such as foliation and banding are described using same thickness designations (e.g., thin-banded).

Fracturing

Term	Length of Most Recovered Core
Unfractured	No observed fractures.
Very slightly fractured	> 3 ft. (1 m).
Slightly fractured	1 to 3 ft. (0.3 to 1 m)
Moderately fractured	0.33 to 1 ft. (0.1 to 0.3 m)
Intensely fractured	0.1 to 0.33 ft. (0.03 to 0.1 m)
Very intensely fractured	Core mostly broken; few intact core segments

Pores or Voids

Term	Pore Size
Porous	Smaller than pinhead. Presence indicated by degree of absorbency
Pitted	Pinhead to ¼ inch across.
Vug	¼ inch across to diameter of core
Cavity	Larger than core diameter

Weathering State

Term	Characteristics
Fresh	No visible signs of decomposition or discoloration
Slightly weathered	Slight discoloration inward from open fractures; otherwise fresh
Moderately weathered	Discoloration throughout. Weaker minerals such as feldspar decomposed. Strength somewhat less than fresh rock, but cores cannot be broken by hand or scraped by knife. Texture preserved.
Highly Weathered	Most minerals somewhat decomposed. Specimens can be broken by hand with effort, or shave with knife. Texture become indistinct, but fabric preserved.
Extremely weathered (saprolite)	Minerals decomposed to soil, but fabric and structure preserved
Decomposed (residual soil)	Rock fully decomposed to plastic soils. Rock fabric and structure completely destroyed.

Hardness

Term	Field Test
Soft	Can be scratched with fingernail.
Medium Hard	Easily scratched by penknife
Hard	Difficult to scratch by penknife.
Very hard	Cannot be scratched by penknife.

Grain-Size

Term	Size
Microcrystalline / Aphanitic*	No visible grains
Fine grained	0.06 - 0.25 mm
Medium grained	0.25 - 0.5 mm
Coarse grained	0.5 - 2.0 mm

*Aphanitic applies to detrital rocks

Common Abbreviations

Abbr.	Definition	Abbr.	Definition	Abbr.	Definition
BkN	broken	JxF	joint crosses foliation	si	silt
CAL	calcareous or calcite	l	laminae	SZ	sheer zone
cl	clay	//	parallel	U	unfoliated or unstratified
F	foliation	m	mud in opening	v	vuggy
Fe	iron staining	MB	mechanical break	VJ	vertical joint
GOG	gouge	QTZ	quartz	w	weathered
HJ	horizontal joint	s	solution enlargement	WZ	weathered zone
J	joint *	S	stratification	x	crossing
J//F	joint is parallel to foliation	sa	sand	Z	Zone

* The term "joint" may indicates any natural fracture, including bedding plane fractures.

Example Graphic Log