

Ms. Christine Matlock
Senior Environmental Engineer
Hazardous Waste Section
Waste Management & Radiological Protection Division
Department of Environment, Great Lakes and Energy
525 West Allegan Street
Constitution Hall, Atrium North
Lansing, MI 48909

Arcadis of Michigan, LLC
28550 Cabot Drive
Suite 500
Novi
Michigan 48377
Phone: 248 994 2240
www.arcadis.com

Date: May 23, 2023
Our Ref: 30171056

Subject: Revised - 2023 Interim Groundwater Monitoring Work Plan
RACER Trust, Plants 2, 3, & 6, Lansing, Michigan

Dear Ms. Matlock,

On behalf of the Revitalizing Auto Communities Environmental Response (RACER) Trust, Arcadis of Michigan, LLC (Arcadis) prepared this 2023 revised Interim Groundwater Monitoring Work Plan (IGMP) to support the Resource Conservation and Recovery Act (RCRA) Facility Investigation and Corrective Measures Study (CMS) prepared for RACER Trust Lansing Industrial Land Plants 2, 3, and 6 located in Lansing, Michigan (Site; **Figure 1**). The revised IGMP provides an outline of the continued interim groundwater monitoring activities at the Site. The overall goal of the interim groundwater monitoring is to evaluate potential changing groundwater conditions and plume stability at the Site, and to verify the results of the *Preliminary Geochemical and Plume Stability Assessment Report* (Arcadis 2014b) and the updated plume stability evaluations included as part of the Annual Groundwater Monitoring Reports (Arcadis 2015, 2016, 2017, 2018, 2019, 2020b, 2021, 2022).

The primary revisions to this IGMP include an overall reduction in sampling frequency at monitoring wells shown to be stable to decreasing in concentration over time, and the expansion of the plan to include new wells installed as part of ongoing investigation activities. Although volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), and dissolved metals continue to be monitored, the primary focus of the IGMP at this time is the stability of 1,4-dioxane and per- and polyfluoroalkyl substances (PFAS), and performance monitoring related to the lower 1,4-dioxane biosparge system and storm water discharge monitoring related to the modifications associated with PFAS. The overall objectives of the IGMP are to evaluate:

- Metals including areas with concentrations in perched groundwater near the site boundary (RFI Areas 6, 7, 5-8, and 16) and areas with metals known to be site-related (Plant 3, Area 14).
- 1,4-Dioxane plume stability and performance monitoring associated with the weathered bedrock biosparge system (lower 1,4-dioxane plume).
- Plume stability and sentinel monitoring of site related PFAS impacts at Plants 2, 3, and 6.
- Sampling of perched groundwater in areas identified with semi-volatile organic compounds (SVOCs) in soil to verify SVOCs are not leaching to groundwater above EGLE Part 201 Criteria.
- Monitoring of light non-aqueous phase liquid (LNAPL) thickness at monitoring wells to verify LNAPL is stable and not migrating.

- Monitor the Lansing Township municipal wells (TWP-90-03, TWP-90-04, and TWP-90-05), located west of Plants 2 and 3, annually for low-level 1,4-dioxane.
- Monitor PFAS in storm sewer outfalls at Plants 2, 3, and 6.

Data collected as part of the IGMP will be evaluated after each event and reported semi-annually. Changes to the IGMP may be proposed as part of either the Semi-annual Groundwater Monitoring Report to be submitted in the fourth quarter of each year or the Annual Groundwater Monitoring Report to be submitted in the second quarter of each following year. A review of the interim groundwater monitoring activities will be completed following the Michigan Department of Environment, Great Lakes and Energy's (EGLE) completion of its corrective measures approval process.

Interim Monitoring Plan Scope of Work

As discussed with EGLE, the IGMP has been revised to include an overall reduction in sampling frequency at monitoring wells shown to be stable to decreasing in concentration over time, and the expansion of the plan to include new wells installed as part of ongoing investigation activities. The constituents of concern and gauging/sampling frequency for all monitoring wells are outlined on the revised groundwater sampling matrix included as **Table 1**. **Table 1** includes changes to the IGMP matrix in red text and a column summarizing rationale for 2023 IGMP changes.

Groundwater Elevation Gauging

Groundwater elevation and LNAPL thickness monitoring is being completed as outlined in **Table 1** and shown on **Figure 2**. Site-wide groundwater elevation monitoring will be completed semi-annually to collect data needed to evaluate trends in groundwater levels at the Site. Monitoring wells are gauged using an electronic water level meter accurate to 0.01-feet.

Measurement of LNAPL thickness at Plant 2 and Plant 3 will be completed semi-annually. NAPL wells will be gauged using an oil/water interface probe. Gauging methods will be consistent with the approved Field Sampling Plan (Arcadis 2011a). All gauging events will be completed within 24 hours with exceptions only resulting from access or other issues.

Groundwater Sampling

Monitoring wells will be sampled as outlined in **Table 1** and shown on **Figures 3 through 8**. Groundwater sampling includes quarterly, semi-annual, annual, biennial, and quadrennial frequencies determined by factors such as constituents of concern (COC), location relative to site impacts, demonstrated plume stability, and performance monitoring objectives. The more comprehensive site-wide sampling event (including the Lansing Township municipal wells) will be conducted on an annual basis with additions of the biennial and quadrennial sampling during appropriate years. Annual sampling events will be cycled between the second and fourth quarters to capture seasonal variability. The semi-annual sampling event will be conducted on wells that are key to further evaluating plume stability and potential migration. Quarterly events primarily include newly installed wells that require additional data (e.g., seven sampling events) to evaluate stability.

Field sampling and gauging methods as well as quality assurance/quality control procedures will be consistent with the Field Sampling Plan (Arcadis 2011a) and Quality Assurance Project Plan (QAPP) (Arcadis 2011b). Groundwater samples will be collected in a manner consistent with the low-flow sampling techniques in the

Arcadis technical guidance instruction (TGI) for low-flow sample collection, and generally consistent with EGLE's Remediation and Redevelopment Division (RRD) Op Memo 2, Attachment 5 (EGLE 2004). Low flow sampling protocols and PFAS specific considerations are described further in TGIs included as **Attachment 1**. Samples will be collected using a peristaltic pump or submersible bladder pump, as appropriate, and submitted under chain of custody protocol to the analytical laboratory. An emphasis will be placed on collecting low-turbidity samples (less than 10 nephelometric turbidity units [NTUs]) for metals analysis. Field parameters, including dissolved oxygen, oxidation-reduction potential, turbidity, and specific conductivity will be monitored for stability during sampling and recorded as a field data summary. Groundwater samples will be submitted for one or more of the following analyses to the following laboratories:

- *1,4-Dioxane* – on-site monitoring wells will be analyzed using United States Environmental Protection Agency (USEPA) Method 8260B selected-ion method (SIM). The Lansing Township municipal wells and select bedrock monitoring wells will be collected quarterly, semi-annually, annually, and biennially and analyzed using USEPA Drinking Water Method 522. Wells selected for 1,4-dioxane analysis are shown on **Figure 3**. Samples to be analyzed for 1,4-Dioxane analysis will be sent to Merit Laboratories (Merit) located in East Lansing, Michigan.
- *Target Compound List (TCL) VOCs* – defined in **Table 3** of the QAPP (Arcadis 2011b), samples will be collected quarterly, semi-annually, annually, and biennially and analyzed by USEPA Method SW8260B, Revision 2 or SW8260C, Revision 3. Wells selected for VOC analysis are shown on **Figure 4**. Samples to be analyzed for VOCs analysis will be sent to Merit Laboratories (Merit) located in East Lansing, Michigan.
- *Select Total Metals* – samples will be collected quadrennially (i.e., once every four years) for select wells in areas of the Site identified with metals impacts in soil. Metals identified with consistent drinking water criteria exceedances (arsenic, chromium, copper, lead, nickel, and vanadium) will be analyzed by USEPA Method 6020. Hexavalent chromium in Plant 3, Area 14 will be analyzed by USEPA Standard Method 3500 Cr B 2011. Wells selected for metals analysis are shown on **Figure 5**. If turbidity below 10 nephelometric turbidity units (NTU) cannot be achieved during metals sampling, the sample will be filtered and submitted for both dissolved and totals metals analysis, using USEPA Method 6020. Samples to be analyzed for metals analysis will be sent to Merit Laboratories (Merit) located in East Lansing, Michigan.
- *SVOCs* – samples will be collected quadrennially for select wells in areas of the Site identified having SVOC impacts in soil. Wells selected for SVOC analysis are shown on **Figure 6**. Samples to be analyzed for SVOCs analysis will be sent to Merit Laboratories (Merit) located in East Lansing, Michigan.
- *PFAS* – samples will be collected and evaluated on a quarterly, semi-annual, and annual basis. Currently samples for PFAS will be analyzed for the 28 PFAS contained in the draft Michigan Department of Environment, Great Lakes, and Energy (EGLE) PFAS Minimum Laboratory Analyte List (EGLE, updated 2019) using modified USEPA Method 537 with isotope dilution (DoD QSM 5.1). Upon approval of the Draft USEPA Method (USEPA 1633) or other analytical requirements, RACER will discuss modifying the analytical approach with EGLE at that time. Wells selected for PFAS analysis are shown on **Figure 7**. Samples to be analyzed for PFAS analysis will be sent to SGS Accutest Laboratory located in Orlando, Florida; Pace Analytical located in West Columbia, South Carolina, or Pace Analytical located in Baton Rouge, Louisiana.

Quarterly sampling data will be reviewed during quarterly RACER-EGLE update meetings or EGLE will otherwise be provided with any anomalous or significant results following each quarterly event.

LNAPL Monitoring

As noted above, LNAPL gauging will be completed semi-annually at LNAPL monitoring wells located on Plants 2 and 3, as shown on **Figure 1**. LNAPL is present in the central portion of Plant 2 (Area 5-2) and in the north-central portion of Plant 3 (Area 17). Trend plots indicate that, in general, LNAPL thickness (when present) gradually increases until it reaches equilibrium within the well and then stabilizes. For the deeper LNAPL, the wells take longer to equilibrate with the confined LNAPL conditions relative to the static water level within the formation. The comprehensive *Plant 2 LNAPL Conceptual Site Model* was provided to EGLE for review on February 20, 2020 (Arcadis 2020a). Based on the monitoring results, there is no indication of LNAPL migration.

Storm Sewer Sampling

Historical storm sewer sampling is summarized in the RCRA Facility Investigation Supplemental Phase 2 Activities Summary Report (Arcadis, 2014a). Storm sewer sampling began at ten sampling locations in 2012 and only the southern outfall of Plant 6 (P6-MH2-SW) indicated sporadic detections of metals and xylenes slightly above groundwater-surface water interface (GSI) criteria. Soils impacted with xylenes were excavated from the southern Plant 6 area (Areas 7 and 9) and subsequent annual sampling results at the southern Plant 6 outfall were non-detect for xylenes, and metals were below GSI criteria. In 2017, Plant 3 storm sewers were sampled for PFAS. Detections above Rule 57 criteria resulted in modifications completed in Fall 2018 and Winter 2019/20. PFAS sampling was conducted on Plants 2 and 6 in 2019 and 2018, respectively, with Rule 57 exceedances resulting in modifications completed in Winter 2019/20, Fall 2020, and Spring 2021.

Quarterly monitoring (sampling or inspecting as appropriate) of the outfalls and select interior locations was completed following each modification event on Plants 2, 3, and 6. Routine outfall monitoring for PFAS has been added to this IGMP and is shown on **Figure 8**.

Quality Control/Quality Assurance

As discussed in Sections 12.2 and 12.3 of the QAPP (Arcadis 2011b), quality control (QC) samples will be collected during the sampling events and included at the following frequency:

- One duplicate (DUP) per every ten samples.
- One matrix spike and matrix spike duplicate (MS/MSD) per every 20 samples.
- One field blank per sampler per sampling event.
- One equipment blank (rinse blank) per pump per sampling event, as well as additional equipment blanks from the water level meters used for PFAS sampling.

Additionally, trip blanks will be included with each cooler containing samples for VOC analysis. One groundwater sample delivery group per plant from each event will undergo complete Tier II validation as defined in USEPA *Innovative Approaches to Data Validation*, USEPA Region III (USEPA 1995). Validation reports will be included along with laboratory analytical reports.

Reporting

A summary of groundwater monitoring results will be provided to EGLE following each semi-annual sampling event. A semi-annual report will be prepared following the second quarter sampling event and consist of a brief memorandum describing the results of the first and second quarter sampling events. The semi-annual report will include the following:

- A table summarizing analytical data for the quarterly and semi-annual events,
- A table summarizing groundwater elevations,
- A table summarizing measured LNAPL thickness,
- Figures summarizing COC criteria exceedances, and
- A summary of the field parameters recorded at each well during low-flow sampling.
- Low-flow groundwater sampling field logs and a summary of the field parameters recorded at each well during low-flow sampling, and
- A brief narrative summarizing the first and second quarter results.

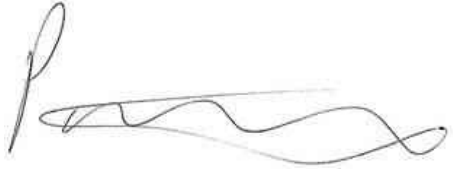
An annual report will be submitted following the fourth quarter sampling event and provide a more detailed narrative documenting any changes observed at the Site over the course of the year. The annual report will also propose changes to the IGMP, as appropriate, based on the results of the sampling. Any proposed changes to the IGMP must be approved by the EGLE before they will be implemented. The annual report will include the following:

- A table summarizing analytical data for the quarterly, semi-annual, and annual monitoring events (and will include biennial or quadrennial data, if collected),
- A table summarizing groundwater elevations,
- A table summarizing the measured LNAPL thickness,
- Groundwater concentration trend graphs with Mann-Kendall analysis completed for all monitoring that exceed criteria (or have in the past) and have at least seven samples available for analysis,
- Figures summarizing COC criteria exceedances for the annual event,
- Figures summarizing groundwater elevation contours for each water bearing unit, and a narrative discussion of current groundwater flow at the site and any potential changes to groundwater flow based on recent data.
- Groundwater elevation trend graphs and narrative discussing any trends in groundwater elevation or changes observed over the course of the year.
- Low-flow groundwater sampling field logs and a summary of the field parameters recorded at each well during low-flow sampling, and
- Copies of the laboratory analytical reports for the year (including QA/QC results).

Christine Matlock, Joe Rogers, John McCabe
Michigan Department of Environment, Great Lakes, and Energy
May 23, 2023

Should you have any questions or need further information, please contact Dave Favero of RACER Trust at (217) 741-6235 (dfavero@racertrust.org), or Patrick Curry at (810) 225-1926 (patrick.curry@arcadis-us.com).

Sincerely,
Arcadis of Michigan, LLC

A handwritten signature in black ink, appearing to read 'Patrick Curry', with a stylized, flowing script.

Patrick Curry, PG, CPG
Technical Expert

Email: patrick.curry@arcadis.com
Direct Line: (810) 225-1926

Copies:

Dave Favero, RACER Trust
Project File

Enclosures:

Tables

- 1 Revised Interim Groundwater Monitoring Summary

Figures

- 1 Site Location
- 2 Groundwater and LNAPL Gauging Plan
- 3 1,4-Dioxane Monitoring Plan
- 4 VOCs Monitoring Plan
- 5 Metals Monitoring Plan
- 6 SVOCs Monitoring Plan
- 7 PFAS Monitoring Plan
- 8 Storm Sewer Monitoring Plan

Attachments

- 1 PFAS Sampling Guidance

References

- Arcadis. 2011a. Field Sampling Plan. RACER Trust, Lansing, Michigan Plants 2, 3, and 6 Industrial Land. August 26.
- Arcadis. 2011b. Quality Assurance Project Plan. RACER Trust, Lansing, Michigan Plants 2, 3, and 6 Industrial Land. August 26.
- Arcadis. 2014a. RCRA Facility Investigation Supplemental Phase 2 Activities Summary Report, RACER Trust, Plants 2, 3 & 6, Lansing, Michigan, February 26.
- Arcadis. 2014b. Preliminary Groundwater Geochemical and Plume Stability Assessment. Plants 2, 3, and 6, Industrial Land, Lansing, Michigan. April 24 (as amended).
- Arcadis. 2015. 2014-2015 Annual Groundwater Monitoring Report. RACER Trust Plants 2, 3, and 6, Lansing, Michigan. June 26.
- Arcadis. 2016. 2015-2016 Annual Groundwater Monitoring Report, RACER Trust, Plants 2, 3, & 6 Industrial Land, Lansing, Michigan. June 27.
- Arcadis. 2017. Annual Groundwater Monitoring Report. RACER Trust, Plants 2, 3, & 6, Lansing, Michigan. May 5.
- Arcadis. 2018. 2017 Annual Groundwater Monitoring Report. RACER Trust, Plants 2, 3, & 6, Lansing, Michigan. May 7.
- Arcadis. 2019. 2018 Annual Groundwater Monitoring Report. RACER Trust, Plants 2, 3, & 6, Lansing, Michigan. May 14.
- Arcadis 2020a. Plant 2 LNAPL Conceptual Site Model. RACER Lansing Plants 2, 3, and 6, Lansing, Michigan. February 20.
- Arcadis. 2020b. 2019 Annual Groundwater Monitoring Report. RACER Trust Industrial Land, Lansing, Michigan. May 4.
- Arcadis, 2021. 2020 Annual Groundwater Monitoring Report. RACER Trust Lansing Industrial Land. Lansing, Michigan. May 6.
- Arcadis. 2022. 2021 Annual Groundwater Monitoring Report. RACER Trust Industrial Land, Lansing, Michigan. May 12.
- EGLE. 2004. RRD Op Memo 2, Attachment 5 – Michigan Department of Environmental Quality. Remediation and Redevelopment Division. Operational Memorandum No. 2. Sampling and Analysis – Attachment 5. October 22, 2004.
- USEPA. 1995. Innovative Approaches to Data Validation. USEPA Region III (June 1995).

Table

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte				Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	SVOCs			
Plant 2								
Perched								
LMW-12-01	7-12	SA					LNAPL Monitoring	
LMW-12-02	5-10	SA					LNAPL Monitoring	
LMW-12-03D	17.3-22.3	SA					LNAPL Monitoring	
LMW-12-03S	4-9	SA					LNAPL Monitoring	
LMW-12-04	16-21	SA					LNAPL Monitoring	
LMW-12-05	7-12	SA					LNAPL Monitoring	
LMW-12-06	4-9	SA					LNAPL Monitoring	
LMW-12-07	4-9	SA					LNAPL Monitoring	
LMW-12-08	8-13	SA					LNAPL Monitoring	
LMW-14-12D	18-23	SA					LNAPL Monitoring	
LMW-14-13D	17.5-22.5	SA					LNAPL Monitoring	
LMW-14-14D	18-23	SA					LNAPL Monitoring	
LMW-14-15D	18-23	SA					LNAPL Monitoring	
LMW-15-16D	19.5-24.5	SA					LNAPL Monitoring	
LMW-15-17D	20-25	SA					LNAPL Monitoring	
MW-01(2)	10-20	SA	B				VOC sentinel	
MW-12-07	10-15	SA					groundwater elevation monitoring	
MW-12-08	19-24	SA					groundwater elevation monitoring	
MW-12-09	14-19	SA	B	B		A	VOC Sentinel, perched 1,4-dioxane sentinel, PFAS sentinel	1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances PFAS: sampling frequency decrease from SA to A – stable trend
MW-12-18	28-33	SA	B			A	VOC sentinel, PFAS sentinel	VOCs: location has always been non-detect for VOCs (only exception: 1,1-DCE at 1 to 2 ug/L is the only VOC detected), but will continue to monitor this boundary well PFAS: sampling frequency decrease from SA to A – consistent non-detects
MW-14-54	14-19	SA	B				VOC monitoring	
MW-14-55	13-18	SA	Qd				VOC monitoring	VOCs: sampling frequency decrease from B to Qd - intermittent VOC detections are consistently below criteria
MW-14-57	15-20	SA		A			perched 1,4-dioxane monitoring	
MW-14-58R	22-27	SA	B	A		A	perched 1,4-dioxane monitoring, PFAS Monitoring	MW-14-58 was abandoned and replaced with MW-14-58R in 2021 PFAS: sampling frequency decrease from SA to A – stable to decreasing trend
MW-14-59	12-17	SA	B	A	Qd	A	perched 1,4-dioxane monitoring, SVOC evaluation, PFAS monitoring	SVOCs: location is delineated but will still be monitored PFAS: sampling frequency decrease from SA to A – stable trend
MW-14-60	15-20	SA	B	A	Qd	A	perched 1,4-dioxane monitoring, SVOC evaluation, PFAS monitoring	SVOCs: location is delineated but will still be monitored PFAS: sampling frequency decrease from SA to A – stable to decreasing trend
MW-14-62	12-17	SA	B	A	Qd	A	perched 1,4-dioxane monitoring, PFAS Monitoring	SVOCs: location is delineated but will still be monitored PFAS: sampling frequency decrease from SA to A – stable to decreasing trend
MW-21-139	7-12	SA		SA		SA	perched 1,4-dioxane monitoring	New well installed in 4Q 2021 1,4-D: sampling frequency decrease from Q to SA – no 1,4-D exceedances PFAS: sampling frequency decrease from Q to SA – stable trend

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte				Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	SVOCs			
Plant 2								
MW-22-153	25-30	SA	Q	Q			perched 1,4-dioxane monitoring	New well installed in 2Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event
MW-22-155	25.5-30.5	SA		Q			perched 1,4-dioxane monitoring	New well installed in 3Q 2022. Installed W of MW-14-58R / MW-22-153 for delineation.
MW-22-156	23-28	SA		Q			perched 1,4-dioxane monitoring	New well installed in 3Q 2022. Installed W of MW-14-58R / MW-22-153 for delineation.
MW-22-157	24-29	SA		Q			perched 1,4-dioxane monitoring	New well installed in 3Q 2022. Installed W of MW-14-58R / MW-22-153 for delineation.
P2-MW-02	31-41	SA				A	groundwater elevation monitoring	PFAS: added PFAS analysis
P2-MW-03	27-32	SA					groundwater elevation monitoring	
P2-MW-04	26-36	SA		A	Qd	A	perched 1,4-dioxane monitoring, SVOC evaluation	SVOCs: location is delineated but will still be monitored PFAS: added PFAS analysis
P2-SB-03	14-19	SA					groundwater elevation monitoring	
P2-SB-06	24-29	SA					groundwater elevation monitoring	
P2-SB-20	8-13	SA					groundwater elevation monitoring	
P2-SB-37	5-10	SA					LNAPL Monitoring	
PMW-01	2.59-7.59	SA					LNAPL Monitoring	
PMW-02	2.59-7.59	SA					LNAPL Monitoring	
PMW-03	1.2-6.2	SA					LNAPL Monitoring	
Deep Overburden and Weathered Bedrock								
MW-13-43	72-77	SA		SA			lower 1,4-dioxane monitoring	
MW-13-45	72-77	SA		SA			lower 1,4-dioxane monitoring	
MW-13-51	77-87	SA					lower 1,4-dioxane sentinel	1,4-D: removed 1,4-D sampling - has always been non-detect for 1,4-D
MW-14-56	71-76	SA		A		A	lower 1,4-dioxane sentinel	PFAS: sampling frequency decrease from SA to A - consistent non-detects
MW-14-61	70-75	SA	A	SA	Qd	A	lower 1,4-dioxane sentinel, SVOC Monitoring, PFAS Monitoring	SVOCs: location is delineated but will still be monitored PFAS: sampling frequency decrease from SA to A - no PFAS exceedances
MW-14-63	68-73	SA		A			lower 1,4-dioxane sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-15-72	63-68	SA	B	SA	Qd	A	lower 1,4-dioxane monitoring	VOCs: sampling frequency decrease from A to B – consistent non-detects SVOCs: location is delineated but will still be monitored PFAS: sampling frequency decrease from SA to A - consistent non-detects
MW-15-73	78-83	SA		B			lower 1,4-dioxane monitoring	1,4-D: sampling frequency decrease from A to B - no 1,4-D exceedances; connection to APC plume
MW-16-74	66-71	SA		A			lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from SA to A - no 1,4-D exceedances
MW-16-75	66-71	SA		A			lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from SA to A - no 1,4-D exceedances
MW-16-76	70-75	SA		A			lower 1,4-dioxane sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-16-77	66-71	SA		A			lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from SA to A - no 1,4-D exceedances
MW-16-78	68-73	SA		A			lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from SA to A - has always been non-detect for 1,4-D
MW-16-80	68-73	SA		A			lower 1,4-dioxane monitoring	1,4-D: sampling frequency decrease from SA to A - no 1,4-D exceedances; connection to APC plume
MW-16-81	70-75	SA	B	SA		A	lower 1,4-dioxane monitoring	VOCs: sampling frequency decrease from A to B - consistent non-detects PFAS: sampling frequency decrease from SA to A - consistent non-detects

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte				Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	SVOCs			
Plant 2								
MW-16-82	70-75	SA		A			lower 1,4-dioxane monitoring	1,4-D: sampling frequency decrease from SA to A - no 1,4-D exceedances
MW-16-83	71-76	SA		B			lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from A to B - has always been non-detect for 1,4-D
MW-16-84	72-77	SA	A	SA			lower 1,4-dioxane monitoring	
MW-16-85	74-79	SA	B	SA			lower 1,4-dioxane monitoring	VOCs: sampling frequency decrease from A to B - consistent non-detects
MW-17-86	73-78	SA	B	SA			lower 1,4-dioxane monitoring	VOCs: sampling frequency decrease from A to B - consistent non-detects
MW-19-115	72.5-77.5	SA		SA			lower 1,4-dioxane monitoring	
MW-19-116	65-70	SA		SA			lower 1,4-dioxane monitoring	
MW-19-117	54-59	SA		SA			lower 1,4-dioxane monitoring	
MW-19-120	66-71	SA	A	SA			lower 1,4-dioxane monitoring	VOCs: sampling frequency decrease from SA to A - consistent non-detects
MW-19-121	66-71	SA		SA				Incorporating into IGMP
MW-19-122	59-64	SA		SA				Incorporating into IGMP
MW-19-123	66-71	SA		SA				Incorporating into IGMP
MW-19-124	65-70	SA		SA				Incorporating into IGMP
MW-20-126	69-74	SA		SA				Incorporating into IGMP
MW-20-127	72-77	SA		SA				Incorporating into IGMP
MW-20-128	65-70	SA		SA				Incorporating into IGMP
MW-20-129	64-69	SA		SA				Incorporating into IGMP
MW-20-130	63-68	SA		SA		SA	PFAS Sentinal	New well installed in 3Q 2020
MW-21-140	67-72	SA		SA			lower 1,4-dioxane monitoring	New well installed in 4Q 2021
MW-21-142	71.5-76.5	SA		SA			lower 1,4-dioxane monitoring	New well installed in 4Q 2021
PW-14-01	71.6-76.8	SA		SA			lower 1,4-dioxane monitoring	
PW-14-02	75-80	SA	Qd	SA			lower 1,4-dioxane monitoring	VOCs: sampling frequency decrease from B to Qd - has always been non-detect for VOCs
TW-14-02	67-72	SA	Qd	SA			lower 1,4-dioxane monitoring	VOCs: sampling frequency decrease from B to Qd - has always been non-detect for VOCs
TW-15-12	73-78	SA		SA				
Bedrock								
MW-12-01	87-110	SA		B ⁽¹⁾			bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work 1,4-D: sampling frequency decrease from A to B - consistent non-detects
MW-12-02	87-110	SA		B ⁽¹⁾			bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work 1,4-D: sampling frequency decrease from A to B - no 1,4-D exceedances of DW
MW-12-05R	100-112	SA		A ⁽¹⁾			bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-12-06	80.6-99.5	SA		A ⁽¹⁾			bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-13-44	96-115	SA		A ⁽¹⁾			bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-17-87	100-112	SA		A ⁽¹⁾			bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-19-118D	175-190	SA		A ⁽¹⁾			bedrock sentinel	

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte				Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	SVOCs			
Plant 2								
MW-19-118S	145-160	SA		A ⁽¹⁾			bedrock sentinel	
MW-19-125	100-115	SA		A ⁽¹⁾			bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
Lansing Township Wells								
TWP-03	-	-		A ⁽¹⁾			Municipal Well	
TWP-04	-	-		A ⁽¹⁾			Municipal Well	
TWP-05	-	-		A ⁽¹⁾			Municipal Well	
Storm Sewer								
P2-MH-2	-	-				Q	PFAS sewer monitoring	Incorporating into IGMP
P2-MH-9	-	-				Q	PFAS sewer monitoring, typically dry, no sample	Incorporating into IGMP
P2-MH-W	-	-				Q	PFAS sewer monitoring	Incorporating into IGMP

Notes:

Wells shown in gray shading are part of biosparge performance monitoring, not part of previous formal IGMP submission. Additional details included in Table 7.

* Site wide gauging to alternate between semi-annual events to account for seasonal variability. Semi-annual gauging includes all wells sampled semi-annually.

** Select metals includes arsenic, nickel, lead, vanadium, chromium, and copper.

(1) = Analyzed for 1,4-dioxane via low-level USEPA Method 522

New wells will be added to the figures and incorporated into the annual monitoring once 4 samples are collected and a COC list is determined.

ft bgs = feet below ground surface

M = Monthly

Q = Quarterly

SA = Semi-annual

A = Annual (2Q or 4Q of each year, each year rotates which quarter)

B = Biennial (starting 2nd quarter of 2020)

Qd = Quadrennial (every 4 years, starting 2020)

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte						Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	Select Metals**	Hexavalent Chromium	SVOCs	PFAS		
Plant 3										
Perched										
CH-14-RO	7-12	SA			Qd	Qd		A	metals monitoring	Select metals / hexavalent chromium: sampling frequency decrease from A to Qd, location is delineated but will still be monitored PFAS: sampling frequency decrease from SA to A - stable to decreasing trend
LMW-12-09	3-8	SA							LNAPL Monitoring	
LMW-12-10	14-19	SA							LNAPL Monitoring	
LMW-12-11	15-20	SA							LNAPL Monitoring	
MW-05(3)	10-15	SA	B						VOC sentinel	VOCs: sampling frequency decrease from A to B – consistent non-detects
MW-13-31	5-10	SA							groundwater elevation monitoring	
MW-13-32	5-10	SA			Qd		Qd		groundwater elevation monitoring / perimeter SVOC & Metals monitoring	Select metals: sampling frequency decrease to quadrennial, location is delineated but will still be monitored SVOCs: location is delineated but will still be monitored
MW-14-65	5-10	SA							groundwater elevation monitoring	
MW-18-88	6-11	SA	B		Qd	Qd		SA	PFAS monitoring / sentinel VOC & Metals	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work VOCs: sampling frequency decrease from A to B – consistent non-detects Select metals / hexavalent chromium: sampling frequency decrease from A to Qd - location placement is redundant/not required PFAS: sampling frequency decrease from Q to SA - monitoring downgradient wells for migration
MW-18-89	7-12	SA						A	PFAS monitoring	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work PFAS: sampling frequency decrease from Q to A - stable trend
MW-18-90	15-20	SA						A	PFAS monitoring	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work PFAS: sampling frequency decrease from Q to A - stable to decreasing trend
MW-18-91	7-12	SA						A	PFAS monitoring	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work PFAS: sampling frequency decrease from Q to A - stable trend
MW-18-92	23-28	SA						A	PFAS sentinel	PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-18-95	4.5-9.5	SA						SA	PFAS monitoring	PFAS: sampling frequency decrease from Q to SA - stable to decreasing trend
MW-18-96	7-12	SA						A	PFAS sentinel	PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-18-98	7-12	SA						SA	PFAS sentinel	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work PFAS: sampling frequency decrease from Q to SA - stable trend
MW-18-99	9-14	SA						SA	PFAS sentinel	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work PFAS: sampling frequency decrease from Q to SA - monitoring downgradient wells for migration
MW-18-100	8-13	SA						SA	PFAS sentinel	
MW-18-102	10-15	SA						A	PFAS sentinel	PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-18-103	5-10	SA						A	PFAS monitoring	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work PFAS: sampling frequency decrease from Q to A - monitoring downgradient wells for migration, connection to off-site property to the north
MW-18-104	5-10	SA						A	PFAS sentinel	PFAS: sampling frequency decrease from SA to A - stable trend
MW-18-105	6-11	SA						SA	PFAS monitoring	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work PFAS: sampling frequency decrease from Q to SA - stable trend
MW-18-106	5-10	SA							PFAS sentinel	PFAS: remove PFAS sampling - stable to decreasing trend

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte						Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	Select Metals**	Hexavalent Chromium	SVOCs	PFAS		
Plant 3										
MW-19-107	23-28	SA						SA	PFAS sentinel	
MW-19-108	23-28	SA						SA	PFAS sentinel	
MW-19-110	8-13	SA						A	PFAS sentinel	PFAS: well is consistently dry and cannot be sampled, but will still be attempted annually
MW-19-111	20-25	SA						SA	PFAS sentinel	
MW-19-112	9-14	SA						A	PFAS sentinel	PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-19-113	16-21	SA						A	PFAS sentinel	PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-19-114	6-11	SA						A	PFAS sentinel	PFAS: sampling frequency decrease from SA to A – no PFAS exceedances
P3-SB-07	11-16	SA							groundwater elevation monitoring	
P3-SB-28	8-13	SA					Qd		groundwater elevation monitoring	SVOCs: location is delineated but will still be monitored
UNK-10	11-16	SA							VOC sentinel	VOCs: remove VOCs sampling - has always been non-detect for VOCs
UNK-11	6.5-11.5	SA					Qd		VOC monitoring/SVOCs monitoring, VOCs sentinel well	VOCs: remove VOCs sampling - has always been non-detect for VOCs SVOCs: location is delineated but will still be monitored
UNK-15	11-16	SA						SA	PFAS monitoring	Gauging: decrease gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work PFAS: sampling frequency decrease from Q to SA - stable to decreasing trend
Deep Overburden and Weathered Bedrock										
MW-02-01(3)	59-69	SA							groundwater elevation monitoring	
MW-02-02(3)	74-84	SA		B					lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from A to B – consistent non-detects
MW-02-03(3)	79-89	SA							groundwater elevation monitoring	
MW-02-04(3)	76-86	SA		B	Qd			A	lower 1,4-dioxane/PFAS/metals sentinel	1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances Select metals: sampling frequency decrease from A to Qd - location placement is redundant PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-04-03(3)	80-90	SA							groundwater elevation monitoring	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-04-04(3)	72-82	SA							groundwater elevation monitoring	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-12-20	75-80	SA		B					lower 1,4-dioxane sentinel	
MW-12-21	70-75	SA	B	SA					lower 1,4-dioxane monitoring	
MW-13-22	89-94	SA	B	A					lower 1,4-dioxane monitoring	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-13-23	69-74	SA		B					lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances
MW-13-24	69-74	SA		B					lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances
MW-13-25	67-72	SA		A					lower 1,4-dioxane monitoring	1,4-D: sampling frequency decrease from SA to A – no 1,4-D exceedances
MW-13-26	72-77	SA							groundwater elevation monitoring	
MW-13-27	67-72	SA							groundwater elevation monitoring	
MW-13-29	68-73	SA		A					lower 1,4-dioxane monitoring	
MW-13-30	72-77	SA							groundwater elevation monitoring	
MW-13-34	74-79	SA	B	SA					lower 1,4-dioxane monitoring	
MW-13-40	72-77	SA							groundwater elevation monitoring	
MW-13-41	77-82	SA	B						lower VOC sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-13-46	68-73	SA		A					lower 1,4-dioxane monitoring	1,4-D: sampling frequency decrease from SA to A – consistent non-detects
MW-13-48	65-70	SA	B	SA					lower 1,4-dioxane monitoring	
MW-13-49	73-78	SA		B					lower 1,4-dioxane	1,4-D: sampling frequency decrease from A to B – consistent non-detects
MW-14-64	98.6-103.6	SA		B					lower 1,4-dioxane sentinel	1,4-D: sampling frequency decrease from A to B – consistent non-detects
MW-15-71	110-115	SA		B					lower 1,4-dioxane sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte						Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	Select Metals**	Hexavalent Chromium	SVOCs	PFAS		
Plant 3										
MW-18-93	77.5-82.5	SA						A	Lower PFAS Sentinel	PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-18-94	72-77	SA						A	Lower PFAS, 1,4-Dioxane Sentinel	1,4-D: remove 1,4-D sampling - has always been non-detect for 1,4-D PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-18-97	85-90	SA						A	Lower PFAS Sentinel	1,4-D: remove 1,4-D sampling - no 1,4-D exceedances PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-18-101	80-85	SA		B				SA	Lower PFAS Sentinel	1,4-D: sampling frequency decrease from A to B – has always been non-detect for 1,4-D, redundant with MW-02-02(3)
MW-19	55-65	SA		B					lower 1,4-dioxane sentinel	VOCs: remove VOCs sampling - has always been non-detect for VOCs 1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances
MW-22	52.5-62.5	SA							groundwater elevation monitoring	
MW-23	52-62	SA						A	PFAS sentinel	PFAS: sampling frequency decrease from SA to A – no PFAS exceedances
MW-91-2R	75-80	SA		B	Qd	Qd		A	lower 1,4-dioxane, PFAS and metals sentinel	MW-91-2 was abandoned and replaced with MW-91-2R in 2019 1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances Select metals / hexavalent chromium: sampling frequency decrease from A to Qd, location is delineated but will still be monitored PFAS: sampling frequency decrease from SA to A - has always been non-detect for PFAS
MW-93-1	65-75	SA							groundwater elevation monitoring	
PW-14-03	85-90	SA		SA					lower 1,4-dioxane monitoring	
TW-14-06	82-87	SA		SA						Incorporating into IGMP
TW-15-11	85-90	SA		SA						Incorporating into IGMP
Bedrock										
MW-04-01(3)	95-105	-							No longer part of sampling or gauging	Set at a similar interval to other bedrock wells, but this well has a static water level typically 10-15 ft higher than other bedrock wells. It may installed within an isolated pocket of rock with an anomalous head. The well has not been gauged since 2017. The well has always been ND for all compounds and was dropped from the IGMP in 2018. If future monitoring suggests this area needs a bedrock well, our recommendation would be a replacement.
MW-04-02(3)	126-136	SA							groundwater elevation monitoring	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-12-04	77-100	SA							groundwater elevation monitoring	
MW-13-28	99-115.5	SA		A ⁽¹⁾					bedrock sentinel	
MW-13-37	97-112	SA		B ⁽¹⁾					1,4-D sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work 1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances
MW-13-38	107-124	SA		B ⁽¹⁾					bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work 1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances
MW-13-39B	97-112	SA							groundwater elevation monitoring	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-13-47	99-119	SA		B ⁽¹⁾					bedrock sentinel	1,4-D: sampling frequency decrease from A to B – no 1,4-D exceedances
MW-19-119D	180-195	SA		A ⁽¹⁾					bedrock sentinel	
MW-19-119S	145-160	SA		A ⁽¹⁾					bedrock sentinel	
MW-88-1	103.5-140	SA							groundwater elevation monitoring	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-91-3	105-117	SA							bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-91-4	116-132.5	SA							groundwater elevation monitoring	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-91-5	112.5-128	SA		B ⁽¹⁾					bedrock sentinel	1,4-D: sampling frequency decrease from A to B - has always been non-detect for 1,4-D, redundant location with MW-19-119D/S
MW-91-6	82-98	SA		B ⁽¹⁾					bedrock sentinel	1,4-D: sampling frequency decrease from A to B – consistent non-detects

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte						Primary Function	Reason(s) for 2023 Change	
			VOCs	1,4-Dioxane	Select Metals**	Hexavalent Chromium	SVOCs	PFAS			
Plant 3											
Storm Sewer											
P3-MH-284	-	-						Q	PFAS sewer monitoring	Incorporating into IGMP	
P3-MH-NE	-	-						Q	PFAS sewer monitoring, typically dry, no sample	Incorporating into IGMP	

Notes:

Wells shown in gray shading are part of biosparge performance monitoring, not part of previous formal IGMP submission. Additional details included in Table 7.

* Site wide gauging to alternate between semi-annual events to account for seasonal variability. Semi-annual gauging includes all wells sampled semi-annually.

** Select metals includes arsenic, nickel, lead, vanadium, chromium, and copper.

(1) - Analyzed for 1,4-dioxane via low-level USEPA Method 522

ft bgs = feet below ground surface

Q = quarterly

SA = semi-annual

A = annual

B = biennial (starting 2nd quarter of 2020)

Qd = Quadrennial

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte					Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	Select Metals**	SVOCs	PFAS		
Plant 6									
Perched									
MW-02-02(6)	35-45	SA	B	A		Qd		perched 1,4-dioxane monitoring, SVOC evaluation	SVOCs: sampling frequency decrease to quadrennial, location is delineated but will still be monitored
MW-03-02	30-40	SA						groundwater elevation monitoring	
MW-03-04	33-43	SA						groundwater elevation monitoring	
MW-03-05	35-45	SA	B	A				perched 1,4-dioxane sentinel	
MW-03-06	30-40	SA	B	A				perched 1,4-dioxane sentinel	
MW-03-08	35-45	SA						perched VOC monitoring	VOCs: remove VOCs sampling - has always been non-detect for VOCs
MW-04-05(6)	20-30	SA	SA				A	perched PFAS sentinel	VOCs: added VOCs analysis
MW-12-10R	10-15	SA					A	groundwater elevation monitoring, PFAS	
MW-12-11	13-18	SA					A	PFAS Sentinel	
MW-12-12	13-18	SA					SA	PFAS monitoring	Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: sampling frequency decrease from Q to SA - stable to decreasing trend
MW-12-13	18.5-23.5	SA			Qd		SA	PFAS monitoring	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work Select metals: sampling frequency decrease from A to Qd, location is delineated but will still be monitored PFAS: sampling frequency decrease from Q to SA - stable to decreasing trend
MW-12-14	25-30	SA						groundwater elevation monitoring	
MW-12-15	18-23	-						Potential PFAS Monitoring if needed/ No gauging necessary	
MW-12-16	28-33	SA						boundary monitoring	
MW-13-35	25-30	-						Potential PFAS Monitoring if needed/ No gauging necessary	
MW-13-36R	5.5-10.5	SA			Qd		SA	PFAS monitoring	Gauging: decrease gauging frequency to be part of annual site-wide event Select metals: sampling frequency decrease from A to Qd, location is delineated but will still be monitored PFAS: sampling frequency decrease from Q to SA - stable to decreasing trend
MW-14-66	14-19	SA			Qd			metals sentinel	Select metals: sampling frequency decrease from B to Qd, no criteria exceedances
MW-14-67	13-18	SA			Qd		A	metals/PFAS sentinel	Gauging: decrease gauging frequency to be part of annual site-wide event Select metals: sampling frequency decrease from B to Qd, no criteria exceedances PFAS: sampling frequency decrease from Q to A – stable trend, redundant with other locations in the area
MW-14-69	41-46	SA						groundwater elevation monitoring	
MW-14-70	16-21	SA					A	PFAS Sentinel	Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: sampling frequency decrease from Q to A – stable trend, redundant with other locations in the area
MW-20-131	5-10	SA	SA				SA	PFAS monitoring	New well installed in 4Q 2020.
MW-20-132	6-11	SA	SA				SA	PFAS monitoring	New well installed in 4Q 2020.
MW-21-133	10-15	SA					SA	PFAS monitoring	New well installed in 2Q 2021.

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte					Primary Function	Reason(s) for 2023 Change	
			VOCs	1,4-Dioxane	Select Metals**	SVOCs	PFAS			
Plant 6										
MW-21-134	11-16	SA					SA	PFAS monitoring	New well installed in 2Q 2021.	
MW-21-135	22-27	SA					SA	PFAS monitoring	New well installed in 2Q 2021.	
MW-21-136	9-14	SA					A	PFAS monitoring	New well installed in 2Q 2021 PFAS: sampling frequency decrease from SA to A - no PFAS exceedances	
MW-21-137	7-12	SA					A	PFAS monitoring	New well installed in 2Q 2021 PFAS: sampling frequency decrease from SA to A – consistent non-detects	
MW-21-138	24-29	SA					A	PFAS monitoring	New well installed in 2Q 2021 PFAS: sampling frequency decrease from SA to A – consistent non-detects	
MW-22-143	26-31	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-144	19.5-24.5	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-145	10.5-15.5	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-146	5.5-10.5	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-147	7.5-12.5	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-148	24.5-29.5	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-149	5.5-10.5	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-150	13-18	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-151	13-18	SA					Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	
MW-22-152	10-15	SA	SA				Q	PFAS monitoring	New well installed in 1Q 2022 Gauging: decrease gauging frequency to be part of annual site-wide event PFAS: will be sampled quarterly for minimum 4 quarters or until establishing trends, then may decrease frequency if applicable	

Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte					Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	Select Metals**	SVOCs	PFAS		
Plant 6									
MW-22-154	16-11	SA	Q					VOCs monitoring	New well installed in 3Q 2022. Installed in Osborn Park for VC monitoring (NE of P6 gate).
MW-22-158	16-21	SA					Q	PFAS monitoring	New well installed in 4Q 2022. Installed east of Plant 6 for off-site PFAS monitoring.
MW-22-159	26-31	SA					Q	PFAS monitoring	New well installed in 4Q 2022. Installed east of Plant 6 for off-site PFAS monitoring.
MW-22-160	14-19	SA					Q	PFAS monitoring	New well installed in 4Q 2022. Installed east of Plant 6 for off-site PFAS monitoring.
MWBP-10-UST5-6	28-38	SA			Qd			VOCs/metal monitoring	VOCs: remove VOCs sampling - has always been non-detect for VOCs Select metals: sampling frequency decrease from B to Qd, location is delineated but will still be monitored
MWBP-11-UST1-4	9-19	SA			Qd			VOCs/metal monitoring	VOCs: remove VOCs sampling - no VOCs exceedances Select metals: sampling frequency decrease from B to Qd, location is delineated but will still be monitored
MWBP-12-UST1-4	15-25	SA	B		Qd	Qd		VOCs/metal monitoring, SVOC evaluation	Select metals: sampling frequency decrease from B to Qd, location is delineated but will still be monitored SVOCs: location is delineated but will still be monitored
P6-MW-01	23-28	SA						groundwater elevation monitoring	
P6-SB-07	15-20	SA				Qd	A	PFAS monitoring	Gauging: decrease gauging frequency to be part of annual site-wide event SVOCs: location is delineated but will still be monitored PFAS: sampling frequency decrease from Q to A – stable trend
P6-SB-18	3-8	SA						groundwater elevation monitoring	
P6-SB-21	3-8	SA						groundwater elevation monitoring	
P6-SB-35	3-8	SA						groundwater elevation monitoring	
P6-SB-37	5-10	SA						groundwater elevation monitoring	
Deep Overburden and Weathered Bedrock									
MW-13-52	70-80	SA		B				lower 1,4-dioxane sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work 1,4-D: sampling frequency decrease from A to B - has always been non-detect for 1,4-D
MW-13-53	73-83	SA						lower 1,4-dioxane sentinel	1,4-D: remove 1,4-D sampling - has always been non-detect for 1,4-D
MW-21-141	72-77	SA		SA				lower 1,4-dioxane sentinel	New well installed in 4Q 2021
Bedrock									
MW-04-01(6)	78-88	SA		B				bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-04-04R	82-110	SA		B			A	bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-04-06R	74-99.5	SA		B			A	bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work
MW-12-03	57-80	SA						groundwater elevation monitoring	
MW-13-50	85-107	SA		B				bedrock sentinel	Gauging: increase gauging frequency to be part of semi-annual gauging event for bedrock/weathered bedrock GWEC work

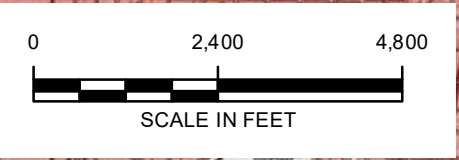
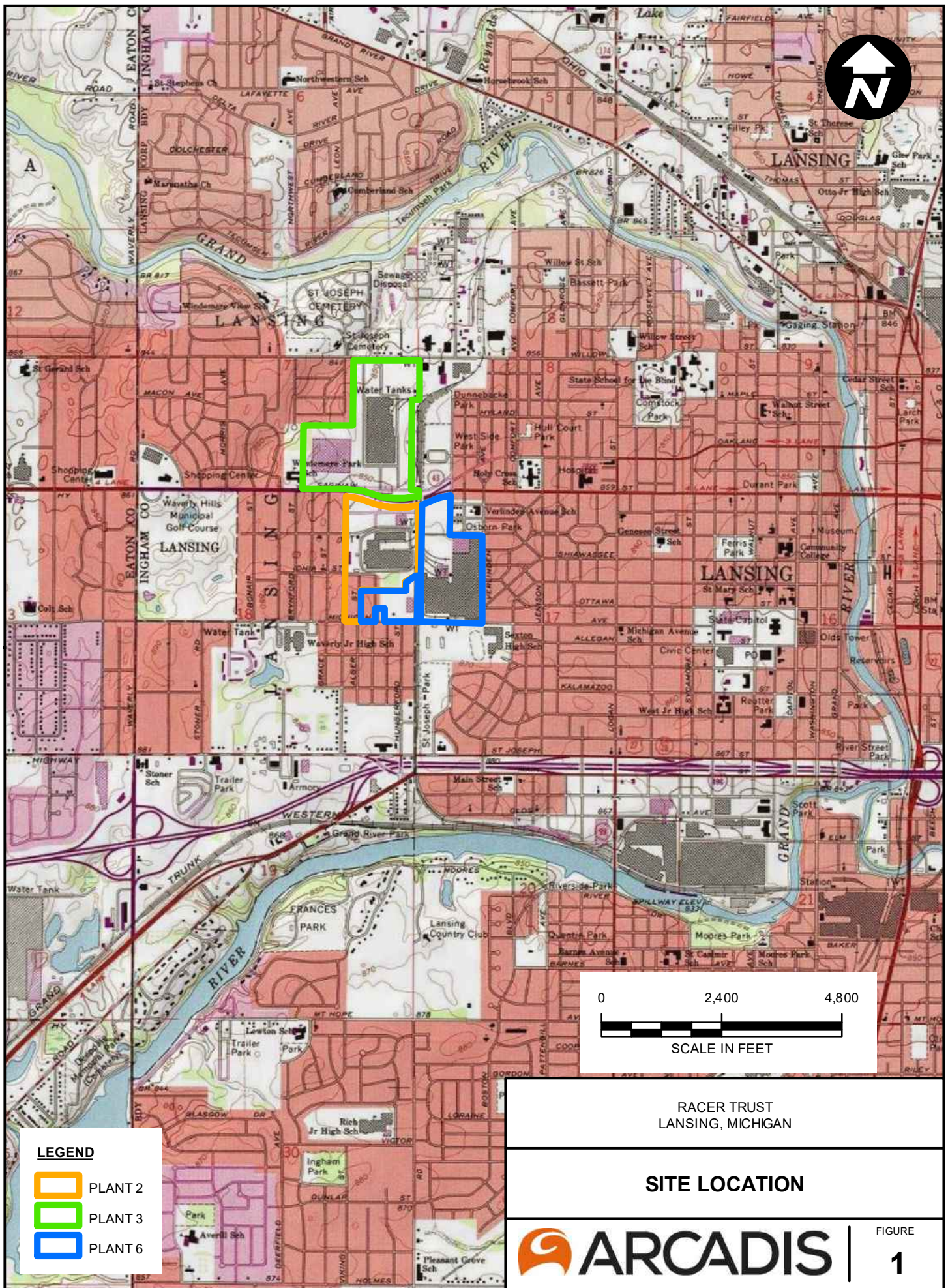
Table 1
Revised Interim Groundwater Monitoring Summary
Revised December 2022
RACER Trust Plants 2, 3, and 6 - Lansing, Michigan



Well	Screen Interval (ft bgs)	Gauging*	Analyte					Primary Function	Reason(s) for 2023 Change
			VOCs	1,4-Dioxane	Select Metals**	SVOCs	PFAS		
Plant 6									
Storm Sewer									
Osborn-MH-1	-	-					Q	PFAS sewer monitoring	Incorporating into IGMP
Verlinden-MH-1	-	-						PFAS sewer monitoring	Incorporating into IGMP PFAS: removing from list and drains to Verlinden-MH-5
Verlinden-MH-2	-	-						PFAS sewer monitoring	Incorporating into IGMP PFAS: removing from list and drains to Verlinden-MH-5
Verlinden-MH-3	-	-						PFAS sewer monitoring	Incorporating into IGMP PFAS: removing from list and drains to Verlinden-MH-5
Verlinden-MH-4	-	-						PFAS sewer monitoring	Incorporating into IGMP PFAS: removing from list and drains to Verlinden-MH-5
Verlinden-MH-5	-	-					Q	PFAS sewer monitoring	Incorporating into IGMP
MichAve-MH-3	-	-					Q	PFAS sewer monitoring	Incorporating into IGMP
MichAve-MH-4	-	-						PFAS sewer monitoring	Incorporating into IGMP PFAS: removing from list and drains to Verlinden-MH-5

Notes:
* Site wide gauging to alternate between semi-annual events to account for seasonal variability. Semi-annual gauging includes all wells sampled semi-annually.
** Select metals includes arsenic, nickel, lead, vanadium, chromium, and copper.
***TAL metals defined in Table 3 of the Quality Assurance Project Plan (ARCADIS 2011b).
ft bgs = feet below ground surface
Q = quarterly
SA = semi-annual
A = annual
B = biennial (starting 2nd quarter of 2020)
Qd = Quadrennial

Figures

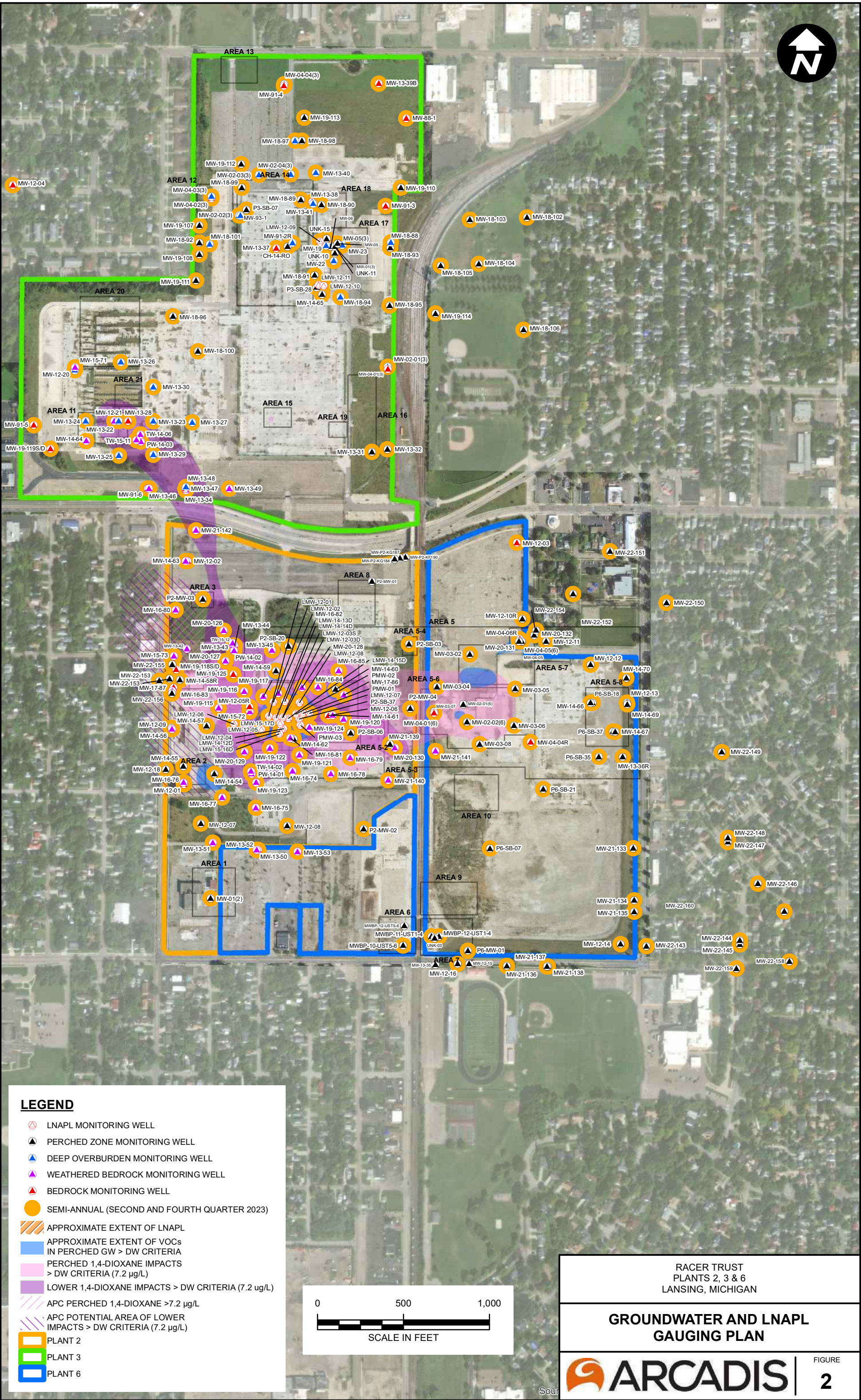


LEGEND

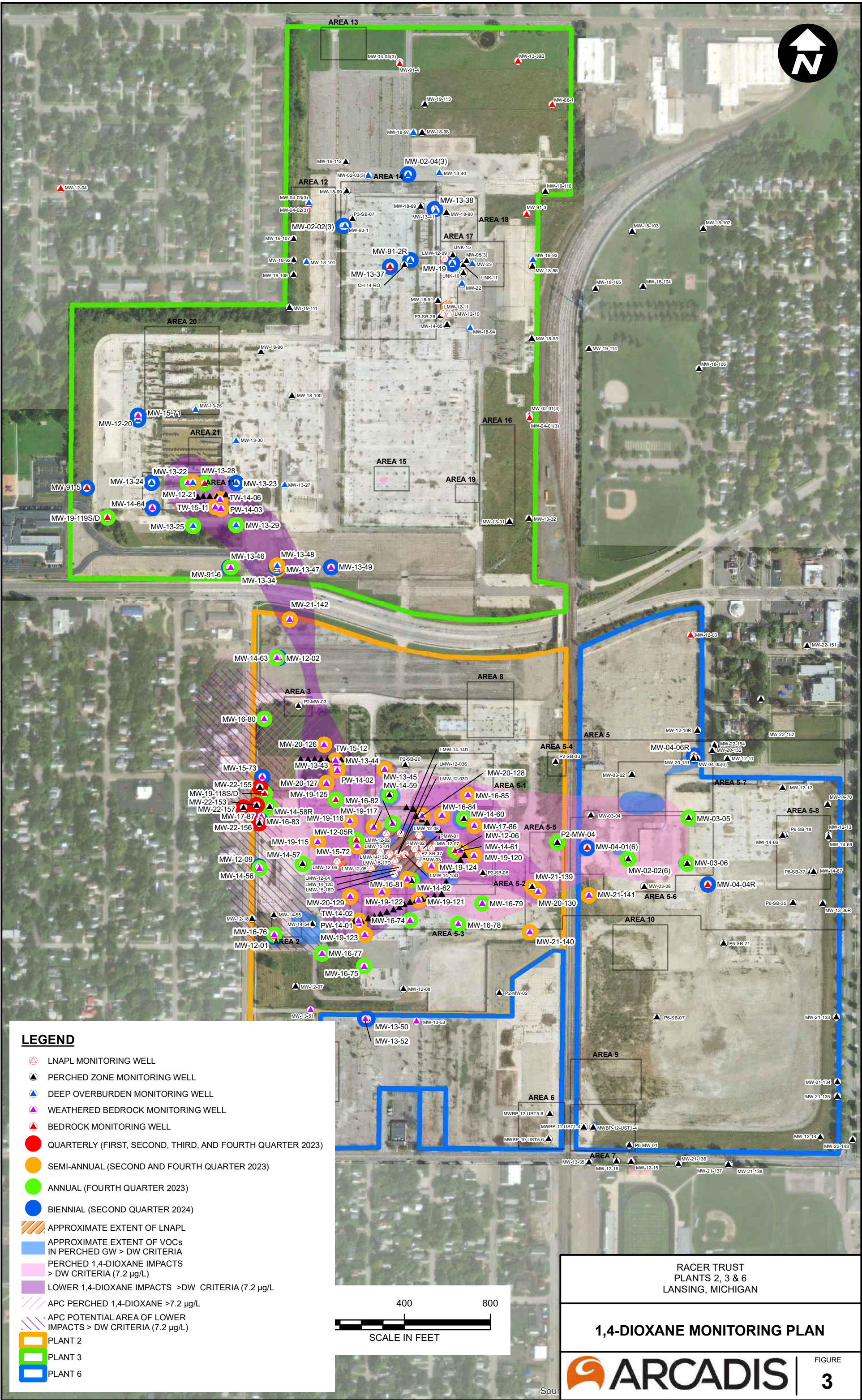
-  PLANT 2
-  PLANT 3
-  PLANT 6

RACER TRUST LANSING, MICHIGAN	
SITE LOCATION	
 ARCADIS	FIGURE 1

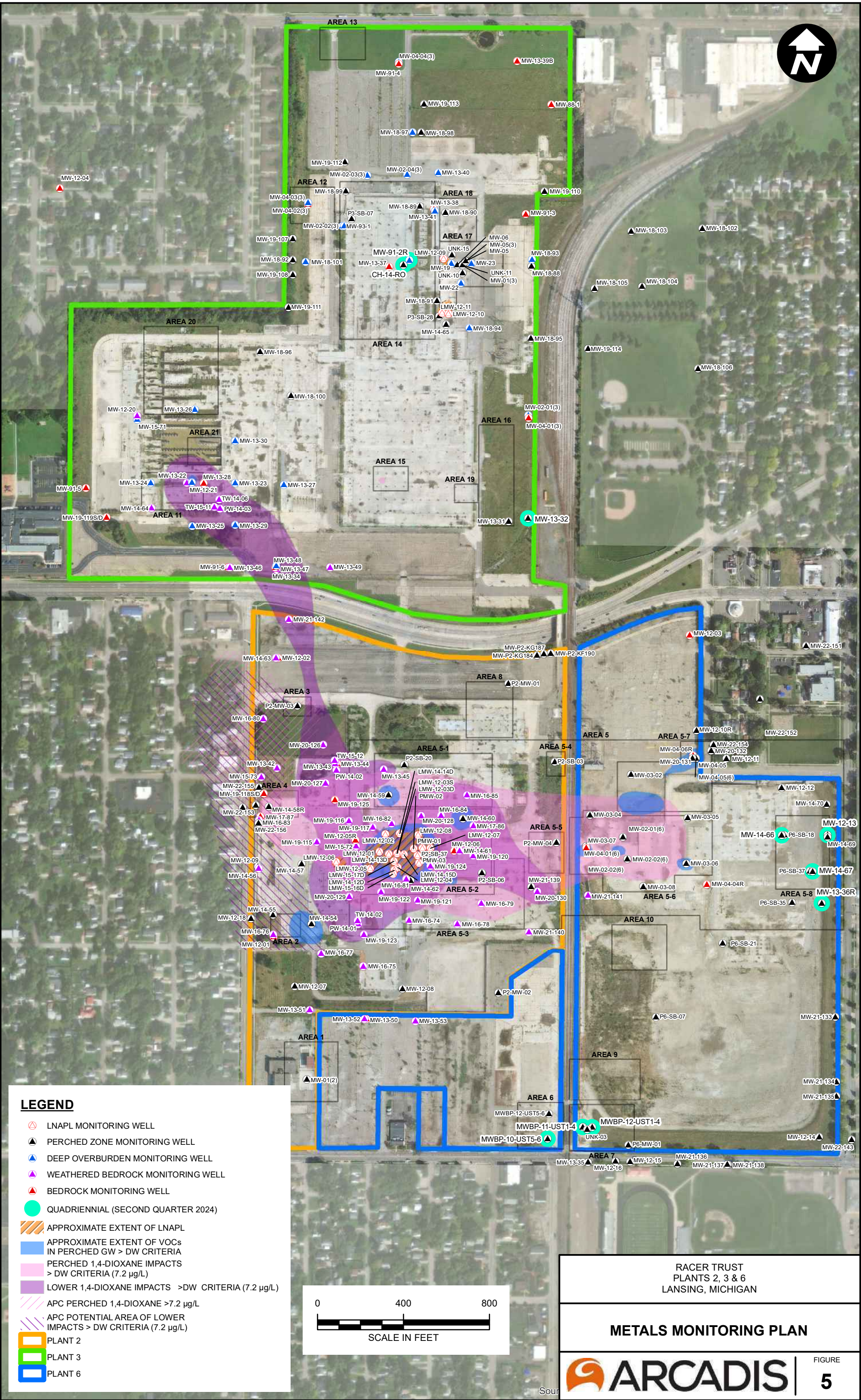
CITY: KNOXVILLE DIV: ENV DB: A SMITH PIC: J BARRETT PM: T LINDER TM: A VILLHAUER TR: PROJECT NUMBER: 30112892 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl
T:_ENV\RACER\Buffalo\WDXds\2022 IGMP Plan\Fig 2 - Gauging IGMP Plan.mxd PLOTTED: 5/8/2023 3:04:02 PM BY: V Davis



CITY: KNOXVILLE DIV: ENV DB: A SMITH PIC: J BARRETT PM: T LINDER TM: A VILLHAUER TR: PROJECT NUMBER: 30112892 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl
T:_ENV\RACER\Buffalo\WDXds\2022 IGMP Plan\Fig 3 - 1,4-Dioxane IGMP Plan.mxd PLOTTED: 5/8/2023 3:02:09 PM BY: VDavis

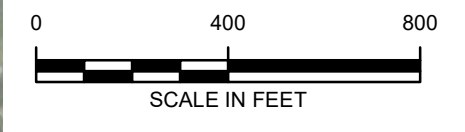


CITY: KNOXVILLE DIV: ENV DB: A SMITH PIC: J BARRETT PM: T LINDER TM: A VILLHAUER TR: PROJECT NUMBER: 30112892 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl
T:_ENV\RACER\Buffalo\WDXs\2022 IGMP Plan\Fig 5 - Metals IGMP Plan.mxd PLOTTED: 5/8/2023 2:59:34 PM BY: V Davis



LEGEND

- LNAPL MONITORING WELL
- PERCHED ZONE MONITORING WELL
- DEEP OVERBURDEN MONITORING WELL
- WEATHERED BEDROCK MONITORING WELL
- BEDROCK MONITORING WELL
- QUADRIENNIAL (SECOND QUARTER 2024)
- APPROXIMATE EXTENT OF LNAPL
- APPROXIMATE EXTENT OF VOCs IN PERCHED GW > DW CRITERIA
- PERCHED 1,4-DIOXANE IMPACTS > DW CRITERIA (7.2 µg/L)
- LOWER 1,4-DIOXANE IMPACTS >DW CRITERIA (7.2 µg/L)
- APC PERCHED 1,4-DIOXANE >7.2 µg/L
- APC POTENTIAL AREA OF LOWER IMPACTS > DW CRITERIA (7.2 µg/L)
- PLANT 2
- PLANT 3
- PLANT 6



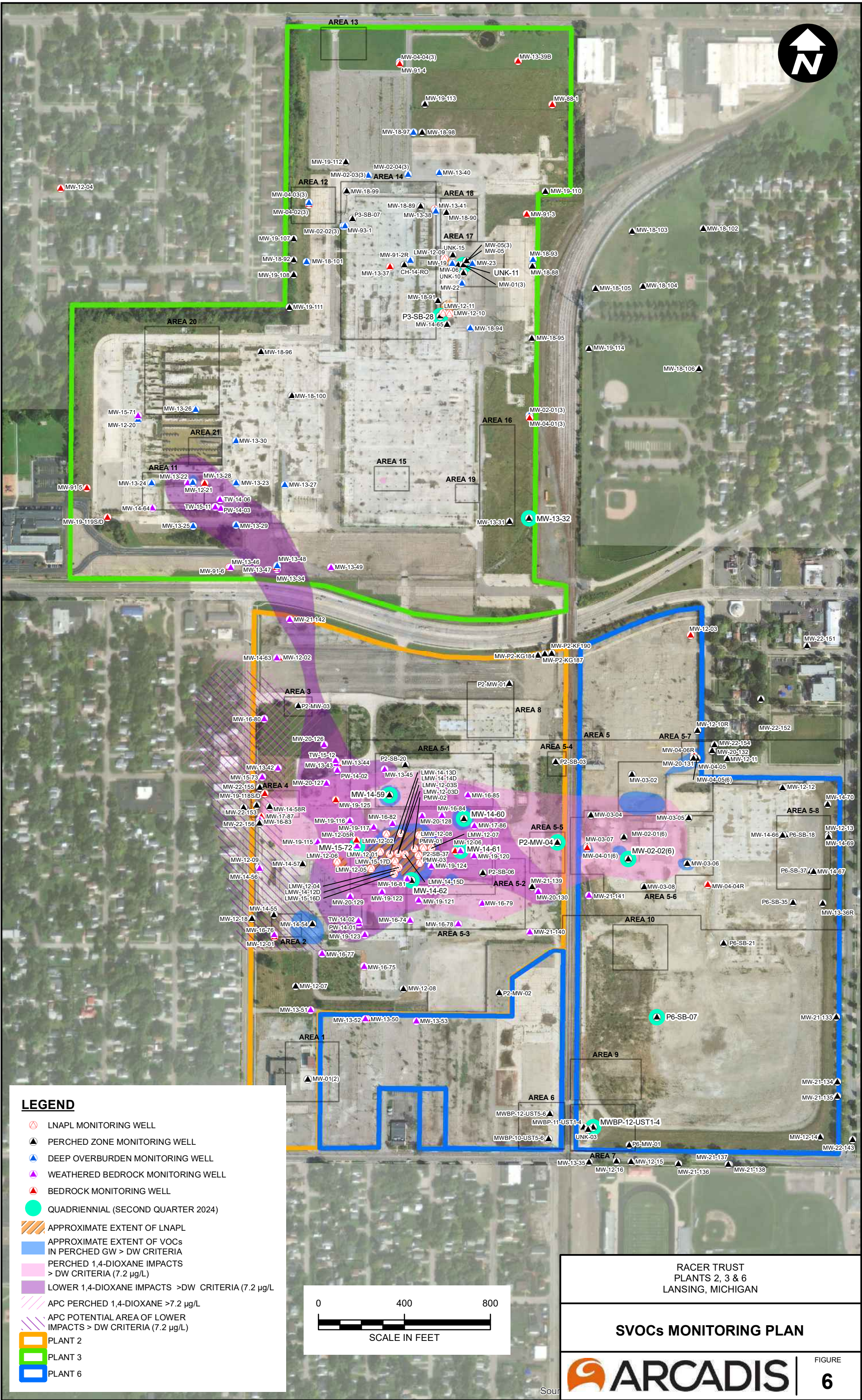
RACER TRUST
PLANTS 2, 3 & 6
LANSING, MICHIGAN

METALS MONITORING PLAN

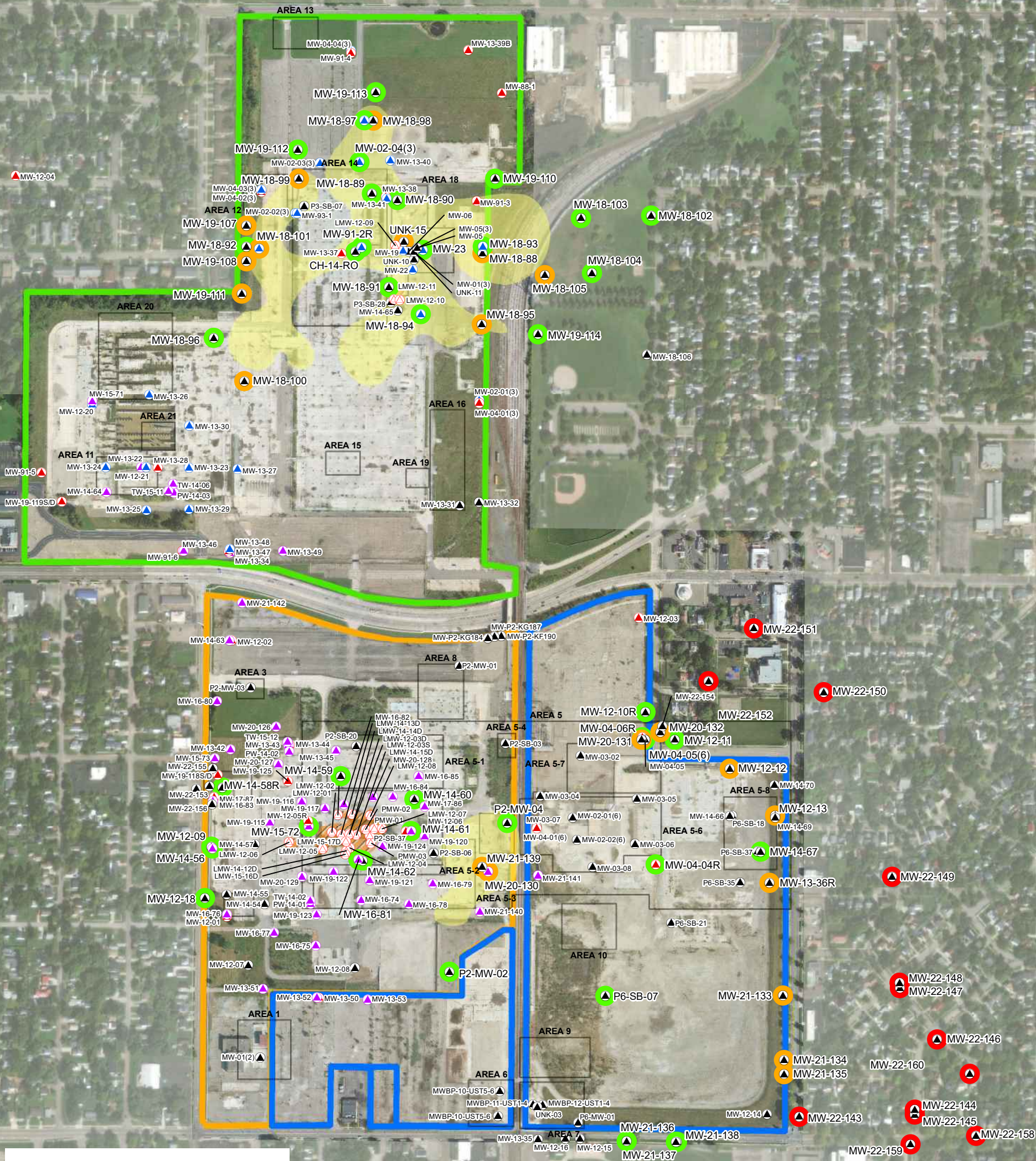
ARCADIS

FIGURE
5

CITY: KNOXVILLE DIV: ENV DB: A SMITH PIC: J BARRETT PM: T LINDER TM: A VILLHAUER TR: PROJECT NUMBER: 30112892 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl
T:_ENV\RACER\Buffalo\MXDs\2022 IGMP Plan\Fig 6 - SVOCs IGMP Plan.mxd PLOTTED: 5/8/2023 2:50:10 PM BY: V Davis



CITY: KNOXVILLE DIV: ENV DB: A SMITH PIC: J BARRETT PM: T LINDER TM: A VILLHAUER TR: PROJECT NUMBER: 30112892 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl
T:\ENV\RACER\Buffalo\WDXs\2022 IGMP Plan\Fig 7 - PFAs IGMP Plan.mxd PLOTTED: 5/8/2023 2:55:27 PM BY: VDavis

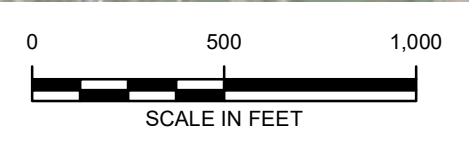


LEGEND

- LNAPL MONITORING WELL
- PERCHED ZONE MONITORING WELL
- DEEP OVERBURDEN MONITORING WELL
- WEATHERED BEDROCK MONITORING WELL
- BEDROCK MONITORING WELL
- QUARTERLY (FIRST, SECOND, THIRD, AND FOURTH QUARTER 2023)
- SEMI-ANNUAL (SECOND AND FOURTH QUARTER 2023)
- ANNUAL (FOURTH QUARTER 2023)
- APPROXIMATE EXTENT OF PFOS EXCEEDING GSI CRITERIA OF 12 ng/L
- APPROXIMATE EXTENT OF LNAPL
- PLANT 2
- PLANT 3
- PLANT 6

NOTES:

ADDITIONAL WELLS TO BE ADDED FOLLOWING PLANT 6 PFAS CHARACTERIZATION ACTIVITIES.



RACER TRUST
PLANTS 2, 3 & 6
LANSING, MICHIGAN

PFAS MONITORING PLAN



FIGURE

7

CITY: Novi DIV: ENV PIC: J. BARRETT PM: T. LINDER TR: J. SALING PROJECT NUMBER: 30112892 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl
T:_ENV\RACER\Buffalo\MXDs\2022 P2 P3 P6 Storm Sewer Modifications Completion Report\Figure 1 - Site Location_08302022.mxd PLOTTED: 8/30/2022 4:11:42 PM BY: KPullen



LEGEND

- STORMWATER MANHOLE - SAMPLED QUARTERLY IF DISCHARGING
- STORMWATER MANHOLE TO DISCONTINUE SAMPLING

PLANT BOUNDARIES

- PLANT 2
- PLANT 3
- PLANT 6



NOTE: AERIAL IMAGERY FROM ESRI ARCGIS ONLINE.

RACER TRUST
PLANTS 2, 3 & 6
LANSING, MICHIGAN

STORM SEWER MONITORING PLAN



Attachment 1

PFAS Sampling Guidance

TGI – Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

Rev: 3

Rev Date: April 5, 2023

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	October 12, 2018	All	Updated and re-written as TGI with new branding and content	Marc Killingstad
	1	May 8, 2020	Pages 5, 10-11	Added clarification/details for equipment requirements and procedure steps based on USEPA guidance	Marc Killingstad
	2	April 5, 2022	All	Updated to new branding template and minor edits	Marc Killingstad
	3	April 5, 2023	All	Annual review completed by SME. Document version number and document date updated.	Marc Killingstad

Approval Signatures

Prepared by:

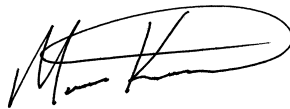
4/5/2023



Xuan Xu (Preparer)

Date

Reviewed by:



4/5/2023

Marc Killingstad (Subject Matter Expert)

Date

1 Introduction

Groundwater samples are collected from monitoring wells to evaluate groundwater quality. The protocol presented in this Technical Guidance Instruction (TGI) describes the procedures to purge monitoring wells and collect groundwater samples using the low flow purging/sampling methodology. This protocol has been developed in accordance with the United States Environmental Protection Agency (USEPA) Region I *Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells* (EQASOP-GW4; September 19, 2017).

2 Intended Use and Responsibilities

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 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 is 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, regulation-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.

3 Scope and Application

Both filtered and unfiltered groundwater samples may be collected using this low-flow sampling method. Filtered samples will be obtained using a 0.45-micron disposable filter. Project teams will evaluate the last time the monitoring wells were developed and determine if additional development might be necessary. Water samples will not be taken immediately following well development. Sufficient time will be allowed for the groundwater flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well

construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

4 Personnel Qualifications

Arcadis field sampling 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 identified in the site-specific Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilizing to the field, the groundwater sampling team will review and be thoroughly familiar with relevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP)/field sampling plan, Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field sampling 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. Additionally, the groundwater sampling team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization.

5 Equipment List

Specific to this activity, the following materials (or equivalent) will be used:

- Site-specific HASP and health and safety documents identified in the HASP
- Field Implementation Plan (FIP) that includes site map, well construction records, sampling plan (sample analyses, sample volume required, and sample holding time), and prior groundwater sampling records (if available)
- Field notebook and/or smart device (phone or tablet)
- Low-flow sampling field forms (**Attachment A**)
- Appropriate personal protective equipment (PPE) (e.g., latex or nitrile gloves, safety glasses, etc.) as specified in the HASP
- Well keys and other tools to remove manhole covers (manual torque wrench with 9/16" socket and flat head screwdriver typical)
- Photoionization detector (PID) or Flame ionization detector (FID) (as appropriate, depending on site-specific constituents of concern)
- Electronic water-level indicator (e.g., Solinst Model 101) or oil/water interface probe with 0.01- foot accuracy (oil/water as appropriate, note that sampling will not be performed when sheen or light non-aqueous phase liquid [LNAPL] is present)
- Down-hole multi-parameter water-quality sonde (temperature/pH/specific conductivity/oxidation reduction [ORP]/turbidity/dissolved oxygen) meter coupled with flow-through-cell for measurements, for example:

- YSI 6-Series Multi-Parameter Instrument
- Horiba U-22 Multi-Parameter Instrument.
- Hydrolab Series 3 or Series 4a Multiprobe and Display.

NOTE: *Transparent, small volume flow-through-cells (e.g., 250 milliliters or less) are preferred as they allow for easy detection of air bubbles and sediment buildup in the cell, which can interfere with the monitoring instrument probes. A small volume cell also allows for quick turnover of water in the cell between measurements of the indicator field parameters. It is recommended to use a flow-through-cell and monitoring probes from the same manufacturer and model to avoid incompatibility between the probes and flow-through-cell.*

- Plastic sheeting (e.g., Weatherall Visqueen) to protect all down-hole sampling equipment from contact with potential sources of contamination.
- Decontamination equipment
 - Non-phosphate laboratory soap (Alconox or equivalent), brushes, and clean buckets, and/or clean wash tubs—new buckets or tubs will be purchased if it cannot be determined if the present items are clean
 - Distilled or de-ionized water for equipment decontamination
- Indelible ink pen
- 150-foot measuring tape (or sufficient length for the maximum site depth requirement)
- Sampling pump, which may consist of one or more of the following:
 - Submersible pump (e.g., Grundfos Redi-Flo 2)
 - Peristaltic pump (e.g., ISCO Model 150)
 - Bladder pump (e.g., Marschalk System 1, QED Micropurge, Geotech)
- Appropriate controller and power source for pump:
 - Submersible and peristaltic pumps require electric power from either a generator or a deep cell battery
 - Submersible pumps such as Grundfos require a pump controller to run the pump
 - Bladder pumps require a pump controller and a gas source (e.g., air compressor or compressed N₂ or CO₂ gas cylinders)
- Teflon® tubing or Teflon®-lined polyethylene tubing of an appropriate size for the pump being used
 - For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) will be used through the pump apparatus
 - Teflon® will not be used when sampling for per- and polyfluoroalkyl substances (PFAS)
- Graduated cylinder and stopwatch or other device to measure time to determine pumping rate
- Appropriate water sample containers (supplied by the laboratory)
- Appropriate blanks (trip blank supplied by the laboratory)
- Sample labels and Chain-of-Custody forms (COC)
- 0.45-micron disposable filters (if field filtering is required)

- A supplemental turbidity meter (e.g., Horiba U-10, Hach 2100P, LaMotte 2020) may be required for specific projects and will be specified in the project FIP/ work plan and the kick-off notes.
 - If used, in-line 'T' and valve allows for collection of water for turbidity measurements before the pump discharge enters the flow-through cell

NOTE: The maintenance requirements for the above equipment generally involve decontamination or periodic cleaning, battery charging, and proper storage, as specified by the manufacturer. For operational difficulties, the equipment will be serviced by a qualified technician.

6 Cautions

Different USEPA regions and/or state regulatory agencies may stipulate deviations from this document. It is the responsibility of the Project Team (Project Manager and Technical Lead) to be fully aware of the requirements from the applicable regulatory framework.

Weather

- If heavy precipitation occurs, and no cover over the sampling area and monitoring well can be erected, sampling may be discontinued until adequate cover is provided. Rainwater could compromise groundwater samples.
- Avoid extreme weather situations. Be aware that thermal currents and vertical mixing of cold and warm water inside the well casing could create a convection cell within the well and compromise data collection (e.g., biological mechanisms).
 - Direct sunlight and hot ambient temperatures may cause the groundwater in the tubing or flow-through-cell to heat up and de-gas. This may result in the loss of volatile organic compounds (VOCs) and dissolved gases. Shade the equipment from direct sunlight, keep the tubing as short as possible and avoid the hottest times of the day.
 - Sampling during freezing conditions may adversely impact the data quality objectives. USEPA recommends low-flow sampling be conducted at air temperatures above 32°F (0°C) or taking special precautions to prevent groundwater from freezing in the equipment.

Cross-Contamination

- To mitigate potential cross-contamination, groundwater samples are to be collected in a pre-determined order from least impacted to impacted based on previous analytical data. If no analytical data are available, collect samples in order of up-gradient, then furthest down-gradient to source area locations.
- Note that permanent markers could introduce volatile constituents into the samples; *therefore, indelible ink is recommended* to be used for labels on sample containers or sample coolers.
- When using a gasoline generator, this power source will be set-up at least 30 feet downwind from the well to avoid exhaust fumes to contaminate samples.

Pumps

- Preferred methods of extracting groundwater are adjustable rate, submersible pumps - such as centrifugal pumps or bladder pumps – constructed of stainless steel or polytetrafluoroethylene (PTFE, i.e., Teflon®). However, *PTFE will not be used when sampling for per- and polyfluoroalkyl substances (PFAS). PTFE could contain PFAS.*

- When using a bladder pump for collecting VOCs and dissolved gases, “best practice” is to set-up the pump to deliver sufficient water to fill a 40 mL VOC vial.
- The use of peristaltic pumps will be based on the type of data to be collected. *Because the use of a peristaltic pump can result in de-gassing of VOC and / or dissolved gases from groundwater, a different type of pump will be considered if these compounds are of concern.*
- *Manual or motor driven inertial pumping devices are not recommended because they cause greater disturbance during purging and pumping than regular pumps and are less easily controlled. This could cause a higher degree of data variability.*

Tubing

- When sampling for VOCs, SVOCs, pesticides, PCBs and inorganics, use of PTFE (Teflon®) or PTFE-lined tubing is preferred. However, PTFE tubing will not be used when sampling for PFAS.
- PVC, polypropylene or polyethylene tubing may be used when sampling for metals or other inorganics.
- Tubing with inside diameters of 1/4 or 3/8 inch is recommended because this will help ensure tubing remains water filled when operating at very low pumping rates.

General Precautions

- Store and/or stage empty and full sample containers and coolers out of direct sunlight.
- It may be necessary to field filter the groundwater for some parameters (e.g., metals) during collection, depending on preservation, analytical method, and project quality objectives. The task-kick-off notes and the FIP/work plan will list the samples that require field filtering.
- Be careful not to overtighten lids with Teflon® liners or septa (e.g., 40 mL vials). Over-tightening can cause the glass to shatter or impair the integrity of the Teflon® seal.

7 Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel.

Appropriate personal protective equipment (PPE) will be always worn in line with the task and the site-specific 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.

Access to wells may expose field personnel to hazardous materials such as contaminated groundwater or non-aqueous phase liquid (NAPL) (e.g., oil). Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biologic hazards (e.g. ticks in long grass/weeds around well head), and potentially the use of sharp cutting tools (scissors, knife)—open well caps slowly and keep face and body away to allow to vent any built-up pressure; only use non-toxic peppermint oil spray for stinging insect nests; review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives, and use appropriate hand protection.

Generators and cord and plug equipment will employ an overcurrent protection device such as an integrated ground fault circuit interrupter (GFCI) cord. Grundfos pump controllers will not run properly with a GFCI, so the power source will be equipped with other overcurrent protection means.

Overtightening of lids with Teflon® liners can cause the glass to shatter and create a risk for hand injuries.

8 Procedure

Field personnel will set up and perform low-flow sampling in accordance with the following procedures.

1. Review FIP and groundwater sampling records from previous sampling events (if available) prior to mobilization to estimate the optimum pumping rate and anticipated drawdown for each well to perform sampling as efficiently as possible (i.e., reach a stabilized pumping condition).
2. Calibrate field instruments according to manufacturer procedures for calibration and record calibration procedure and results in field log.
3. All equipment will either be new or decontaminated in accordance with appropriate guidance document (*TGI – Groundwater and Soil Sampling Equipment Decontamination*) prior to use.
4. Visually inspect the well to ensure that it is undamaged, properly labeled and secured
 - a. Damage or other conditions that may affect the integrity of the well will be recorded in the Field Activity Daily Log and brought to the attention of the designated Field Manager and/or Project Manager
 - b. Record well construction and conditions on the Low-Flow Sampling Field Form (**Attachment A**).
5. Place clean plastic sheeting on the ground near the well to keep monitoring and sampling equipment off the surface unless the equipment is elevated above the ground (e.g., on a table).
6. Open the well cover while standing upwind of the well. Remove the well cap and place it on the plastic sheeting. If appropriate or required for site-specific conditions, insert the photoionization detector (PID) probe approximately 4 to 6 inches into the casing or the well headspace and cover it with a gloved hand. Record the PID reading in the field log. Perform air monitoring in the breathing zone according to the HASP and/or JSA.
7. Measure and record the initial depth to groundwater prior to placing the pumps.
8. Prepare and install the pump in the well.

NOTE: Groundwater will be purged from the wells using an appropriate pump. If the depth to water is below the sampling range of a peristaltic pump (approximately 25 feet below ground surface), a submersible or bladder pump will be used, provided that the well is constructed with a casing diameter of at least two (2) inches (the minimum well diameter capable of accommodating such pumps). For smaller diameter wells, where the depth to water is below the sampling range of a peristaltic pump, alternative sampling methods (i.e., bailing or small diameter bladder pumps) will be used to purge and sample the groundwater. Bladder pumps are preferred over peristaltic and submersible pumps to prevent volatilization if sampling of VOCs and/or dissolved gasses is required. Purge water will be collected and containerized according to the direction of the project team.

- a. For submersible and non-dedicated bladder pumps, decontaminate the pump according to site decontamination procedures. Non-dedicated bladder pumps will require a new bladder and attachment of an air-line, sample discharge line, and safety cable prior to placement in the well. Attach the air-line tubing to the air-port on the top of the bladder pump. Attach the sample discharge tubing to the water port on the top of the bladder pump. Take care not to reverse the air and discharge tubing lines during bladder pump setup, as this could result in bladder failure or rupture. Attach and secure a safety cable to the eyebolt on the top of pump (if present, depending on pump model used). Slowly lower the pump, safety cable, tubing, and electrical lines into the well to a depth corresponding to the approximate center of the saturated screen section of the well. Avoid twisting

and tangling of safety cable, tubing, and electrical lines while lowering the pump into the well; twisted and tangled lines could result in the pump becoming stuck in the well casing. Also, make sure to keep tubing and lines from touching the ground or other surfaces while introducing them into the well, as this could lead to unintended contamination.

- b. If using a bladder pump, connect the air-line to the pump controller output port. The pump controller will be connected to a supply line from an air compressor or compressed gas cylinder using an appropriate regulator and air hose. Tighten the regulator connector onto the gas cylinder (if used) to prevent leaks. Teflon® tape may be used on the threads of the cylinder to provide a tighter seal. Once the air compressor or gas cylinder is connected to the pump controller, turn on the compressor or open the valve on the cylinder to begin the gas flow. Turn on the pump controller power (if an on/off switch is present) and verify that all batteries are charged and fully functioning before starting the pump.
 - c. If a peristaltic pump is being used, slowly lower the sampling tubing into the well to a depth corresponding to the approximate center of the saturated screen section of the well. The pump intake or sampling tube must be kept at least two (2) feet above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.
 - d. If using an in-line 'T' and valve, install between pump discharge water line and the bottom inlet port of the flow-through cell. Attach a short piece of tubing to the outlet. This set-up will be used to collect samples for turbidity readings.
9. Connect the pump discharge water line to the bottom inlet port on the flow-through cell connected to the multi-parameter water-quality sonde and make sure to record equipment/instrument identification (manufacturer and model number).
10. Before starting the pump, ensure that the water level inside the well has stabilized (i.e., measure the water level multiple times after deploying the pump in the well).
11. Start pumping the well at 200 to 500 milliliters (mL) per minute (or at lower site-specific rate if specified) and adjust the pumping rate to cause little or no water level drawdown in the well (less than 0.3 feet below the initial static depth to water measurement): the water level should stabilize, however, this is not always possible.
12. If the well diameter is of sufficient size, measure the water level every 3 to 5 minutes (or as appropriate, lower flow rates may require longer time between readings) during pumping.
13. Maintain a steady flow rate to the extent practicable and do not break pump suction or cause entrainment of air in the sample.
14. Record pumping rate adjustments and depths to water.

If necessary, reduce pumping rates to the minimum capabilities of the pump to avoid pumping the well dry and/or to stabilize indicator parameters; if the recharge rate of the well is very low, use alternative purging techniques, which will vary based on the well construction and screen position.

For wells screened across the water table, the well may be pumped dry, and sampling can commence as soon as the volume in the well has recovered sufficiently to permit collection of samples.

For wells screened entirely below the water table, the well can be pumped until a stabilized level (which may be greater than the maximum displacement goal of 0.3 feet) is maintained and monitoring for stabilization of field indicator parameters can commence; if a lower stabilization level cannot be

maintained, the well may be pumped until the drawdown is at a level slightly higher than top of the well screen.

15. After water levels have stabilized and a sufficient volume has been purged (see note below), continue pumping and begin monitoring field indicator parameters using a multi-parameter water-quality sonde coupled with a flow-through-cell.

NOTE: The final purge volume must be greater than the stabilized drawdown volume plus the pump's tubing volume. If the drawdown has exceeded 0.3 feet and stabilizes, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.

16. Use the flow to measure all indicator field parameters, except for turbidity, every 3 to 5 minutes (or after each volume of the flow-through cell has been purged or other appropriate interval); turbidity samples will be collected before the flow-through-cell using the T-valve and a clean container such as a glass beaker.
17. Record field indicator parameters on the groundwater sampling log.
18. The well is considered stabilized and ready for sample collection when three consecutive readings are within the following limits:
- **Turbidity** within $\pm 10\%$ for values greater than 5 nephelometric turbidity units [NTUs] or if three turbidity values are less than 5 NTUs, consider the values stabilized
 - **Dissolved Oxygen (DO)** within $\pm 10\%$ for values greater than 0.5 mg/L or if three DO values are less than 0.5 mg/L, consider the values stabilized
 - **Specific Conductance** within $\pm 3\%$
 - **Temperature** within $\pm 3\%$
 - **pH** within ± 0.1 unit
 - **Oxidation/Reduction Potential (ORP)** within ± 10 millivolts (mV)

NOTE: Alternate stabilization goals may exist in different geographic regions, consult the site-specific FIP/work plan for stabilization criteria).

NOTE: While achieving turbidity levels less than 5 NTU and a stable drawdown of less than 0.3 feet is desirable, sample collection may still take place provided the indicator field parameter criteria in this procedure are met.

19. If the parameters have stabilized but turbidity remains relatively high (e.g., greater than 50 NTUs), the pump flow rate may be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible. If groundwater turbidity has been minimized (i.e., consecutive readings within $\pm 10\%$) and the values for all other parameters have stabilized, the well may be sampled; however, consult specifications in the FIP/work plan and/or the project technical lead prior to sampling.
20. If after one (1) hour of purging indicator field parameters have not stabilized, consult specifications in the FIP/work plan and/or the project technical lead prior to sampling.
- In general, three potential options are available if stabilization criteria are not met:
- a. Continue purging until stabilization is achieved.
 - b. Discontinue purging, do not collect any samples, and record in field logbook/on the sampling form that stabilization could not be achieved (documentation must describe attempts to achieve stabilization).

- c. Discontinue purging, collect samples, and provide full explanation of attempts to achieve stabilization. There is a risk that the analytical data obtained under these conditions, particularly metals and hydrophobic organic analytes, may reflect a sampling bias and, as a result, the data may not meet the data quality objectives of the sampling event.

NOTE: DO is extremely susceptible to various external influences (including temperature or the presence of bubbles on the DO meter); therefore, great care will be taken to minimize the agitation or other disturbance of water within the flow-through cell while collecting these measurements. If air bubbles are present on the DO probe or in the discharge tubing, remove them before taking a measurement. If DO values are not within acceptable range for the temperature of groundwater, again check for and remove air bubbles on the probe before re-measuring. The table below may be used as a general guide for DO values under various temperatures; however, understand that the table corresponds to freshwater solubility and groundwater contaminants may affect oxygen solubility. If DO value is 0.00 or less, then the meter will be serviced and re-calibrated. If DO values are above possible results, then the meter will be serviced and re-calibrated.

NOTE: During extreme weather conditions, stabilization of field indicator parameters may be difficult to attain. Modifications to the sampling procedures to alleviate these conditions (e.g., measuring the water temperature in the well adjacent to the pump intake) will be documented in the field logbook/on the sampling form.

NOTE: If other field conditions are suspected of preventing stabilization of certain parameters, detailed observations will be documented in the field logbook/on the sampling form.

Oxygen Solubility in Fresh Water

Temperature (degrees C)	Dissolved Oxygen (mg/L)
0	14.6
1	14.19
2	13.81
3	13.44
4	13.09
5	12.75
6	12.43
7	12.12
8	11.83
9	11.55
10	11.27
11	11.01
12	10.76
13	10.52
14	10.29
15	10.07
16	9.85
17	9.65
18	9.45
19	9.26
20	9.07
21	8.9
22	8.72
23	8.56
24	8.4
25	8.24
26	8.09
27	7.95
28	7.81
29	7.67
30	7.54
31	7.41
32	7.28
33	7.16
34	7.05
35	6.93

*Reference: Vesilind, P.A., Introduction to
Environmental Engineering, PWS Publishing
Company, Boston, 468 pages (1996)*

21. Complete the sample label(s) and cover the label(s) with clear packing tape to secure the label onto the container.
22. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container.
 - a. If a flow-through analytical cell is being used to measure field parameters, the flow-through cell will be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection.
 - b. Under no circumstances will analytical samples be collected from the discharge of the flow- through cell.
 - c. If an in-line 'T' and valve are used, the valve needs to be removed as well.

- d. Samples will be collected in the following order: VOCs, total organic carbon (TOC), semi-volatile organic compounds (SVOCs), metals and cyanide, and others (or other order as defined in the site-specific FIP/work plan).
 - e. When the container is full, tightly screw on the cap.
23. If sampling for total and filtered metals and/or polychlorinated biphenyls (PCBs), a filtered and unfiltered sample will be collected.
- a. Install an in-line, disposable 0.45-micron particle filter on the discharge tubing after the appropriate unfiltered groundwater sample has been collected.
 - b. Continue to run the pump until an initial volume of “flush” water has been run through the filter in accordance with the manufacturer’s directions (generally 100 to 300 mL).
 - c. Collect the filtered groundwater sample by diverting flow out of the filter into the appropriately labeled sample container.
 - d. When the container is full, tightly screw on the cap.
24. Secure with packing material and store the samples on ice in an insulated transport container provided by the laboratory and include a temperature blank in each container to be shipped.
25. Record on the Low-Flow Sampling Field Form (and bound field logbook) the time at which sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance and the presence or lack of odors or sheens), and the values of the stabilized field indicator parameters as measured during the final reading during purging (**see Attachment A**).
26. Turn off the pump and air compressor or close the gas cylinder valve if using a bladder pump setup.
27. Slowly remove the pump, tubing, lines, and safety cable from the well.
- a. If using dedicated tubing, do not allow the tubing or lines to touch the ground or any other surfaces which could contaminate them.
 - b. If using dedicated tubing, it will be folded - without pinching it - to a length that will allow the well to be capped and also facilitate retrieval of the tubing during later sampling events.
 - c. Use a length of rope or string to tie the tubing to the well cap.
 - d. Alternatively, if tubing and safety line are to be saved and reused for sampling the well at a later date, coil the tubing neatly and placed in a clean plastic bag that is clearly labeled with the well ID ensuring the bag is tightly sealed before placing it in storage.
28. Secure the well and properly dispose of personal protective equipment (PPE) and disposable equipment.
29. Complete the procedures for packaging, shipping, and handling with the associated Chain-of-Custody.
30. Complete decontamination for flow-through analytical cell and submersible or bladder pump, as appropriate (*TGI – Groundwater and Soil Sampling Equipment Decontamination*).
31. At the end of each day of the sampling event, perform calibration check of field instruments and record procedure and results in field log.

9 Waste Management

Materials generated during groundwater sampling activities, including disposable equipment and excess purge water, will be stored on site in appropriately labeled containers and disposed of properly. 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 waste containers are properly labeled and documented in the field logbook.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

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

In general, forms (e.g., Low-Flow Sampling Field Forms), logs/notes (including daily field and calibration logs), digital records, and Chain-of-Custody records will be maintained by the field team lead.

Field logs and Chain-of-Custody records will be transmitted to the Arcadis Project Manager and/or Task Manager, as appropriate, at the end of each day unless otherwise directed. Electronic data files will be sent to the project team and uploaded to the electronic project folder daily.

Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

11 Quality Assurance

Quality assurance procedures shall be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP.

Unless described otherwise in the project-specific FIP/work plan, QAPP, or Sampling and Analysis Plan, quality assurance/quality control samples will be collected as follows:

- One duplicate for every 10 samples
- One laboratory matrix/matrix spike sample for every 20 samples
- In addition to the quality control samples to be collected in accordance with this TGI, the following quality control procedures will be observed in the field:
- Collect samples from monitoring wells, in order of increasing concentration, to the extent known based on review of historical site information if available
- Equipment blanks will include the pump and tubing (if using disposable tubing) or the pump only (if using tubing dedicated to each well)
- Collect equipment blanks after wells with higher concentrations (if known) have been sampled

- Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures—calibrate instruments at the beginning of each day, verify the calibration at the end of each day, and record all calibration activities in the field notebook
- Clean all groundwater sampling equipment prior to use in the first well and after each subsequent well following the procedure for equipment decontamination

12 References

USEPA. 1986. *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* (September 1986).

USEPA. 1991. *Handbook Groundwater, Volume II Methodology*, Office of Research and Development, Washington, DC. USEPN62S, /6-90/016b (July 1991).

USEPA Region I. 2017. *Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells* (EQASOP-GW4; September 19, 2017).

U.S. Geological Survey (USGS). 1977. *National Handbook of Recommended Methods for Water-Data Acquisition: USGS Office of Water Data Coordination*. Reston, Virginia.

13 Attachments

Attachment A – Low Flow Sampling Field Form

Attachment A

Low-Flow Sampling Field Form

GROUNDWATER SAMPLING FORM



Page ____ of ____

Project No. _____ Well ID _____ Date _____

Project Name/Location _____ Weather _____

Measuring Pt. Description _____ Screen Setting (ft-bmp) _____ Casing Diameter (in.) _____ Well Material _____ PVC _____ SS _____

Static Water Level (ft-bmp) _____ Total Depth (ft-bmp) _____ Water Column (ft) _____ Gallons in Well _____

MP Elevation _____ Pump Intake (ft-bmp) _____ Purge Method: _____ Centrifugal _____ Submersible _____ Other _____ Sample Method _____

Pump On/Off _____ Sample Time: _____ Volume Purged _____ Purge Start _____ Gallons Purged _____ Sample ID _____ Sampled by _____ Purge End _____ Replicate/Code No. _____

Time	Minutes Elapsed	Rate (gpm)/(mL/min) 200mL/min +	Depth to Water (ft) -0.3	Gallons Purged	pH ± 0.1	Cond. (µMhos)/(mS/cm) ± 3%	Turbidity (NTU) ± 10%	DO (mg/L) ± 10%	Temp. (°C)/(°F) ± 3%	Redox (mV) ± 10mV	Appearance	
											Color	Odor
Stabilization Calculations (±)												
Stabilization Criteria					± 0.1 s.u.	±3%	± 10% or within 1 NTU ⁽¹⁾	± 10%	±3%	±10 mV		

(1) Turbidity < 50 NTU and ±10% or within 1 NTU of a previous reading when <10 NTU

Constituents Sampled	Container	Number	Preservative

Comments _____

Well Casing Volumes					
Gallons/Foot	1" = 0.04	1.5" = 0.09	2.5" = 0.26	3.5" = 0.50	6" = 1.47
	1.25" = 0.06	2" = 0.16	3" = 0.37	4" = 0.65	

Well Information

Well Location:	_____	Well Locked at Arrival:	Yes / No
Condition of Well:	_____	Well Locked at Departure:	Yes / No
Well Completion:	Flush Mount / Stick Up	Key Number To Well:	_____

GW Samp Form
6/17/2022

TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide

Rev: 10

Rev Date: January 26, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	April 27, 2017	All	Initial Release	Erica Kalve Erika Houtz Sue Tauro
	1	June 19, 2018	1 through 4 and 17	Updated Information on Sampling Materials	Erica Kalve Erika Houtz
	2	October 15, 2018	6 to 16	Minor updates on laboratory elements, updates to decontamination procedures, and clarification on equipment and reagent blank collection	Erika Houtz Erica Kalve
	3	December 17, 2018	4, 6, 17	Removed Sharpies from acceptable field writing implements; Changed language in Section 3.2 and Section 10.5 to provide stricter guidance for DoD projects.	Erika Houtz, Erica Kalve
	4	March 26, 2019	4,5	Removed Citranox from acceptable Decon solutions in Table 1a, added all fluoropolymer containing materials to prohibited items in Table 1b. Made a correction that Liquinox contains trace levels of 1,4 Dioxane, not Alconox.	Erika Houtz
	5	October 16, 2020	14	Added Air Force preference to sample surface water at surface for Air Force investigations.	Erika Houtz

6	March 23, 2021	4, 5, 7, 12, 13, 14, 15, 16, 17	Made clarifications that fine/ultra-fine point Sharpies are allowed. Referenced 2018 MDEQ sampling guidance. Made updates to 'After Sample Collection' in Section 7.	Kevin Engle
7	April 18, 2021	All	Changed title from Poly- and Perfluoroalkyl Substances to "Per- and Polyfluoroalkyl Substances" and changed PFASs to PFAS.	Rosario Varrella, Erika Houtz
8	May 4, 2021	12, 13, 15, 16	Clarified that sample containers should have an HDPE lined screw cap and that LDPE plastic sheeting should be used.	Kevin Engle, Erika Houtz
9	October 20, 2021	Note that numbers have shifted one page forward relative to prior versions. 5, 7, 9-12, 15, 16, 18-25.	Specific acceptable sunscreen and insect repellent brands were added to Table 1. Clarified language regarding footwear and H&S trainings. Laboratories section and Section 10.5 was updated to reflect new laboratory names and an updated version of the QSM. Sections 5 and 6 were updated to provide clearer language on health and safety protocols for sunscreen, insect repellent, and rain events. Added language to specify decontamination of reusable equipment prior to initial use in Section 7.1. Section 8 on Waste Management was updated to state that	Kevin Engle, Erika Houtz

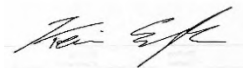
waste storage and disposal should be determined in the site specific workplan. Section 9 was updated to include Rite in the Rain® notebooks as approved for PFAS sampling. Changed the term “sample port” to “sample location” when describing where to place plastic sheeting. Section 10.1 was updated to indicate an equipment blank can be collected for unvetted hazard controls that contact a sample. References were updated to include the newer version of the DoD QSM, MDEQ Sampling Guidance, and California State Water Board PFAS Sampling Guidance.

10	January 26, 2022	Various, Section 7	TGI formatted to comply with new QMS TGI template and Arcadis brand compliance. Indicated to avoid use of anti-fog spray on safety glasses due to possible presence of PFAS.

Approval Signatures

Prepared by:

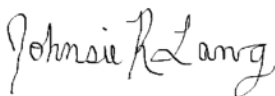
1/26/2022



Kevin Engle, PG Geologist (Preparer)

Date

Reviewed by:



1/26/2022

Johnsie Lang, PhD (Subject Matter Expert)

Date

1 Introduction

This document is intended to provide guidance to field staff sampling for Per- and Polyfluoroalkyl Substances (PFAS). The content in this document describes the intended use, scope and application, personnel qualifications, equipment, cautions, health and safety considerations, procedures, waste management, data recording and management, and quality assurance of PFAS sampling.

2 Intended Use and Responsibilities

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 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 is 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, regulation-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.

3 Scope and Application

The purpose of this Technical Guidance Instructions (TGI) is to provide guidance on field sampling to be used for **Per- and Polyfluoroalkyl Substances (PFAS)**. This protocol was adapted from various sources including Arcadis Australia, Transport Canada, and the U.S Army Corp of Engineers (USACE) Omaha. In general, sampling techniques used for PFAS site characterization are consistent with conventional sampling techniques used in the environmental industry, but special consideration is made regarding PFAS-containing materials and cross-contamination potential. **Table 1a** provides a summary of materials that have been approved for site investigation; this list is expected to grow longer as industry experience increases. **Table 1b** provides a summary of field equipment and materials that have available testing information and/or industry knowledge regarding

PFAS cross-contamination potential, and it is recommended that these materials be prohibited for sample collection; for materials that are suspected of containing PFAS and/or to retain PFAS, these recommendations are considered preliminary and subject to change. Further discussion of approved and prohibited materials is found throughout this document.

Table 1a: Summary of Acceptable Sampling Equipment and Materials for PFAS Site Investigations

Sampling Materials	Additional Considerations	References
<i>Water Sampling Materials</i>		
High density polyethylene (HDPE) or silicone tubing materials	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
HDPE HydraSleeves™	Low density polyethylene (LDPE) HydraSleeves™ are not recommended	USACE 2016; MassDEP 2017
<i>Drilling and Soil Sampling Materials</i>		
PFAS-free drilling fluids	--	DER 2016
PFAS-free makeup water	Confirm PFAS-free water source via laboratory analysis prior to investigation	--
Acetate liners	For use in soil sampling	USACE 2016
<i>Sample Containers and Storage</i>		
HDPE sample containers with HDPE lined lids for soil and water samples	Laboratory should provide; whole bottle analysis of aqueous samples combined with a solvent rinse of bottle is recommended	DER 2016, MassDEP 2017
Ice contained in plastic (polyethylene) bags (double bagged)	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
<i>Field Documentation</i>		
Ball point pens	--	MassDEP 2017
Standard paper and paper labels	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Fine/Ultra-Fine point Sharpies®	Larger point Sharpies® should be avoided.	MDEQ 2018
<i>Decontamination</i>		
Water-only decontamination	Confirm PFAS-free water source via laboratory analysis prior to investigation	DER 2016

Sampling Materials	Additional Considerations	References
Alconox® or Liquinox® followed by deionized water or PFAS-free water rinse	Liquinox® known to contain trace levels of 1,4-dioxane	NHDES 2016; USACE 2016; MassDEP 2017
Methanol, isopropanol, or acetone	Special health and safety precautions are necessary	UNEP 2015; USACE 2016
<i>Sun and Biological Protection</i>		
OFF Deep Woods, Sawyer Permethrin	Apply >10 m away from sampling area	MDEQ 2018
Banana Boat, Coppertone, Neutrogena, Meijer, and L'Oreal Sunscreens	Apply >10 m away from sampling area	MDEQ 2018

Note: This list is considered preliminary and additional materials may be added as additional information becomes available. Project teams are expected to follow a methodical evaluation process of materials to be used and confirm acceptance prior to implementation of field activities.

Table 1b: Summary of Sampling Equipment and Materials Not Recommended for PFAS Site Investigations.

Sampling Materials	Known PFAS-Containing Materials	Suspected PFAS-Containing Materials	Materials with Potential to Retain PFAS	References
<i>Water Sampling Materials</i>				
Teflon®, PTFE-containing or other fluoropolymer coated or containing field equipment (e.g., tubing, bailers, liners, tape, plumbing paste, pump parts)	x			DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Passive diffusion bags			x	MassDEP 2017
LDPE HydraSleeves™			x	USACE 2016; MassDEP 2017
Water particle filters			x	MassDEP 2017
<i>Drilling and Soil Sampling Materials</i>				
Aluminum foil			x	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Drilling fluid containing PFAS	x	x		DER 2016
<i>Sample Containers and Storage</i>				
Glass sample containers with lined lids			x	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017

Sampling Materials	Known PFAS-Containing Materials	Suspected PFAS-Containing Materials	Materials with Potential to Retain PFAS	References
LDPE containers and lined lids			x	USACE 2016
Teflon® or PTFE- lined lids on containers (e.g., sample containers, rinsate water storage containers)	x			DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Reusable chemical or gel ice packs (e.g., BlueIce®)		x		DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Field Documentation				
Self-sticking notes and similar office products (e.g., 3M Post-it-notes)		x		DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Waterproof paper, notebooks, and labels	x			DER 2016, MassDEP 2017
Markers		x		NHDES 2016
Decontamination				
[Some] detergents and decontamination solutions (e.g., Decon 90® Decontamination Solution)	x	x		DER 2016; NHDES 2016; MassDEP 2017

Note: For materials that are suspected of containing PFAS, or have the potential to retain PFAS, project specific considerations may provide adequate justification for use during the field event. For example, further evaluation may be conducted in the form of pre-field equipment blank sample analysis.

Given the extremely low detection limits associated with PFAS analysis and the many potential sources of trace levels of PFAS, field personnel are advised to err on the side of caution by strictly following these protocols, frequently replacing nitrile gloves, and rinsing field equipment to help mitigate the potential for false detections of PFAS. A summary of other specific items related to field sampling for PFAS are discussed in the sections below.

This TGI applies to all Arcadis and subcontractor personnel involved in field sampling for PFAS.

4 Personnel Qualifications

4.1 Sampling Personnel

Field personnel must have current health and safety training, including 40-hour HAZWOPER training, up to date 8-hour refresher, site supervisor training, and site-specific training, as needed. In addition, field personnel will be versed in the other relevant SOPs (e.g., low flow sampling) and will possess the skills and experience necessary

to successfully complete the desired field work. The site Health and Safety Plan (HASP) and other documents will identify any other training requirements such as site-specific safety training or access control requirements.

4.2 Laboratories

These laboratories are example laboratories that could be used to analyze environmental media for PFAS, pending project approval:

- United States: Pace, SGS, Vista, ALS, and Eurofins
- Canada: AXYS-SGS and Bureau Veritas

Other laboratories may be used if they are appropriately accredited for PFAS analysis according to any project requirements. It is recommended that a laboratory is Environmental Laboratory Accreditation Program (ELAP)-accredited for PFAS analysis in accordance with the Department of Defense (DoD) Quality Systems Manual (QSM) 5.3 Table B-15 or any subsequent updates. **For all data collection efforts at DoD sites, PFAS data must be obtained using a method that is DoD ELAP-accredited under QSM 5.3 or later.**

5 Equipment List

The following equipment and materials must be available for sampling:

- Site plan of sampling locations, relevant work plan (or equivalent), and this TGI;
- Appropriate health and safety equipment, as specified in the site HASP;
- Dedicated plastic sheeting (preferably high-density polyethylene [HDPE]) or other clean surface to prevent sample contact with the ground;
- Conductivity/temperature/pH meter;
- Dissolved oxygen meter, oxidation reduction potential meter, and turbidity meter;
- Depth to water meter;
- If using low-flow groundwater sampling techniques, peristaltic pump (groundwater sampling)/bladder pump (with PFAS free bladder/ HDPE bladder), flow through cell, and accompanying HDPE and silicone tubing;
- Hydrasleeves™, if using Hydrasleeves™ for groundwater sampling;
- Metal trowel for soil samples; specialized soil/sediment sampling equipment as required;
- Brushes for scrubbing sampling equipment;
- Pens, pencils, and/or fine/ultra-fine point Sharpies® for writing;
- Clipboards, field binders, and field note pages that are not waterproof;
- Labeled sample bottles:
 - o Water: HDPE bottles fitted with polypropylene screw cap only; some types of PFAS samples (primarily drinking water) may require preservative, which will be indicated by the laboratory conducting the analysis. The laboratory will specify the sample bottle volume.

- o Soil and sediment: HDPE bottles fitted with polypropylene screw cap only; no preservatives. The laboratory will specify the sample bottle volume.
- If high concentrations of PFAS related to class B firefighting foams are expected, bring additional small vials to conduct field-based shaker tests for foaming;
- Ziploc® bags to hold ice and samples;
- Bottles containing “PFAS-free” water used for reagent blanks;
- Labeled, thoroughly decontaminated coolers for samples with ice; Blue ice is not permitted;
- Deionized or distilled water for initial decontamination rinsing;
- “PFAS-free” water provided by the laboratory for final decontamination rinsing;
- Methanol, isopropanol, or acetone if able to be brought safely to field site; especially important for decontamination during soil sampling;
- Alconox or Liquinox®;
- Packing and shipping materials;
- Groundwater and/or Sampling Log; and
- Chain-of-Custody (COC) Forms.

6 Cautions

6.1 Food Packaging

Some food packaging may be treated with PFAS-containing chemicals to prevent permeation of oil and water in the food outside of the packaging. To avoid potential food packaging-related PFAS contact:

- Do not bring any food outside of the field vehicles onsite and eat snacks and meals offsite.
- Wash hands after eating.
- Remove any field garments or outer layers prior to eating. Do not put them back on until done eating and hands are washed.

6.2 Field Gear

6.2.1 Clothing

Many types of clothing are treated with PFAS for stain and water resistance, in particular outdoor performance wear under brand names such as Gore-Tex®. To avoid potential clothing-related PFAS contact:

- Do not wear any outdoor performance wear that is water or stain resistant, or appears to be. Err on the side of caution.

- Wear pre-laundered (multiple washings, i.e., 6+) clothing that is not stain resistant or waterproof (unless made from the materials listed in Section 5.3.1).
- Natural fabrics such as cotton are preferred. Synthetic fabrics may also be acceptable if there is no indication on the label that the fabric is water and stain resistant.
- Most importantly, avoid contacting your clothing with sampling equipment, bottles, and samples.

6.2.2 Personal Protective Equipment

Safety Footwear

Some safety footwear has been treated to provide a degree of waterproofing and increased durability and may represent a source of trace PFAS. If at all possible, Gore-Tex footwear should not be worn and safety footwear without waterproofing should be worn; footwear that provides adequate safety from physical hazards is required and takes precedence over potential PFAS concerns. To avoid any PFAS cross contamination to samples from footwear:

- Do not contact your footwear with equipment, bottles, or samples in any way.
- Do not allow gloves used for sampling to come in contact with safety footwear.

Nitrile Gloves

Wear disposable nitrile gloves at all times. Don a new pair of nitrile gloves **before** the following activities at each sample location:

- Decontamination of re-usable sampling equipment;
- Contact with sample bottles or “PFAS-free” water bottles;
- Insertion of anything into the sample ports (e.g., HDPE tubing); and
- Handling of any quality assurance/quality control (QA/QC) samples including field blanks and equipment blanks.

Don a new pair of nitrile gloves **after** the following activities:

- Handling of any non-dedicated sampling equipment;
- Contact with contaminated surfaces; or
- When judged necessary by field personnel.

6.3 Personal Hygiene

- Shower at night.
- Do not use personal care products after showering such as lotions, makeup, and perfumes, UNLESS medically necessary.
- Use sunscreen and insect repellent as necessary for health and safety, i.e., if sampling is to occur outdoors in direct sunlight and/or if insect hazards may be present. Specific products that are acceptable for PFAS

sampling are listed in Table 1 and in Section 6.1. Apply sunscreen and insect repellent prior to initiating field sampling. If sunscreen and/or repellent need to be reapplied, ensure a safe distance away from the sampling locations and equipment (i.e., more than 10 meters (m) away). Wash hands after application and don new gloves following hand washing.

6.4 Visitors

Visitors to the site are asked to remain at least 10 m from sampling areas.

7 Health and Safety Considerations

7.1 Biological and Environmental Hazard Controls

7.1.1 Sunscreens and Insect Repellents

When site conditions warrant, insect repellent and sunscreen should be applied. Some insect repellents and sunscreen have been approved for PFAS sampling by individual states. According to Michigan Department of Environmental Quality (MDEQ; now known as Michigan Department of Environment, Great Lakes, and Energy [EGLE]), the products below are allowable (MDEQ 2018). Note that California State Water Quality Control Board's PFAS sampling guidance refers to MDEQ/EGLE's allowable list of sunscreens and insect repellents (California State Water Quality Control Board 2020).

Insect Repellents

- OFF Deep Woods
- Sawyer Permethrin

Sunscreen

- Banana Boat Sport Performance Sunscreen Lotion Broad Spectrum SPF 30
- Meijer Sunscreen Lotion Broad Spectrum SPF 30
- Neutrogena Ultra-Sheer Dry-Touch Sunscreen Broad Spectrum SPF 30
- Banana Boat for Men Triple Defense Continuous Spray Sunscreen SPF 30
- Banana Boat Sport Performance Coolzone Broad Spectrum SPF 30
- Banana Boat Sport Performance Sunscreen Lotion Broad Spectrum SPF 30
- Banana Boat Sport Performance Sunscreen Stick SPF 50
- Coppertone Sunscreen Lotion Ultra Guard Broad Spectrum SPF 50
- Coppertone Sport High-Performance AccuSpray Sunscreen SPF 30
- Coppertone Sunscreen Stick Kids SPF 55
- L'Oréal Silky Sheer Face Lotion 50+
- Meijer Clear Zinc Sunscreen Lotion Broad Spectrum SPF 15, 30 and 50
- Meijer Wet Skin Kids Sunscreen Continuous Spray Broad Spectrum SPF 70
- Neutrogena Beach Defense Water + Sun Barrier Lotion SPF 70
- Neutrogena Beach Defense Water + Sun Barrier Spray Broad Spectrum SPF 30
- Neutrogena Pure & Free Baby Sunscreen Broad Spectrum SPF 60+

Please plan for sampling events and purchase these products ahead of time. For any sunscreens and bug sprays, including those listed above, always follow these instructions for application:

- Insect repellents and sunscreen should be applied away from the work area prior to initiating sampling.
- When re-applying, stay at least 10 m away from the sampling locations and equipment.
- Wash hands after application and don new nitrile gloves.

7.1.2 Rain Event

Special care should be taken when rain is falling at the project site:

- Field sampling during extreme rainfall should be avoided if possible. If sampling needs to take place during a rain event (or other extreme weather condition), ensure the rain gear or other safety clothing is appropriate. For example, rain gear made from the following materials is allowable: polyurethane, PVC, wax coated fabrics, rubber/neoprene, uncoated Tyvek® (MDEQ 2018).
- If project timelines are tight, consider the use of a gazebo tent that can be erected over the top of the monitoring well to provide shelter from the rain. The canopy material is possibly a PFAS-treated surface and should be managed as such; therefore, wear gloves when moving the tent, change them immediately after moving the tent, and avoid further contact with the tent until all sampling activities have been finished and the team is ready to move on to the next site.

7.1.3 Other H&S Considerations

- ***If an unapproved or potentially suspect hazard control is needed for health and safety, apply or keep that control away from the samples, document its use in field notes, and, if it does contact a sample, take an equipment blank with that material.***
- The ability to safely access the surface water sampling locations must be verified before sampling.
- Field activities must be performed in accordance with the site HASP, a copy of which will be present onsite during such activities.
- Safety hazards associated with sampling surface water include fast-moving water, deep water, and steep slopes close to sampling sites. Use extreme caution when approaching sampling sites.
- If thunder or lightning is present, discontinue sampling and take cover until 30 minutes have passed after the last occurrence of thunder or lightning.
- Use caution when removing well caps as well may be under pressure, cap can dislodge forcefully and cause injury.
- Avoid the use of anti-fog sprays on glasses, which may contain PFAS. It's recommended to instead purchase pre-treated anti-fog safety glasses.

8 Procedure

8.1 Field Equipment Cleaning

Reusable field sampling equipment will require cleaning before initial use and between uses. For groundwater sampling, between uses, decontaminate the flow-through cell and any non-dedicated equipment (i.e., interface probe of depth to water meter) that comes into contact with well water. Trowels and other materials used to sample soil samples will also require decontamination, although dedicated, single use equipment such as liners should be used where possible.

After donning a new pair of nitrile gloves:

- Rinse sampling equipment with Alconox or Liquinox® cleaning solution; Scrub equipment with a plastic brush if needed;
- Rinse two times with distilled water or deionized water;
- Rinse one time with “PFAS-free” water or once with methanol/isopropanol/acetone, if it is available, and once with “PFAS-free” water; organic solvents are especially useful for decontaminating soil sampling equipment. If organic cleaning solvents cannot be brought to site, scrub equipment a second time after a single distilled or deionized water rinse, then rinse two times with distilled or deionized water and once with “PFAS-free” water (i.e., two scrubbing and four water rinsings total).
- Collect all rinsate in a sealed pail for disposal. Do not reuse decontamination solutions between sampling locations.

8.2 Borehole/Monitoring Well Development

If a drill rig is being used to drill for soil cores or to install monitoring wells, wear clean nitrile gloves before collecting each continuous soil sample. Additional requirements include the following:

- Verify in writing with the manufacturer that single-use liners used to collect each sample are made of a material that does not contain PFAS;
- Collect soil samples in laboratory-supplied HDPE bottles.
- Store the sample bottles in coolers and keep at a temperature of 0 to 6°C until transported to the laboratory.

8.2.1 Well Condition Survey/ Water Level Monitoring

Using equipment that has been thoroughly decontaminated according to the procedures in Section 7.1, conduct the well condition surveys and water level monitoring:

- Conduct monitoring well inspections and record water levels.
- Use an interface probe to evaluate presence/absence of non-aqueous phase liquid (NAPL).
- Measure the depth to water from the top of the polyvinyl chloride (PVC) riser and the total depth of the well.
- Record information in the field notes.

8.2.2 Monitoring Well Development and Purging

Follow these requirements for monitoring well development and purging:

- Do not use Teflon™ tubing for purging or sample collection. HDPE tubing is acceptable.
- Do not re-use materials between wells. Upon completion of use, remove all disposable materials (such as HDPE and/or silicone tubing) and place in heavy duty garbage bags for disposal.
- During development of the well, create sufficient energy to agitate the water column and create flow reversals in the well screen, filter pack and formation to loosen fine-grained materials and draw them into the well. The pumping or bailing action should then draw all drilling fluids and fine-grained material out of the borehole and adjacent formation and then out of the well. Review the Arcadis Monitoring Well Development guidance (Arcadis 2010) for more detailed information.
- Follow the low-flow purge and sampling techniques per the U.S. Protection Agency's (EPA's) guidance document titled *Low Stress (Low Flow) purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells* (2010) and ASTM's standard titled *Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations* (2002). Also available for review is the Arcadis Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells (Arcadis 2011).
- To purge the well, if using HDPE tubing and a peristaltic pump, insert the end of the tubing to the approximate depth of the midpoint of the screened section of the monitoring wells. Measure the length of HDPE tubing to be inserted into each monitoring well and pre-cut it to approximate lengths (such as the previously measured arm span of a field technician) to avoid contact with any materials other than the monitoring well and peristaltic pump. Flow rates should be as low as can be reasonably achieved. Collect and appropriately dispose of purge water.
- Silicone tubing should direct the purge water through a flow-through cell for field parameter measurements of pH, conductivity, temperature, dissolved oxygen, and turbidity. Calibrate the instrument in the field prior to use. Decontaminate the instrument and flow-through cell at each monitoring well location before purging.
- Record field parameters in intervals (generally of 3-minute duration) to ensure purge water has cycled through the flow-through cell. Sample the wells after field parameter measurements indicate stabilization, which allows collection of representative formation water (generally acceptable standards are three consecutive pH readings to within ± 0.1 units, and three consecutive conductivity, temperature and dissolved oxygen measurements to within 3%). Turbidity must be monitored, but does not need to be used as a stabilization indicator of purge completion. Record field parameter measurements at each well. Drawdown should be monitored throughout the purge.
- If wells are suspected to be dewatering throughout the purge (i.e., reduced flow rate/difficulty pumping water or bubbles begin to come through the flow through cell), turn off the pump and allow the water level to recover for ½ hour, followed by sample collection. Document these activities in the field notes.

8.3 Sample Collection

Different laboratories may supply sample collection bottles of varying sizes depending on the type of media to be sampled.

8.3.1 Sample Containers

- Collect samples in HDPE bottles fitted with a HDPE lined (no Teflon™) screw cap.
- Complete bottle labels after the caps have been placed back on each bottle.
- Do not use glass bottles due to potential loss of analyte through adsorption. This is particularly important for aqueous samples.
- Review with analytical lab the sample size, sample container, etc. depending upon the type of PFAS analysis that is being requested.

8.3.2 Soil Sampling

Before Sample Collection

- Place LDPE plastic sheeting adjacent to the sample location for use as a clean work area, if conditions allow. Otherwise, prevent sampling equipment from contacting the ground or other surface that could compromise sample integrity.
- Trowels or drilling equipment that will come into contact with a sample should be decontaminated prior to sample collection, preferably with methanol/isopropanol/acetone;
- Don a new set of nitrile gloves. Do not use gloved hands to subsequently handle papers, pens, clothes, etc., before collecting samples.
- Use the HDPE bottles that are supplied by the laboratory. Make sure that the caps remain on the bottle until immediately prior to sample collection.

During Sample Collection

- Collect soil samples using a clean stainless-steel trowel or with single-use PFAS-free liners;
- Place soil samples in labeled HDPE bottles supplied by the laboratory.
- Note the time on the sample label.
- Collect any necessary duplicates/co-located samples and matrix spikes – verify with laboratory whether they need to be collected in separate sample bottles.
- Collect any necessary equipment blanks. The best timing to collect equipment blanks is immediately after the collection of a sample likely to contain high concentrations of PFAS, after the sampling equipment has been appropriately decontaminated.
- Collect any necessary field reagent blanks. This sample should be collected after field staff return from an offsite break (e.g., lunch) to capture any potential cross-contamination from field personnel.

After Sample Collection

- Place each sample bottle in two sealed Ziploc® bags. Another brand of LDPE bag is acceptable.
- Record the label information and time of sampling in the field notes.
- Place soil sample bottles in coolers that are durable in transportation and keep the temperature between 0 and 6°C until transported to the laboratory. Do not use blue ice.

8.3.3 Groundwater Sampling

Before Sample Collection

- Place LDPE plastic sheeting adjacent to the sample location for use as a clean work area, if conditions allow. Otherwise, prevent sampling equipment from contacting the ground or other surface that could compromise sample integrity.
- Don a new set of nitrile gloves. Do not use gloved hands to subsequently handle papers, pens, clothes, etc., before collecting samples.
- Use the labeled HDPE bottles that are supplied by the laboratory. Make sure that the caps remain on the bottle until immediately prior to sample collection.
- Measure depth to water and field parameters. Turbidity and the physical appearance of the purged water should be noted on the Groundwater Sampling Log.

During Sample Collection

- Start groundwater sample collection upon stabilization of field parameters.
- If low-flow groundwater sampling techniques are being used, disconnect the silicone tubing from the flow-through cell, enabling collection of groundwater samples without passing through the cell.
- Hydrasleeves are also considered acceptable for sampling of PFAS in groundwater – consult the project manager to determine which technique should be used. In general, low flow sampling is preferable.
- Collect groundwater samples (to the neck of the bottle, some headspace is acceptable) from the dedicated sampling ports at the center of the well screen. While collecting the sample, make sure the bottle cap remains in the other hand of the sampler, until replaced on the bottle.
- To mitigate cross contamination, collect groundwater samples in a pre-determined order from least impacted to greater impacted based on previous analytical data or knowledge about past activities at the site. If no analytical data are available, samples are to be collected in the following order:
 1. First sample the upgradient well(s).
 2. Next, sample the well located furthest downgradient of the interpreted or known source.
 3. The remaining wells should be progressively sampled in order from downgradient to upgradient, such that the wells closest to the interpreted or known source are sampled last.
- NOTE: If high concentrations of PFAS related to class B firefighting foams are expected in a groundwater sample, conduct a Shaker test by collecting and shaking a small portion of the sample (~10 to 25 mL) on site in a small disposable vial. If foaming is noted within the sample, document the foaming when samples are

submitted for analysis; the 'shaker test' vial can then be disposed. This shaker test provides information about how each of the samples should be handled analytically.

- After collecting the sample, tightly screw on the polypropylene cap (snug, but not too tight). This will minimize leaking or cross contamination of the sample. Most PFAS, including all analytes measured by USEPA Method 537, are not volatile at environmental pH.
- Note the time on the sample label.
- Collect any necessary duplicates and matrix spikes. As the laboratory should be analyzing the entire aqueous sample rather than sub-sampling, separate bottles will be required for these samples.
- Collect any necessary equipment blanks. The best timing to collect equipment blanks is immediately after the collection of a sample likely to contain high concentrations of PFAS, after the sampling equipment has been appropriately decontaminated.
- Collect any necessary field reagent blanks. This sample should be collected after field staff return from an offsite break (e.g., lunch) to capture any potential cross-contamination from field personnel.
- Do not rinse PFAS sample bottles during sampling. Do not filter samples.

After Sample Collection

- Place each sample bottle in two sealed Ziploc® bags. Another brand of LDPE bag is acceptable.
- Record the label information and time of sampling in the field notes and COC. Note 'shake test' results if appropriate.
- Place groundwater samples in coolers that are durable in transportation and keep the temperature between 0 and 6°C until transported to the laboratory. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**

Treat all disposable sampling materials as single use and dispose of them appropriately after sampling at each monitoring well.

8.3.4 Sediment Sampling

Before Sample Collection

- Place LDPE plastic sheeting adjacent to the sample location for use as a clean work area, if conditions allow. Otherwise, prevent sampling equipment from contacting the ground or other surface that could compromise sample integrity.
- Don a new set of nitrile gloves. Do not use gloved hands to subsequently handle papers, pens, clothes, etc., before collecting samples.
- Use the HDPE bottles that are supplied by the laboratory. Make sure that the caps remain on the bottle until immediately prior to sample collection.

During Sample Collection

- Where surface water samples and sediment samples are collected at the same location, collect surface water samples first to minimize siltation.

- Collect sediment samples either manually using a stainless-steel trowel or using a petite ponar grab sampler, depending on field conditions at each sampling location during sampling program.
- Collect sediment samples from the upper 10 cm of sediment.
- For a sample to be acceptable overlying, low turbidity water must be present.
- Decant the overlying water and use a stainless-steel trowel to collect only the upper 5 centimeters (cm) of sediment.
- Collect sediment samples directly into laboratory-supplied bottles that are suitable in both material and size.
- Do not overfill the sample bottle.
- Make sure that the sample does not contain vegetation, that the sediment is undisturbed, and that the sampler shows no signs of winnowing or leaking.
- Make sure bottle caps remain in the gloved hand of the sampler until sampling is complete and caps are replaced on the bottle.
- Note the time on the sample label.
- Collect any necessary duplicates and matrix spikes.
- Collect any necessary equipment blanks. The best timing to collect equipment blanks is immediately after the collection of a sample likely to contain high concentrations of PFAS, after the sampling equipment has been appropriately decontaminated.
- Collect any necessary field reagent blanks. This sample should be collected after field staff return from an offsite break (e.g., lunch) to capture any potential cross-contamination from field personnel.

After Sample Collection

- Place each sample bottle in two sealed Ziploc® bags. Another brand of LDPE bag is acceptable.
- Record the label information and time of sampling in the field notes.
- Place samples in coolers that are durable in transportation and keep the temperature between 0 and 6°C until transported to the laboratory. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**
- Measure surface water pH, conductivity, temperature, and total dissolved solids (TDS) at each location after both surface water and sediment sampling is completed.

8.3.5 Surface Water Sampling

Before Sample Collection

- Place LDPE plastic sheeting adjacent to the sample location for use as a clean work area, if conditions allow. Otherwise, prevent sampling equipment from contacting the ground or other surface that could compromise sample integrity.
- Don a new set of nitrile gloves. Do not use gloved hands to subsequently handle papers, pens, clothes, etc., before collecting samples.

- Use the HDPE bottles that are supplied by the laboratory. Make sure that the caps remain on the bottle until immediately prior to sample collection.

During Sample Collection

- Avoid sampling the surface, in general.
- However, for Air Force investigations, collect samples from the water surface.
- Where surface water samples and sediment samples are collected at the same location, collect surface water samples first to minimize siltation.
- Collect surface water samples directly into laboratory-supplied bottles; wide-mouth bottles may be preferable to narrow mouth bottles for ease of surface water collection.
- Make sure bottle caps remain in the gloved hand of the sampler until sampling is complete and caps are replaced on the bottle.
- Note the time on the sample bottle.
- Collect any necessary duplicates and matrix spikes. As the laboratory should be analyzing the entire aqueous sample rather than sub-sampling, separate bottles will be required for these samples.
- Collect any necessary equipment blanks. The best timing to collect equipment blanks is immediately after the collection of a sample likely to contain high concentrations of PFAS, after the sampling equipment has been appropriately decontaminated.
- Collect any necessary field reagent blanks. This sample should be collected after field staff return from an offsite break (e.g., lunch) to capture any potential cross-contamination from field personnel.

After Sample Collection

- Place each sample bottle in two sealed Ziploc® bags. Another brand of LDPE bag is acceptable.
- Record the label information and time of sampling in the field notes.
- Place samples in coolers that are durable in transportation and keep the temperature between 0 and 6°C until transported to the laboratory. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**
- Measure surface water pH, conductivity, temperature, and TDS at each location after both surface water and sediment sampling.

8.4 Shipping

- If samples cannot be shipped the same day as collected, arrange an appropriate means of keeping the samples cool overnight and maintain the temperature between 0 and 10°C for the first 48 hours after collection, and then between 0 and 6°C thereafter.
- Store samples in appropriate transport bottles (coolers) with ice (Ziploc® bags for use as ice containers) with appropriate labeling. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**

- Complete the appropriate procedures for COC, handling, packing, and shipping.
- Fill out and check COC Forms against the labels on the sample bottles progressively after each sample is collected.
- Place all disposable sampling materials (such as plastic sheeting, and health and safety equipment) in appropriate containers.
- Ship samples via courier service with priority overnight delivery. Tracking numbers for all shipments should be provided and recorded after they have been sent out to ensure their timely delivery.
- Do not ship samples via Fed Ex for Saturday delivery.

9 Waste Management

All rinsate should be collected in a sealed pail for disposal. Drill cuttings and purge water will be managed as specified in the Field Sampling Plan (FSP) or Work Plan, and according to state and/or federal requirements. PPE and decontaminated fluids will be contained separately and staged at the sampling location. Containers must be labeled at the time of collection. Labels will include date, location(s), site name, city, state, and description of matrix contained (e.g., soil, groundwater, PPE). General guidelines for investigation derived waste (IDW) handling and storage are set forth in a separate IDW guidance document (Arcadis 2009).

Typical waste characterization procedures include collection of a composite sample of the drill cutting material and a composite sample of the purge water for laboratory analysis. Samples are typically analyzed for disposal toxicity characteristic leaching procedure (TCLP) analysis for metals and VOCs. For PFAS, a simple leach test with neutral pH water may be more indicative of actual risk. Additionally, generators of waste are required to include analysis of other constituents that are reasonably believed to be present including (in this case) PFAS.

Waste storage and final waste disposition should be determined in the site specific workplan.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

If digital data collection isn't possible, waterproof field books should be avoided for field notes. Instead, field notes on loose paper on Masonite, plastic, or aluminum clip boards is preferred. Please note that newer Rite in the Rain® notebooks are approved for PFAS sampling. Other requirements for field notes include:

- Pens, pencils, and fine/ultra-fine point Sharpies® may be used.
- Keep field notes and writing implements away from samples and sampling materials.
- One person should conduct sampling while another records field notes.

- Do not write on sampling bottles unless they are closed.

10.1 Other Project Documentation

- Complete groundwater and/or soil sampling logs.
- Make sure COC Forms are properly completed. Verify which PFAS analytes (e.g., just PFOS and PFOA, some or all of the 537 list, etc.) are required for analysis and note on the COC.

11 Quality Assurance

Refer to quality control requirements for the project to ensure that appropriate quality assurance and quality control (QA/QC) samples are collected. When collecting QA/QC samples, the same guidelines apply as when collecting regular samples – specifically that:

- Samples should be collected in laboratory-supplied HDPE bottles;
- Bottle caps must remain in the hand of the sampler until replaced on the bottle;
- Labels must be completed after the caps have been placed back on each bottle; and
- Samples must be stored in appropriate transport bottles (coolers) with ice (Ziploc® bags for use as ice containers) with appropriate labeling. **Do not use blue ice. Store PFAS samples in a separate cooler from other types of samples.**

11.1 Equipment Blanks (if relevant)

QA/QC sampling typically includes daily collection of equipment blanks using the laboratory-supplied “PFAS-free” water. For peristaltic pump tubing, laboratory supplied “PFAS-free” water should be poured into a clean HDPE sample bottle and then pumped through new HDPE tubing using the peristaltic pump (with new silicone tubing). The best timing to collect equipment blanks is immediately after the collection of a sample likely to contain high concentrations of PFAS, after the sampling equipment has been appropriately decontaminated. Note that an equipment blank can also be collected if an unapproved or potentially suspect hazard control is needed for health and safety and it contacts a sample, i.e., that material would be exposed to PFAS free water then the water would be collected in a separate sample container.

11.2 Field Duplicates

QA/QC sampling typically includes the collection of one field duplicate for every 10 or 20 samples collected. Each duplicate sample will be collected immediately after the initial sample of which it is a duplicate into a separate laboratory-provided sample bottle. Do not indicate to the laboratory which sample the duplicate replicates, i.e., it should be given a blind reference on the COC and sample name such as “duplicate”.

11.3 Field Reagent Blanks

QA/QC sampling for PFAS typically includes the submission of one laboratory supplied field reagent blank per day. The field reagent blank sample is brought to the site in a laboratory-supplied sample bottle. Field staff

transfer the laboratory-supplied reagent blank to an empty sample bottle. This sample should be collected after field staff return from an offsite break (e.g., lunch) to capture any potential cross-contamination from field personnel and should be placed in the same cooler as the other PFAS samples.

11.4 Matrix Spikes (optional in some cases)

QA/QC sampling includes submitting a sample to be used as a matrix spike if the project requires it. If a separate sample bottle is required, an additional sample will be collected immediately after the initial sample of which it is a duplicate into a separate laboratory-supplied sample bottle.

11.5 Laboratory Analytical QA/QC

- Arcadis recommends that any request for PFAS analysis in groundwater or soil should be conducted by an ELAP-accredited method compliant with QSM 5.3 Table B-15. Requirements laid out in Table B-15 strictly govern acceptable laboratory data quality for PFAS analysis in environmental samples. **For all data collection efforts at DoD sites, PFAS data must be obtained using a method that is DoD ELAP-accredited under QSM 5.3 or later.**
- Laboratory QA/QC should consist of one laboratory blank and one laboratory control sample (or blank spike) per batch of samples, and additional QA/QCs as indicated by the laboratory QA/QC procedures.
- Isotope dilution should be used for quantification with isotope-labeled surrogate standards, as available, according to the guidelines of QSM 5.3 Table B-15. The USEPA has two drinking water methods (USEPA Method 537.1 and USEPA Method 533). Method 537.1 does not allow for isotope dilution but USEPA Method 533 requires isotope dilution.
- For drinking water, groundwater, and surface water samples, laboratories must extract the entire sample and include a solvent rinse of the bottle for analysis. Aqueous samples should generally not be sub-sampled prior to analysis, unless they are high concentration and require serial dilution (US DoD 2017).
- Soil samples should be analyzed in their entirety or thoroughly homogenized before extraction and analysis.
- As part of the internal QA/QC of laboratory results, relative percent difference (RPD) should be calculated between samples and corresponding field or laboratory duplicates. The laboratory quality assurance portion of the laboratory certificates should be reviewed to verify that all calculations/recoveries were within acceptable limits as established by the laboratory method and guidelines in Table B-15 of QSM 5.3 or later (USDOD 2019).

12 References

Arcadis Australia. 2017. Soil and Concrete Sampling for PFAS. April.

Arcadis. 2010. Monitoring Well Development, Rev. #2.2. March 22.

Arcadis. 2009. Investigation-Derived Waste Handling and Storage, Rev. #2. March 6.

Arcadis. 2011. Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells, Rev. #4. February 2.

- ASTM. 2002. ASTM D6771-02 - Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations (Withdrawn 2011). Available at: <https://www.astm.org/Standards/D6771.htm>.
- California State Water Quality Control Board. 2020. Per- and Polyfluoroalkyl Substances (PFAS) Sampling Guidelines for Non-Drinking Water. September.
https://www.waterboards.ca.gov/pfas/docs/sept_2020_pfas_sampling_guidelines.pdf
- Department of Environment Regulation (DER). Government of Western Australia. 2016. Interim Guideline on the Assessment and Management of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS). Contaminated Sites Guidelines. February.
- Michigan Department of Environmental Quality (MDEQ). 2018. General PFAS Sampling Guidance. October.
https://www.michigan.gov/documents/pfasresponse/General_PFAS_Sampling_Guidance_634597_7.pdf
- Massachusetts Department of Environmental Protection (MassDEP). 2017. DRAFT Fact Sheet, Guidance on Sampling and Analysis for PFAS at Disposal Sites Regulated under the Massachusetts Contingency Plan. January.
- New Hampshire Department of Environmental Services (NHDES). 2016. Perfluorinated Compound (PFC) Sample Collection Guidance. November.
- United Nations Environment Programme (UNEP). 2015. PFAS analysis in water for the Global Monitoring Plan of the Stockholm Convention, Set-up and guidelines for monitoring. Jana Weiss, Jacob de Boer, Urs Berger, Derek Muir, Ting Ruan, Alejandra Torre, Foppe Smedes, Branislav Vrana, Fabrice Clavient, and Heidelore Fiedler. Division of Technology, Industry and Economics. Geneva. April.
- United States Army Corps of Engineers (USACE). 2016. DRAFT – Standard Operating Procedure 047: Per/Poly Fluorinated Alkyl Substances (PFAS) Field Sampling. Revision: 1. March.
- U.S. Army Corps of Engineers – Omaha District. 2016. Chemistry Requirements – PFAS.
- U.S. Department of Defense (DoD). 2019. Consolidated Quality Systems Manual (QSM) for Environmental Laboratories, Version 5.3. In conjunction with the U.S. Department of Energy. May.
- U.S. Environmental Protection Agency. 2009. USEPA Method 537: Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS), version 1.1, September. National Exposure Research Laboratory, Office of Research and Development.
- U.S. Environmental Protection Agency. 2010. Low Stress (Low Flow) purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells. Available at: <https://www.epa.gov/quality/low-stress-low-flow-purging-and-sampling-procedure-collection-groundwater-samples-monitoring>.
- Transport Canada. February 2016, Per-and Polyfluorinated Alkyl Substances (PFAS) Field Sampling Guidance.