Revitalizing Auto Communities Environmental Response (RACER) Trust

# APPROVAL REQUEST: LOWER 1,4-DIOXANE PROPANE BIOSPARGE PILOT TEST

Plants 2 and 3, Industrial Land
Lansing, Michigan

May 20, 2016

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Plants 2 and 3, Industrial Land, Lansing, Michigan

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| bgs | below ground surface |
| CSIA | compound-specific isotope analysis |
| DAP | diammonium phosphate |
| DO | dissolved oxygen |
| ft/d | feet per day |
| g/L | grams per liter |
| in | inch |
| LEL | Lower explosive limit |
| MDEQ | Michigan Department of Environmental Quality |
| NFPA | National Fire Protection Association |
| NREPA | Natural Resources Environmental Protection Act |
| PFM | passive flux meter |
| PLC | process logic controller |
| PVC | polyvinyl chloride |
| qPCR | quantitative polymerase chain reaction |
| RACER | Revitalizing Auto Communities Environmental Response |
| RCRA | Resource Conservation and Recovery Act |
| ROI | radius of influence |
| RFI | RCRA Facility Investigation |
| Sch | schedule |

# 1 INTRODUCTION

Revitalizing Auto Communities Environmental Response (RACER) Trust retained Arcadis U.S., Inc. (Arcadis) to perform groundwater and soil remediation at the Lansing Plants 2, 3, and 6 (Site) located in Lansing, Michigan (see Figure 1). The purpose of this work plan is to provide information required to obtain Michigan Department of Environmental Quality (MDEQ) approval to perform a propane biosparge test in accordance with a groundwater discharge permit exemption pursuant to R323.2210(u) of the Part 22 Rules promulgated under Part 31 of Natural Resources Environmental Protection Act (NREPA).

The application of enhanced in situ co-metabolic biodegradation is a technology used for decades to mitigate chlorinated volatile organic compounds. More recently, research and field demonstrations have shown enhanced co-metabolic biodegradation of 1,4-dioxane is a viable mechanism for treating 1,4-dioxane in groundwater. Enhanced in situ co-metabolic biodegradation using propane biosparging is one of the remedies under consideration for the lower 1,4-dioxane plume at the Site. Propane biosparging is a remedy in which propane, nutrients, and propane oxidizing micro-organisms, also known as propanotrophs, are delivered to the subsurface through wells to enhance in situ co-metabolic biodegradation of 1,4-dioxane. Propane biosparging relies on the fact that propane oxidizing bacteria are able to degrade 1,4-dioxane while using propane as a primary source of food and energy (Vainberg et al. 2006). The propane and oxygen are used to proliferate seeded propanotrophs, but the propane will be limited such that 1,4-dioxane is consumed as a secondary carbon source. Oxygen will be provided in excess to ensure sufficient electron acceptors.

Propane biosparging has the potential to be a relatively sustainable and cost effective approach to reduce concentrations in the lower 1,4-dioxane plume at the Site. Arcadis has therefore prepared the following work plan to perform a propane biosparging pilot test at the Site to determine whether it can be implemented cost-effectively as a remedy for the lower 1,4-dioxane plume at the Site.

## 1.1 Lower 1,4-Dioxane Plume Overview

The lower 1,4-dioxane plume is present in the deep overburden and weathered bedrock at depths generally ranging from 70 to 90 feet below grade. The lower 1,4-dioxane plume, extending from the Plant 3 “coliseum” area to the south-central portion of Plant 2, has been delineated with numerous vertical aquifer profiling borings and monitoring wells. The central and southern portions of the lower 1,4-dioxane plume in Plant 2 and the general Site layout are presented on Figure 2.

At the 1,4-dioxane source area, the plume is present in the saturated, deep overburden and weathered bedrock zones. South of the source area, the lower 1,4-dioxane plume coalesces and migrates primarily within the weathered bedrock zone. The transition from weathered bedrock to consolidated rock is gradational and, for the purposes of this propane biosparge test, the weathered bedrock zone is estimated to be approximately 10 to 15 feet thick, gradually transitioning into hardened bedrock. The bedrock consists of the Grand River Formation to the north and Saginaw Formation to the south. The contact between these units is in the north end of Plant 2. The Grand River Formation is fine- to medium-grained sandstone that occupies erosional valleys within the Saginaw Formation (United States Geological Survey and National Park Service 2000). The Saginaw Formation consists of finer-grained sandstone with thin layers of shale that vary in thickness.

Groundwater elevation measurements collected from the monitoring wells installed along the lower 1,4-dioxane plume reflect a complex heterogeneous aquifer structure. Due to large vertical gradients observed at certain areas of the Site, the observed groundwater elevation varies depending on the specific depth of a well. Based on the evaluation presented in the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Phase 2 Supplemental Report (Arcadis 2014), as well as analyses completed in March and April 2014 using passive flux meters (PFMs; EnviroFlux, Inc.), and the tracer study conducted in September through December of 2015 (Arcadis 2016), the groundwater flow along the lower 1,4-dioxane plume appears to be southerly, consistent with the plume morphology. The Passive Flux Meter and Transducer Study Memorandum (Arcadis 2015; as revised) presents a summary of the PFM study and results.

## 1.2 Propane Biosparge Pilot Test Objectives

The objectives of the pilot test are to evaluate whether the formation is spargeable, and if so, whether an in situ biosparging barrier (biobarrier) capable of 1,4-dioxane biodegradation can be established at the Site. The pilot test will be conducted near the toe of the lower 1,4-dioxane plume in the southern Plant 2 area (Figure 2). The pilot test location was selected based on the following:

- A network of existing wells in place from the hydraulic testing completed in 2014 can be incorporated into the biosparge pilot test.
- The hydrogeologic conditions at this location are considered to be the most challenging for biosparging based on the relatively thin saturated thickness (10 feet) and weathered sandstone (fine sand) with layers of weathered shale (clay). A successful biosparge pilot test in this area will result in a high level of confidence of success across the plume.
- A biobarrier at the toe of the plume could be the first location to implement a barrier approach and pilot testing infrastructure could potentially be incorporated into an interim or final remedy

The pilot test will be performed in two phases. Phase I will consist of a one-day air injection test performed on a single well to determine whether the weathered bedrock formation is spargeable. If Phase I is successful, testing will continue with Phase II, during which additional pilot test wells will be installed, and a mixture of propane, nutrients and propanotrophs will be delivered to the formation for a period of several months to provide data needed to quantitatively evaluate whether biological treatment is occurring in situ.

# 2 PHASE I PROPANE BIOSPARGE PILOT TEST

Phase I of the pilot test will consist of a simple one-day air injection test to determine whether the formation is sufficiently permeable for sparging. Phase I objectives include:

- Determine whether it is possible to deliver air into the weathered bedrock at an acceptable injection pressure
- Gather data to help confirm and/or refine design assumptions and additional pilot well placement for Phase II of the test.

## 2.1 Initial Pilot Test Well Installation

One biosparge well will be installed near the toe of the plume (Figure 2). The biosparge well will be installed using roto-sonic drilling methods. The screen will be set near the bottom of the weathered bedrock at a depth of approximately 80 feet below ground surface (bgs). The exact screen depth will be determined in the field during drilling dependent on the actual saturated thickness and depth of weathered bedrock encountered. The biosparge well will be constructed with 2-inch diameter schedule (Sch) 40 poly vinyl chloride (PVC) riser pipe with a 2-inch diameter, 2-foot long, 0.010-inch slot machine-slotted Sch 40 PVC well screen. A silica sand filter pack will be placed to one foot above the screen. To provide an adequate seal of the borehole, one foot of very fine choker sand will be placed above the filter pack. Neat cement will be placed to 15 feet above the choker sand, and the remaining annular space for the biosparge well will be filled with a grout seal. The biosparge well will be set in a flush mount protective cover and labeled. Typical biosparge construction details are provided on Figure 3.

## 2.2 Pilot Test Set Up and Equipment

The following equipment will be mobilized to the Site for Phase I of the pilot test.

### 2.2.1 Air Injection Equipment

- Tow-behind air compressor injection manifold equipped with a gate valve for controlling injection pressure/flow rate, and gauges for monitoring airflow, pressure and temperature
- Flexible hose to connect the injection well to the manifold.

### 2.2.2 Monitoring Equipment

- A water-level meter to monitor water levels prior to, during, and after the pilot test
- A dissolved oxygen (DO) meter to monitor and record DO during the pilot test
- Digital or magnehelic gauges to monitor pressure at monitoring wells

## 2.3 Test Operation and Data Collection

Prior to commencement of the pilot test, Arcadis will collect the following baseline parameters from the biosparge well and monitoring wells:

- Groundwater elevations
- Total well depths
- DO

Additionally, Arcadis will record the distances between extraction and injection wells and their associated monitoring points.

Upon completion of baseline monitoring, air will be applied to the pilot test biosparge well at increasing pressure until the formation breakout pressure is exceeded and air begins to flow into the formation. If formation breakout is successful, Arcadis will perform a step test by incrementally increasing airflows and pressures applied to the pilot biosparge well. Arcadis will periodically collect field measurements of water level and groundwater DO from nearby monitoring wells PW-14-01, TW-14-01 and TW-14-02 during the course of the step test to evaluate formation response to sparging. Arcadis will use data from the step test to determine whether it is possible to deliver air into the weathered bedrock at an acceptable injection pressure and if Phase II should be implemented. If Phase I is successful, Arcadis will use data from the step test to confirm and/or update design assumptions for Phase II of the pilot test, such as biosparge airflow rates and pressures. Arcadis will also use the data to determine apparent strength of sparging influence in the formation and help guide placement of additional biosparge pilot and monitoring wells for Phase II of the test.

# 3 PHASE II PROPANE BIOSPARGE PILOT TEST

The second phase of the pilot test will last for approximately three months during which air, propane, and a bioaugmentation solution containing propanotroph bacteria (ENV425) and nutrients (diammonium phosphate [DAP]) will be injected into the biosparge pilot well installed during Phase I and two additional biosparge pilot wells, installed at locations determined based on the monitoring results from Phase I.

The objectives of Phase II of the pilot test are as follows:

- Confirm propane and oxygen distribution within the weathered bedrock
- Evaluate consumption rate of propane and oxygen to determine optimal air/propane flow rates as well as cycle frequency and duration
- Assess microbial community growth over time
- Evaluate the biodegradation of 1,4-dioxane and treatment radius of influence (ROI)
- Evaluate potential for lateral migration of propane and/or pressure buildup within weathered bedrock

## 3.1 Supplemental Well Installation

Arcadis will install two additional biosparge wells and two monitoring wells to provide additional injection and monitoring points for Phase II of the pilot test. These new wells will be installed at a distance of between 5 and 20 feet from the initial biosparge pilot wells, with the locations and spacing selected based on the sparging influence observed in the formation during Phase I of the test.

Wells will be installed using roto-sonic drilling methods. Biosparge pilot well screens will be set at the base of the weathered bedrock approximately 78 to 80 feet bgs with final screen depths selected based on field observations during drilling (following the same rational presented above for the initial pilot test well installed during Phase I). Biosparge pilot well construction and completion will be the same as the initial pilot test well. Typical biosparge pilot well construction details are provided on Figure 3.

The two pilot test monitoring wells will be screened from approximately 65 to 75 feet bgs, within the upper portion of the weathered bedrock. Final screen depths will be selected based on the screened interval of the biosparge wells and the field observations during drilling. Pilot test monitoring wells will be constructed of 2-inch diameter sch 40 PVC riser pipe with a 2-inch diameter, 10-foot long, 0.010-inch slot machine-slotted Sch 40 PVC well screen. A silica sand filter pack will be placed to two feet above the screen. The remaining annular space for the biospargewell will be filled with a bentonite grout seal. Monitoring wells will be set in a flush mount protective cover and labeled. Typical biosparge pilot monitoring well construction details are provided on Figure 3.

## 3.2 Pilot Test Set Up and Equipment

Arcadis will mobilize a propane biosparging system to the Site. Power will be provided to the system by a new electrical service line that will be installed from an existing on-site electrical disconnect located in the vicinity. Components of the system will be appropriately classified based on the potential for explosive gases by adhering to the National Fire Protection Associated (NFPA) code 497. The purpose of adhering to NFPA code 497 is to separate the process and electronic equipment that has the potential to spark from concentrations of propane that could result in an explosion.

### 3.2.1 Injection Equipment

The propane tank and the relevant piping, controls, valves, and other elements, will be located close together and designed as Class I Division II per NFPA code 497. The pressure release valve on the propane tank is considered a potential source of explosive vapors, and it triggers the classification of the area around it as Class I Division II. Guidance is not provided to classify a mixed gas line. Therefore, taking a conservative approach, the mixed gas line is also considered a potential source. An isolation distance of 15 feet or explosion proof barrier will be used to separate process and electronic equipment from the classified area around the propane tank pressure relief valve and mixed gas line per NFPA code 497. All equipment located within the classified area that is not isolated by an explosion proof barrier will be considered Class I Division II and designed in accordance with NFPA code 497.

An air compressor will provide air that will serve as the carrier gas for the propane. Both the compressed air line and the propane line will be equipped with pressure regulators, direct-acting solenoid valves, and back check valves to isolate the gas stream in the event of a system upset condition. Compressed air and propane will be continually metered by mass flow controllers as shown in Figure 4. System operations will be controlled by a process logic controller (PLC) housed in a control panel.

In addition to the pressure regulators, back check valves, seal-offs, equipment spacing specifications, and process safety features, an in-line sensor will be installed to monitor immediately downstream of the air-propane mixing point to monitor the lower explosive limit (LEL) of the mixed gas delivered to the formation. In the event that the LEL in the mixed gas line exceeds 25%, the sensor will send an alarm signal to the PLC that will shut off flows of compressed air and propane and shut down the system.

### 3.2.2 Monitoring Equipment

The following equipment will be used throughout the well monitoring network to determine the influence of the sparge test:

- A water-level meter to monitor water levels prior to, during, and after the pilot test
- An LEL detector to monitor propane concentrations prior to, during, and after the pilot test
- Vacuum gauges of varying sizes (0 to 10 inches [in] of $H_2O$, 0 to 25 in of $H_2O$, 0 to 50 in of $H_2O$, and 0 to 100 in of $H_2O$) to monitor vacuum and pressure throughout the vacuum monitoring well network. Gauges will be connected to air tight, valved ports connected to the tops of each vacuum monitoring point

## 3.3 Baseline Sampling

Prior to the initiation of the Phase II injection but at least two days after well installation and development, Arcadis will collect groundwater samples and field measurements from the following network:

- Three biosparge pilot test wells
- Two new pilot test monitoring wells

- Three existing monitoring wells (PW-14-01, TW-14-01, TW-14-02)
- Four additional monitoring wells screened within the weathered bedrock closest to the pilot test area in each direction (locations to be determined prior to pilot testing).

The four additional monitoring wells will function as sentinel points to monitor for the lateral migration of propane and/or pressure buildup in weathered bedrock groundwater beyond the treatment area. Wells will be purged of three standing well volumes prior to sampling.

Groundwater samples will be analyzed for the following parameters:

- 1,4-Dioxane
- Propane
- Nitrate, nitrite, total Kjeldahl nitrogen, and total phosphorus
- Total organic carbon
- Total and dissolved iron and manganese
- Quantitative polymerase-chain-reaction (qPCR) for propane mono-oxidase gene – four wells only
- Compound-specific isotope analysis (CSIA) – four wells only.

Additionally, Arcadis will record the following field parameters from all sampling locations:

- Depth to water
- pH
- DO – by optical sensor
- Oxidation-reduction potential
- Specific conductance
- Temperature
- Turbidity.

## 3.4 Propane Biosparge Test Operation

Phase II will begin with a two to three day startup/shakedown test. Air and propane will be delivered to the three pilot test wells in cycles controlled by the PLC. The duration and frequency of these flow cycles, air and propane flow rates, and other system operating parameters will be determined during the startup/shakedown test period. The system will continue injecting air and propane into the formation for the remainder of the first two weeks of operation. During this time, flow cycles and other operational settings will be adjusted to distribute dissolved-phase propane and oxygen in the groundwater within the pilot test area. Propane will be delivered to the formation at a concentration of between 15% and 20% of the LEL. The airflow rate to each of the pilot test will be determined during startup testing, but is anticipated to be five standard cubic feet per minute or less. The propane mass flow rate to the formation will be determined during the pilot test based on the airflow rate and other variables, but will likely be in the range of 0.3 to 0.6 pounds per day per well. The LEL will be monitored at nearby monitoring wells screened within the target treatment zone. Monitoring wells will be vented if necessary to prevent propane vapors from accumulating within the well casings.

During the third week of operation, bioaugmentation and nutrient amendment solutions will be injected into the biosparge wells to stimulate growth of propanotrophs in the formation. Approximately four liters bioagumentation solution containing the propanotroph culture ENV425 mixed with approximately 40 liters of extracted groundwater, followed by 20 pounds of DAP mixed in solution with approximately 200 gallons of extracted groundwater will be injected into each of the biosparge wells. The dosage of microbial culture and nutrients is based on previous project experience, but may be adjusted during the course of the pilot test based on laboratory qPCR and CSIA results. Safety data sheets for propane, ENV425 microbial culture, and diammonium phosphate are included in Appendix A. The system will then resume injecting air and propane cyclically for the remainder of the pilot test.

## 3.5 Performance Monitoring

Groundwater samples and field parameters will be collected periodically during the course of the test as performance monitoring data to evaluate the effectiveness of the remedy. Performance monitoring will generally be performed in accordance with Table 1.

If deemed necessary, at the end of the pilot test immediately following system shut down, propane groundwater samples will be collected from the two closest monitoring wells to the biosparge wells every 30 minutes for two hours to confirm dissipation of dissolved-phase propane from the weathered bedrock prior to demobilization.

# 4 INJECTION RECEPTOR ANALYSIS

Deep groundwater encountered at the Site is not used as a drinking water source; there are no drinking water wells located on Site. However, the Site is located partially within a wellhead protection area, and the bedrock aquifer targeted for injection is used as a drinking water source for the City of Lansing and Lansing Township. The biosparge pilot test area is outside the wellhead protection area for Lansing Township and City of Lansing. The locations of the municipal water source wells and wellhead protection areas relative to the Site and pilot test location are shown on Figure 5.

Municipal water wells are generally installed as open bedrock wells with total depths of 400 to 500 feet below grade. The well casings are generally set at 50 or more feet into bedrock to assure well stability. Lansing Board of Water and Light personnel have indicated that these wells are typically capable of pumping several hundred gallons per minute.

A transducer survey was completed at the Site to evaluate the hydraulic connection between the monitoring wells installed along the lower 1,4-dioxane plume and the municipal pumping wells. The results of the study show a hydraulic response at several bedrock wells located near the lower 1,4-dioxane source area at Plant 3. The highest amplitude of response was observed due to the pumping at Lansing Township Well #4, located approximately 1,000 feet west of the “coliseum” area (Figure 5). However, the bedrock in the 1,4-dioxane source area is not impacted, and operation of the municipal wells does not appear to effect the distribution of the lower 1,4-dioxane plume within the weathered bedrock zone (Arcadis 2015).

Because the municipal wells have not affected the distribution of the lower 1,4-dioxane plume over many years, they are unlikely to affect the distribution of injected propane and oxygen during the three month pilot test. The total mass of propane injected into the formation during the course of the pilot test should not exceed 150 pounds. Microbes will consume the majority of the injected propane. Additionally, propane is expected to dissipate rapidly within the formation at the end of the pilot test, which may be confirmed by post injection propane dissipation testing as discussed above. Based on a tracer study conducted in the northern part of Plant 2, seepage velocities for the test area are estimated to range from approximately 2.0 feet per day (ft/d) to 0.5 ft/d (Arcadis 2016). Based on these seepage velocities, the maximum distance dissolved gases are expected to travel is approximately 140 feet downgradient of injection wells. Therefore, dissolved propane is not expected to migrate off site or pose any threat to the off-site municipal wells.

Utilities within the injection areas or immediately downgradient of the injection area are shallow, typically less than 30 bgs. Due to the depth of the proposed injection (greater than 65 feet bgs), the dissolved propane will not contact any underground utilities or pose a threat to surface water.

## 4.1 Estimated Discharges

The estimated potential discharge concentrations during the biosparge pilot test are as follows:

1. Diammonium Phosphate

- A one-time injection of 200 gallons of DAP will be injected into three biosparge wells at approximately 120 grams per liter (g/L). Once dissolved and dissociated in the groundwater and assuming a dilution factor of two upon injection, 44 g/L of phosphate and 16 g/L of ammonium will be present. Based on historical groundwater quality data, a negligible amount of ammonia may be generated in situ from the ammonium. However, the nutrients are expected to be converted by the microorganisms in situ and are not expected to migrate outside of the test area. Nitrate and nitrite will also be monitored as production may stem from the decomposition of microorganisms in situ. Reduced phosphorus is not regulated under MDEQ drinking water criteria and will remain in the test area as a result of the injection.

2. Propane
   - Propane will be injected in a pulsed operation (for example, inject for 30 minutes six times per day) for up to three months at levels of up to 15% to 20% of the LEL. This corresponds to a total mass loading rate of between 0.9 to 1.8 pounds per day for all three biosparge wells, depending on the biosparge flow rate, cycle times, and duration.

3. Propanotroph culture ENV425
   - A one-time injection of a total of 12 liters of ENV425 propanotroph bacteria culture will be injected into the formation during the course of the pilot test. The culture consists of microbial communities in a water-based medium. The culture is comprised of ubiquitous mirobes that will not become invasive or damage the native microbial community.

As discussed above, these materials will be injected in small quantities and will be diluted, consumed or dissipated within the formation shortly after injection, so the risk of migration from the pilot test area is minimal.

# 5 DATA EVALUATION AND REPORTING

The data collected during the biosparge pilot test and associated sampling (if Phase II is completed); will be evaluated to assess the following:

- Propane and oxygen distribution within the weathered bedrock
- Consumption rate of propane and oxygen
- Optimal air/propane flow rates as well as cycle frequency and duration
- Microbial community growth over time
- Biodegradation of 1,4-dioxane and treatment radius of influence
- Potential for lateral migration of propane and/or pressure buildup within weathered bedrock.

Evaluation of these data will determine whether propane biosparging can be implemented as an effective full-scale remedy for the lower 1,4-dioxane plume in the weathered bedrock zone beneath Plants 2 and 3. At the conclusion of the biosparge pilot test, a report will be provided summarizing the data evaluation, conclusions, and recommendations.

# 6 CONTINGENCY PLAN

During Phase I, the pilot test will be terminated if air cannot be safely injected into the weathered bedrock zone.

During Phase II, the pilot test system will be immediately shut down if:

- Propane is detected at or above 10% of the LEL in ambient air in or around the pilot test area
- Excessive pressures in weathered bedrock wells that indicate that sparged gases cannot vent
- Dissolved propane is observed at elevated or increasing concentrations during performance monitoring of four closest weathered bedrock monitoring wells located outside the pilot test treatment area

In the event of a system shutdown, Arcadis will evaluate the monitoring data to determine if, and when, safe operation can resume.

# 7 SCHEDULE

Planning and coordination of this work will begin immediately after receiving MDEQ approval of this work plan. Implementation of Phase I is estimated to begin in the summer of 2016 with Phase II in the fall of 2016. The pilot test is expected to take between 4 and 6 months to complete. A summary report will be completed and provided following the completion of the biosparge pilot test.

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# FIGURES

# APPENDIX A

## Safety Data Sheets

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