November 4, 2016
ECT No.: 13-0685-2000

Mr. Shaun Lehman
MDEQ-OOGM Lansing District Office
Constitution Hall 2 South
525 West Allegan Street
Lansing, MI 48913

Re: **Pilot Study Work Plan – Phase 1**
Hartland 36 Gas Plant
SE/NE/NW Section 36, T03N-R06E
Hartland Township, Livingston County, Michigan

Dear Mr. Lehman:

This Pilot Study Work Plan – Phase 1 (Phase 1 Work Plan) was compiled by Environmental Consulting & Technology, Inc. (ECT) and presents a phased approach to complete pilot testing activities to evaluate groundwater remediation alternatives at the Hartland 36 Gas Plant (Site). Phase 1 Work Plan activities will consist of three components: 1) an aquifer pumping test to obtain data for determining aquifer characteristics (i.e. transmissivity, storativity, etc.) and extraction well radius of influence/capture zone; 2) an extended groundwater extraction and treatment pilot test to evaluate sulfolane concentrations and activated carbon treatment; and 3) an injection test to evaluate the ability of the groundwater aquifer to accept the injection of treated groundwater. Activities associated with Phase 1 pilot testing are detailed herein.

Proposed Pilot Study Phase 2 and Phase 3 will consist of an evaluation of bio-sparging and in-situ chemical oxidation (ISCO), respectively. Work plans associated with Phase 2 and Phase 3 pilot testing activities will be presented as discussed herein.

PROJECT LOCATION

The Site is located in the SE/NE/NW of Section 36, T03N-R06E, on the south side of Lone Tree Road between North Pleasant Valley Road and South Tipsico Lake Road in Hartland Township, Livingston County, Michigan. A Site Location Map, Site and Surrounding Properties Map, and Site Plan are attached as **Figure 1**, **Figure 2**, and **Figure 3**, respectively.

PROJECT SUBMITTALS

The following presents a chronological summary of previous documents submitted to the Michigan Department of Environmental Quality-Office of Oil, Gas, and Minerals (MDEQ-OOGM) by ECT for investigation and assessment activities completed at the Site:

- *Soil Closure Report* dated February 15, 2016.
- *Groundwater Characterization Work Plan* dated February 23, 2016.
- *Groundwater Characterization Work Plan 2* dated July 8, 2016.
- *Project Update Report* dated September 26, 2016.
- *Groundwater Characterization Work Plan 3* dated October 14, 2016.

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PROJECT BACKGROUND

Contaminated soil was discovered in September 2015 during facility decommissioning activities at the former sweetening plant/refrigeration building (sulfolane impact from the chemical Sulfinol®). Remediation activities (excavation) completed from September 2015 through December 2015 resulted in disposal of 13,481.4 tons of soil at the Venice Park Landfill in Lennon, Michigan. Verification of soil remediation (VSR) samples collected from the excavations confirmed remediation of impacted soils. Refer to the *Soil Closure Report* for a detailed summary of soil remediation and sampling activities.

Groundwater investigation activities commenced on October 29, 2016 and are currently ongoing. From October 29, 2015 through October 21, 2016 a total of 13 temporary monitor wells, including two vertical aquifer profile (VAP) locations, and 25 permanent monitor wells, including six monitor well clusters (shallow and deep screened monitor well), have been installed at the Site. The lateral and vertical extents of groundwater impacted with sulfolane have been delineated to non-detectable concentrations. At the date of this document, the maximum sulfolane concentration reported from a permanent monitor well (MW-13) at the Site was 8,800 micrograms per liter (µg/L). Refer to the attached **Figure 3** for monitor well locations. Refer to the attached **Table 1** and **Table 2** for a summary of groundwater analytical results. Data and information from the October 20-21, 2016 monitor well installation event and associated groundwater sampling event completed on November 3, 2016 will be included under separate cover.

Refer to the *Groundwater Characterization Work Plan, Groundwater Characterization Work Plan 2, Project Update Report*, and *Groundwater Characterization Work Plan 3* for detailed summaries of groundwater characterization activities.

PILOT STUDY

As a result of the presence of groundwater impacted with sulfolane above MDEQ-OOGM interim cleanup criteria, an evaluation of viable remedial alternatives is warranted. The remedial alternatives discussed below only consider groundwater, as soils impacted with sulfolane have been mitigated to concentrations below MDEQ-OOGM interim cleanup criteria (refer to ECT Soil Closure Report dated February 15, 2016 and associated MDEQ-OOGM concurrence letter dated March 2, 2016). The following remedial alternatives are presented in a phase pilot study to evaluate the effectiveness to mitigate concentrations of suflolane below MDEQ-OOGM interim cleanup criteria:

- Phase 1 – Pump & Treat
- Phase 2 – Bio-sparging
- Phase 3 – In-situ Chemical Oxidation (ISCO)

Phase 1 Work Plan activities are presented below and will consist of three components: 1) an aquifer pumping test to obtain data for determining aquifer characteristics (i.e. transmissivity, storativity, etc.) and extraction well radius of influence/capture zone; 2) an extended groundwater extraction and treatment pilot test to evaluate sulfolane concentrations and activated carbon treatment; and 3) an injection test to evaluate the ability of the groundwater aquifer to accept the injection of treated groundwater.

Phase 1 – Pump & Treat Test

Groundwater extraction and ex-situ treatment, more commonly referred to as pump & treat, has long been considered a remediation technology that ultimately reaches a point of diminishing returns for contaminants that readily adsorb to soil particles (i.e. typical petroleum and hydrocarbon compounds). However, in the case of sulfolane, the pump & treat technology could prove effective, as discussed below.

Adsorption and mobility data indicate sulfolane will not readily adhere to saturated soils and will migrate at a similar velocity to groundwater flow. This is evident by the low soil-water partioning coefficient (K_d), low organic carbon-water partition coefficient (K_{oc}), low octanol-water partition coefficient (K_{ow}), and high water solubility. The presence of a clay confining layer appears to not only limit the potential for vertical migration of sulfolane, but also prevent downgradient migration (as a result of the clay layer intersecting the groundwater table between the MW-13/MW-13D and MW-18 and the eastern property boundary and non-detectable concentrations reported at MW-6/MW-6S and MW-12S/MW-12D), thereby enhancing the effectiveness of capturing groundwater impacted with sulfolane.

The following activities are presented to assess groundwater pumping and ex-situ activated carbon treatment (i.e. pump & treat) as a viable remedial alternative to mitigate groundwater impacted with sulfolane.

Task 1 – Additional Monitor Well Installation

Prior to initiating the pump & treat pilot test, installation of additional monitor wells is necessary. As depicted on **Figure 3**, the following monitor wells are proposed to be installed:

- MW-20S, MW-20D, MW-20DD – Located upgradient of the former source area to investigate the absence or presence of the clay confining layer and provide additional groundwater monitoring for use with remediation planning. Continuous split-spoon sampling will be completed from approximately 20-60 feet below ground surface (ft bgs) and every 5 feet thereafter to a maximum depth of 100 ft bgs. Monitor wells will be set with screened intervals of approximately 20-25, 60-65, and 95-100 ft bgs, adjusted as warranted based on lithology.
- MW-21D – Located at TMW-012 to provide a permanent monitoring location below the clay layer situated at approximately 44.5-45.5 ft bgs (due to imported fill material as previous depth to clay at TMW-012 was approximately 42.5-43.5 ft bgs). MW-21 will be set with a screened interval of approximately 50-55 ft bgs, with filter pack placed from the well bottom to 2 feet above the screen, cement grout to 10 ft bgs, and auger cuttings to the ground surface.
- MW-22 – Located approximately 20 feet from IW-1 (discussed below) to monitor treated groundwater injection activities. MW-21 will be set with a screened interval of approximately 20-25 ft bgs.

Monitor well construction characteristics will be consistent with previous installation activities completed at the Site, including containerizing residual auger cuttings and development and decontamination water.

Task 2 – Aquifer Pumping Test

In order to evaluate aquifer parameters and gather radius of influence (ROI)/capture zone data for use in potential full scale design, an aquifer drawdown and recovery test will be completed as detailed below.

Extraction Well (EW-1) Details

The extraction well (EW-1) for the pumping test will be located approximately 30 feet southwest of the MW-13 well cluster (refer to the attached **Figure 3**). The location of EW-1 was selected based on the following criteria:

- Downgradient and beyond the limits of the excavation to minimize the potential for preferred migration pathways to the well screen.
- In close proximity to monitor wells with elevated concentrations of sulfolane and suitable for use with pressure transducers for water level data collection.
- The aquifer thickness is approximately 15 feet. The top of the clay confining layer (greater than 4 feet of stiff gray clay) was identified as follows:
  - ~41 ft bgs at MW-14D.
  - ~32 ft bgs at TMW-011.
  - ~30 ft bgs at MW-13D.
  - ~20 ft bgs at SB-1 (no groundwater on top of clay).

EW-1 will be constructed with 5-inch diameter schedule 40 PVC equipped with a 5-inch diameter, 15 foot long, 10-slot stainless steel screen (estimated screened interval of 20-35 ft bgs). The bottom of the well screen will be set immediately above the top of the clay confining layer. EW-1 will be completed with filter pack from the bottom of the well to 2 feet above the screen, bentonite to approximately 10 ft bgs, and auger cuttings to the ground surface. A submersible pump capable of pumping 15 gallons per minute (gpm) will be set in EW-1.

Aquifer Drawdown and Recovery Test Details

A constant rate (15 gpm) drawdown test will be completed by personnel from ECT for a maximum of 48 hours, with the recovery portion not to exceed 24 hours. Extracted groundwater will be discharged to two frac tanks each with a capacity of 490 barrels (bbl), or 20,580 gallons. The frac tanks will be set on a curbed impermeable liner. Extracted groundwater will be transported to an off-site disposal in accordance with applicable regulations.

Water level data will be collected via pressure transducers/datalogger(s) from the following monitor wells during the drawdown and recovery test:

- EW-1, MW-13, MW-13D, MW-14S, MW-14D, and MW-18.

Pressure transducers are anticipated to be programmed to collect readings at the following increments:

Elapsed Time	Measurement Frequency
0 to 1 minute	Every second
1 to 5 minutes	Every 30 seconds
5 to 10 minutes	Every 1 minutes
10 to 20 minutes	Every 2 minutes
20 to 60 minutes	Every 5 minutes
60 to 180 minutes	Every 15 minutes
180 to 360 minutes	Every 30 minutes
360 minute to completion	Every 60 minutes

Water level data will be collected via an electronic water level meter (0.01 feet accuracy) from the following monitor wells during the drawdown test:

- MW-6, MW-6D, MW-11, MW-12S, MW-12D, MW-17S, MW-17D, MW-19S, MW-19D, MW-20S, and MW-20D.

Please note, prior to initiating the pump test, current groundwater analytical data will be evaluated and monitor wells will be sampled for sulfolane, as warranted.

Task 3 – Extended Groundwater Extraction Test

In order to evaluate the ability of groundwater extraction to mitigate sulfolane impact at the Site, an extended groundwater extraction test will be performed subsequent to completion of the aquifer pumping test. The extraction test will be completed at a discharge rate of 10-15 gpm for a period not to exceed 14 consecutive days. Extracted groundwater will be collected in frac tanks and transported to an off-site disposal facility in accordance with applicable regulations. Personnel from ECT will complete daily site visits during the extraction test. Static groundwater levels will be collected with an electronic water level meter from the following monitor wells during each daily site visit:

- MW-6, MW-6D, MW-12, MW-12D, MW-11, MW-13, MW-13D, MW-14S, MW-14D, MW-17S, MW-17D, MW-18, MW-19S, MW-19D, MW-20S, and MW-20D.

Immediately following the conclusion of the groundwater extraction test, groundwater monitoring for sulfolane concentrations will be completed in the following monitor wells:

- EW-1, MW-11, MW-13, MW-13D, MW-14S, MW-14D, MW-17S, MW-17D, and MW-18.

Groundwater sampling will be completed with the use of dedicated polypropylene bailers. Groundwater samples will be submitted for laboratory analysis of sulfolane. Groundwater samples are anticipated to be collected on a bi-weekly basis for a period not to exceed 3 consecutive months.

Task 4 – Activated Carbon Treatment and Treated Water Injection Test

In order to evaluate the ability of activated carbon to treat extracted groundwater impacted with sulfolane, as well as the ability of the groundwater unit to accept groundwater via post-treatment injection, a carbon treatment and injection test will be completed.

The treatment and injection test will be completed for a maximum of 8 hours. Groundwater will be pumped from EW-1 at a maximum rate of 15 gpm through an appropriately sized carbon vessel containing granular coconut shell based carbon mesh size 8x30. Treatment studies completed in Alaska and Alberta (Canada) indicate granular coconut shell based carbon mesh size 8x30 effectively treats groundwater impacted with sulfolane to non-detectable concentrations (laboratory detection level of 10 µg/L). Treated groundwater will be discharged to injection well IW-1, located approximately 60 feet upgradient of proposed monitor well cluster MW-20. Well locations are illustrated on **Figure 3**. The location of IW-1 was selected to satisfy the requirements of R323.2210(u) of the Michigan Administrative Code (Rule 2210), identifying materials permitted to be discharged without a groundwater discharge permit.

During the extraction test, influent and effluent water samples will be collected from the carbon vessel at the test start, the mid-way point, and at test completion for laboratory analysis of sulfolane. In addition, mounding of the groundwater table will be monitored by collecting groundwater levels with an electronic water level meter from proposed monitor wells MW-20S, MW-20D, and MW-22. Water levels will be monitored every 15 minutes from test start through hour one and every 30 minutes thereafter through test completion.

Treatment equipment will be set on a curbed impermeable liner.

IW-1 will be constructed with 4-inch diameter schedule 40 PVC equipped with a 4-inch diameter, 10 foot long, 20-slot stainless steel screen (estimated screened interval of 20-30 ft bgs). IW-1 will be completed with filter pack from the bottom of the well to 2 feet above the screen, bentonite to approximately 10 ft bgs, and auger cuttings to the ground surface.

Task 5 – Phase 1 Pilot Study Report

Subsequent to receipt of data from the second bi-weekly groundwater sampling event following the extended groundwater recovery test, a report will be prepared detailing the results of the Phase 1 Pilot Study. The report will present data obtained from the pilot study including ROI/capture zone estimates, aquifer parameter estimates, initial data for recoverability of sulfolane, etc. Ultimately, the data presented in the report could be utilized for full scale remediation system design,

Phase 2 – Bio-Sparge Test

Air sparging is a remediation alternative that can be utilized to create a phase transfer of dissolved phase groundwater contaminants to a vapor phase via the introduction of air to impacted groundwater. In consideration of site-specific conditions, air sparging is effective for remediating VOCs but not as effective for SVOCs. Alternatively, bio-

sparging is a remediation alternative that provides air (i.e. oxygen) to the subsurface environment thereby enhancing the degradation/attenuation of subsurface contaminants. Successful bio-sparging requires distributing air within the area of impact and minimizing the potential for preferential flow paths. Furthermore, since sulfolane has low volatility, concerns over removing/treating subsurface vapors are not an issue, which is further alleviated by clayey vadose zone soils.

Information with regard to sulfolane contamination in an aerobic environment indicates sulfolane is susceptible to degradation/attenuation. Furthermore, available data from projects completed on groundwater impacted with sulfolane in Alaska and Alberta suggests bio-sparging is an effective remedial alternative, with degradation (to non-detectable concentrations) potentially occurring in less than 7 days.

Subsequent to stabilization of sulfolane groundwater concentrations following the pump & treat pilot test, a bio-sparging pilot test is proposed to be completed. Prior to initiating the test, a bio-sparge pilot test work plan will be submitted to MDEQ-OOGM.

Phase 3 – In-situ Chemical Oxidation (ISCO) Test

In-situ chemical oxidation (ISCO) is typically considered for remediation of contaminants amenable to oxidation. Conditions favoring successful ISCO application include impacted media with low oxidant demand and contaminants that are not strongly adsorbed to solids. The suitability of ISCO at a site requires that the oxidant and delivery method be matched to site conditions. Successful oxidation depends on establishing contact between oxidants and contaminants. Subsurface heterogeneities or preferential flow paths, if not accounted for, can result in untreated contaminants. The oxidant could also be consumed by natural organic matter or dissolved iron, thereby reducing ISCOs effectiveness.

In summary, the most critical success factors are:

- The effectiveness of, and ability to control, the ISCO reaction with the contaminants.
- Maintaining contact between the reagents and the zone to be treated (at the Hartland Site, the size and depth of the impacted area appears manageable).

Groundwater quality information from the Site indicates that conditions in general are oxidative (substantial positive ORP) despite locations (MW-6, MW-7, MW-9, and MW-13) where dissolved oxygen concentrations have been reduced. Sulfolane concentration and chemical oxygen demand in groundwater samples are correlated with depleted DO. Conditions at the Site appear to be appropriate for application of ISCO.

Data from ISCO applications in Alberta suggest degradation via injections of potassium permanganate and persulfate can achieve greater than 75% degradation.

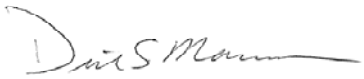
Subsequent to stabilization of sulfolane groundwater concentrations following the bio-sparge pilot test, an ISCO pilot test is proposed to be completed. Prior to initiating the test, an ISCO pilot test work plan will be submitted to MDEQ-OOGM.

CLOSING

ECT sincerely appreciates the opportunity to provide our consulting services on this important project. Should you have questions or require additional information, please do not hesitate to contact me at your convenience at 231.946.8200 or jlewandowski@ectinc.com.

Sincerely,
ENVIRONMENTAL CONSULTING & TECHNOLOGY, INC.

Jeremy S. Lewandowski
Senior Engineer



Dirk S. Mammen
Principal Scientist

CC: Sean Craven – Merit Energy Company

Attachments:

- Figure 1 – Site Location Map
- Figure 2 – Site and Surrounding Properties Map
- Figure 3 – Site Plan
- Table 1 – Sulfolane Analytical Summary & Cleanup Criteria Comparison – Monitor Wells
- Table 2 – Sulfolane Analytical Summary & Cleanup Criteria Comparison – Temporary Monitor Wells

FIGURE 1.

SITE LOCATION MAP

Sources: USGS Quad: Kent Lake, 2015; West Highland, 2015; ECT, 2016.

ECT Environmental Consulting & Technology, Inc.

FIGURE 2.

SITE AND SURROUNDING PROPERTIES MAP

Source: Google Earth, 2016.

ECT Environmental Consulting & Technology, Inc.

Legend

- Monitor Well
- Temporary Monitor Well
- Soil Boring
- Proposed Extraction Well
- Proposed Injection Well
- Proposed Monitor Well

* Not yet integrated into Site Survey

Excavation Boundary

Fenceline

FIGURE ADAPTED FROM SURVEY PERFORMED BY:

Gourdie-Fraser
Municipal | Development | Transportation

MERIT ENERGY COMPANY

ECT Environmental Consulting & Technology, Inc.

MERIT ENERGY COMPANY HARTLAND 36 NATURAL GAS PLANT

130685 - 2000
ECT PROJECT NUMBER

DESIGNED BY	CHECKED BY
-	-

DRAWN BY	APPROVED BY
BJB	JSL

SHEET TITLE

SITE PLAN

SCALE: 1" = 50 @ 11x17

0 25' 50'

NORTH

FIGURE

3

TABLE 1
SULFOLANE ANALYTICAL SUMMARY &
CLEANUP CRITERIA COMPARISON - MONITOR WELLS
Hartland 36 Gas Plant
SE/NE/NW Section 36, T03N-R06E,
Hartland Township, Livingston County, Michigan
ECT Project #13-0685-2000

Sample Location	Screened Interval (ft bgs)	Sulfolane by EPA Method 8270D (µg/L)							
		10/15/2015	11/4-5/2015	11/13/2015	1/27/2016	6/3/2016	8/3-4/2016[10]	9/21-22/2016	10/12/2016
W-Pit	---	**20,000**	---	**14,000**	**---**	---	---	---	**---**
MW-1	20.1 - 25.1	---	ND	---	ND	ND	---	ND	---
MW-2	19.1 - 24.1	---	ND	---	ND	ND	---	ND	---
MW-3	22.0 - 27.0	---	ND	---	---	ND	---	ND	---
MW-4	23.1 - 28.1	---	ND	---	ND	ND	ND	ND	ND
MW-5	18.0 - 23.0	---	ND	---	ND	ND	---	ND	ND
MW-6	25.4 - 30.4	---	ND	---	ND	ND	ND	ND	ND
MW-6D	39.4 - 44.4	---	**---**	---	---	**---**	ND	ND	ND
MW-7	22.6 - 27.6	---	**880**	---	44	**450 (510)[9]**	ND	**210**	---
MW-8	24.6 - 29.6	---	---	---	---	---	ND	ND	---
MW-9	23.4 - 28.4	---	---	---	---	---	ND	ND	---
MW-10	19.0 - 24.0	---	---	---	---	---	ND	ND	---
MW-11	18.8 - 23.8	---	---	---	---	---	ND	ND	---
MW-12S	20.5 - 25.5	---	---	---	---	---	ND	ND	ND
MW-12D	49.7 - 44.7	---	---	---	---	---	ND	ND	ND
MW-13	19.2 - 24.2	---	---	---	---	---	**6,600**	**8,800**	---
MW-15	23.4 - 28.4	---	---	---	---	---	ND	ND	---
MW-16	18.5 - 23.5	---	---	---	---	---	ND	ND	---
MDEQ-OOGM Cleanup Criteria		**90**							
Collection Method		Grab	LF	Grab	LF	Bailer/PP	LF	LF	LF

Notes

1) ft/bgs - Feet below ground surface.
2) Collection method - Grab, peristaltic pump (PP), low flow (LF), Bailer.
3) µg/L - Micrograms per liter, equivalent to parts per billion (ppb).
4) (---) - Not sampled.
5) ND - Concentration not detected above reporting limit.
6) (###) - Concentration is for duplicate sample.
7) Cleanup criteria for sulfolane established by MDEQ-Office of Oil, Gas, and Minerals (MDEQ-OOGM).
8) Concentrations that are shaded and bold exceed cleanup criteria.
9) Sample also collected and reported "ND" for diisopropanolamine (DIPA).
10) MW-7 analyzed from 8/11/2016 sample collection date.

TABLE 2
SULFOLANE ANALYTICAL SUMMARY & CLEANUP CRITERIA COMPARISON - TEMPORARY MONITOR WELLS

Hartland 36 Gas Plant
SE/NE/NW Section 36, T03N-R06E,
Hartland Township, Livingston County, Michigan
ECT Project #13-0685-2000

Sample Location	Screened Interval (ft bgs)	Sulfolane by EPA Method 8270D (µg/L)		
		10/30/2015	6/2/2016	7/27/2016
TMW-6	35-40	<10	---	---
TMW-6	45-50	<10	---	---
TMW-6	55-60	<10	---	---
TMW-6	65-70	<10	---	---
TMW-01	25-30	---	<11	---
TMW-02	20-25	---	<10	---
TMW-03	18-23	---	<10	---
TMW-04[9]	19-24	---	**2,600**	---
TMW-05	16.5-21.5	---	**4,500**	---
TMW-07[9]	19-24	---	**4,200 (3,900)**	---
TMW-08[9]	19-24	---	**710**	---
TMW-09	18-23	---	**5,900**	---
TMW-010	90-95	---	<10	---
TMW-010	70-75	---	<10	---
TMW-010	45-50	---	<10	---
TMW-011	27-32	---	**4,800**	---
TMW-012	38-43	---	---	**480**
MDEQ-OOGM Cleanup Criteria		**90**		
Collection Method		Grab		

Notes

1) ft/bgs - Feet below ground surface.
2) Collection method - Grab (bailer or peristaltic pump), low flow (LF), Bailer.
3) µg/L - Micrograms per liter, equivalent to parts per billion (ppb).
4) (---) - Not sampled.
5) nd - Concentration not detected above reporting limit.
6) (###) - Concentration is for duplicate sample.
7) Cleanup criteria for sulfolane established by MDEQ-Office of Oil, Gas, and Minerals (MDEQ-OOGM).
8) Concentrations that are shaded and bold exceed cleanup criteria.
9) Sample also collected and reported "nd" for diisopropanolamine (DIPA).