# CORRECTIVE MEASURES IMPLEMENTATION REPORT

# LNAPL RECOVERY BY MULTI-PHASE EXTRACTION: FORMER BUILDING 33, LNAPL AREA 1

## GENERAL MOTORS CORPORATION
## PONTIAC CENTERPOINT CAMPUS
## PONTIAC, MICHIGAN
## MID 005356902



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LIST OF ACRONYMS

| | |
|---|---|
| acfm | Actual cubic feet per minute |
| AOI | Area of interest |
| AQD | Air Quality Division |
| AST | Aboveground storage tanks |
| BACT | Best available control technology |
| bgs | Below ground surface |
| CRA | Conestoga-Rovers & Associates, Inc. |
| ENCORE | Environmental Corporate Remediation Company, Inc. |
| FLUTe | Flexible liner underground technology |
| frac | Fracture |
| ft | Feet |
| GAC | Granular activated carbon |
| GEE | Ground Effects Environmental Services Inc. |
| GM | General Motors Corporation |
| gpm | Gallons per minute |
| "$H_2O$ | Inches of water |
| "Hg | Inches of mercury |
| Hp | Horsepower |
| ITS | Internal Treatment System |
| LEL | Lower explosive limit |
| LNAPL | Light non-aqueous phase liquid |
| MDEQ | Michigan Department of Environmental Quality |
| MPE | Multi-phase extraction |
| P&ID | Process and instrumentation diagram |
| PAL | Pneumatic air-lift |
| PF | Pneumatic fracturing system |
| PID | Photoionization detector |

| | |
|---|---|
| ppmv | Parts per million (volume) |
| psi | Pounds per square inch |
| PTI | Permit to install |
| PVC | Polyvinyl chloride |
| scfm | standard cubic feet per minute |
| SOW | Scope of work |
| THC | Total hydrocarbon |
| U.S EPA | United States Environmental Protection Agency |
| VOC | Volatile organic carbon |
| WST | Web server telemetry |

## 1.0 INTRODUCTION

Conestoga-Rovers & Associates, Inc. (CRA) was retained by Environmental Corporate Remediation Company, Inc. (ENCORE), a wholly-owned subsidiary of General Motors Corporation (GM), to implement Corrective Measures for the recovery of light non-aqueous phase liquid (LNAPL) at LNAPL Area 1 in Area of Interest (AOI) 53. This effort is focused on the remediation of the petroleum plume at LNAPL Area 1 beneath the location of the former Building 33 at the GM Pontiac Centerpoint Campus West (Site). The Site is located at 660 South Boulevard East in Pontiac, Michigan (MID 005356902). The Site location is presented on Figure 1.1. The Site plan is presented on Figure 1.2. The Corrective Measures selected for LNAPL recovery at LNAPL Area 1 were high vacuum multi-phase extraction (MPE) with pneumatic air-lift (PAL) and pneumatic fracturing (PF) and groundwater monitoring. GM proposed the full-scale implementation of MPE/PAL and PF as the final remedy for LNAPL Area 1 in the Corrective Measures Proposal submitted to the United States Environmental Protection Agency (U.S. EPA) on April 21, 2006. The U.S. EPA approved the remedy in its Final Decision and Response to Comments dated August 3, 2006. The remedial drivers for this MPE Corrective Measure included:

- Observed pre-MPE in-well LNAPL thicknesses up to 10.2 feet (ft);
- Potential soil gas explosivity risk; and
- Potentially significant exposures due to volatilization from subsurface and potential vapor migration into indoor air.

This report details the implementation of the MPE remedy and the corresponding results. In addition, investigative activities conducted prior to and during MPE operations, as well as proposed post-MPE evaluation and monitoring are discussed.

This report is organized as follows:

Section 1.0 – Introduction;

Section 2.0 – Project Chronology;

Section 3.0 – Full-Scale MPE System Equipment and Operation;

Section 4.0 – Full-Scale MPE Operations;

Section 5.0 – MPE Shutdown Conclusions; and

Section 6.0 – Post-MPE Evaluation.

## 2.0 PROJECT CHRONOLOGY

The former Building 33 area is located on the west side of the Pontiac Centerpoint Campus. In 1985, GM discovered a petroleum release during a geotechnical investigation for a planned expansion of Building 33. The source of the petroleum leak is believed to be an underground fuel line that supplied a fuel island south of Building 33. The fuel line was discovered to be leaking in 1968/1969. In 1969, the fuel line was abandoned and removed and the underground supply lines were abandoned and capped at both ends. The location of the suspected petroleum leak is presented on Figure 2.1.

A number of investigations have taken place at Building 33 prior to and during the implementation of the MPE Corrective Measure. In addition, MPE was pilot tested in advance of the full-scale implementation. This section provides a chronology of all investigations and activities conducted to date related to the MPE Corrective Measure. Each section contains a summary of the respective activities, with detailed information on the operation and performance of the full-scale MPE system presented in Section 3.0.

### 2.1 HISTORICAL INVESTIGATIONS

Several investigation programs were conducted prior to the evaluation of MPE as a potential Corrective Measure for LNAPL Area 1. These investigations focused on delineating the LNAPL plume and assessing any potential exposures due to the resulting soil and groundwater impacts. Detailed results of these investigations were presented in the following previous submissions to the U.S. EPA:

- Building 33 – Free Product Study Area (CRA, January 1994);
- Subsurface Investigation/Remedial Alternatives Evaluation Report - Building 33 – Free Product Gasoline Plume (CRA, January 1995);
- Review of Existing Conditions Report (CRA, October 1995);
- Supplemental Review of Existing Conditions Report (CRA, December 1995);
- Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Work Plan (CRA, September 1998);
- Building 33 Interim Measures Work Plan (CRA, June 2004);
- Building 33 Additional Investigation Work Plan Memorandum (CRA, July 2004);
- Building 33 Interim Measure Investigation Report (CRA, August 2005); and

- RFI Report (CRA, October 2005)

These submissions collectively summarize previous investigations and historic remedial activities pertaining to the LNAPL plume beneath Building 33 leading to the evaluation of MPE as a potential corrective measure for LNAPL Area 1.

## 2.2 MPE PILOT STUDY

A remedial pilot study was conducted to evaluate the effectiveness of MPE and assess any added benefits of utilizing PF for enhanced recovery. The pilot study was conducted from December 7, 2004 through February 15, 2005, excluding a shutdown from December 18, 2004 through January 5, 2005.

The complete details of the pilot study methodology were provided to U.S. EPA in the Work Plan for the Remedial Pilot Study (CRA, November 2004). The results were presented to U.S. EPA in the Remedial Pilot Study Report (CRA, May 2006). The following presents a brief synopsis of the pilot study.

The hydrocarbons recovered during the pilot study consisted of three distinct fractions: free phase (free product), dissolved phase, and vapor phase. Each of these fractions was measured independently during the pilot study, and summed to arrive at the overall estimated LNAPL equivalent mass removed during the pilot study.

The overall hydrocarbon mass removal rates were highest during the first two weeks of the pilot study and steadily decreased over time. A total of approximately 3,097 gallons of LNAPL equivalent were recovered during the pilot study. The phase-specific hydrocarbon recovery fractions were as follows:

- 53% of the total mass of recovered LNAPL was recovered in the free (liquid) phase;
- 47% of the total mass of recovered LNAPL was recovered in the vapor phase; and
- 0.001% of the total mass of recovered LNAPL was recovered in the dissolved phase.

Total water production (treated groundwater) over the course of the pilot study was 33,951 gallons.

The results of the remedial pilot study indicated that a full-scale MPE/PAL and PF system would be an effective remediation option for the LNAPL beneath Building 33.

## 2.3 SUPPLEMENTAL INVESTIGATION PRIOR TO FULL-SCALE MPE IMPLEMENTATION

A supplemental subsurface investigation was undertaken in May 2006 to refine the delineation of the LNAPL at LNAPL Area 1 and to optimize the layout of extraction wells prior to the implementation of the MPE system. Investigation within the central portion of LNAPL Area 1 was not possible historically due to the nature of the operations and the location of equipment within this portion of the building. However, the demolition of Building 33 in December 2005 made this central portion of LNAPL Area 1 accessible for subsurface investigation. The investigation consisted of the installation and screening of soil borings using visual, olfactory and photoionization detector (PID) methods. In addition, Flexible Liner Underground Technologies (FLUTe) liners were installed at select locations in an attempt to aid the vertical delineation of the smear zone. The soil boring screening confirmed the previous understanding of the suspected areas of petroleum impacts and the vertical extent of the smear zone. This work supported the targeted placement of MPE extraction wells and screen intervals. A memorandum detailing the full methodology and results of this investigation is provided in Appendix A.

## 2.4 FULL-SCALE MPE SYSTEM IMPLEMENTATION

Implementation of the full-scale MPE system was proposed to U.S. EPA in the Corrective Measures Proposal (CRA, April 2006). The detailed methodology for installation and operation of the system was provided to U.S. EPA in the Corrective Measures Work Plan, Former Building 33, LNAPL Area 1 (CRA, August 2006). The following is a brief summary of the implementation of the full-scale MPE system.

A network of extraction and LNAPL perimeter monitoring wells was installed in June 2006 and August 2006 (i.e., RW33-1 through RW33-33). Well construction consisted of 4″ diameter Schedule 40 polyvinyl chloride (PVC) screens (10-slot) and risers. Well screens were typically set at 10 -25 ft below ground surface (bgs). However, evidence of an elevated water table (post-building demolition) in certain areas necessitated a shallower screen interval. Well logs for the extraction wells and LNAPL perimeter monitoring wells are included in Appendix B. Figure 2.1 illustrates the well locations. The elevated water table was most pronounced along the eastern edge of the extraction well network and became less significant moving east to west. The exception to this trend was a significant groundwater mound observed in the vicinity of RW33-31 in the northwest edge of the network. The most-likely explanation for the increased water table elevation was concluded to be increased infiltration through breaches in the building slab following building demolition. The areas of most pronounced increase in groundwater elevation coincided with areas where pits, trenches and sumps were backfilled with gravel during demolition activities. The typical practice during demolition is to break the bottoms of these subsurface structures prior to backfilling to prevent the retention of stormwater. Consequently, stormwater infiltration was readily occurring in sections of the slab where this effect would not have been occurring prior to building demolition. In an attempt to minimize this effect, a tarping strategy was implemented that involved grading the surface of the backfilled pits where the groundwater mounding was most pronounced in order to direct runoff away from the MPE extraction area prior to covering the graded areas with tarps. The tarping strategy that was implemented in March 2007 is illustrated in Figure 2.2.

The State of Michigan Air Permit to Install (PTI) allowing the installation of the MPE system equipment was issued on April 4, 2006 (revised April 10, 2006). Equipment was subsequently brought to the Site between May 2006 and July 2006. Installation of the system equipment and extraction pipe network was completed on July 31, 2006. Full-scale operation of the system commenced on September 6, 2006. A detailed discussion of the operation of the system is provided in Section 3.0.

## 2.5 INVESTIGATION CONDUCTED CONCURRENT WITH FULL-SCALE MPE OPERATIONS

During operation of the full-scale MPE system, occasional trace product was observed in LNAPL perimeter monitoring wells RW33-42, 43 an 45. In order to delineate the free product, subsurface investigations were conducted over several mobilizations occurring from September 4, 2007 through February 11, 2008. The goal of the additional delineation work was to establish a perimeter of monitoring wells with no apparent LNAPL in order to monitor the stability of the LNAPL plume perimeter.

Soil borings were completed in several rounds by stepping out as impacts were detected during field screening of soil borings for evidence of petroleum product impacts. Soil borings were screened for visual and olfactory evidence of petroleum impacts. In addition, soil borings were screened with a PID. The soil interval exhibiting the maximum PID response was further screened with an OilScreenSoil ® Sudan IV jar test to identify the potential presence of free product. When any respective soil boring's zone of maximum PID response exhibited a positive jar test result (i.e., formation of separate phase stained red by hydrophobic dye), a step-out borehole was installed.

Delineation wells were installed at locations where the zone of maximum PID response exhibited a negative jar test result (i.e., no visible dyed separate phase). This process resulted in delineation of the LNAPL by establishing a ring of wells free of LNAPL. The well locations installed during this investigation included RW33-47 through RW33-58.

In addition, several monitoring wells were installed to establish new area perimeter groundwater monitoring points or to replace certain well locations that had been abandoned prior to the demolition of Building 33. These were: MW33-34 to MW33-37; MW33-21R, MW33-27R, and MW33-30R. These well locations were based on the monitoring locations proposed for the area in the Site's Long-Term Monitoring Plan.

All well locations described above are shown in Figure 2.1. The associated soil boring/well logs are provided in Appendix B.

# 3.0 FULL-SCALE MPE SYSTEM EQUIPMENT AND MONITORING

This section presents the materials and equipment used in the full-scale MPE Corrective Measure at the former Building 33.

## 3.1 EQUIPMENT AND MATERIALS

### 3.1.1 EXTRACTION WELLS

Construction details for the extraction wells were previously discussed in Section 2.4. A schematic of a typical extraction well is illustrated in Figure 3.1.

### 3.1.2 FRACTURE WELLS

Eight air fracture (frac) wells were installed at the former Building 33 location. The locations of the wells are identified in Figure 2.1.

The frac wells were driven directly into the ground using a Geoprobe. The frac wells consisted of 1-inch diameter, stainless steel piping material. Each well consisted of a bottom perforated portion that straddled the groundwater/LNAPL interface, extending from the unsaturated zone into the saturated zone for the vertical length of LNAPL impacts, and a non-perforated riser pipe. The riser pipe extended from approximately 10 ft bgs up to approximately 6″ above ground surface. All frac well piping materials were fabricated by Ground Effects Environmental Services Inc. (GEE). Detail of a typical frac well is illustrated in Figure 3.2.

### 3.1.3 EXTRACTION NETWORK PIPING & FITTINGS

All piping materials used to convey extracted vapors and fluids from the MPE wells to the MPE system consisted of a mixture of 3″ and 4″ diameter Schedule 40 PVC pipe. The piping was secured at the top of each MPE wellhead using a custom PVC wellhead assembly designed to allow measurement of various operating parameters and easy well access when necessary. All extraction pipes were routed into one of four PVC headers that were connected via 4″ PVC piping to the system.

A PVC gate valve was installed at each MPE wellhead to allow for flow control and wellhead monitoring (see Figure 3.1).

Compressed air was delivered to the PALs and the frac wells via a mixture of 2″ diameter Schedule 80 PVC pipe and vacuum-rated reinforced flexible hose. Each PAL line and frac well could be isolated via a 2″ brass gate valve.

### 3.1.4 MPE REMEDIATION SYSTEM

The GEE MPVE 27100 system consisted of a 100 horse power (Hp) electric rotary lobe vacuum pump capable of delivering a maximum vacuum of 27 inches of mercury ("Hg) and a maximum air flow rate of 1, 734 actual cubic feet per minute (acfm) at 20″Hg. The system was equipped with an Internal Treatment System (ITS) that included an 840-gallon air/liquid separator (knockout) tank, oil/water separator, and a high efficiency, low maintenance vacuum air stripper, bag filters, and granular activated carbon (GAC). The air stripper was equipped with three 39″ by 72″ air stripping trays complete with diffusers. The ITS is completely enclosed, which eliminated the additional blower (for the air stripper), level controls and transfer pumps typically required for the operation of a modular treatment train of this nature. The vacuum applied at the knockout tank within the ITS was used to operate the air stripper under vacuum.

The system was equipped with a silt removal/settling tank upstream of the ITS. A 350-gallon high-efficiency mud separator tank was utilized as a silt knockout to reduce the solids loading to the system. The silt collected in the knockout tank was periodically removed, characterized, and appropriately disposed of off-Site. In addition, dual stage bag filters (25 and 5 micron) and two 1,000-pound liquid phase GAC units (in series) were utilized downstream of the ITS.

The system oil/water separator was equipped with an internal storage tank that is capable of storing 28-gallons of separated LNAPL. Recovered LNAPL was temporarily stored in the 28-gallon storage tank and subsequently transferred via transfer pump to a 1,000-gallon double-walled aboveground storage tank (AST). The oil/water separator was also equipped with a sludge hopper and progressive cavity mud pump to remove solids within the extracted liquid stream.

The system was equipped with three conductivity level switches for the transfer pump and low-level, high-level, and high high-level shut down controls. The system also contained two 32″ by 42″ clean-out ports and two drain ports. A liquid level sight glass was mounted on the unit for easy viewing of internal processes.

Influent and effluent liquid sampling ports were installed at the inlet and liquid outlet of the MPE unit. Intermediate liquid sampling ports were also located between each of the treatment units. Vapor sampling ports were located at the system's gas stream exhaust point and the exhaust stack of the thermal/catalytic oxidizer.

The system was powered by an on-Site underground electrical feed from Building 34/52. Figure 3.3 presents a schematic of the system. A process and instrumentation diagram (P&ID) of the system is presented in Figure 3.4. Complete system specifications are provided in Appendix C.

### 3.1.5 THERMAL/CATALYTIC OXIDIZER

A thermal/catalytic oxidizer was operated for part of the remediation period to control the emission of volatile organic compounds (VOC) (petroleum vapors) to the ambient air through the system's gas-phase exhaust stream. The oxidizer was operated exclusively in thermal mode. The rated VOC destruction efficiency in full thermal mode (catalyst bed removed) is greater than 99%. The system had a maximum design flow rate of 2,000 standard cubic feet per minute (scfm), with a corresponding exit velocity of approximately 600 feet per minute. This translated into a minimum combustion chamber residence time of 1.5 seconds. The operating temperature in full thermal mode was approximately 1,550°F. Propane was utilized as the supplemental fuel. The oxidizer was equipped with a heat exchanger that provided approximately 50% efficiency. Instrumentation included monitoring of combustion chamber temperature, oxidizer stack temperature, inlet flow rate, and inlet THC concentration. A P&ID of the oxidizer and gas train is presented in Figure 3.5.

### 3.1.6 AIR COMPRESSOR

A single air compressor was used for both PAL and PF purposes. The compressor was a 50 Hp Ingersoll-Rand electric unit capable of providing a maximum airflow rate of 200 acfm at a pressure of 100 pounds per square inch (psi). The compressor was used with a surge tank to pulse air into the extraction and PF wells on a cycled basis as needed.

### 3.1.7 MONITORING AND OTHER RELATED EQUIPMENT

The system was equipped with the following instrumentation to allow process monitoring:

- Water Flow Meter: An ABB 10DX4311 magnetic flow meter was utilized to measure the discharge of separated groundwater from the system. The flow meter was capable of measuring flow in the range of 3-50 gallons per minute (gpm);
- Air Flow Meter: A Rosemount 3051SFA annubar flow meter was utilized to measure the system gas stream exhaust volumetric flow rate;
- Lower Explosive Limit (LEL) Sensor: A Draeger Polytron IREXIL infrared sensor was utilized to continuously monitor the THC concentration in the exhaust gas stream. The sensor operated in the 0-10,000 parts per million volume (ppmv) range; and
- Web Server Telemetry (WST) system: The WST system allowed wireless remote operation and monitoring of the system from any location with internet access through a secure website. The WST system operated in conjunction with the vacuum transmitter and vapor temperature transmitter described below:
  - Vacuum Transmitter: A Wika 892.13.500 vacuum transmitter was utilized to transmit the system applied vacuum to the WST system, and
  - Vapor Temperature Transmitter: A Rosemount 644H SMART system was utilized with a Rosemount Series 644 Temperature Transmitter, direct mount with Rosemount Instruments Model 0183 Thermocouple Sensor to transmit the exhaust vapor stream temperature to the WST system.

The complete specifications of the system are available in Appendix C.

The following monitoring equipment was utilized as needed for the purposes of system optimization, effluent monitoring (both liquid and gas/vapor streams), and data collection from the extraction/monitoring well network:

- Oil/Water Interface Probe: A Solinst Model 122 oil/water interface probe was used as needed to record the depths to LNAPL/groundwater in the MPE/PAL wells and surrounding monitoring wells. The probe was equipped with an infrared sensor and conductivity sensor and was capable of measuring LNAPL thicknesses of 0.005 ft or greater. The presence of LNAPL was indicated by an audible steady tone with a visual steady red light. The presence of groundwater was indicated by an audible pulsed tone with a visual blinking red light;

- Vacuum Gauges: Various vacuum gauges were used to record applied and/or induced vacuum or pressure on MPE wells and surrounding monitoring wells. Gauges for MPE wellheads were capable of reading applied vacuums ranging from 0 to -30"Hg. Gauges for monitoring wells were capable of reading induced vacuums ranging from 0 to -10 inches of water ("$H_2O$), and 0 to -1 "$H_2O$. All vacuum readings from monitoring wells were obtained under sealed conditions using specialized well caps with integrated air-tight quick-connect fittings; and
- Handheld Hydrocarbon Analyzers: A MiniRAE 2000 handheld PID and portable 4-gas analyzers were utilized to periodically evaluate well headspace volatility.

## 3.2 MONITORING AND MEASUREMENT

Monitoring and measurement of various system parameters, extraction well parameters, and monitoring well observations was performed to optimize the operation of the system and collect necessary data regarding hydrocarbon recovery rates and the system's effluent liquid and vapor-phase streams. The details of this monitoring and measurement are discussed in the following subsections and are summarized in Table 3.1.

### 3.2.1 MPE SYSTEM

Operation of the MPE system was monitored on a continuous basis. Specifically, the following parameters were monitored:

- Gas-phase total hydrocarbon concentration;
- Gas-phase discharge volumetric flow rate;
- Treated water volumetric flow rate;
- Pressure/vacuum readings from various points in the system treatment train;
- Vacuum pump power level;
- Vacuum pump run time;
- Vacuum pump exhaust temperature;
- Oxidizer combustion chamber temperature; and
- Monthly total volume of treated water discharged.

These data were used to calculate mass hydrocarbon recovery rates, optimize the system operating parameters, and calculate the liquid and vapor-phase hydrocarbon emission rates. Monitoring equipment used to record and/or collect the necessary data is discussed in Section 3.1.7.

### 3.2.2 MPE WELLHEADS

The MPE wellheads were monitored periodically during system operation for the optimization of operating conditions. Specifically, the following parameters were monitored as required:

- Applied vacuum ("Hg); and
- Depth to LNAPL/groundwater.

Monitoring equipment used to record and/or collect the necessary data is discussed in Section 3.1.7.

### 3.2.3 SURROUNDING MONITORING WELLS

Perimeter delineation monitoring wells and any extraction wells not being utilized for LNAPL recovery were monitored periodically during system operation for the optimization of operating conditions and to confirm the stability of the LNAPL plume. Specifically, the following parameters were monitored:

- Induced vacuum ("$H_2O$); and
- Depth to LNAPL and groundwater.

In addition, monitoring well headspace was periodically monitored for volatility in terms of % LEL.

## 3.3 SAMPLING AND ANALYSIS

Discrete extracted vapor and water samples were collected from the MPE system on a periodic basis and submitted for laboratory analysis of select chemical constituents (refer to Table 3.1 for the details of the frequency of measurement). The sample collection and analysis methodologies are discussed in the following subsections.

### 3.3.1 VAPOR SAMPLING

As previously mentioned, the system LEL sensor continuously monitored the vapor-phase total hydrocarbon content at the system exhaust (upstream of the oxidizer inlet when it was in use). In addition, discrete vapor samples were collected from the system and oxidizer exhaust stacks as required using a vacuum box and tedlar bags. The tedlar bag samples were obtained according to the U.S. EPA Modified Method 18 sampling protocol presented in Appendix D, and submitted for laboratory analysis of total hydrocarbons and benzene.

The purpose for the vapor monitoring and sampling was to: (1) provide a quantitative means of evaluating the mass of hydrocarbons removed in the vapor phase; and (2) provide data to demonstrate compliance with PTIs 61-06 and 61-06A (see Appendix E).

### 3.3.2 TREATED WATER SAMPLING

Treated groundwater was initially stored on-Site in frac tanks and sampled as needed for waste characterization. The treated groundwater was initially shipped off-Site for disposal as the holding tanks that the treated groundwater was discharged to at the time were filled. The City of Pontiac approved the direct discharge of treated groundwater to the City of Pontiac sanitary sewer system in July 2007. A quarterly discharge sampling program was implemented to meet the discharge agreement established with the City of Pontiac. Table 3.1 reflects the respective monitoring frequency.

## 4.0 FULL-SCALE MPE OPERATIONS AND PERFORMANCE

This section presents the system operational methodology and data corresponding to operations between September 2006 and October 2008.

### 4.1 OPERATIONAL STRATEGY

The number and groupings of active extraction wells were varied over time following initial startup. The main reasons for this variation were to maximize recovery, evaluate different operating conditions, and to control the volume of recovered groundwater. Initially, extraction wells were selected based upon historic and current observations of in-well LNAPL. The number of wells extracted from at any given time was limited by a constraint on the quantity of groundwater that could be treated and stored on-Site prior to obtaining the ability to discharge directly to the City of Pontiac sanitary sewer system. In order to establish a more formal extraction strategy that would ensure full coverage of the LNAPL area, the extraction network was arranged into 6 primary extraction configurations compromised of 11-12 wells each in April 2007. These extraction configurations are illustrated in Figures 4.1 and 4.2. The configurations were designed to allow the complete coverage of the plume while maintaining an optimal number of active extraction wells at any given time. The decision to change from one configuration to the next was made if:

- Recovery rates were observed to decrease significantly from the initial and/or the highest levels achieved for that grouping (e.g., rate drops from 20 gallons per day to 5 gallons per day); or
- Recovery rates were stable at a low rate (e.g., initial rate of 3 gallons per day, and remains stable at that level for 1-2 weeks).

Each configuration was operated twice in this manner. Since some configurations overlapped, many wells in the extraction network were operated multiple times. After 2 complete cycles of the 6 primary extraction configurations, a two-week shutdown period was implemented on September 9, 2008 to allow hydraulic conditions to return to static and monitor the extraction network for the presence of LNAPL. Any wells which exhibited significant LNAPL layers (greater than 6") following the shut-down period were targeted for one final extraction effort which began on September 29, 2008. Final extraction was discontinued once the recovery rate stabilized at a low level. As such, the operation of the MPE system was concluded with the approval of U.S. EPA on October 15, 2008.

It should be noted that three perimeter wells that were not part of the extraction network operated by the MPE system were observed to have sporadic trace in-well LNAPL observations during the operation of the full-scale MPE system (RW33-42, RW33-43, and RW33-45). These wells are discussed in more detail in Section 4.6.

## 4.2 MAJOR OPERATIONAL DETAILS

During operation, the system typically achieved an applied vacuum of 15-21"Hg at an air flow rate of 800-1,300 acfm, or 70-110 acfm per extraction well. As described in Section 3.2.1, various system parameters were logged electronically on a continuous basis. All electronic data log files associated with the operation of the system are provided in electronic format in Appendix F.

Operational challenges related to both mechanical issues and the lack of an appropriate discharge option for the unexpectedly high water production were experienced at various times throughout the first 10 months following startup. These issues resulted in significant periods of downtime during this period. Consequently, average system up-time since startup in September 2006 was approximately 65%. However, following the resolution of the initial operational issues, the system has run near continuously with average system up-time in the last 12 months in excess of 90%. A detailed daily account of system up-time and down-time is provided by the monthly system Activity Logs included in Appendix G.

## 4.3 LNAPL/GROUNDWATER RECOVERY PERFORMANCE

The total amount of hydrocarbons recovered during the Corrective Measure consisted of three distinct fractions: free phase (free product), dissolved (or aqueous) phase, and vapor phase. Each of these fractions, as well as the overall results, are discussed in the following sections.

### 4.3.1 FREE PHASE MASS REMOVAL RATES

Free product or free phase mass removal rates were measured by recording the volume of LNAPL transferred to the 1,000-gallon LNAPL AST over time. The cumulative free phase LNAPL recovery data indicate that the average recovery rate throughout the duration of full-scale MPE operations was less than 0.5 gallons per day. The total amount of free phase LNAPL recovered during the full-scale MPE implementation was approximately 133 gallons or 907 pounds. This equates to 4.8% of the total LNAPL recovery (volume basis). This proportional recovery varies significantly compared with the free phase recovery during the MPE pilot study where approximately 53% (by volume) of the total LNAPL was recovered as free liquid LNAPL. This suggests that the bulk of the recoverable liquid free product was recovered during the MPE pilot study. A summary of both pilot-scale and full-scale MPE free phase LNAPL recovery is provided as Table 4.1. The cumulative free phase hydrocarbon recovery for the full-scale MPE implementation is provided graphically in Figure 4.3.

### 4.3.2 AQUEOUS PHASE MASS REMOVAL RATES

The aqueous phase mass removal during the MPE pilot study was determined to be negligible at less than 0.25 pounds of hydrocarbons, or 0.001% of total LNAPL recovered. Consequently, the specific quantification of aqueous phase recovery was not conducted during full-scale MPE operations.

### 4.3.3 VAPOR PHASE MASS REMOVAL RATES

Vapor phase total hydrocarbon content was measured from the MPE system LEL sensor on a continuous basis. The hydrocarbon concentration data (ppmv as hexane) obtained from the MPE system LEL sensor and the exhaust gas stream flow rate were combined to determine the vapor phase mass removal rates by the following calculation:

$$\overline{M}_v = C_{v1} \times Q_v \times \frac{MW}{387} \times \frac{60\ \text{min}}{\text{hour}}$$

Where:

$\overline{M}_v$ = Vapor phase mass removal rate (lbs/hour)
$C_{v1}$ = Vapor phase hydrocarbon concentration as hexane (ppmv)
$Q_v$ = Vapor stream volumetric flow rate (scfm)
$MW$ = Molecular weight of hexane (86.1766 lb/lbmol)
387 = Molar volume of an ideal gas at 70°F ($ft^3$/lbmol)

The vapor phase hydrocarbon recovery data as recorded by the system instrumentation is presented in Appendix F. The cumulative vapor phase hydrocarbon recovery is provided graphically in Figure 4.3. Figure 4.4 presents a graphical representation of the daily vapor-phase recovery rate over time highlighting the specific extraction configurations.

The cumulative vapor phase LNAPL recovery data indicate that the overall average recovery rate throughout the duration of full-scale MPE operations was 5.5 gallons per day. The total amount of vapor phase LNAPL recovered during the full-scale MPE implementation was approximately 2,653 gallons or 18,116 pounds. This equates to 95.2% of the total LNAPL recovery (volume basis). A summary of both pilot-scale and full-scale MPE vapor-phase LNAPL recovery is provided as Table 4.1.

#### 4.3.4 TOTAL LNAPL RECOVERY

The system operated for a total of 11,534 hours. This equates to approximately 480 days of run-time. Summing the LNAPL recovery in the various phases already discussed results in an overall LNAPL recovery of 2,786 gallons for the full-scale MPE system. Figures 4.5 and 4.6 illustrate the total LNAPL recovery rate and cumulative LNAPL recovery over time, respectively.

With reference to Figure 4.5, the maximum daily LNAPL recovery rate achieved during full-scale MPE operations was 60 gallons per day for a brief time interval following system startup. The daily recovery rate exhibited a consistent declining trend shortly after start-up before approaching the x-axis (i.e., zero recovery rate) after approximately 5,800 operating hours. Following this point, the daily recovery rate continued on a fairly steady-state asymptotic trend fluctuating around 2 gallons per day for the majority of the operating period from December 2007 until system shutdown in October 2008.

With reference to Figure 4.6, the cumulative recovery curve exhibits three distinct sections according to significant slope changes. These changes in cumulative recovery curve slope correspond to significant changes in the average LNAPL recovery rate over the respective time period covered by each segment of distinct slope (see Figure 4.5). The slope of Section 3 in Figure 4.5 provides another indication of the low recovery that has been achieved for the last half of the recovery period. The slope of Section 3 indicates an average recovery rate for this period of 1.8 gallons per day.

The daily LNAPL recovery data table used to generate these figures is included in Appendix H. The data table in Appendix H also includes notes detailing major operational changes that altered the recovery conditions. Appendix I includes various other performance graphs used to monitor the daily operation of the MPE system. A summary of both pilot-scale and full-scale MPE total LNAPL recovery is provided as Table 4.1.

## 4.4 PAL AND PF OPERATION

The MPE system was initially operated in vacuum-only mode (i.e., vacuum applied at the top of each extraction well). It became apparent that operating in this mode was mounding the water table in the vicinity of the extraction wells. The result was that the sections of the extraction well screens open to air flow underwent a cumulative reduction. This, in turn, reduced the available air flow to the vacuum pump, which resulted in the vacuum pump operating in an overheated condition. The increased water table elevation within many of the extraction wells was also reducing the available (dewatered) impacted soil zones for potential LNAPL recovery.

To overcome these issues, the operation of PAL in the extraction wells was commenced on November 6, 2006. Initially, the extraction depth in each extraction well was limited to just below the lowest impacted soil zone. This was done to expose the impacted soil zones at each active extraction well while minimizing the volume of recovered groundwater. It was necessary to minimize the amount of recovered groundwater at this time in order to make it feasible to operate the system while discharging water to 20,000-gallon frac tanks. An agreement was reached with the City of Pontiac on June 29, 2007 to allow the direct discharge of the system treated water to the City of Pontiac sanitary sewer system. At this point, the extraction depth in the active extraction wells was lowered to the bottom of the wells to maximize dewatering in the adjacent formation. All active extraction wells were operated in this manner starting on June 29, 2007. The periodic use of PF also commenced on June 29, 2007 whenever recovery stabilized or decreased in a given extraction configuration. An indication of when PF was conducted is provided in Figure 4.4. This was performed in an attempt to maximize the LNAPL recovery potential of the respective configuration. However, no conclusive relationship between the operation of PF and increased recovery rate could be established. In addition, there was some concern that the injection of compressed air into the subsurface could potentially induce some lateral spreading of LNAPL if subsurface heterogeneities allowed injected air to escape the vacuum influence of the extraction network. Consequently, PF was not performed after December 13, 2007 as the potential benefits did not appear to outweigh the potential risk of inducing LNAPL migration.

## 4.5 OXIDIZER OPERATION

A State of Michigan Air Permit to Install (PTI 61-06) was obtained for the operation of the MPE system with the oxidizer on April 4, 2006 and revised on April 10, 2006. The oxidizer was operated exclusively in thermal mode (i.e., catalyst bed removed). The combustion chamber temperature set point was 1,550°F. The MPE system data log files that recorded the combustion chamber temperature are provided in Appendix F.

The vapor-phase total hydrocarbon concentration being recovered by the system was much lower than expected (i.e., much lower than what was observed during the MPE pilot study). Consequently, burner inlet hydrocarbon loading was low, and the quantity of supplemental fuel (propane) to maintain the required combustion chamber temperature was excessive. As a result, oxidizer operational costs were initially much higher than expected. Given that the vapor-phase hydrocarbon concentrations were much lower than expected, CRA re-evaluated the control equipment requirements of the system. This was accomplished by revising the Best Available Control Technology (BACT) analysis that was submitted with the original application for PTI 61-06. The revised BACT analysis showed that the current vapor-phase hydrocarbon concentrations were low enough that control equipment was not required. As such, GM submitted an application to the Michigan Department of Environmental Quality (MDEQ) Air Quality Division (AQD) to modify PTI 61-06 accordingly. The AQD subsequently issued PTI 61-06A on August 28, 2007, removing the requirement to employ control equipment. Summaries of the air emissions associated with both iterations of the air permit are provided in Tables 4.2 and 4.3. At the conclusion of MPE operations, PTI 61-06A was voided pursuant to correspondence from the MDEQ AQD dated February 25, 2009. Copies of PTIs 61-06 and 61-06A, as well as the MDEQ AQD letter voiding PTI 61-06A, are provided in Appendix E.

## 4.6 WELL MONITORING

### 4.6.1 LNAPL/GROUNDWATER ELEVATION MONITORING

LNAPL and groundwater elevation measurements were obtained from all monitoring and active extraction wells (all inactive extraction wells were used as monitoring wells). These measurements were typically obtained on a weekly basis throughout operation of the MPE system. The measurements were used to aid the daily operation of the system by providing the following information:

- Monitor for LNAPL presence/thickness changes under changing hydraulic conditions;
- Monitor the hydraulic influence of any given extraction configuration on the surrounding formation; and
- Confirm that active extraction wells were being effectively evacuated to the desired depth.

The monitoring was also used to confirm the stability of the LNAPL plume. LNAPL/groundwater elevation monitoring graphs for each well in the Building 33 area are included in Appendix J. Additionally, groundwater elevation contours/flow maps and well dewatering figures for the final operation of each extraction configuration are included in Appendix K.

The well level monitoring confirmed that operating extraction wells were successfully dewatered to completely expose the zone of petroleum impacts in the vicinity of each well. This maximized the hydraulic recovery potential of the MPE system as LNAPL is able to move more easily through unsaturated soil.

As previously mentioned, observations of LNAPL at LNAPL perimeter monitoring wells were limited to sporadic trace observations at RW33-42, 43 and 45. A summary of observations for these wells follows:

- RW33-42
  - LNAPL detected in 5 of 82 monitoring events
  - Maximum LNAPL = 0.13 ft

- RW33-43
  - LNAPL detected in 9 of 107 monitoring events
  - Maximum LNAPL = 0.01 ft

- RW33-45
  - LNAPL detected in 3 of 142 monitoring events
  - Maximum LNAPL = 0.01 ft

The recovery of LNAPL was not performed at these wells as the in-well thicknesses were minimal and non-persistent, indicating that the LNAPL in these areas is most likely to be immobile. No LNAPL was detected in any of the other LNAPL perimeter wells. Consequently, the well monitoring data point to an overall condition of plume stability (i.e., no lateral spreading).

The groundwater flow maps in Appendix K demonstrate that the MPE system influenced all areas of observed LNAPL at some point in the period of MPE operations by inducing a significant hydraulic gradient towards each respective extraction configuration. The hydraulic influence typically extended well beyond each respective extraction configuration while operating.

With respect to the entire LNAPL Area 1 well network, the number of wells with observed LNAPL and the observed in-well LNAPL thicknesses are significantly decreased following the conclusion of MPE operations compared with pre-MPE levels. Pre-MPE in-well LNAPL thicknesses were as high as 10.2 ft, whereas the maximum in-well LNAPL thickness measured during 6 months of monthly post-MPE well level monitoring has been 0.26 ft. In addition, the number of wells exhibiting LNAPL decreased from 18 around full-scale MPE startup to a maximum of 5 wells with trace levels during 6 months of monthly post-MPE well level monitoring.

### 4.6.2 WELL HEADSPACE PRESSURE MONITORING

Well headspace pressure measurements were obtained from all monitoring and active extraction wells. These measurements were typically obtained in conjunction with the well level monitoring discussed in the previous section. The measurements were used to:

- Monitor the applied vacuum at each extraction well; and
- Monitor the vacuum influence of the system on the surrounding formation.

The vacuum applied to the formation at each extraction well typically varied in the range of 14"Hg-18"Hg, confirming that a high vacuum was successfully applied to the formation during the Corrective Measure. Well-headspace pressure contour maps for the final operation of each extraction configuration are included in Appendix K. The contour maps show that the system vacuum influence extended to all areas of observed LNAPL at some point during the recovery period. This is demonstrated by the negative well headspace pressures observed at monitoring wells around each respective extraction configuration. This confirms that a significant vacuum gradient was induced in the formation towards the extraction points.

## 4.7 TREATED GROUNDWATER DISCHARGE

The total volume of groundwater recovered and treated was 1,201,794 gallons. The initial 315,402 gallons were temporarily stored in frac tanks on-Site prior to characterization and off-Site disposal. The remaining 886,392 gallons of treated groundwater were discharged to the City of Pontiac sanitary sewer system.

## 5.0 MPE SHUTDOWN CONCLUSIONS

As stated in U.S. EPA's Final Decision (2006), MPE would be used to "aggressively recover LNAPL to the extent practical." The MPE end-point criterion was established in Table 2.1 of the Long-Term Monitoring Plan (CRA, 2007) as "mass recovery until no longer practical." Table 2.1 of the Long-Term Monitoring Plan further established that the end-point would be confirmed when the "cumulative MPE recovery curve reaches asymptotic." This criterion was described in the Corrective Measures Work Plan, Former Building 33, LNAPL Area 1 (CRA, 2006):

> *Operation of the system will be deemed complete when the recovery rate exhibits a sustained asymptotic trend. Following this point, further recovery with MPE technology will be impracticable. Remaining residual LNAPL will be assumed to be effectively unrecoverable.*

A sustained asymptotic recovery trend was demonstrated by:

1. Recovery rate trend over time: As previously noted, the daily recovery rate exhibited a consistent declining trend shortly after start-up before approaching the x-axis (i.e., zero recovery rate) after approximately 5,800 operating hours. Following this point, the daily recovery rate continued on a steady-state asymptotic trend fluctuating around 2 gallons per day for the majority of the operating period from December 2007 until system shutdown in October 2008. This trend is clearly established by the daily recovery rate curve presented in Figure 4.5; and

2. Cumulative recovery over time: The cumulative recovery curve provides additional evidence of a steadily declining recovery rate. Figure 4.6 shows that the cumulative recovery curve has three segments of distinct slope (or average recovery rate over the respective time period covered by each segment of distinct slope). The three segments indicate the following average recovery rates for the respective operating time periods covered by each segment:

   - Segment 1 (0-38 days): 22 gallons per day,
   - Segment 2 (39-227 days): 8 gallons per day, and
   - Segment 3 (228-481 days): 1.8 gallons per day.

The system performance and well network monitoring data discussed in Section 4.0 indicate that an aggressive recovery environment was successfully induced in the impacted areas of the formation by the MPE system, and that all areas of observed

LNAPL were subject to the hydraulic and vacuum influence of the system at some point during MPE operations. In addition, operation of the system has been near continuous for the last 12 months of operations with average system up-time in excess of 90%. Consequently, the endpoint for the MPE Corrective Measure has been successfully achieved. As noted in U.S. EPA's *A Decision-Making Framework for Cleanup if Sites Impacted with Light Non-Aqueous Phase Liquids (LNAPL)* (March, 2005):

> *If an LNAPL recovery system is operating and the recovery is approaching a low rate, the design, installation, and operating parameters and procedures should be reviewed to determine if the system is operating properly, or any changes in operation should be implemented. If after this review, the system is judged to be operating effectively, then it is likely that the remaining LNAPL is essentially immobile.*

As such, it is likely that the remaining LNAPL is immobile, and effectively unrecoverable under normal hydraulic conditions.

The U.S. EPA agreed via conference call on October 15, 2008 that the MPE endpoint had been reached. The system was subsequently shut down, decommissioned, and dismantled. All extraction and monitoring wells were left intact in order to conduct a comprehensive evaluation of post-MPE conditions (see Section 6.0).

## 6.0 POST-MPE EVALUATION

An evaluation will be conducted to determine whether any potential unacceptable exposures exist within LNAPL Area 1 following the conclusion of the MPE Corrective Measure. A sampling and analysis program will be implemented, with concurrence from U.S. EPA, to assess the post-Corrective Measure conditions in soil gas, soil, groundwater and LNAPL. The goals of the proposed scope of work (SOW) are to:

- Determine the potential for explosion hazard associated with the volatilization of constituents from residual LNAPL; and
- Determine the significance of potential exposures to any remaining hazardous constituents in residual LNAPL, and residual LNAPL-impacted soil and groundwater.

The proposed SOW includes soil gas, soil, groundwater and LNAPL monitoring activities. The evaluation will be conducted in the second quarter of 2009. A work plan for the collection of the data to be used in the post-MPE evaluation was submitted to U.S. EPA on April 3, 2009.

Longer-term monitoring of the stability of the residual LNAPL and groundwater quality are addressed as part of the Long-Term Monitoring Plan for the Site.

## 7.0 REFERENCES


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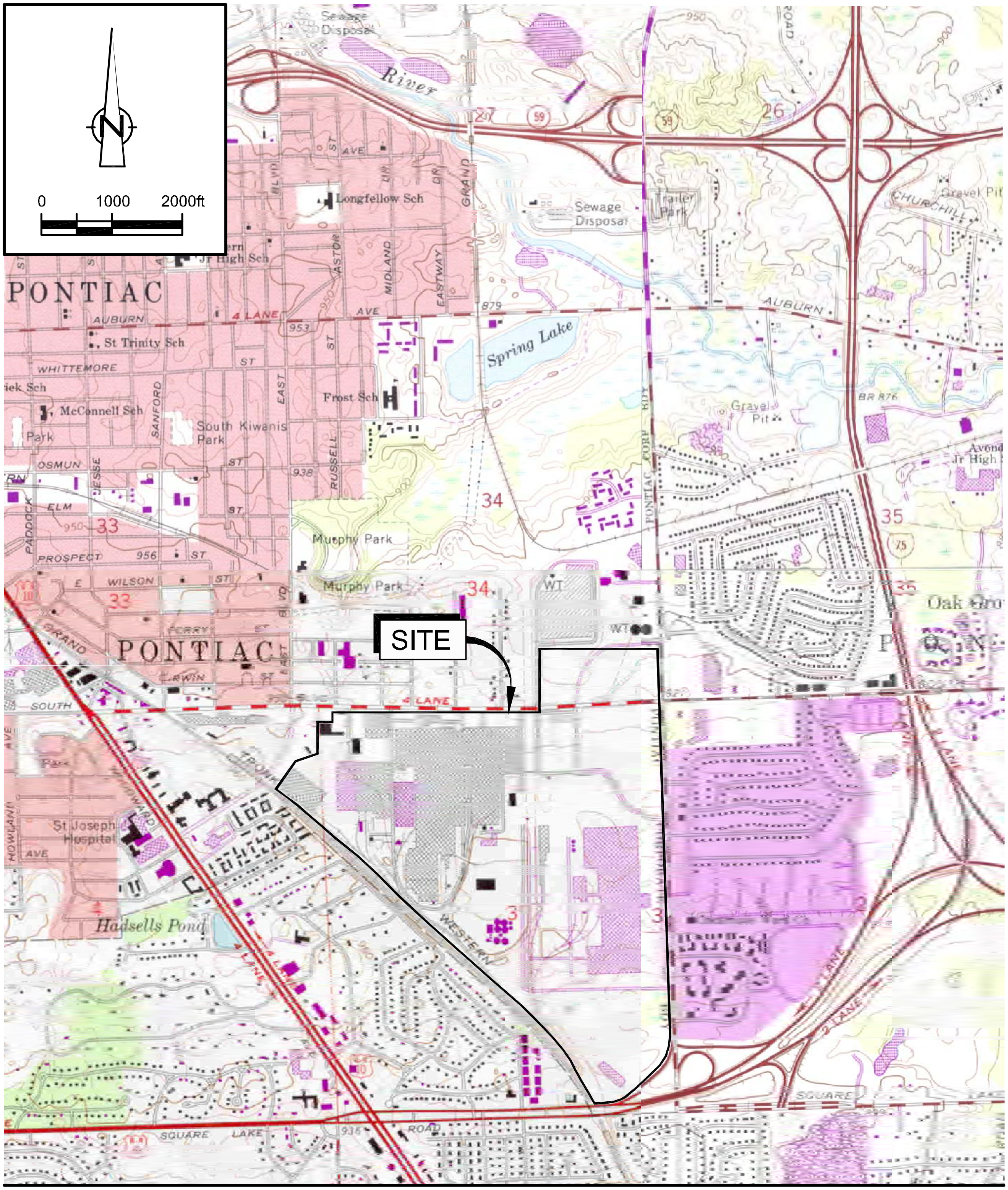
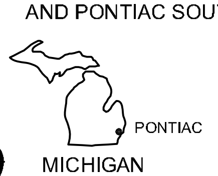



SOURCE: USGS QUADRANGLE MAPS;
BIRMINGHAM, ROCHESTER, PONTIAC NORTH,
AND PONTIAC SOUTH, MICHIGAN

figure 1.1




SITE LOCATION
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

07097-05(062)GN-WI029 JAN 15/2009

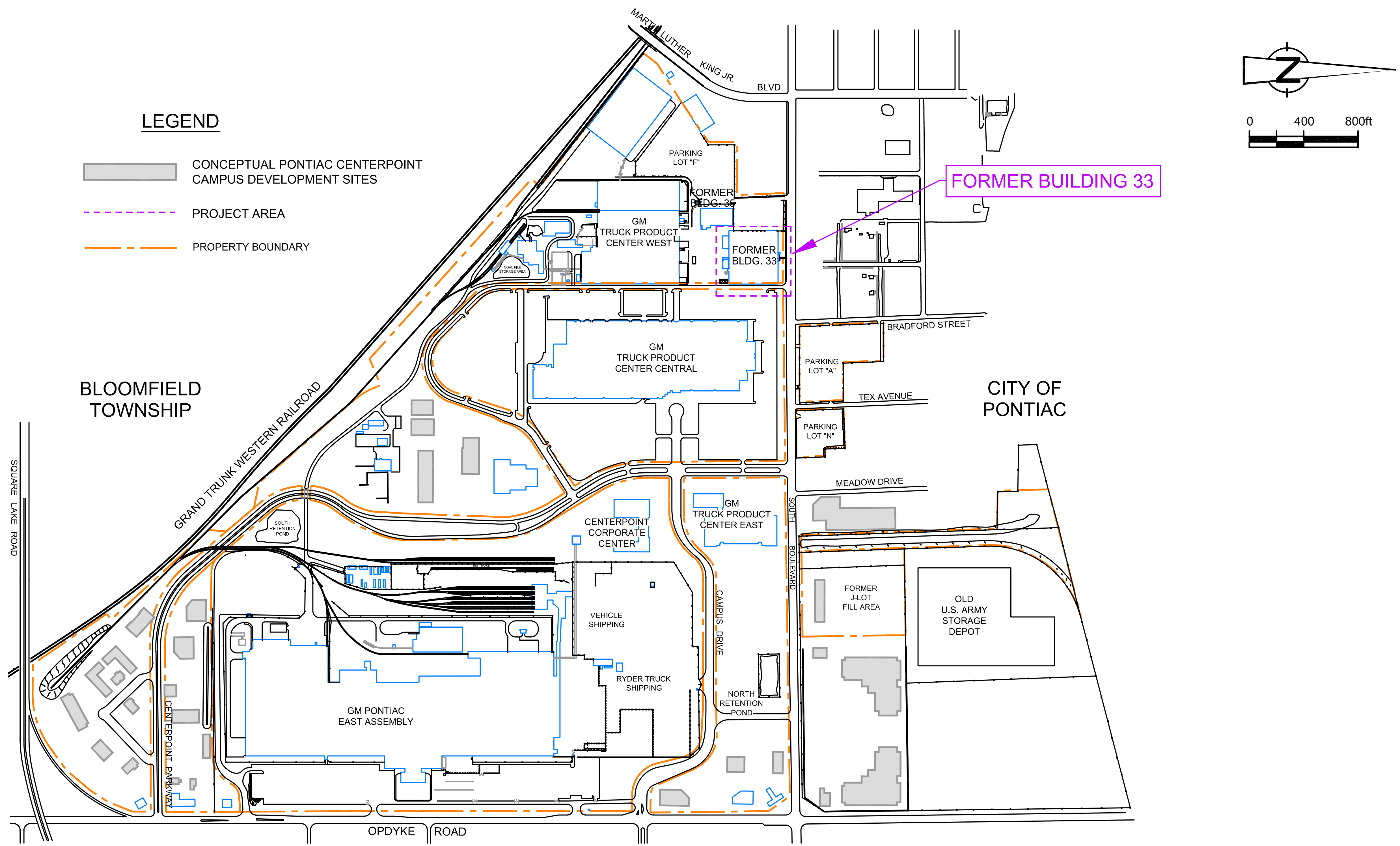



figure 1.2

SITE PLAN
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

07097-05(062)GN-WI027 JAN 15/2009

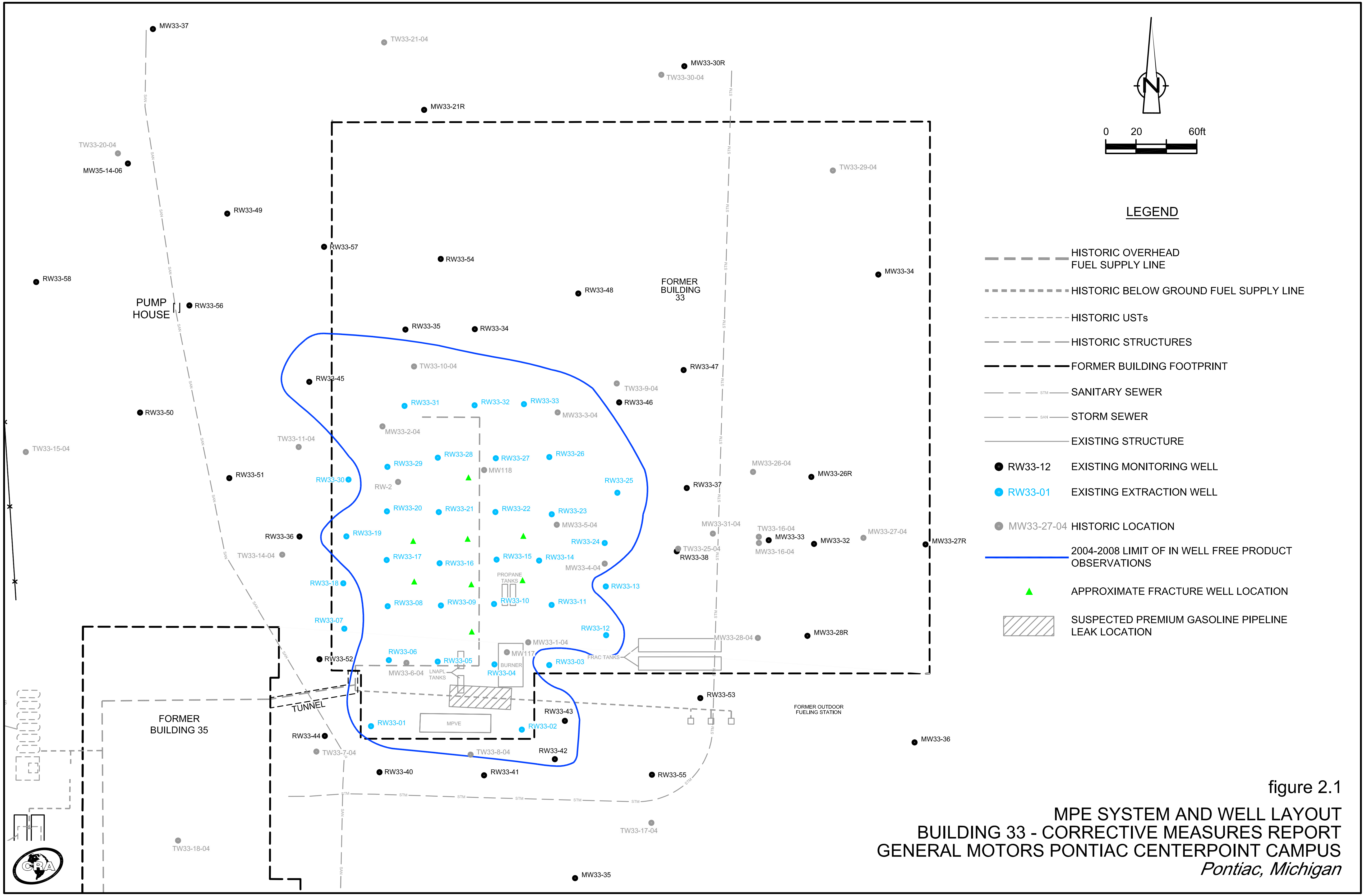
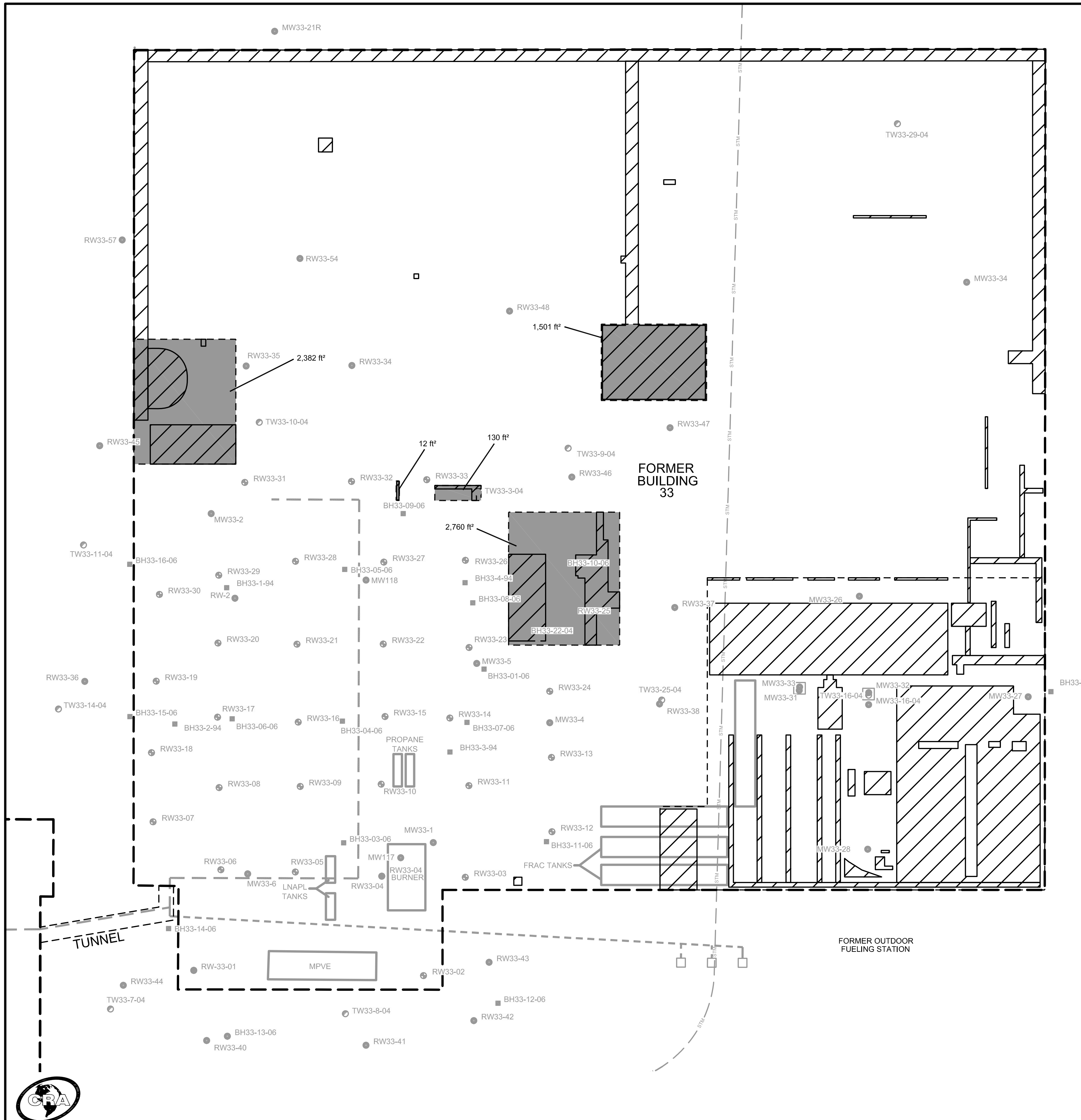



figure 2.1

MPE SYSTEM AND WELL LAYOUT
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

07097-05(062)GN-WI033 JAN 19/2009



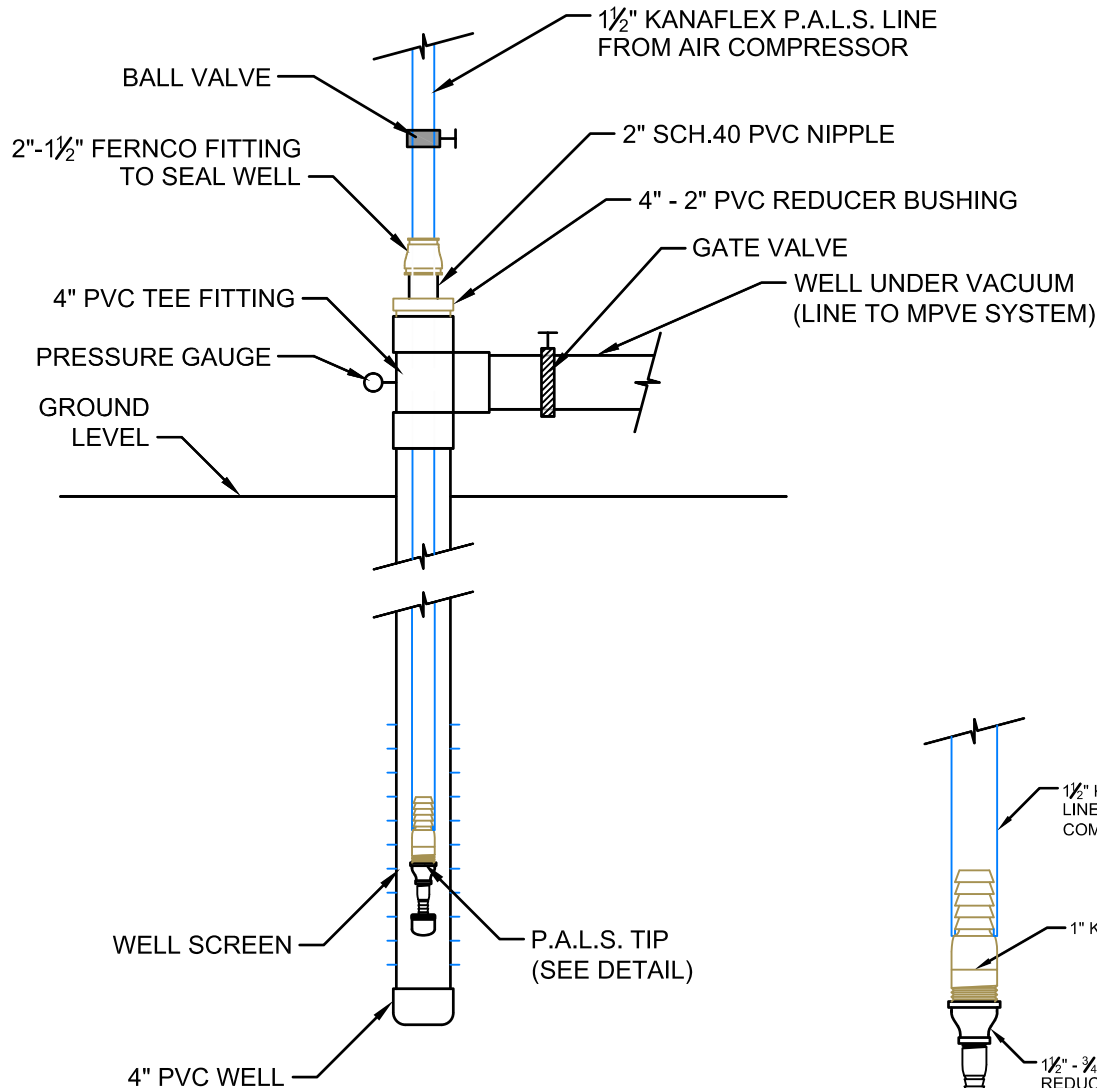

## LEGEND

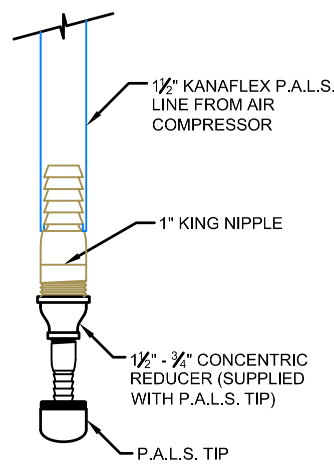
- HISTORIC OVERHEAD FUEL SUPPLY LINE
- HISTORIC BELOW GROUND FUEL SUPPLY LINE
- HISTORIC USTs
- HISTORIC STRUCTURES
- FORMER BUILDING FOOTPRINT
- EXISTING STRUCTURE
- MW33-16 ABANDONED MONITORING WELL LOCATION
- TW33-19-04 ABANDONED TEMPORARY MONITORING WELL LOCATION
- BH33-12-04 HISTORIC BOREHOLE LOCATION
- RW33-28 EXTRACTION WELL
- GRAVEL SURFACE
- CAPPED AREA

figure 2.2

GENERAL CAPS FOR GRAVEL SURFACES AND AREAS
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

07097-05(062)GN-WI032 JAN 19/2009



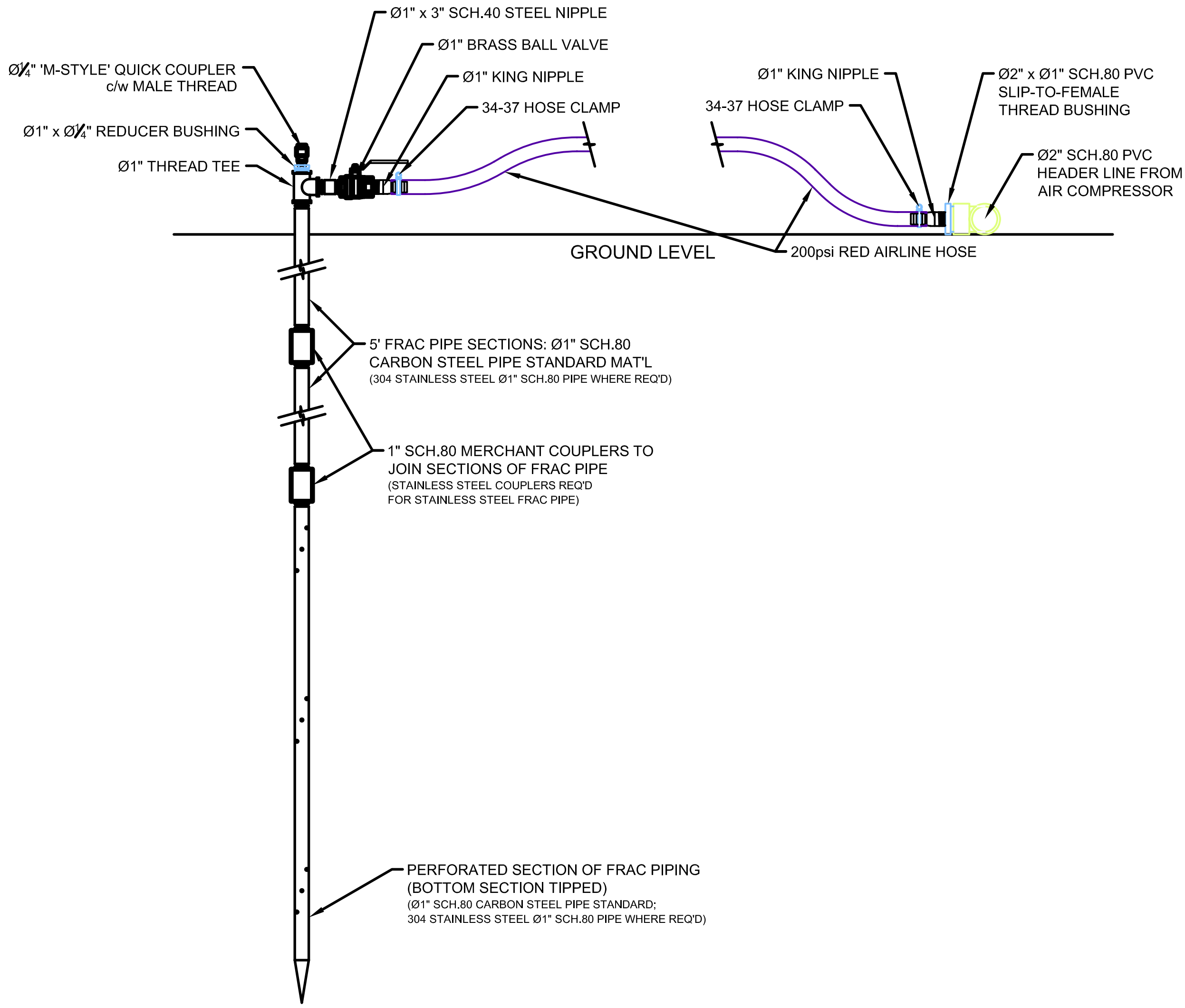

P.A.L.S. TIP DETAIL

SOURCE: GROUND EFFECTS ENVIRONMENTAL SERVICES, INC.

figure 3.1

TYPICAL EXTRACTION WELL DETAIL
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

07097-05(062)GN-WI023 JAN 15/2009




SOURCE: GROUND EFFECTS ENVIRONMENTAL
SERVICES, INC.

figure 3.2

TYPICAL FRACTURE WELL DETAIL
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

CRA

07097-05(062)GN-WI024 JAN 15/2009

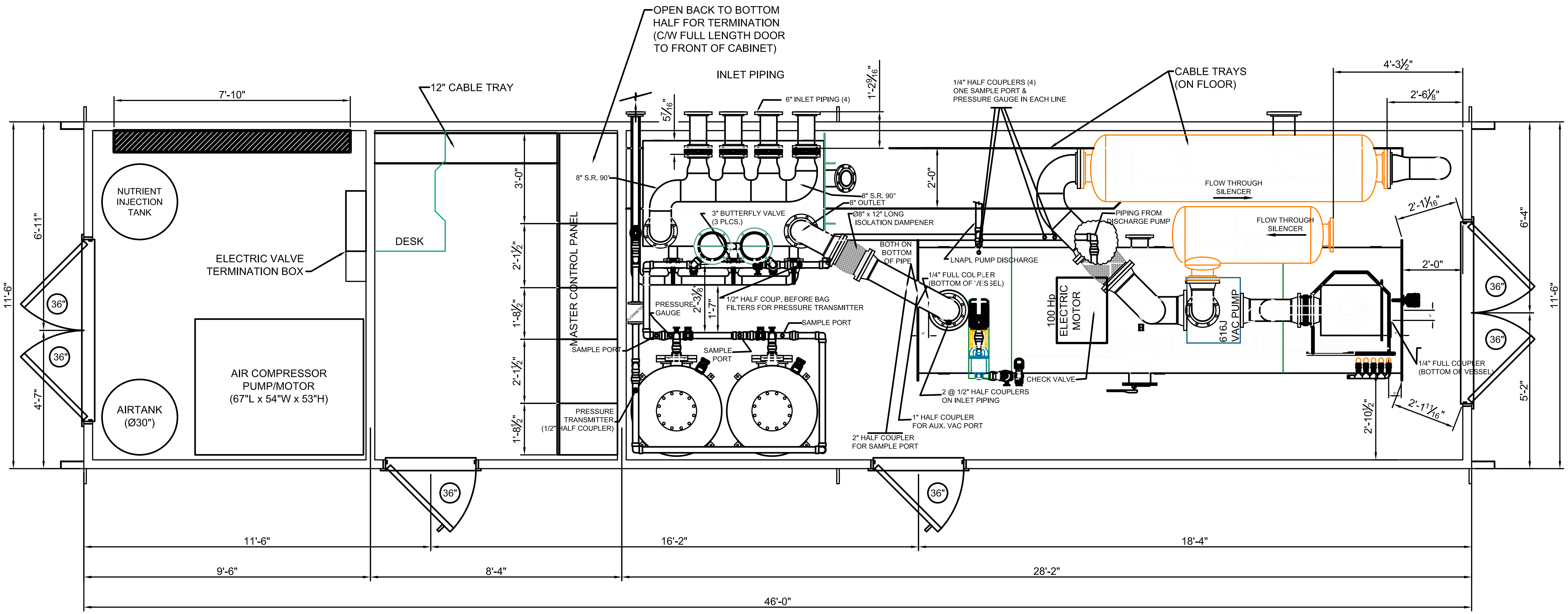
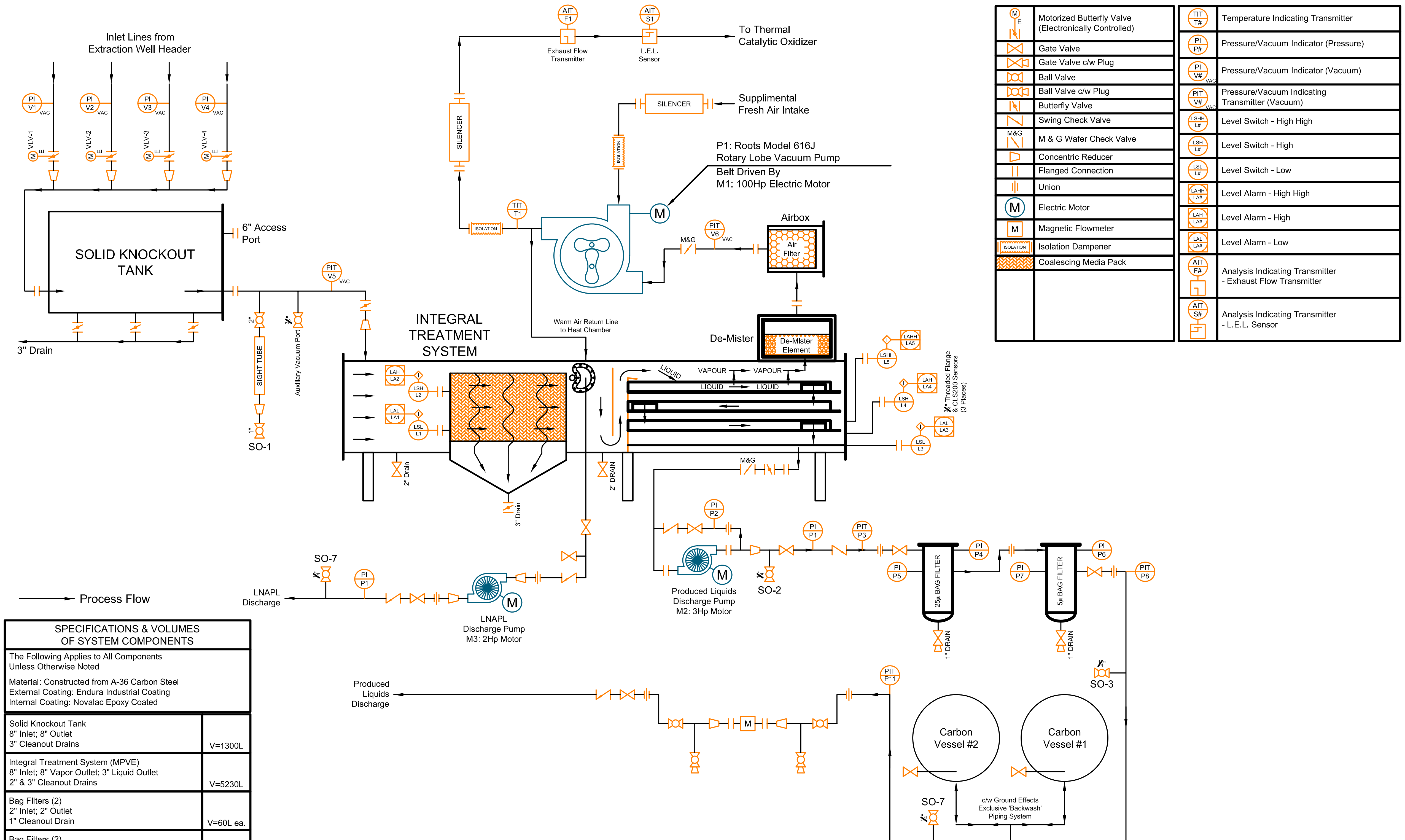



figure 3.3

MPVE 27100 SYSTEM SCHEMATIC
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

SOURCE: GROUND EFFECTS ENVIRONMENTAL SERVICES, INC.

07097-05(062)GN-WI025 JAN 15/2009




| SPECIFICATIONS & VOLUMES OF SYSTEM COMPONENTS | |
|---|---|
| The Following Applies to All Components Unless Otherwise Noted<br>Material: Constructed from A-36 Carbon Steel<br>External Coating: Endura Industrial Coating<br>Internal Coating: Novalac Epoxy Coated | |
| Solid Knockout Tank<br>8" Inlet; 8" Outlet<br>3" Cleanout Drains | V=1300L |
| Integral Treatment System (MPVE)<br>8" Inlet; 8" Vapor Outlet; 3" Liquid Outlet<br>2" & 3" Cleanout Drains | V=5230L |
| Bag Filters (2)<br>2" Inlet; 2" Outlet<br>1" Cleanout Drain | V=60L ea. |
| Bag Filters (2)<br>2" Inlet; 2" Outlet<br>1" Cleanout Drain | V=1100L each |

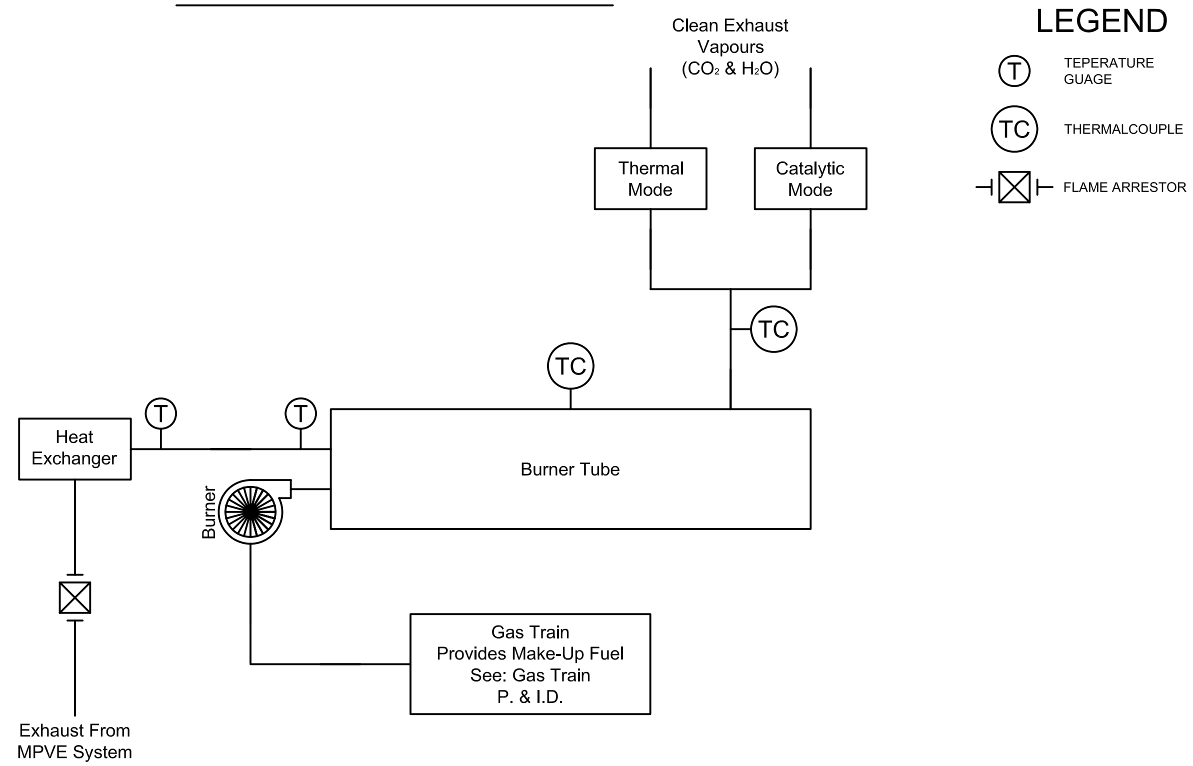
figure 3.4

MPVE 27100 SYSTEM PROCESS & INSTRUMENTATION DIAGRAM
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

SOURCE: GROUND EFFECTS ENVIRONMENTAL SERVICES, INC.

07097-05(062)GN-WI026 APR 15/2009

## THERMAL OXIDIZER P & I.D.




## GAS TRAIN P & I.D. DRAWING

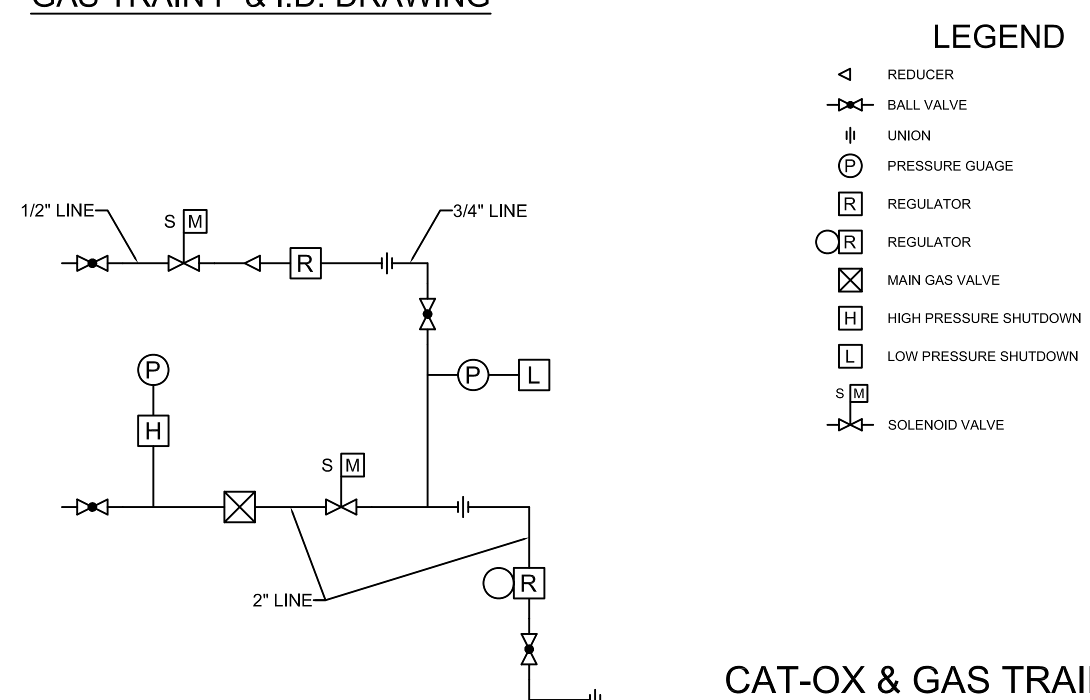



figure 3.5

CAT-OX & GAS TRAIN PROCESS & INSTRUMENTATION DIAGRAMS
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

SOURCE: Ground Effects Environmental Services Inc.

07097-05(062)GN-WI028 JAN 15/2009

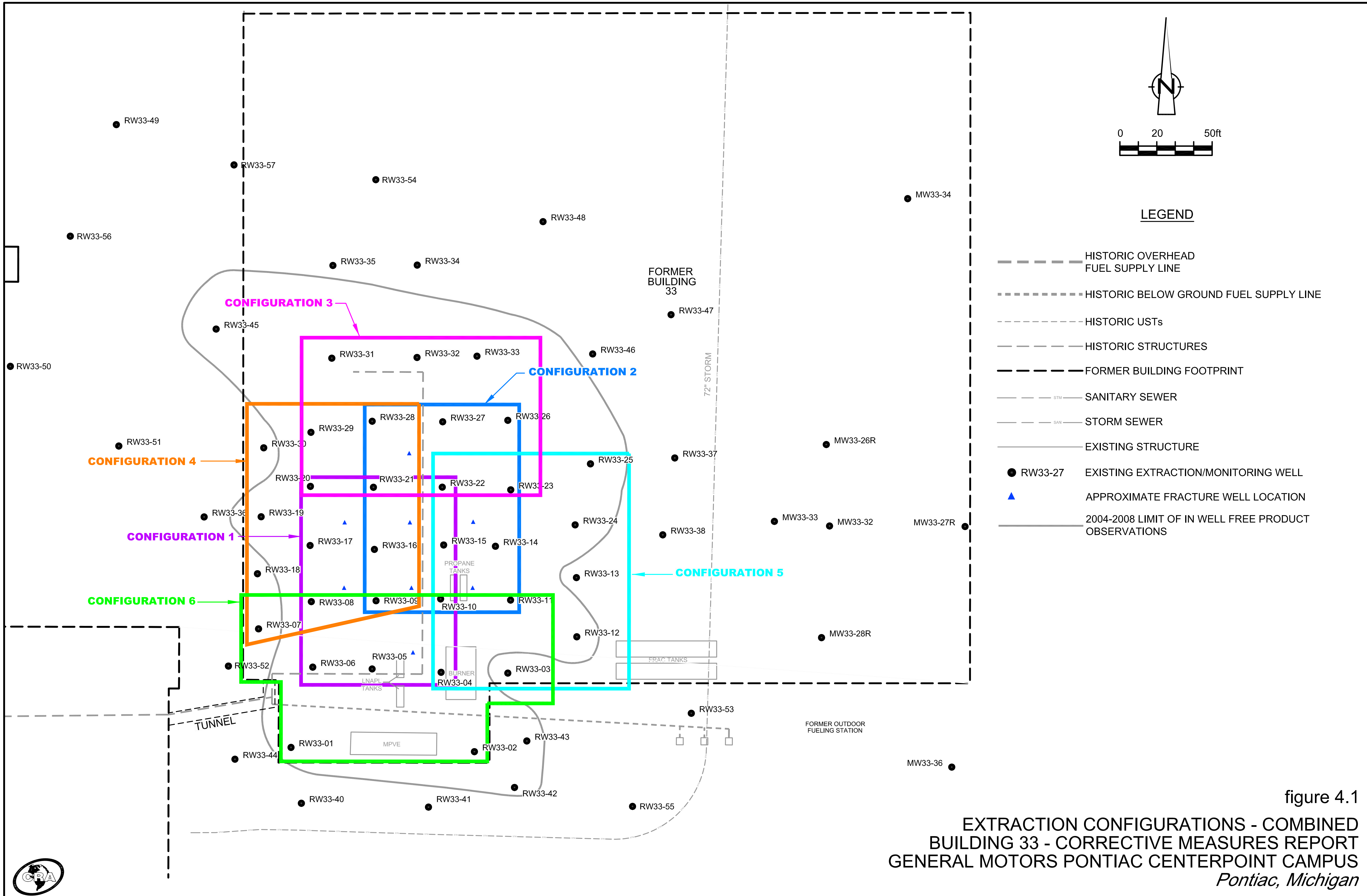
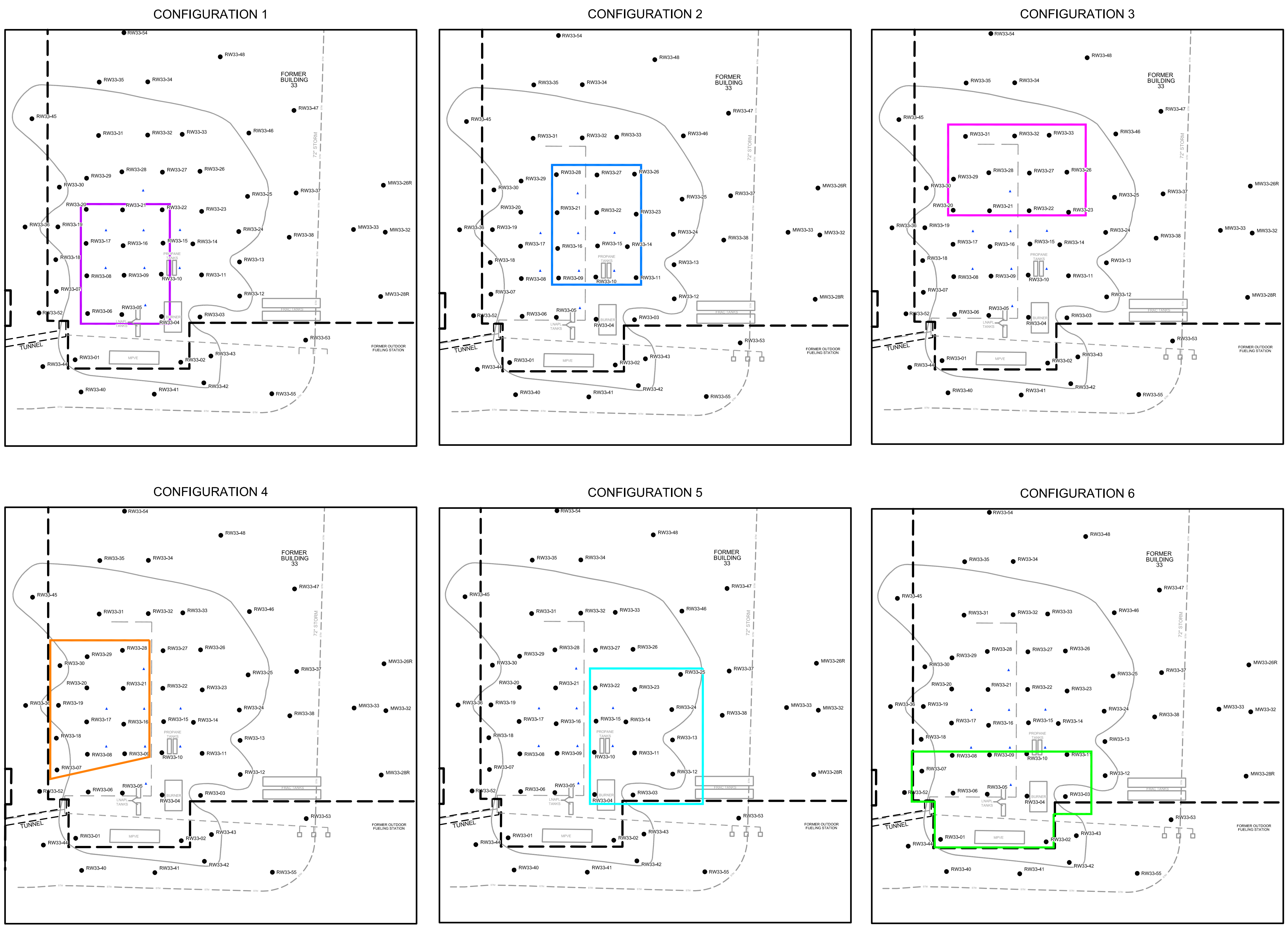



figure 4.1

EXTRACTION CONFIGURATIONS - COMBINED
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

07097-05(062)GN-WI030 JAN 19/2009




**LEGEND**

- HISTORIC OVERHEAD FUEL SUPPLY LINE
- HISTORIC BELOW GROUND FUEL SUPPLY LINE
- HISTORIC USTs
- HISTORIC STRUCTURES
- FORMER BUILDING FOOTPRINT
- SANITARY SEWER
- STORM SEWER
- EXISTING STRUCTURE
- RW33-27 EXISTING EXTRACTION/MONITORING WELL
- APPROXIMATE FRACTURE WELL LOCATION
- 2004-2008 LIMIT OF IN WELL FREE PRODUCT OBSERVATIONS

figure 4.2

EXTRACTION CONFIGURATIONS - SHOWN INDIVIDUALLY
BUILDING 33 - CORRECTIVE MEASURES REPORT
GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS
*Pontiac, Michigan*

07097-05(062)GN-WI031 JAN 19/2009

Figure 4.3
Phase-Specific and Total Cumulative LNAPL Recovery vs. Cumulative Water Production
Former Building 33 LNAPL Area 1 MPE System
General Motors Pontiac Centerpoint Campus
Pontiac, Michigan

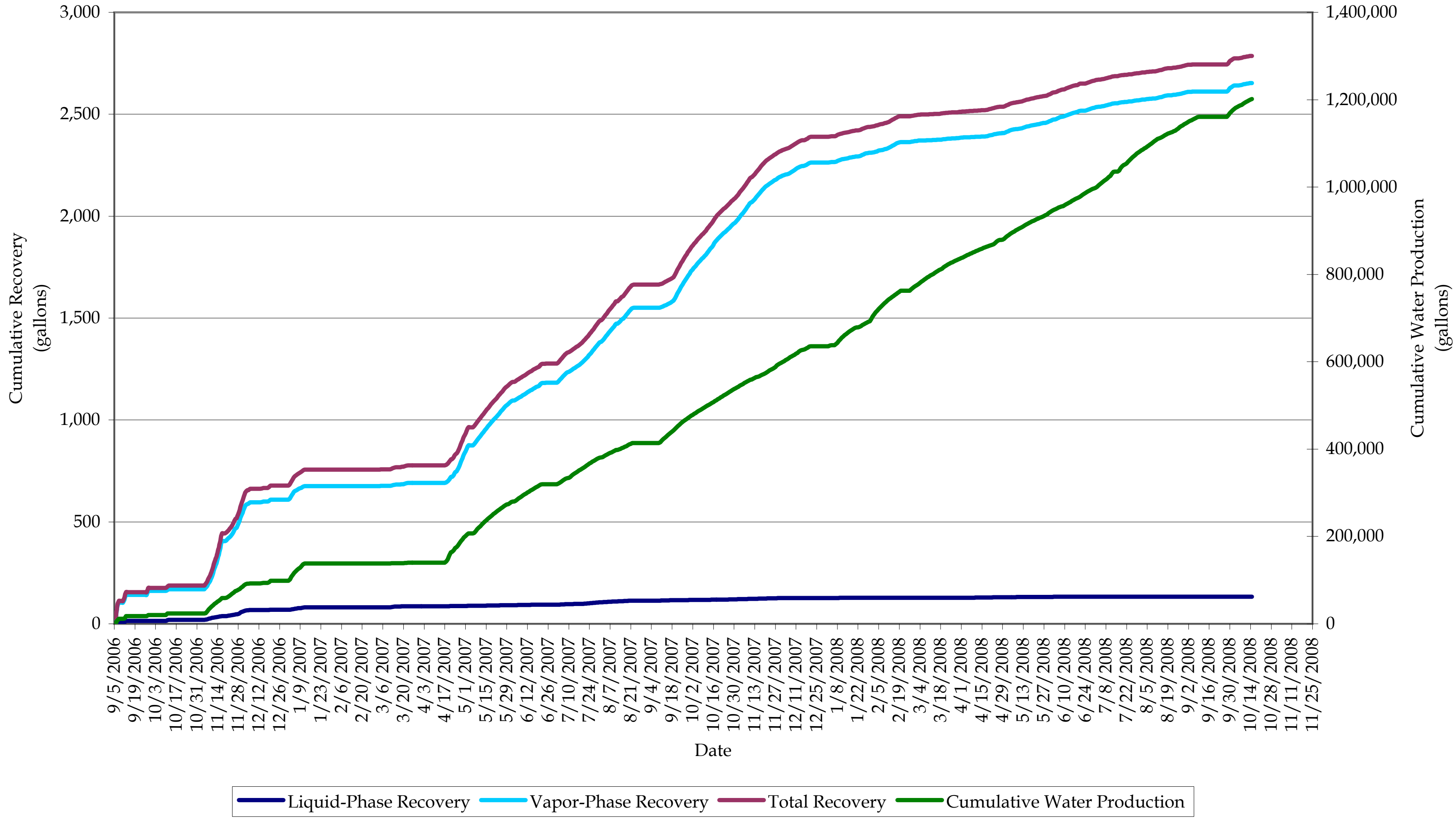


Figure 4.4
Vapor Phase LNAPL Recovery Rate vs. Water Production Rate
Former Building 33 LNAPL Area 1 MPE System
General Motors Pontiac Centerpoint Campus
Pontiac, Michigan

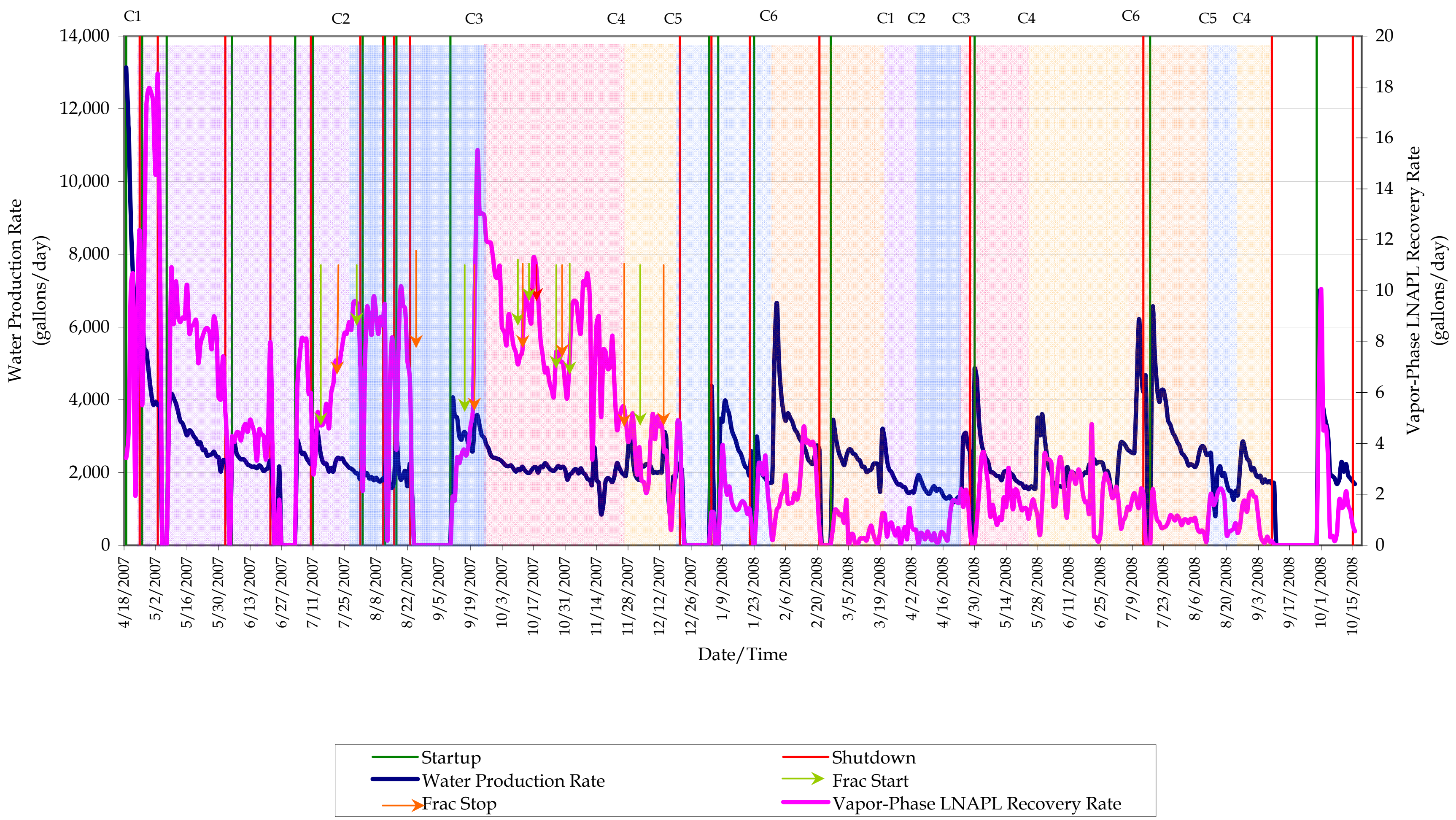


Figure 4.5
LNAPL Recovery Rate
Former Building 33 LNAPL Area 1 MPE System
General Motors Pontiac Centerpoint Campus
Pontiac, Michigan

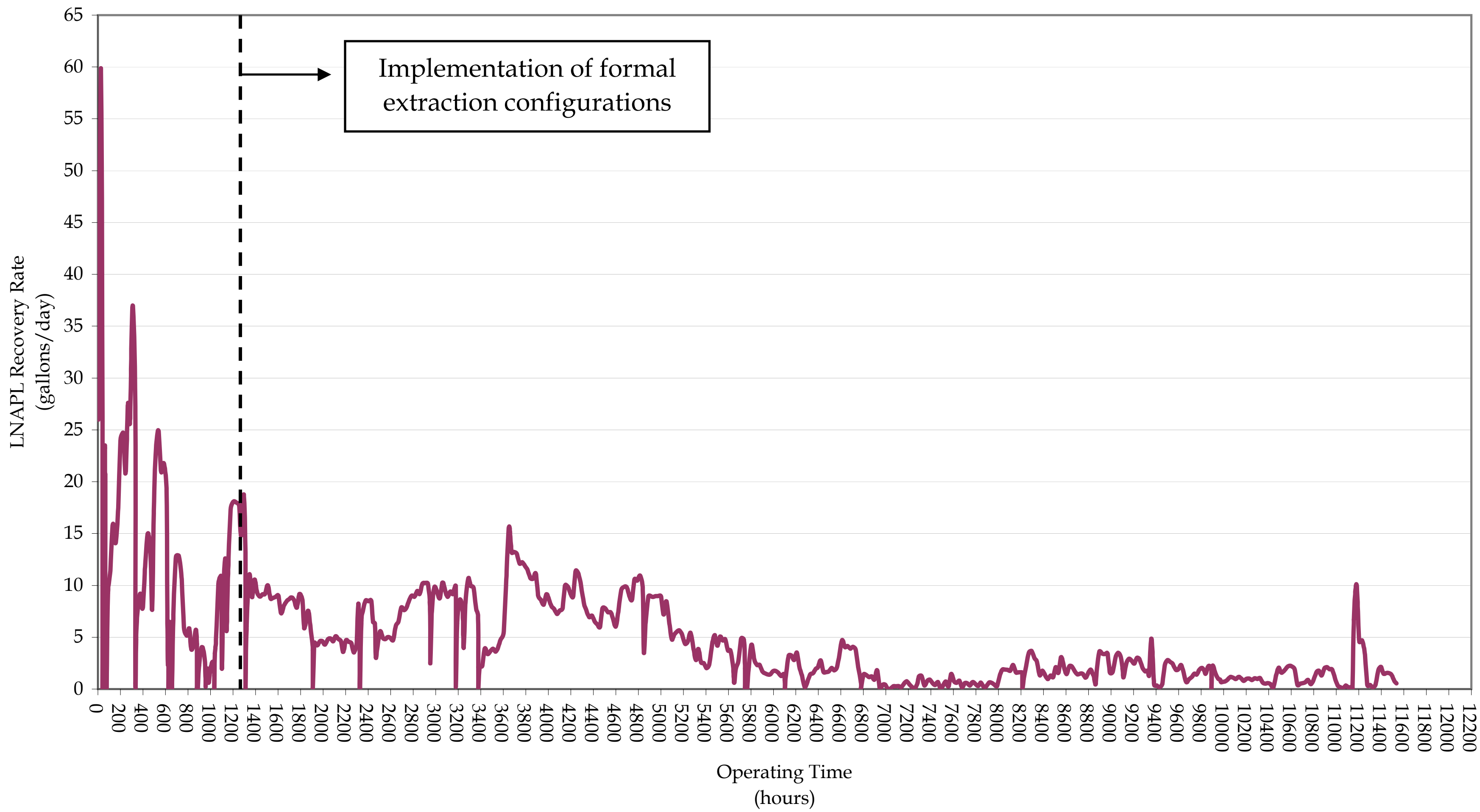


Figure 4.6
Cumulative LNAPL Recovery
Former Building 33 LNAPL Area 1 MPE System
General Motors Pontiac Centerpoint Campus
Pontiac, Michigan

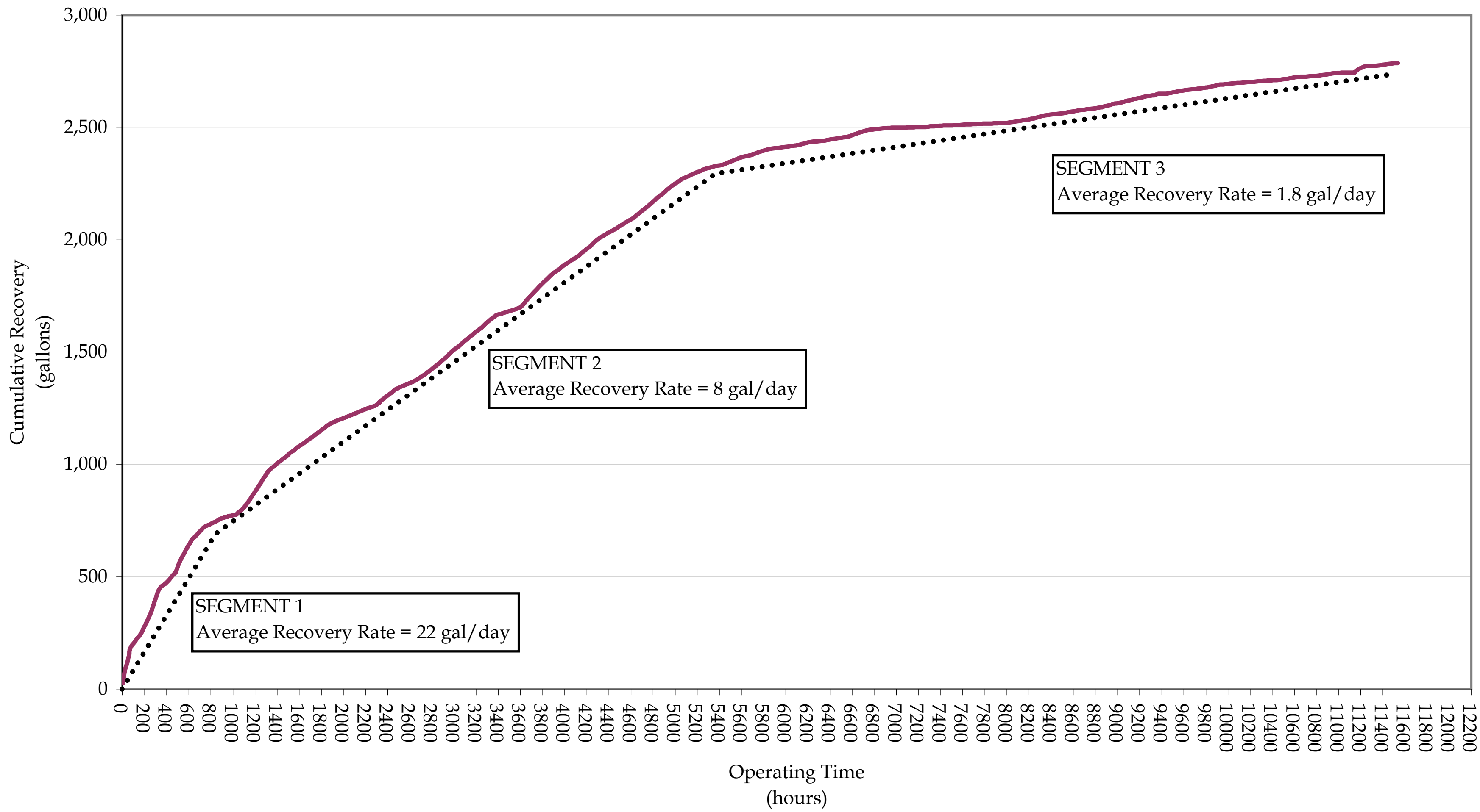


**Table 3.1**
**SUMMARY OF MONITORING AND MEASUREMENT**
**BUILDING 33 CORRECTIVE MEASURES REPORT**
**GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS**
**PONTIAC, MICHIGAN**

| Location | Parameter | Method | Frequency |
|---|---|---|---|
| MPVE 27100 System | Applied vacuum ("Hg) | A | Continuous |
| | Air flow rate through system (cfm) | A | Continuous |
| | System treated groundwater discharge quality (chemical constituents) | M | While Discharging to Frac Tanks - As Needed<br>While Discharging to City of Pontiac Sewer - Quarterly |
| | System granular activated carbon water treatment efficiency (chemical constituents) | M | As needed |
| | Total hydrocarbon concentration in vapor phase (% LEL or ppm, on a continuous basis via infrared sensor) | A | Continuous |
| | Total hydrocarbons and benzene concentrations in vapor phase | M | Weekly - Month 1<br>Monthly - thereafter |
| | Oxidizer combustion chamber and stack temperatures | A | Continuous during oxidizer operation |
| | Total liquid (LNAPL and groundwater) extracted (gallons) | A | Continuous |
| | Total LNAPL removed (gallons) | M | Weekly, or when on-Site |
| | Separated groundwater discharge flowrate (gpm) | A | Continuous |
| | Applied air injection pressure for PFS (psi) | A | Continuous during PFS operation |
| MPE Wellheads | Applied vacuum ("Hg) | M | Weekly |
| | Depth to LNAPL/groundwater | M | Weekly |
| Monitoring Wells | Induced vacuum ("$H_2O$) | M | Weekly |
| | Depth to LNAPL and groundwater | M | Weekly |
| | Well headspace volatility/% LEL | M | As needed |

Notes:
M - manual measurement
A - automated measurement via system instrumentation

**Table 4.1**
**PILOT AND FULL-SCALE MPE RECOVERY SUMMARY**
**BUILDING 33 CORRECTIVE MEASURES REPORT**
**GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS**
**PONTIAC, MICHIGAN**

| *Implementation Stage* | *Recovery Phase* | *Total Hydrocarbon Recovery* | | | *% of Total Recovery* |
|---|---|---|---|---|---|
| | | *Pounds* | *Liters* | *Gallons* | |
| **Pilot-Study** | LNAPL | 11,266 | 6,245 | 1,650 | 53.3 |
| | Vapor | 9,880 | 5,477 | 1,447 | 46.7 |
| | Water | 0.2 | 0.1 | 0.03 | 0.001 |
| | **TOTAL** | **21,147** | **11,722** | **3,097** | |
| **Full-Scale** | LNAPL | 907 | 503 | 133 | 4.8 |
| | Vapor | 18,116 | 10,042 | 2,653 | 95.2 |
| | **TOTAL** | **19,023** | **10,545** | **2,786** | |
| **OVERALL TOTALS** | | **40,170** | **22,267** | **5,883** | |

**Table 4.2**
**AIR EMISSIONS RECORDKEEPING - STATE OF MICHIGAN PTI 61-06**
**BUILDING 33 CORRECTIVE MEASURES REPORT**
**GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS**
**PONTIAC, MICHIGAN**

| *Date* | *Elapsed Run Time (hours)* | *Flowrate (scfm)* | *VOC Concentration (ppmv as C)* | *Benzene Concentration (ppmv)* | *VOC Mass Flowrate (pounds/hour)* | *Benzene Mass Flowrate (pounds/hour)* | *VOC Cumulative Mass Emissions (tons)* | *Benzene Cumulative Mass Emissions (tons)* | *VOC Cumulative Emissions (% of Permit Limit)* | *Benzene Cumulative Emissions (% of Permit Limit)* |
|---|---|---|---|---|---|---|---|---|---|---|
| 9/25/2006 | 71.8 | 1,429 | 13 | 0.320 | 0.03 | 0.006 | 0.0012 | 0.000200 | 0.012 | 0.091 |
| 10/11/2006 | 74.2 | 1,414 | 110 | 0.047 | 0.29 | 0.0008 | 0.0016 | 0.000201 | 0.016 | 0.091 |
| 11/9/2006 | 156.3 | 1,013 | 63 | 0.01 | 0.12 | 0.0001 | 0.0065 | 0.000206 | 0.065 | 0.094 |
| 11/15/2006 | 284.9 | 1,056 | 20 | 0.073 | 0.04 | 0.0009 | 0.0090 | 0.000266 | 0.090 | 0.121 |
| 11/23/2006 | 397.0 | 944 | 21 | 0.15 | 0.04 | 0.002 | 0.0111 | 0.000363 | 0.111 | 0.165 |
| 11/29/2006 | 513.9 | 1,083 | 17 | 0.045 | 0.03 | 0.001 | 0.0131 | 0.000398 | 0.131 | 0.181 |
| 12/6/2006 | 626.9 | 973 | 12 | 0.01 | 0.02 | 0.000 | 0.0144 | 0.000404 | 0.144 | 0.184 |
| 12/14/2006 | 628.1 | 974 | 10 | 0.11 | 0.02 | 0.001 | 0.0144 | 0.000405 | 0.144 | 0.184 |
| 1/3/2007 | 694.3 | 1,240 | 28 | 0.17 | 0.06 | 0.003 | 0.0165 | 0.000490 | 0.165 | 0.223 |
| 1/11/2007 | 869.9 | 1,288 | 10 | 0.19 | 0.02 | 0.003 | 0.0187 | 0.000751 | 0.187 | 0.342 |
| 3/14/2007 | 947.8 | 1,078 | 29 | 0.01 | 0.06 | 0.000 | 0.0209 | 0.000757 | 0.209 | 0.344 |
| 4/24/2007 | 1,133.4 | 1,306 | 21 | 0.12 | 0.05 | 0.002 | 0.0257 | 0.000934 | 0.257 | 0.424 |
| 5/17/2007 | 1,555.7 | 1,282 | 36 | 0.26 | 0.09 | 0.004 | 0.0439 | 0.001790 | 0.439 | 0.814 |
| 6/19/2007 | 2,271.7 | 1,178 | 27 | 0.18 | 0.06 | 0.003 | 0.0652 | 0.002715 | 0.652 | 1.234 |
| 7/17/2007 | 2,623.1 | 1,116 | 27 | 0.12 | 0.06 | 0.002 | 0.0752 | 0.003001 | 0.752 | 1.364 |
| 8/15/2007 | 3,238.1 | 1,076 | 38 | 0.077 | 0.08 | 0.001 | 0.0987 | 0.003311 | 0.987 | 1.505 |

Notes:
- scfm: standard cubic feet per minute (i.e., corrected to 68 $^{o}$F, 29.92"Hg)
- VOC: volatile organic compounds (laboratory reports total non-methane organic compounds)
- Cells highlighted in yellow represent non-detect laboratory results. The reported result represents the laboratory reporting limit.
- Permit limits: 10 tons per year VOCs
0.22 tons per year benzene

Example Calculation:
*- Emission rate of VOC*

$$\frac{lb}{hr}\,VOC = \frac{\frac{C_{VOC}}{10^{6}} \times Q \times MW \times 60\,\frac{min}{hr}}{385\,\frac{ft^{3}}{lb \cdot mol}}$$

Where: $C_{VOC}$ = exhaust VOC concentration expressed as ppmv
Q = exhaust flowrate expressed as scfm
MW = molecular weight of carbon in lb/lb mol
385 = molar volume of an ideal gas at standard conditions

**Table 4.3**
**AIR EMISSIONS RECORDKEEPING - STATE OF MICHIGAN PTI 61-06A**
**BUILDING 33 CORRECTIVE MEASURES REPORT**
**GENERAL MOTORS PONTIAC CENTERPOINT CAMPUS**
**PONTIAC, MICHIGAN**

| *Date* | *Monthly Run Time (hours)* | *Flowrate (scfm)* | *Benzene Concentration (ppmv)* | *Benzene Mass Flowrate (pounds/hour)* | *VOC Cumulative Mass Emissions (pounds)* | *VOC Cumulative Mass Emissions (tons)* | *Benzene Cumulative Mass Emissions (tons)* | *VOC Cumulative Emissions (% of Permit Limit)* | *Benzene Cumulative Emissions (% of Permit Limit)* |
|---|---|---|---|---|---|---|---|---|---|
| Sep-07 | 486.2 | 1,237 | 5.5 | 0.0828 | 1126.2 | 0.563 | 0.020141 | 5.63 | 9.15 |
| Oct-07 | 736.6 | 1,342 | 3.1 | 0.0506 | 2803.8 | 1.402 | 0.038794 | 14.02 | 17.63 |
| Nov-07 | 684.8 | 1,339 | 2.8 | 0.0456 | 4230.4 | 2.115 | 0.054420 | 21.15 | 24.74 |
| Dec-07 | 461.7 | 1,315 | 0.14 | 0.0022 | 4703.3 | 2.352 | 0.054937 | 23.52 | 24.97 |
| Jan-08 | 553.3 | 1,268 | 0.47 | 0.0073 | 5026.2 | 2.513 | 0.056945 | 25.13 | 25.88 |
| Feb-08 | 547.9 | 1,305 | 1.0 | 0.0159 | 5401.2 | 2.701 | 0.061297 | 27.01 | 27.86 |
| Mar-08 | 730.8 | 1,300 | 0.10 | 0.0016 | 5517.3 | 2.759 | 0.061875 | 27.59 | 28.12 |
| Apr-08 | 641.8 | 1,288 | 0.24 | 0.0038 | 5676.2 | 2.838 | 0.063082 | 28.38 | 28.67 |
| May-08 | 697.7 | 1,288 | 0.18 | 0.0028 | 6064.5 | 3.032 | 0.064067 | 30.32 | 29.12 |
| Jun-08 | 675.9 | 1,268 | 0.11 | 0.0017 | 6500.4 | 3.250 | 0.064640 | 32.50 | 29.38 |
| Jul-08 | 606.9 | 1,258 | 0.27 | 0.0041 | 6748.6 | 3.374 | 0.065895 | 33.74 | 29.95 |
| Aug-08 | 737.7 | 1,243 | 0.14 | 0.0021 | 6998.6 | 3.499 | 0.066676 | 34.99 | 30.31 |
| Sep-08 | 240.9 | 1,255 | 0.07 | 0.0010 | 7139.1 | 3.570 | 0.066798 | 35.70 | 30.36 |
| Oct-08 | 353.0 | 1,260 | 0.30 | 0.0046 | 7310.1 | 3.655 | 0.067610 | 36.55 | 30.73 |

Notes:
- scfm: standard cubic feet per minute (i.e., corrected to 68 °F, 29.92"Hg)
- Cells highlighted in yellow represent non-detect laboratory results. The reported result represents the laboratory reporting limit.
- Permit limits: 10 tons per year VOCs
0.22 tons per year benzene

Example Calculation:
*- Emission rate of VOC*

$$\frac{lb}{hr} VOC = \frac{\frac{C_{VOC}}{10^6} \times Q \times MW \times 60 \frac{min}{hr}}{385 \; ft^3/lb \cdot mol}$$

Where: $C_{VOC}$ = exhaust total hydrocarbon concentration expressed as ppmv (as hexane)
Q = exhaust flowrate expressed as scfm
MW = molecular weight of hexane in lb/lb mol
385 = molar volume of an ideal gas at standard conditions