Remediation of Deep LNAPL from Glacial Soils Using High Vacuum Multi-Phase Extraction (MPE), Pneumatic Air Lift (PAL), and Pneumatic Fracturing

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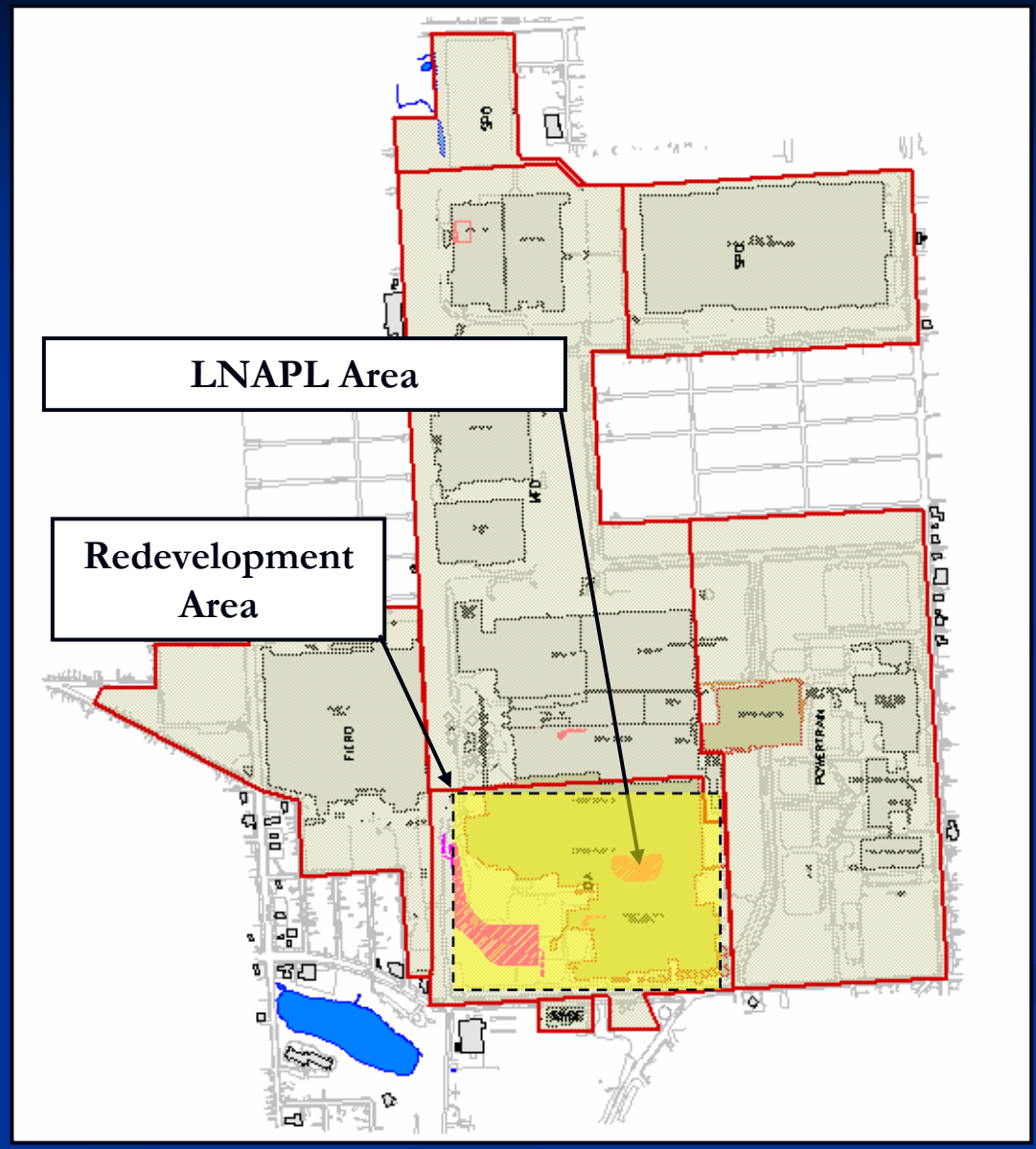
Background

- Subject Site – 600 acre General Motors Corporation (GM) manufacturing facility in eastern Michigan;
- South portion of Site (approximately 100 acres) leased to a 3rd party and undergoing redevelopment for the construction of an 800,000 square foot building;
- Area referred to as Redevelopment Area.

Background



Background (Cont'd)

- Environmental Corporate Remediation Company, Inc. (ENCORE), a wholly owned subsidiary of GM, and the Encore Environmental Consortium LLC (EEC) are conducting a RCRA Facility Investigation (RFI) at the Site;

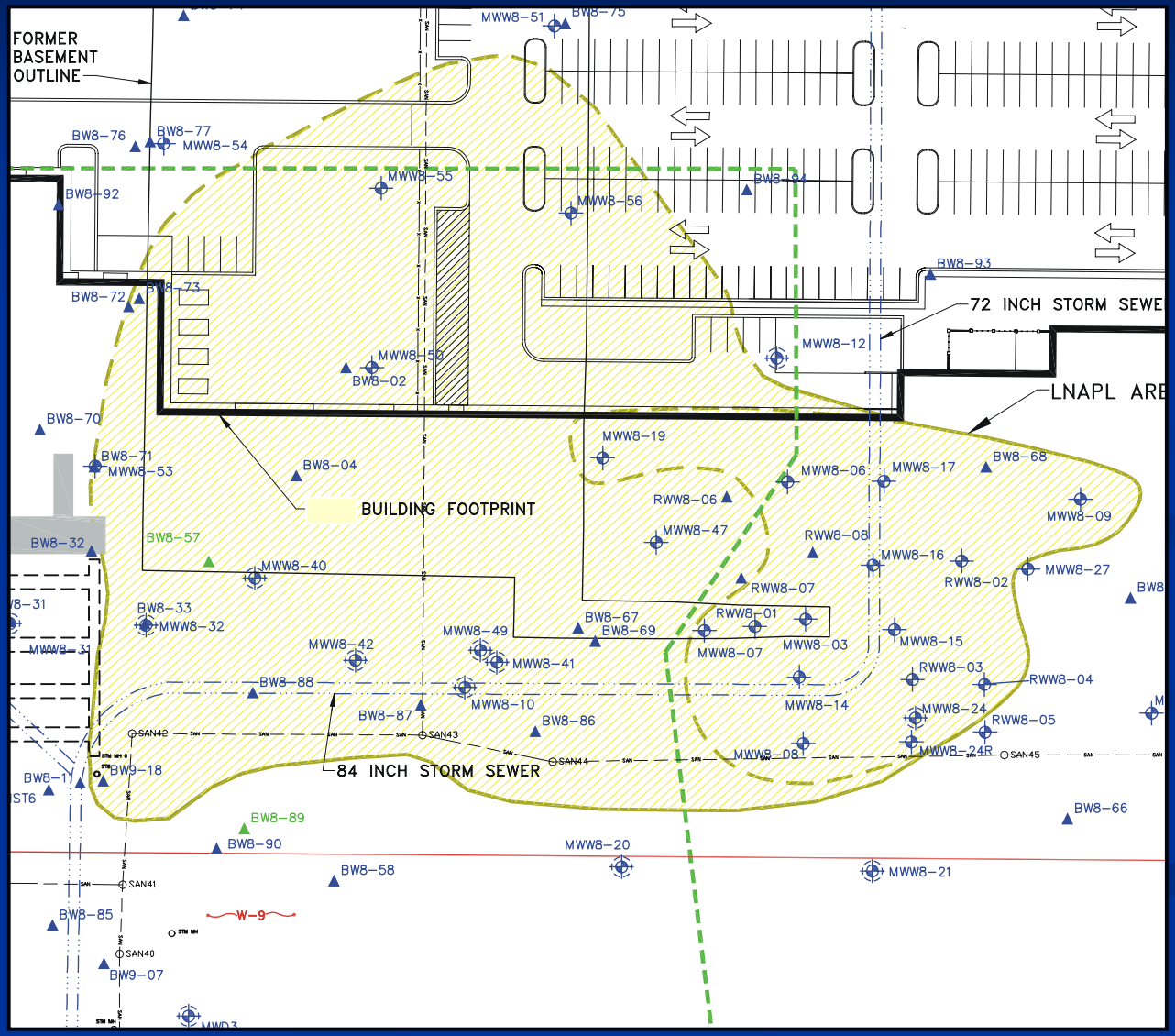
- LNAPL was discovered in various locations in the Redevelopment Area.

Background (Cont'd)

- ENCORE is undertaking the aggressive recovery of LNAPL in support of the construction schedule in the Redevelopment Area (not based on risk);

- This paper focuses on the LNAPL remediation efforts conducted in one of the LNAPL areas in the Redevelopment Area.

LNAPL Area


FORMER
BASEMENT
OUTLINE
BUILDING FOOTPRINT
84 INCH STORM SEWER
72 INCH STORM SEWE
LNAPL ARE
MWW8-51
BW8-75
BW8-76
BW8-77
MWW8-54
MWW8-55
BW8-92
MWW8-56
BW8-94
BW8-93
BW8-72
BW8-73
MWW8-12
MWW8-50
BW8-02
BW8-70
BW8-71
MWW8-53
BW8-04
MWW8-19
MWW8-06
MWW8-17
BW8-68
RWW8-06
MWW8-09
MWW8-47
RWW8-08
BW8-32
BW8-57
MWW8-40
MWW8-16
MWW8-27
RWW8-02
RWW8-07
BW8-33
MWW8-32
BW8-67
BW8-69
RWW8-01
MWW8-49
MWW8-42
MWW8-07
MWW8-03
MWW8-15
MWW8-41
RWW8-03
RWW8-04
BW8-88
MWW8-10
MWW8-14
MWW8-24
BW8-87
BW8-86
RWW8-05
SAN42
SAN43
SAN44
MWW8-08
MWW8-24R
SAN45
BW9-18
BW8-89
BW8-66
BW8-90
MWW8-20
BW8-58
MWW8-21
SAN41
BW8-85
W-9
SAN40
BW9-07
MWD3

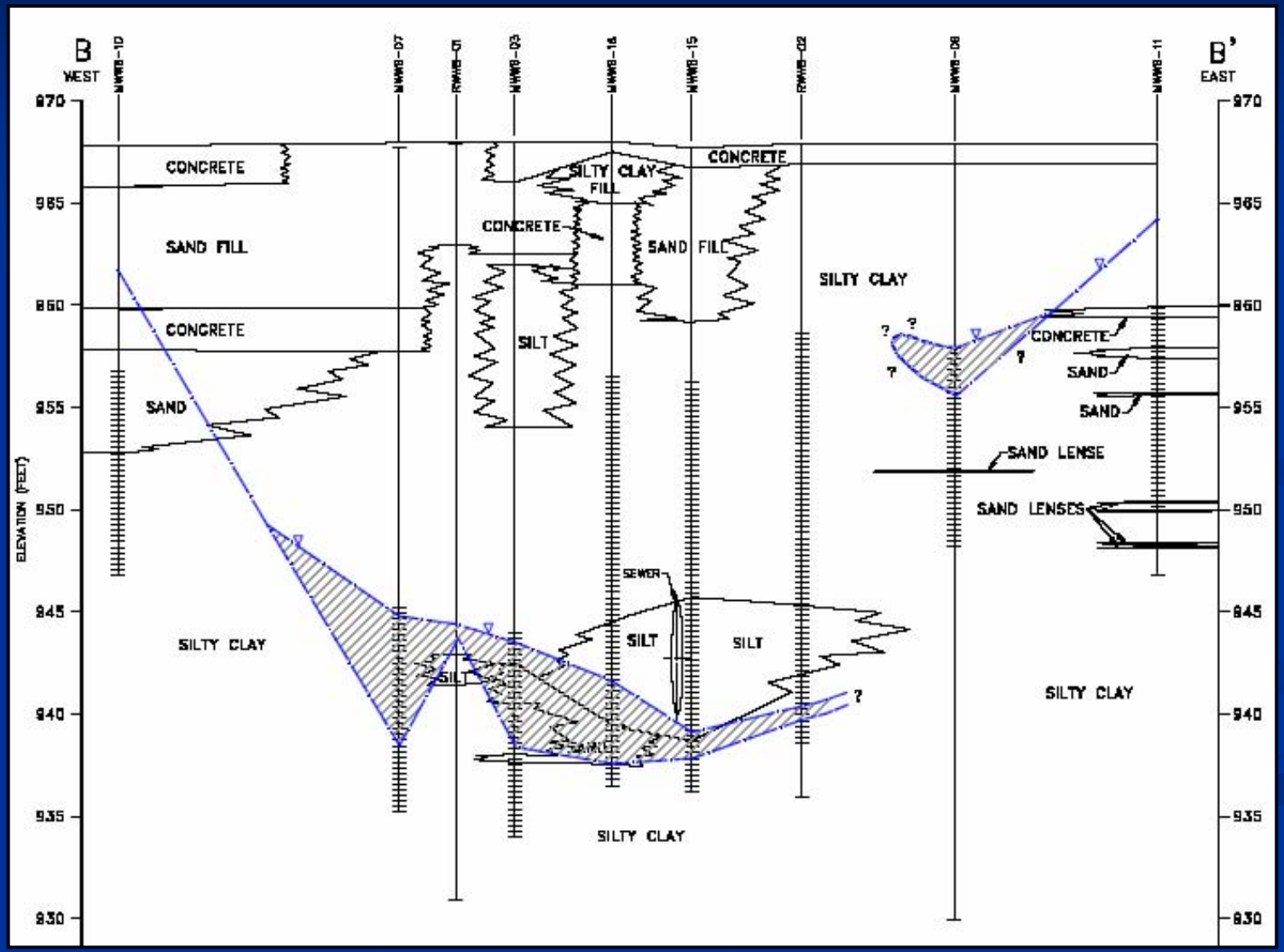
Geology/Hydrogeology

- Geology is comprised of low permeability glacial soils (silts and clays with occasional sand seams);
- Depth to air/LNAPL interface in the LNAPL Area is approximately 30 feet bgs;
- LNAPL thicknesses vary from a sheen to 12 feet;
- LNAPL has been characterized as a weathered No. 2 fuel oil/diesel with lesser amounts of No. 6 fuel oil.

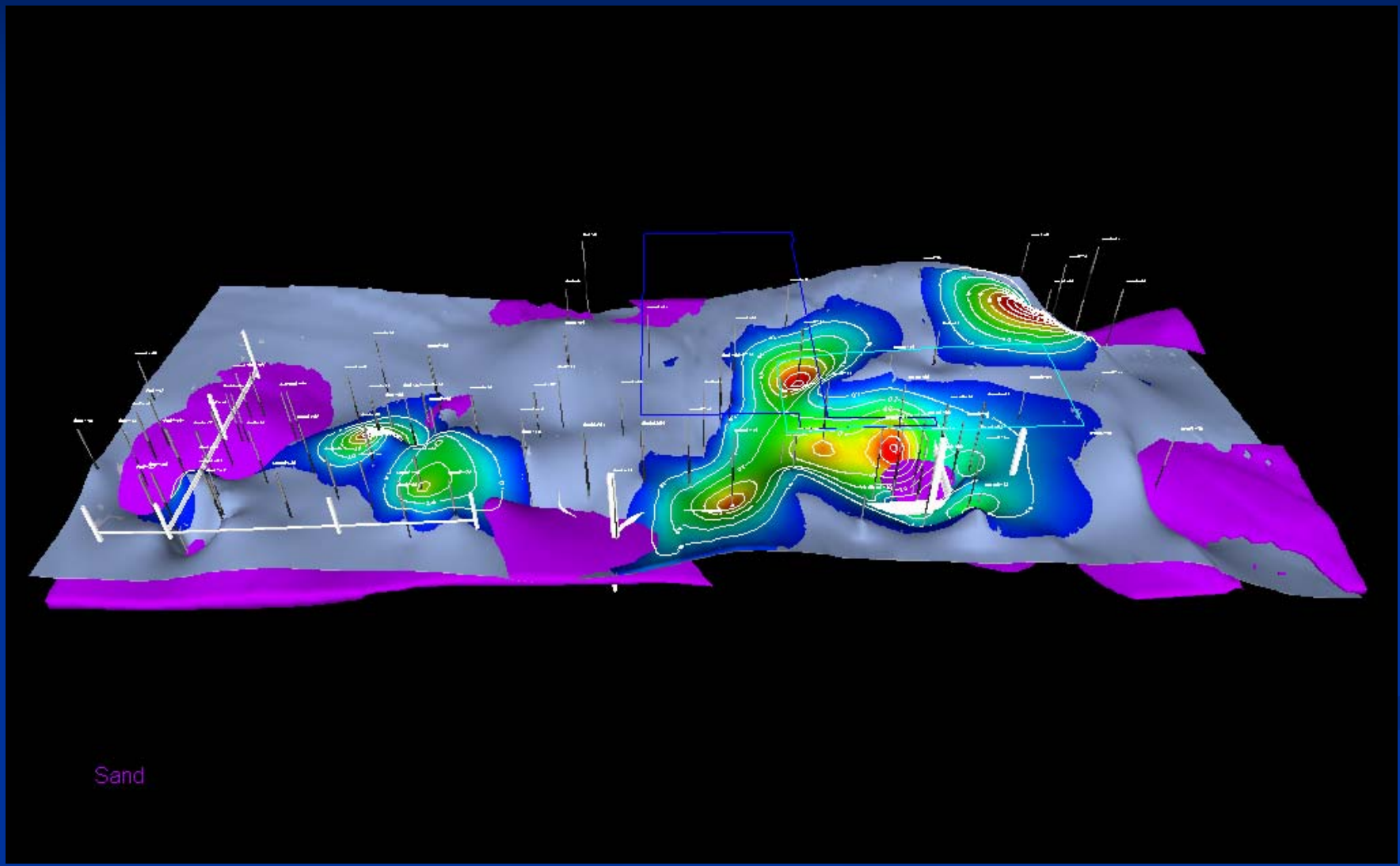
Subsurface Structures

- Subsurface concrete structures (basements, walls, etc.) in the Redevelopment Area remaining from buildings previously demolished;
- A large diameter storm sewer (72-inch) runs through the LNAPL Area at a depth of approximately 30 feet;
- The LNAPL appears to be migrating to/collecting around the storm sewer.

Subsurface Structures (Cont'd)



Subsurface Structures (Cont'd)



Previous Remedial Efforts

- Pneumatic skimmers were used from February through November 2004 to remove LNAPL from part of the LNAPL Area;
- Three skimmers were rotated amongst various wells containing LNAPL in an effort to maximize recovery volumes;
- Approximately 590 gallons of LNAPL was recovered over the 8-month period.

Rationale for Aggressive Recovery

- Construction of building in Redevelopment Area is scheduled to commence Spring 2006;
- GM is aggressively recovering as much LNAPL as practical beneath the proposed building footprint;
- LNAPL recovery efforts outside the building footprint may continue after Spring 2006.

Technology Description

- High vacuum Multi-Phase Extraction (MPE) has been shown to be a superior technology (in comparison to traditional pump and treat methods) for recovering LNAPL from low permeability formations;

- However, high vacuum alone is generally limited to recovering LNAPL from depths of 25 feet or less (due to vacuum lift limitations).

Technology Description (Cont'd)

- Pneumatic Air Lift (PAL) may be used in conjunction with MPE to enable the evacuation of LNAPL/groundwater from extraction wells;

- Pneumatic Fracturing (PF) is used to artificially create a more permeable secondary porosity to better allow the flow of LNAPL through low permeable formations; fracture propagation continues with continued (or pulsed) air injection.

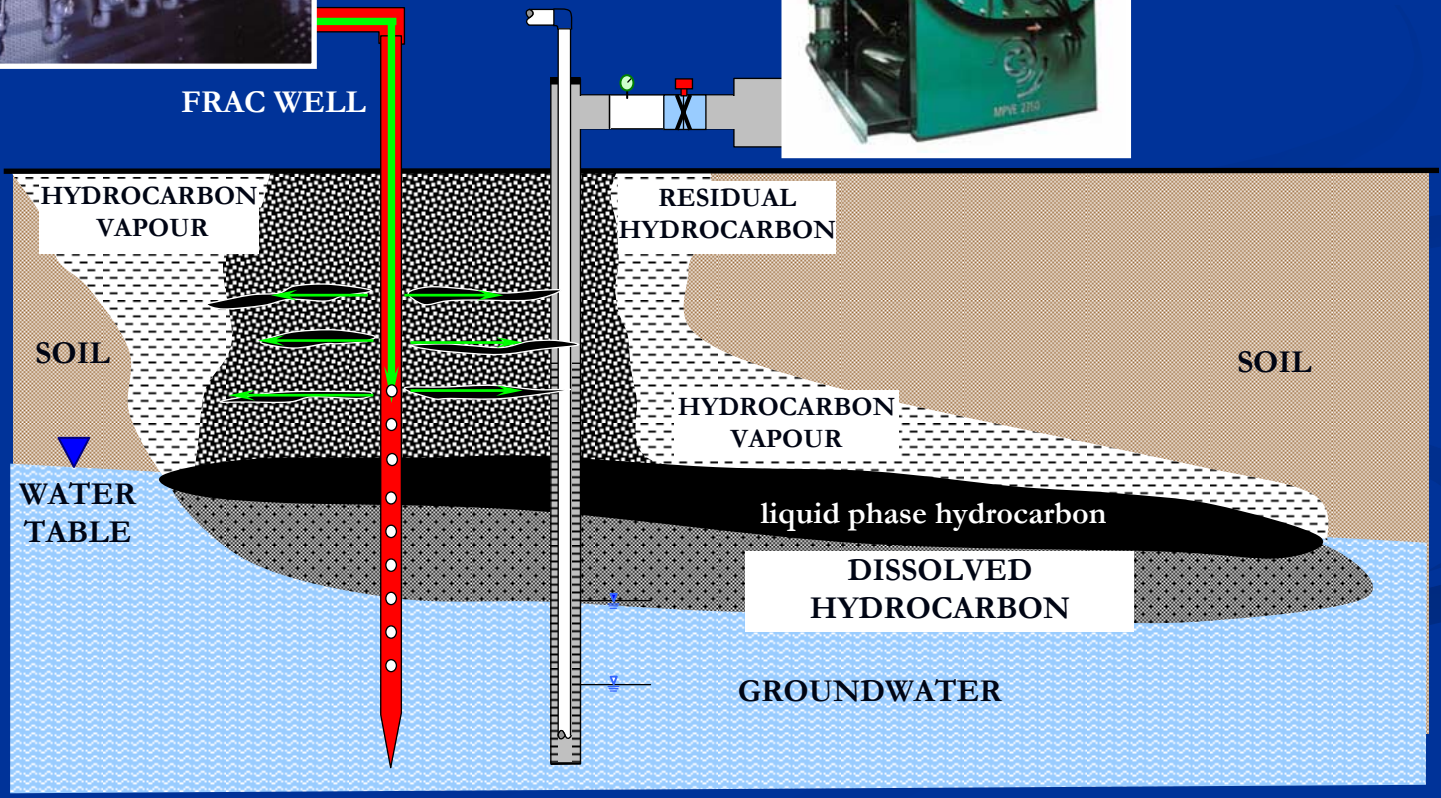
Technology Description (Cont'd)

- When PF wells are surrounded by MPE/PAL wells, the resulting high pressure differential between the air injection and vacuum extraction creates a "push-pull" effect enhancing the flow of LNAPL (including previously trapped LNAPL) to recovery wells.

Technology Description (Cont'd)

PF (Pneumatic Fracturing)

MPVE



Technology Description (Cont'd)

Remedial Pilot Study

- Remedial pilot study conducted using a mobile Multi-Phase Vacuum Extraction Unit (MPVE 2425) manufactured by Ground Effects Environmental Services Inc. of Regina, Saskatchewan;
- MPVE 2415 consists of 15 horsepower vacuum pump capable of exerting a maximum vacuum of 24 inches of mercury (“Hg) and achieving a maximum airflow rate of 225 standard cubic feet per minute (scfm).

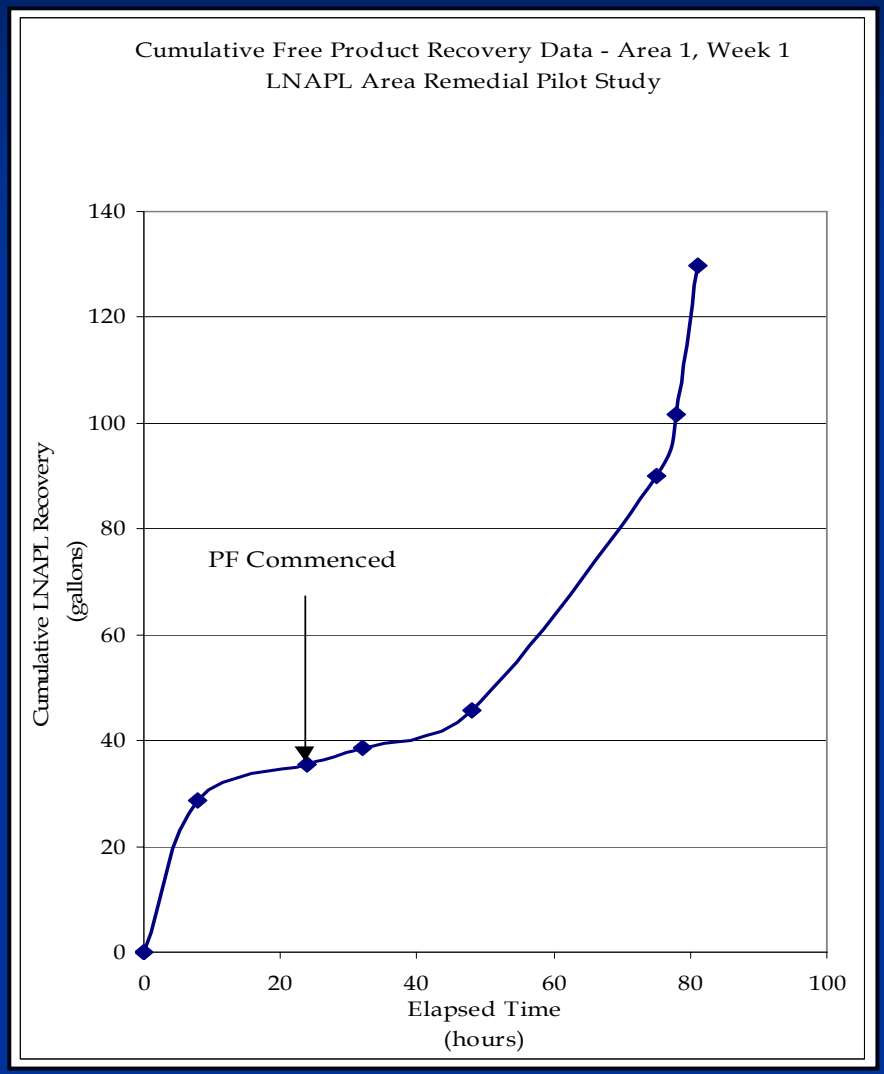
Remedial Pilot Study (Cont'd)

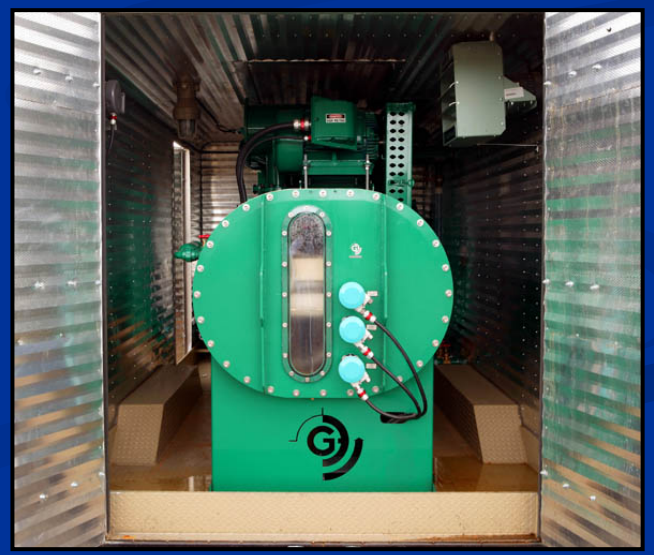
- Study was conducted in two areas of the LNAPL Area (Study Area 1 and Study Area 2);
- Area 1 considered to yield the most LNAPL (based on pneumatic skimming);
- Area 2 considered to yield the least LNAPL;
- 1 day of MPE/PAL followed by 3 days of MPE/PAL and PF in each area.

Remedial Pilot Study (Cont'd)

- Pilot study results indicate that fracturing effectively enhanced LNAPL recovery in Study Area 1;
- Results from Study Area 2 were inconclusive due to failure of PF compressor;
- Based on results from Area 1, a full-scale MPE/PAL and PF remediation alternative was recommended for the LNAPL Area.

Remedial Pilot Study (Cont'd)



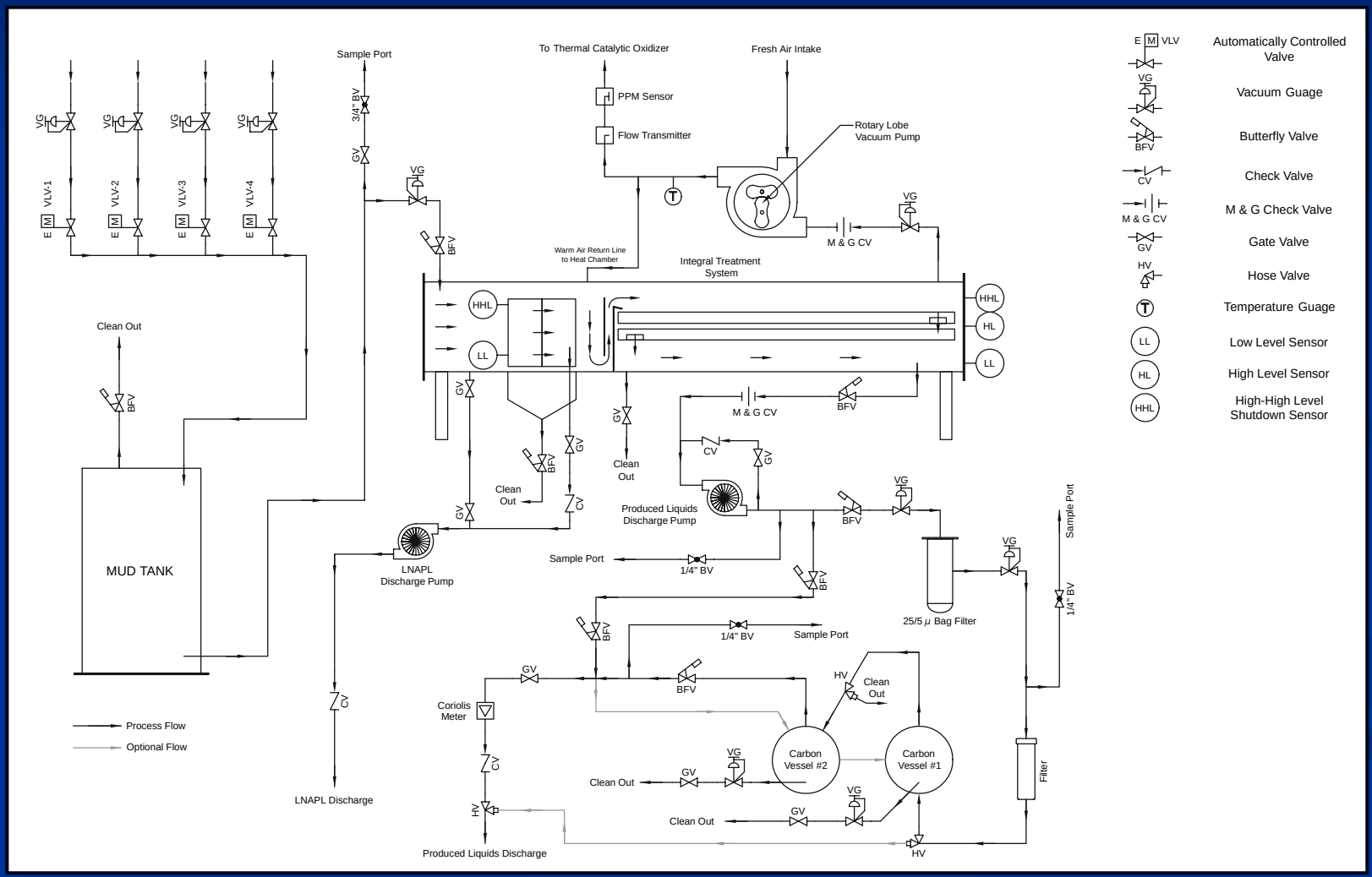


Equipment

- Three Ground Effects systems were selected for LNAPL recovery:
  - MPVE 2750 Titan (27 “Hg, 1000 scfm, 50 Hp);
  - MPVE 2750 (27 “Hg, 1000 scfm, 50 Hp);
  - MPVE 27100 Titan (27 “Hg, 2000 scfm, 100 Hp).

- Titan systems are equipped with wireless remote monitoring telemetry capabilities.

Equipment (Cont'd)

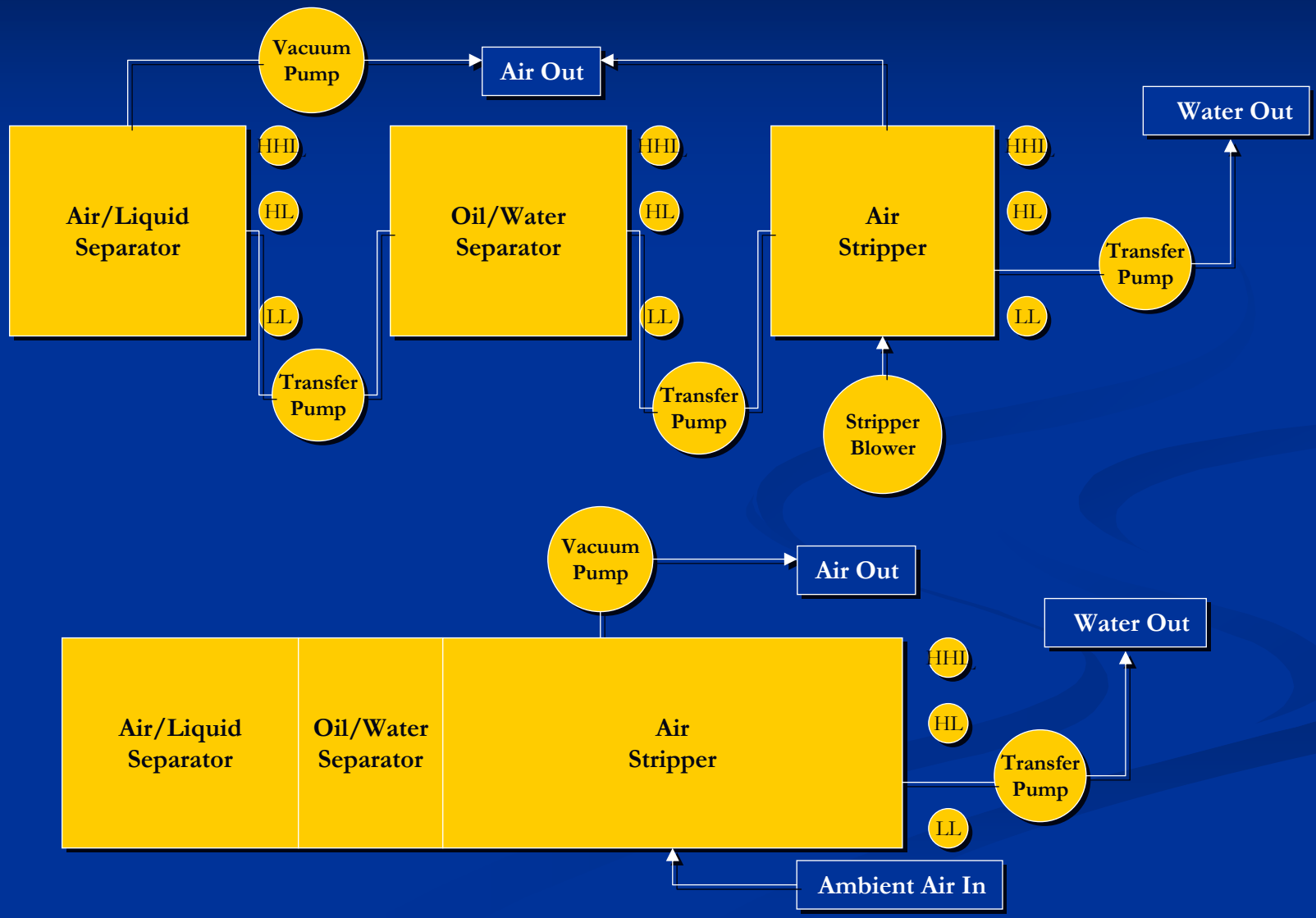


Equipment (Cont'd)

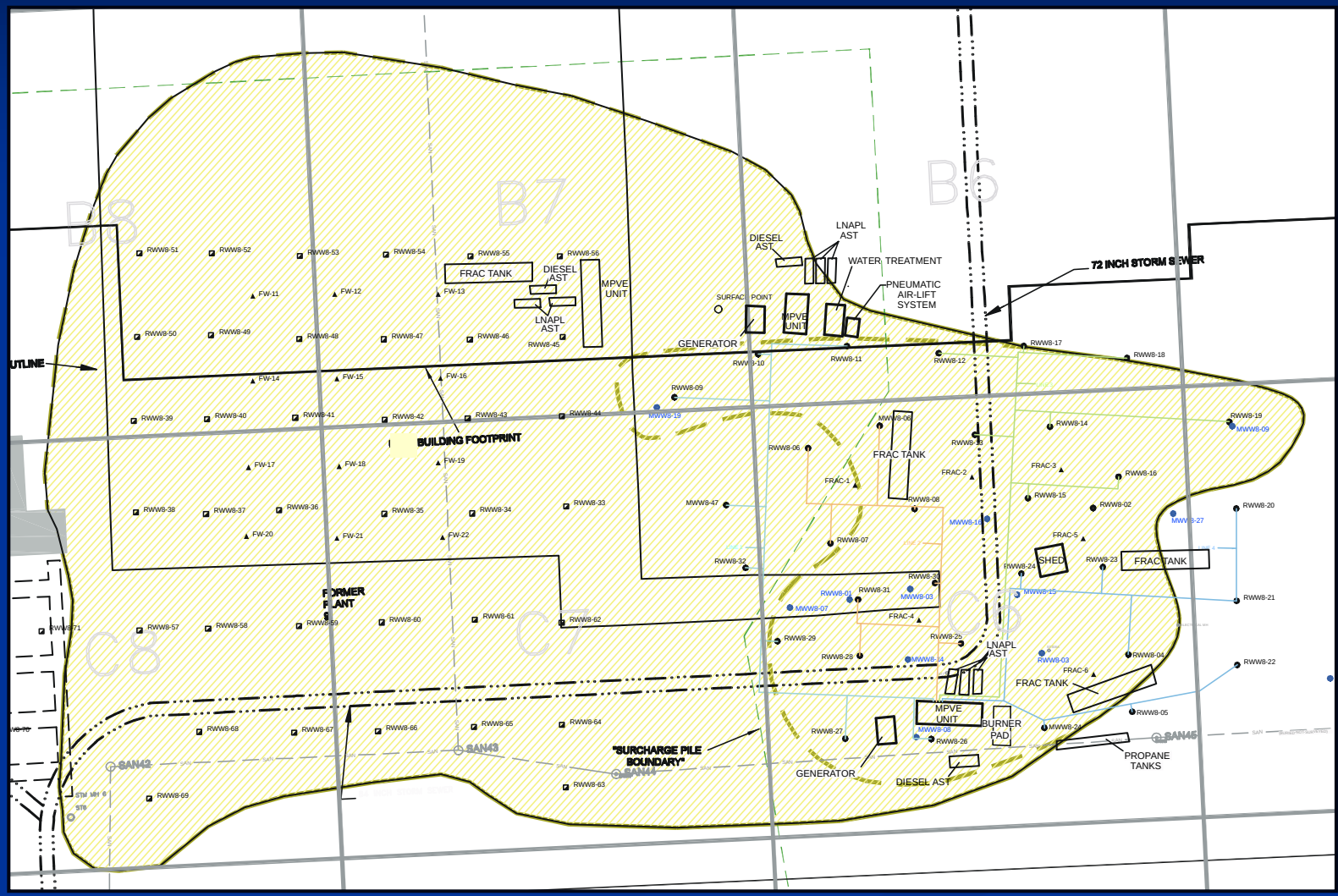
Equipment (Cont'd)

- Ground Effects MPVE systems designed using the concept of ***"less moving parts";***
- The integrated treatment system (ITS) reduces the need of an air stripper blower, several liquid transfer pumps and multiple level controls associated with conventional systems;
- Less moving parts translates into less equipment downtime/maintenance and hence, greater run times.

Equipment (Cont'd)



Overall System Configuration

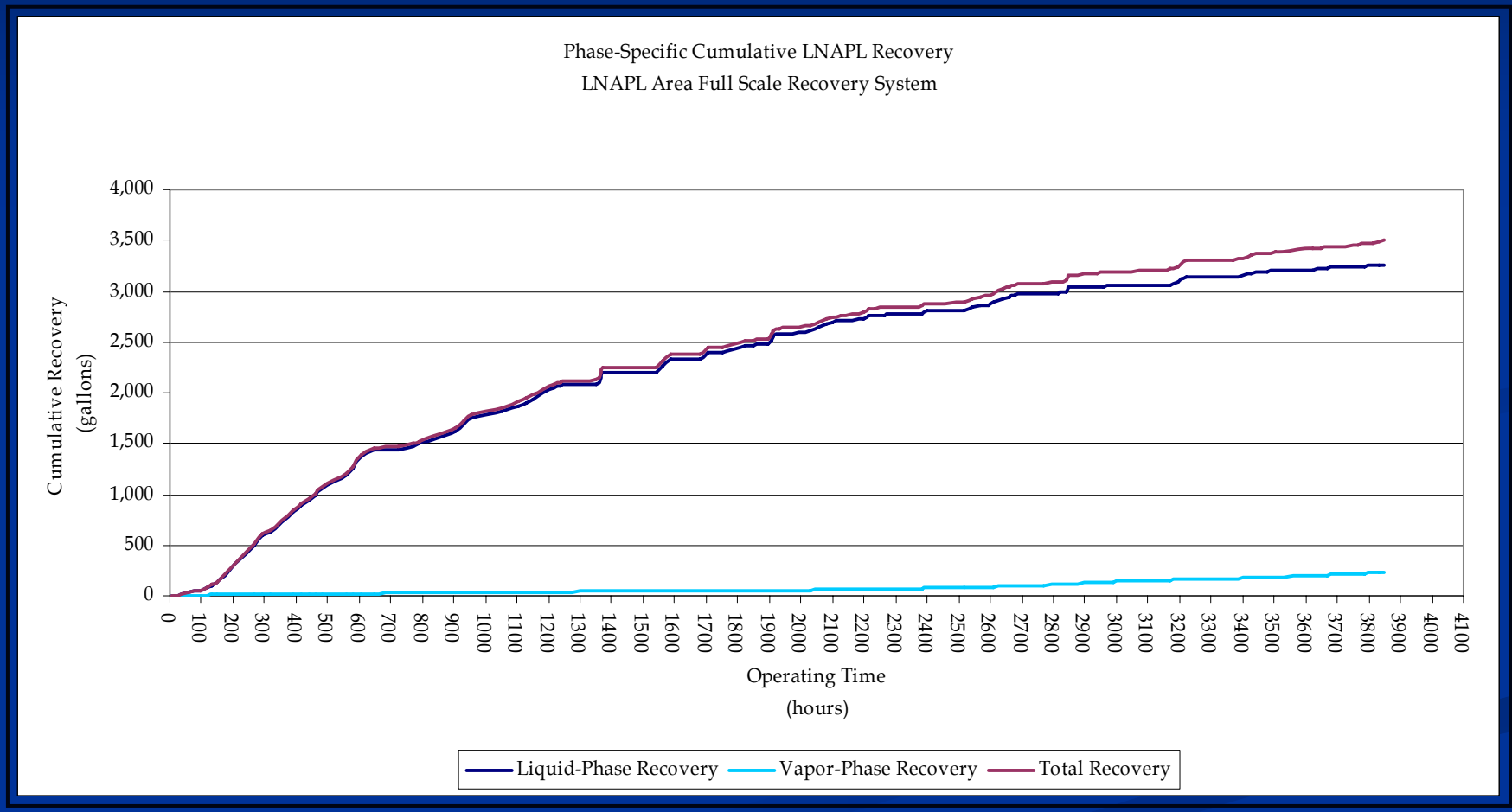


Overall System Configuration

Performance – MPVE 2750 Titan

- Operating since March 1, 2005 in southeast portion of the LNAPL Area;
- Extracting from 12 MPE/PAL wells simultaneously and injecting air in 2-3 PF wells;
- Recovered 3,500 gallons (U.S.) of LNAPL;
- 90-98% of LNAPL recovery is in the free phase;
- Recovered 60,000 gallons of groundwater.

Performance – MPVE 2750 Titan



Performance – MPVE 2750

- Operated temporarily (two months) in southeast portion of the LNAPL Area with no significant recovery; currently operating in north portion;
- Extracting from 12 MPE/PAL wells simultaneously and injecting air in 2-3 PF wells;
- Recovered <50 gallons (U.S.) of LNAPL;
- 90-98% of LNAPL recovery is in the free phase;
- Recovered 20,000 gallons of groundwater.

Performance – MPVE 27100 Titan

- Operating since August 31, 2005 in southwest portion of the LNAPL Area;
- Extracting from 24 MPE/PAL wells simultaneously and injecting air in 3-4 PF wells;
- Recovered <100 gallons (U.S.) of LNAPL;
- 90-98% of LNAPL recovery is in the free phase;
- Recovered 60,000 gallons of groundwater.

Overall Performance

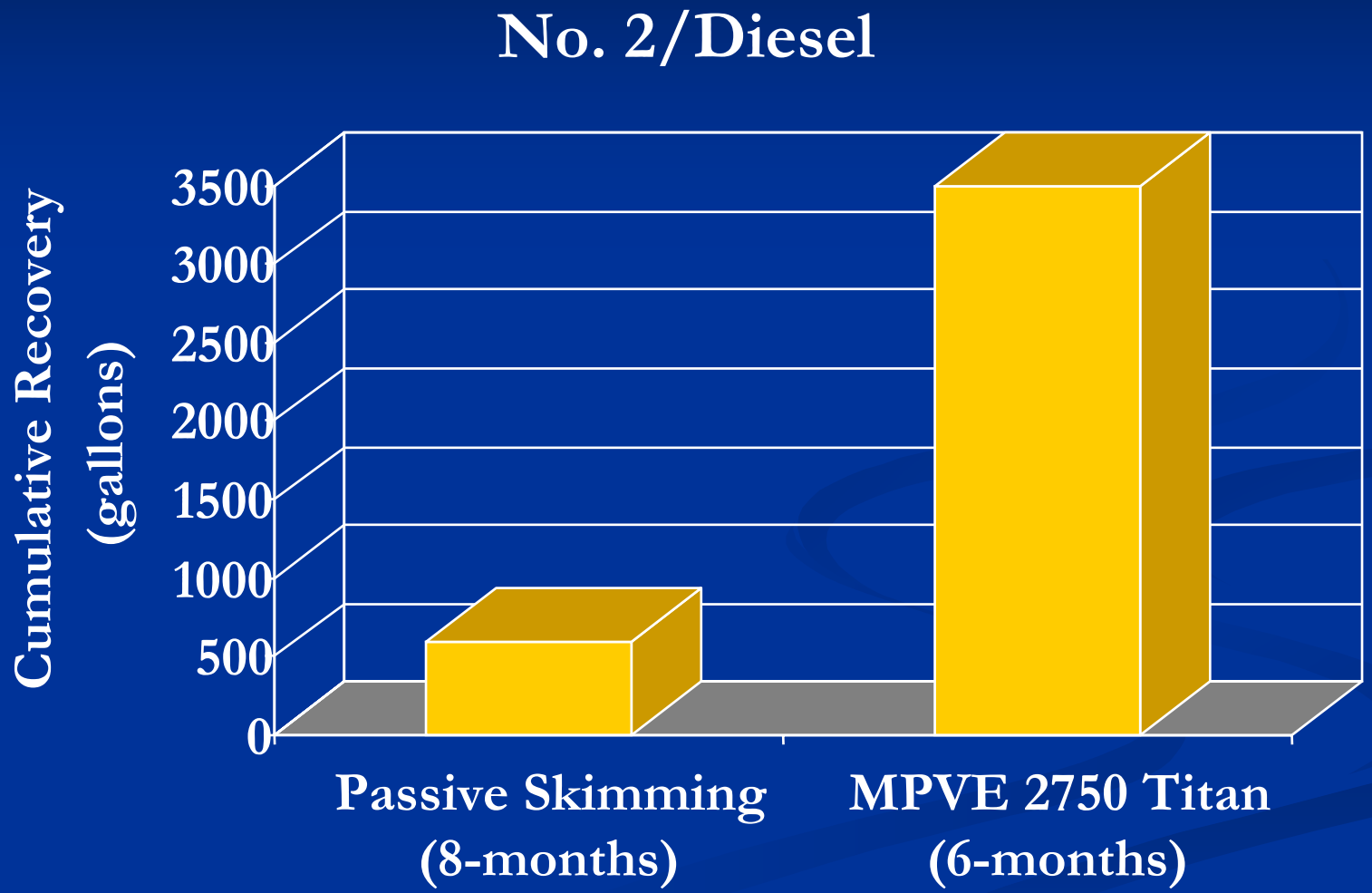
- Have recovered approximately 4,400 gallons of LNAPL as of September 30, 2005;
- Have recovered approximately 160,000 gallons of water as of September 30, 2005;
- LNAPL and water volumes above include recoveries during pneumatic skimming, remedial pilot study, and full-scale implementation.

Comparison of LNAPL Recovery Methods

- Pneumatic skimming in southeast portion of the LNAPL Area recovered approximately 590 gallons of LNAPL over an 8-month period;

- MPE/PAL and PF in southeast portion of the LNAPL Area recovered approximately 3,500 gallons of LNAPL over 6-month period.

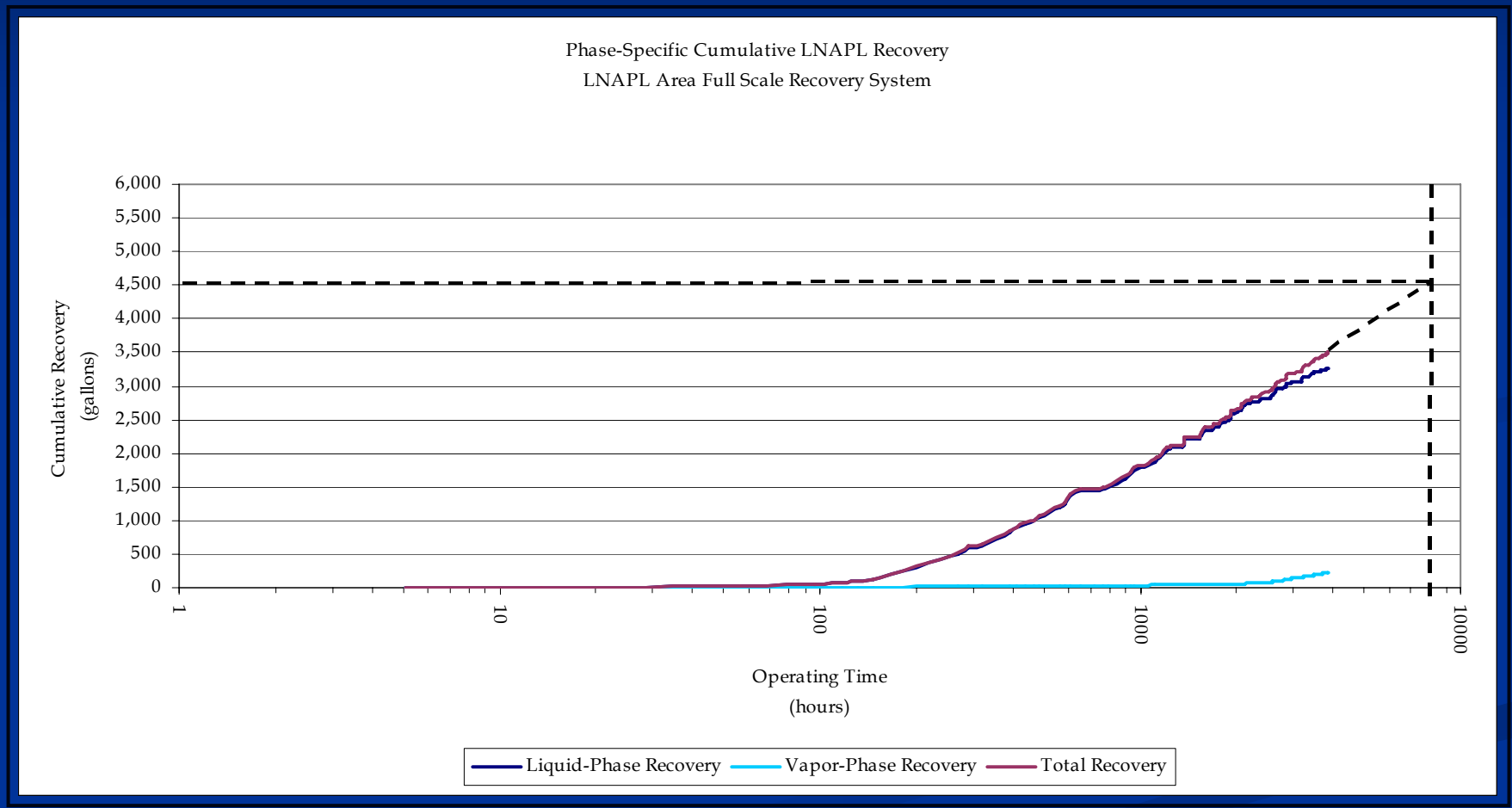
Comparison of LNAPL Recovery Methods



Remediation Endpoints

- Primary driving force behind remediation program was the redevelopment agreement negotiated with 3rd party;
- Previous risk calculations indicated that LNAPL did not pose an unacceptable health risk to intended current or future users of Redevelopment Area;
- Objective of remediation was to aggressively remove as much LNAPL as possible beneath building footprint prior to building construction.

Remediation Endpoints (Cont'd)



Factors to Consider / Lessons Learned

- The application of high vacuum to MPE wells without the use of PAL lines resulted in excessive build-up of silt in wells, essentially cementing the PAL line in place. Consequently, high vacuum is only used in conjunction with the PAL operation;

- The excessive removal of silt from MPE/PAL wells required the implementation of an up-front silt knock-out tank to prevent fouling of the ITS.

Factors to Consider (Cont'd)

- Excessive pressures were identified in monitoring wells several hundred feet away from fracture wells despite the operation of high vacuum MPE/PAL wells surrounding the fracture wells;

- Pressures in surrounding wells are closely monitored and the operation of the system is periodically modified to minimize pressure build-ups beyond the zone of vacuum influence.

Factors to Consider (Cont'd)

- Biological sludge-like material identified in recovered LNAPL in ITS, fouling the oil/water separation process and forcing periodic internal cleanings of the system(s);

- Use of biocide helping to control sludge production, however, periodic internal cleaning of ITS still necessary.

Factors to Consider (Cont'd)

- Greatest LNAPL recoveries were achieved from wells with relatively small in-well LNAPL thicknesses, coincide with screens in more permeable sand seams;

- Continually changing the selection of extraction and fracture wells to maximize LNAPL recovery and minimize water recovery (trial and error process).

Conclusions

- The use of MPE/PAL and PF is an effective, aggressive remediation technology for recovering LNAPL from depths in excess of 30 feet in low permeability soils;

- LNAPL recoveries using MPE/PAL and PF were approximately 6 times greater than using pneumatic skimmers.

Conclusions (Cont'd)

- Pneumatic fracturing can result in large pressure increases extending beyond the zone of high vacuum influence;
- Careful consideration must be evaluated in the early design stages to determine the feasibility of fracturing;
- Pneumatic fracturing may not be appropriate for smaller sites with potentially sensitive receptors nearby (e.g. retail petroleum facilities with neighbouring residences or buildings).

Conclusions (Cont'd)

- Use of MPE/PAL and PF is considered a very aggressive LNAPL recovery alternative that may not necessarily be justified as a remedial option based on risk or property use;

- The use of such an aggressive recovery option should be evaluated in the early design stages for feasibility.

Conclusions (Cont'd)

- The use of wireless satellite telemetry has enabled the remote monitoring and adjustment of the operation of the Titan systems to maximize LNAPL recovery;

- The use of telemetry has also reduced the amount of field time required to operate the systems.

Conclusions (Cont'd)

- The observation of biosolids within the ITS suggests the occurrence of significant LNAPL degradation in the subsurface;

- The MPE/PAL and PF processes are introducing air flow into previously anaerobic zones, stimulating aerobic biodegradation of LNAPL.

Acknowledgements

- The authors wish to thank General Motors Corporation for their contributions to this paper and to the ongoing LNAPL recovery efforts.