REDOX TECH

Steam Enhanced Extraction (SEE)

Technology Description

- Superheated water is injected through temporary direct push injection points.
- When the superheated water enters the formation, there is a pressure decrease away from the injection point and the water flashes to steam
- Fluids, which are a combination of air, fuel vapors, NAPL and water, are simultaneously recovered with an extraction system (liquid ring pump, ICE, downhole pump)
- Vapors and air are treated with activated carbon or catox
- Liquid is collected for disposal or treated and water is discharged to sewer
- The goal is to increase groundwater temperature by about 10 to 20 C, not boil off water as in other technologies

Benefits of SEE

- Heat reduces viscosity (resistance to flow) of fluid so it can migrate for recovery
- Heat increases vapor pressure so product is transferred to gas phase
- Injected fluid displaces LNAPL for recovery
- Simultaneous injection and fluid recovery creates a large gradient for recovery
- Injection targets the capillary fringe and smear zone which is often the long-term source of LNAPL

Steam Enhanced Extraction (SEE) Project Overview for Lynwood Springs Project Area

Site Background:

- Light non-aqueous phase liquid (LNAPL) discovered in 1999
- Source: Underground storage tank (UST) from a gas station operating from 1965 to early 2000s

Project Goals:

- Remove free product on 1.7 acre site without spreading LNAPL
- Remediate dissolved phase contaminants using magnesium sulfate
- No Atmospheric emissions because of SCAQMD regulations and proximity to elementary school

Steam-Enhanced Extraction (SEE):

- Increased temperature helps increase vapor pressure and reduce viscosity of the free product
- Steam injection aimed to increase the target interval temperature by 15°C
- Target interval: Free product and historical smear zone in source area

Placement of temporary extraction locations and steam injection locations

Scope of Work

Redox Tech was onsite from August 7th through November 3rd of 2023. The team spent a total of 65 days onsite.

Injected Quantities:

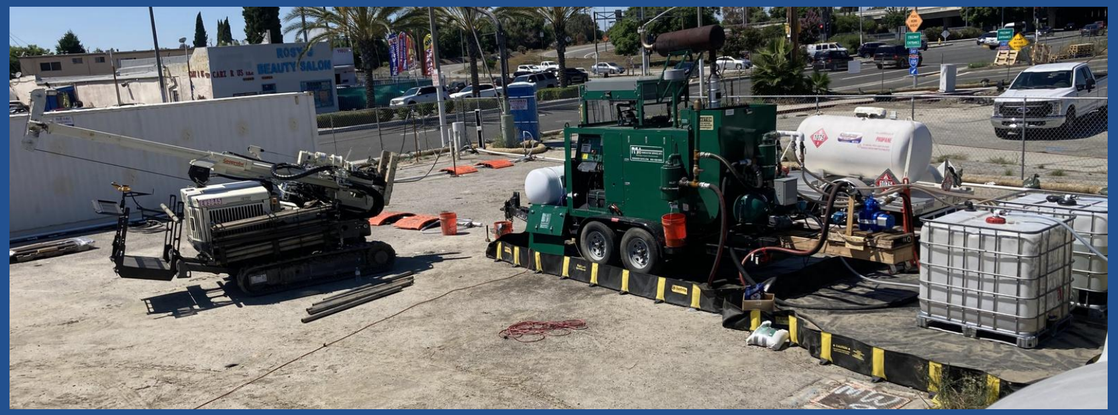
- 88,303 gallons of superheated water mixed with 10,150 pounds of magnesium sulfate was injected into 242 total injection locations
- Injection volume per location ranged from 282 to 1,375 gallons of superheated water
- Injected up to 9 locations simultaneously targeting a flow rate of 1.0 gpm
- Injection temperature, pressure, and flow rate was collected for each individual location and recorded daily

Extraction location with a magnehelic gauge installed

Steam location next to extraction location

Extracted Quantities:

- 45,432 gallons of total fluid, 4,355,730 cubic feet of vapor, and 32,580 pounds of gasoline was extracted from the 244 temporary locations and 12 wells
- Dual phase extraction system operated 24 hours a day beginning on 8/14
- Minimum extraction time per location was 21 hours.
- Vacuum data was collected at each extraction location using a magnehelic gauge and recorded daily



Injection and Extraction Locations

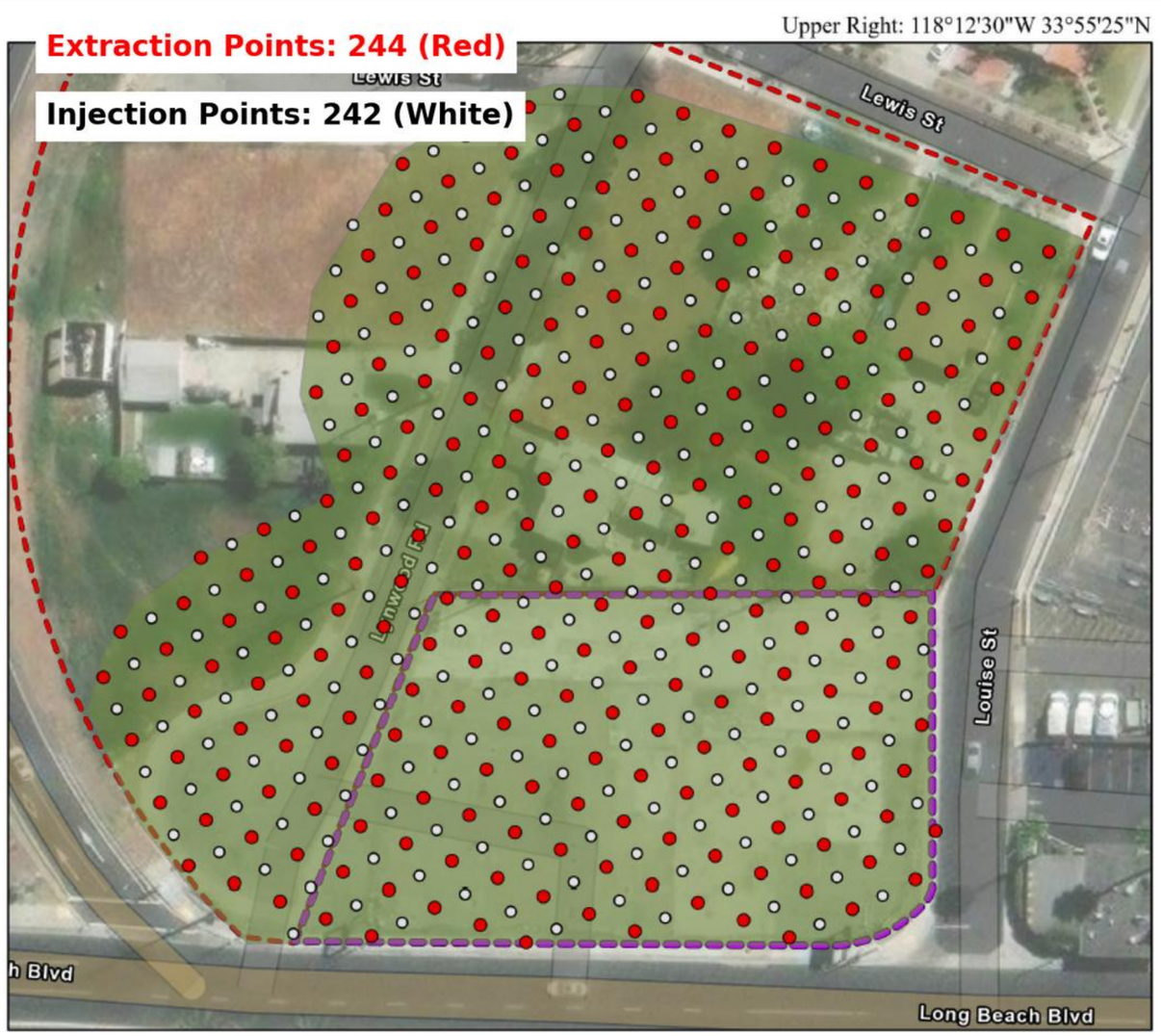
Temporary Injection Locations:

- Injected from 242 1.5-inch injection locations using an expendable point and point holder to inject the superheated water and magnesium sulfate
- Locations were spaced 20ft on center
- Injected at varies depths of 30, 36, and 37 feet below ground surface

Temporary Extracted Locations:

- Extracted from 244 temporary 2.25-inch extraction locations, 10 permanent wells, and 2 temporary 2-inch wells
- Temporary locations used a 4ft retractable screen set between depths of 34-38 ft or 38-42 ft bgs
- Each location used a 0.5-inch stinger set in the middle of the screen.
- The stinger was connected via 1-inch suction hose to 2-inch PVC, which connected to the ICE machine by a 2-inch suction hose

Site Layout



Internal Combustion Engine (ICE) Removal Process and Equipment

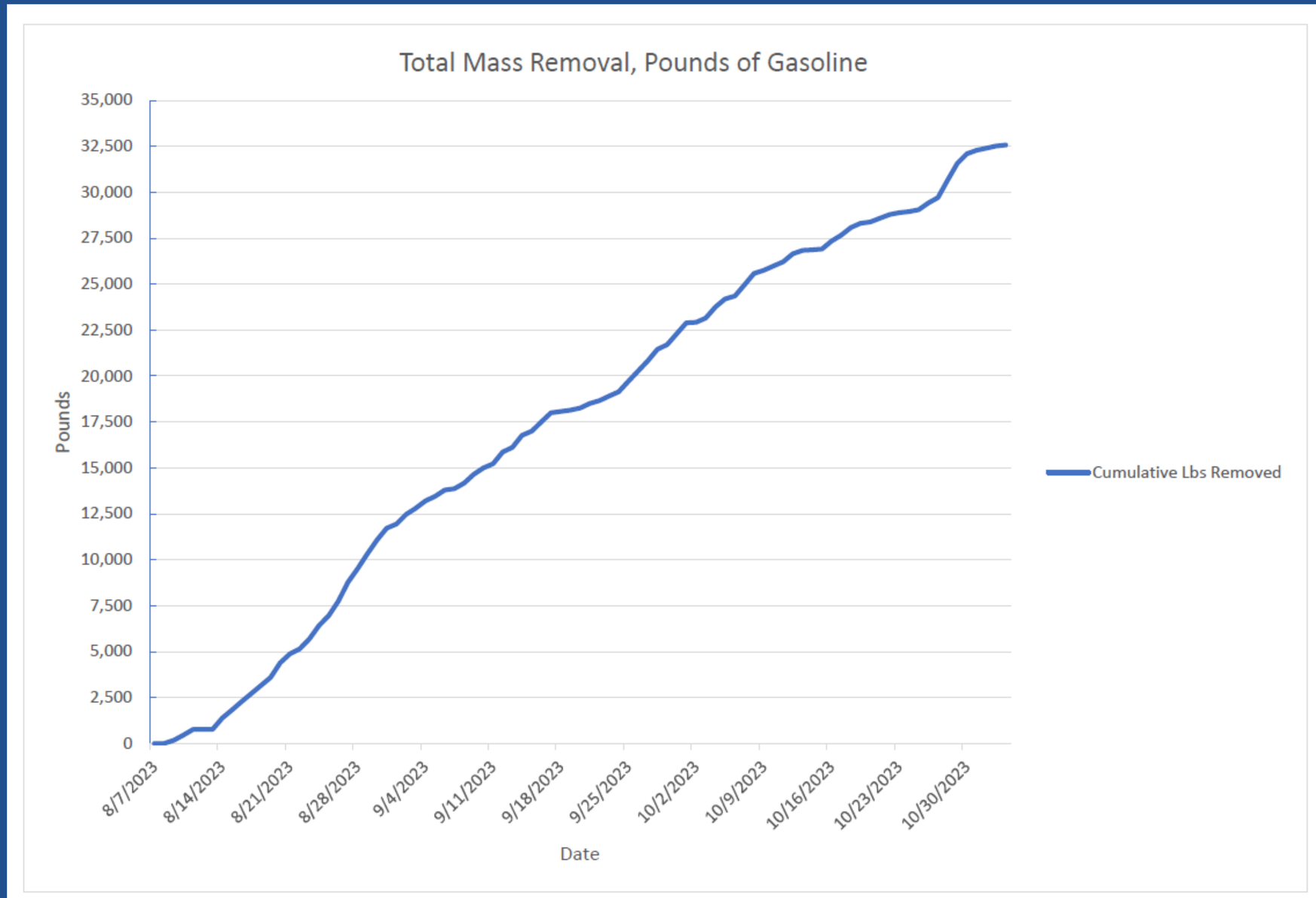
Extraction Removal Process:

- Extracted vapor and fluid went to ICE machine
- A knock out tank separated the liquid and vapor
- Processed vapor was used as a fuel source for the internal combustion engine
- Extraction pumps were placed in wells to increase the cone of depression and extraction volume
- Liquid was filtered through -
  - An oil-water separator
  - A 10-micron filter system
  - 2,000 pound of carbon vessel
- Treated water was stored in a 2,700-gallon poly tank, tested, and discharged

Extraction Equipment Utilized:

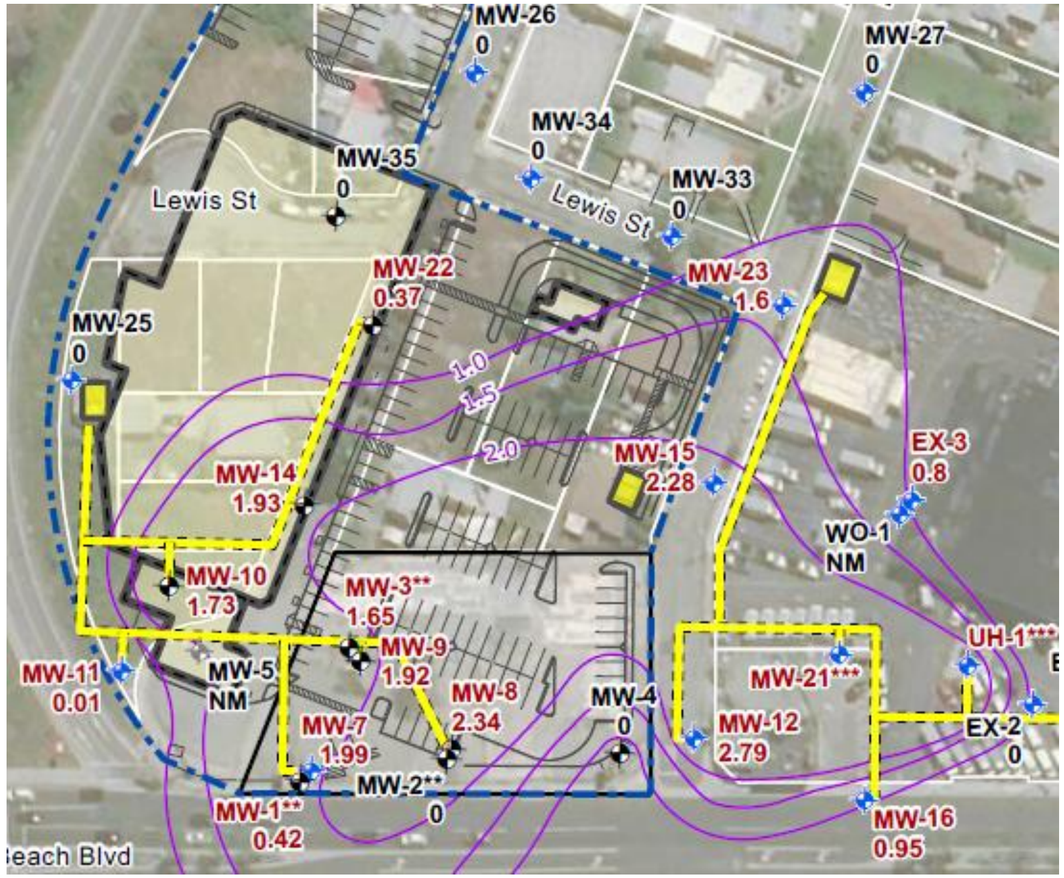
- Internal Combustion Engine (ICE)
- Oil Water Separator (OWS)
- 250-gallon hopper tote with high level float switch
- (2) 250-gallon totes for free product recovery
- 1/2 horsepower stainless steel centrifugal pump with flowmeter
- 10-micron filter
- 2,000-pound carbon vessel
- 2,700-gallon water storage tank with high level float switch
- 2-inch pneumatic bladder pump to extract groundwater
- 4-inch pneumatic lift pump to extract groundwater

Data was measured by RSI's SAVE Machine



Pre and Post Project levels of LNAPL in Monitoring wells

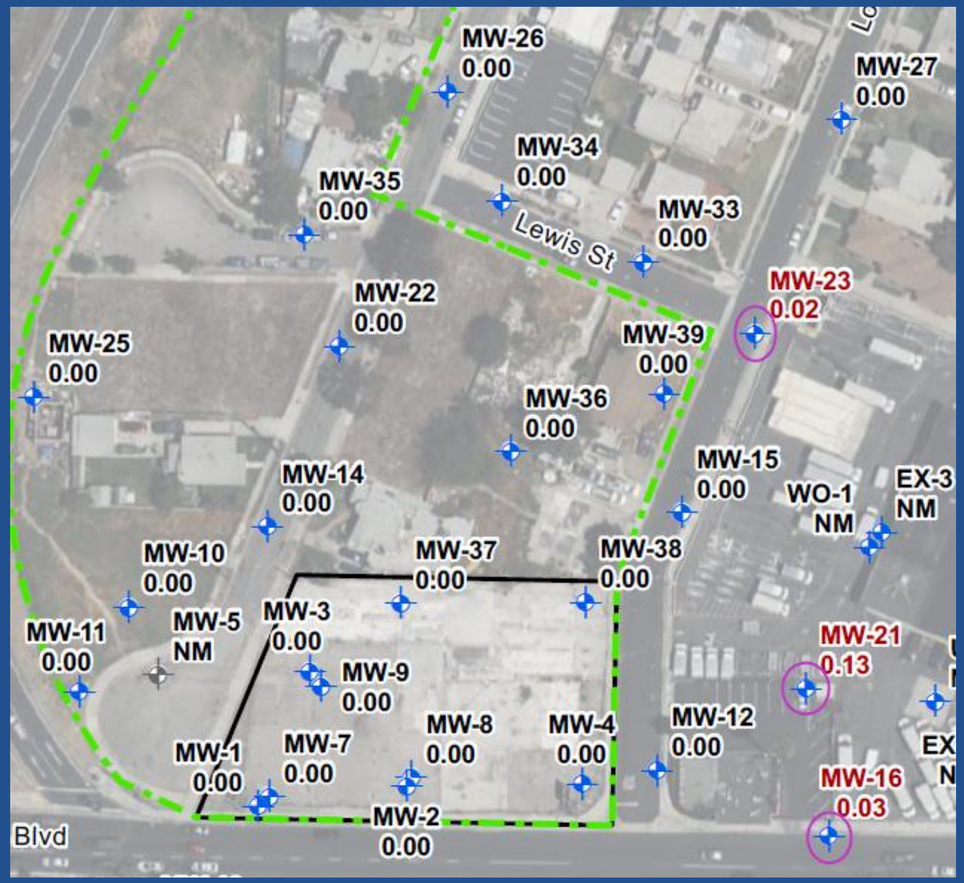
- Wells with product pre injection: 16
- Wells with product post injection: 3 (MW-16, MW-21, and MW-23)



Pre project levels of free product. Data was recorded on 8/5/21

Maximum dissolved phase TBH-g concentration ug/L:

- 10/25/23, MW-3 at 320,000 ug/L (during steam project)
- 2/21/24, MW-15 (off site well) at 100,000 ug/L



Post Project levels of free product. Data was recorded on 2/22/24

MW-7 pre steam, 8/8

MW-7 post steam, 8/30

Project Goals Revisited:

1. **Remove free product to prepare for a long-term vapor extraction system**

- **Free product was only sampled in 3 wells post injection and all were off-site**

2. **Remediate groundwater on-site using magnesium sulfate**

- **Overall reduction of TPH-g on-site, will need continued monitoring**

3. **Control off-site migration of contaminants**

- **Free product thickness in wells to south of the site was less than before SEE**

Questions?

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REDOX TECH

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