Steam-Enhanced Biodegradation of TCE in Mixed LNAPL Under Active Building Naval Air Station North Island

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A7 Session

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Project Team

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Presentation Overview

1. Introduction/Background
2. Vapor Intrusion Time Critical Removal Action Scope
3. SVE Results
4. Effects of Steam Injection
5. Summary of Results/Lessons Learned

Project Objective

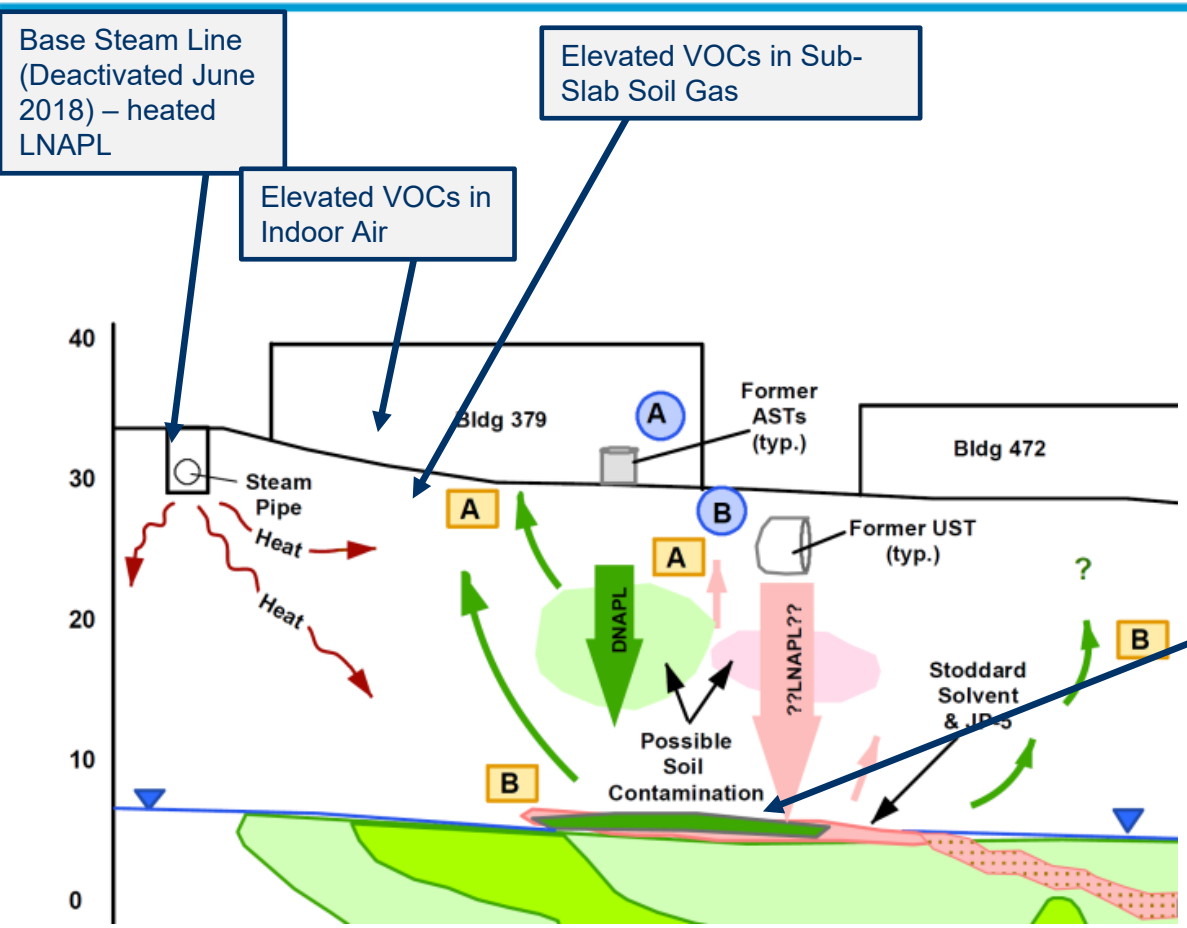
- ***Concerns***:
  - –Highly used building (379), critical to mission operations, occupants to elevated cVOC levels in indoor air
  - –cVOCs are dissolved in petroleum hydrocarbon LNAPL

- ***Challenges:***
  - –Reducing cVOCs within LNAPL while protecting building occupants, using a combination of SVE and steam injection
  - –Demonstrate reduction of source, based on cVOC analyses of LNAPL and other lines of evidence
  - –Demonstrate anaerobic biodegradation of cVOCs in LNAPL

1.1 Site Location

- B379 has a LNAPL plume (petroleum hydrocarbons) with dissolved cVOCs (TCE and 1,1,1-TCA)
- Vapor Investigations in 2014 indicated elevated levels of cVOCs in indoor air
- A Time Critical Removal Action (TCRA) was initiated for Vapor Intrusion (VI) in 2015

1.2 Conceptual Site Model (Building 379)



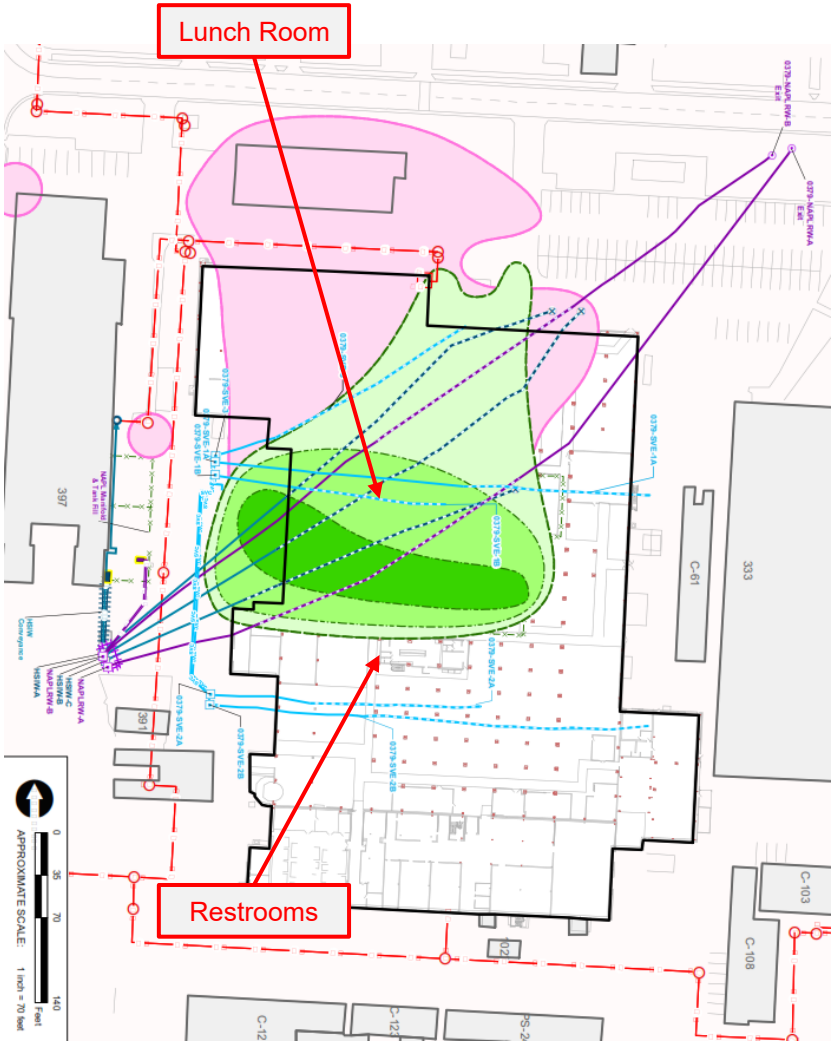
LNAPL at 23' bgs includes:
98% TPH : JP-5, Stoddard Solvent
2%: cVOCs - TCE, 1,1,1-TCA

Time Critical Removal Action initiated 2015 to address VOCs in Indoor Air

1.3 Background

- In 2014, ~ LF of cracks/joints in the floor were sealed
- SVE started in 2016 with 2 horizontal SVE wells (10 ft bgs), with initial extraction rates > 100 lbs/day (sealing enhanced the ROI)
- In 2017 it was observed that the LNAPL (23 ft bgs) had elevated temperatures (up to 140 ºF), due to heat radiating from the Base steam line (6 ft bgs)
- Heating of the soil and NAPL occurred over decades, exacerbating VI
- High temperature (and moisture content) of extracted vapor was impacting the performance of the treatment system (3C system from GEO)
- Initial thought was to mitigate the effects of the steam line (such as vent wells) but instead Navy elected to use the steam to increase the volatilization of cVOCs; since a robust SVE system was already in place
- Steam injection wells (horizontal) were installed in 2017 under the LNAPL, and plumbed into the Base steam; steam was injected from January to June 2018, at which time the Base steam system was discontinued
- Steam injection resumed late 2021 using a steam boiler

2.0 VI TCRA Scope



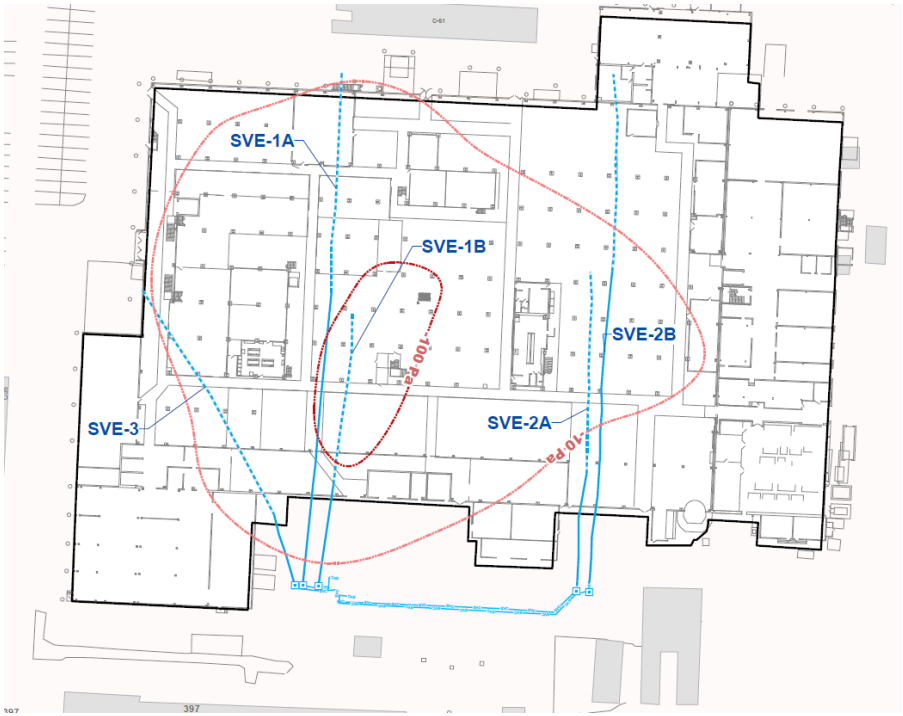
- Offered relocation to sensitive receptors, modified operation of the ventilation system
- Sealed over 15,000 LF of cracks/joints
- Sealed pathways in restrooms, floor in lunch-room received seal coat
- Deployed Air Purification Units in selected rooms
- Installed 2 dual-screened horizontal SVE well under Building 379
- Extraction started on May 18, 2016
- System enhancements constructed in 2017:
  - 3 new horizontal SVE wells
  - 3 Steam injection wells
  - 2 LNAPL Recovery wells

2.1 VI TCRA Scope

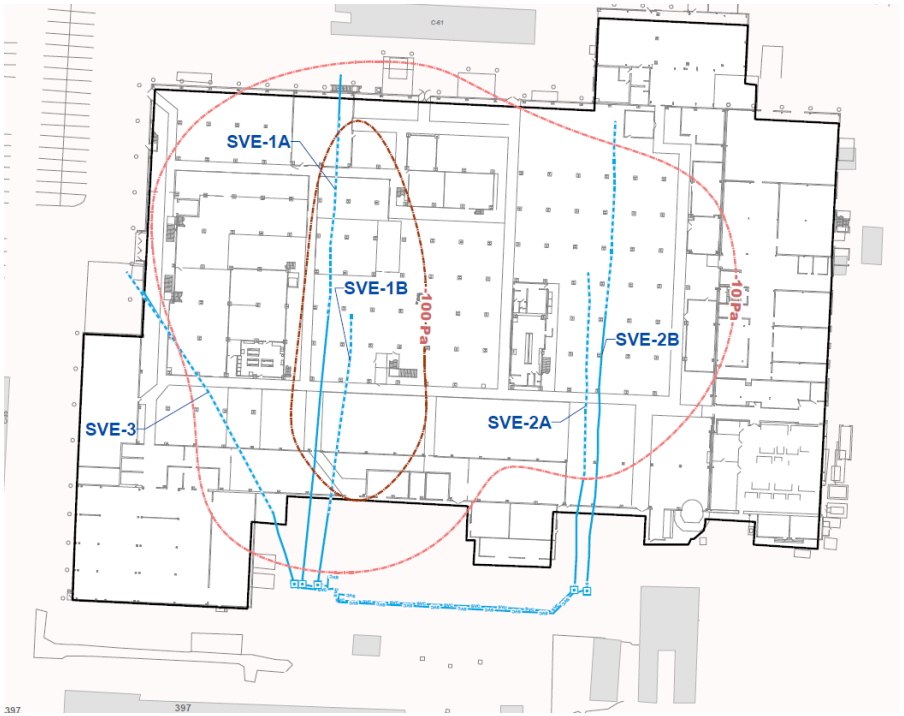
- **Vapors recovered and treated using C3 (condensation/cryogenic/compression) system from GEO**
- **Too rich to treat with GAC/ThOX/CatOX**
- **Extracted vapor is routed through vapor liquid separator**
- **Condenser condenses vapors into liquids:**
  - Condensate filtration
  - Coil coalescing filtration
  - Two heat exchangers
  - Two 1,000-lb activated carbon vessels

3.1 SVE Results: Sub-Slab Vacuum Responses

February 2019 – SVE-1A,B, SVE-2A,B, & SVE-3



August 2019 – SVE-1A,B, SVE-2A,B, & SVE-3

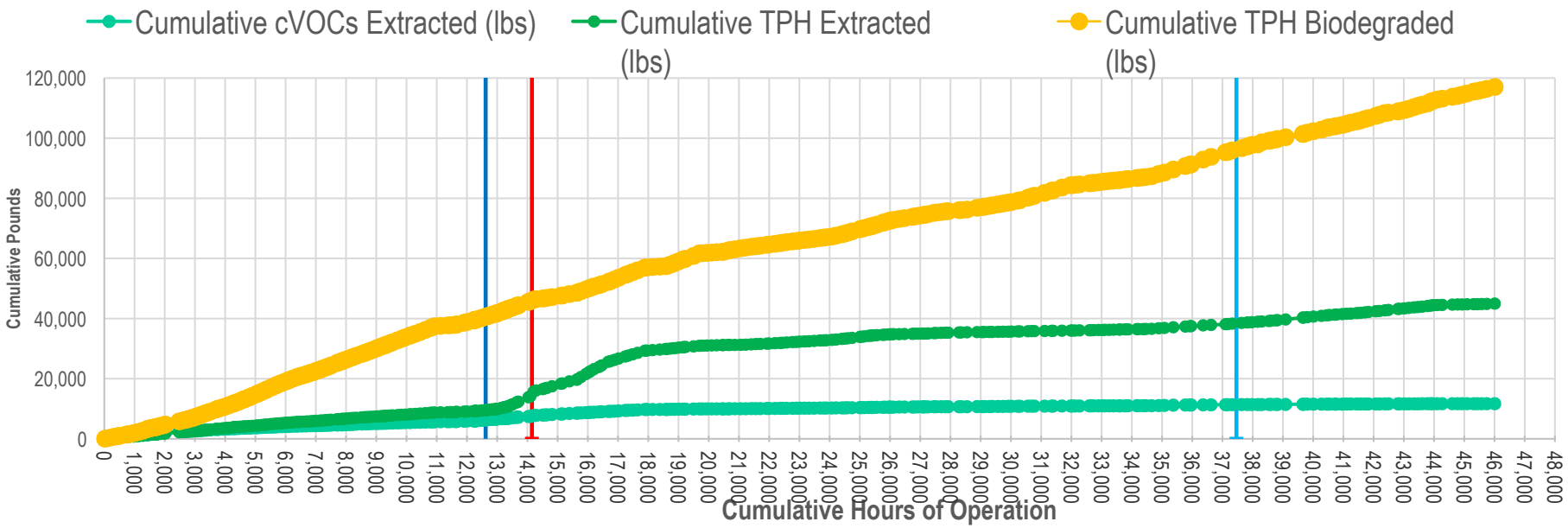


Results in Pascals (Pa)

Most of the building is under vacuum

3.2 SVE Results: Extraction Metrics

Figure 1 - Cumulative Mass Removal Trends of the SVE System



- ~ 9,000 gallons of TPH/cVOCs have been recovered and recycled by the SVE system
- ~18,000 gallons of TPH have been biodegraded aerobically Levels of cVOCs and TPH in extracted vapor have decreased
- **Levels of cVOCs were reduced to acceptable levels after SVE was initiated (and remain low to date)**

3.3 SVE Results: TCE in Indoor Air

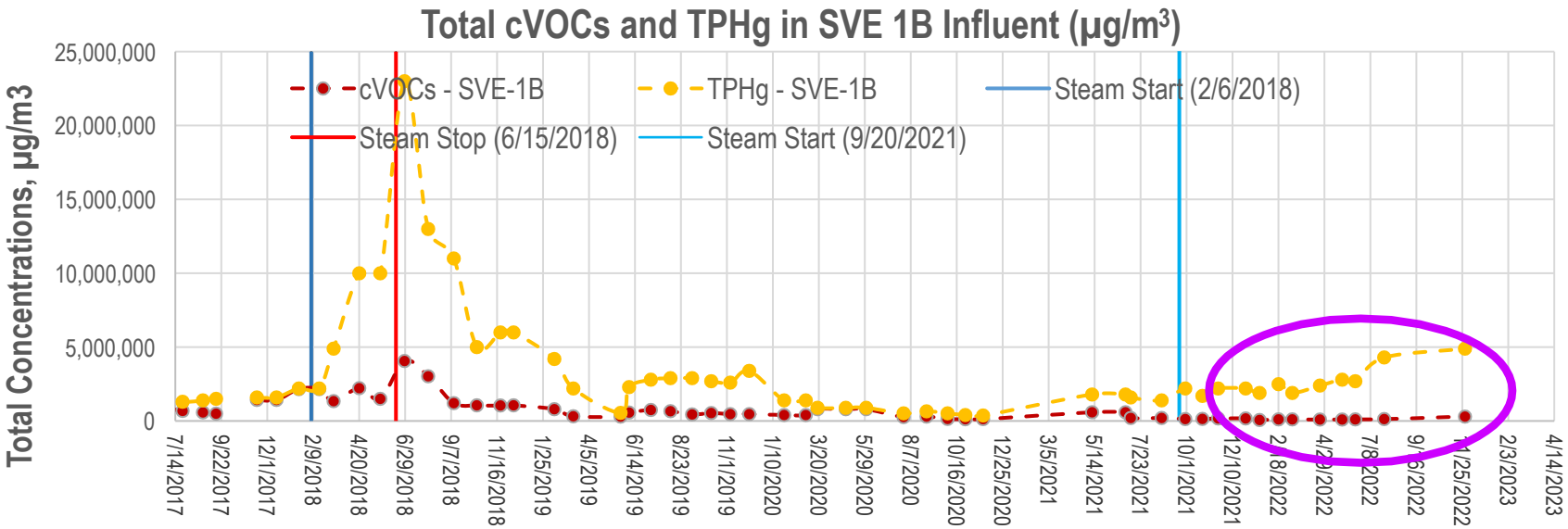
- 56 events of indoor air sampling have been completed since 2016
- **No exceedance of ARAL for TCE after SVE operations started in May 2016**
- Levels of TCE in indoor air in the Lunch Room and Women's Restroom were above screening levels prior to SVE
- These decreased significantly after the SVE was initiated – the highest TCE was 2.4 and 1.8 µg/m^3 at these locations

3.4 Transition from Mitigating VI to Source Reduction

- SVE was initially intended to mitigate VI (NAPL at 23 feet bgs, wells screened at 10 feet bgs) by keeping sub-slab under vacuum
- Injection of steam enhanced source reduction – volatilization of dissolved cVOCs was the main intent, **volatilization + anaerobic biodegradation of cVOCs was the result**
- Steam injection was initially done for < 6 months in 2018 (using the same steam that exacerbated VI to begin with)
- Steam injection resumed in late 2021 (after 2 years of planning)

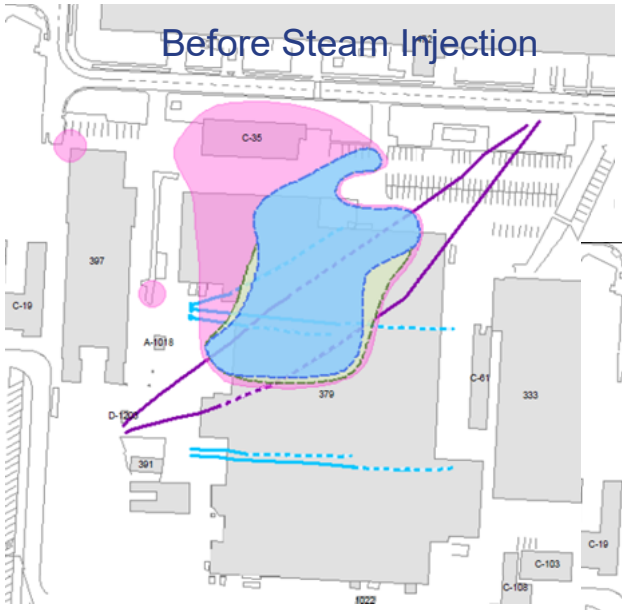
4.1 Effect of 2018 Steam Injection – Extracted Vapor

No.	Parameter	Before	After
1	VOC Reading (PID): SVE-1B Influent	1,500 ppm	4,200 ppm
2	VOC Reading (PID): SVE-3 Influent	130 ppm	520 ppm
3	Temperature of Extracted Vapor	70 ºF	85 ºF
4	Liquids per day in Effluent of C3 System	20 gallons	40 gallons



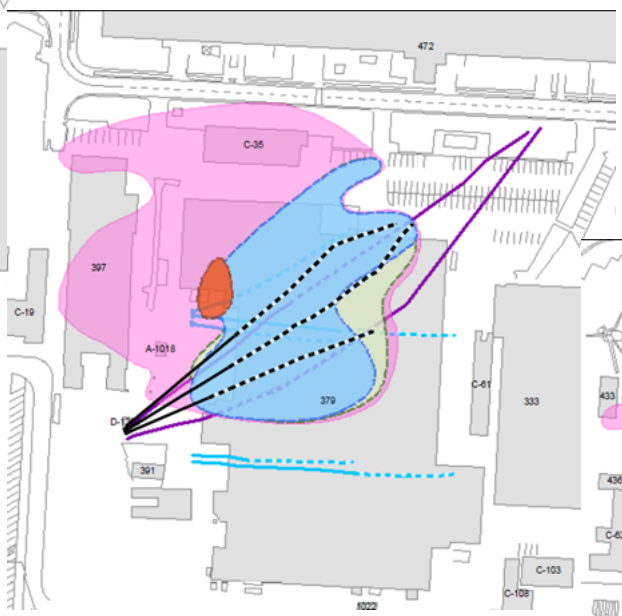
4.2 Effect of Steam Injection – Vinyl Chloride in LNAPL

Before Steam Injection



October 2017

Steam Injection from January to June 2018 (VC observed in LNAPL at 1 location)



October 2018

Pink = LNAPL Extent
Green = TCE in LNAPL
Blue = *cis*-1,2-DCE in LNAPL
Red = VC in LNAPL

1 Year after Steam Injection stopped

May 2019

NAPL Recovery Wells
SVE Wells
Steam Injection Wells

4.2 Effect of Steam Injection –Vinyl Chloride in LNAPL (contd.)

1 Year after Steam Injection stopped

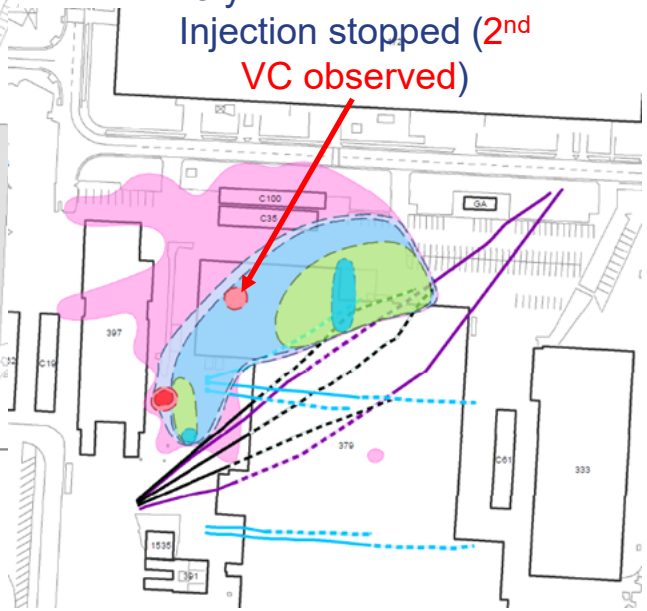
May 2019

2 Years after Steam Injection stopped

May 2020

Pink = LNAPL Extent
Green = TCE in LNAPL
Blue = *cis*-1,2-DCE in LNAPL
Red = VC in LNAPL

3 years after Steam Injection stopped (2nd VC observed)

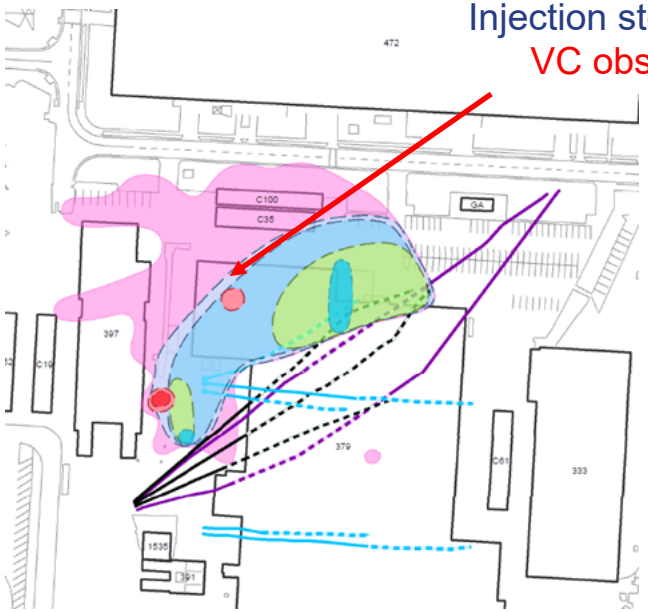


May 2021

NAPL Recovery Wells
SVE Wells
Steam Injection Wells

4.2 Effect of Steam Injection – Vinyl Chloride in LNAPL (contd.)

3 years after Steam Injection stopped (2nd VC observed)



May 2021

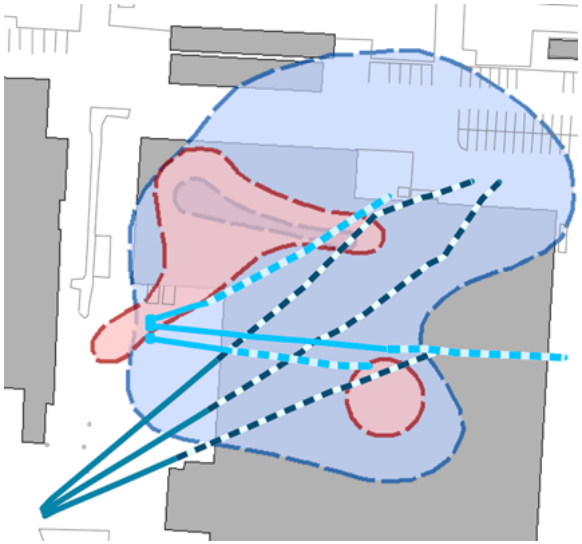
NAPL Recovery Wells
SVE Wells
Steam Injection Wells

9 months after Steam Injection resumed

May 2022

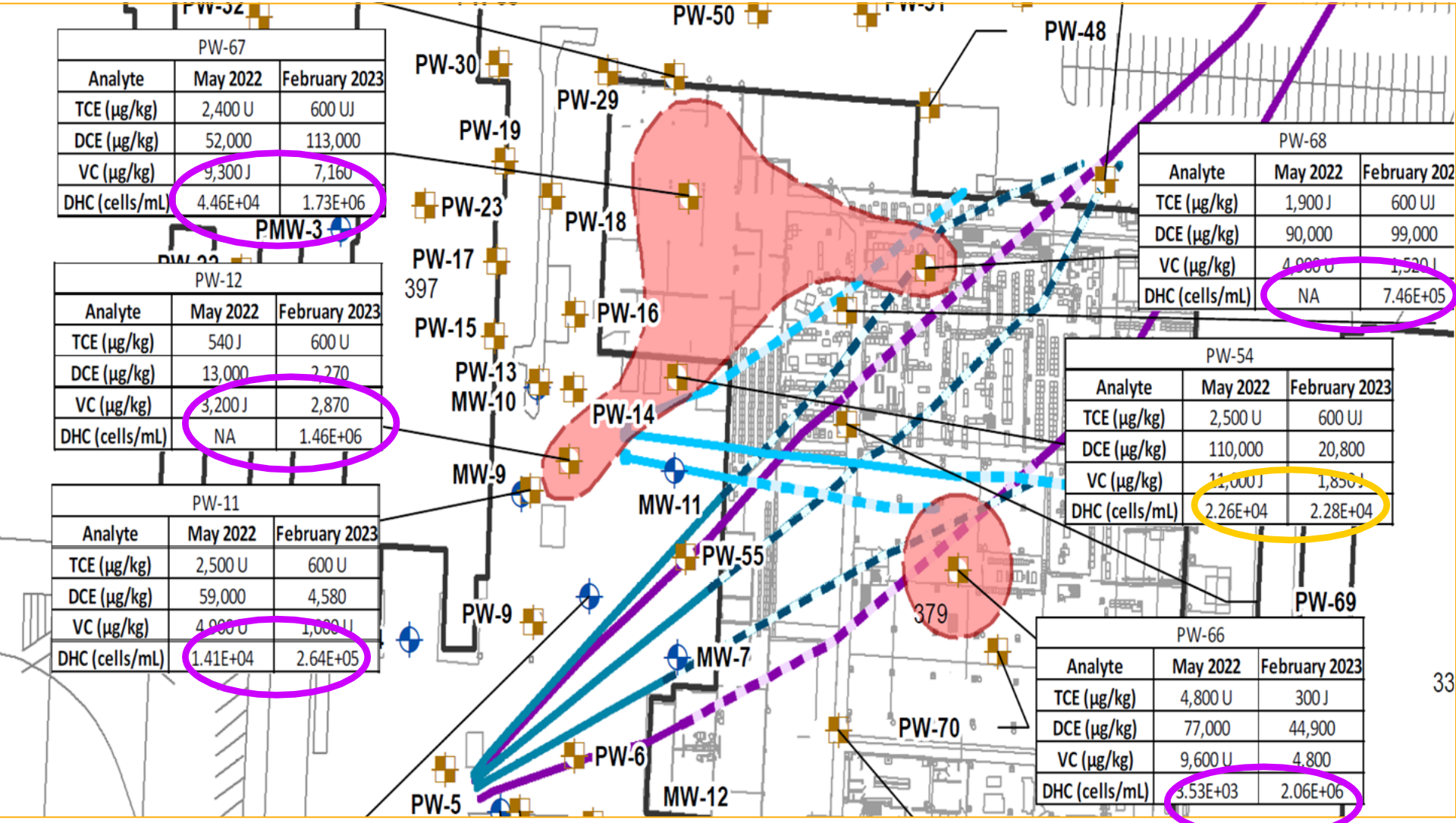
Pink = LNAPL Extent
Green = TCE in LNAPL
Blue = *cis*-1,2-DCE in LNAPL
Red = VC in LNAPL

18 months after Steam Injection resumed

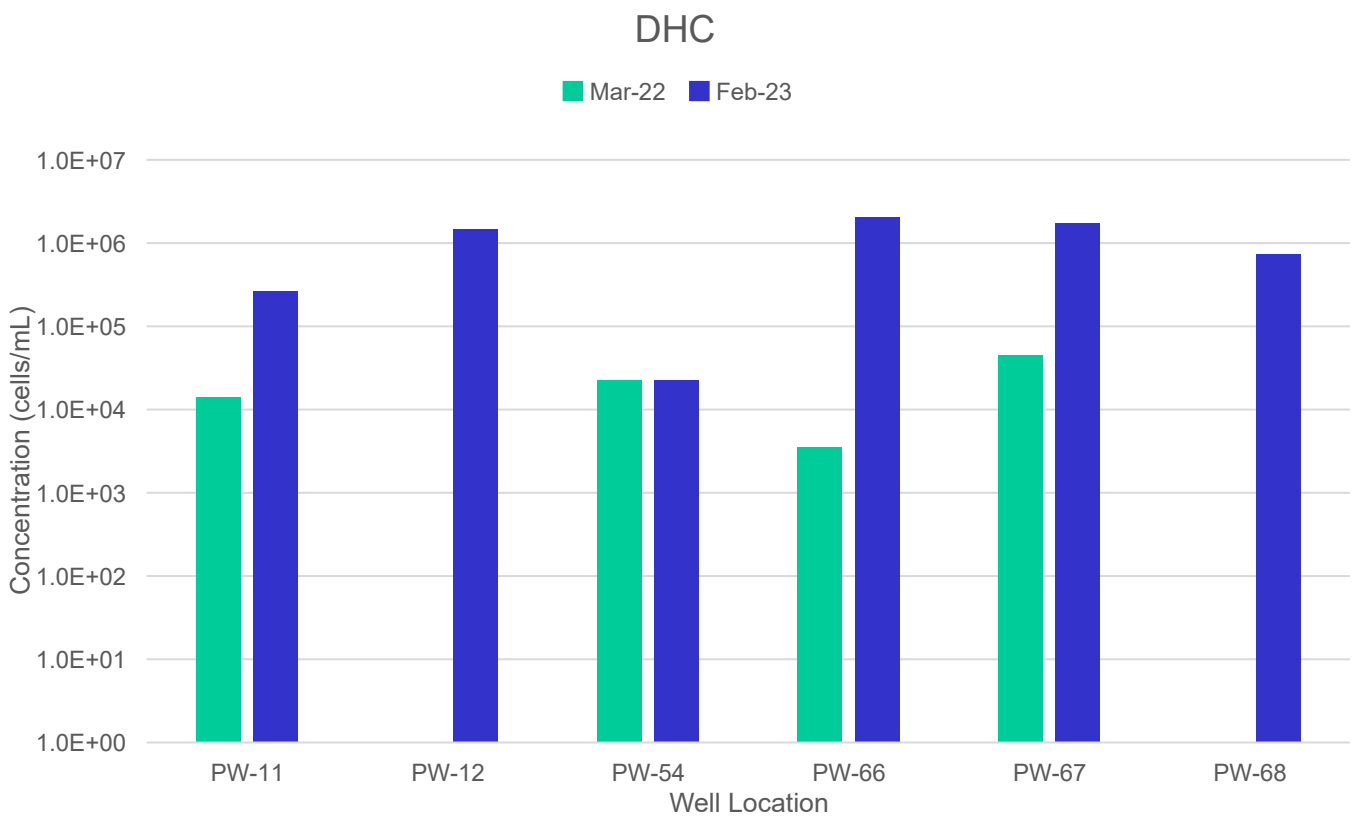


February 2023

4.3 VC in NAPL and DHC in NAPL-GW Interface (18 months after Steam Injection resumed)



4.4 DHC in NAPL-Groundwater Interface



5.0 Summary of Results/Lessons Learned

- SVE has recovered >9,000 gallons of TPH/cVOCs and an additional >18,000 gallons of TPH have been degraded (aerobically)
- First Steam injection (January to June 2018):
  - Elevated product temperatures observed even 24 months later
  - VC observed in LNAPL (and soil gas) indicating anaerobic biodegradation of TCE within TPH-LNAPL (initially 1 and then 2 locations)
- VC observed at 5 locations after resuming steam injection in late 2021
- DHC thriving in groundwater samples collected from just below LNAPL; confirming that biodegradation (anaerobic) is occurring in LNAPL
- Under the right conditions it is possible to degrade TCE dissolved in TPH-LNAPL

QUESTIONS?