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An In Situ Treatment Train for Mitigation of Vapour Intrusion from LNAPL in a Residential Area, Calgary, Alberta

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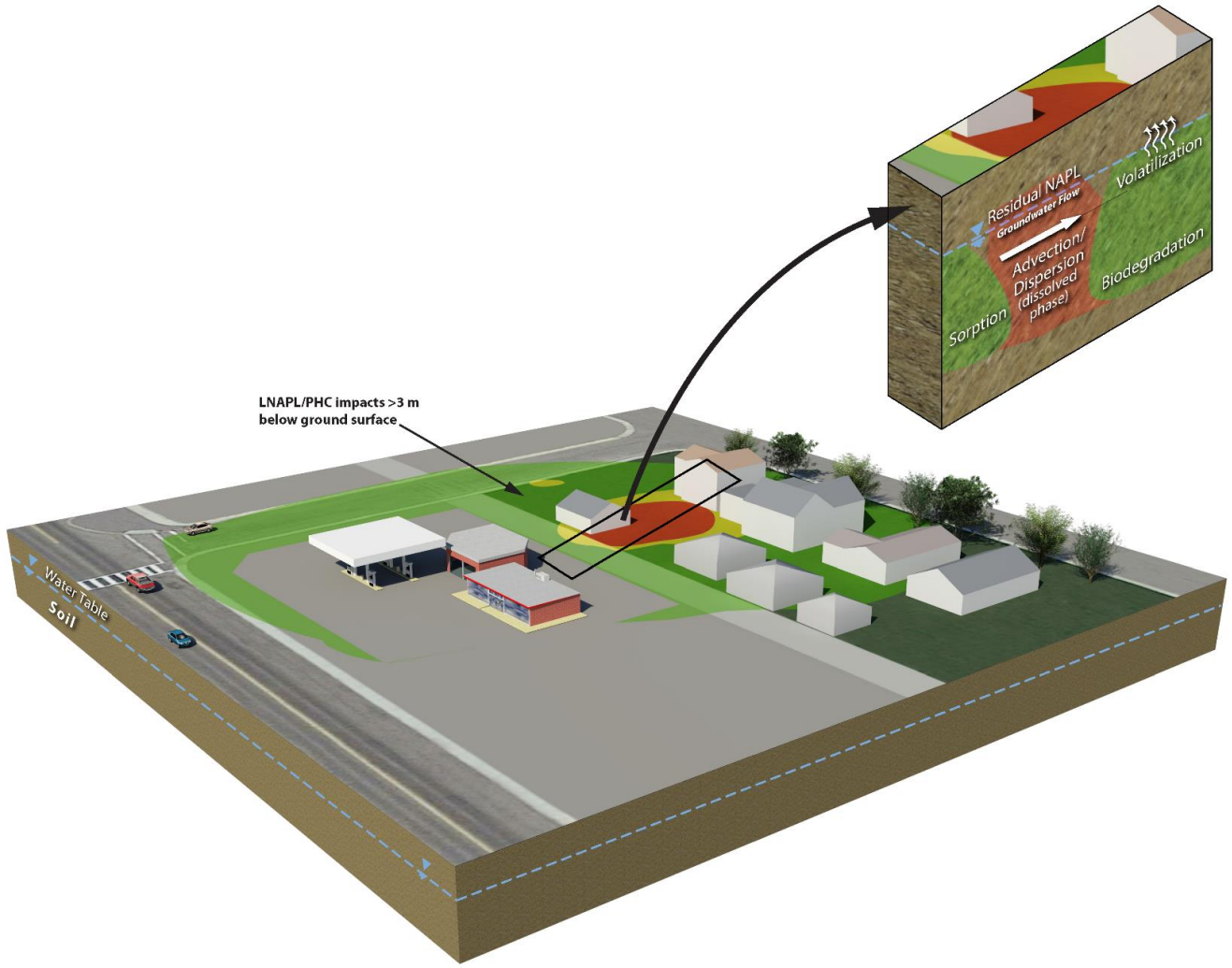
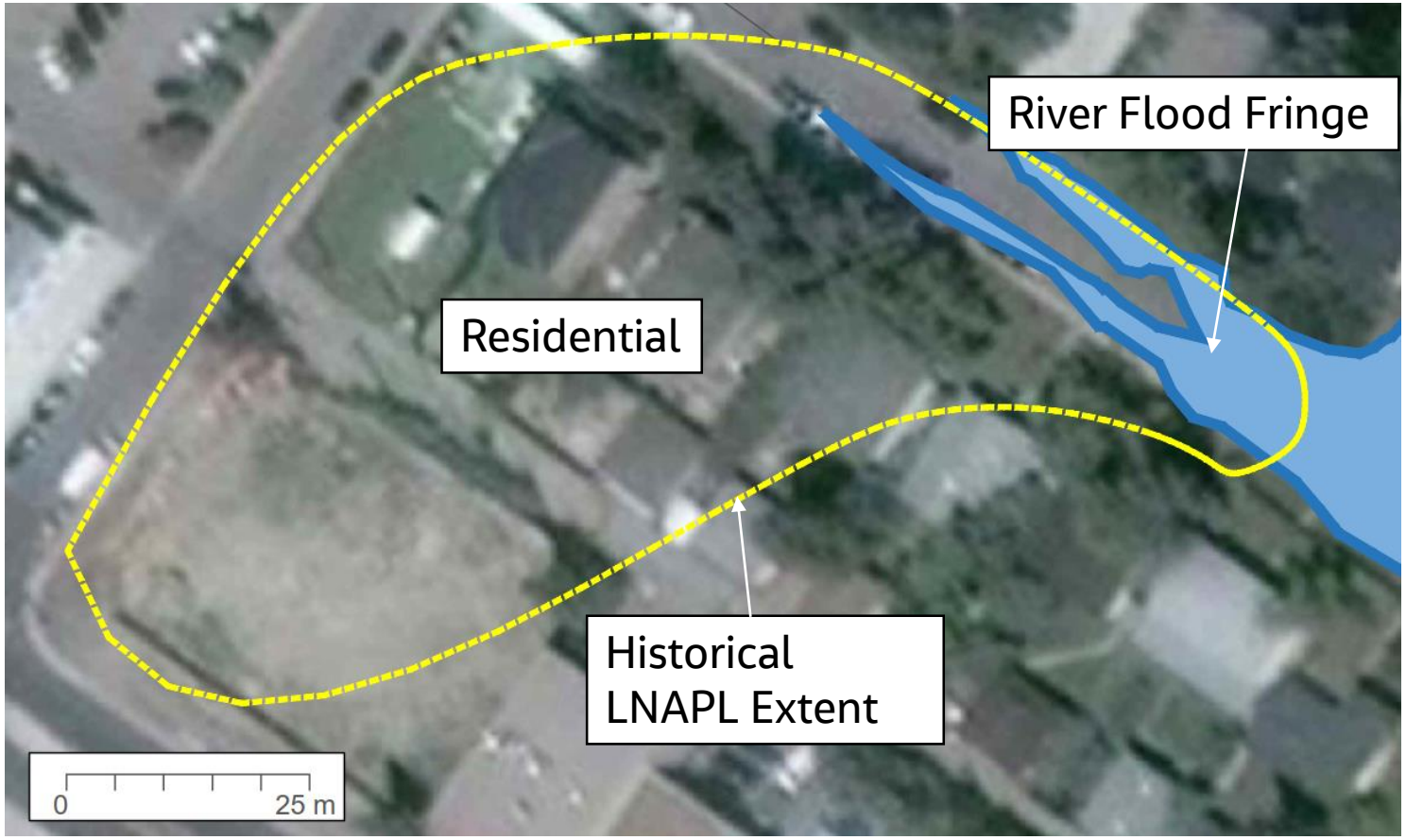
Background

- 7,000 L to 9,000 L petroleum product released from a service station over several months in 2010.
- Odours noted in the basement of a nearby, downgradient, private residence.
- Project environment: densely populated residential/commercial neighbourhood. Less than 100 m upgradient of a major river.
- Depth of impacts: >3-4 m below grade in fractured and competent siltstone and sandstone



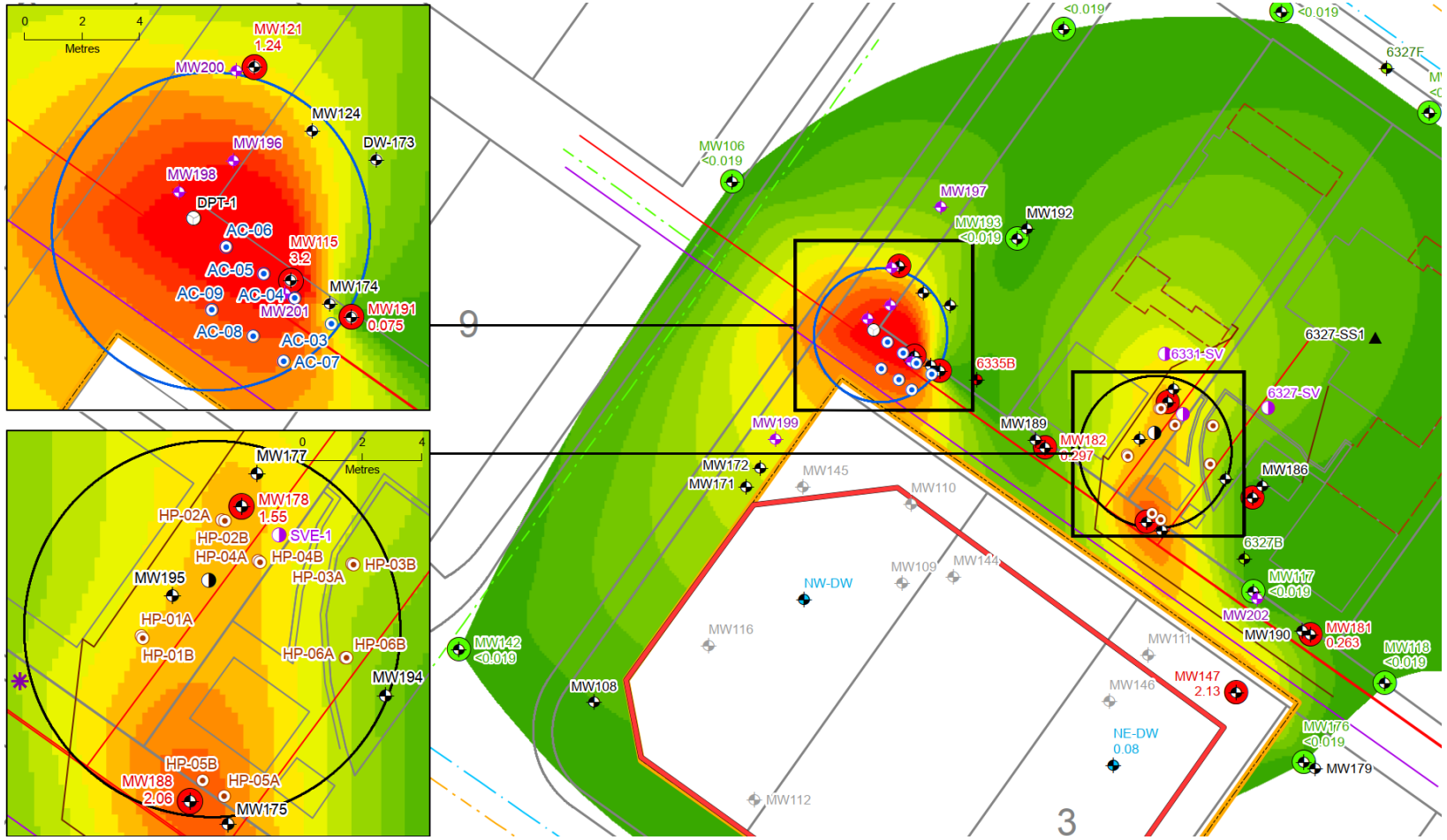
Remedial Drivers and Technology Goals

- Risk drivers: drinking water, vapour inhalation, freshwater aquatic life
- In situ remedy for source reduction
- Technology must be:
  - Effective large-scale
  - Be cost-effective
  - Capable of reducing dissolved contaminant concentration by >95% in an aggressive timeframe (<2 years)
    - Benzene – 8.8 mg/L ↓ 0.005 mg/L
    - F2 – 9.9 mg/L ↓ 0.019 mg/L
- MNA in dissolved plume outside of LNAPL footprint

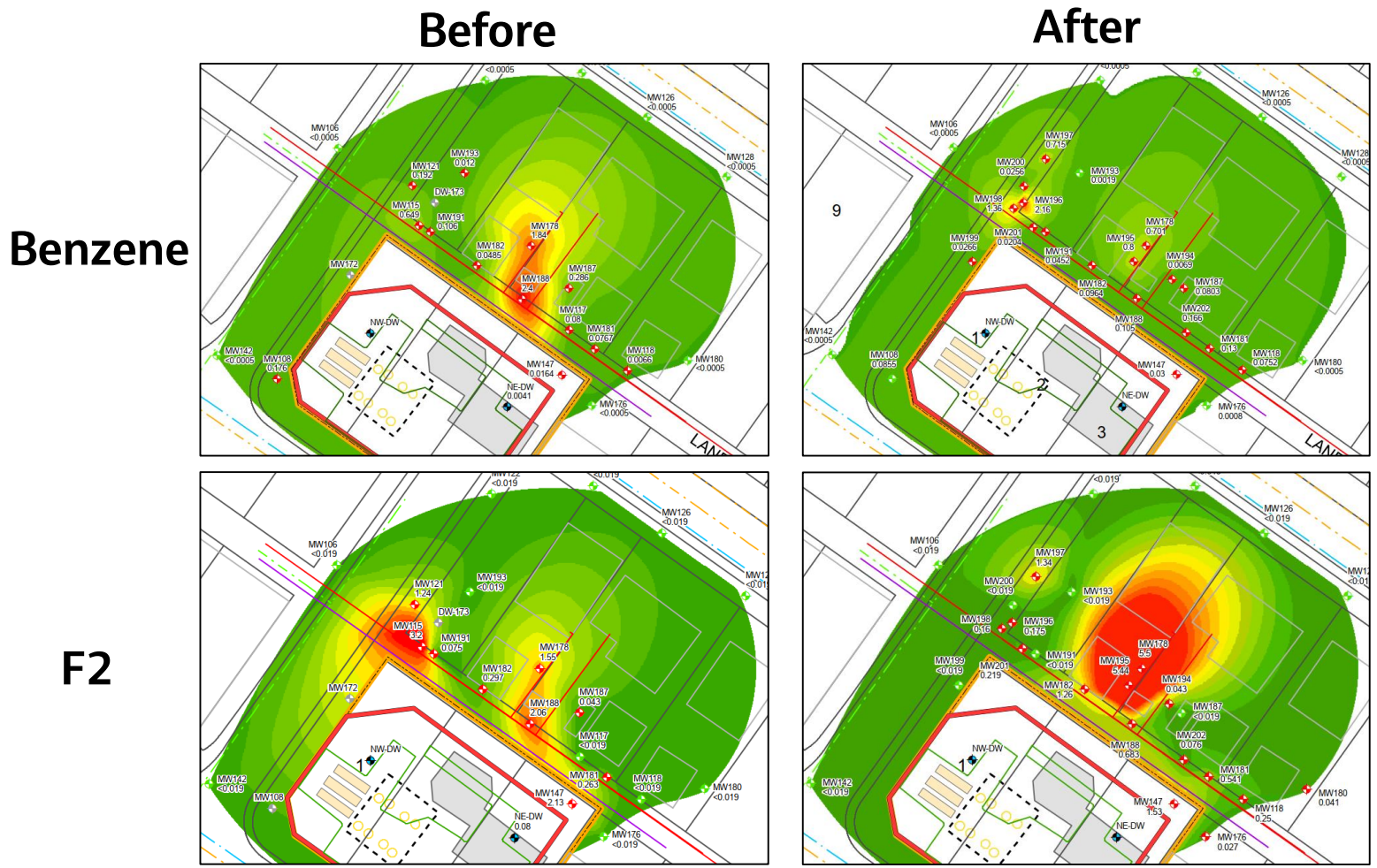


Pilot Test

- Two technologies tested:
  - In situ chemical oxidation (ISCO)
  - BOS 200®, a blend of granular activated carbon (GAC) and gypsum, as a source of slow-release sulphate, micronutrients, and microbes.



Pilot Test Results



BOS 200®:

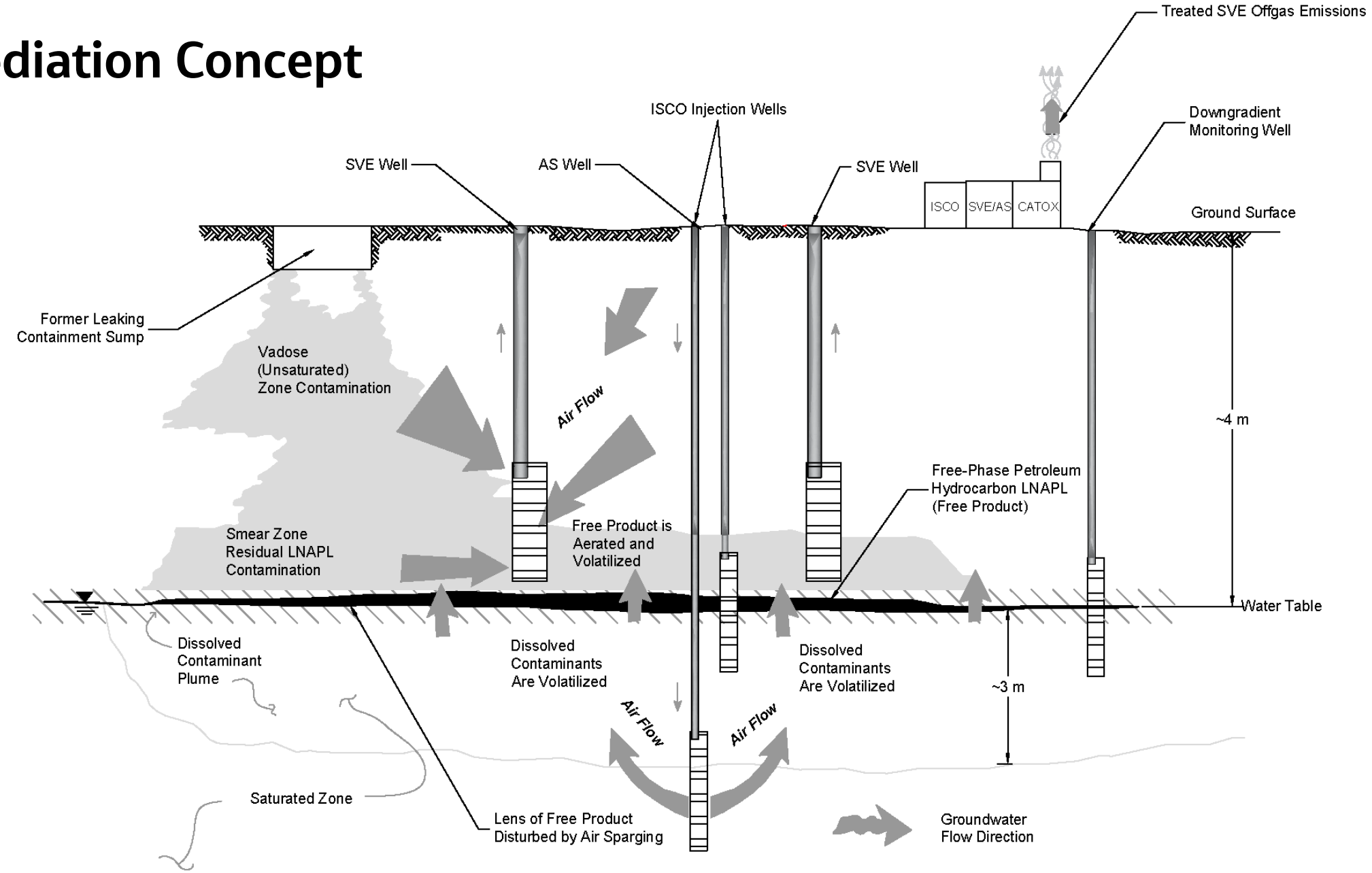
- 1,540 L 31% solution injected
- Effective at reducing contaminant concentrations in short term
- Likely difficult deployment full-scale

ISCO:

- 54,500 L of catalyzed H_2O_2 injected
- After the first day of injections, LNAPL was observed in several monitoring wells, up to 12 cm thick
- Pilot test terminated due to excessive off-gassing
- 150 L LNAPL removed

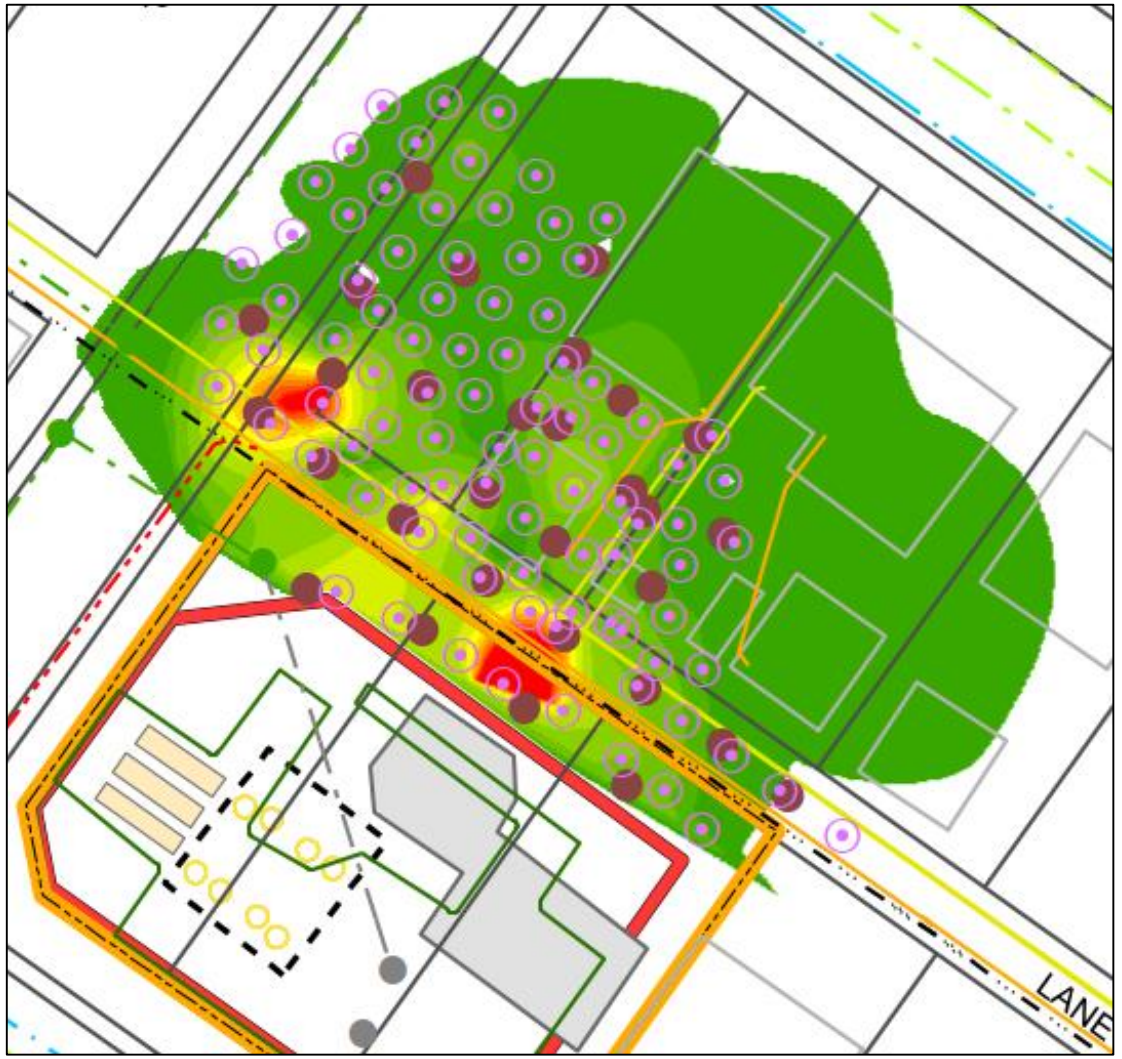
Conclusion: Proceed with ISCO, full-scale, with pre-treatment to reduce LNAPL mass to reduce vapour risk

Remediation Concept



Site Preparation

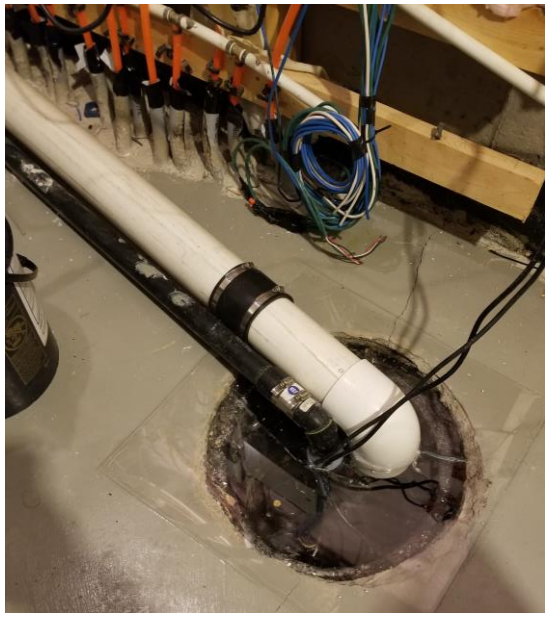
- Install 94 nested injection well pairs on 6-8 m spacing (3-4 m ROI from pilot test) to treat two groundwater zones:
  - Shallow wells screened from 3.8 – 4.7 mbgs
  - Deep well screened from 5.6 – 6.6 mbgs
- Install 30 soil vapour extraction (SVE) wells



Vapour Intrusion Mitigation

- Vapour mitigation measures:
  - Robust SVE system with wells installed at conservative ROI to mitigate vapour migration away from AS/ISCO injection points
  - Vapour treatment via catalytic oxidation interlocked with SVE
  - Sub-slab depressurization (SSD) systems in affected residences, interlocked with SVE to operate at 10% LEL influent vapour concentration or in the event of power failure
  - Continuous in-house vapour monitoring
  - Call-out system for high vapour alarm/SSD activation or increase in basement vapour concentrations

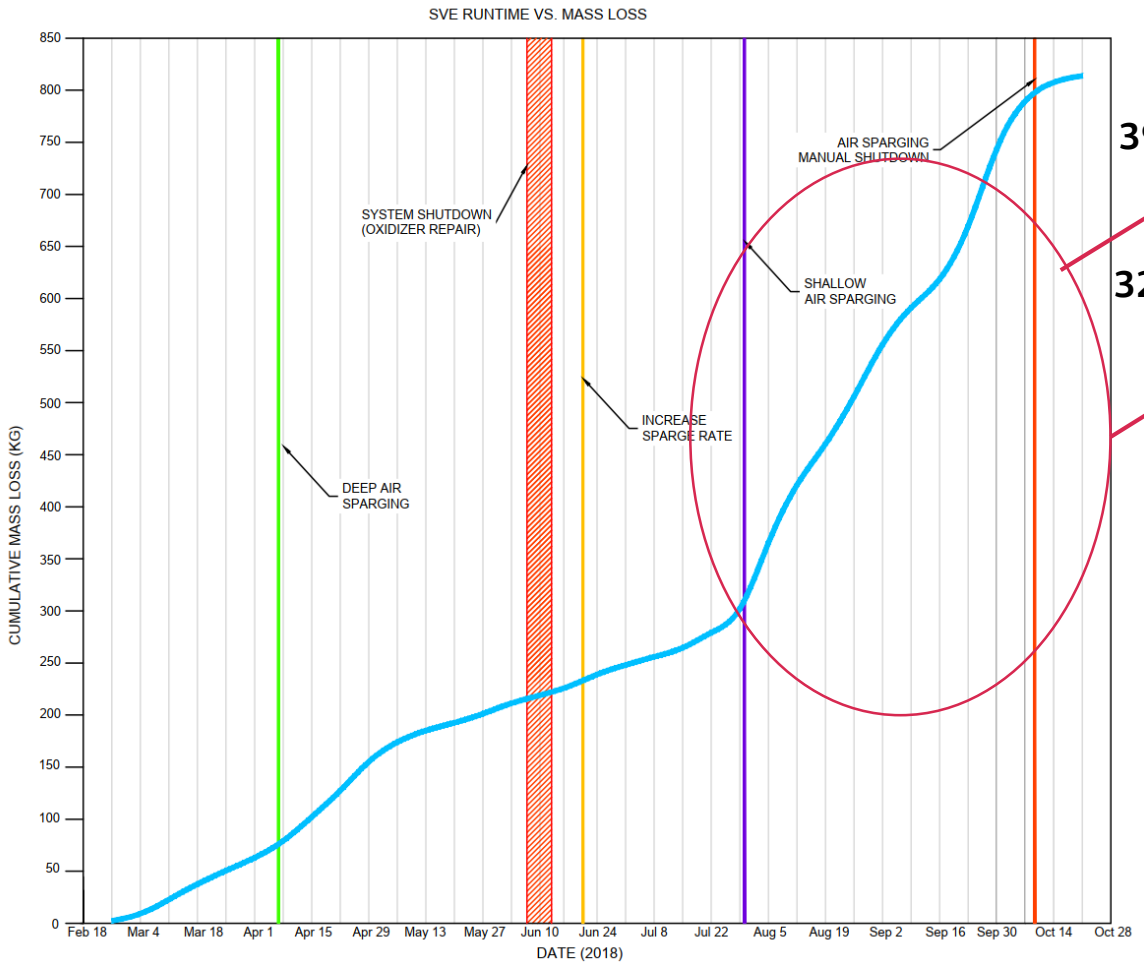
https://netronix.io/platform/environet

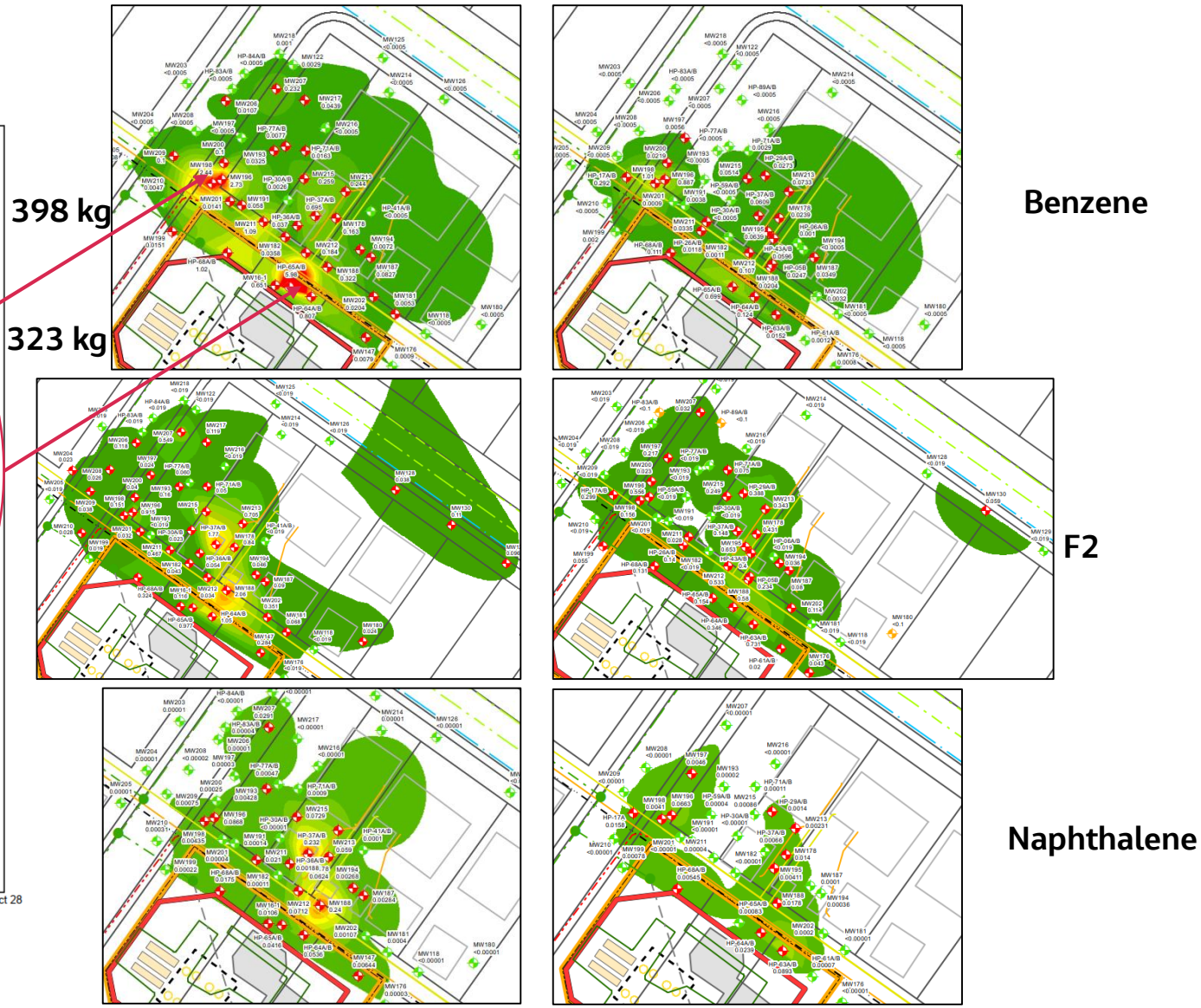


Air Sparging

- 16-line manifold, all lines operating simultaneously with SVE to capture generated vapours
- Injection pressure and flow monitored on AS daily
- Vacuum, flow, temperature, and off-gas vapour concentration measured in SVE daily to allow for quantification of hydrocarbon mass removal
- Flow rate of SVE:AS monitored and adjusted daily to maintain a minimum 2:1 ratio for duration of operation

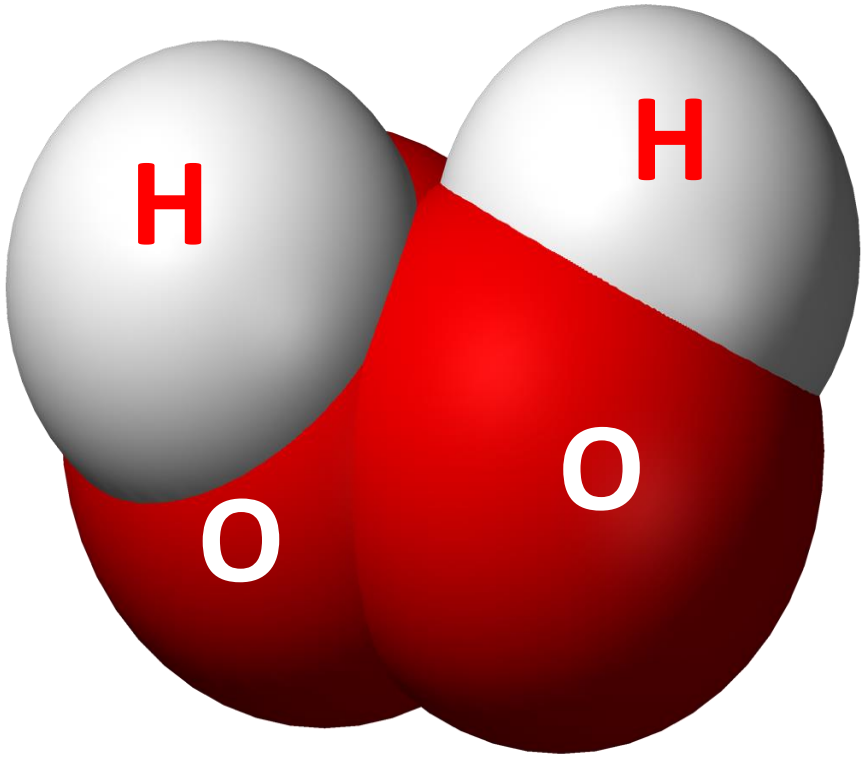
Estimated Mass Loss





ISCO

- The first stage of design involved estimation of the remaining soil and groundwater mass and completing spatial analysis to apportion H_2O_2 quantities to the injection well pairs.
- Treatment areas were designated in groups of 16 injection points, with 4 injected into at a time; 8 total per day.
- 50% H_2O_2 was delivered to the site and continuously diluted to 10% in-line, blended with ferrous sulphate and EDTA.

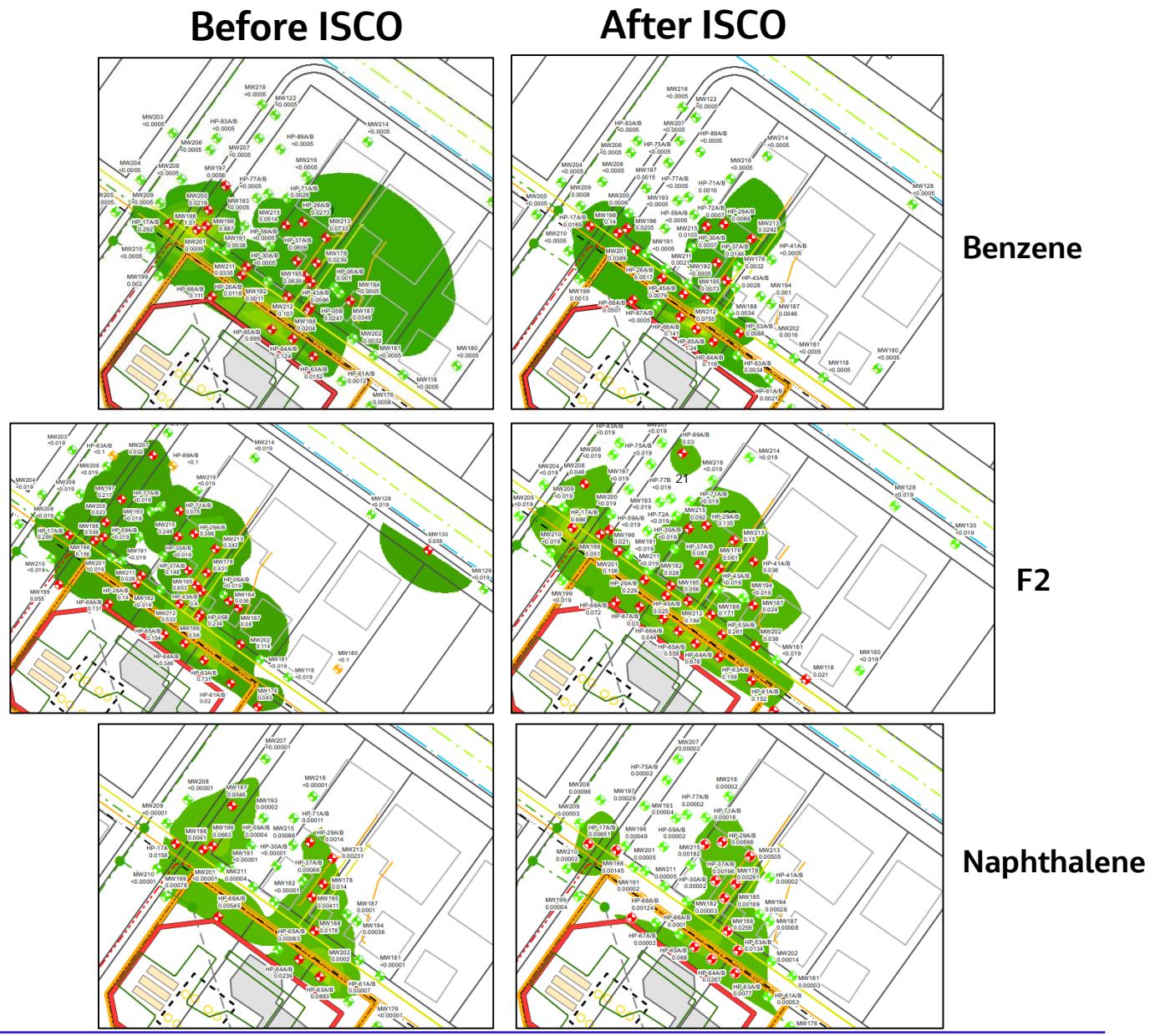


Safety Measures

- SVE wells nearest the residences were operated throughout the ISCO program at a sufficient flow rate to induce slight vacuum below the basement floor slab, but not high enough to draw vapours towards the structure.
- Groups of 4 injection points were established so as not to inject into two adjacent points at a time to minimize potential for overlapping ROIs.
- Injection pressures were maintained below 20 psi, with flow rates at or below 20 L/min.
- Simultaneous injection of catalyst and H_2O_2 allowed for better control of the timing and strength of the reaction in comparison to sequential injection.

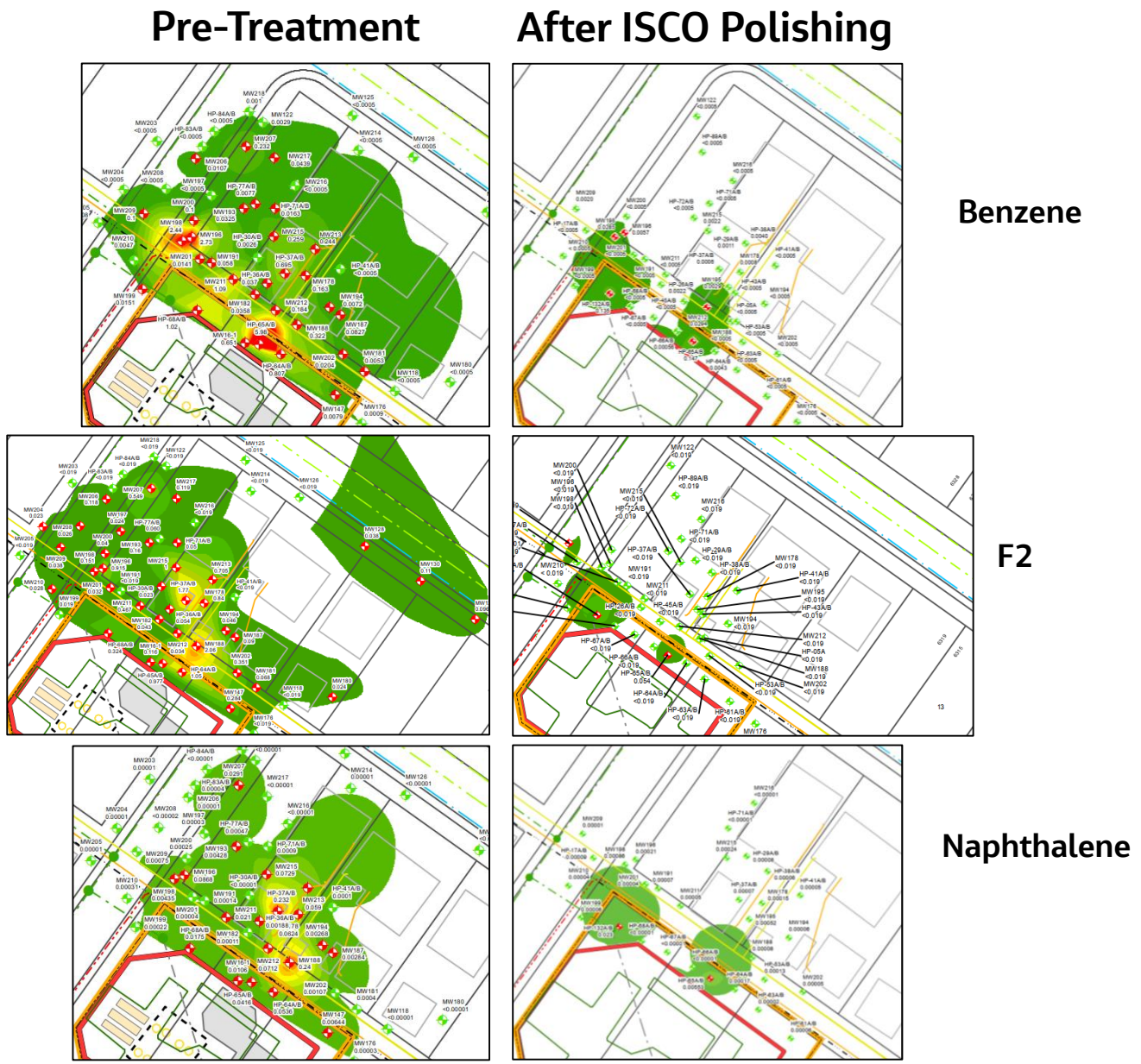
ISCO Results – Round 1

- 841,000 L catalyzed 10% H2O2 injected over 9-week period in 2019
- Estimated mass removal: 160 kg
- Key observations:
  - Groundwater mounded between 1 m and 2 m above baseline
  - Daily temperature increase in less impacted zones ranged from 1 to 5°C. In more impacted zones, the temperature increase was 10 to 19°C above baseline
  - ORP sustained at ~250 to 300 mV



ISCO Polishing

- An additional 247,000 L catalyzed 10% H2O2 injected over 4 weeks in 2020 (1,088,000 L total).
- 82 kg additional hydrocarbon mass removed from the subsurface (1,065 kg total)
- Residual dissolved mass addressed with source removal in 2021.



Lessons Learned

- Pilot tests are a key element of any in situ remedy
- LNAPL can be safely remediated in situ, even with occupied structures nearby, provided that proper precautions are taken:
  - Multi-level vapour mitigation
  - Consistent/constant site presence
  - Trust among all parties involved

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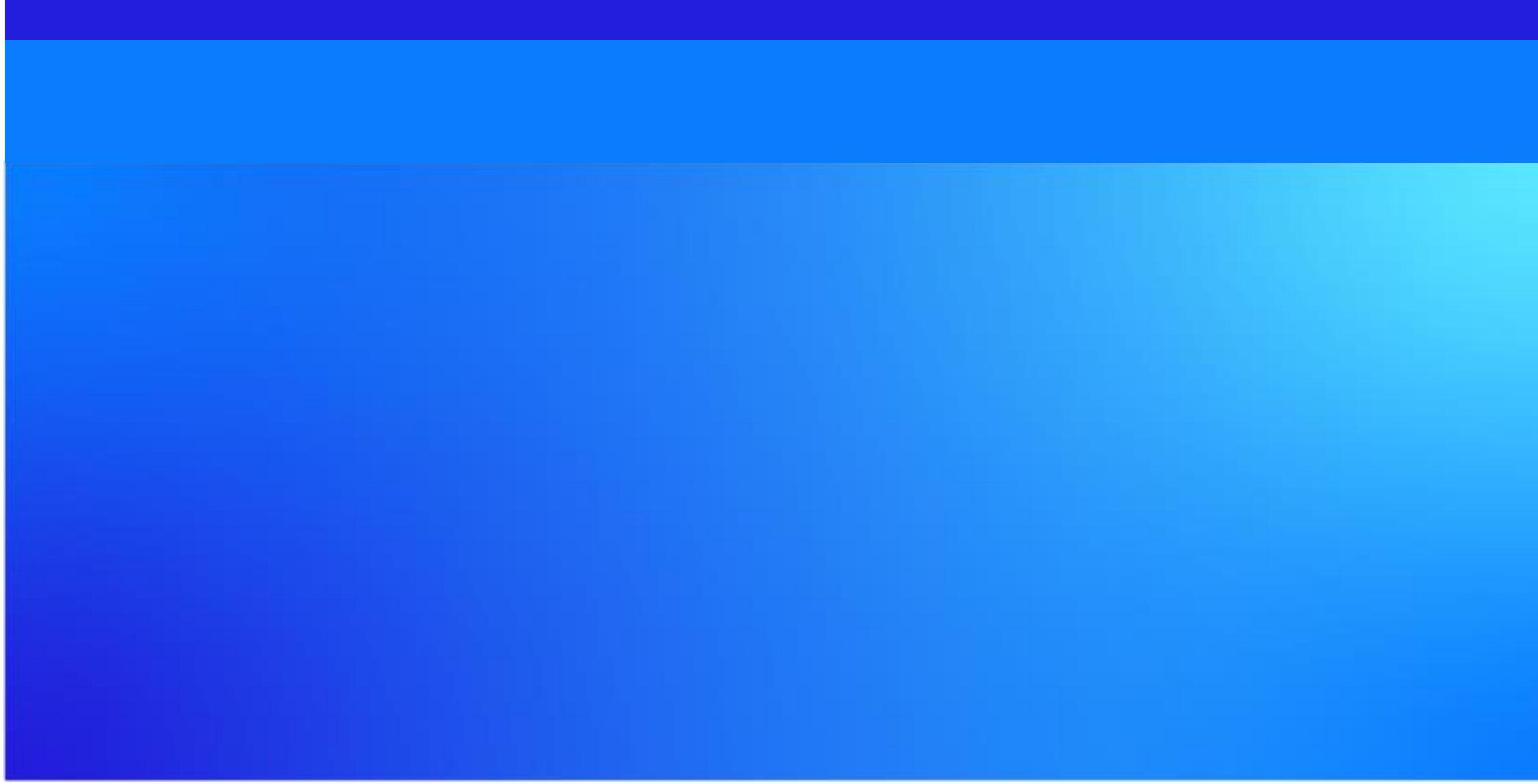

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