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Sustainable change.

Adaptive Management in Groundwater Remediation Via Source Zone Depletion at the Nation's Most Impacted Carbon Tetrachloride Site

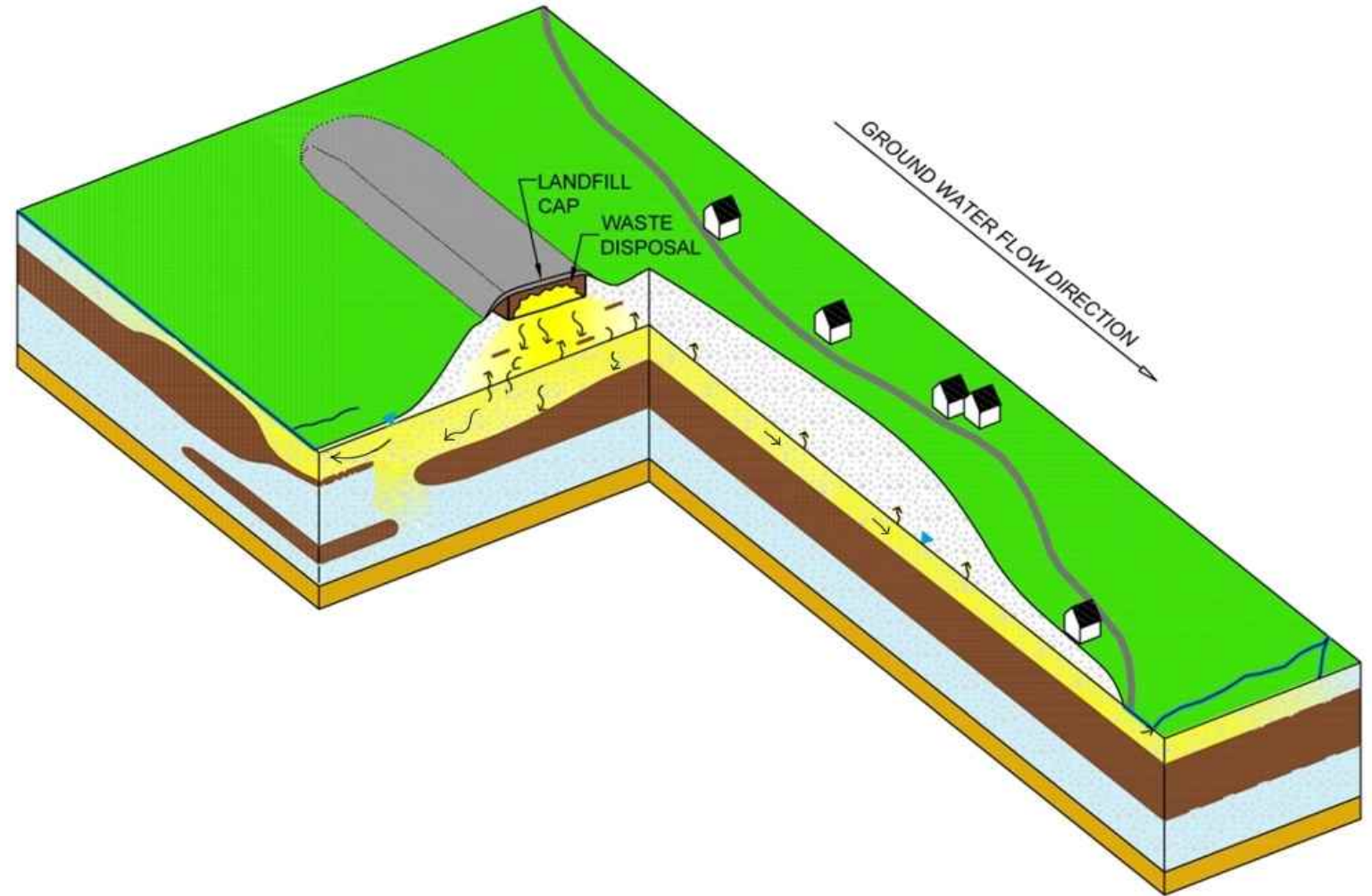
2024 Battelle Chlorinated Conference

Presented By: David Heidlauf, CPG

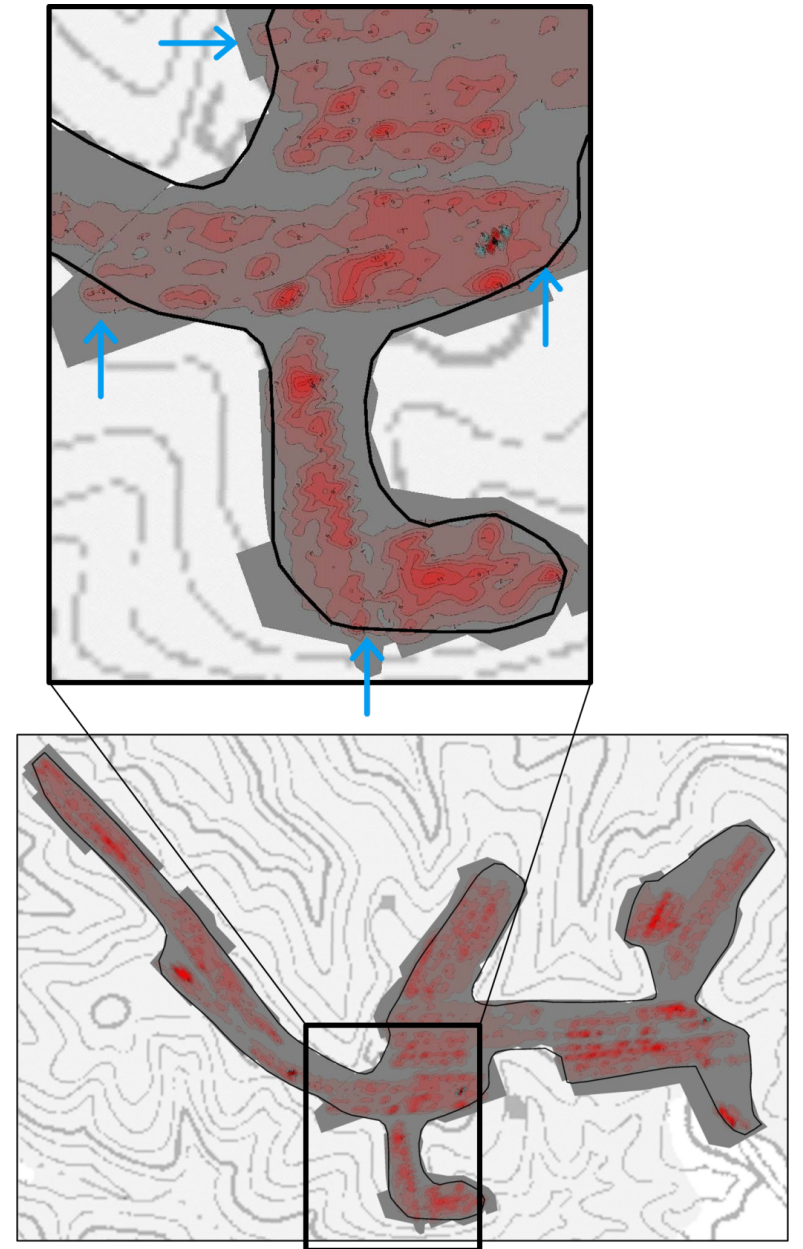
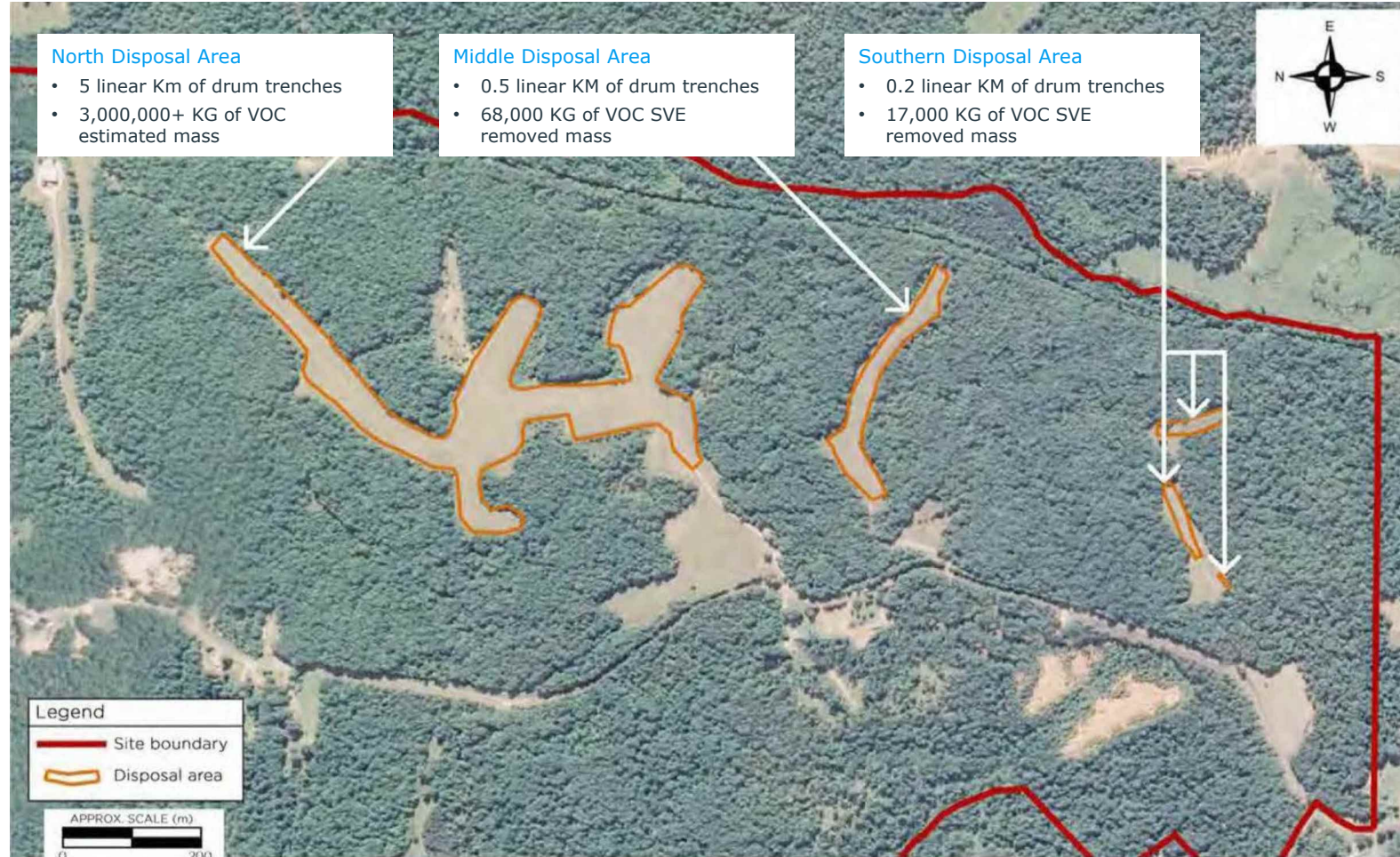


Problem Statement

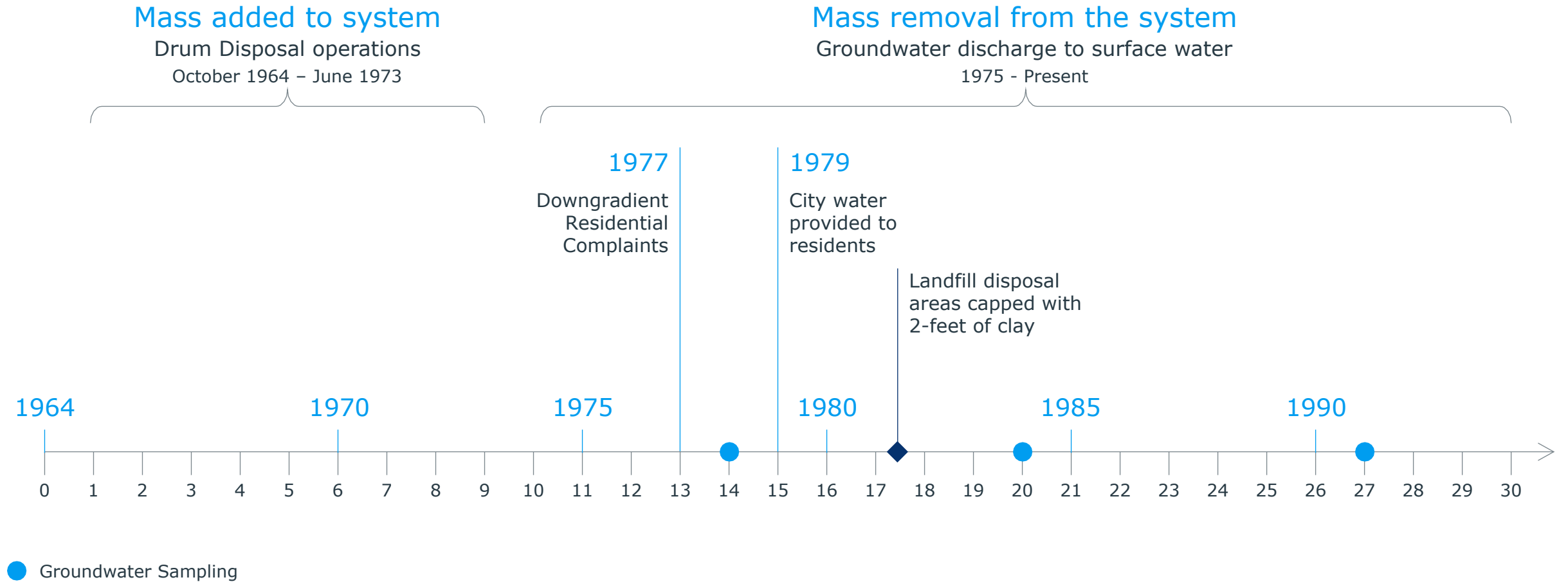
- Mega-superfund site with 200,000 drums of buried pesticide manufacturing waste with carbon tetrachloride as carrier solvent
- Mississippi embayment unconsolidated sediments with multi-hydrostratigraphic units
- Multi historically flawed CSMs lead to failed source area and groundwater remedies
- Updated CSM used for new source area remedy design and implementation
- New Groundwater Remedy To be Determined



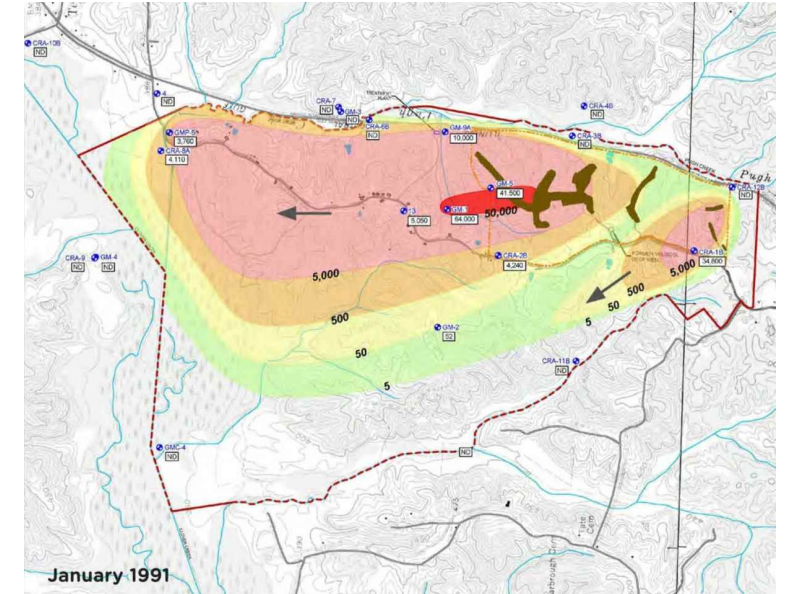
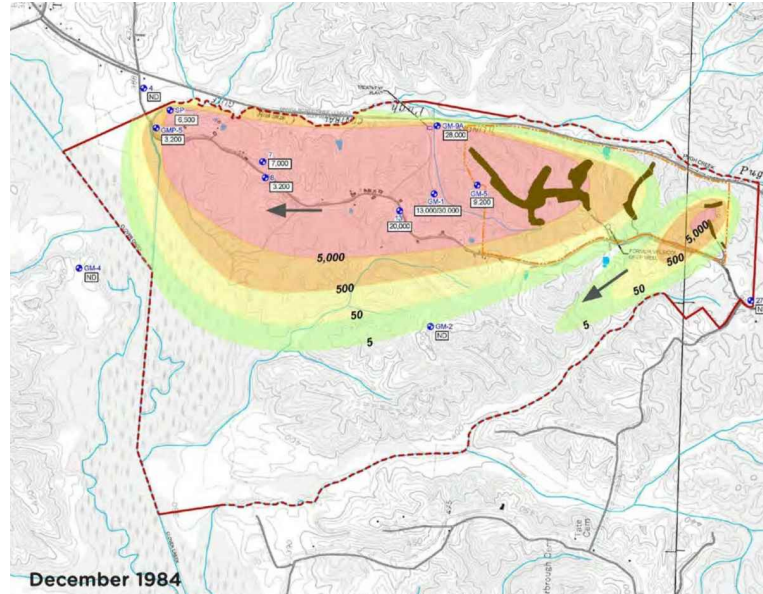
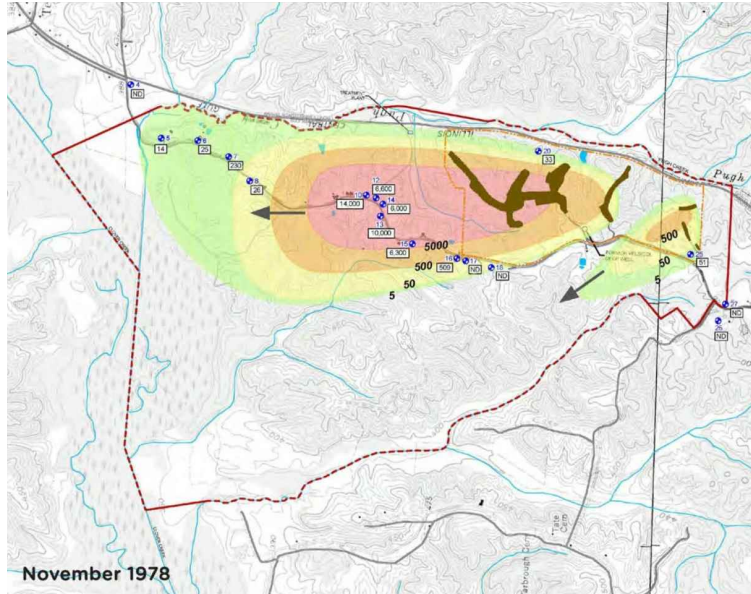
Waste Disposal Areas



First 30 Years of Site Timeline



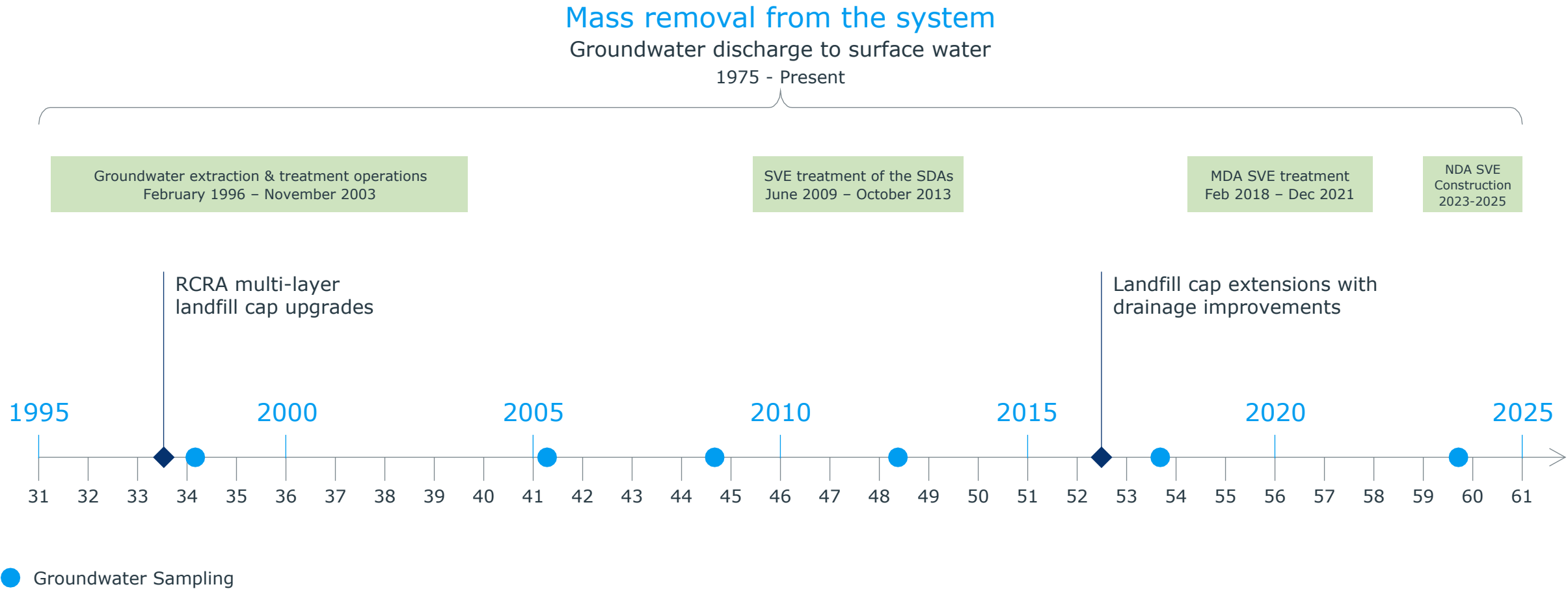
Phase 1 – Plume Development 1964–1991



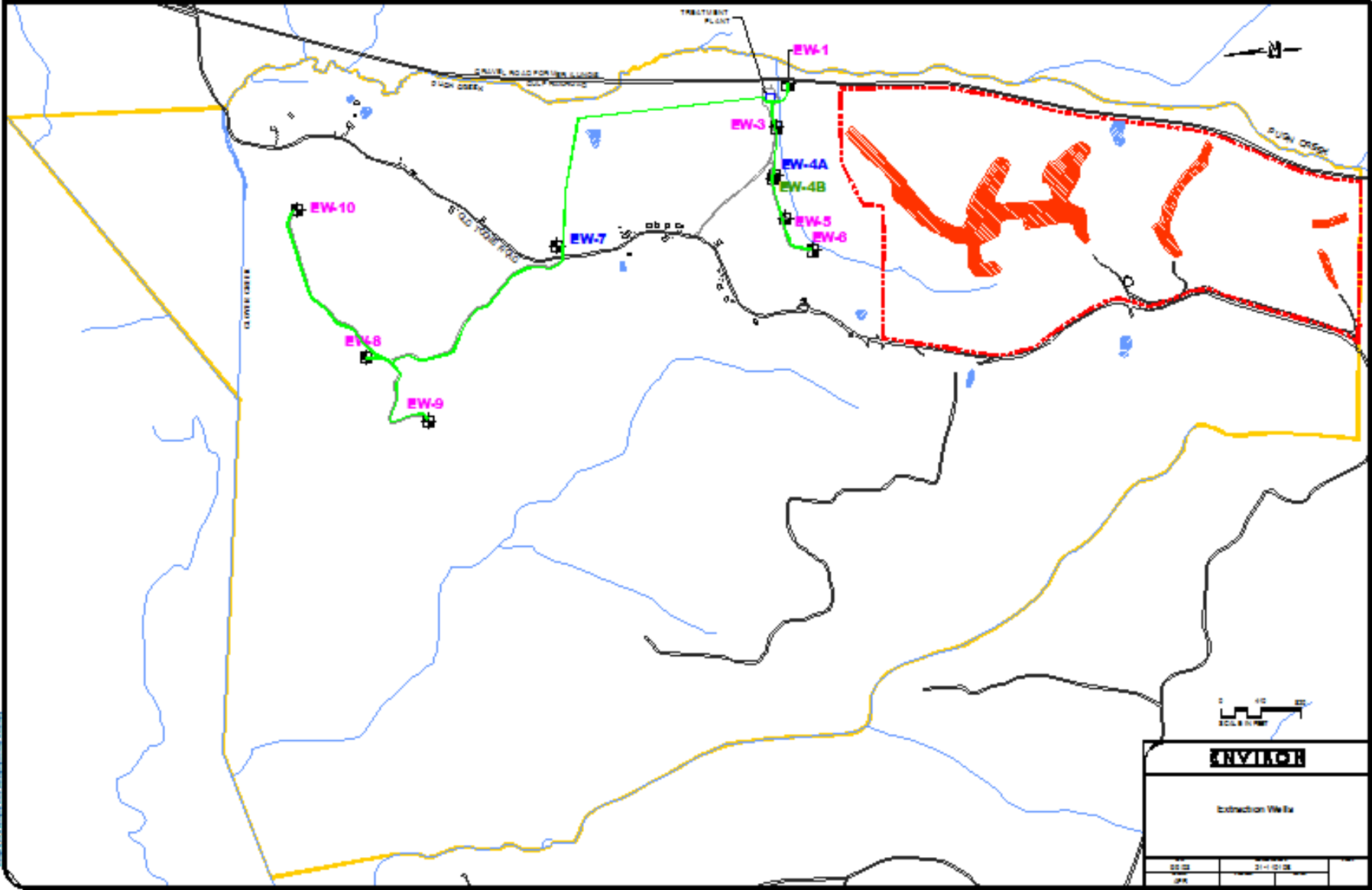
Carbon tetrachloride concentration ■ > 50,000 µg/L ■ 5,000-50,000 µg/L ■ 500-5,000 µg/L ■ 50-500 µg/L ■ 5-50 µg/L

In 1991, the maximum CT groundwater concentration of 64,000 ug/L equated to 8% of its solubility limit and was more than 4 orders of magnitude greater than its RAO of 5 ug/L

Second 30 Years of Site Timeline

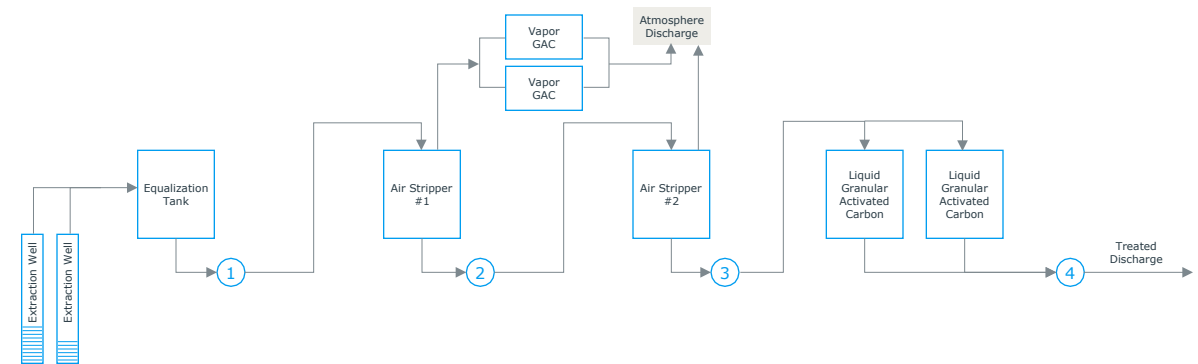


Pump & Treat 1996-2003

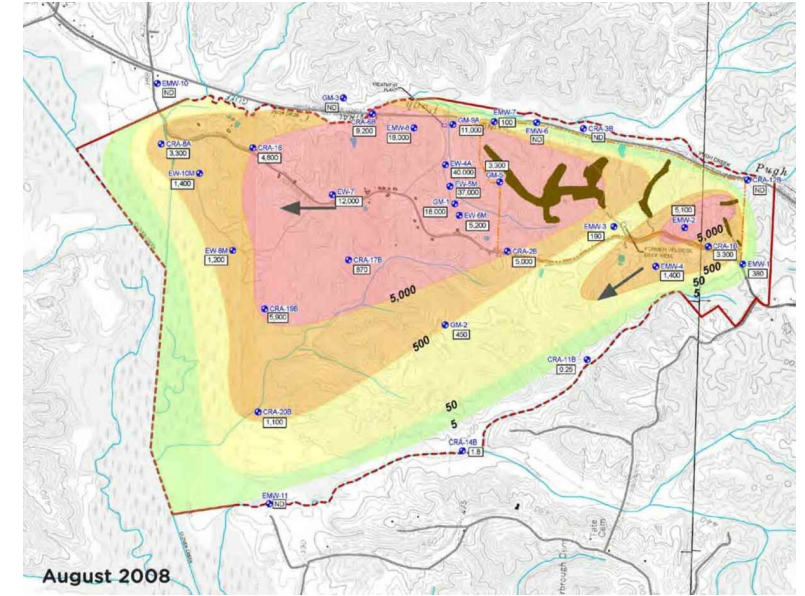
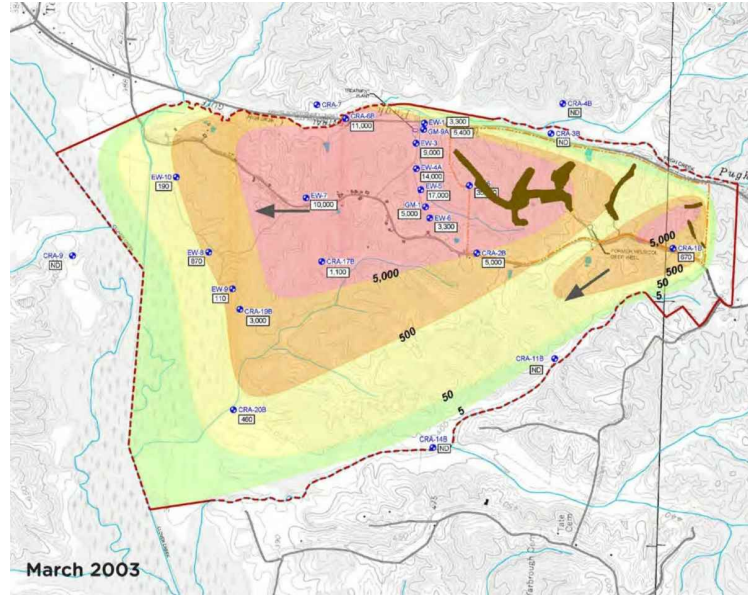
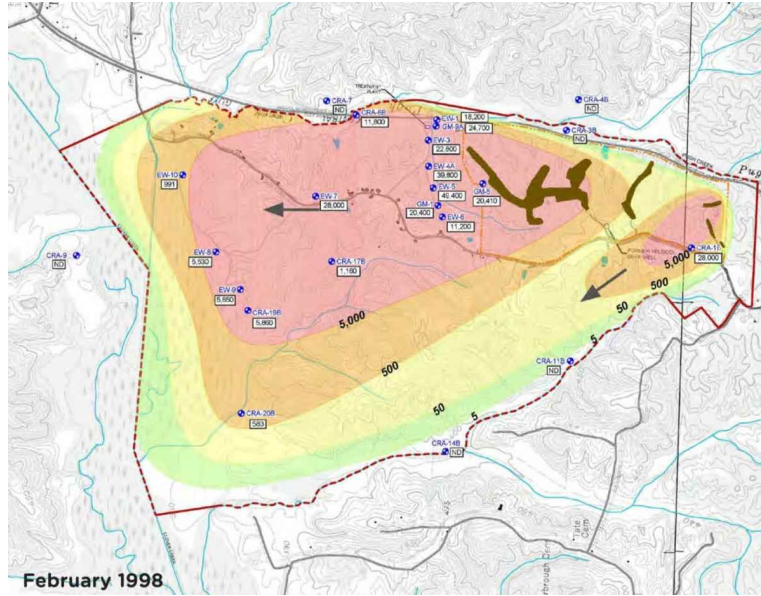


Pump & Treat 1996–2003

- 6 POC & 4 Plume Reduction extraction wells
- Air stripping & GAC with GAC vapor treatment
- Treated $\sim 3,000,000,000$ Liters
- Removed $\sim 50,000$ KGs VOCs
- VOC Removal Rate ~ 1 KG/60,000 L
- Most EWs Cross-connected Aquifers
- 50% Q & 4% of Mass from the Semi-Confined Aq.
- In 02/03 Operated at 54% (830 LPM) of target rate
- POC EWs Failed to Achieve Plume Containment
- Poor Condition of Treatment Equipment at Shutdown



Phase 2 – Plume Development – Pump & Treat 1996–2003



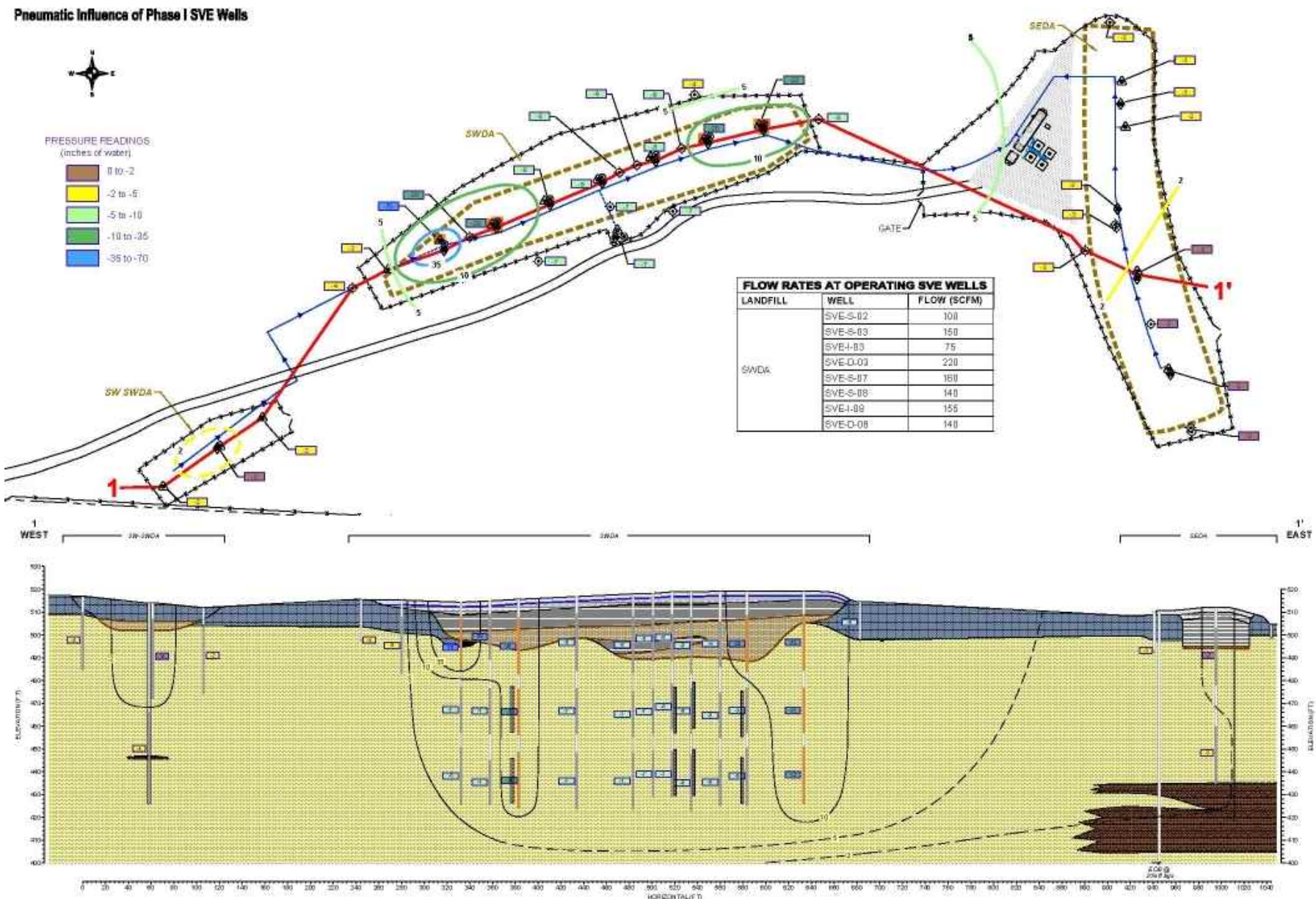
Carbon tetrachloride concentration ■ > 50,000 µg/L ■ 5,000-50,000 µg/L ■ 500-5,000 µg/L ■ 50-500 µg/L ■ 5-50 µg/L

POC VOC concentrations decreased by 67% after 7 years of P&T, but recovered to 80% of pre-P&T levels within 5 years of after cessation of P&T operations

SDA SVE Pilot Test Remediation 2009–2013



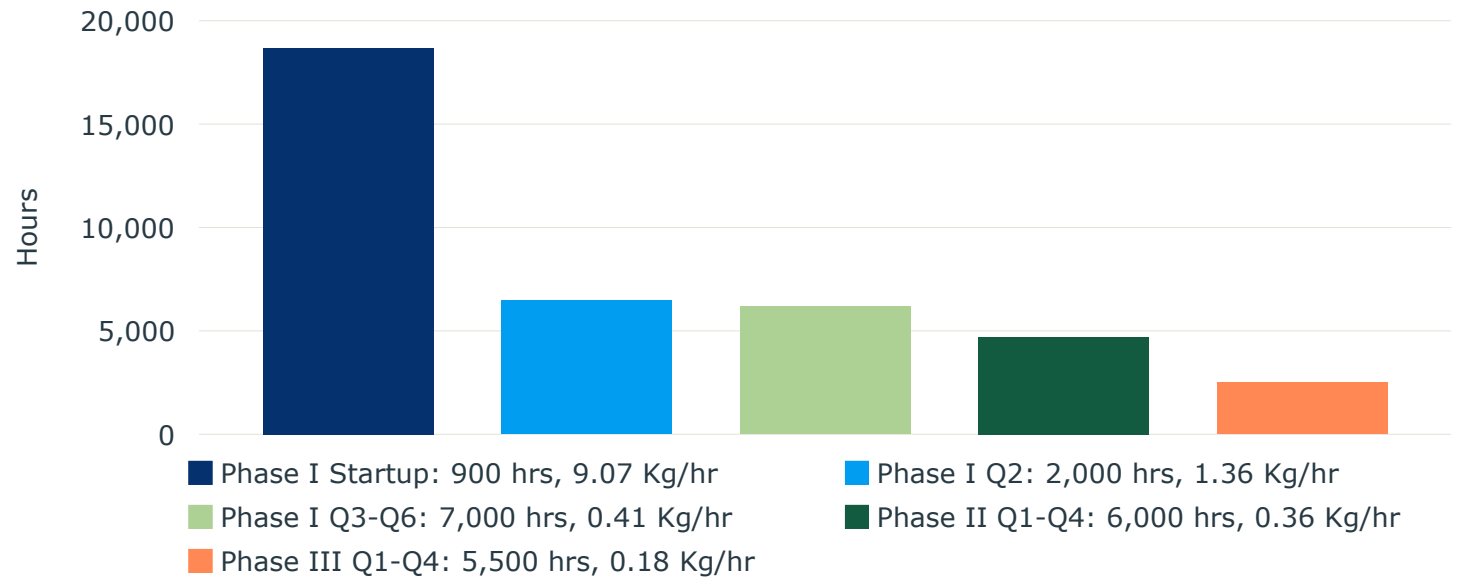
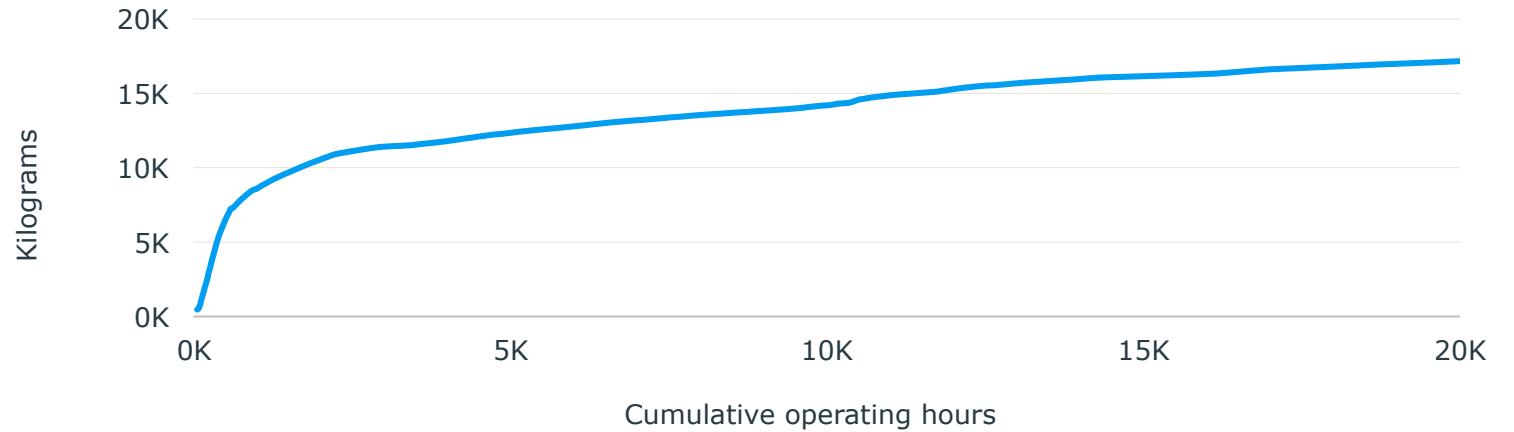
SDA SVE Pilot Test Extraction Well Layout



SDA SVE Pilot Test – June 2009 to October 2013



- System Operated 22,000 hours
- Removed 1,500 Pore Volumes
- Soil Gas Concentrations Reduced by 97%+
- Removed 17,000 KGs of VOCs

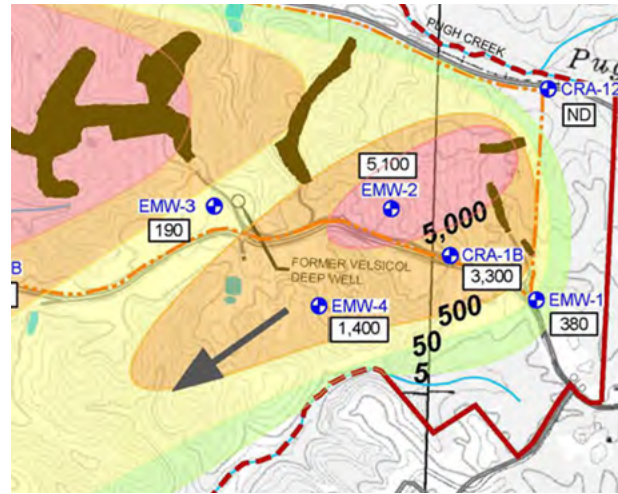


Phase 3 - Plume Development - SDA SVE 2009-2013

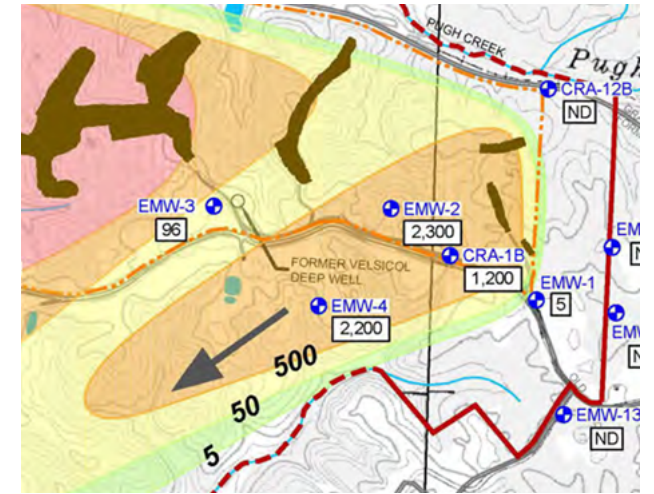


Following SDA SVE Treatment of the Vadose Zone, CT groundwater concentrations for three monitoring wells located 150, 300, and 500 meters downgradient from the SDA have decreased by one to two orders of magnitude

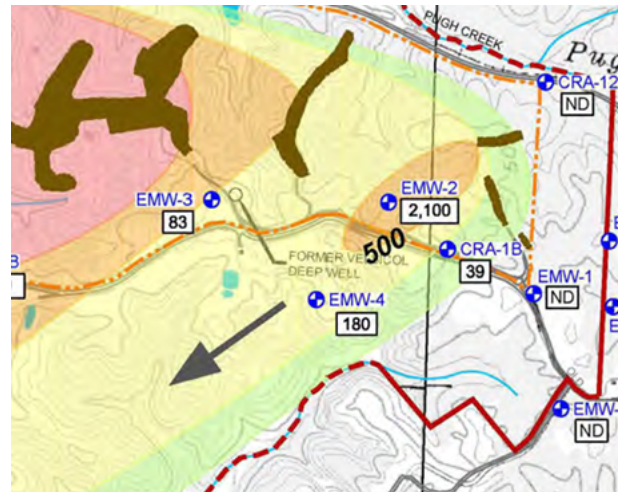
August 2008



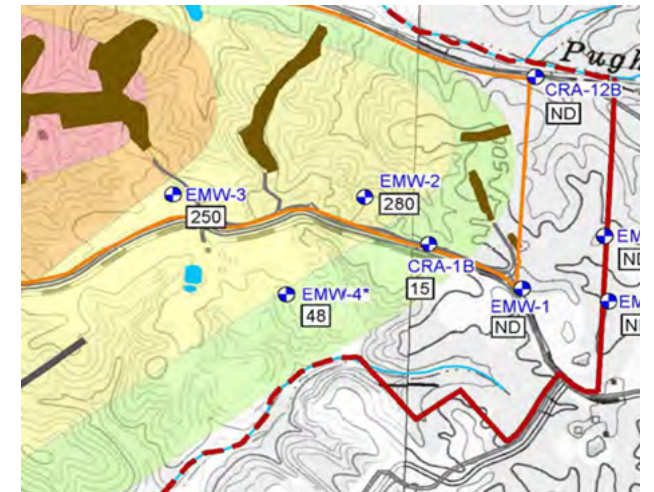
July 2012



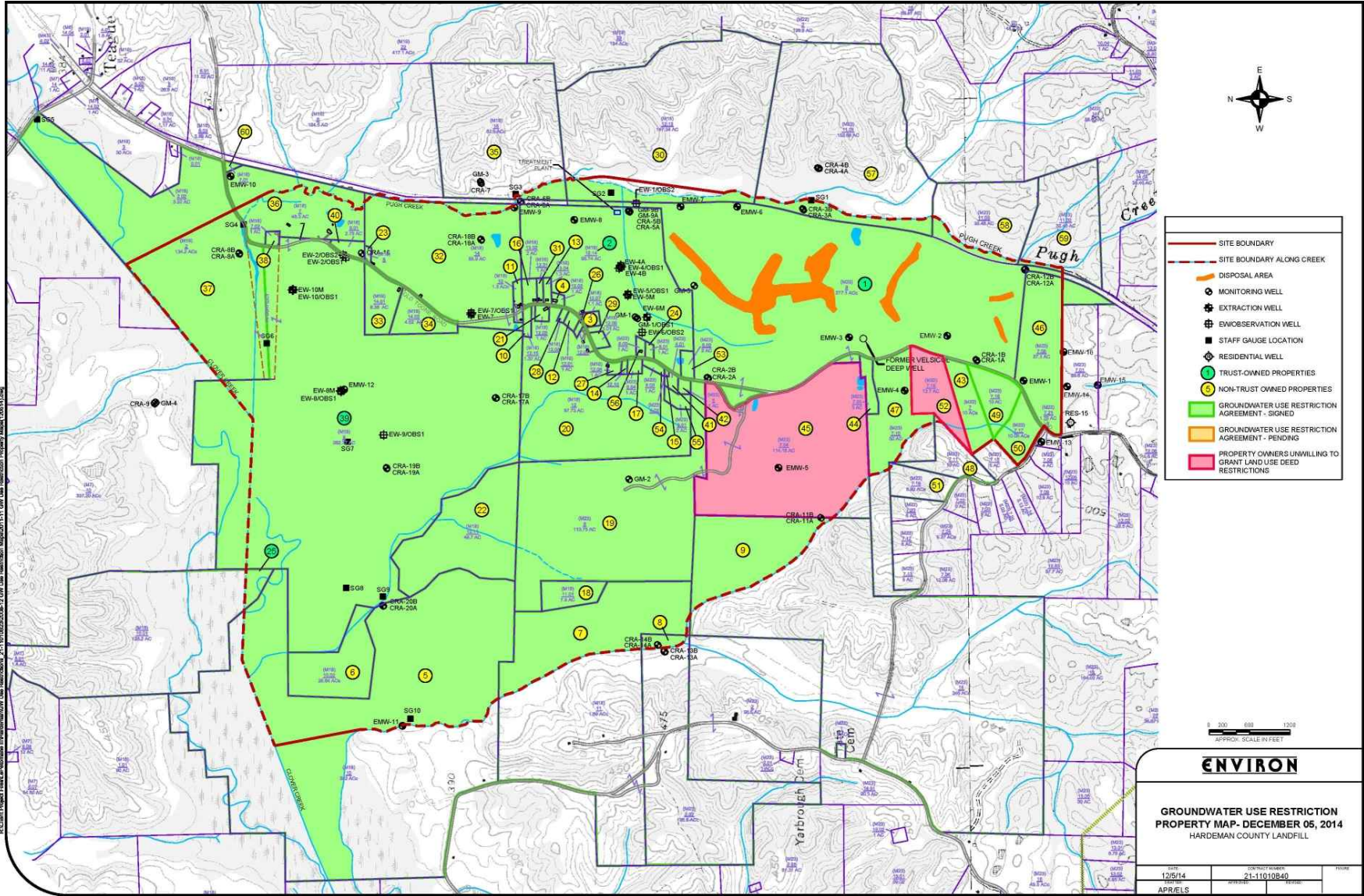
August 2017



August 2023



Groundwater Use Restriction Institutional Controls - 2014



Landfill Cap Upgrades 2015–2016

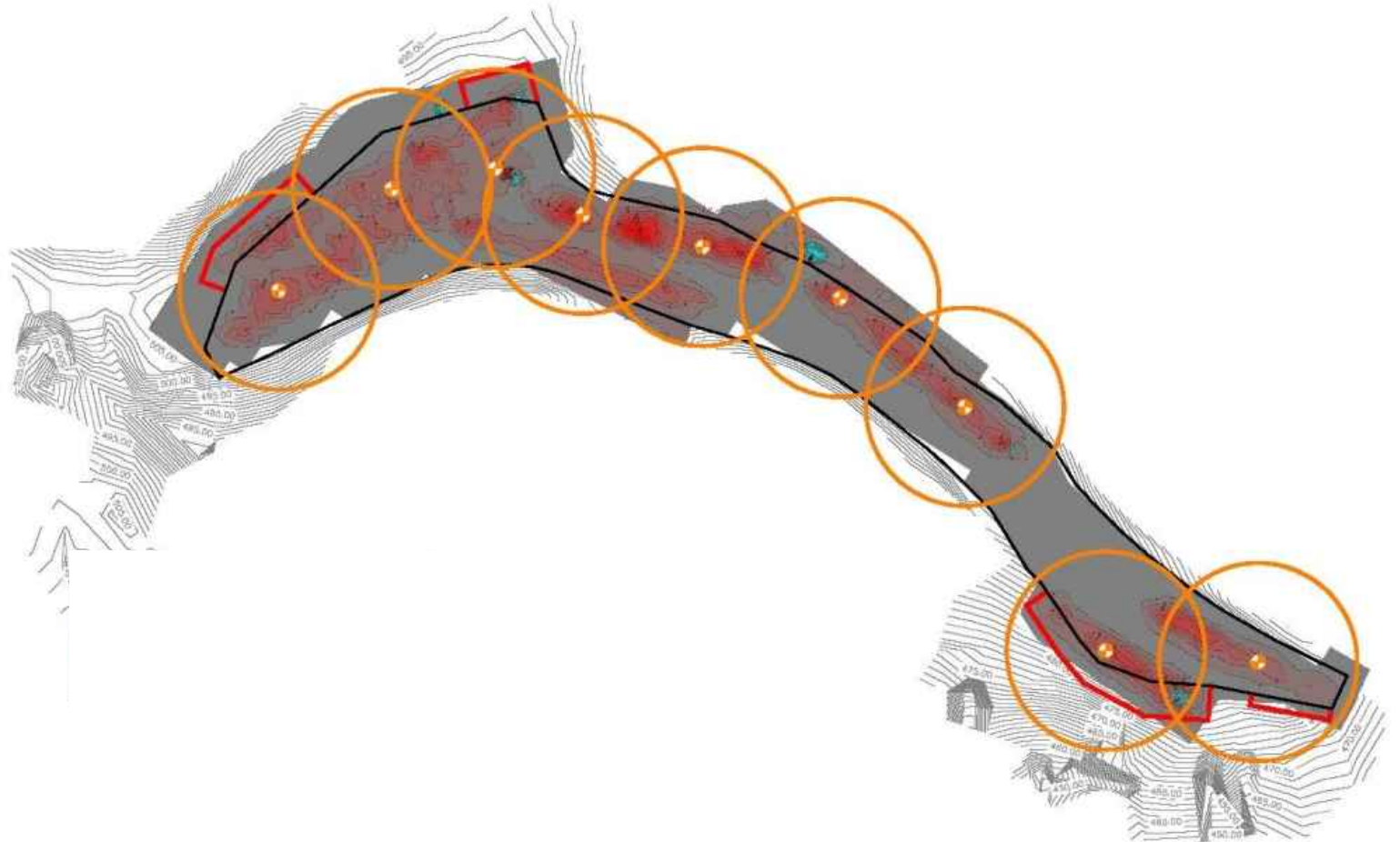


3-Acre MDA SVE Treatment Feb 2018 to Dec 2021

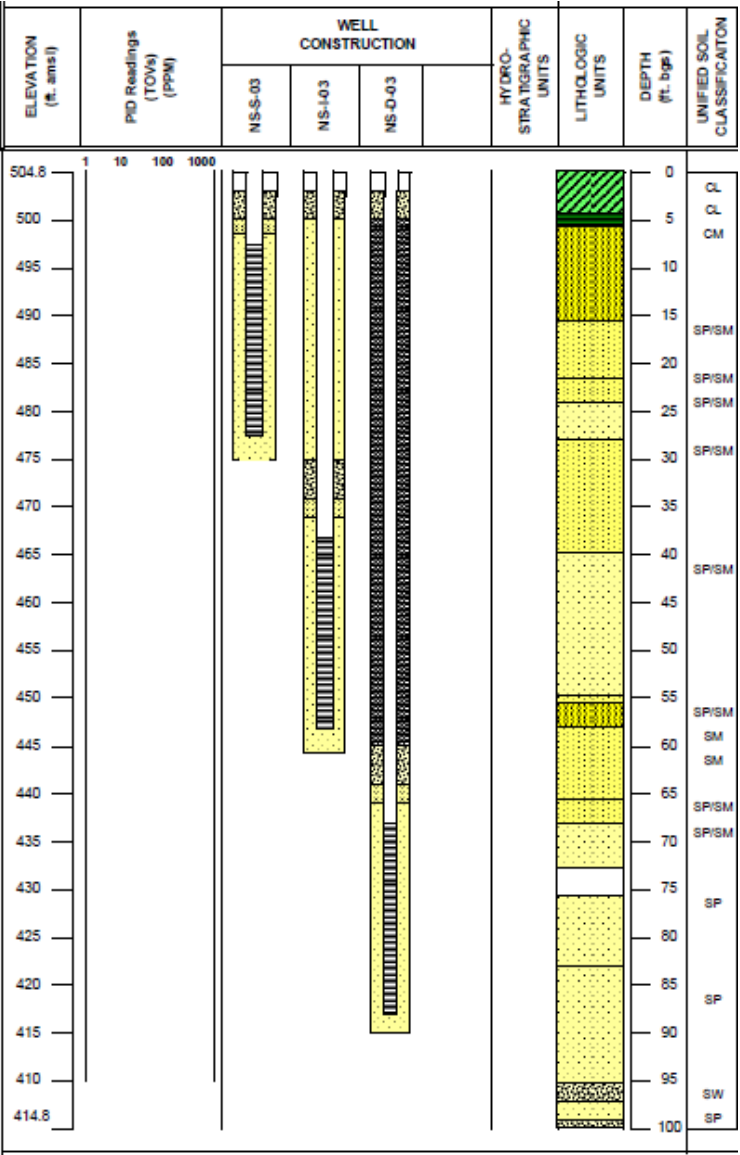


Soil Gas Concentrations Reduced
by 97%+

Removed 68,000 KGs of VOCs



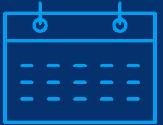
NDA Higher VOC Soil Gas Concentrations Increasing with Depth



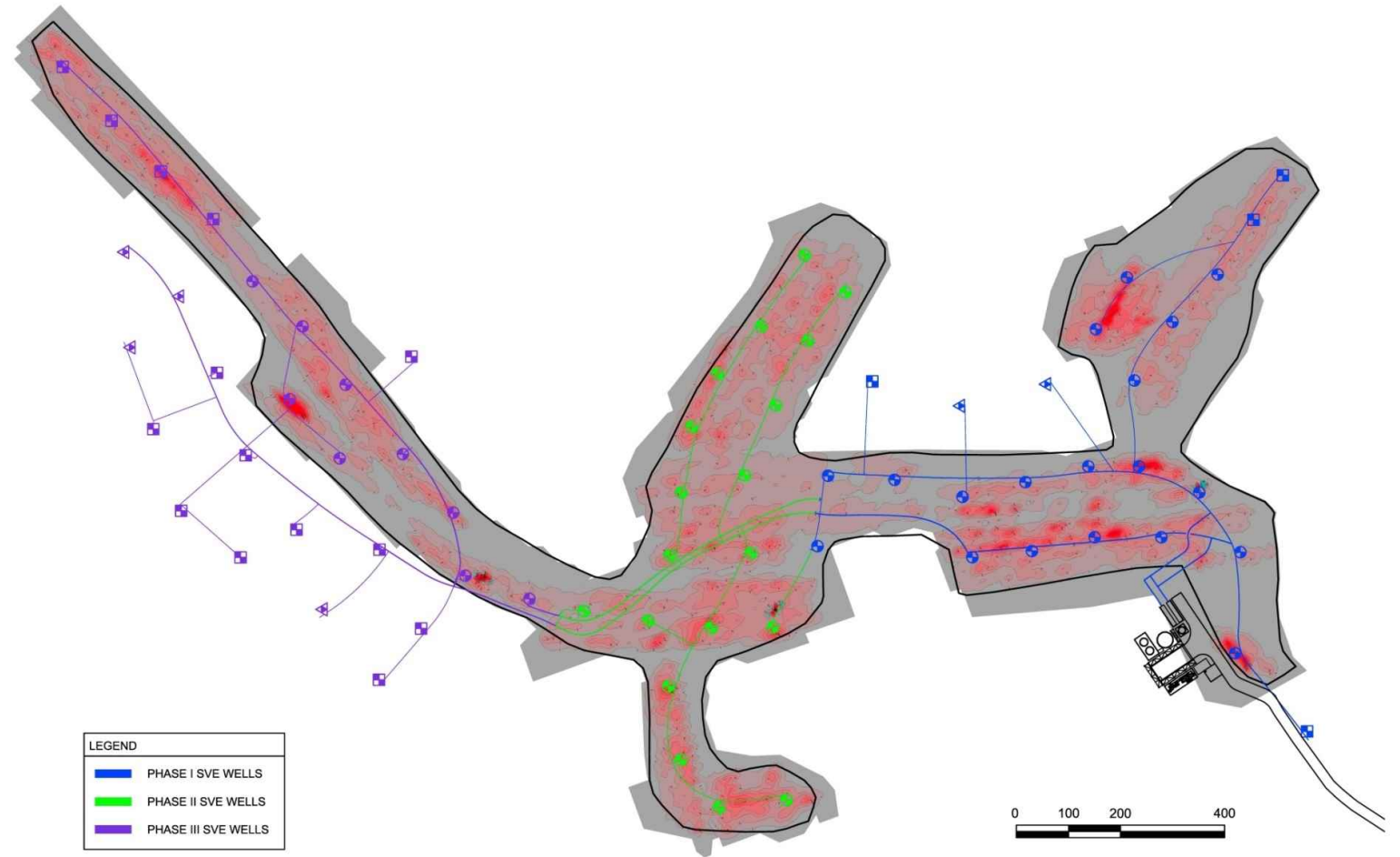
Mean CT



20-Acre NDA SVE System Under Construction



Projected Remediation Timeframe
2026 – 2038+ Projected VOC
Mass to be Removed
3,000,000+ KGs

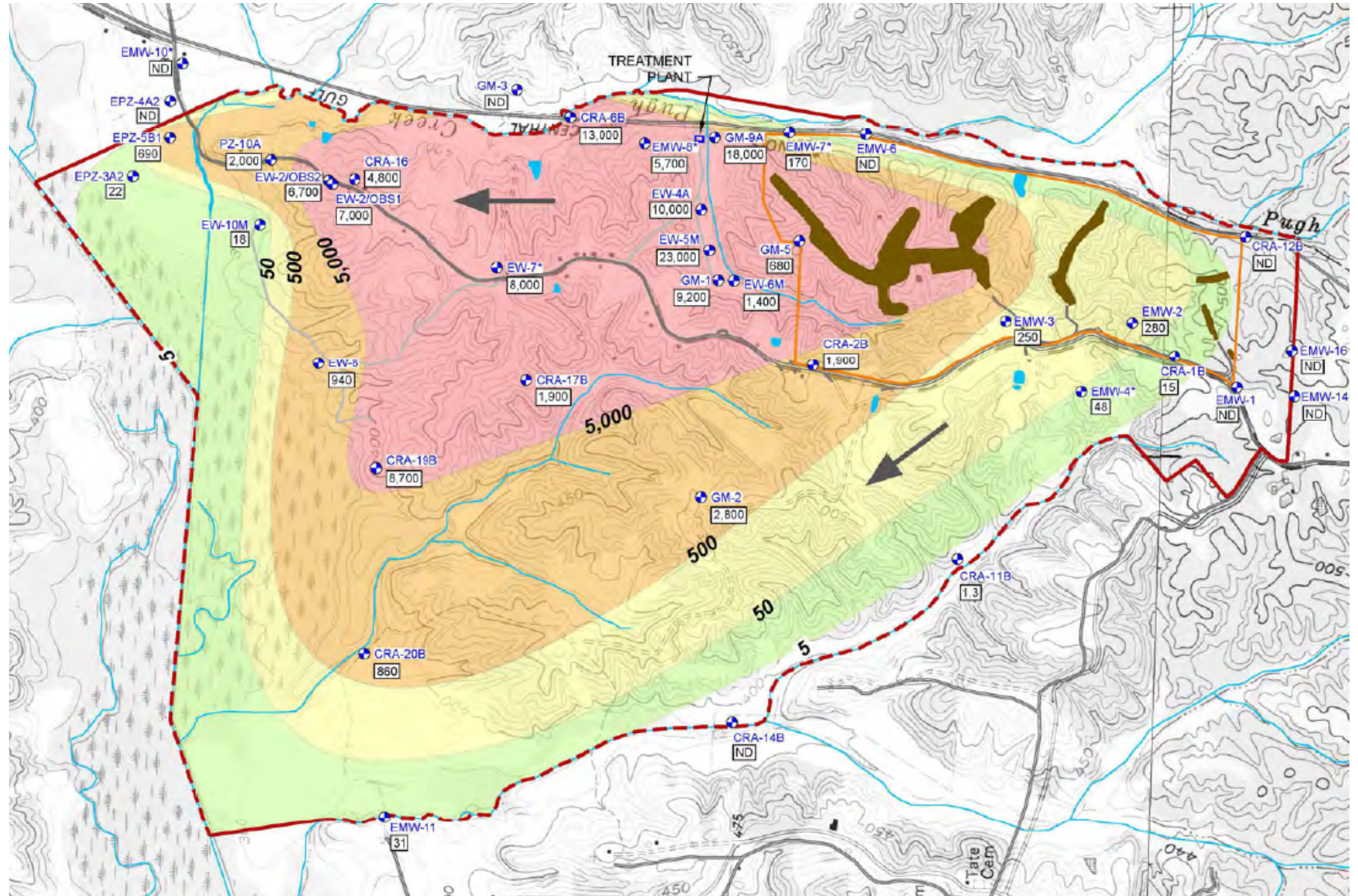


Contaminant Mass Summary

- 200,000 drums of principal threat pesticide manufacturing waste to be left in place
- DNAPLs are present within the disposal area source zones and are likely present in the saturated zone underlying the drum disposal areas
- SVE Source Area Remediation that Reduces VOC Soil Gas Concentrations by 97%+
- Vast majority (~95% ?) drums compromised
- After completion of SVE Remedy there will still be a residual VOC source within the vadose zone

- > **1964 -1973**
~ 200,000 Pesticide Manufacturing Waste Drums Buried
- > **1975 – Ongoing**
Impacted GW discharge to Clover Cr - #KG VOCs?
- > **1996 – 2003**
GW P&T Removed 50,000 KG VOCs
- > **2009 – 2013**
SDA SVE PT Removed 17,000 KG VOCs
- > **2018 – 2021**
MDA SVE Remediation Removed 68,000 KG VOCs
- > **2026 – 2038+**
NDA SVE Remediation targeting 3,000,000+ KG VOCs
- > **Date?**
Future Groundwater Remedy TBD

2023 CT Unconfined aquifer Iso- concentration Map



Unconfined Aquifer Wetland Discharge Zone Natural Attenuation capacity

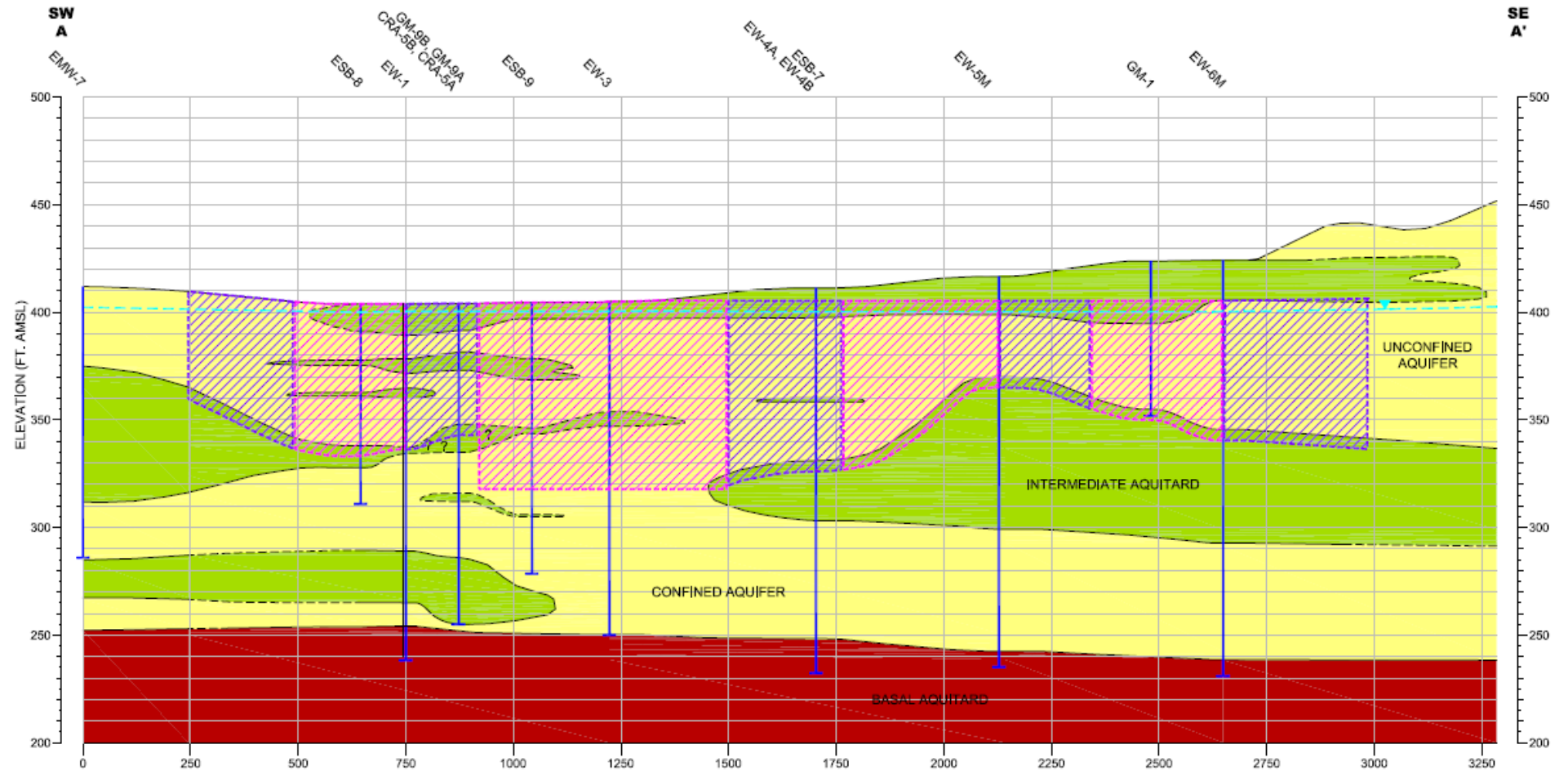
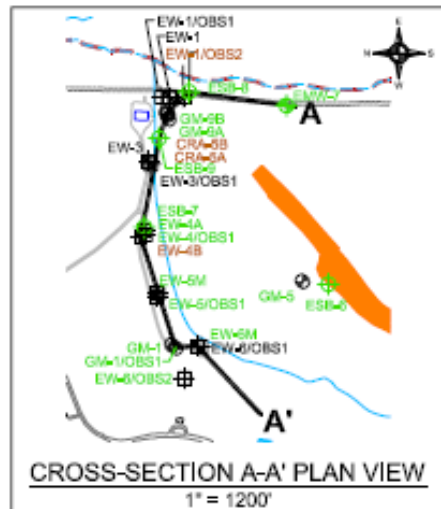
- The Unconfined & Semi-Confined Aquifer Plumes discharge into a Wetland.
- VOCs are naturally remediated by a variety of biologic and non-biologic mechanisms.
- Wetland VOC Natural Attenuation occurs via biodegradation, dilution, and evaporation.
- Surface water one mile downstream from the discharge zone is non-detect for VOCs.



Unconfined Aquifer Plume trends

- 01 > Plume boundaries are topographically controlled and have been stable for the last 25 years.
- 02 > POC VOC concentrations decreased by 67% after 7 years of P&T, but recovered to 80% of pre-P&T levels within 5 years of after cessation of P&T operations.
- 03 > POC VOC concentrations have decreased by approximately 55% over the last 25 years.
- 04 > In 2023, the maximum POC well CT concentration of 23,000 ug/L equates to 2.9% of its solubility limit in water and is 4,600 times greater than its RAO of 5 ug/L.
- 05 > SVE treatment alone of the SDA source zone resulted in a one to two order of magnitude decrease in downgradient CT concentrations following 10 years after completion of treatment.

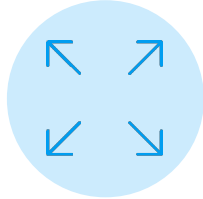
Potential Future POC Groundwater Treatment Window



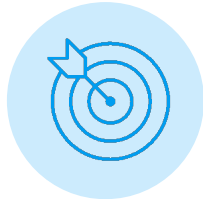
Envisioned Groundwater Path Forward



SVE Remediation of Northern Disposal Area



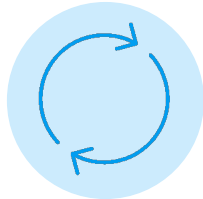
Additional Characterization of POC Valley GW Treatment Window



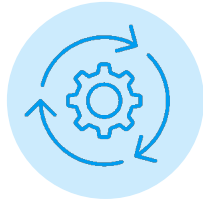
Focused Feasibility Study with Pilot Study(s)

- In-Situ Bioremediation and Funnel & Gate for POC Valley
- Downgradient Monitored Natural Attenuation

Amended ROD

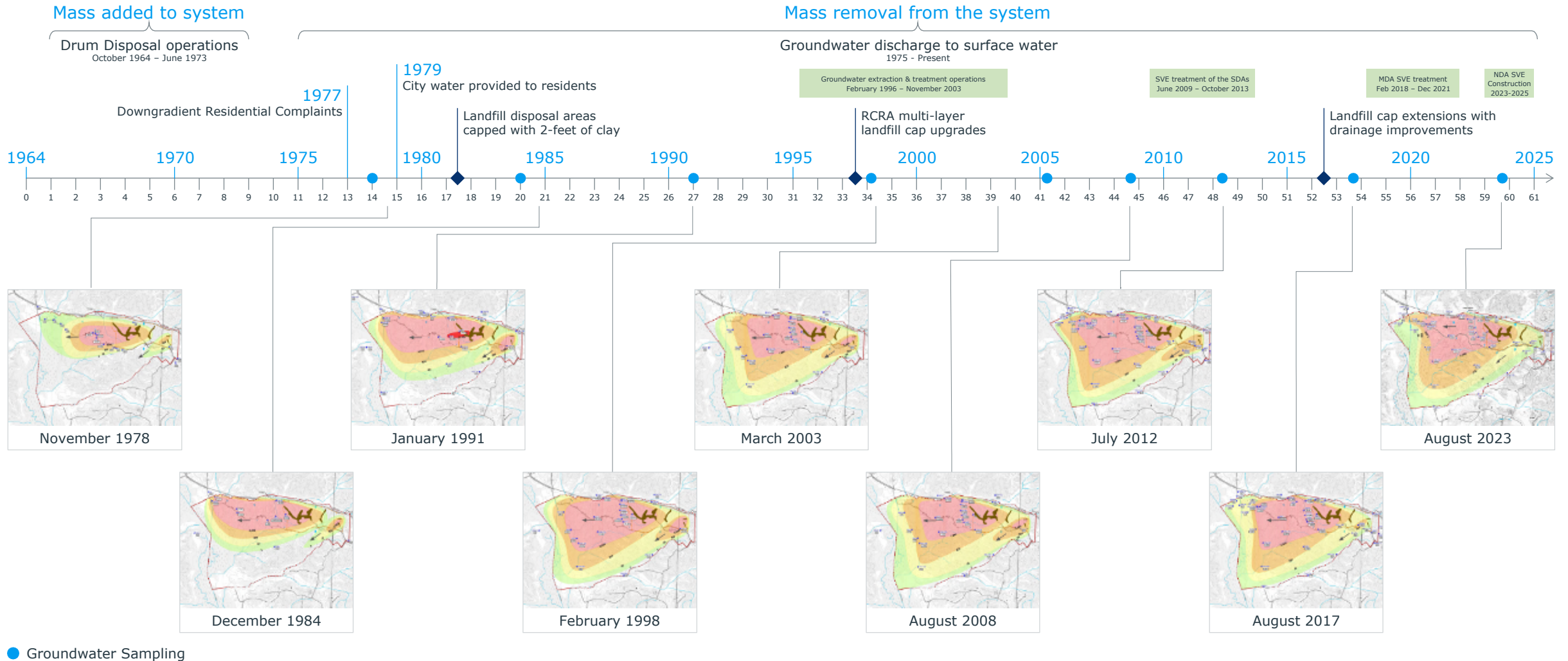


- Conduct Pre-Design Investigation
- Remedy Design
- Remedy Construction and Implementation
- Institutional Controls to Safeguard Discharge Wetlands



Technical Impracticability Waiver

Unconfined Aquifer CT Plume Evolution – 1978 to 2023



Questions and acknowledgements

Co-Authors

Bruce Kennington, Ramboll, Chicago

Kit Carson, Ramboll, Denver



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Sustainable change.

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