Comparison of In-Situ Bioremediation of Perchlorate and Chlorinated Solvents at Three Sites in Close Proximity: Challenges and Lessons Learned

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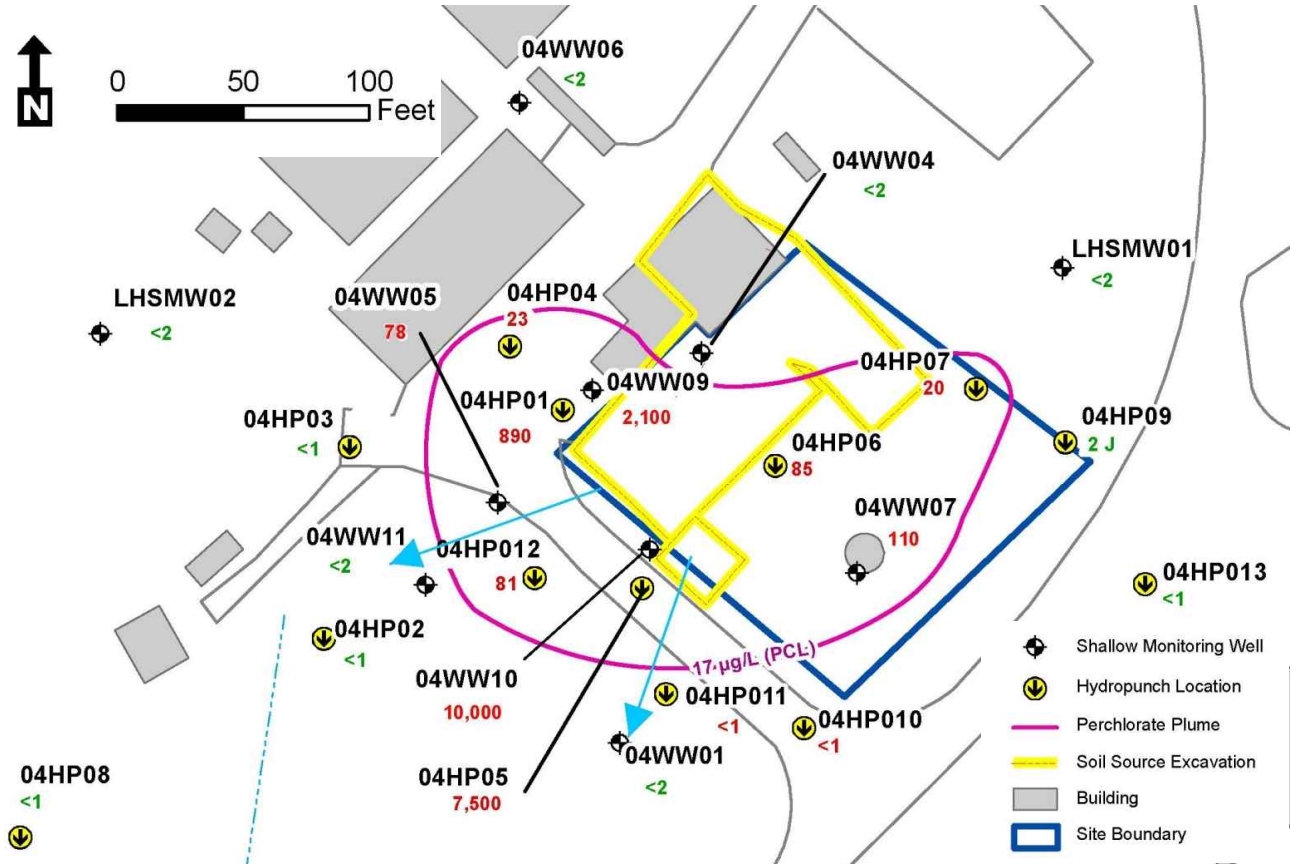
SITE DESCRIPTIONS AND PROJECT HISTORY

- In Situ Bioremediation (ISB) was proposed at a former U.S. Army Ammunition Plant, to address elevated perchlorate and/or chlorinated solvents in groundwater at three sites for a project beginning in 2017
- The three sites were at different stages of remediation when the project began
  - Site A – Record of Decision (ROD) complete; Remedial Design and Remedial Action Work Plan (RD/RAWP) needed; no recent groundwater data (2011)
  - Site B – ROD and RD complete; interim remedy in place; RAWP needed; significant new well installation program planned in RD to monitor proposed remedy, but wells not yet installed
  - Site C – ROD and RD/RAWP in place for MNA remedy; MNA deemed inadequate after 3 years of monitoring; RD/RAWP for Contingency ISB Remedy needed
- Project awarded by Army as a Firm Fixed Price Contract on a “best value” award basis

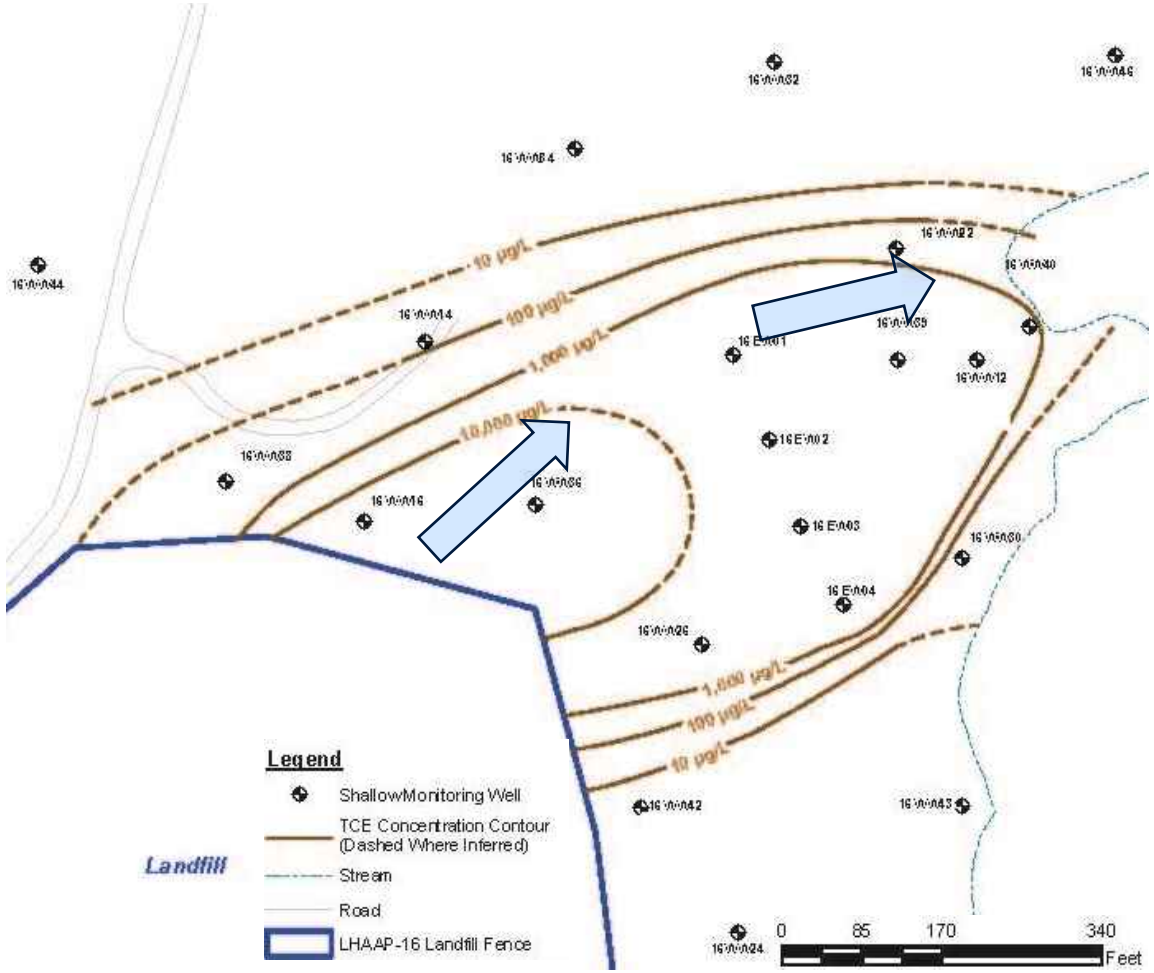
SITE A – FORMER WASTEWATER TREATMENT PLANT

- ~1/2-acre plume of perchlorate in groundwater (GW) at 6 to 20 feet below ground surface (bgs)
- Soil source addressed by excavation
- GW perchlorate concentrations up to 5,410 µg/L measured in 2010
- Site had a Record of Decision (ROD) in place but had not been sampled since 2011
- Project began with new round of sampling in 2018 and plume had shifted significantly to the west
- Sampling in 2019 revealed larger plume by ~25% with concentrations up to 10,000 µg/L



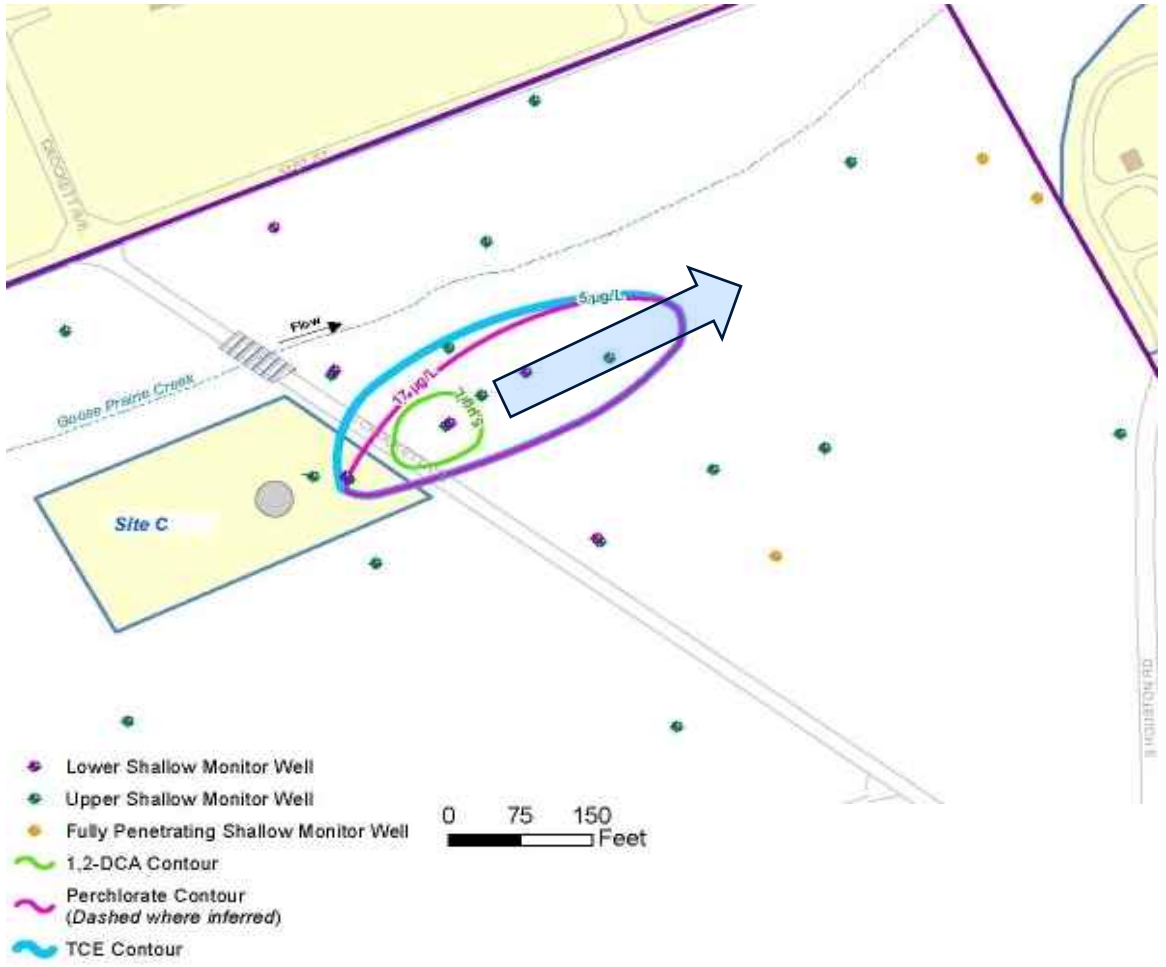
SITE B – GROUNDWATER PLUME FROM CLOSED LANDFILL

- ~12 Acre combined TCE and perchlorate plume in shallow and intermediate zone GW at 15 to 60 feet bgs
- Landfill capped but GW plume source remains in place
- TCE concentrations up to 18,000 µg/L (2000) and perchlorate up to 91,000 µg/L (2018)
- Interim groundwater extraction remedy was in place for plume control with approved ROD and RD for ISB remedy
- 24 new monitoring wells (MW) installed prior to remedy implementation for injection/performance monitoring
- New wells sampled in 2019 revealed contamination beyond the bayou and changes in the potentiometric contours



SITE C – FORMER SUMP WATER TANK SITE

- ~1 Acre combined TCE and perchlorate plume in upper and lower shallow and zone GW at 30 to 60 feet bgs
- ~183 Cubic yards of perchlorate contaminated soil southwest of road removed in 2013
- TCE concentrations up to 620 µg/L (2018) and perchlorate up to 91,000 µg/L (2018)
- MNA remedy deemed inadequate after 3 years due to perchlorate migration and marginal conditions for reductive dechlorination
- Contingency remedy of in-situ bioremediation implemented in March 2020

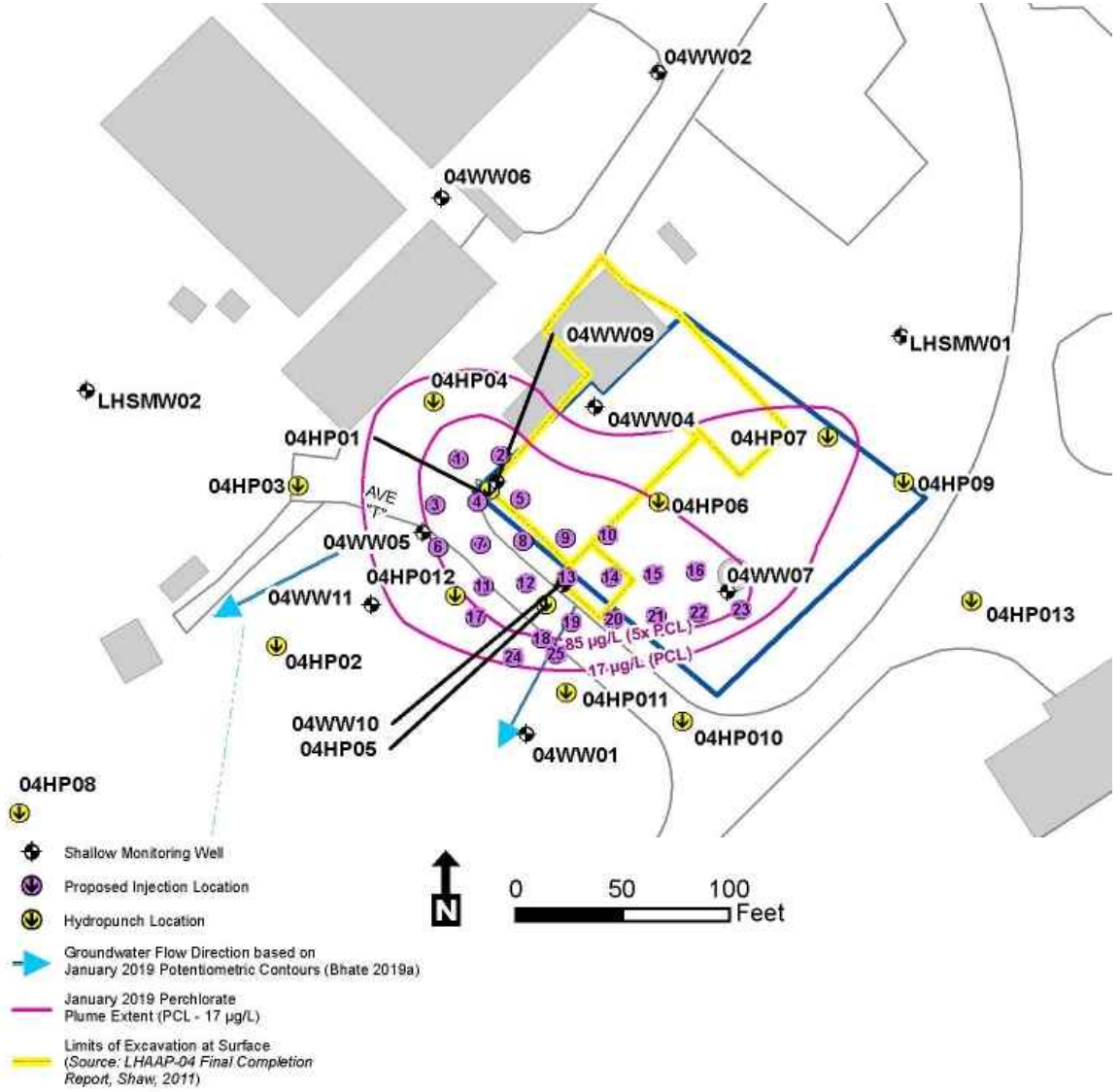


COMMON ELEMENTS BETWEEN THE SITES

- Sites are all within 2 miles of each other
- Fine grained groundwater bearing zones with wide variability in permeability, likely due to the presence of paleochannels
- Leaky or non-existent aquitard between uppermost water bearing zones
- Significant relationship between groundwater elevation and concentration (mostly inverse)
- Remedies implemented included injection of emulsified vegetable oil mixture to enhance reductive dechlorination of TCE and perchlorate
- Sites B and C were also bioaugmented with SDC-9™ during injections

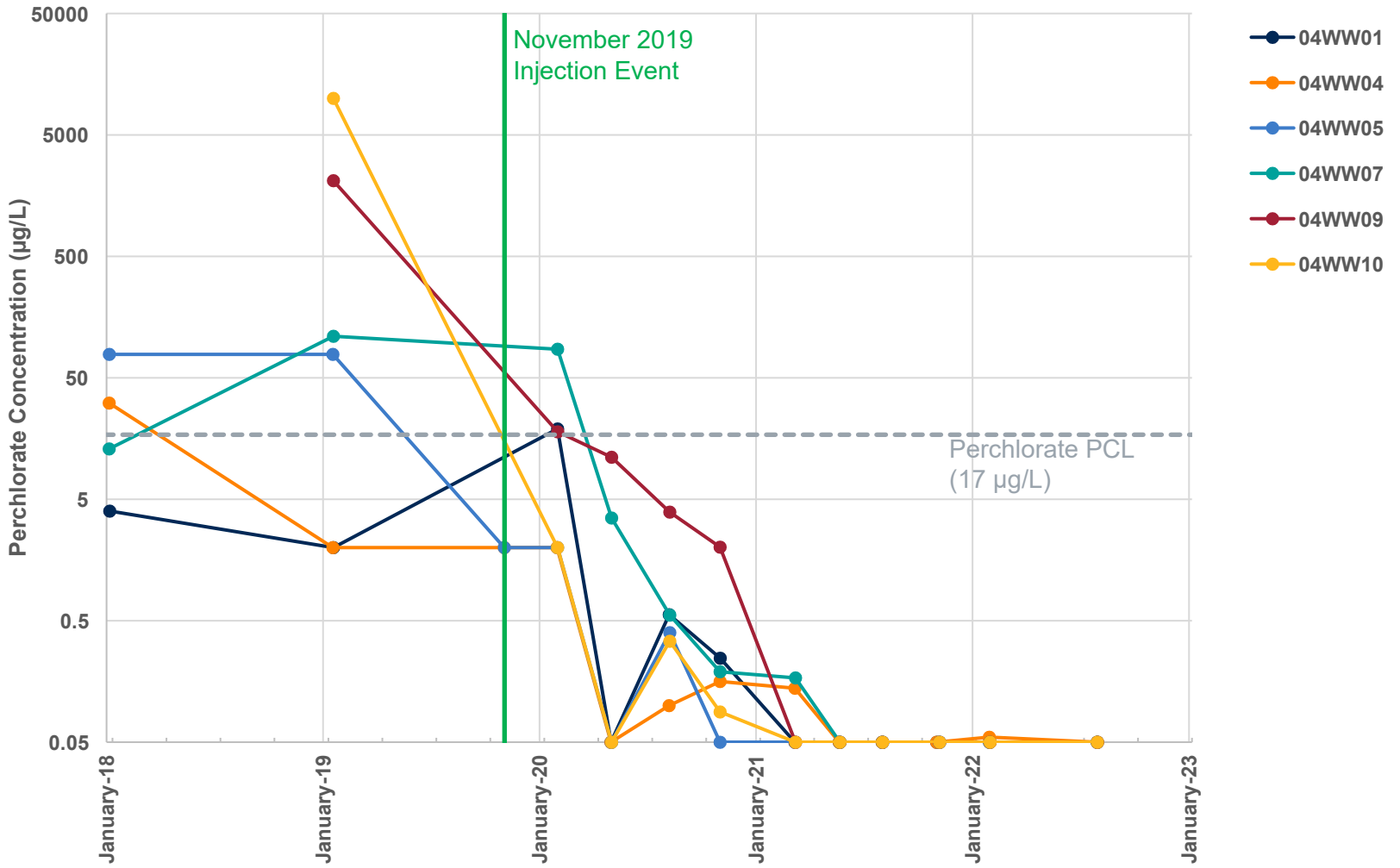
SITE A REMEDY IMPLEMENTATION

- Approximately 36,000 gallons injected into 25 direct push locations
- Injections targeted to the area with perchlorate concentrations 5X the TCEQ Protective Concentration Level of 17 µg/L and shifted downgradient
- Four locations injected simultaneously
- Significant daylighting occurred, particularly in the former excavation area
- Shallow depths of injection required slow flow rates and low injection pressure

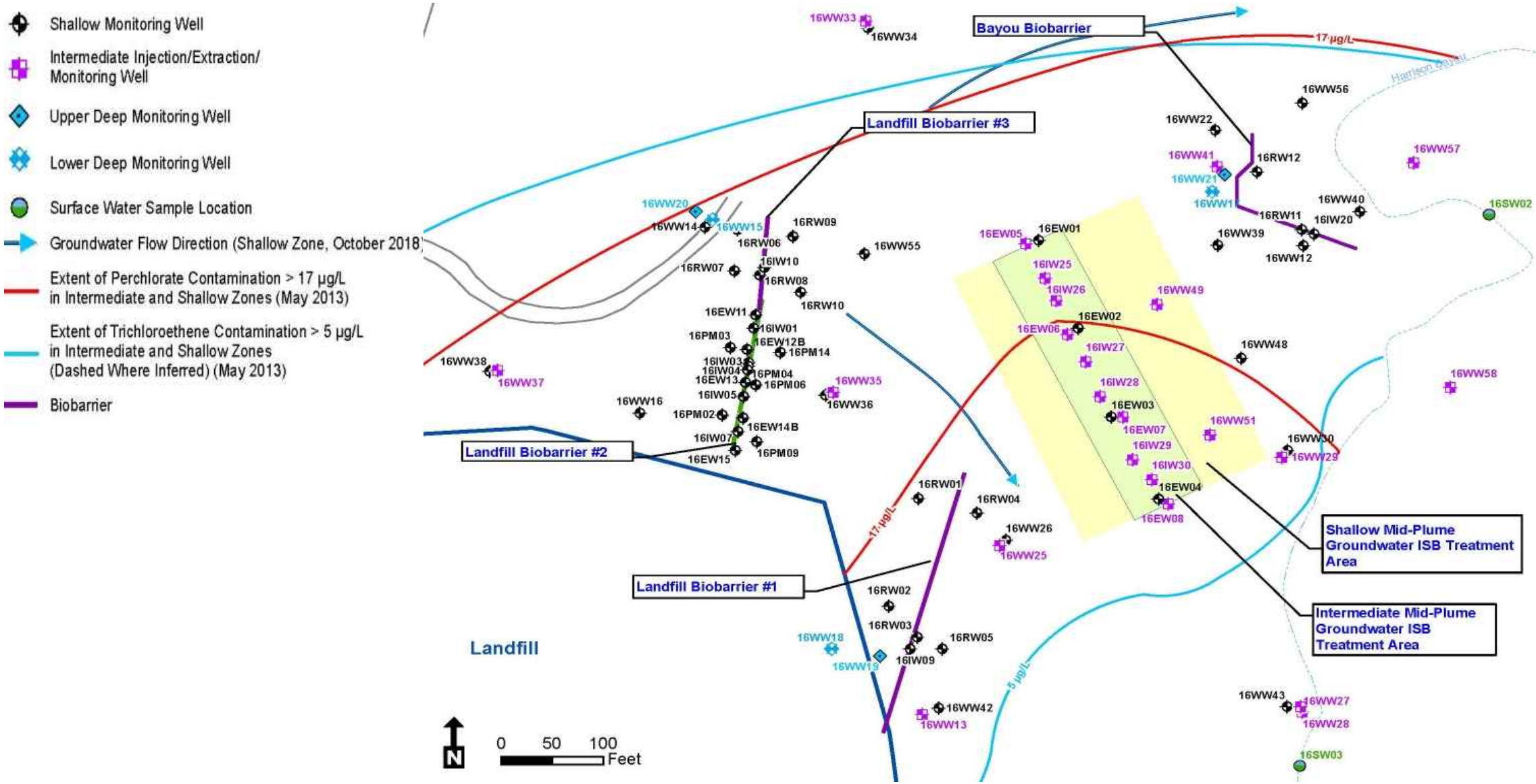


SITE A RESULTS

- Dissolved Oxygen dropped to <0.1 mg/L in most locations within 3-6 months
- ORP -100 to -300 mV by 6 months post-injection
- Following injections in November 2019, all concentrations were below the PCL within 6 months
- All concentrations ND within 1 year
- Groundwater returning to aerobic conditions with no sign of rebound



SITE B REMEDY IMPLEMENTATION



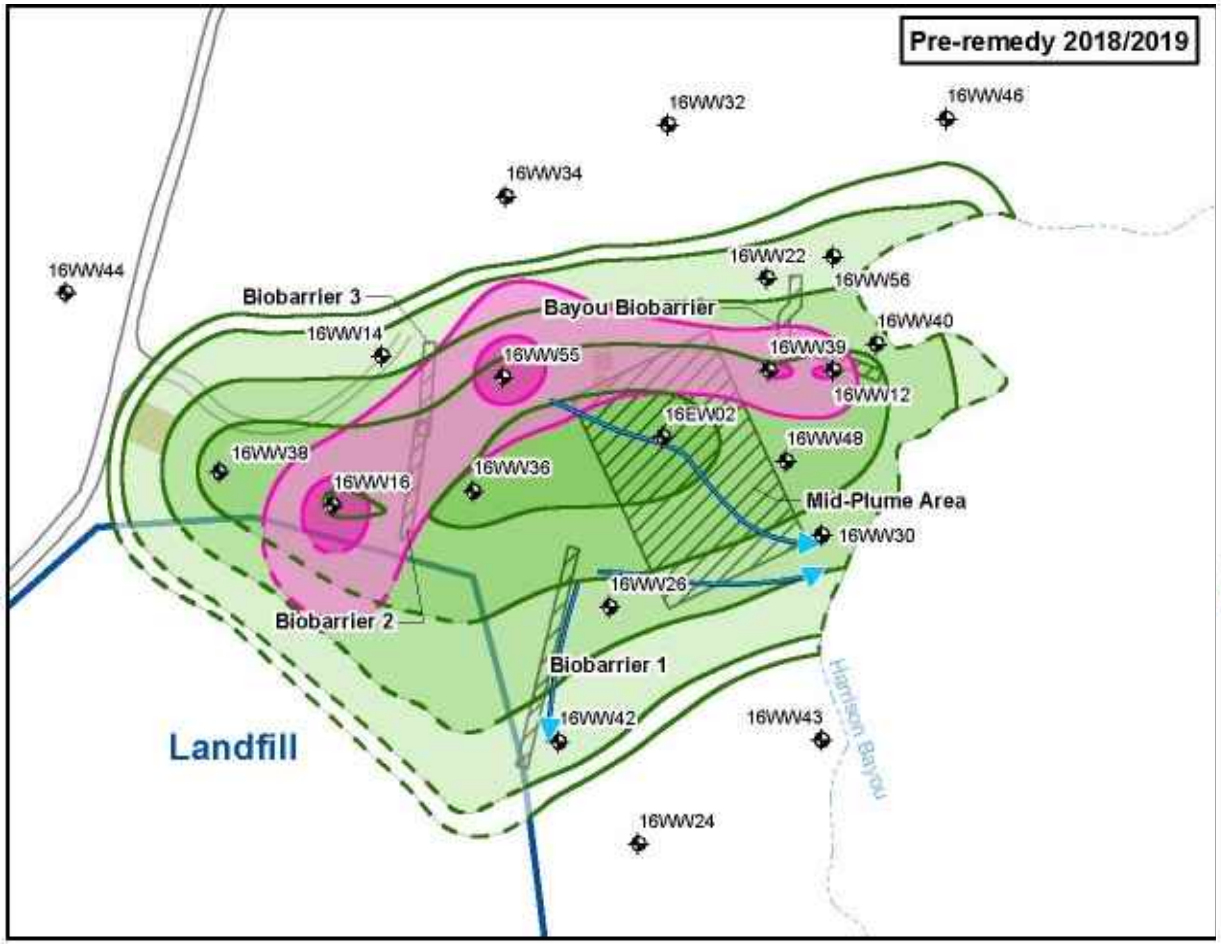
SITE B REMEDY DETAILS

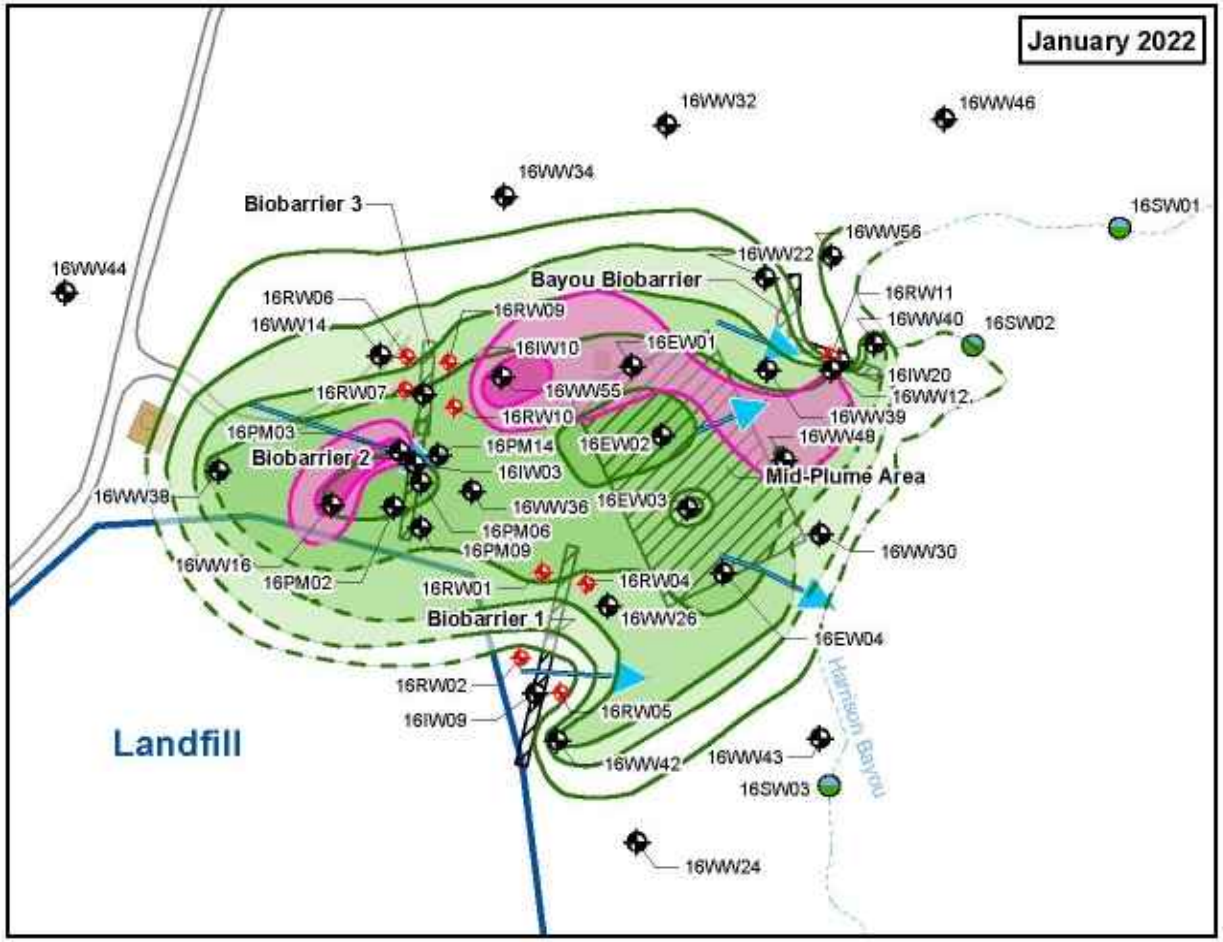
- Three shallow zone biobarriers downgradient of the Landfill (EVO+Lactate)
- One shallow zone biobarrier adjacent to the bayou (EVO+ZVI)
- One injection grid in the mid-plume shallow zone (EVO+Lactate)
- One mid-plume treatment cell (temporary recirculation) in the intermediate zone
- 80 DPT injection points
- 22 Injection wells, including 4 intermediate extraction wells from interim groundwater extraction remedy
- Approximately 105,000 gallons of EVO/Lactate solution injected in all of the areas along with 3,500 pounds of ZVI in the Bayou Biobarrier
- All areas received bioaugmentation with SDC-9™

SITE B RESULTS

- Initial DO/ORP conditions generated in shallow zone injection areas were very favorable for reductive dechlorination
- TCE and Perchlorate within treatment areas showed initial declines consistent with expectations in some areas, but not all
- Perchlorate concentrations have been significantly reduced site-wide
- Design effectiveness (bromide tracer) results suggested lower ROI than estimated in design
- Distribution of amendments was sporadic and may have been influenced by paleochannels and topography that were not fully evaluated in the design
- Bayou Biobarrier with ZVI included worked very well for the portion of the plume it intercepted, but the design location did not fully account for topographic influences on groundwater flow and shallow groundwater may be bypassing the barrier to the south
- The mid-plume recirculation program intended to achieve better intermediate zone distribution did not succeed based on bromide tracing and may have enhanced aerobic conditions unnecessarily
- Planned use of injection locations for performance monitoring caused difficulties with biofouled wells and residual injection amendments

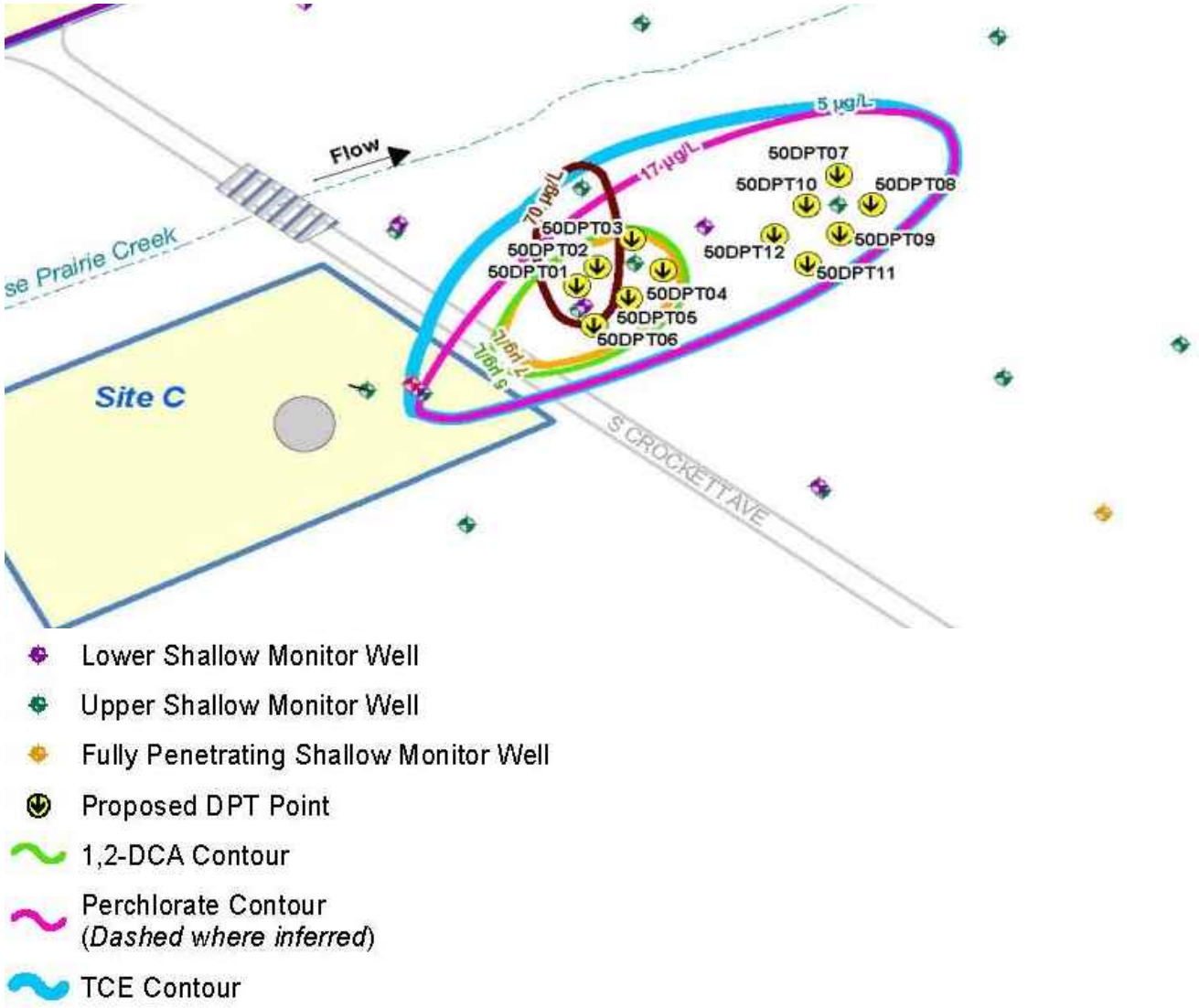
SITE B PLUME COMPARISON



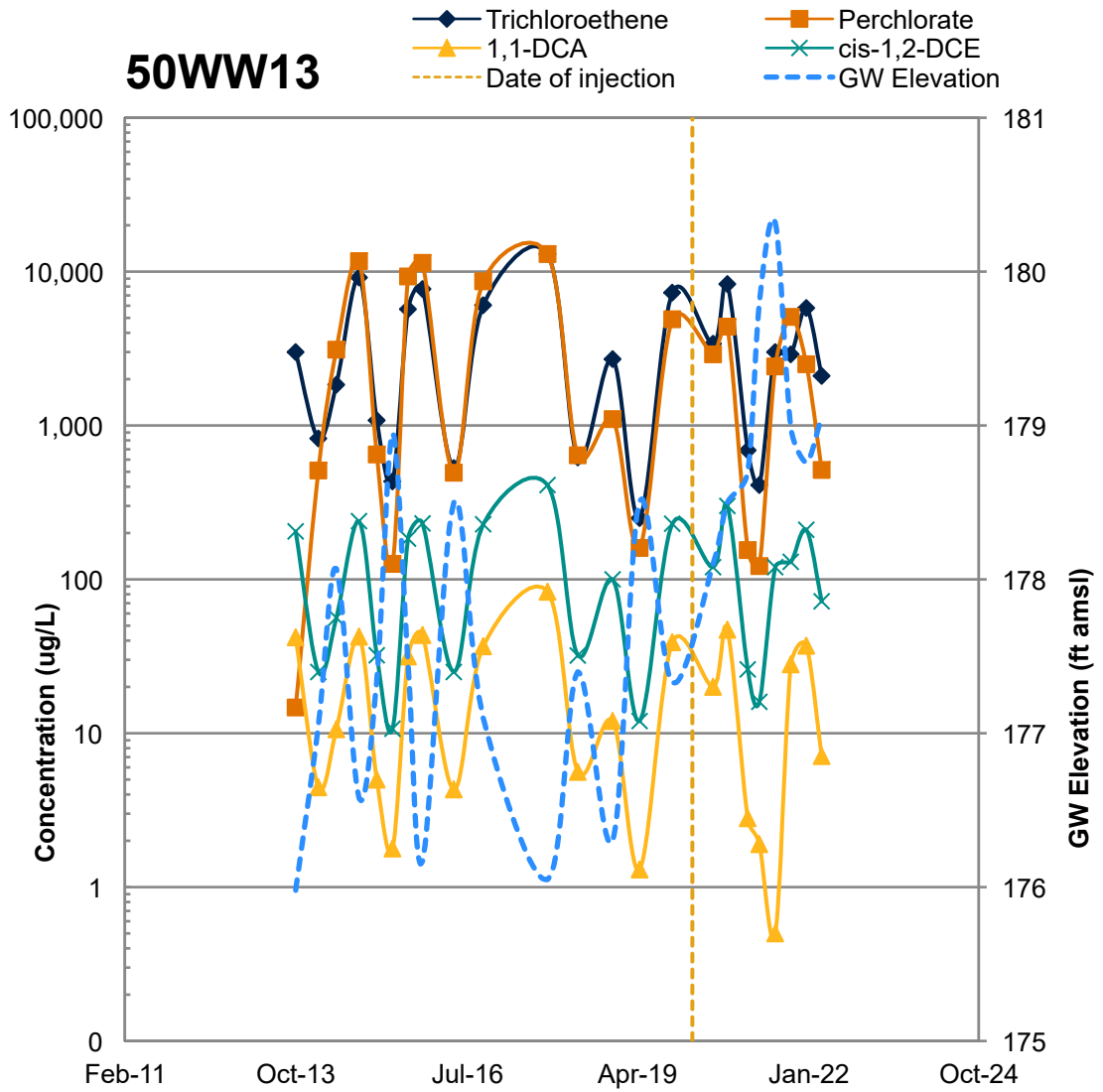


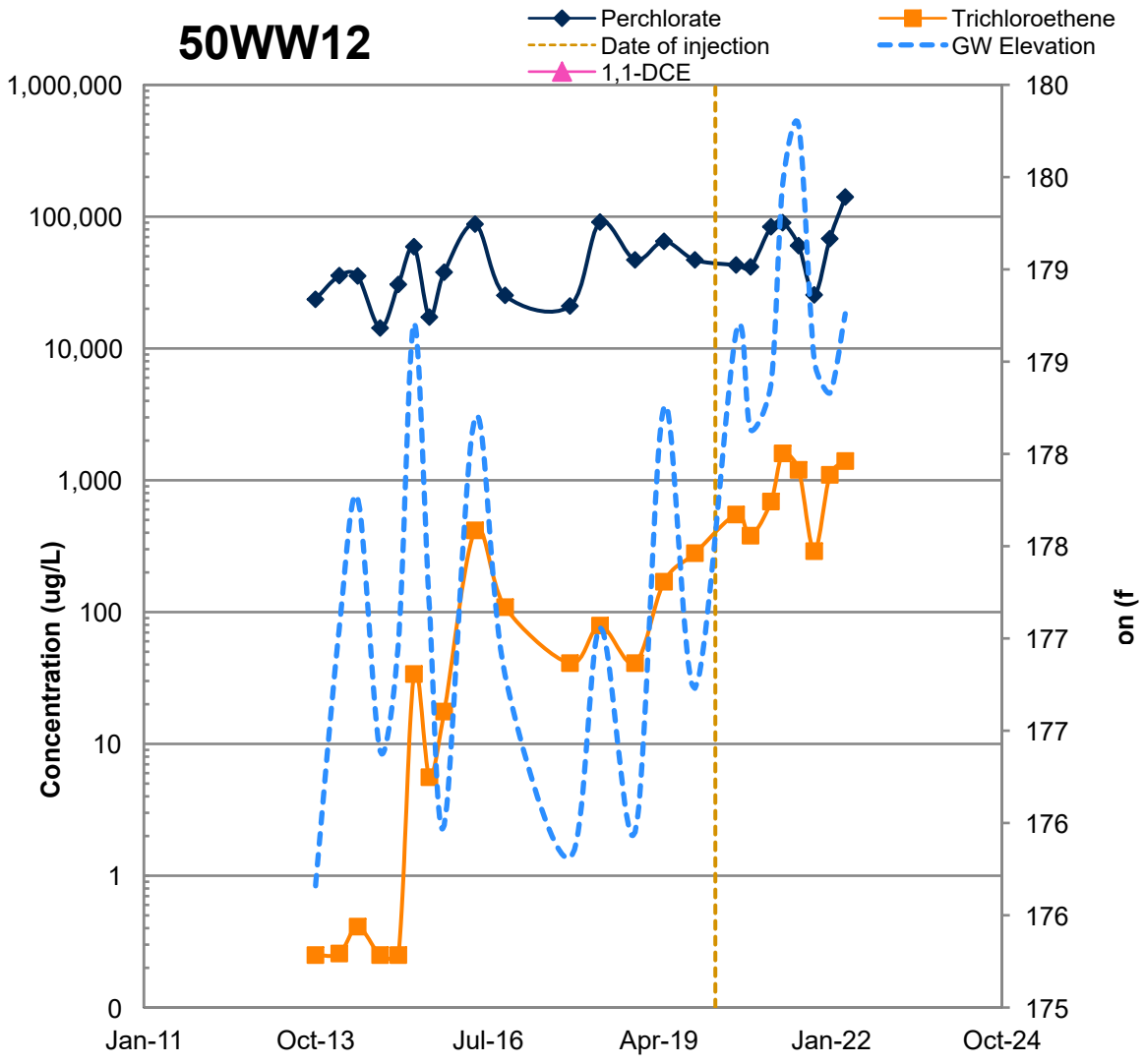
SITE C CONTINGENCY REMEDY IMPLEMENTATION

- Two treatment areas:
  - Area around 50WW12 (upper shallow only)
  - Area Around 50WW13 and 50WW14 (upper and lower shallow)
- 6 DPT locations injecting EVO solution with SDC-9™ bioaugmentation from 18 to 60 feet bgs
- 6 DPT locations injecting same solution from 18 to 35 feet bgs
- Approximately 44,000 gallons of solution injected



SITE C RESULTS





LESSONS LEARNED – SITE A

- Gathering new data PRIOR to the Remedial Design/Work Plan stage gave us the opportunity to recognize that the plume had migrated
- Allowed design to match the existing available resources and still successfully remediate the plume
- In hindsight, lower injection volumes with higher amendment content might have reduced the daylighting challenges, but it is hard to argue with the results

LESSONS LEARNED – SITE B

- The Remedial Design included the installation of many new wells prior to the remedy implementation, but did not include a step to evaluate the data provided by the wells
- Simplistic depiction of groundwater flow without accounting for new well data and significant topography led to sub-optimal placement of some of the injection areas/biobarrier
- The design of recirculation in the mid-plume intermediate area was not adequately backed up by pre-design testing for adequate ROI/coverage
- Use of wells that had been extraction wells for injection/recirculation and then as performance sampling locations did not work
- More detailed analyses such as Compound Specific Isotope Analysis and use of tools such as Passive Flux Meters would provide better monitoring of remedy performance than simply looking at COC concentrations and geochemical conditions
- In complex groundwater situations where there is potential interaction with surface water, the relationship between the two should be evaluated much earlier in the process

LESSONS LEARNED – SITE C

- There is likely to be additional vadose source material or a significant shallow smear zone influencing perchlorate concentrations at 50WW12
- The use of other tools such as CSIA or passive flux meters can overcome some of the challenges of monitoring COC concentrations in wells with high seasonal fluctuations or variable groundwater elevations
- Programming a Contingency Remedy into a ROD is a good idea, but costing the remedy prior to identification of deficiencies in the current remedy can be problematic
- It is likely that the very high perchlorate levels at this site and in locations at Site B may be inhibiting biological degradation of TCE

FINAL THOUGHTS

- Performance-based contracting has undeniably driven innovation in remediation and brought down the costs for government funded projects, while shortening the time to achieve the goals at many sites
- The use of performance-based contracting for both the investigation/evaluation and remedial implementation phases on a project may lead to inadequate evaluation and/or insufficiently robust monitoring programs
- “Best Value” contract awards can encourage more robust designs and monitoring, but only if the evaluators reward teams that don’t propose bare bones approaches
- “Low price/Technically Acceptable” award criteria should be limited to sites where the scope is well defined for all vendors and should be not be used where innovation and more robust data gathering is needed to form a clear picture of a geologically complex site to design an appropriate remedy/monitoring program

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QUESTIONS

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