Investigation and Remediation Strategy for a Fast-Moving 1,4-Dioxane Plume at a Military Site

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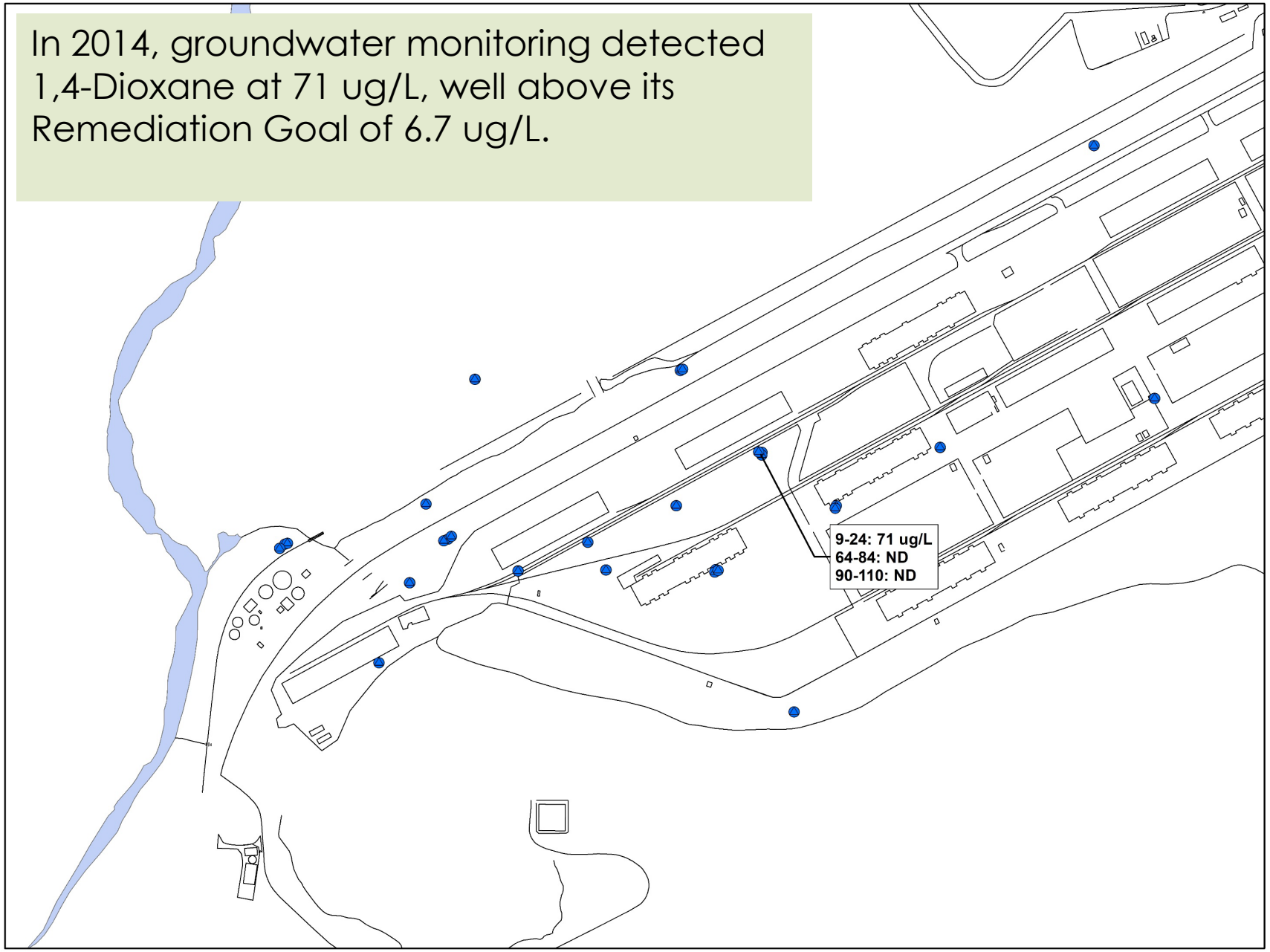
Site Background

- Site is within a military installation.
- 1,4-dioxane is a synthetic industrial chemical often found in groundwater at sites contaminated with chlorinated solvents because of its widespread use as a stabilizer for chlorinated solvents (most commonly 1,1,1-trichloroethane).
- Hydrophilic and highly miscible in water.
- 1,4-Dioxane was detected in groundwater at the Site in 2003 and was identified as a Chemical-of-Concern in the Record-of-Decision (ROD) and subject to Long-Term Monitoring. A specific source was not found.
- The ROD was updated to include the chemical for active remediation of the "source area" in groundwater.
- The term "source area" refers to the highest concentrations of the chemical in groundwater (investigations and remediation).

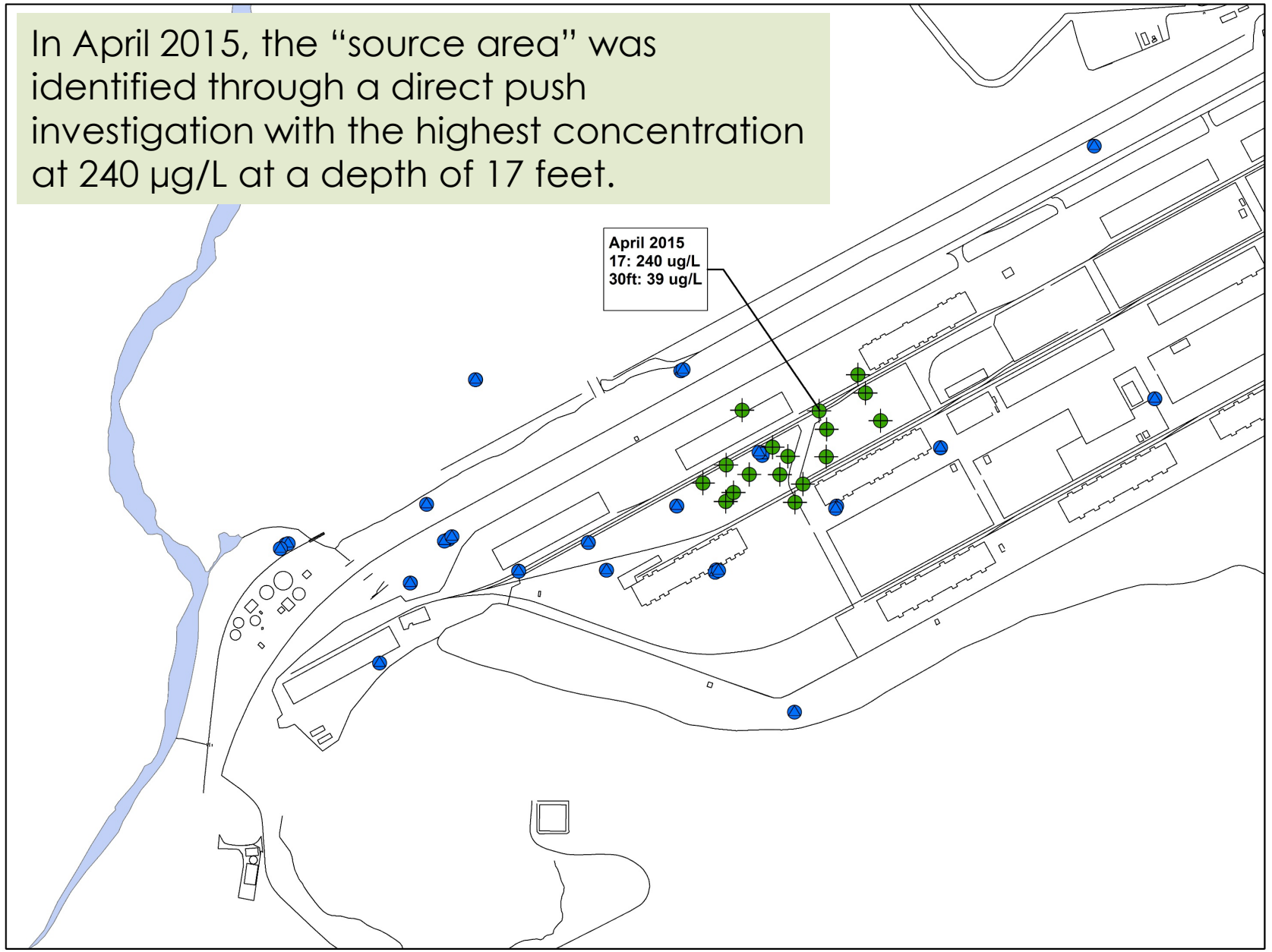
Site Background

- Facilities at the Site include industrial operations, warehouses, and office buildings.
- Groundwater is found in alluvial and flood plain deposits, which occur to a total depth of approximately 110 feet below ground surface
- Depth to groundwater at the Site ~12 feet.
- Controlling geology - interbedded layers of silty sand, sand and silt down to 55 feet (very minor clay layers).

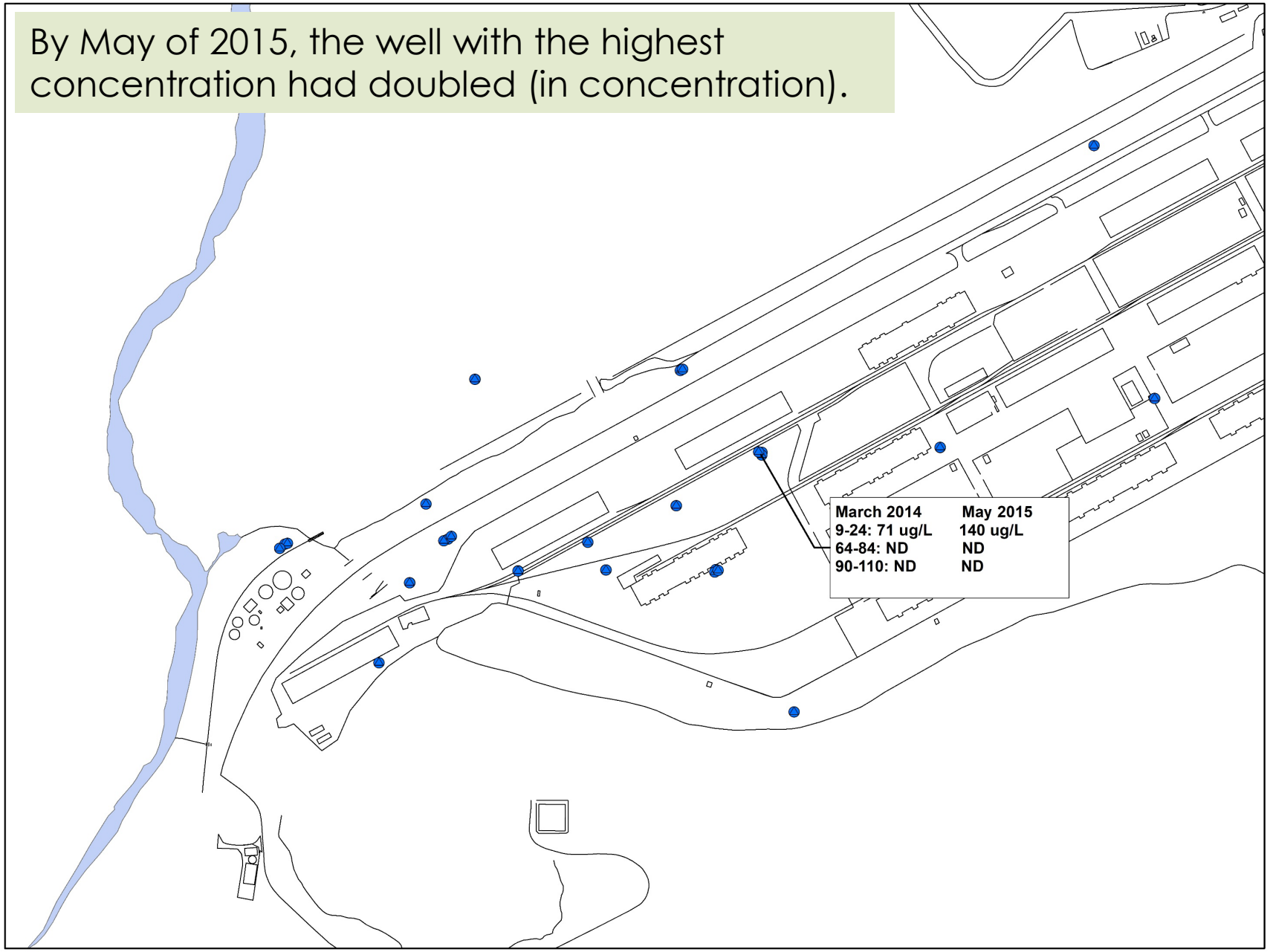
In 2014, groundwater monitoring detected 1,4-Dioxane at 71 ug/L, well above its Remediation Goal of 6.7 ug/L.



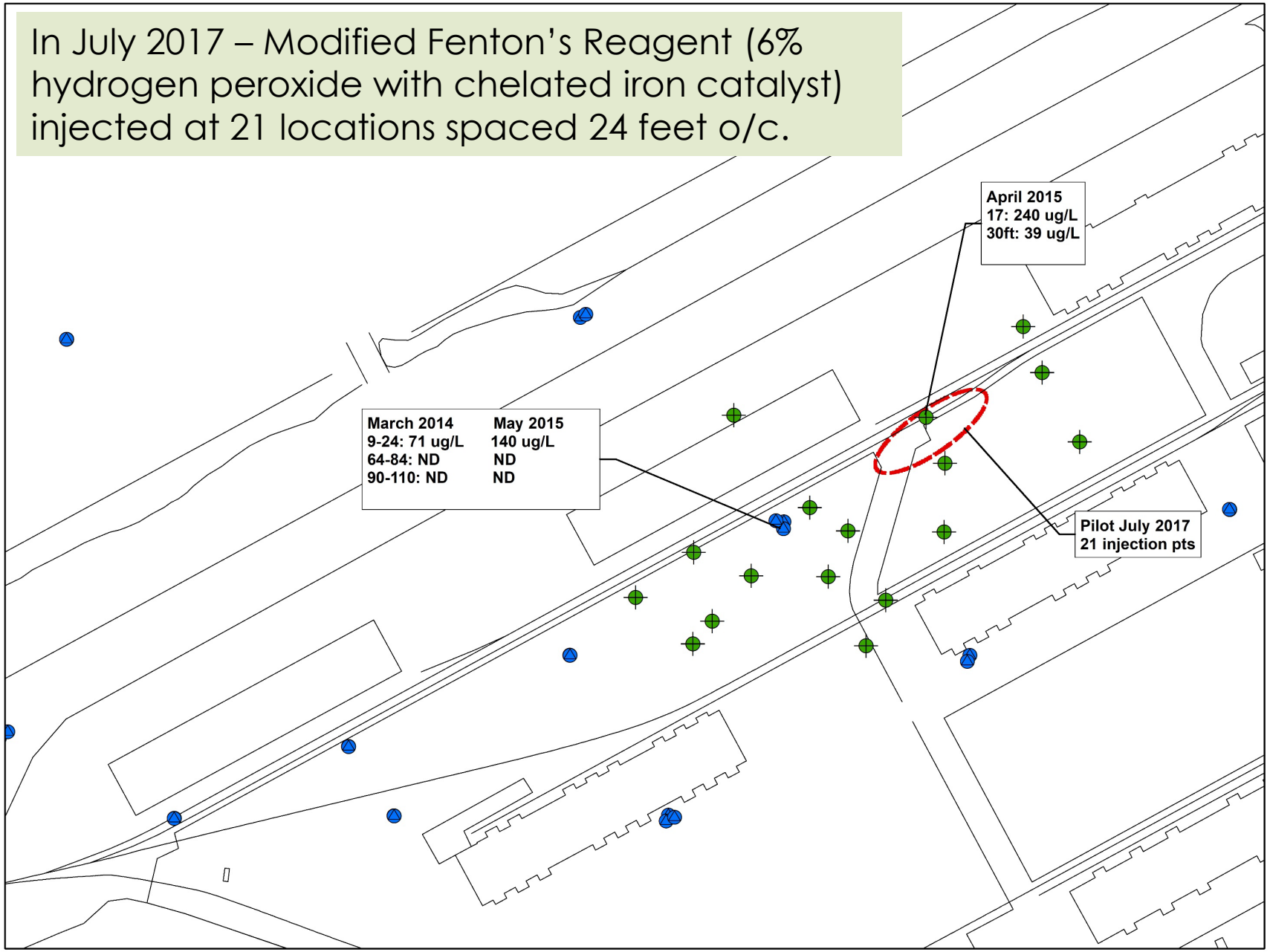
In April 2015, the "source area" was identified through a direct push investigation with the highest concentration at 240 µg/L at a depth of 17 feet.



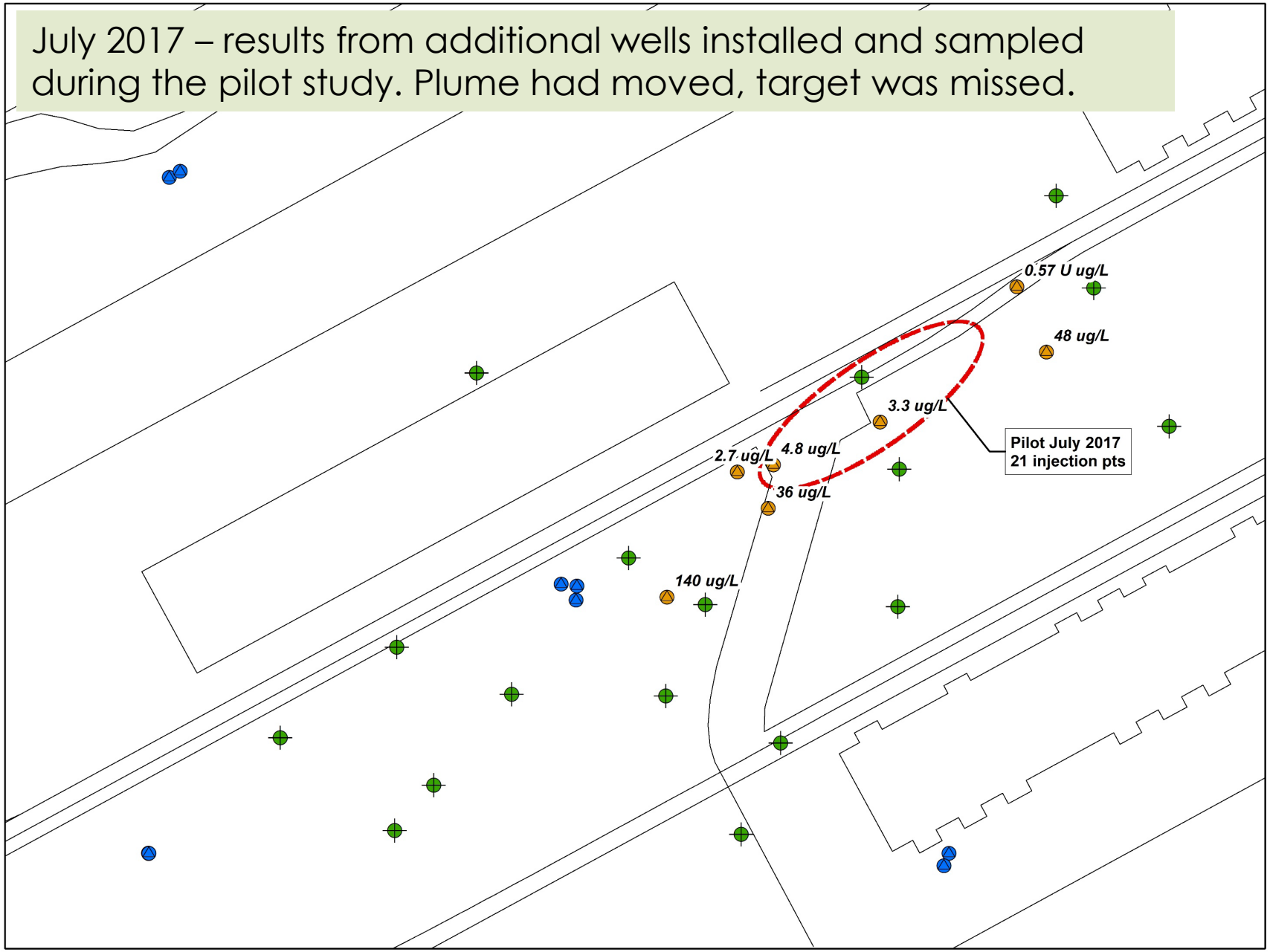
By May of 2015, the well with the highest concentration had doubled (in concentration).



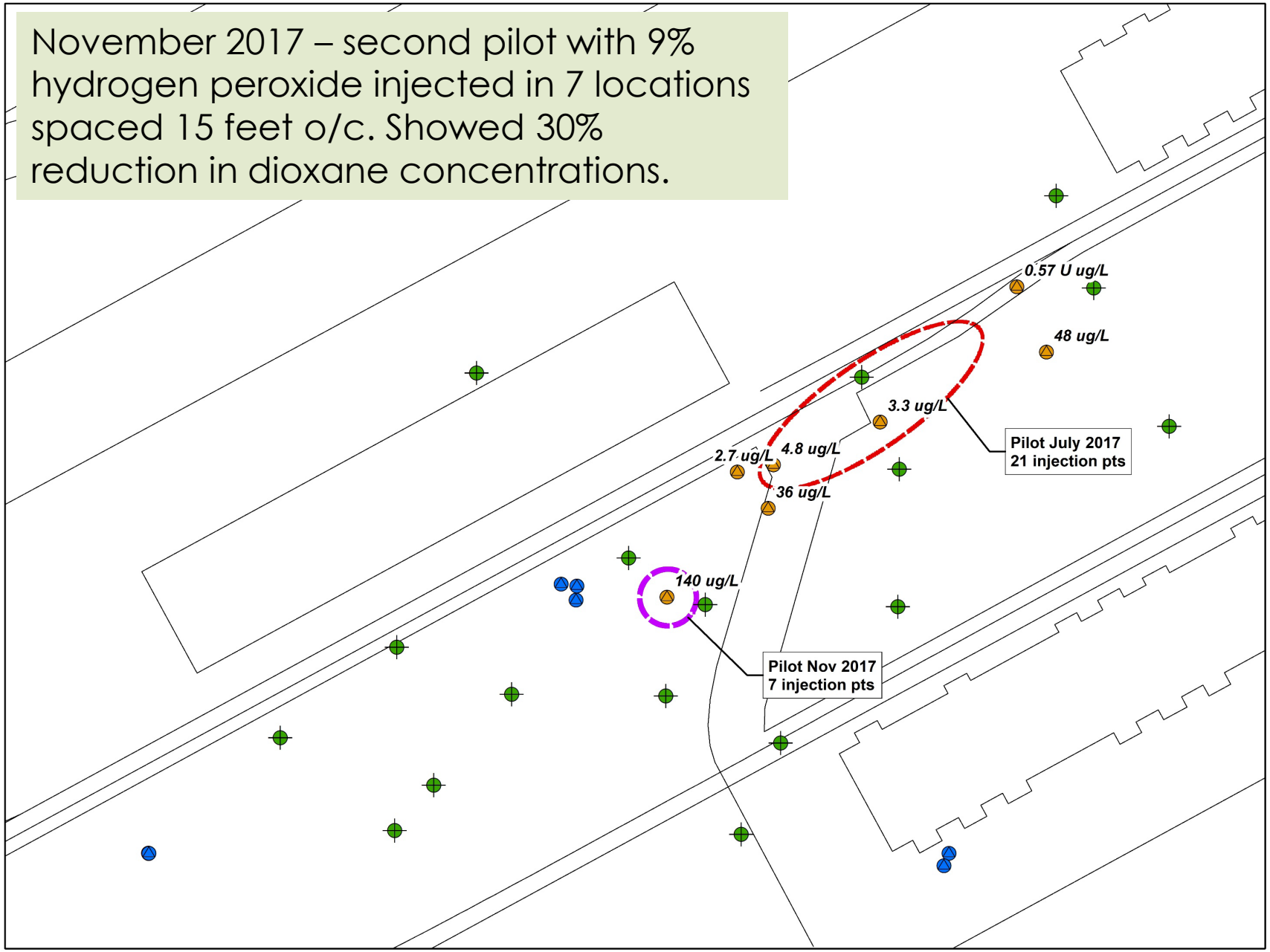
In July 2017 – Modified Fenton's Reagent (6% hydrogen peroxide with chelated iron catalyst) injected at 21 locations spaced 24 feet o/c.



July 2017 – results from additional wells installed and sampled during the pilot study. Plume had moved, target was missed.



November 2017 – second pilot with 9% hydrogen peroxide injected in 7 locations spaced 15 feet o/c. Showed 30% reduction in dioxane concentrations.

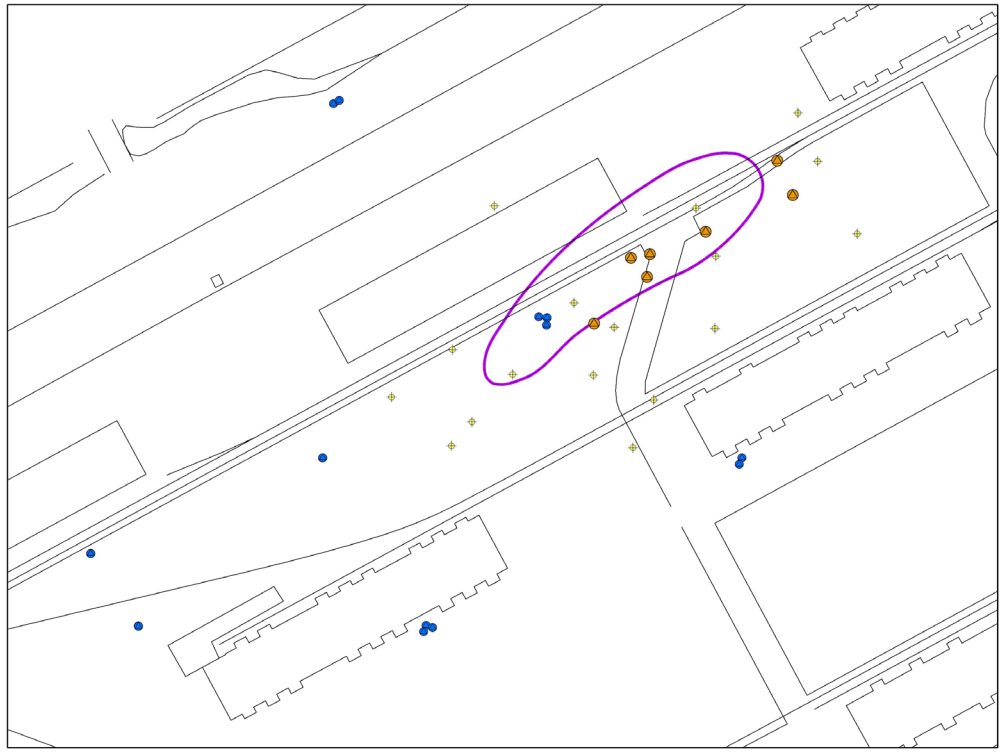


Contract for full-scale In-Situ Chemical Oxidation of the Dioxane Plume

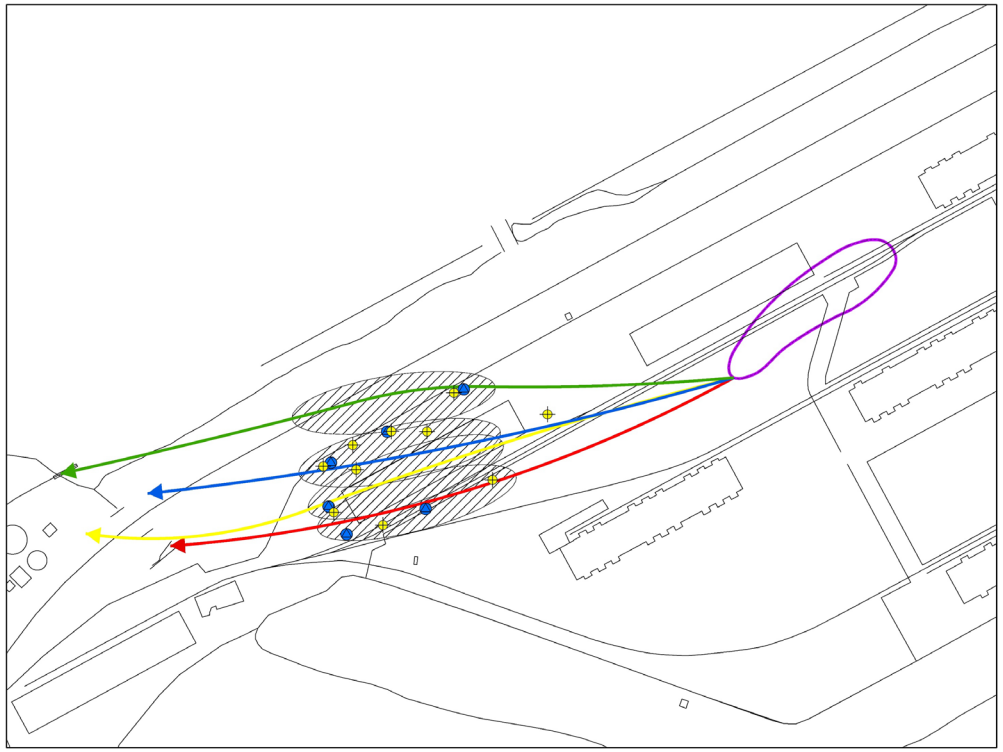
- Problem
  - Fast moving plume
  - Don't know where it is
  - Where its going (presumably downgradient)
  - Or how fast

Solution: Predict location of the source area (>100 ug/L) one year ahead

- Sufficient data between 2015 and 2020.
- Grouped data into temporally-related clusters to represent the source area in time and space.
- Determined the 100 ug/L plume in 2015.
- Determined rate of movement of unit mass of the plume: ~200 ft/year.

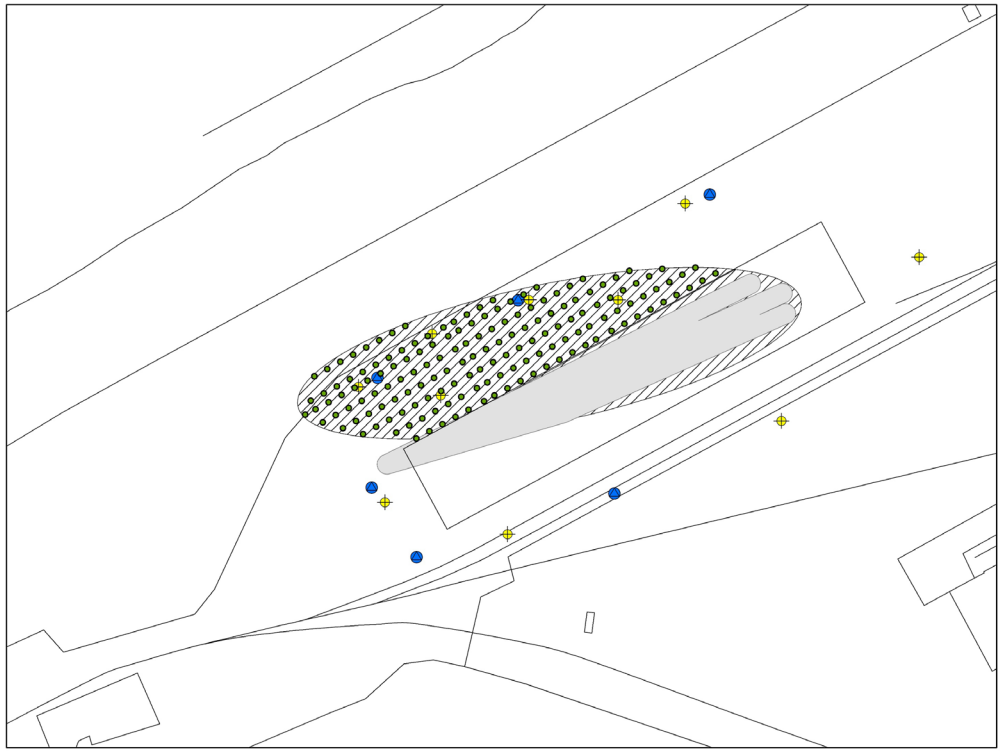


- Simplified plume shape.
- Determined flow paths.
- Mapped path of plume along flow paths at calculated rate.
- Predicted location in January 2021.
- Design Plan included pre-injection location verification followed by injections.

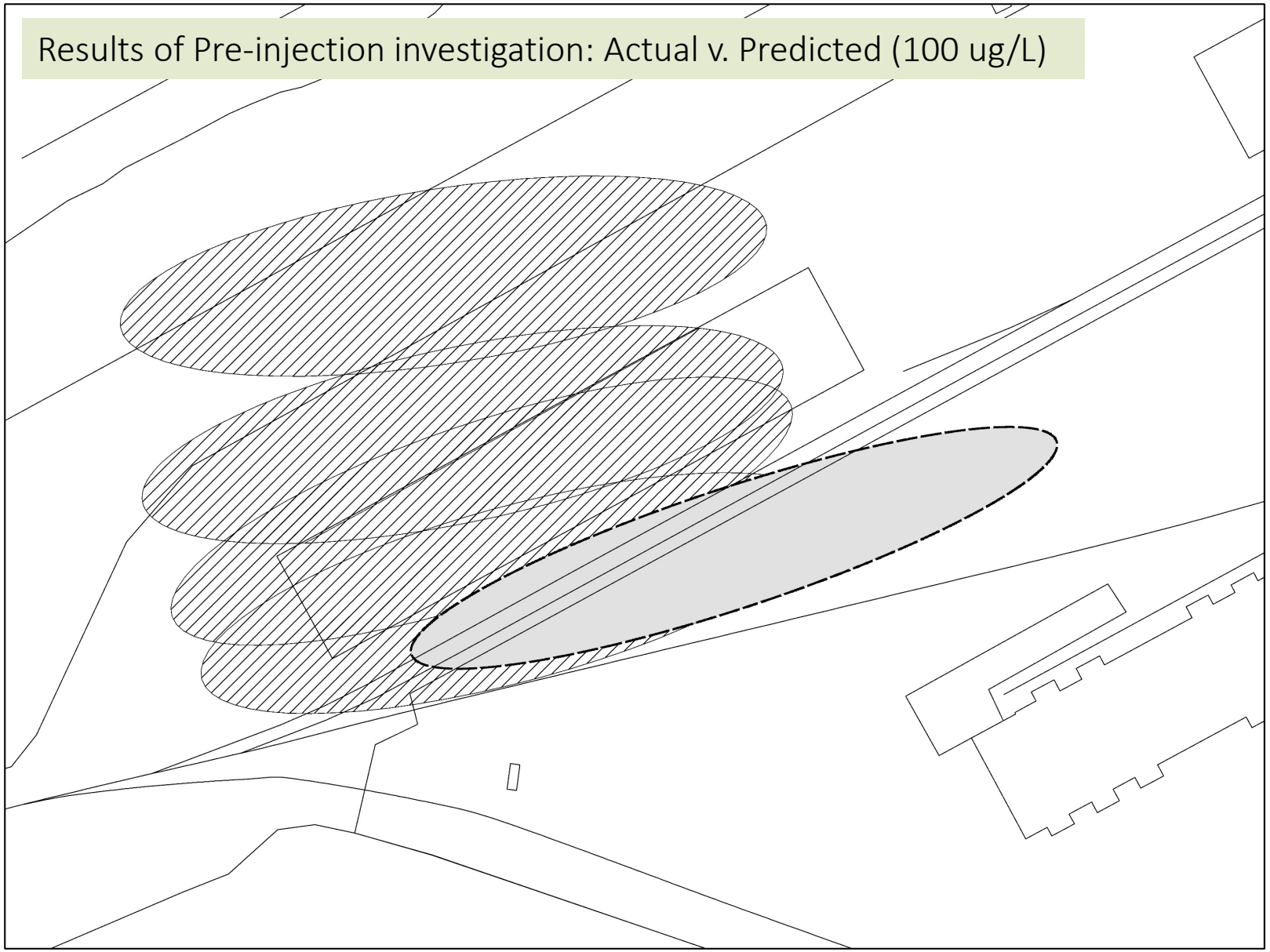


Design Plan included pre-injection sampling

- Pre-injection investigation: borings and wells.
- Design - assume part of plume is beneath the building (worst case).
- Horizontal ISCO injections.
- Vertical ISCO injection points.

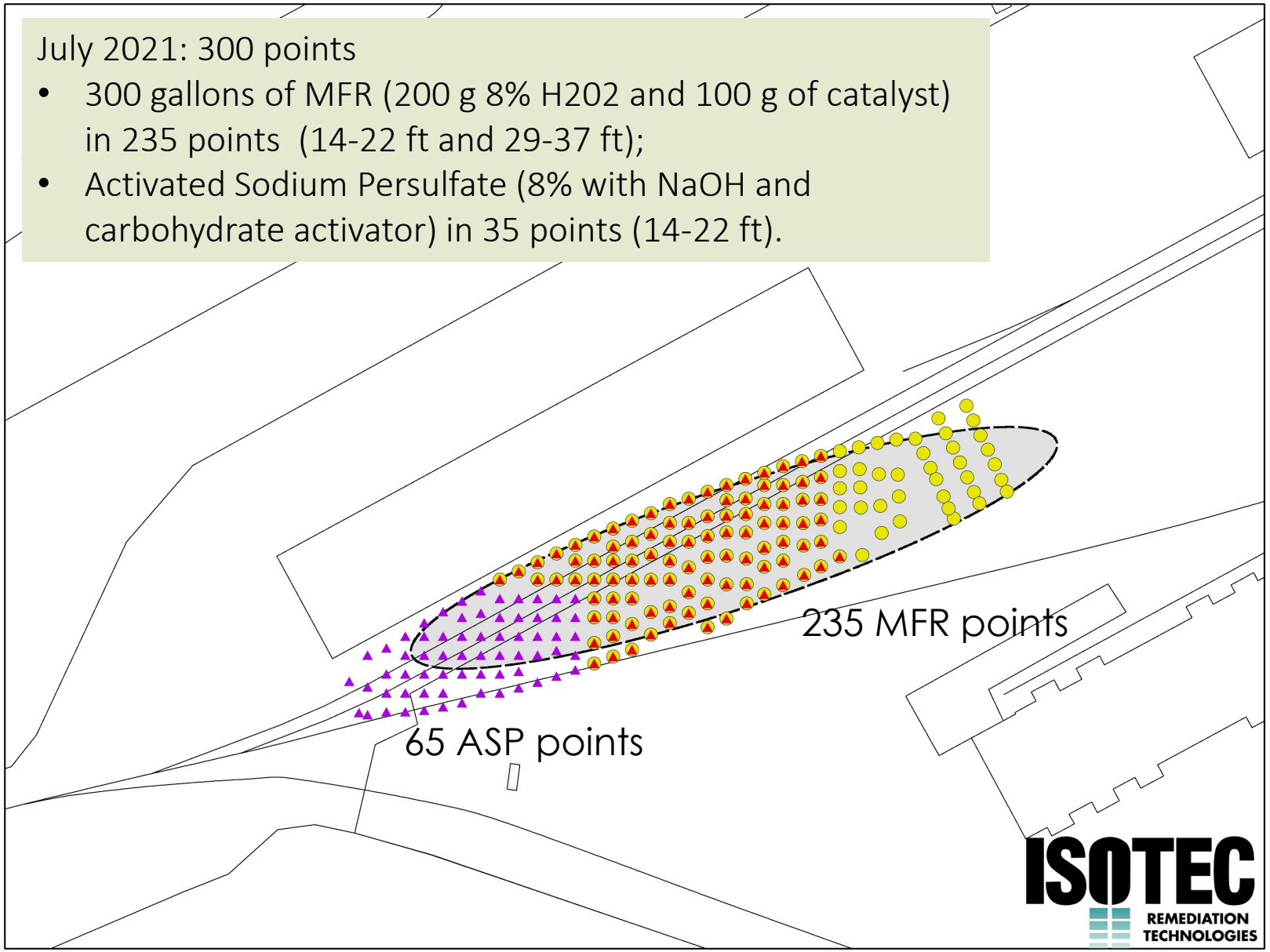


Results of Pre-injection investigation: Actual v. Predicted (100 ug/L)

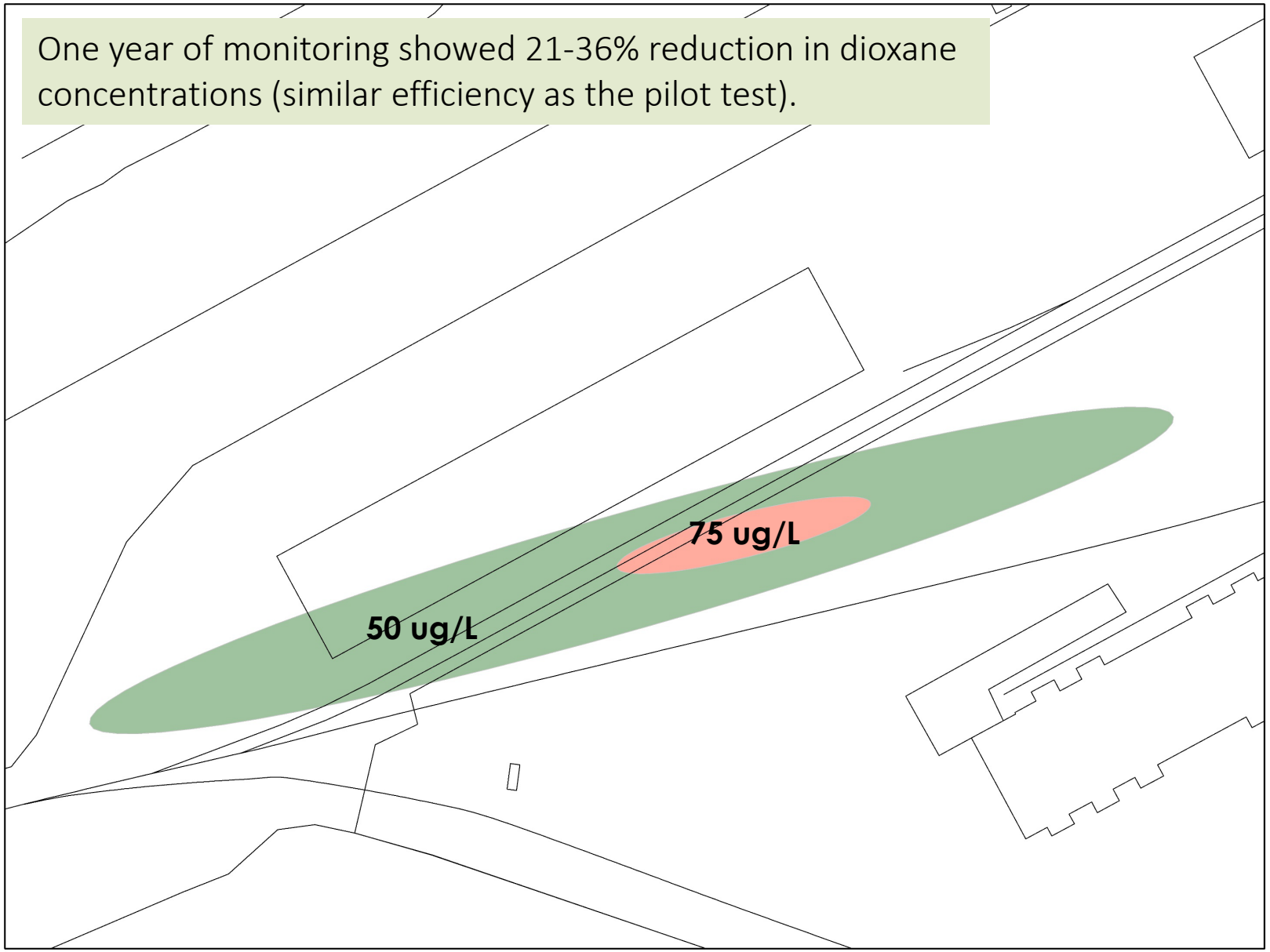


July 2021: 300 points

- 300 gallons of MFR (200 g 8% H202 and 100 g of catalyst) in 235 points (14-22 ft and 29-37 ft);
- Activated Sodium Persulfate (8% with NaOH and carbohydrate activator) in 35 points (14-22 ft).



One year of monitoring showed 21-36% reduction in dioxane concentrations (similar efficiency as the pilot test).



Conclusions

- **Important to collect and visualize all existing data and avoid missing the target**
- Simple calculations
- Make your plan flexible to accommodate modifications
- ISCO needs multiple injections (30% efficiency = 5-injection cycle)

Questions?