



Solar Thermal Activation of Persulfate for ISCO Source Zone Treatment at Former Industrial Site

T. Schöne, P. Jacobs, R. Engelhardt (TAUW)

Pedro Aquino (Grupo EPA)

Jesse Overgord (Philips)

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What is presented?

- **Part 1: Background information**
- **Part 2: Remedial Design**
- **Part 3: Results, Outlook and Lessons Learned**



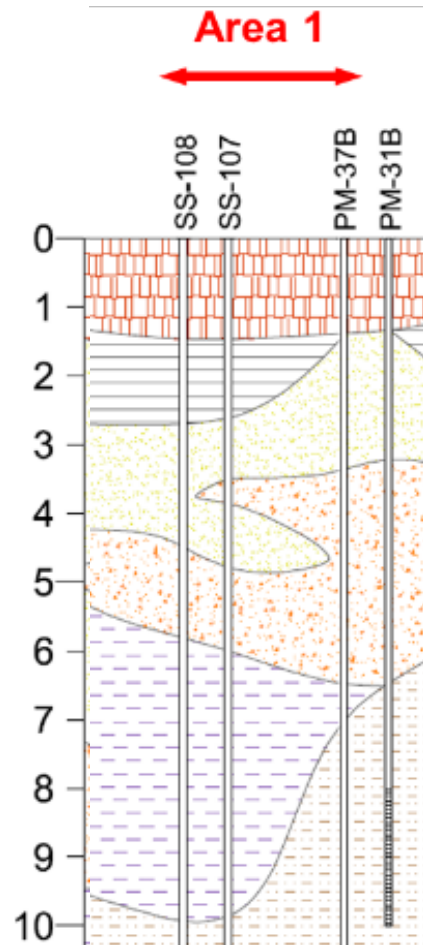


Part 1: Background information

Former industrial site located in São Paulo, Brazil

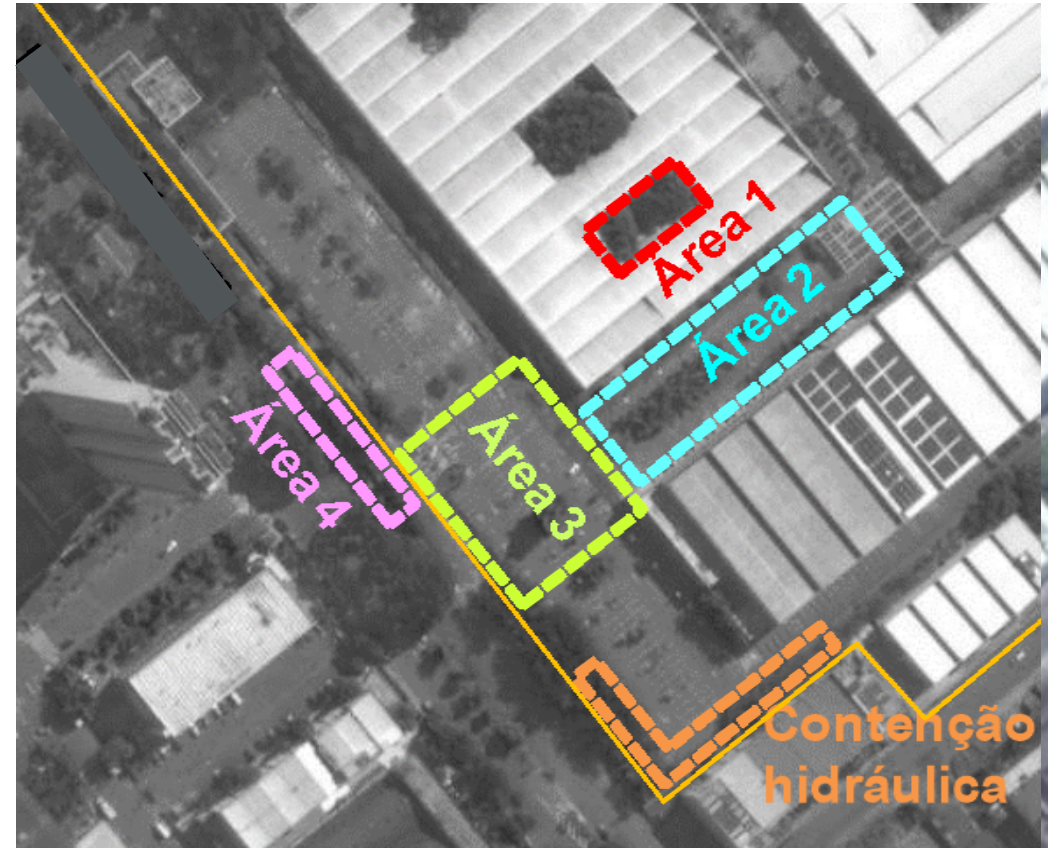


Large-scale contamination with CVOC on site



- Alluvial deposits
- Alternating layers of sand/gravel and silt/clay

Heterogeneous soil



ISCO recirculation preferred remediation approach for Area 1

- Max. 13,000 mg/kg 1,1,1-TCA, 1500 mg/kg TCE in soil
- max 94,000 µg/L 1,1,1-TCA, 12,000 µg/L TCE in groundwater
- ~380 m² treatment area

Remediation targets

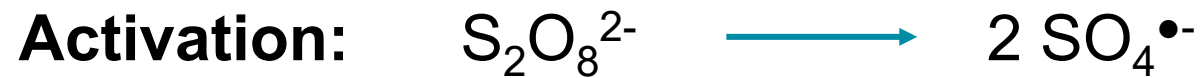
1. Mitigation of risks
2. Elimination of hot spots
3. Mass removal



Activation of persulfate required due to presence of 1,1,1-TCA

- Oxidizer: $\text{Na}_2\text{S}_2\text{O}_8$ (sodium persulfate salt), KLOZUR® SP

Persulfate anion $\text{S}_2\text{O}_8^{2-}$ (2.1 V)



Sulfate radical $\text{SO}_4^{\bullet-}$ (2.6 V)

Hydroxyl radical $\text{OH}^{\bullet}$ (2.8 V)

Superoxide radical $\text{O}_2^{\bullet-}$ (-2.4 V)

} oxidative

} reductive

Heat-activation of persulfate favored by natural conditions



1

High natural groundwater temperatures

2

High solar radiation



Benefits

1. No additional chemicals needed
2. Minimized persulfate demand
3. Green energy solution

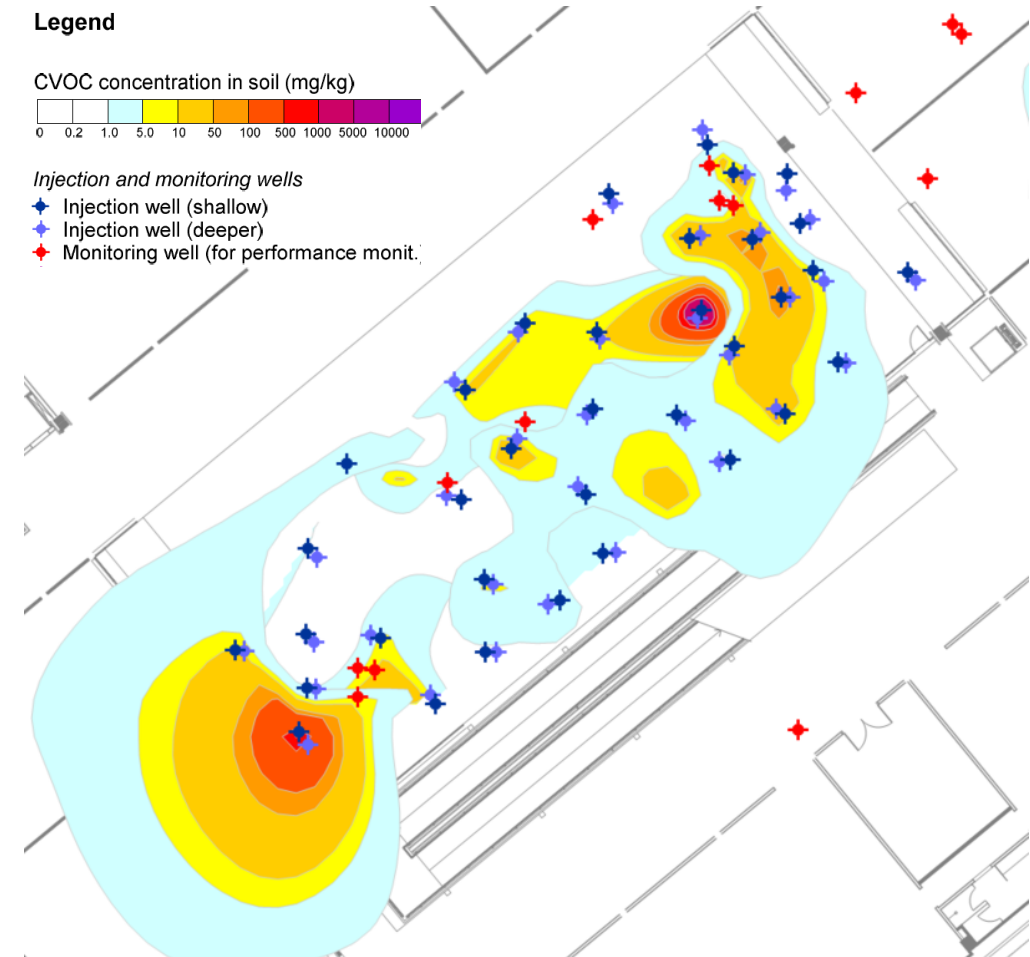


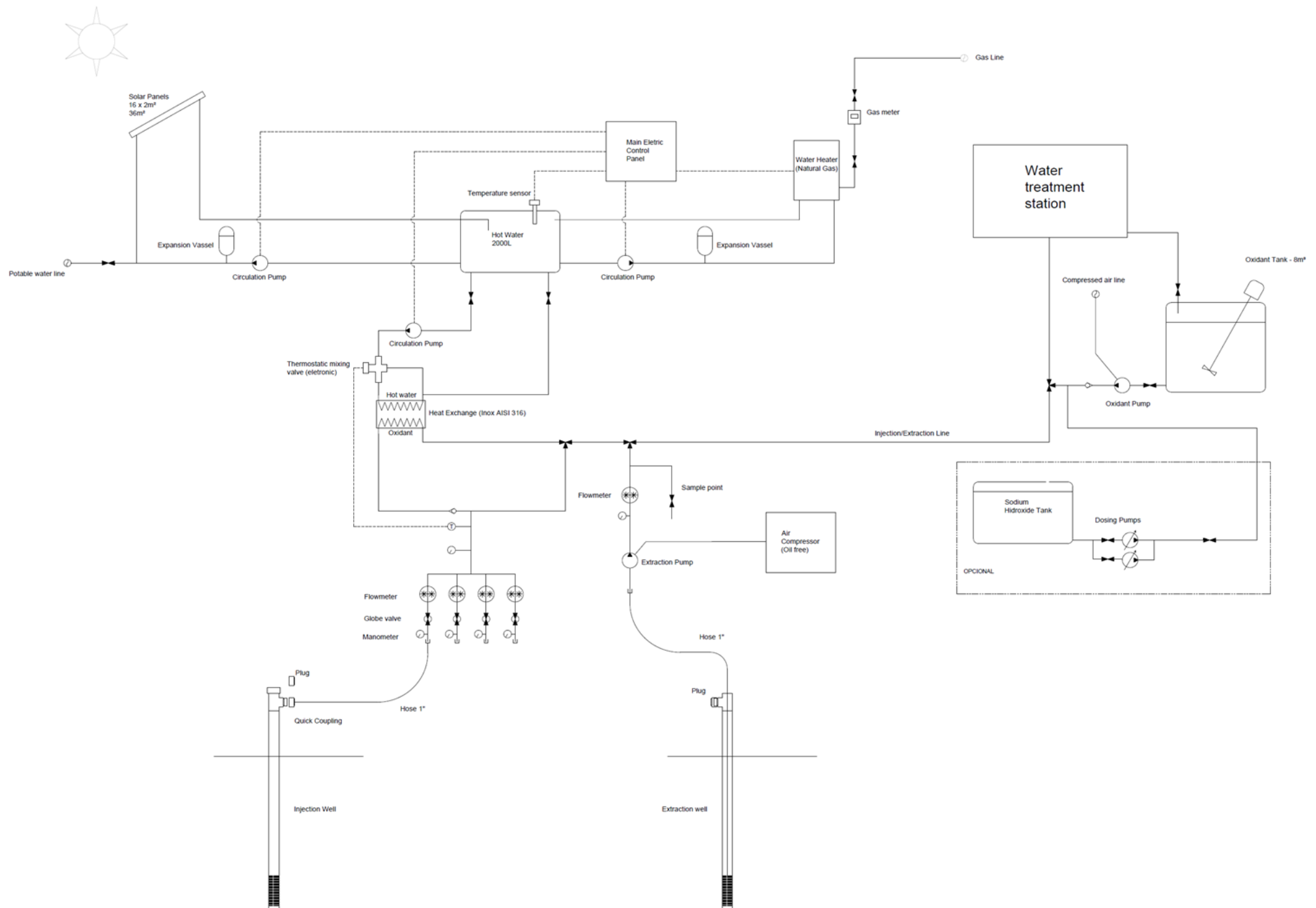


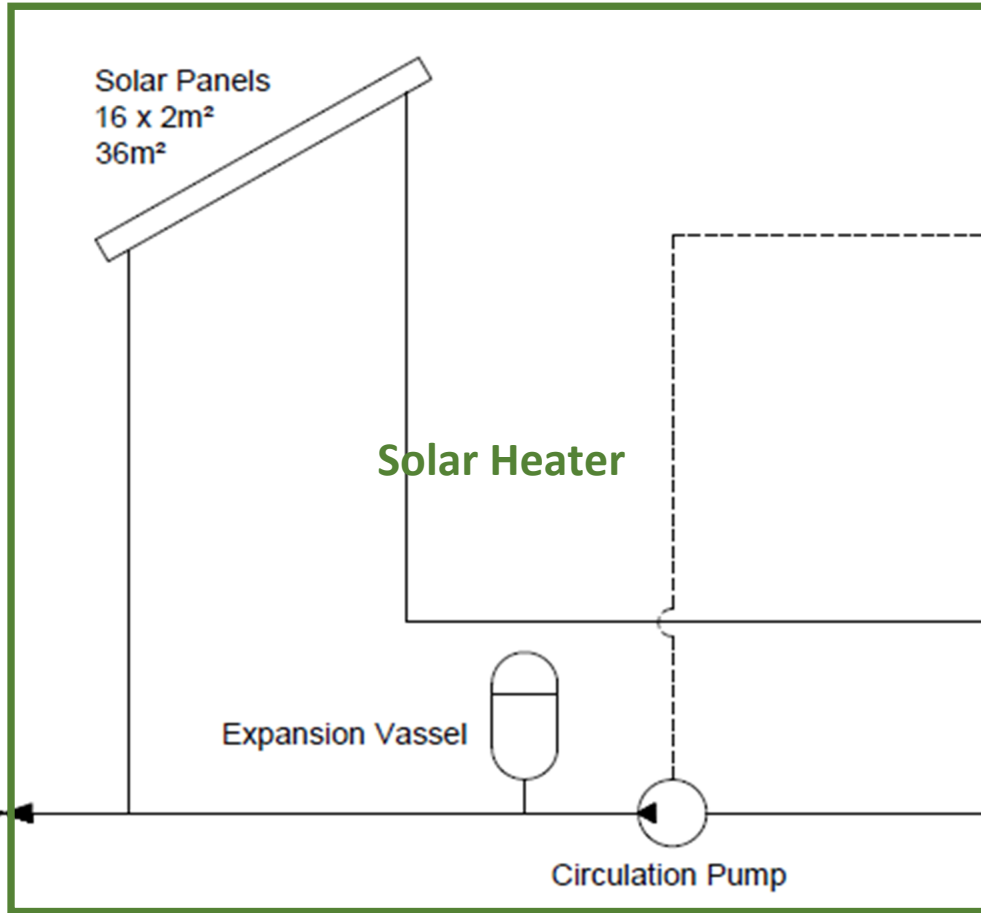
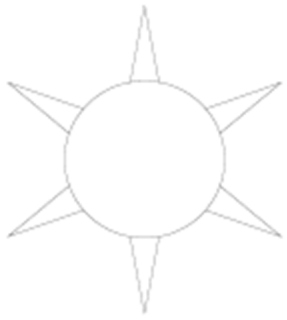
Part 2: Remedial Design

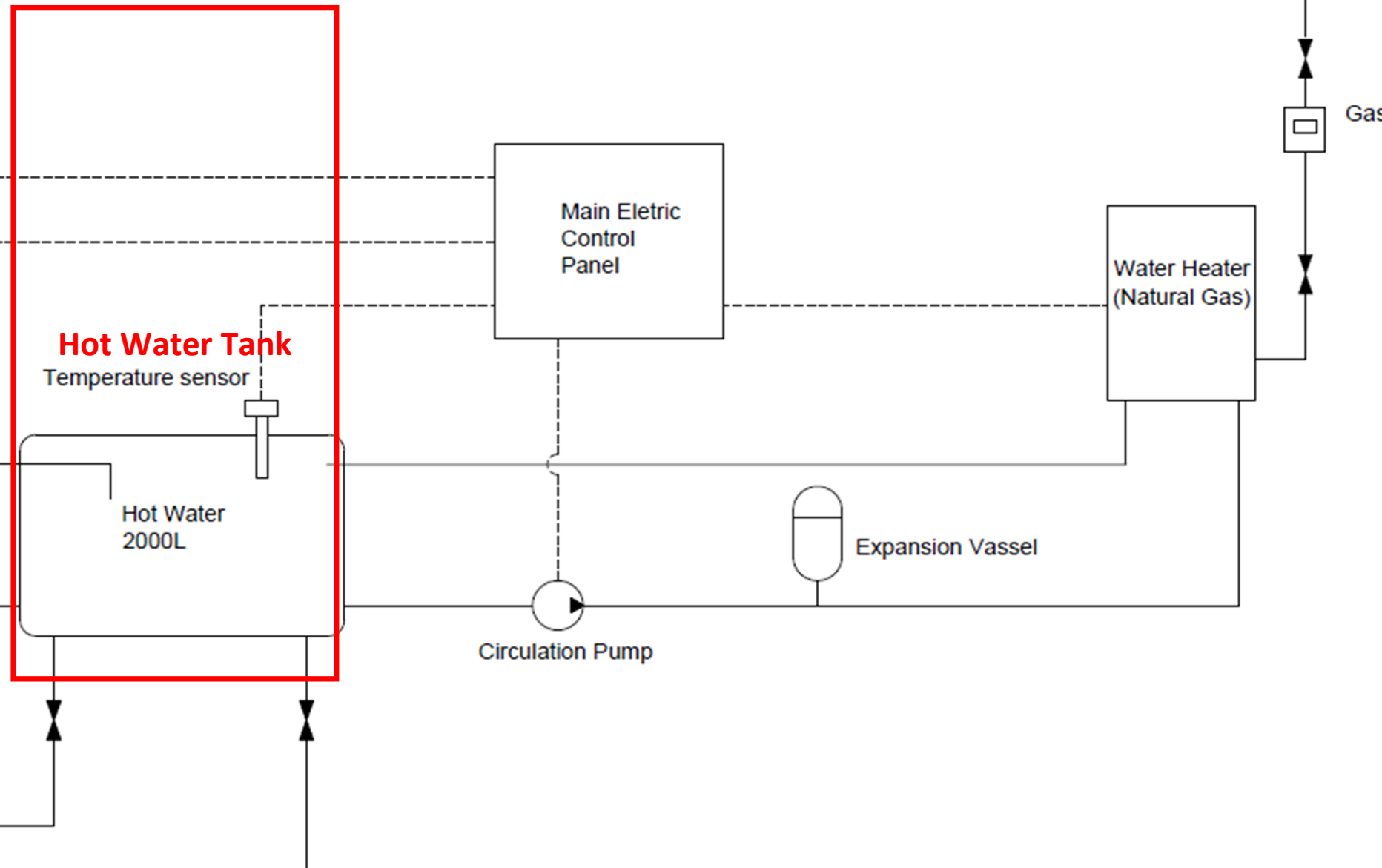
Heterogeneous soil addressed by dense well network

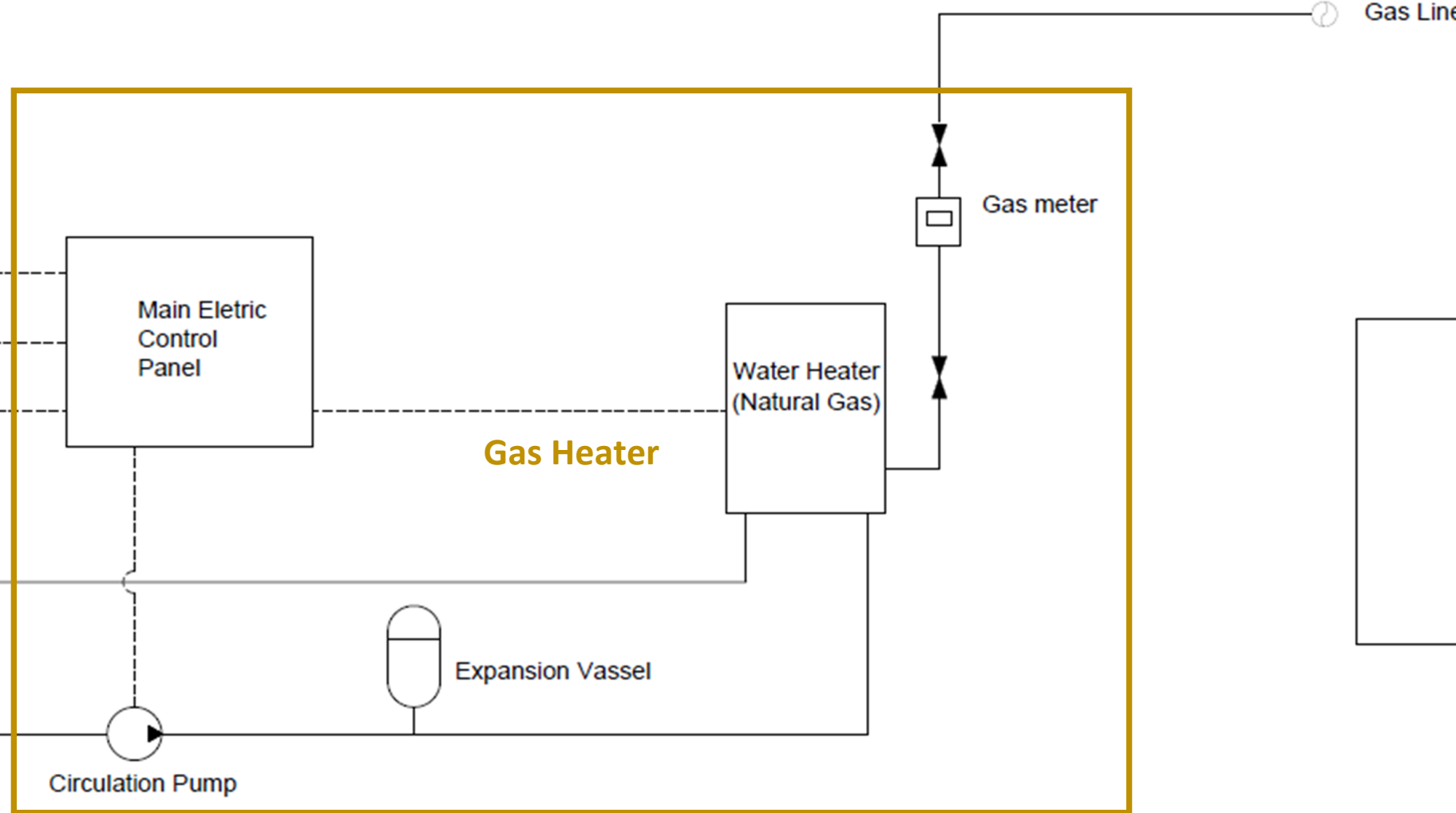
- 69 injection/extraction wells
- Two treatment depths: 1-5 and 5-9.5 m bgl
- 3-5 m distance between wells

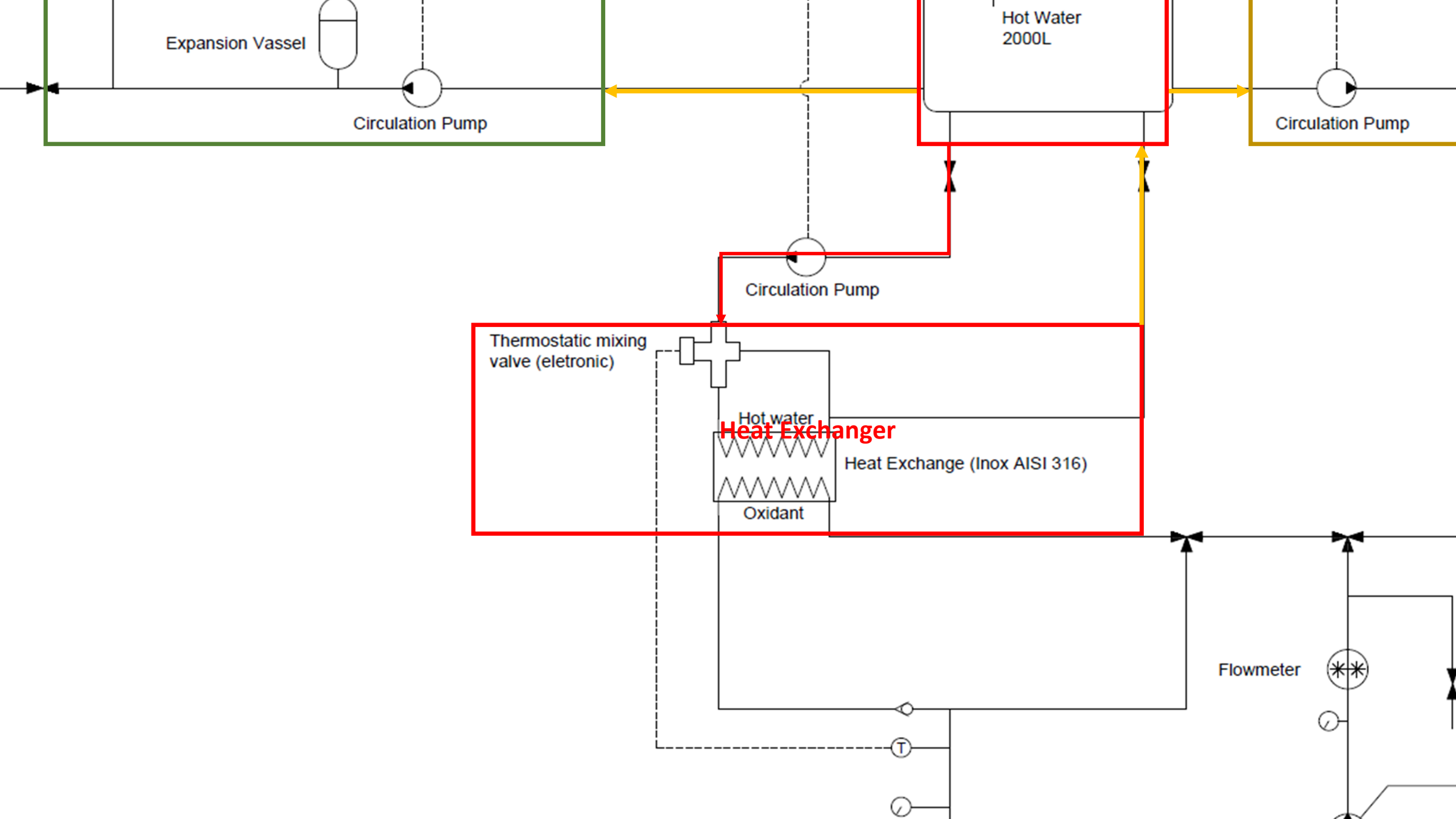


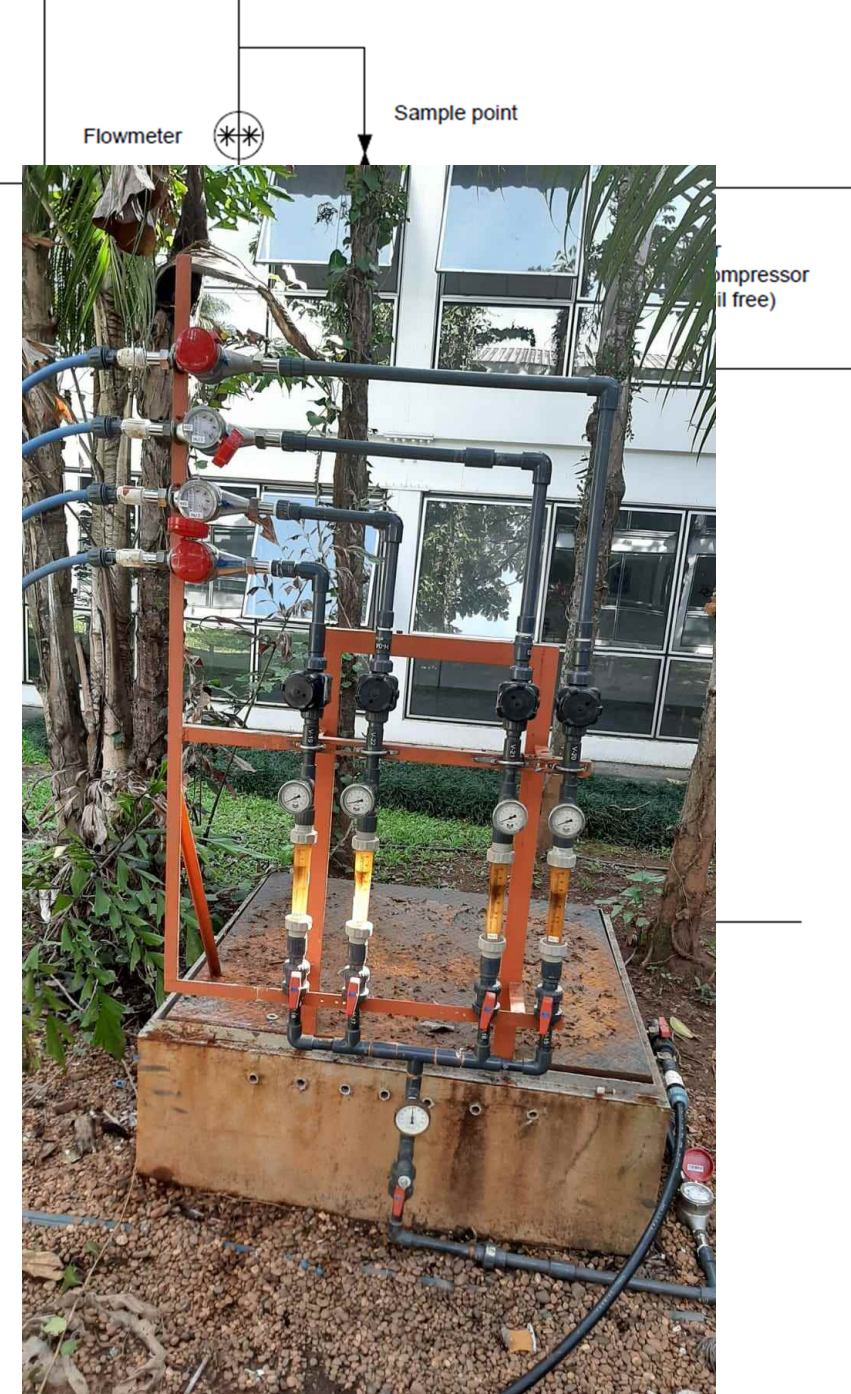
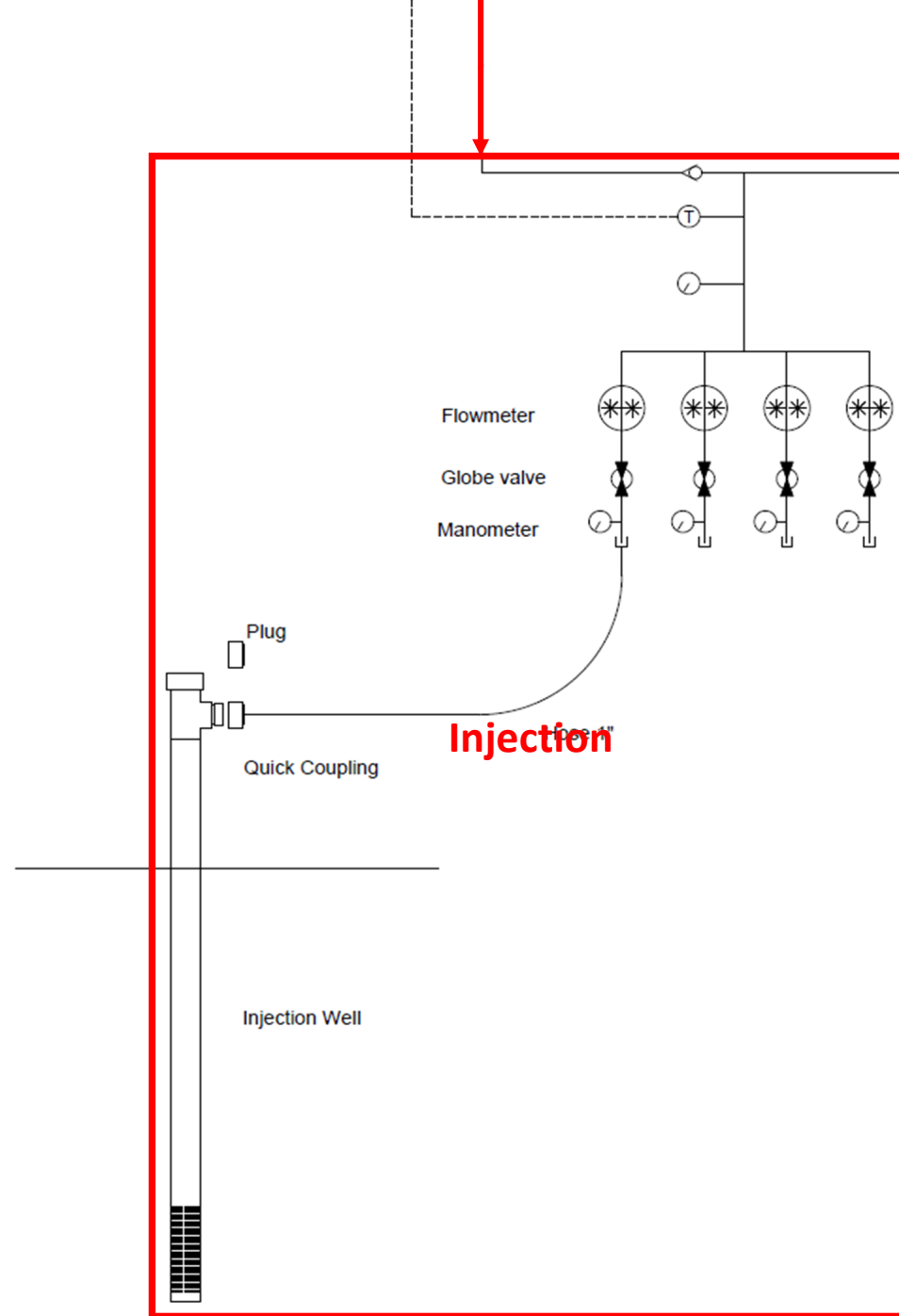


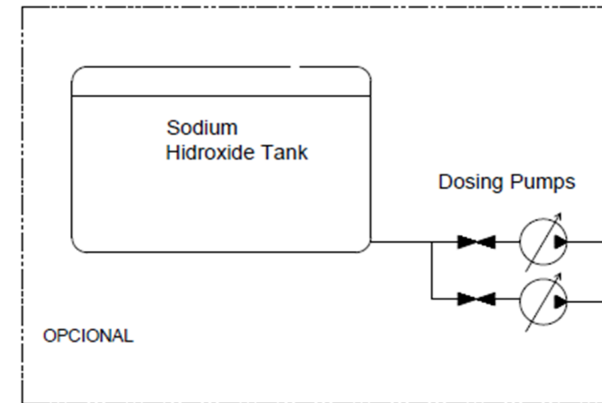
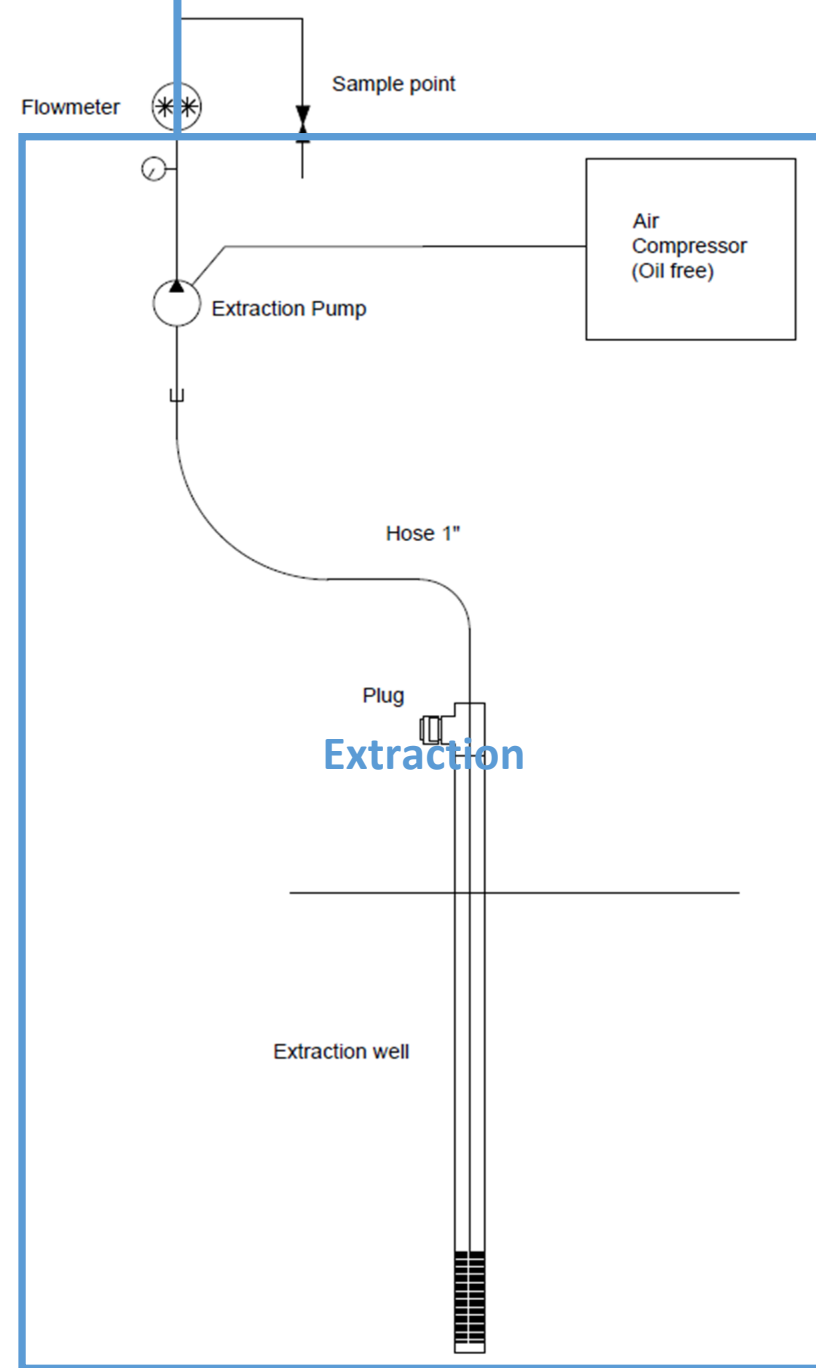
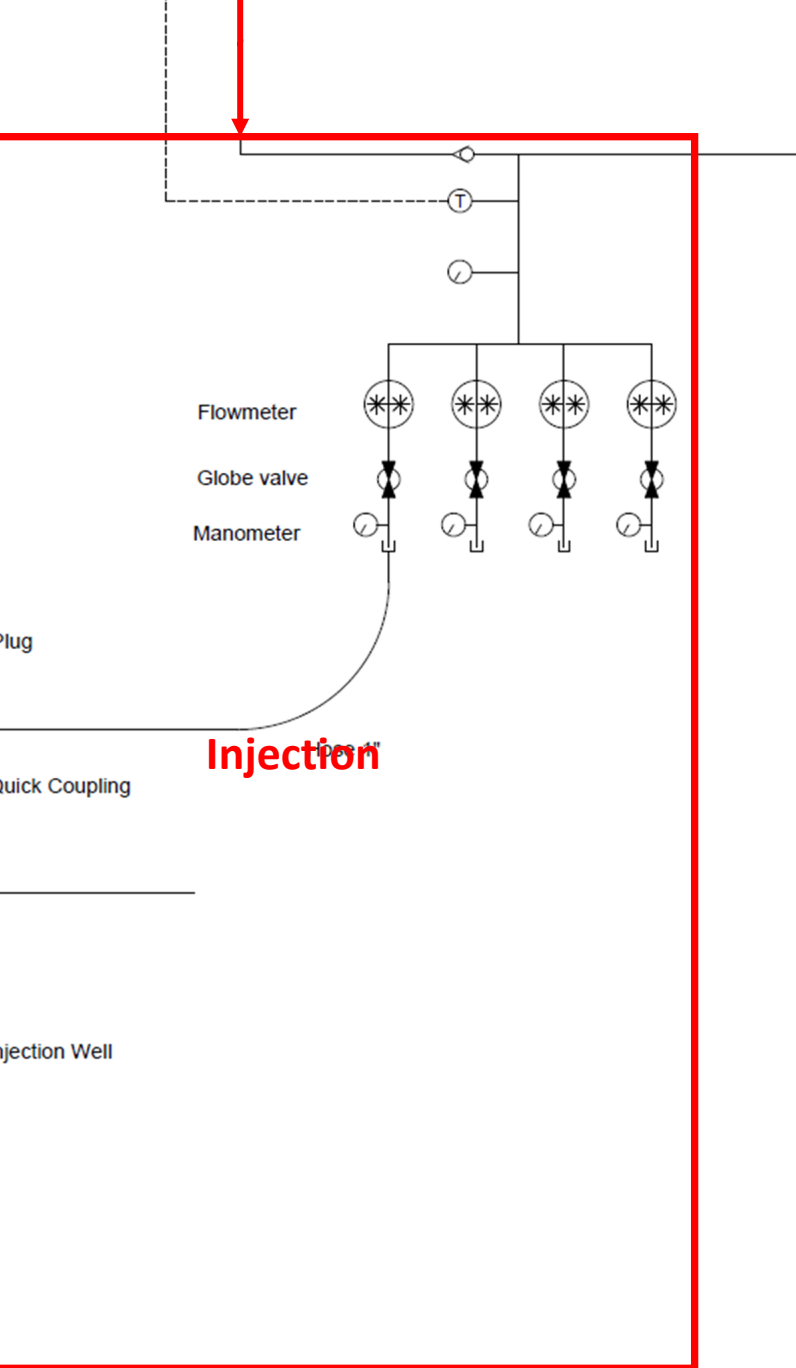


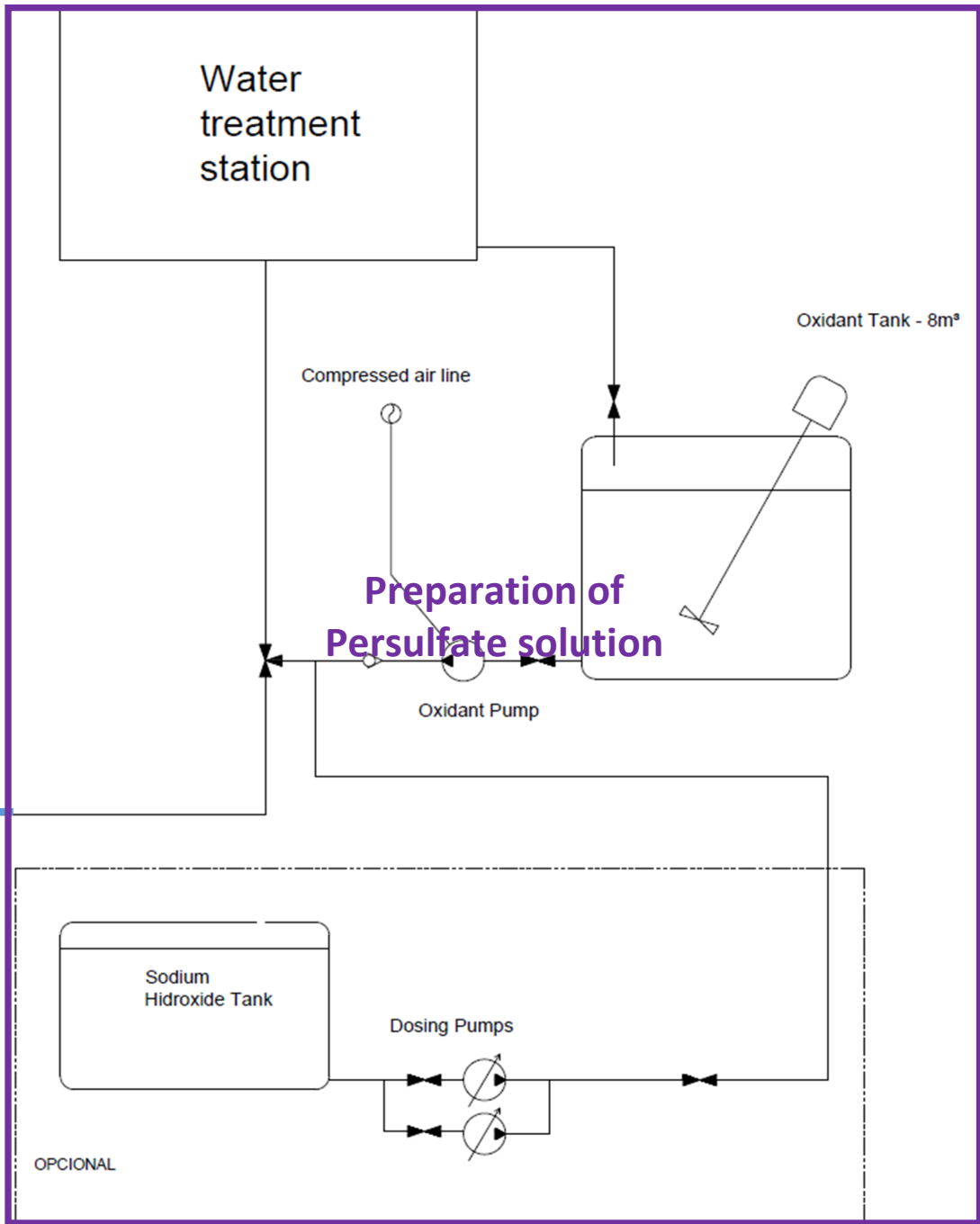
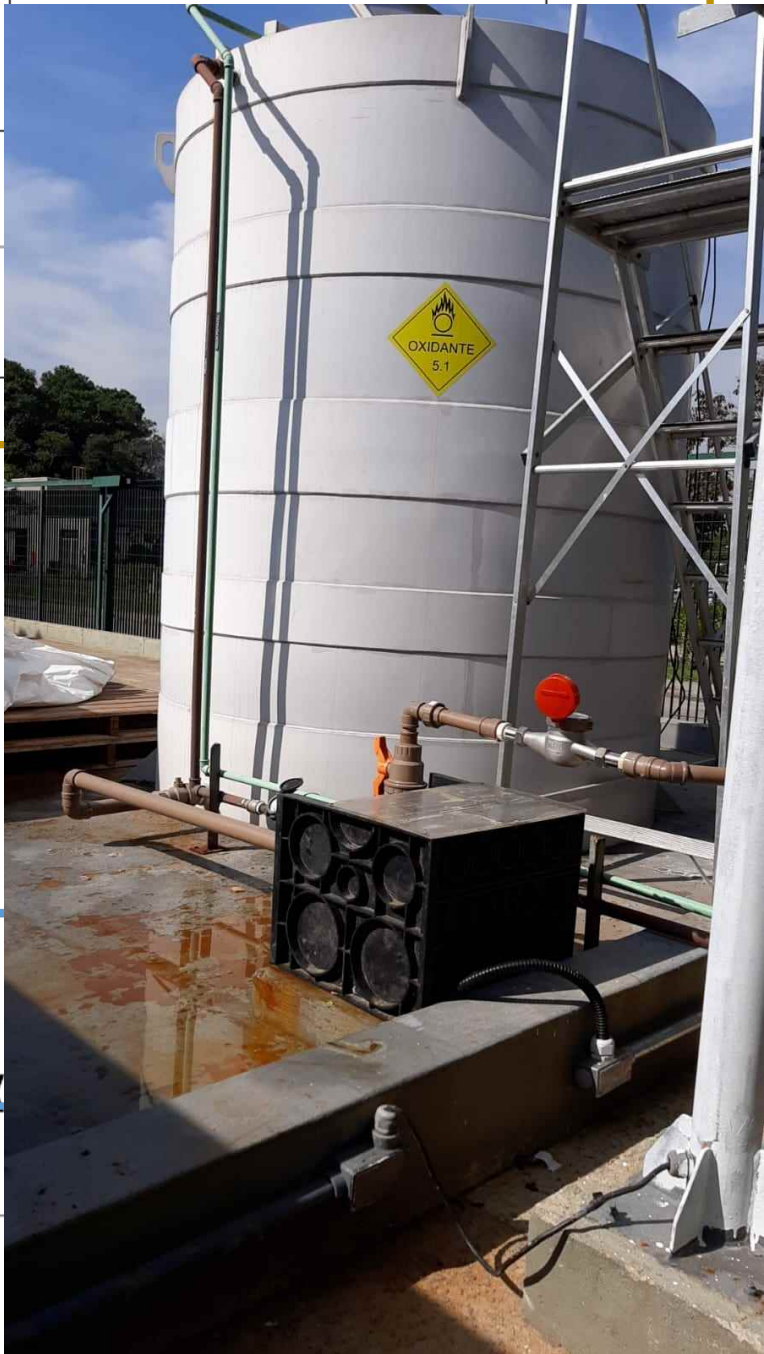
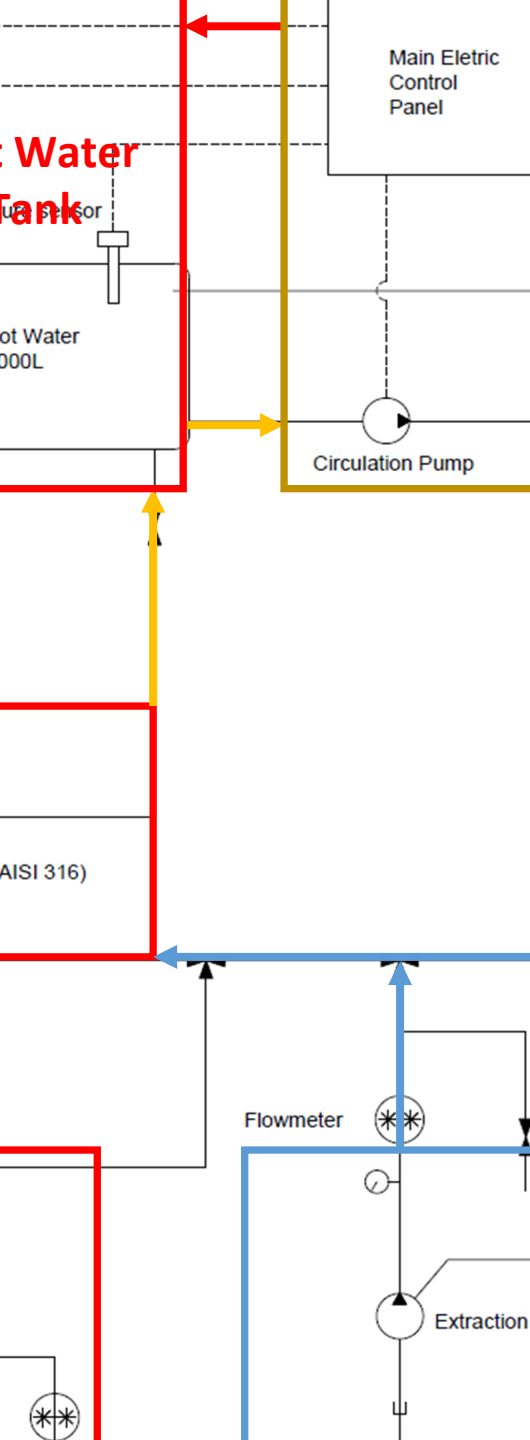


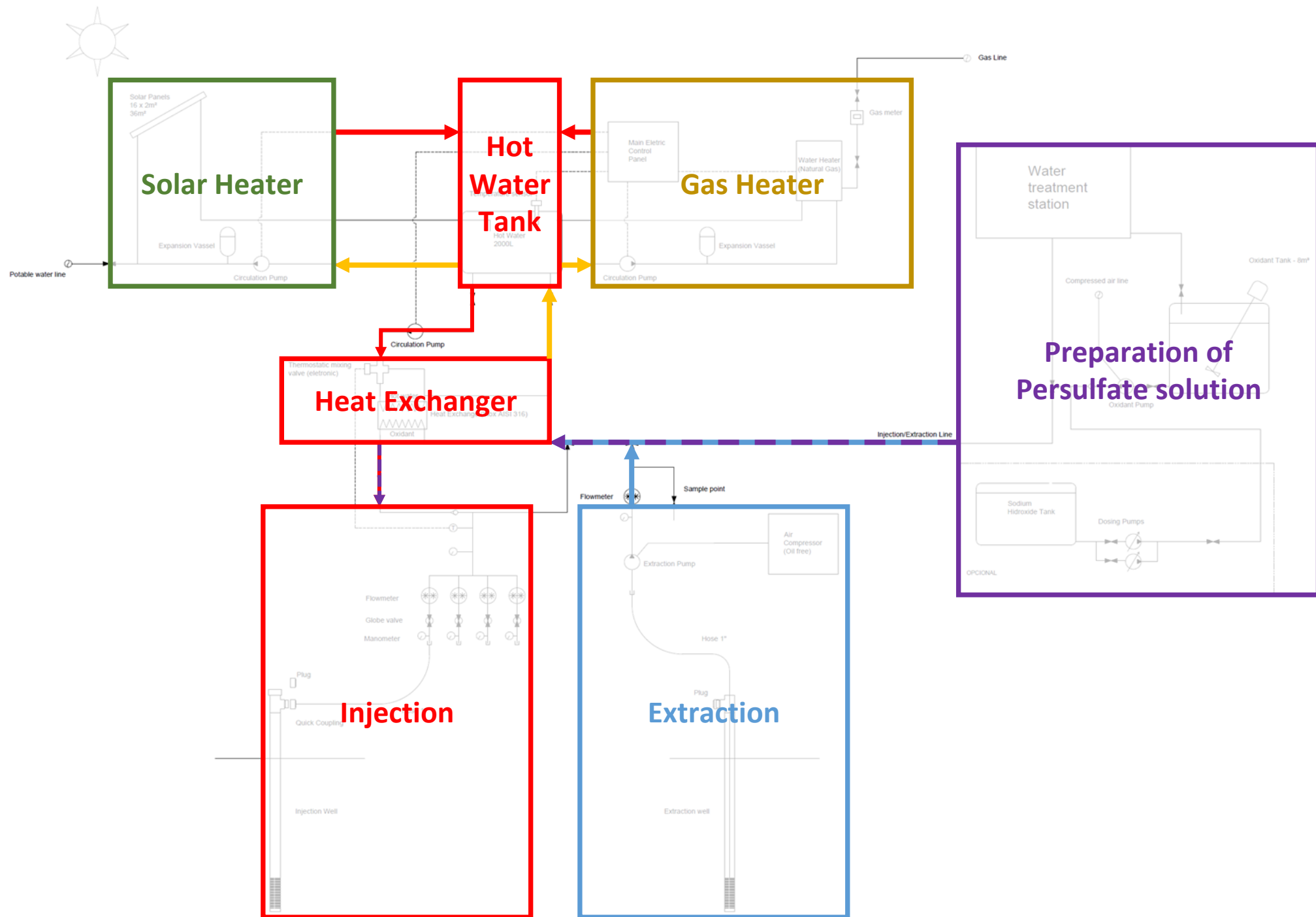












Multiple application strategy enables progressive insights

1st Cycle

Injection

Incubation

Extraction

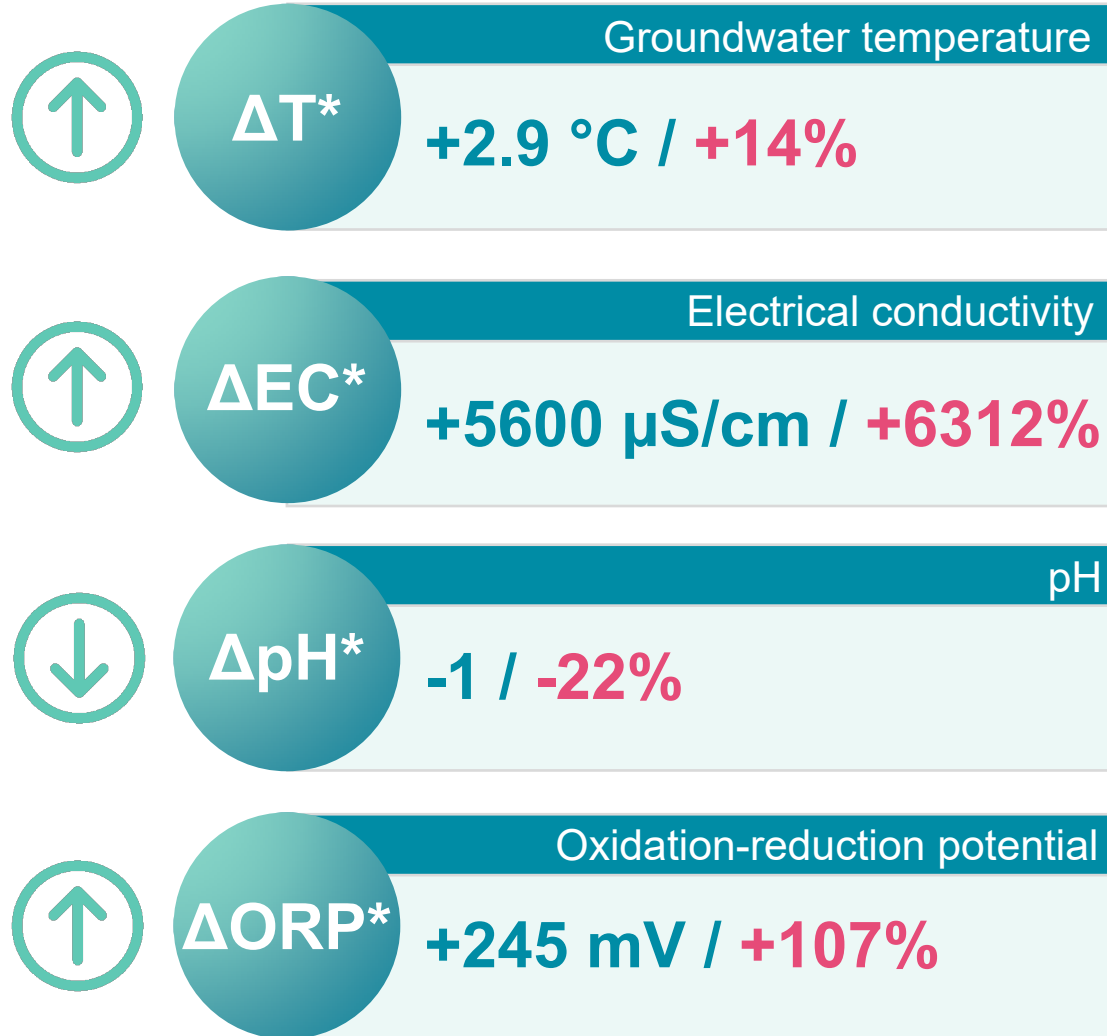






Part 3: Results, Outlook and Lessons Learned

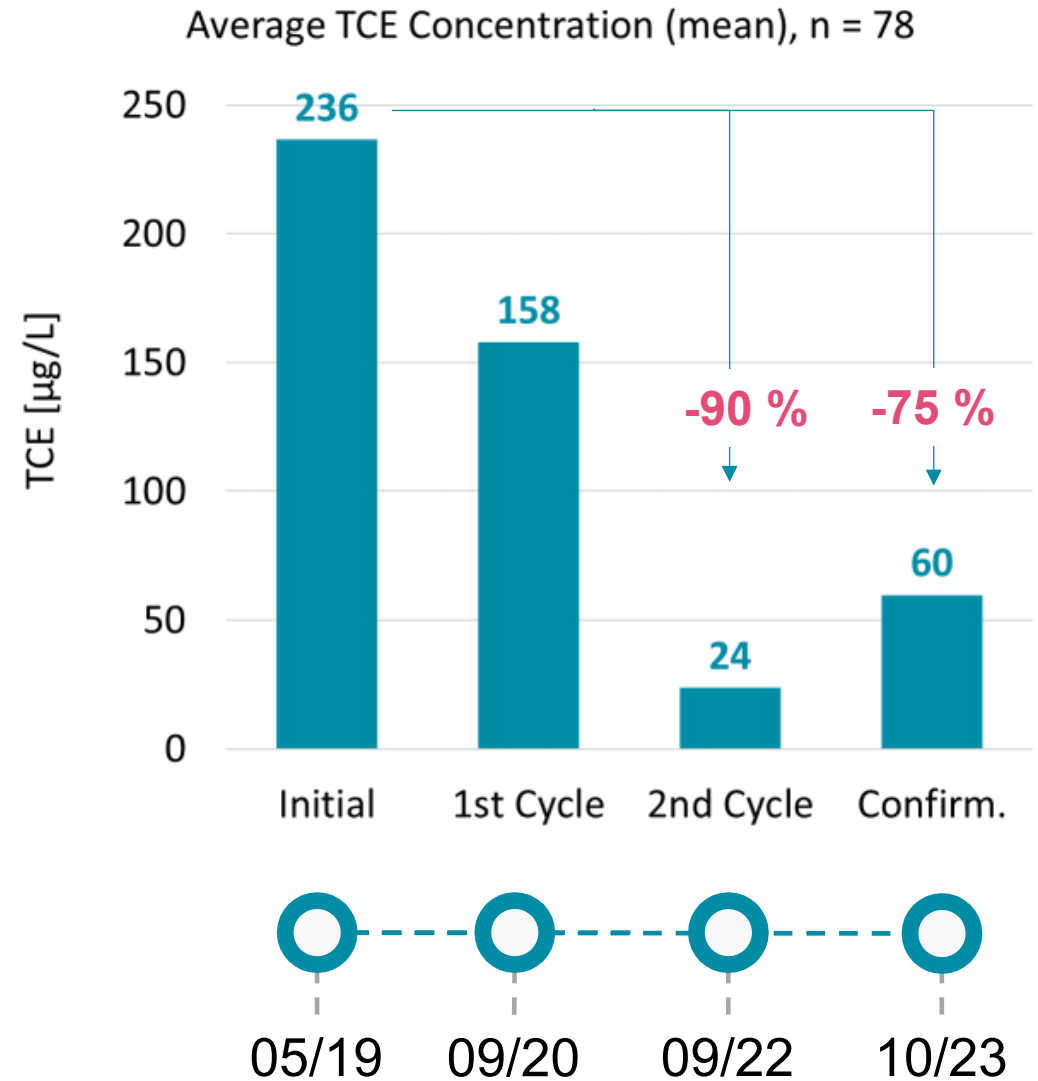
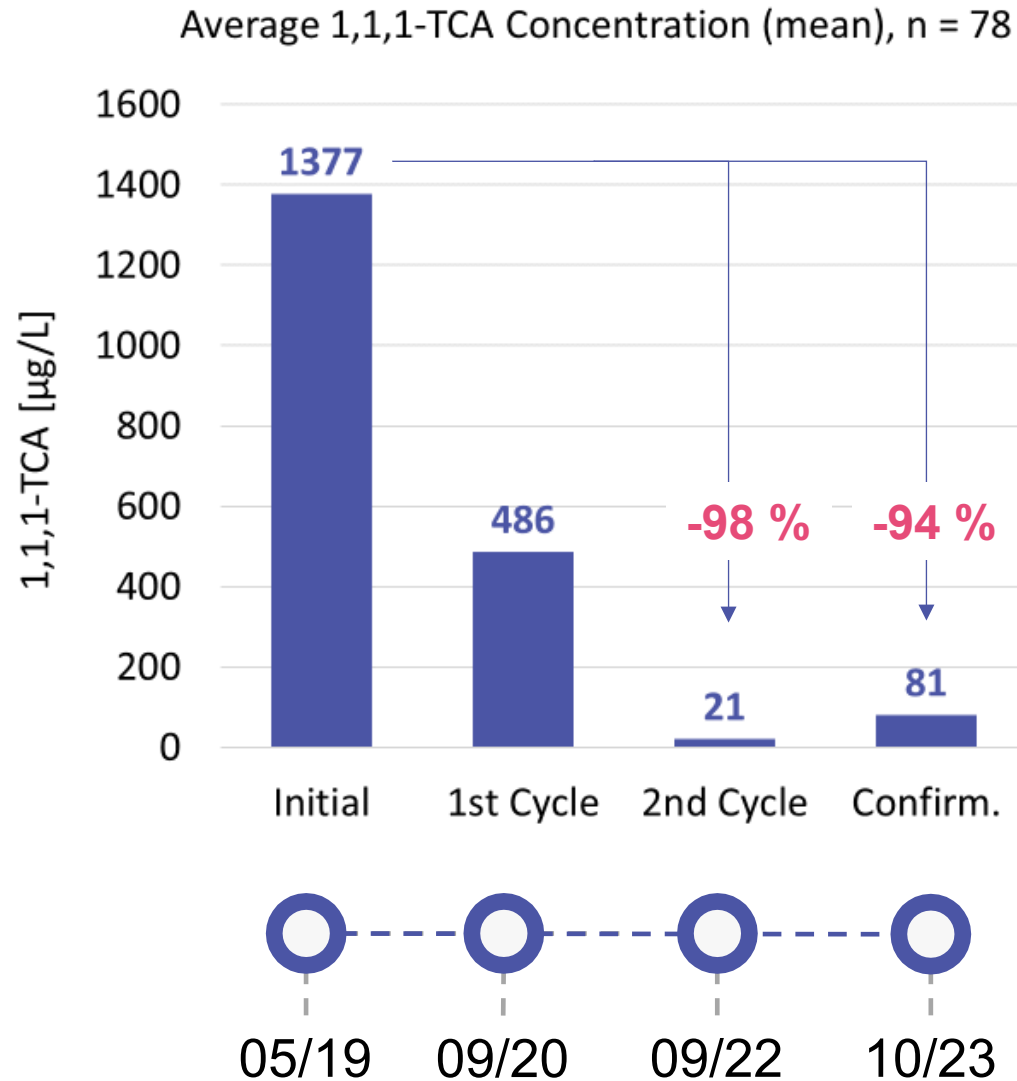
Persulfate signature indicated by changes in geochemical parameters



*average difference between after and before treatment in all extraction wells



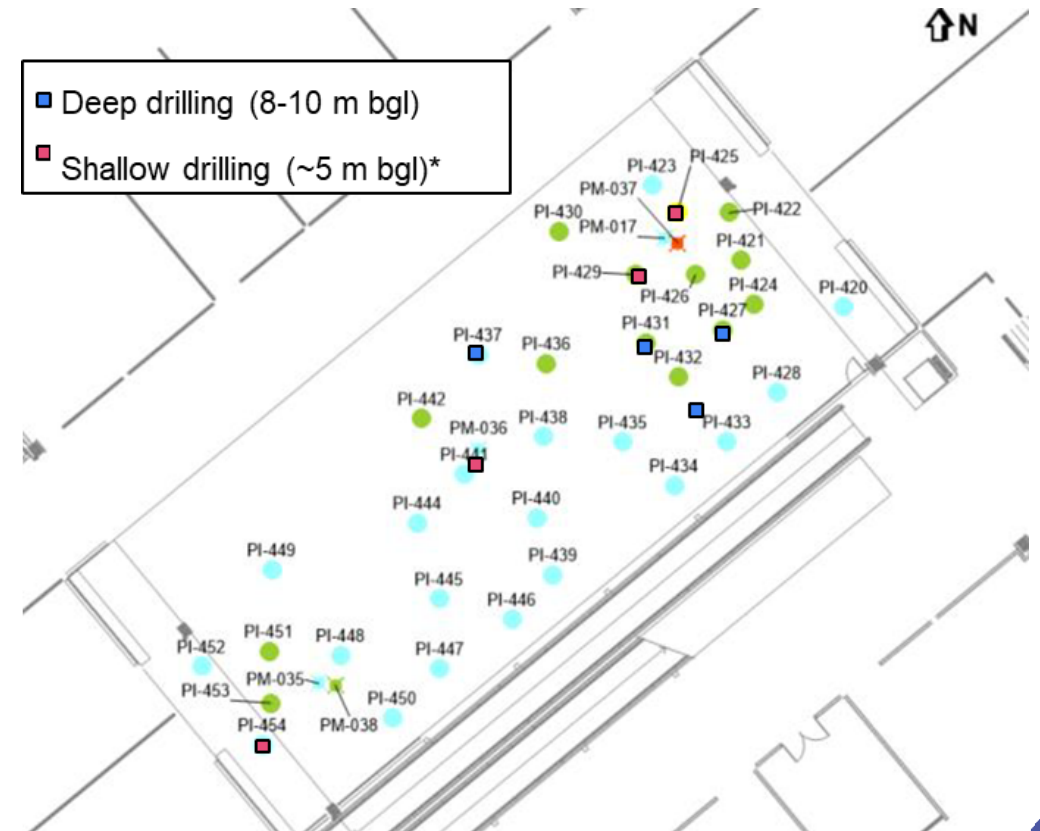
Significant CVOC reduction in groundwater after two ISCO cycles



Heat-stimulated bioremediation as potential polishing step

Outlook

- Confirmation of remediation success in soil
- Depending on results:
 - Transition to post-treatment monitoring
 - Adapted third ISCO application
 - Use of solar thermal system to stimulate microbiology for natural degradation as polishing step



Lessons learned

1. Solar thermal heat-activation of persulfate can be a green activation mechanism
2. Pre- and postheating the aquifer could potentially increase remediation efficiency
3. Dense well spacing and circulation are suitable measures to address soil heterogeneities
4. Multiple application strategy enables progressive insights and consideration of these
5. Flexible use of wells allows modification of flow regimes





Tim Schöne



+49 1520 939 56 41



tim.schoene@tauw.com



www.tauw.com