PRESENTED BY JUSTIN KERL, PG

Combining Nature Based and In Situ Technologies to Develop a Full Scale Remedy to Address a Dissolved Arsenic Plume at an Industrial Facility

BATTELLE CHLORINATED CONFERENCE 2024

DENVER, COLORADO

6 JUNE 2024

Sustainability is our business

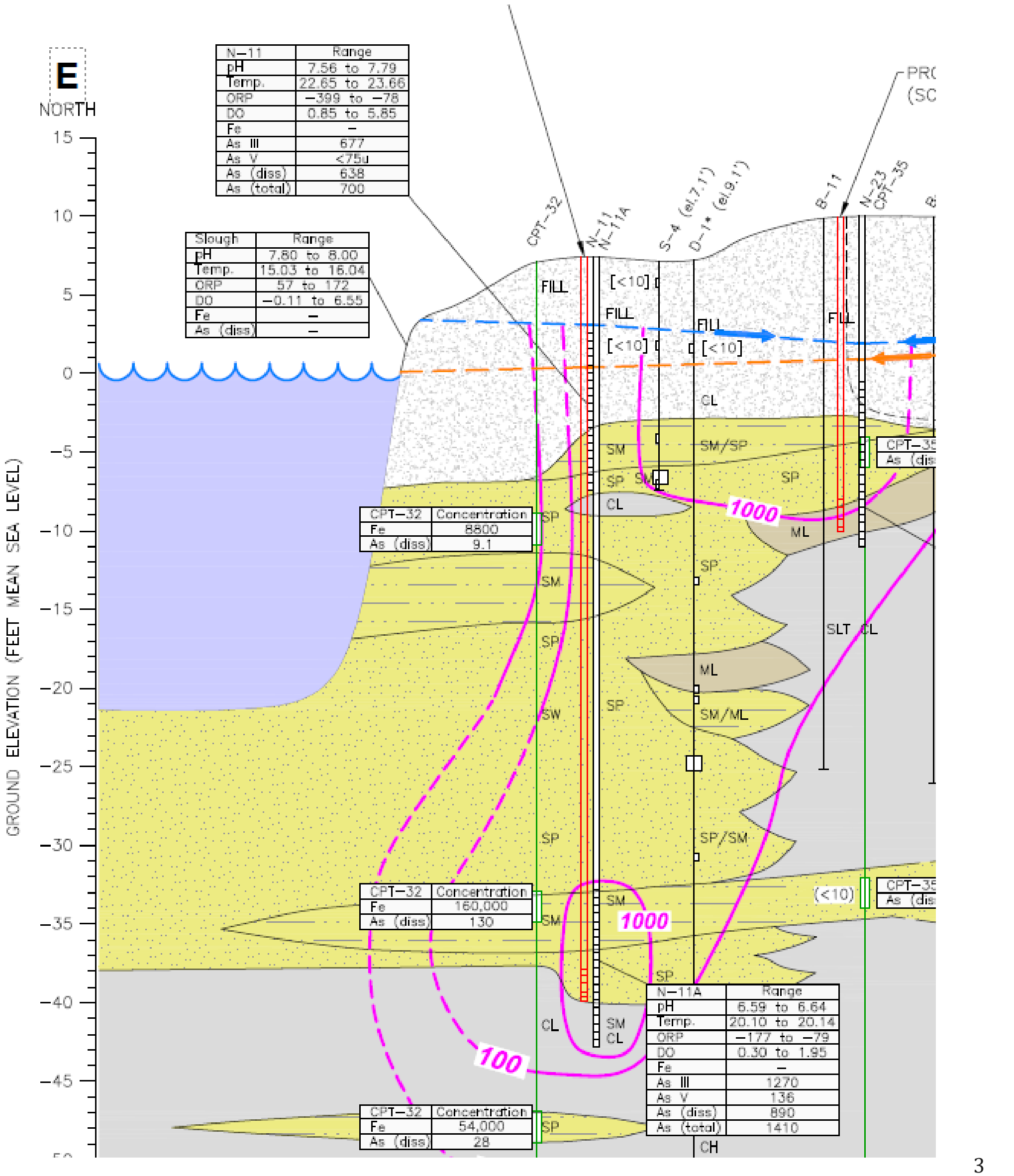
Agenda

ERM

Introduction

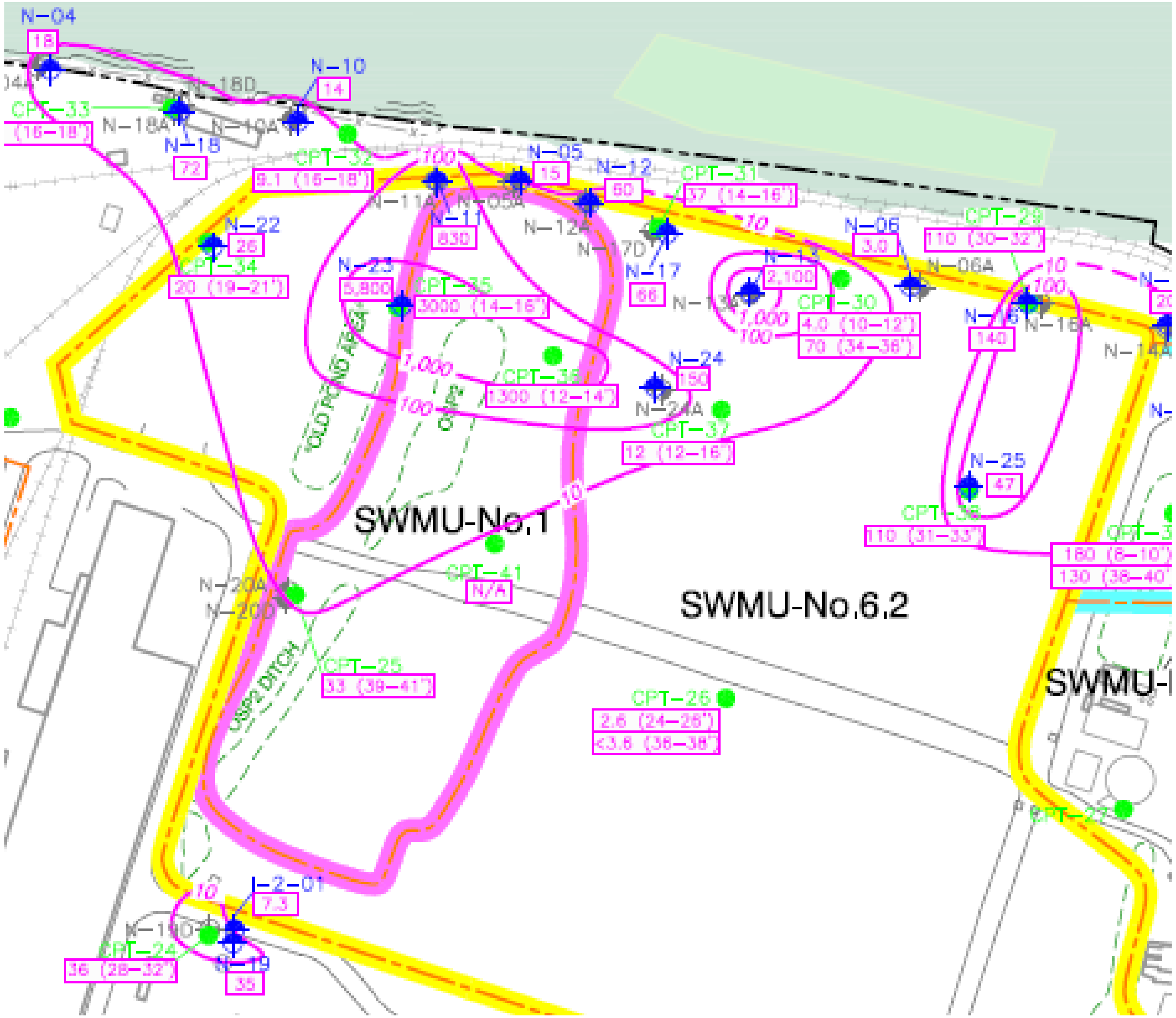
Site Background

- Active Industrial Facility located along tidally influenced water body in California
- Consists of two impacted sandy aquifer zones, shallow zone (0 to 35 ft below ground surface (bgs)) and intermediate (35 to 75 ft bgs)
- Constituent of concerns (COC):
  - Dissolved arsenic (up to 9,100 µg/L)
  - Total petroleum hydrocarbons (diesel, motor oil, Bunker C range)



Remedial Objective

- Provide source and margin control
- Constraints:
  - Low O&M effort
  - Site access constraints (everything temporary/below ground)
- Long-term Effectiveness
  - Permanent arsenic sequestration



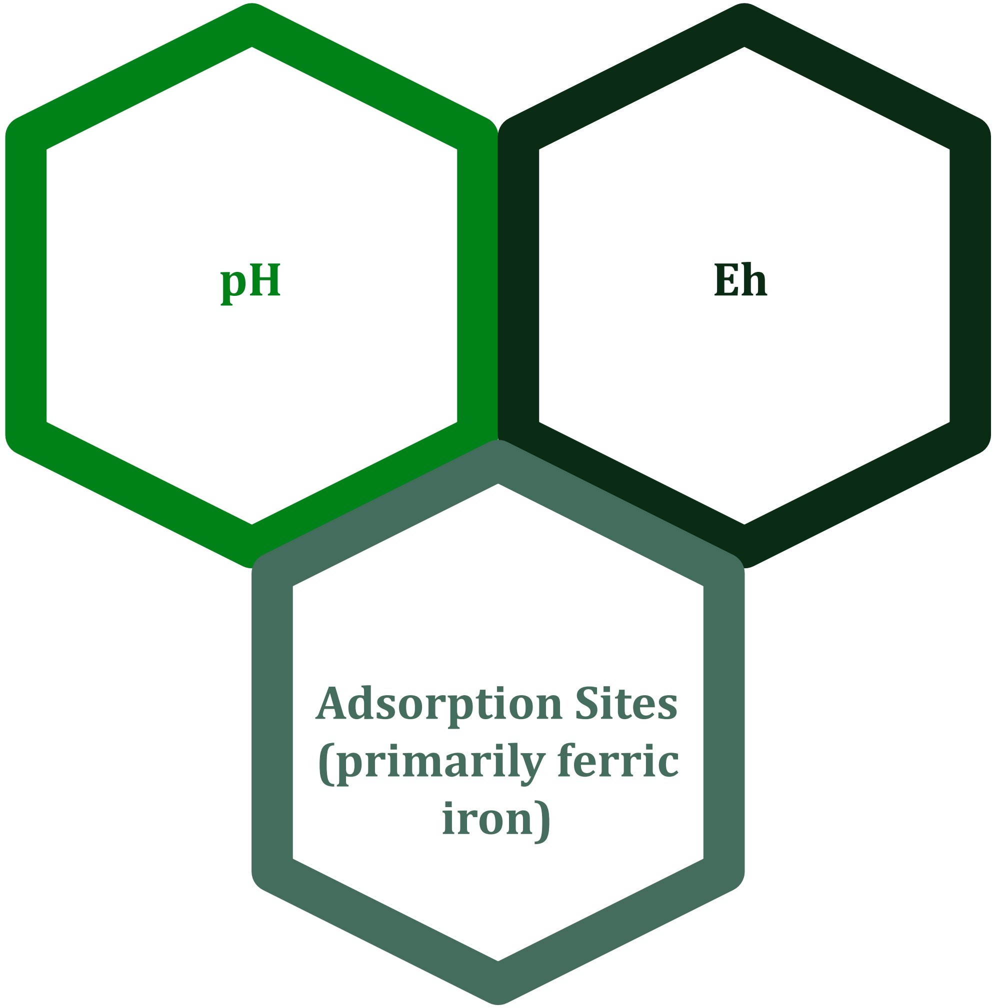
Arsenic Mobility in Groundwater

Primarily a function of three factors:

Generally, arsenic is least soluble under oxidizing conditions, at a neutral pH and in the presence of ferric iron (iron[III]).

Under oxidizing conditions/neutral pH, arsenic is expected to precipitate out and form stable and generally immobile compounds such as ferric arsenate.

Can’t destroy arsenic, but only change state.



Remedy Evaluation

Treatability Study

Seven treatment schemes including iron oxyhydroxide (FeOOH), GeoBind, FerroBlack, Persulfate/FeOOH, ZVI/gypsum, EHC-M, and Green Tea Extract.

95% arsenic removal using Klozur Persulfate + FeOOH treatment.

Tidal Study

Assess tidal effect on geochemistry and arsenic migration

Mixing and tidal influence created natural barrier for arsenic migration

ISCO Pilot Study

Implemented ISCO pilot study using Persulfate + FeOOH

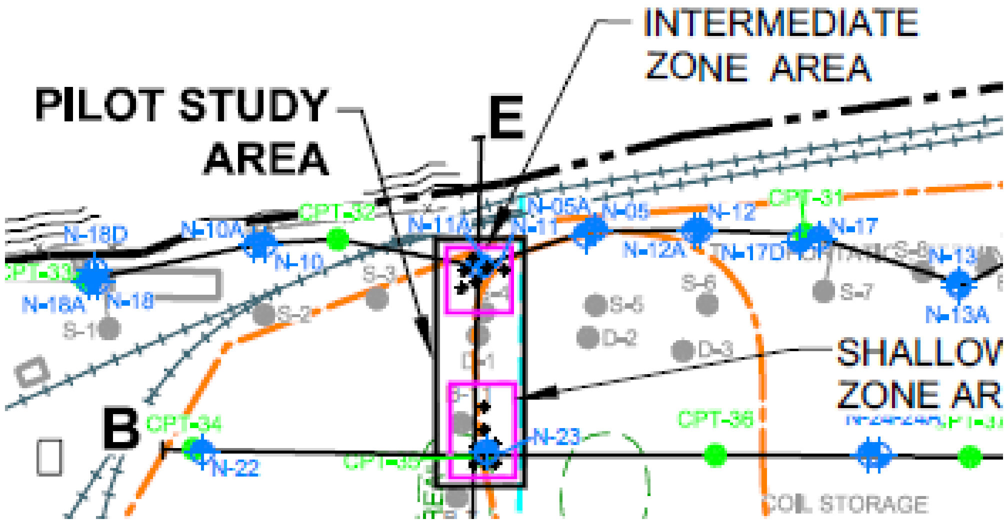
ISCO Pilot Study results were short-lived and challenging lithologic distribution

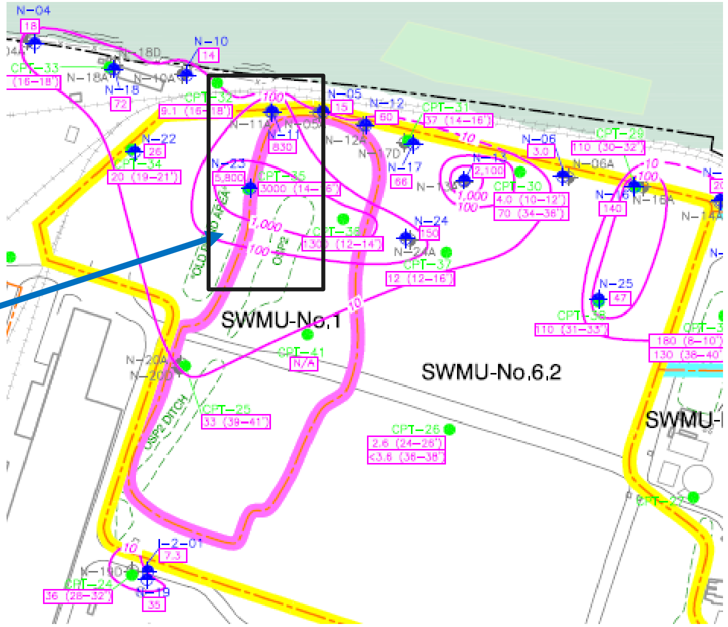
Approach

Approach

<u>Airsparge Pilot Study Objectives</u>

- Test a modified oxidant delivery approach using airsparge to overcome the difficulties that affected ISCO performance (longevity distribution).
- Evaluate the effect of oxygen delivery to alter the geochemistry and allow for co-precipitation/stabilization with native dissolved iron
- Secondary benefit of sparged air of promoting bioremediation of organic carbon or TPH
- Evaluate the distribution of injected air in the saturated zone and the ability of injected air to make the desired geochemical changes in the groundwater.

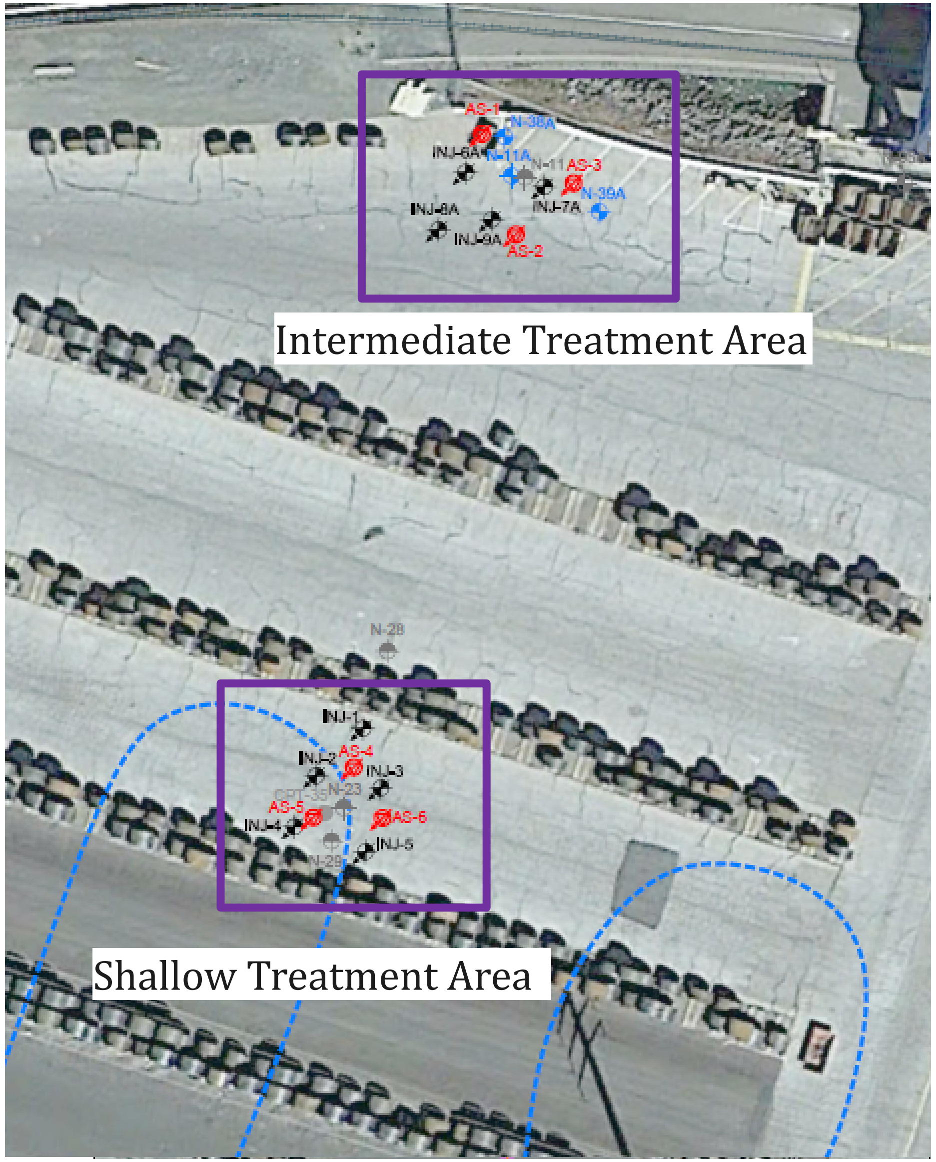




Pilot Study Area

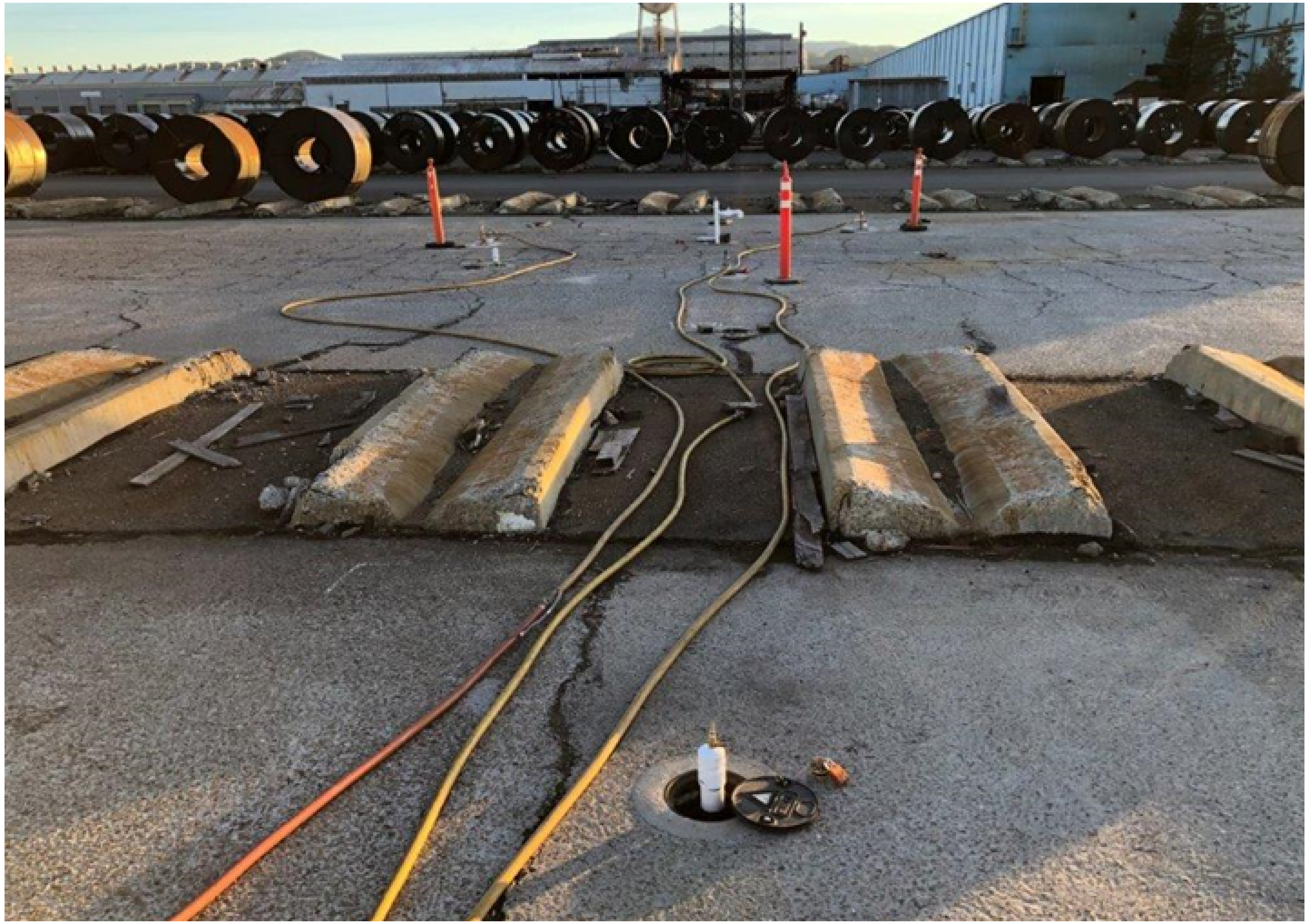
Pilot Study Overview

- Mobilize airsparge delivery system (compressed air)
- Installed six air sparge wells, three in the shallow zone (0 to 35 feet below ground surface (bgs)) and intermediate zone (35 to 75 feet bgs)
- Conducted a 1-week step test followed by 7 weeks of rotational air delivery with an 8-week rebound assessment



Performance Monitoring

- DO/Redox
- Helium concentrations
- Pressure
- Water levels
- PID



Results/Lessons Learned

Results

- Good radial distribution
  - ROI of up to 44 ft was achieved within the shallow zone
  - ROI of up to 37.5 ft was observed within the intermediate zone
- Percent reduction range from 75% to 99% with the exception of N-28 (50%)
- Longevity/Permanence
- Decreases in iron and arsenic support the hypothesis that co-precipitation is occurring within the aquifer.
- Geochemical observations within the pilot study areas were supportive of an oxidative shift in the groundwater environment.

Monitoring Well	Dissolved Arsenic Concentrations (µg/L)		
	Baseline	8 Weeks (end of pilot)	16 Weeks (end of rebound monitoring)
N-11	450	37	230
N-23	5,900	34	68
N-28	9,100	4,700	9,800

Monitoring Well	Dissolved Arsenic Concentrations (µg/L)		
	Baseline	8 Weeks (end of pilot)	16 Weeks (end of rebound monitoring)
N-11	450	37	230
N-11A	500	150	100
N-38A	3,000	2.6	18
N-39A	43	2.5	8.2

Results

Sample ID	Event	Sample Date	Interval (feet bgs)	pH	Dissolved Oxygen (mg/L)	ORP (mV)
				Field Measurements		
Intermediate Air Sparging Area						
N-11	Baseline	12/27/2018	5 to 15	7.84	0.23	-200.1
	Week 2 Air Sparge Operation	1/30/2019	5 to 15	7.09	1.29	20.2
	Week 4 Air Sparge Operation	2/11/2019	5 to 15	7.42	0.18	163.4
	Week 6 Air Sparge Operation	2/25/2019	5 to 15	6.17	3.50	338.9
	Week 8 Air Sparge Operation	3/13/2019	5 to 15	6.82	1.70	27.0
	Week 1 Rebound	3/20/2019	5 to 15	6.22	1.46	234.5
	Week 2 Rebound	3/27/2019	5 to 15	6.12	0.71	285.1
	Week 4 Rebound	4/8/2019	5 to 15	7.20	0.11	29.0
	Week 8 Rebound	5/6/2019	5 to 15	16.37*	0.55	358.7*
N-11A	Baseline	12/27/2018	39 to 49	5.54	0.66	-93.6
	Week 2 Air Sparge Operation	1/30/2019	39 to 49	2.87	4.44	13.0
	Week 4 Air Sparge Operation	2/11/2019	39 to 49	2.75	4.41	189.2
	Week 6 Air Sparge Operation	2/25/2019	39 to 49	3.85	2.20	372.2
	Week 8 Air Sparge Operation	3/13/2019	39 to 49	2.92	4.51	453.5
	Week 1 Rebound	3/20/2019	39 to 49	2.94	2.19	389.0
	Week 2 Rebound	3/27/2019	39 to 49	2.92	1.67	416.6
	Week 4 Rebound	4/8/2019	39 to 49	3.80	0.18	270.9
	Week 8 Rebound	5/6/2019	39 to 49	7.98*	1.01	592.8*
N-38A	Baseline	12/27/2018	40 to 50	6.57	0.40	-197.3
	Week 2 Air Sparge Operation	1/30/2019	40 to 50	5.49	4.95	14.5
	Week 4 Air Sparge Operation	2/11/2019	40 to 50	5.86	5.01	166.8
	Week 6 Air Sparge Operation	2/25/2019	40 to 50	4.95	4.09	4.1
	Week 8 Air Sparge Operation	3/13/2019	40 to 50	5.68	8.08	213.4
	Week 1 Rebound	3/20/2019	40 to 50	5.16	2.91	304.6
	Week 2 Rebound	3/27/2019	40 to 50	5.54	3.42	375.4
	Week 4 Rebound	4/8/2019	40 to 50	6.16	0.17	70.1
	Week 8 Rebound	5/6/2019	40 to 50	8.43*	0.80	363.4*
N-39A	Baseline	12/27/2018	40 to 50	6.87	0.33	-127.1
	Week 2 Air Sparge Operation	1/30/2019	40 to 50	6.38	1.01	29.4
	Week 4 Air Sparge Operation	2/11/2019	40 to 50	6.87	1.58	159.3
	Week 6 Air Sparge Operation	2/25/2019	40 to 50	6.38	3.01	106.1
	Week 8 Air Sparge Operation	3/13/2019	40 to 50	5.67	6.52	220.0
	Week 1 Rebound	3/20/2019	40 to 50	6.63	1.39	79.6
	Week 2 Rebound	3/27/2019	40 to 50	4.29	1.10	379.0
	Week 4 Rebound	4/8/2019	40 to 50	6.22	0.18	71.6
	Week 8 Rebound	5/6/2019	40 to 50	11.75*	0.56	284.0*

Sample ID	Event	Sample Date	Screen Interval (ft bgs)	GW Zone	Dissolved Arsenic (µg/L)		Iron (µg/L)
Site Monitoring Well Data							
Intermediate Wells							
N-11	Baseline	12/27/2018	5 to 15	Shallow	450		530
N-11-DUP		12/27/2018	5 to 15	Shallow	450		500
N-11	Week 4	2/11/2019	5 to 15	Shallow	190		4,800
N-11	Week 8	3/13/2019	5 to 15	Shallow	37		3,300
N-11	Rebound Week 4	4/8/2019	5 to 15	Shallow	170		13,000
N-11	Rebound Week 8	5/6/2019	5 to 15	Shallow	230		6,300
N-11A	Baseline	12/27/2018	39 to 49	Intermediate	500		880,000
N-11A	Week 4	2/11/2019	39 to 49	Intermediate	280		240,000
N-11A	Week 8	3/13/2019	39 to 49	Intermediate	150		250,000
N-11A	Rebound Week 4	4/8/2019	39 to 49	Intermediate	160		530,000
N-11A	Rebound Week 8	5/6/2019	39 to 49	Intermediate	100		520,000
N-38A	Baseline	12/27/2018	40 to 50	Intermediate	3,000		200,000
N-38A	Week 4	2/11/2019	40 to 50	Intermediate	0.63	J	1,600
N-38A	Week 8	3/13/2019	40 to 50	Intermediate	2.6		7,400
N-38A	Rebound Week 4	4/8/2019	40 to 50	Intermediate	16		50,000
N-38A	Rebound Week 8	5/6/2019	40 to 50	Intermediate	18		86,000
N-39A	Baseline	12/27/2018	40 to 50	Intermediate	43		18,000
N-39A	Week 4	2/11/2019	40 to 50	Intermediate	1.0		1,200
N-39A	Week 8	3/13/2019	40 to 50	Intermediate	2.5		1,300
N-39A	Rebound Week 4	4/8/2019	40 to 50	Intermediate	3.9		49,000
N-39A	Rebound Week 8	5/6/2019	40 to 50	Intermediate	8.2		68,000

Lessons Learned

- Conduct pilot tests
  - Complex lithologic heterogeneities caused distribution challenges
- Mounding/water level rise was a challenge but we were able to address it during step test phase
  - Perform step testing such that you can optimize delivery parameters (flow rate)
  - Pulse locations – channel flow/less preferential pathway delivery/less power needs
  - Renewable power potential with pulsed operation
  - Did not compromise the ROI

ERM

Conclusions

Conclusion

- Longevity
  - Once reach oxidative state, able to maintain/self sustain aerobic conditions for years (continue to see reduced concentrations over 5 years)
- Using naturally locally available oxidizers and adsorptions sites (native ferric iron and air) with tidal oxygenation at the margin
- Up to 99% reduction of arsenic concentration at several performance wells including several below MCLs (10 ug/L)

- Full Scale design using horizontal wells pending regulatory review

Thank you

If further information is required, please contact:

Justin Kerl, PG

Justin.kerl@erm.com

Special Thanks to my colleague Arun Chemburkar, PE.