A HIGHLY SUSTAINABLE ACTIVE REMEDIAL TOOL FOR DEGRADING PETROLEUM AND CHLORINATED CONTAMINANTS, EVEN IN CLAY FORMATIONS

REMEDIATION TECHNOLOGIES SYMPOSIUM 2022 (Banff, Alberta)

Eric Vonde
Atlas Technical Consultants
Denver, Colorado

ACKNOWLEDGMENTS

- Song Jin, PhD and Paul Fallgren

- Advanced Environmental Technologies, LLC (AET)
- Fort Collins, Colorado

AGENDA

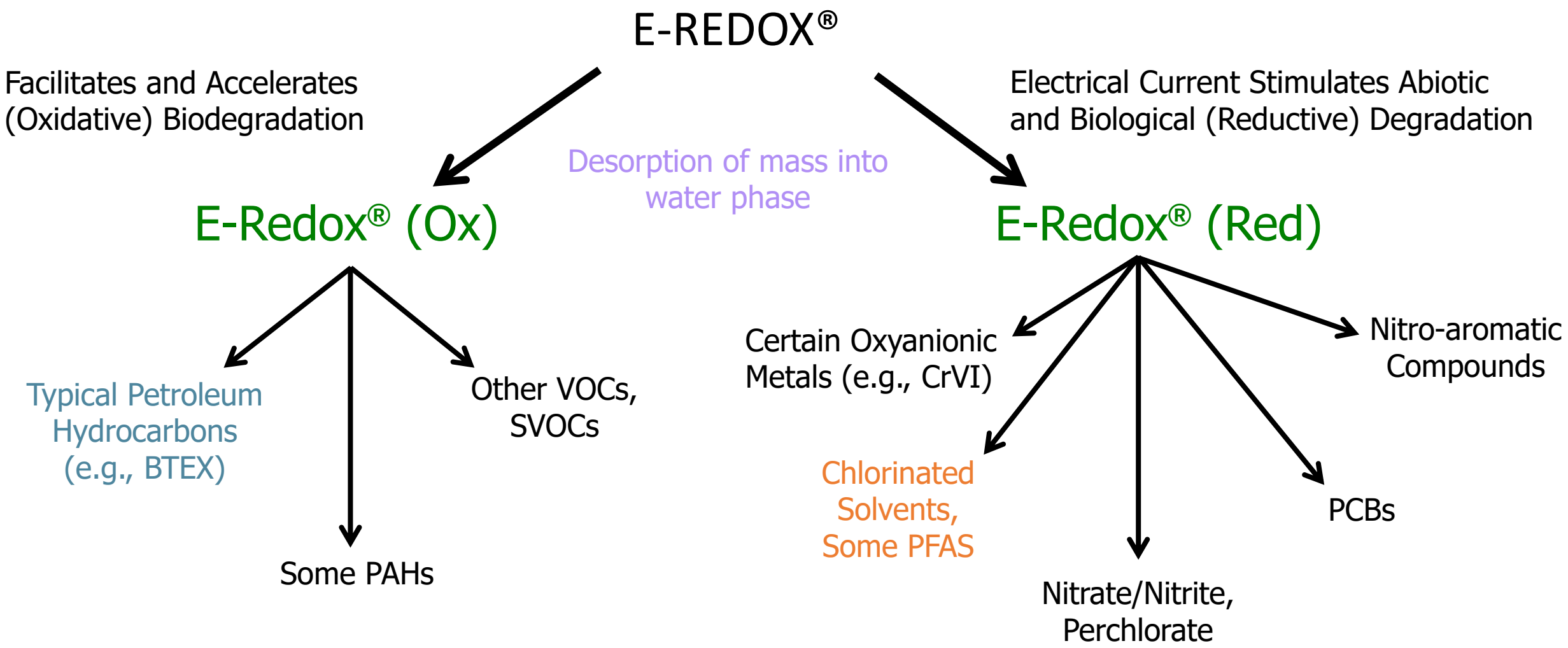
I. E-Redox® Oxidation
II. Sustainability Analysis (Petroleum)
III. E-Redox® Reduction
IV. Sustainability Analysis (Chlorinated Solvents)

ELECTRO-CHEMICAL-REDOX REACTIONS (E-REDOX®)

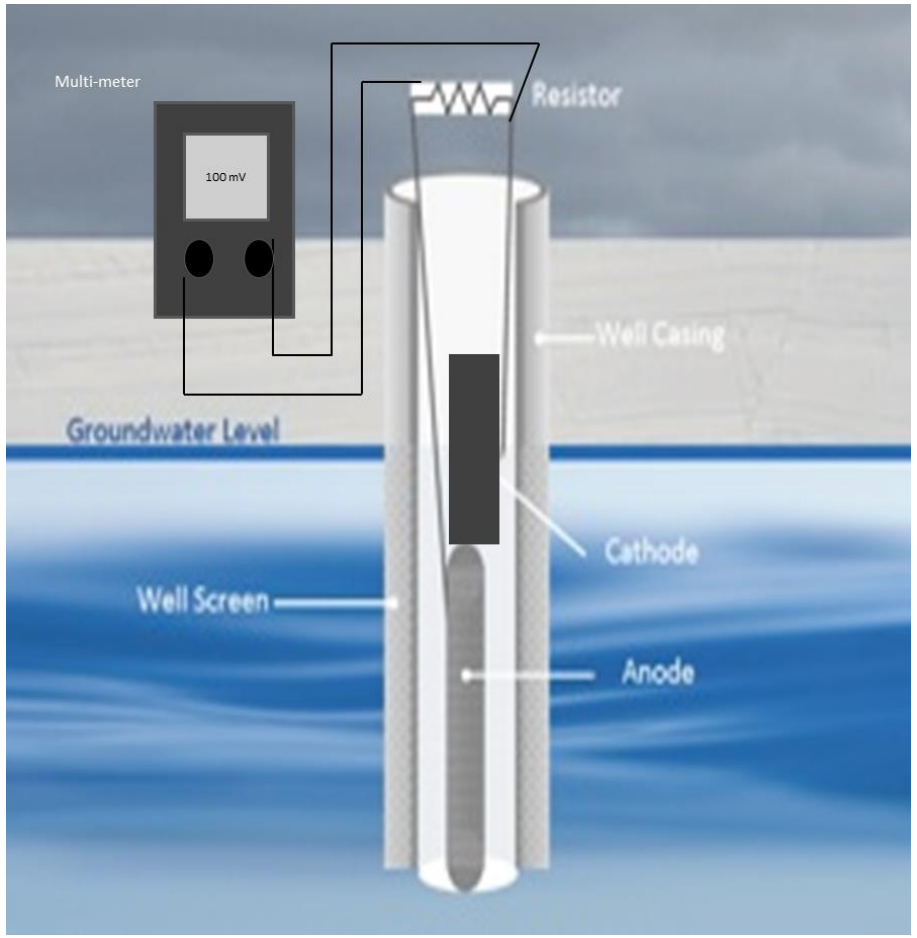
1 Reactions via electron transport and shifts of charges and molecular configurations at particle/water interface

2 Friendly for fine-grained lithology with higher electrical conductivities: silts & clays

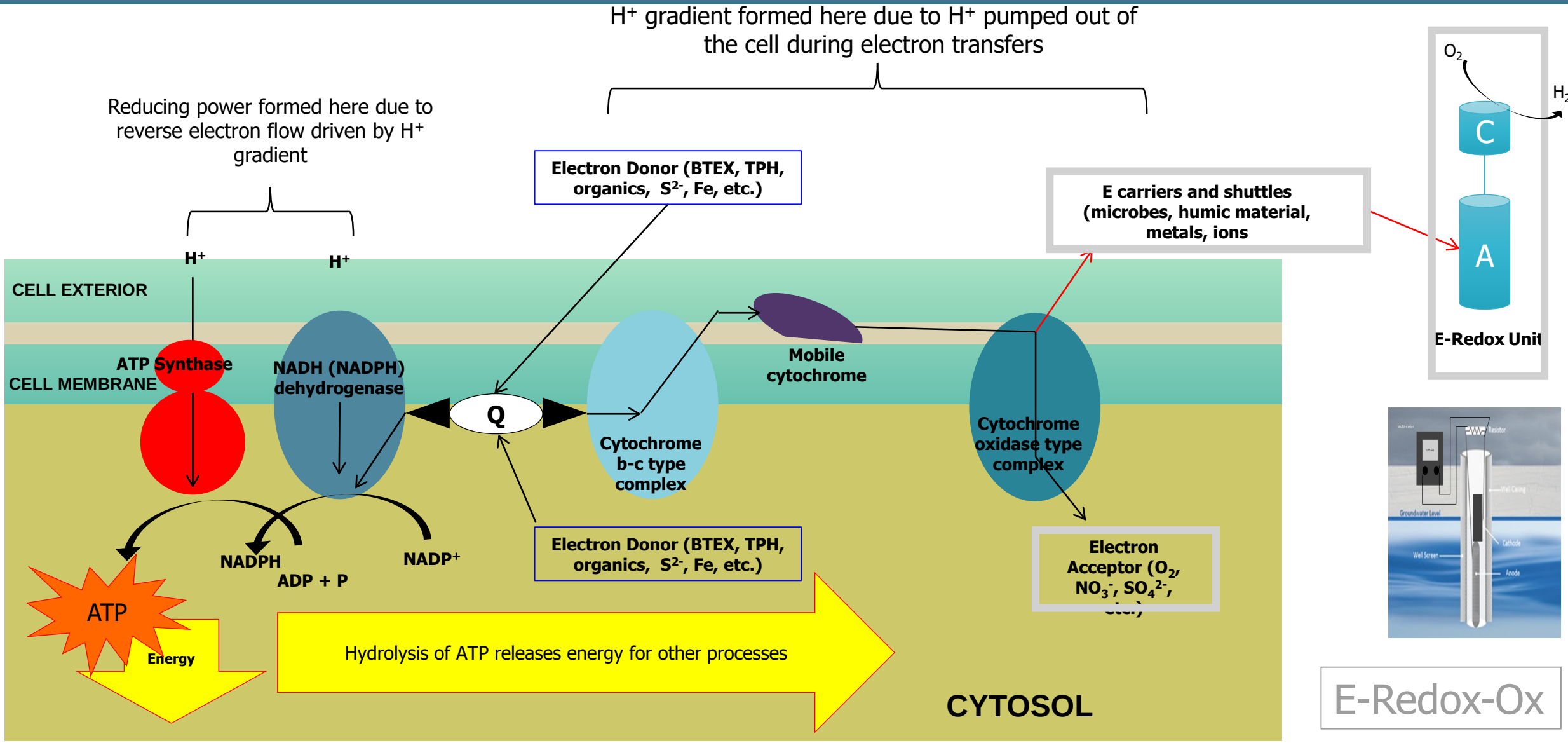
E-REDOX® PROCESS OVERVIEW



E-REDOX® (OXIDATION)

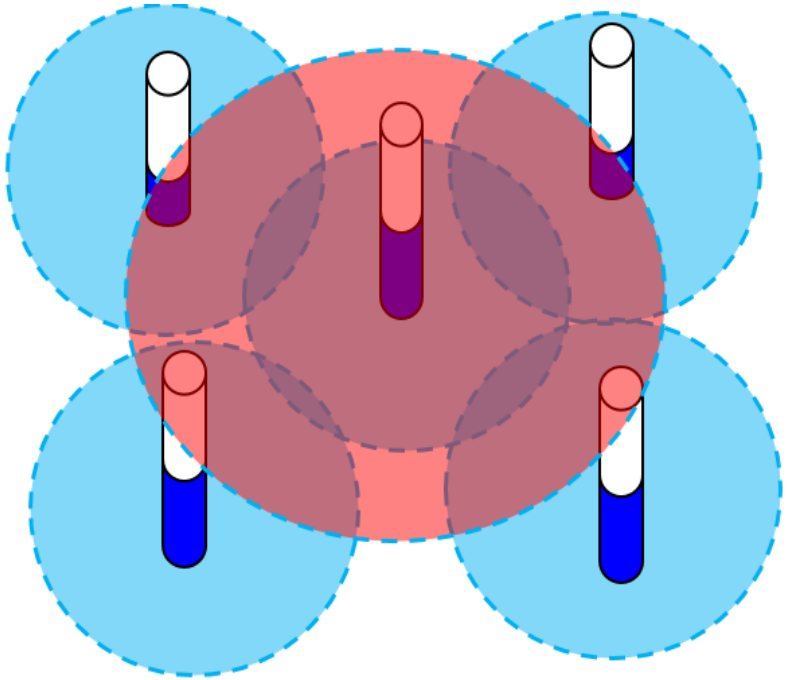


E-REDOX®



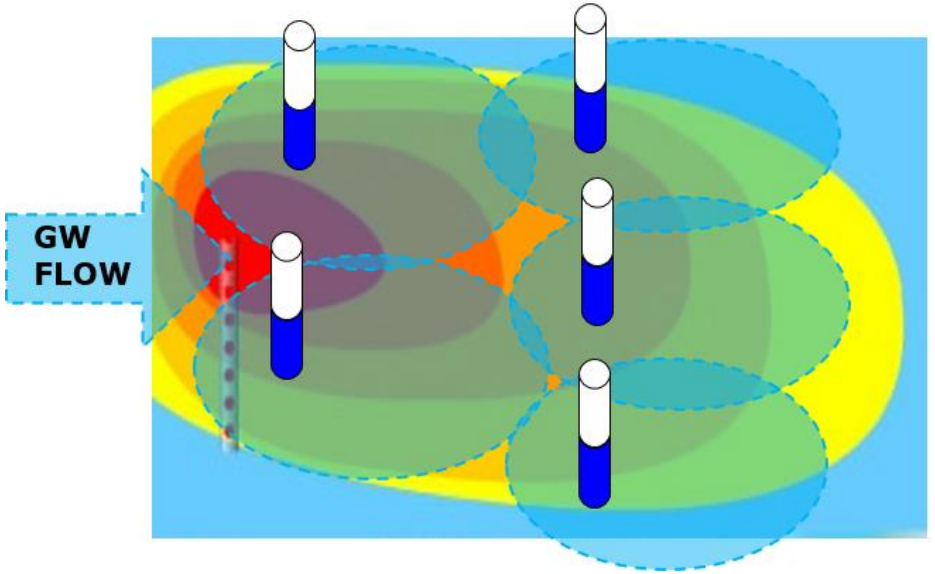
E-Redox-Ox

E-REDOX®



E-Redox® as reactive barrier for larger plume treatment

E-Redox® for source and small plume treatment



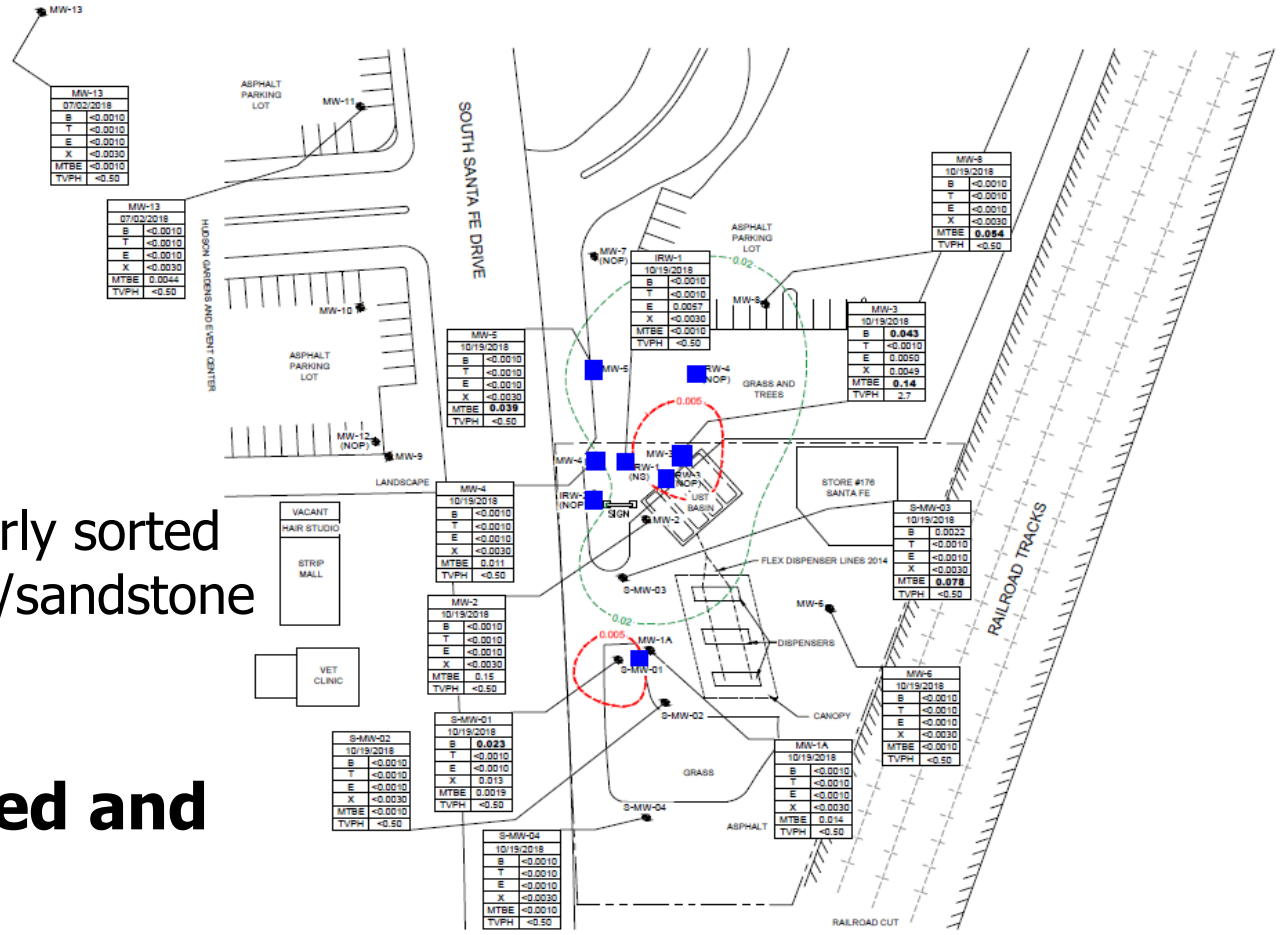
E-REDOX® (OX) FOR PETROLEUM DEGRADATION

CASE STUDY - ACTIVE FUELING STATION LITTLETON, COLORADO

Primary Contaminant of Concern:
Benzene

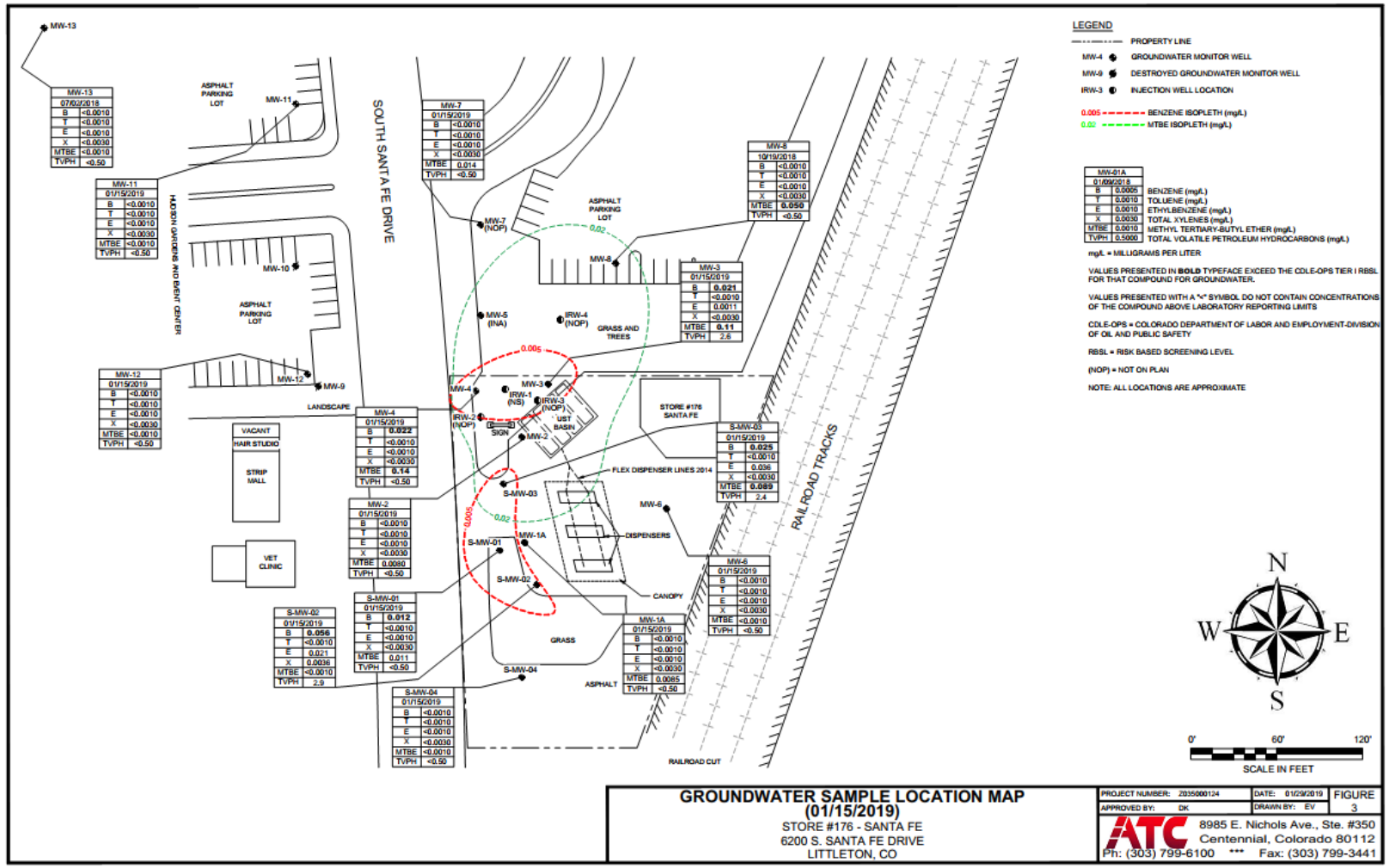
Area of Contamination Mass:
~37,500 square feet

Subsurface Lithology:
Heterogeneous lithology consisting of a gravelly poorly sorted sand and silt with some clays overlaying a claystone/sandstone bedrock



Previous Remedial Technologies Utilized and the Site:
- Hydrogen Peroxide Injection
- Chemically Oxygenated Granular Activated Carbon™ Injections

SITE MAP


LEGEND
PROPERTY LINE
MW-4 GROUNDWATER MONITOR WELL
MW-9 DESTROYED GROUNDWATER MONITOR WELL
IRW-3 INJECTION WELL LOCATION
0.005 BENZENE ISOPLETH (mg/L)
0.02 MTBE ISOPLETH (mg/L)
MW-01A
01/09/2018
B 0.0005 BENZENE (mg/L)
T 0.0010 TOLUENE (mg/L)
E 0.0010 ETHYLBENZENE (mg/L)
X 0.0030 TOTAL XYLENES (mg/L)
MTBE 0.0010 METHYL TERTIARY-BUTYL ETHER (mg/L)
TVPH 0.5000 TOTAL VOLATILE PETROLEUM HYDROCARBONS (mg/L)
mg/L = MILLIGRAMS PER LITER
VALUES PRESENTED IN BOLD TYPEFACE EXCEED THE CDLE-OPS TIER I RBSL FOR THAT COMPOUND FOR GROUNDWATER.
VALUES PRESENTED WITH A "<" SYMBOL DO NOT CONTAIN CONCENTRATIONS OF THE COMPOUND ABOVE LABORATORY REPORTING LIMITS
CDLE-OPS = COLORADO DEPARTMENT OF LABOR AND EMPLOYMENT-DIVISION OF OIL AND PUBLIC SAFETY
RBSL = RISK BASED SCREENING LEVEL
(NOP) = NOT ON PLAN
NOTE: ALL LOCATIONS ARE APPROXIMATE
SOUTH SANTA FE DRIVE
HUDSON GARDENS AND EVENT CENTER
ASPHALT PARKING LOT
GRASS AND TREES
LANDSCAPE
VACANT HAIR STUDIO
STRIP MALL
VET CLINIC
STORE #176 SANTA FE
UST BASIN
SIGN
FLEX DISPENSER LINES 2014
DISPENSERS
CANOPY
GRASS
ASPHALT
RAILROAD TRACKS
RAILROAD CUT
MW-13 07/02/2018 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE <0.0010 TVPH <0.50
MW-11 01/15/2019 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE <0.0010 TVPH <0.50
MW-12 01/15/2019 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE <0.0010 TVPH <0.50
MW-7 01/15/2019 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE 0.014 TVPH <0.50
MW-8 10/19/2018 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE 0.050 TVPH <0.50
MW-3 01/15/2019 B 0.021 T <0.0010 E 0.0011 X <0.0030 MTBE 0.11 TVPH 2.8
MW-4 01/15/2019 B 0.022 T <0.0010 E <0.0010 X <0.0030 MTBE 0.14 TVPH <0.50
MW-2 01/15/2019 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE 0.0080 TVPH <0.50
S-MW-03 01/15/2019 B 0.025 T <0.0010 E 0.036 X <0.0030 MTBE 0.089 TVPH 2.4
MW-6 01/15/2019 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE <0.0010 TVPH <0.50
MW-1A 01/15/2019 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE 0.0085 TVPH <0.50
S-MW-01 01/15/2019 B 0.012 T <0.0010 E <0.0010 X <0.0030 MTBE 0.011 TVPH <0.50
S-MW-02 01/15/2019 B 0.056 T <0.0010 E 0.021 X 0.0036 MTBE <0.0010 TVPH 2.9
S-MW-04 01/15/2019 B <0.0010 T <0.0010 E <0.0010 X <0.0030 MTBE <0.0010 TVPH <0.50
MW-1 MW-2 MW-3 MW-4 MW-5 (INA) MW-6 MW-7 (NOP) MW-8 MW-9 MW-10 MW-11 MW-12 MW-13
IRW-1 (INS) IRW-2 (NOP) IRW-3 (NOP) IRW-4 (NOP)
S-MW-01 S-MW-02 S-MW-03 S-MW-04
0.005 0.02
N W E S
0' 60' 120'
SCALE IN FEET
GROUNDWATER SAMPLE LOCATION MAP
(01/15/2019)
STORE #176 - SANTA FE
6200 S. SANTA FE DRIVE
LITTLETON, CO
PROJECT NUMBER: 2035000124
DATE: 01/29/2019
FIGURE 3
APPROVED BY: DK
DRAWN BY: EV
ATC
8985 E. Nichols Ave., Ste. #350
Centennial, Colorado 80112
Ph: (303) 799-6100 *** Fax: (303) 799-3441

E-REDOX® SYSTEM FIELD INSTALLATION

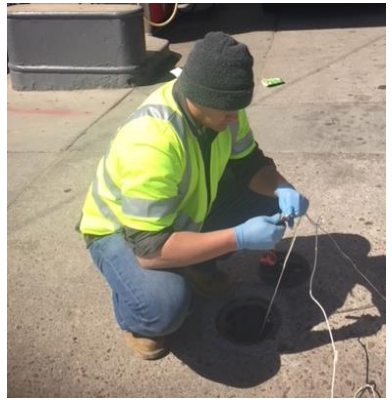
Site

Health and safety meeting

Pre-Installation Monitoring

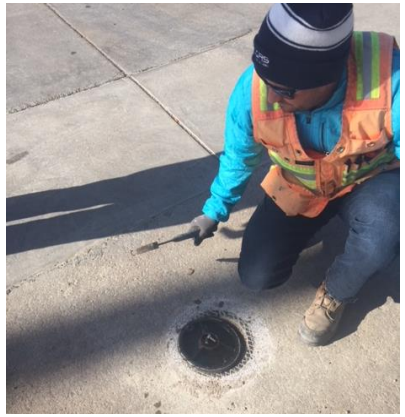
E-Redox® Unit Prep

Implementation



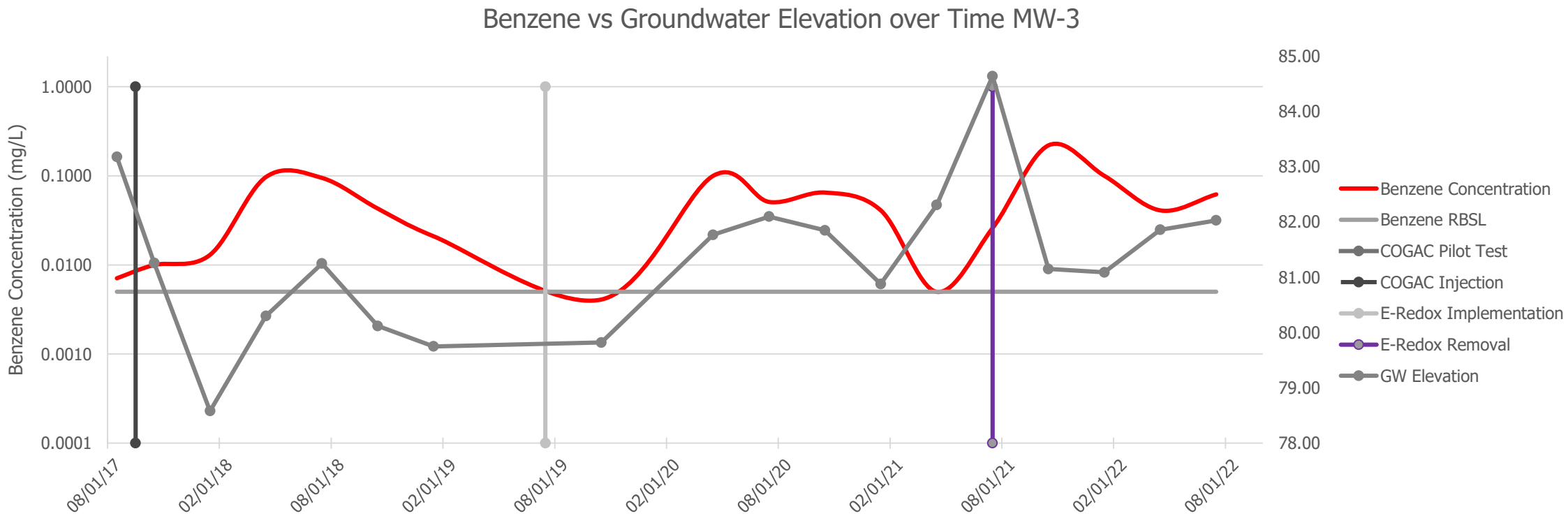
Securing E-Redox® Unit

Voltage Monitoring

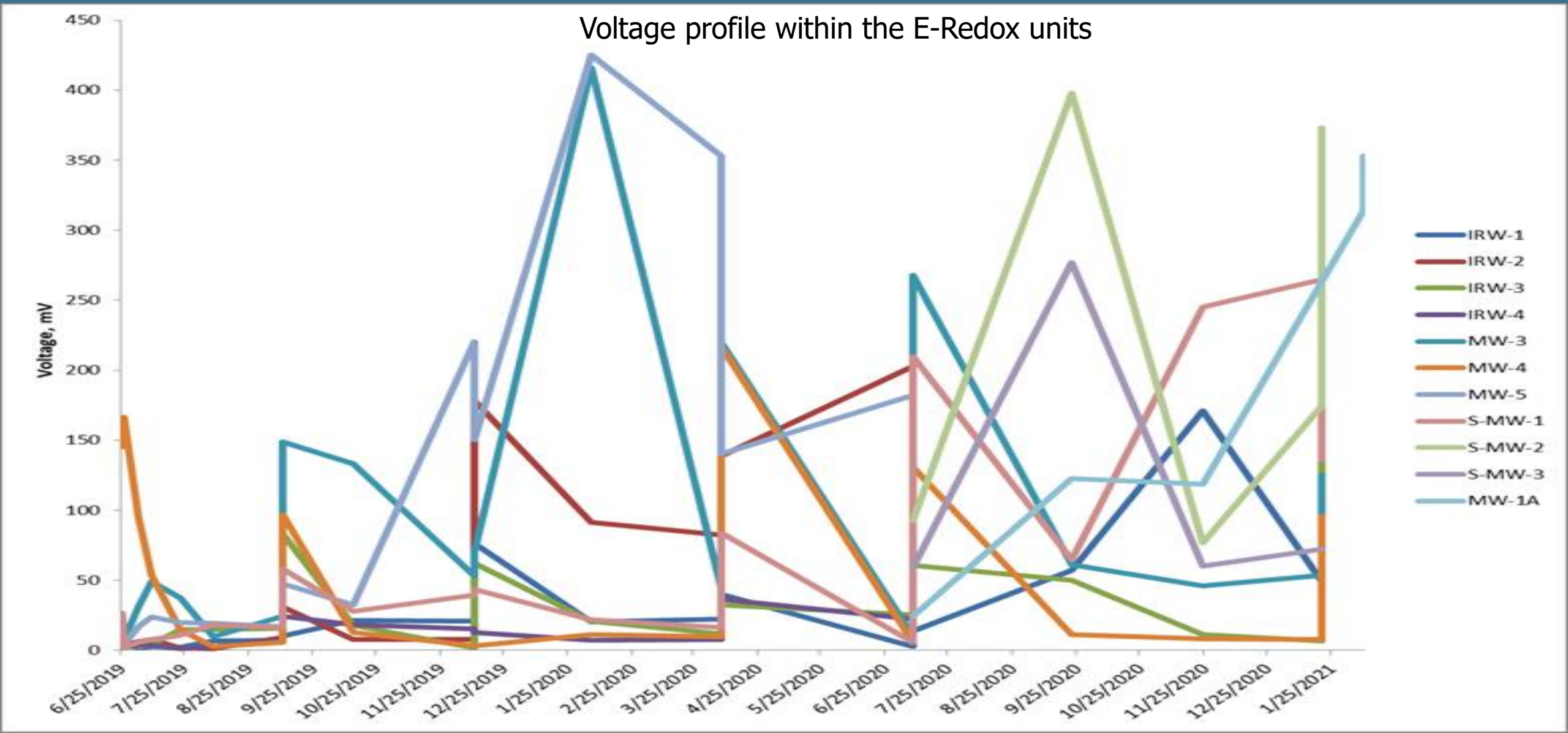


Close Well Cover

BENZENE HYDROGRAPH



E-REDOX® VOLTAGE PROFILE



SUSTAINABLE REMEDIATION

1	Minimize energy use & maximize renewable energy use
2	Minimize air pollution & GHG emissions
3	Minimize water use & impacts to water resources
4	Reduce, reuse and recycle materials and waste
5	Minimize land use & protect ecosystems

E-REDOX® (O_X) + NUTRIENT AMENDMENT

Assumptions:

- Nutrients LCA and additional onsite gravimetric injection
- 2 year in-situ remediation
- Quarterly maintenance
- Maintaining 15 wells

Total CO_2 Emissions:

1.25 metric tons, primarily from transportation

CHEMICAL OXIDATION (FOR COMPARISON)

Assumptions:

- 20 injection wells, 2 rounds of injections
- 55 gallons/persulfate, per injection
- 1000 HP engine to drive injections
- 500 gallons hydrocarbons released

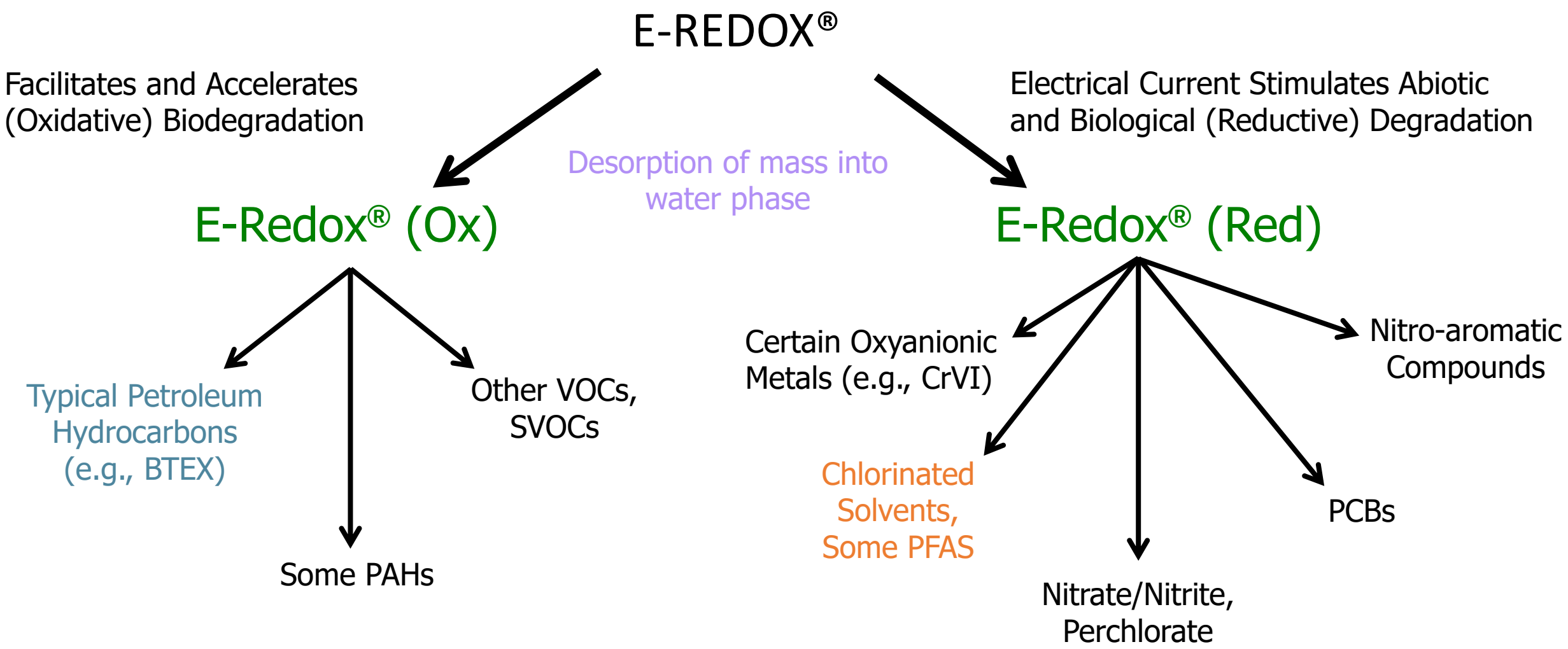
Total CO_2 Emissions:

23.53 metric tons, primarily from equipment operation

CONCLUSION

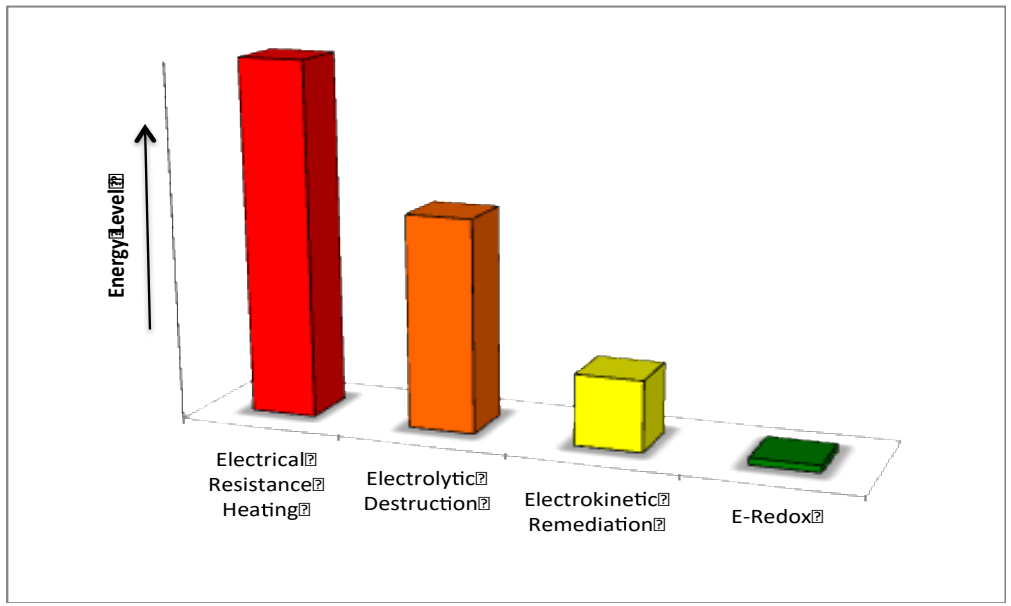
- E-Redox® technology degrades benzene to meet compliance level within 22 months
- Unrestricted by tight matrices such as clay
- Minimal O&M
- Voltage profile in E-Redox® used for real-time monitoring of biodegradation in groundwater

E-REDOX® PROCESS OVERVIEW

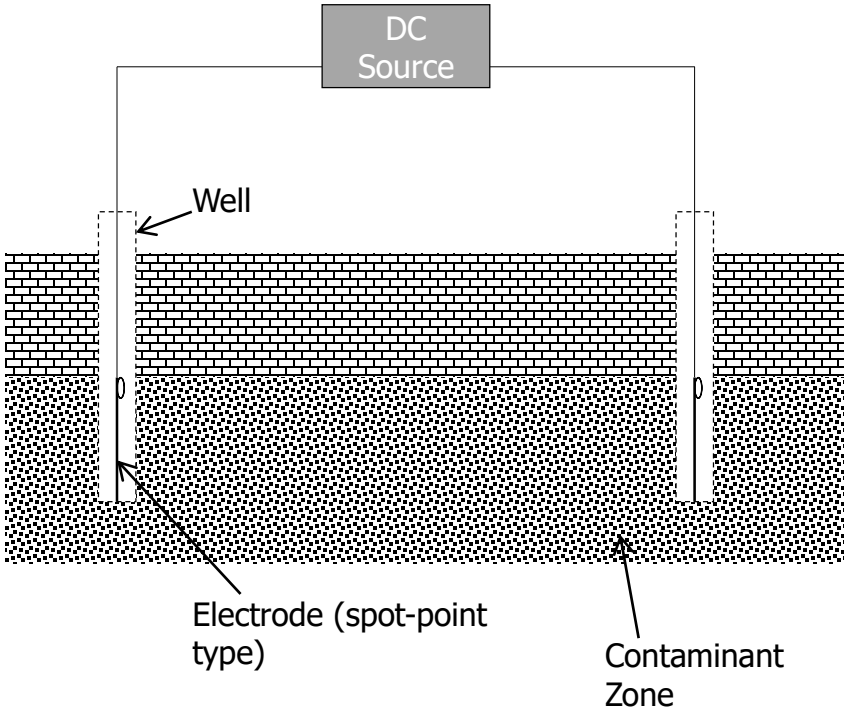


E-REDOX® (REDUCTION)

- Establishes a low-voltage/low-amperage static electric field in the contaminated matrix.
- Promotes reductive destruction and desorption of source compounds from soil into water



(<100 W light bulb/module)



Patented by AET, 1st Field Application 2014
Jin et al., 2008. Chem Eng J, 140:642
Jin and Fallgren 2009, J Haz Mat, 153:127
Luo et al., 2010. Chem Eng J, 160:185

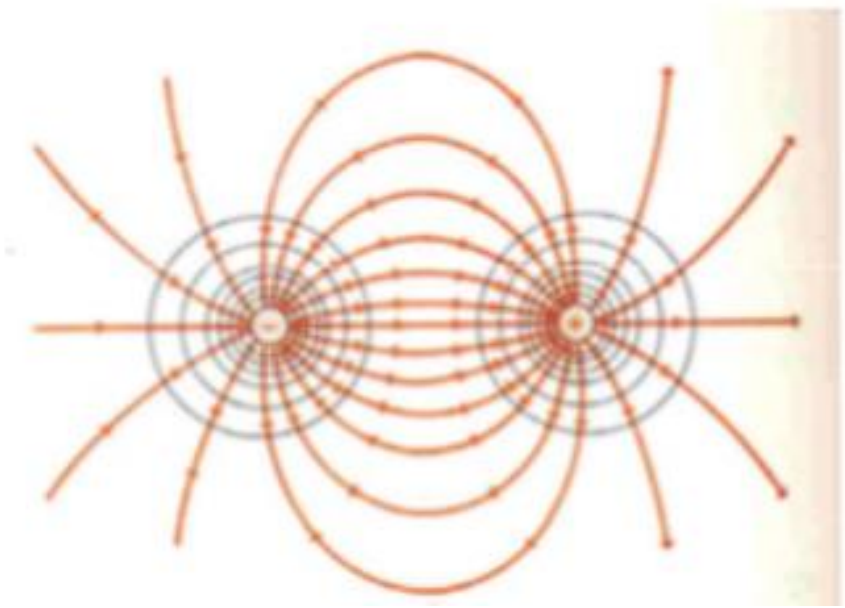
“MICRO-CONDUCTOR / CAPACITOR” MECHANISM

- Soil particles in the influenced matrix act as micro-conductors, become polarized, and act as micro-capacitors
  - Reductive destruction of chlorinated solvents

- Constant shifts of surface charge on soil particles “disturb” the “water cage” configuration and weaken the constituent's adsorption
  - Desorption of contaminants from soil into water
  - Elimination of “rebounds”

- ** Dietmar Rahner, Dresden U of Technology, 2002*

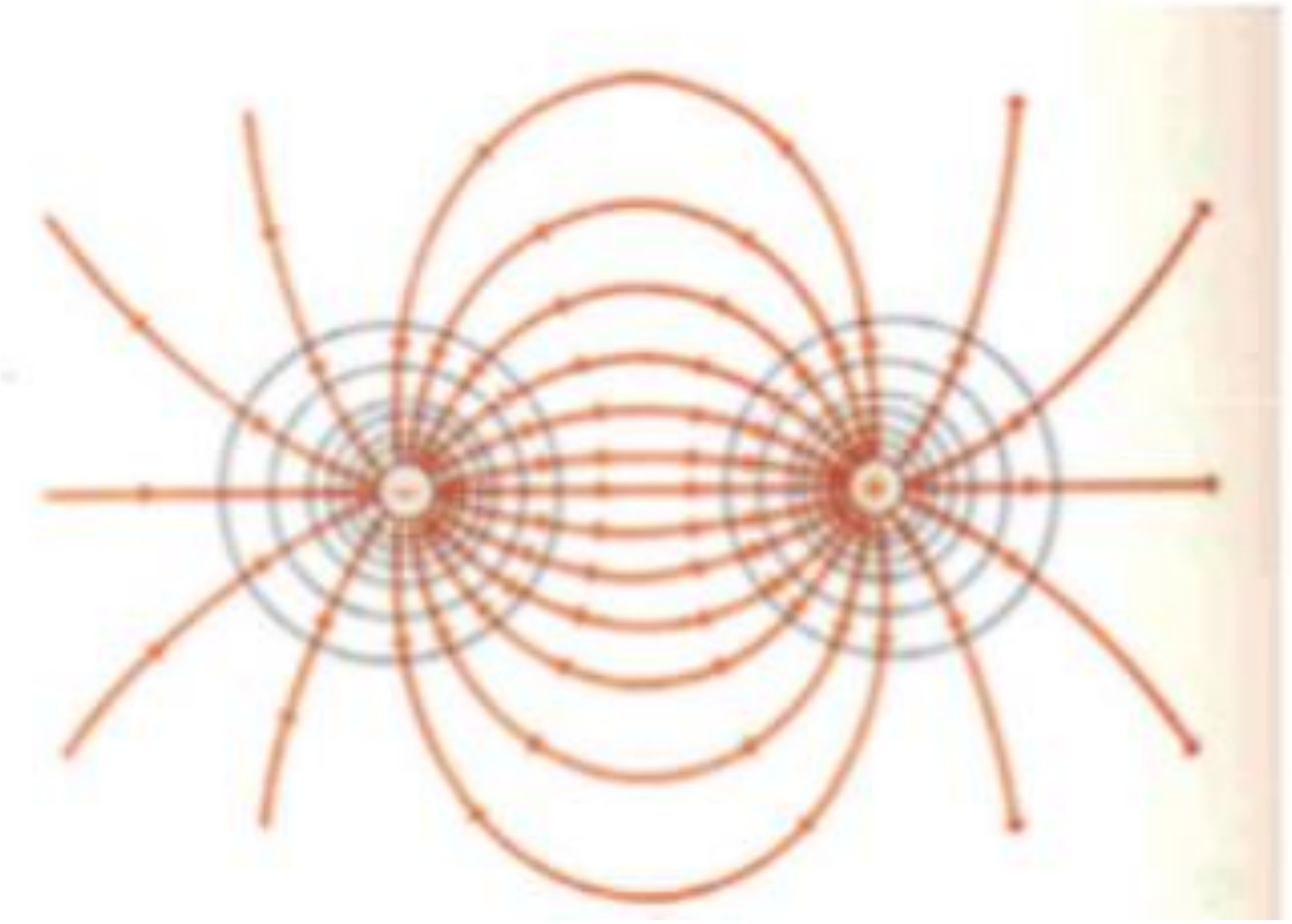
E-Redox® (Red)



STATIC ELECTRIC FIELD

- Field data indicate a radius of influence (ROI) of ~25-30 ft in clay and silts; >40 ft for matrices with injection history of carbon, ZVI, or other conductive compounds

- Electrodes spacing: ~25 ft for mixed saturated and unsaturated matrices

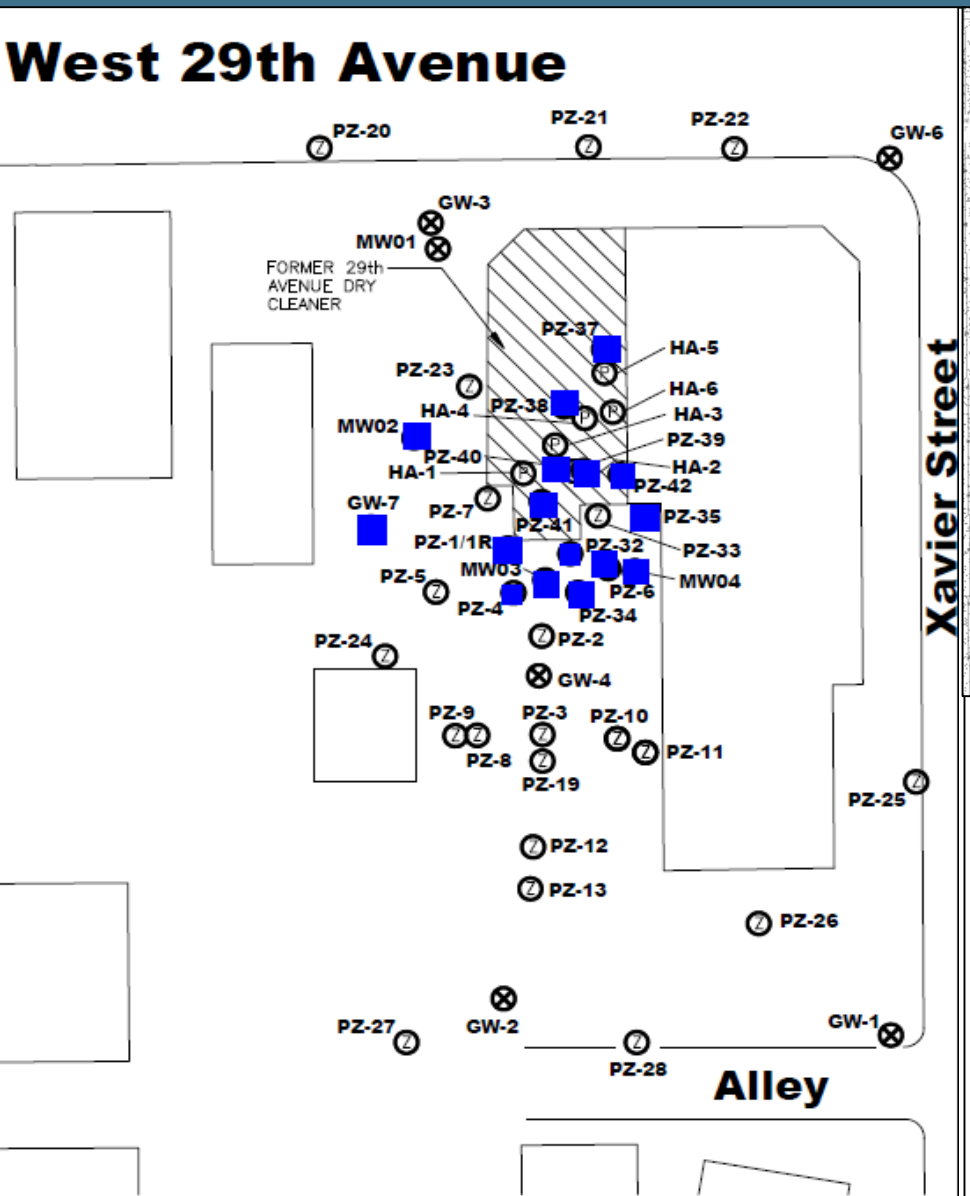


DEGRADATION OF PERCHLOR0ETHYLENE (PCE) IN GROUNDWATER

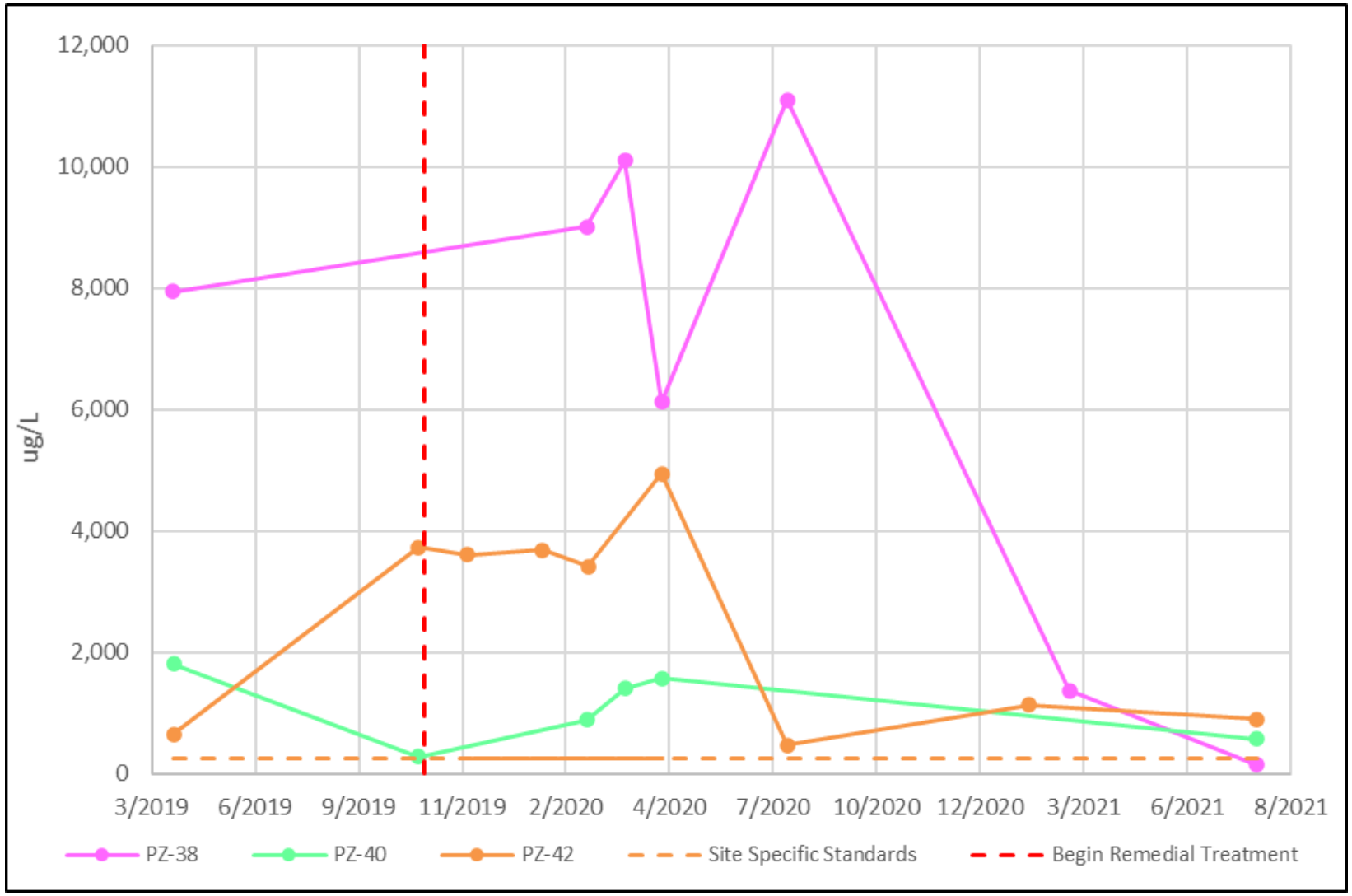
- Location: Denver, CO
- Site History: Former dry cleaner
- Site Area: 0.3 acres
- Contaminant: Tetrachloroethene (PCE)
- Contaminated Matrix: Groundwater

- Site acquired to convert into a 42-unit multifamily apartment building
- Past Remediation Efforts:
  - In situ chemical oxidation using permanganate
  - Reducing agents
- Residual PCE persisted despite past remediation efforts
- NOTE: This is an AET project in collaboration with RE Solutions LLC

E-REDOX® (REDUCTION) IMPLEMENTATION



DEGRADATION OF PERCHLOROETHYLENE (PCE) IN GROUNDWATER



LIFE CYCLE ASSESSMENTS OF E-REDOX® (RED) TECHNOLOGIES

- LCAs of E-Redox-Red technology
  - Based on completed projects at former dry cleaners and industrial/manufacturing sites (4-6 units consisting of 2-3 electrodes per unit), operated on municipal power
- LCAs conducted using SiteWise™ (v. 3)

GHG EMISSIONS FOR E-REDOX® (RED)

- Typical overall project GHG emissions primarily from construction materials and equipment use for new wells and/or abandonment
- First year GHG emissions for E-Redox-Red = **3.34** metric tons CO_2-e
- For comparison: Pump & treat (with activated carbon separation) GHG = **1,965** metric tons CO_2-e
- Energy Consumption by E-Redox-Red: ~50 W/unit

Eric Vonde
Atlas Technical Consultants
Denver, Colorado
Phone Number – (303) 248 8848
Email: eric.Vonde@oneatlas.com

Song Jin PhD and Paul Fallgren
Advanced Environmental Technologies, LLC
Fort Collins, Colorado
Phone Number: (970) 449 9711
Email: songjin@aetecs.com

www.oneatlas.com