NAVFAC
Naval Facilities Engineering Command
SOUTHERN DIVISION

Systematic Approach to Optimization of a Permanganate In Situ Chemical Oxidation System

Operable Unit 4, Naval Training Center Orlando

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Accelerating Site Closeout – Improving Performance – & Reducing Costs Through
OPTIMIZATION
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Project Team

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Overview

- Operable Unit 4, Former Naval Training Center Orlando
- In situ chemical oxidation (ISCO) design
- ISCO performance data
- Optimization efforts
  - Supporting laboratory work
  - Source zone delineation
- Optimization alternatives
- Conclusions/lessons learned

NTC Orlando, Operable Unit 4 (OU 4)

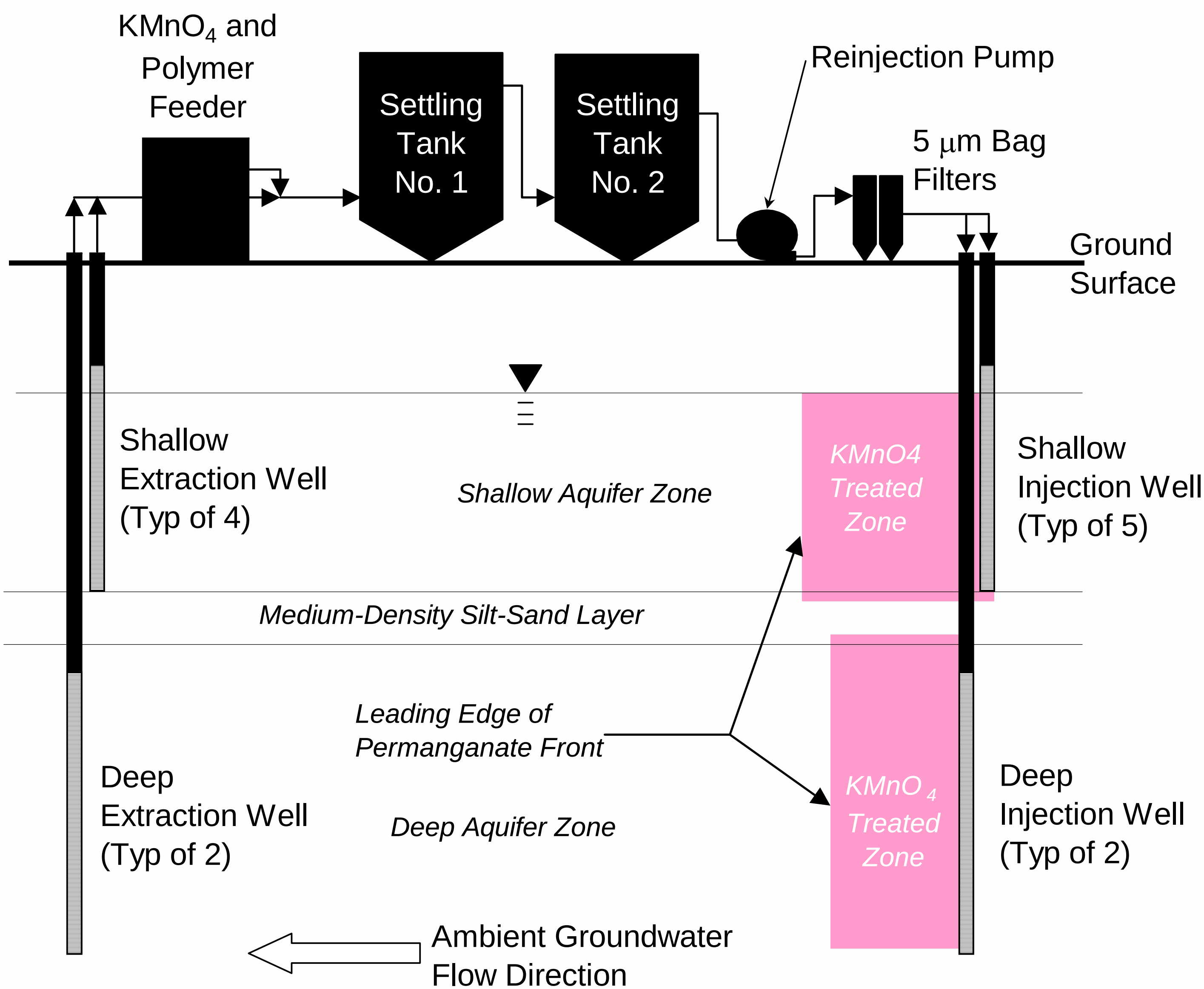
Operable Unit 4, NTC Orlando

- ❑Building 1100 was industrial dry cleaning facility
- ❑PCE detected in groundwater as high as 23 mg/L
- ❑PCE detected in soil as high as 2,940 mg/kg
- ❑TCE and cis-1,2-DCE detected as high as 13.2 mg/L and 4.6 mg/L, respectively
- ❑70-foot saturated thickness of very fine to fine-grained silty sand
- ❑Hydraulic conductivity = 10 to 100 ft/day
- ❑Depth to water = 5 to 6 ft bgs
- ❑Total organic carbon (TOC) ranges from 200 to 8200 mg/kg

ISCO Design

- Pilot test conducted in 2000
- 5 Shallow injection wells
  - Total shallow injection rate = 10 GPM
- 2 Deep injection wells
  - Total deep injection rate = 5 GPM
- Design MnO_4^- concentration = 1,000 mg/L
- Aboveground re-circulation system designed to remove manganese dioxide solids and re-inject permanganate into aquifer
- Theoretical permanganate “front” to treat organic compounds (natural and contaminants) in situ
- Operational difficulties prohibited use of polymer feed system for enhanced manganese dioxide particle flocculation

ISCO Re-circulation System



ISCO Equipment

Aboveground Settling Tanks

$KMnO_4$ Drum Feeders

ISCO Equipment

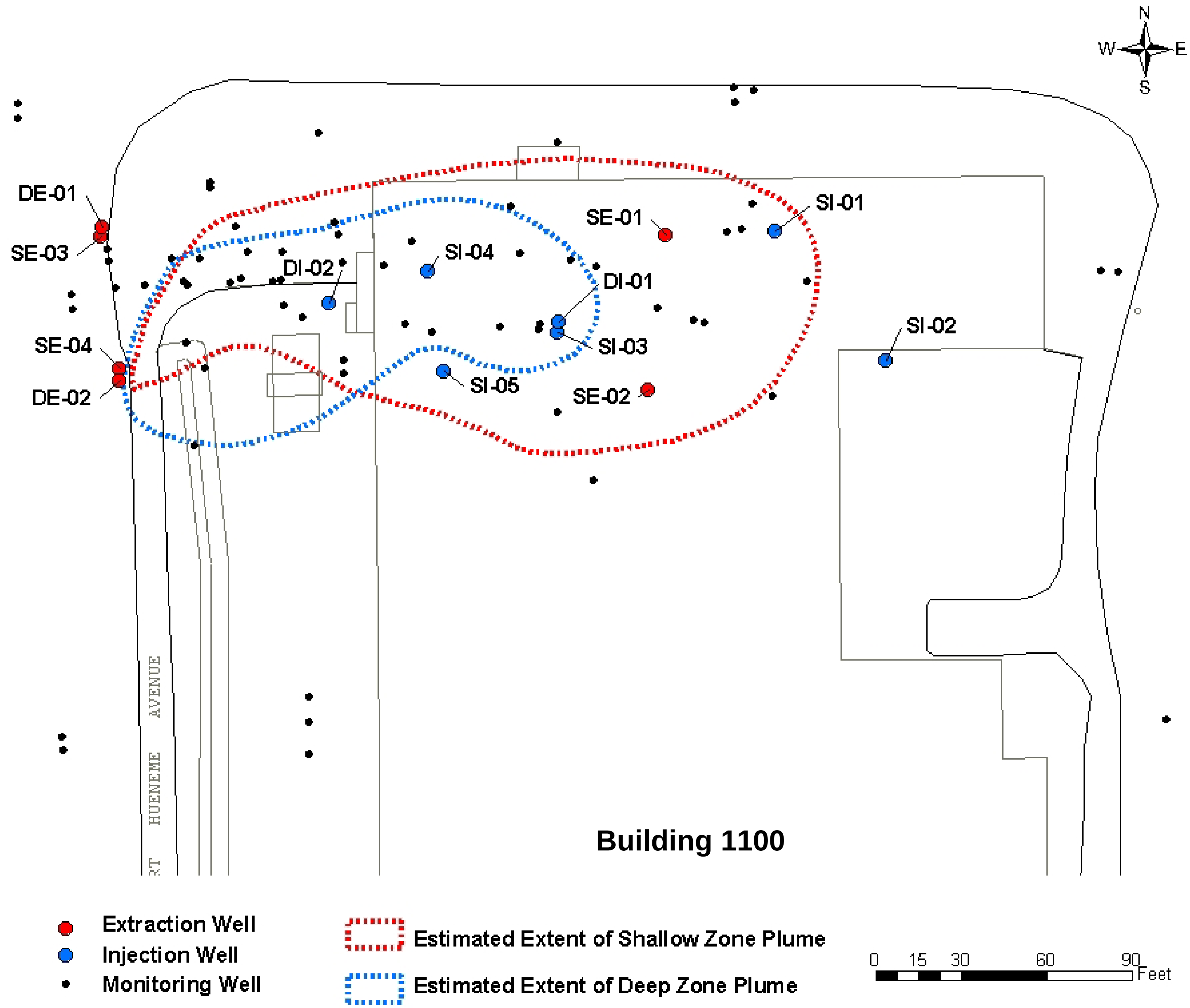
Extraction Manifold

Injection Manifold

Bag Filter System

Target Treatment Zone

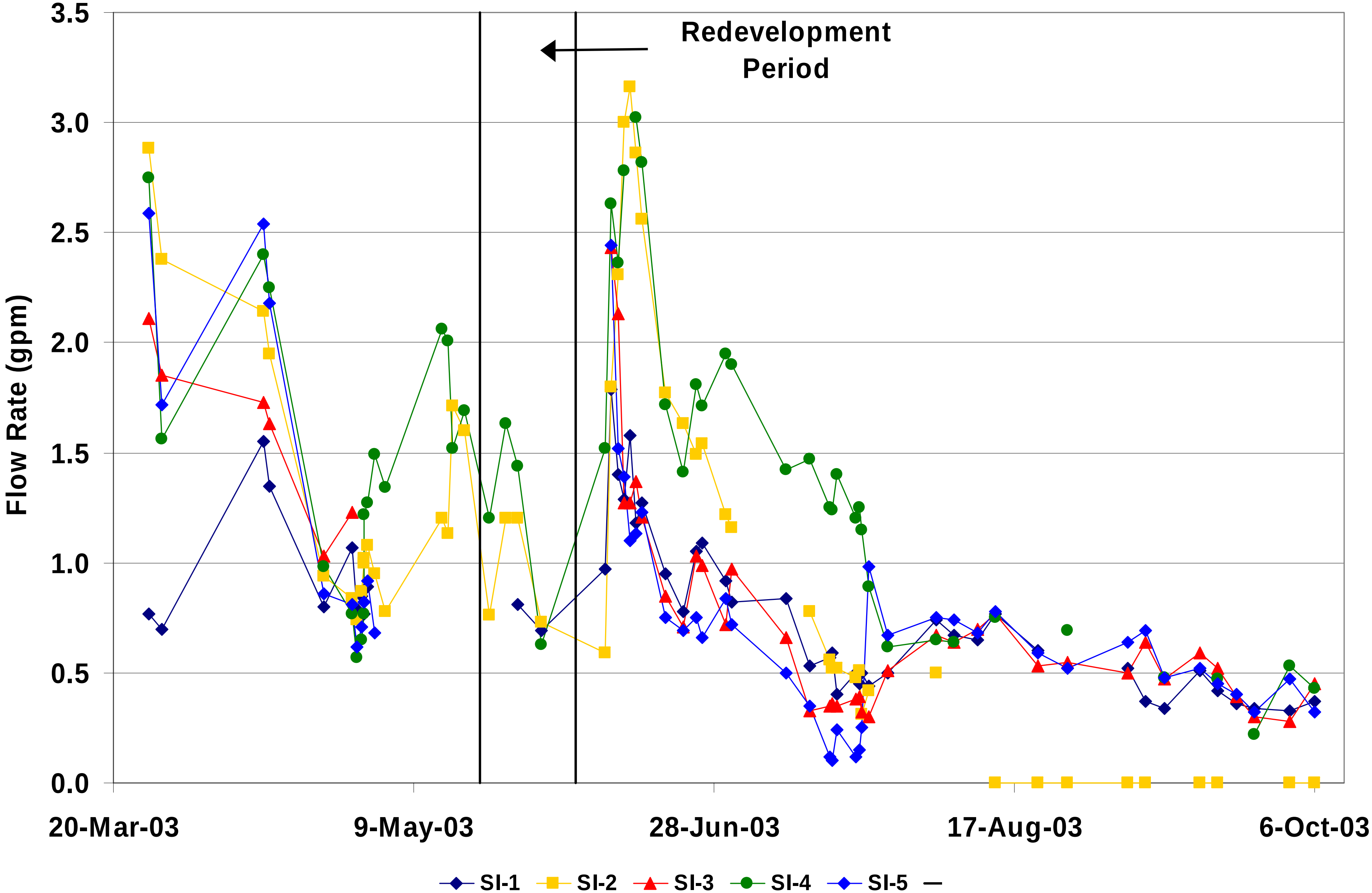
ISCO Well Field



ISCO Performance

- Low sustainable injection rates (< 0.5 gpm per well)
- Water levels increased in injection wells
- Low MnO_4^- loading to the aquifer
- Erratic subsurface distribution of MnO_4^-
- Injection well fouling/formation plugging caused by accumulation of manganese dioxide (MnO_2) particles
- Excessive downtime caused by O&M activities (e.g. power failure, well redevelopment, feeder operation)

Shallow Injection Well Performance

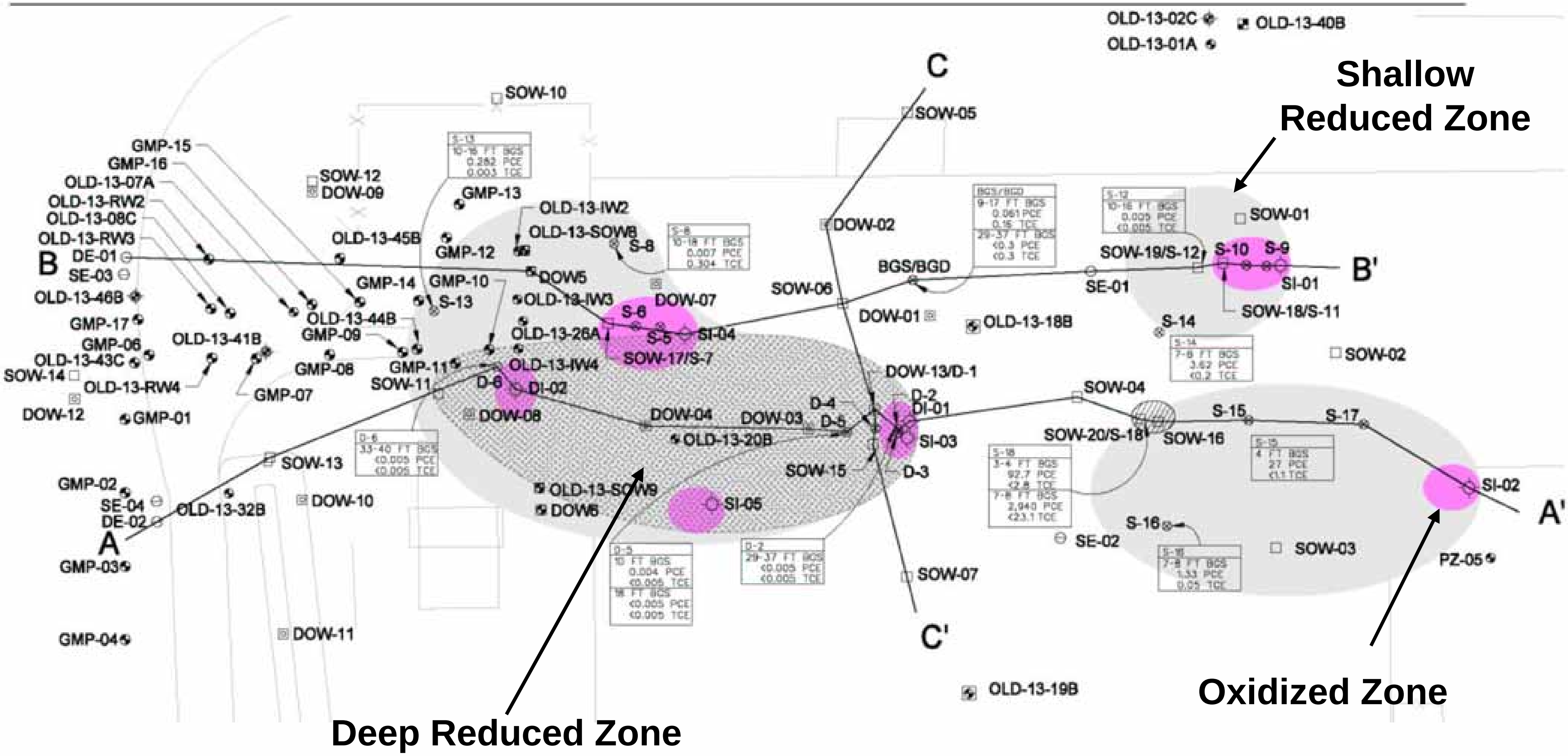


MnO_2 Particle Generation

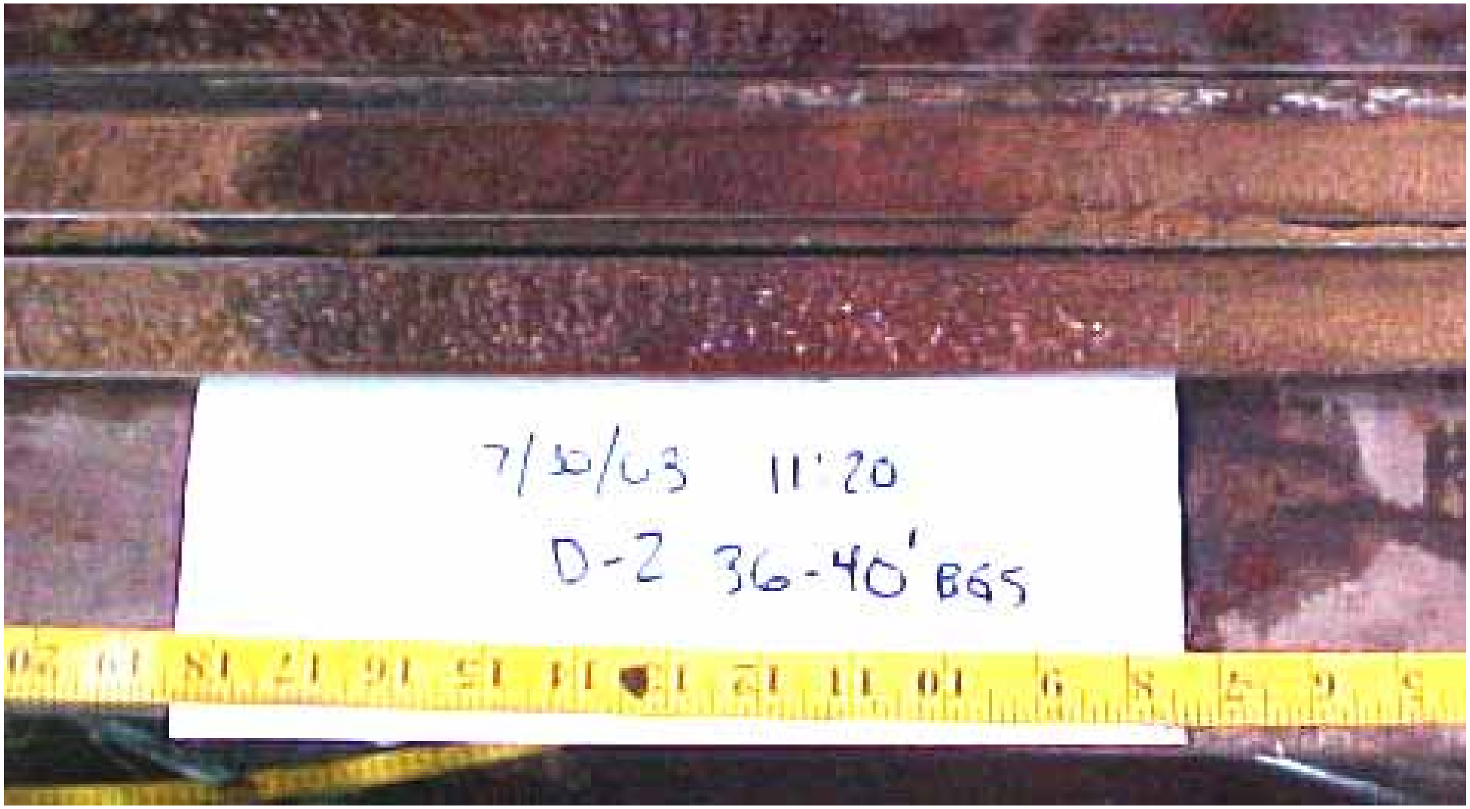
New Filter

Spent Filter

Subsurface Distribution of MnO_4^-



Soil Coring – Oxidized Zones



Permanganate Staining

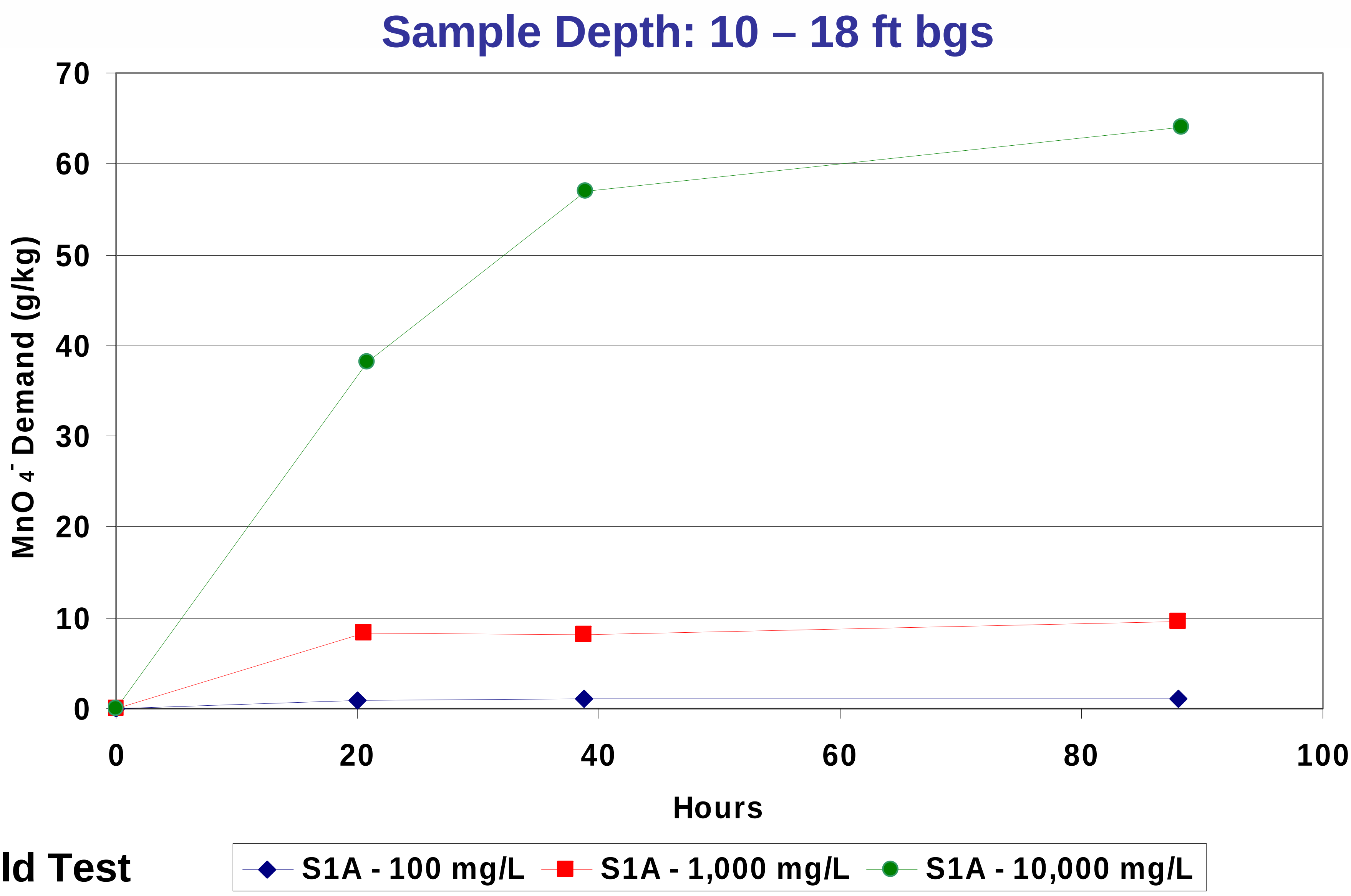
Soil Oxidant Demand (SOD)

- Original SOD estimate was based on 30-minute batch test by permanganate vendor
- Field and laboratory batch tests confirmed SOD ranges from 1 – 10 g/kg for 1,000 mg/L MnO_4^-
- Lab flow-through column tests yielded SOD estimate of 0.3 to 0.4 g/kg for 1,000 mg/L MnO_4^-
- Two methods to minimize natural oxidant demand:
  - Lower permanganate concentration
  - Faster flow rate (less oxidant contact time with porous media)
- Lab column tests with MnO_4^- concentration of 250 – 500 mg/L experienced no plugging, pressure increase, or flow reduction

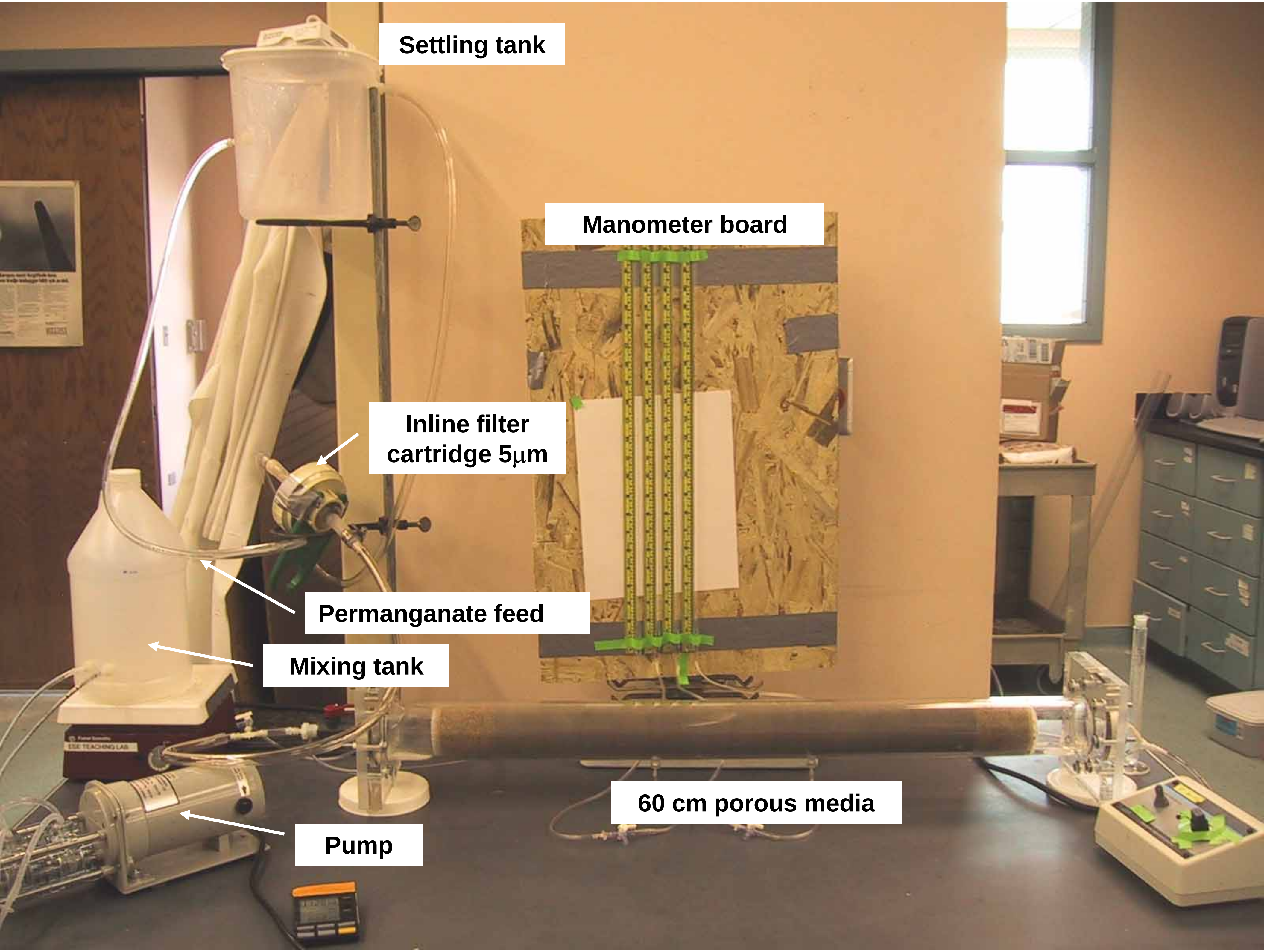
Soil Oxidant Demand Testing

Field Laboratory Setup

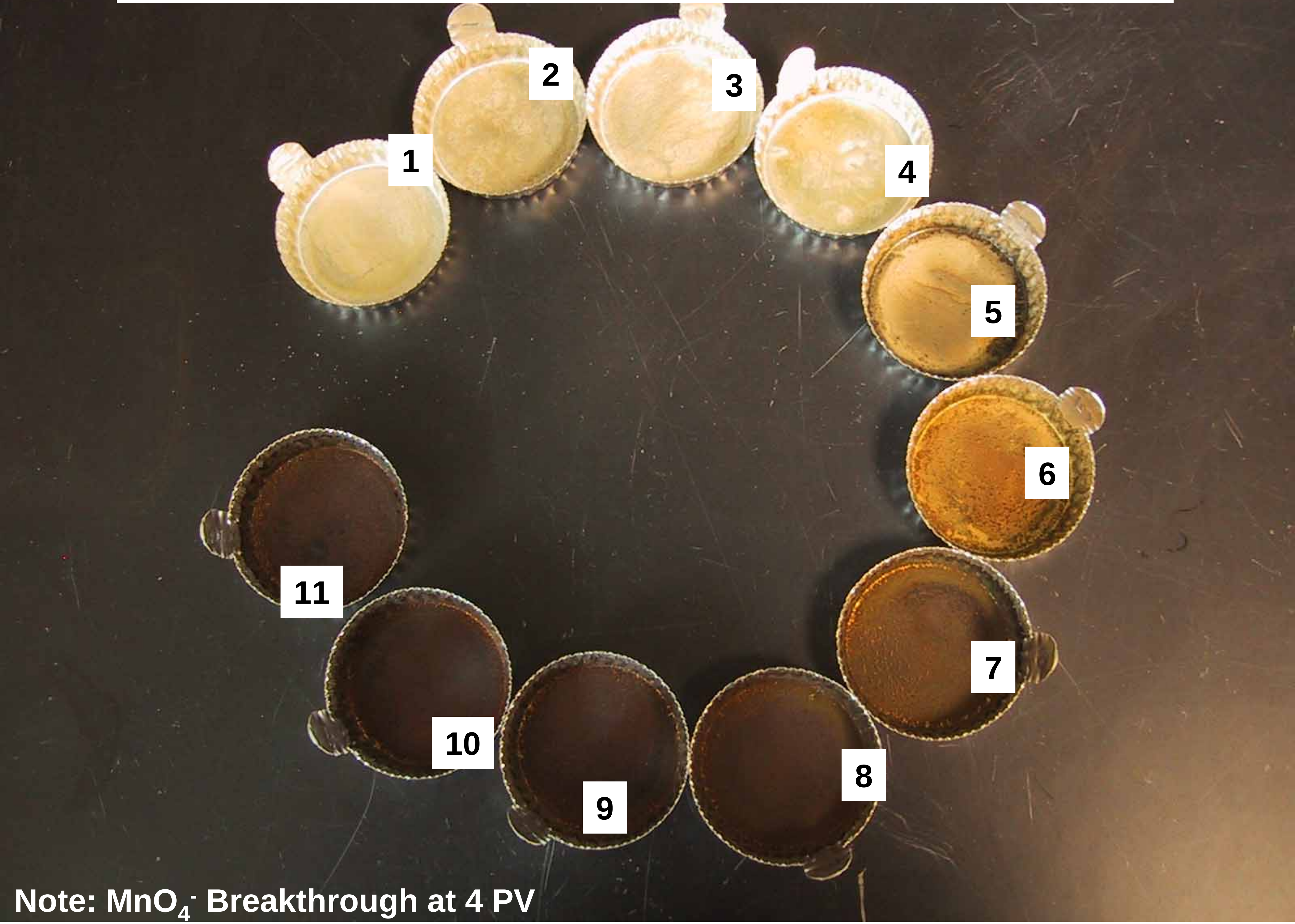
Soil Oxidant Demand Testing



* Field Test

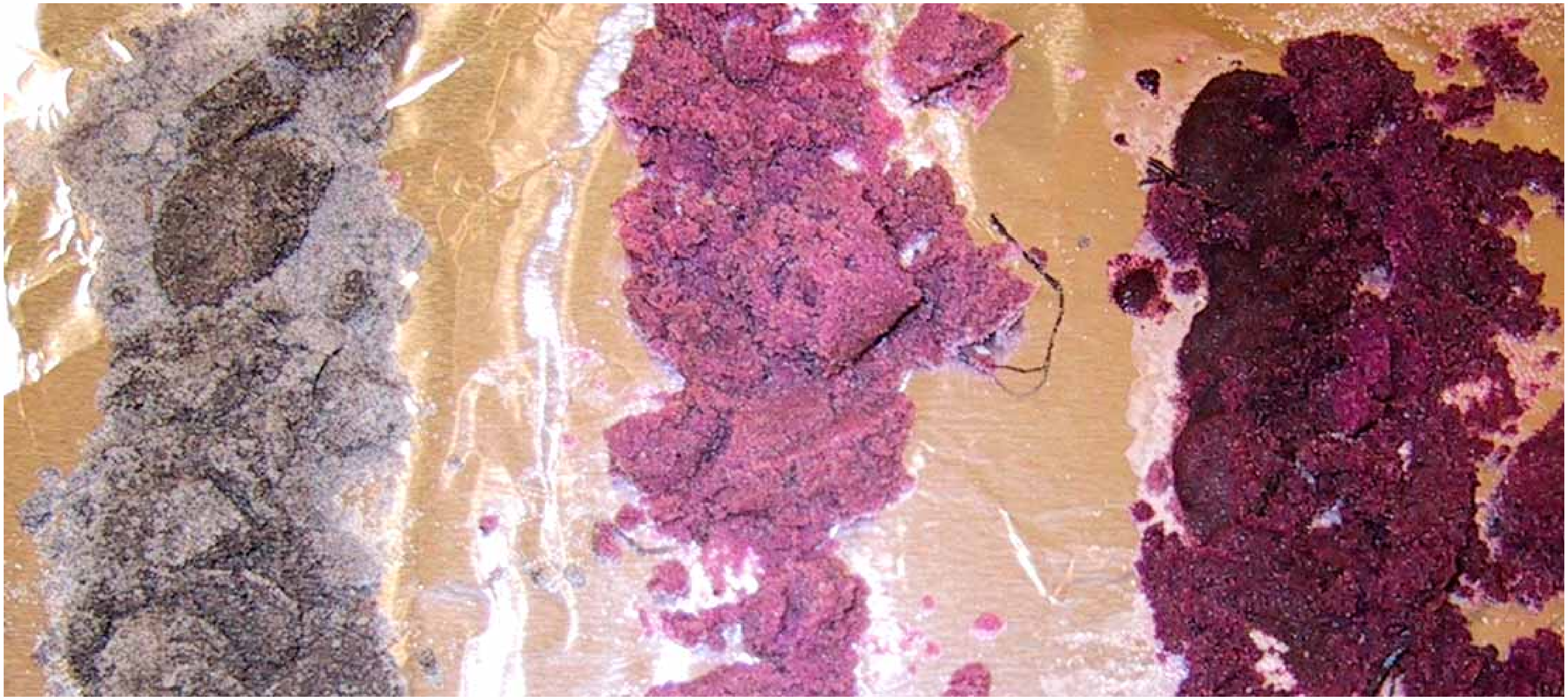

Settling tank
Manometer board
Inline filter cartridge 5μm
Permanganate feed
Mixing tank
60 cm porous media
Pump

Total solids in column effluent for each Pore Volume of throughput



Soil Oxidant Demand Testing

Soil Prior to Treatment	1,000 mg/L $KMnO_4$	4,000 mg/L $KMnO_4$

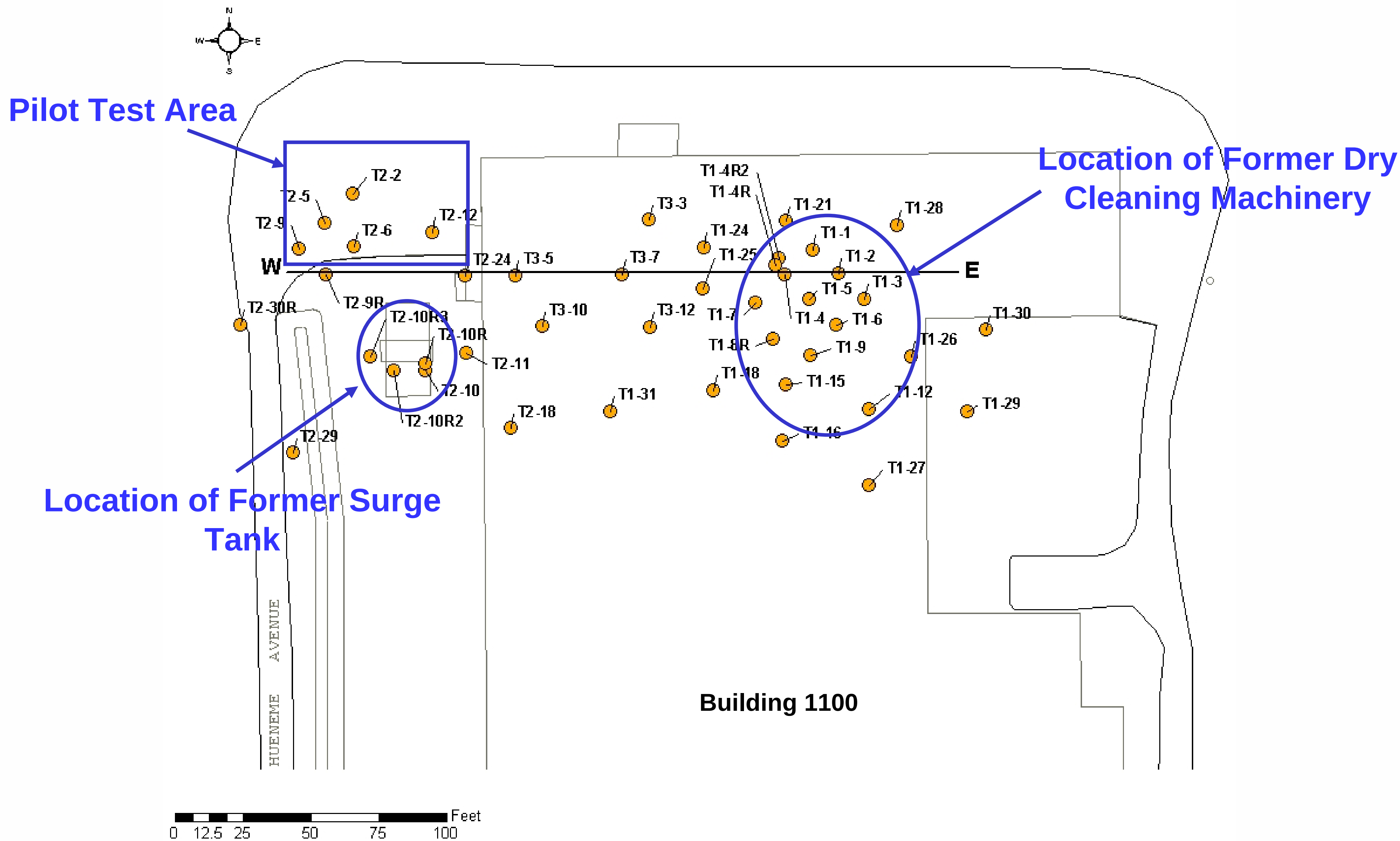


Building Demolition

MIP Investigation

- Building demolition allowed better access to site for detailed DNAPL source zone characterization
- Goals of Membrane Interface Probe (MIP) investigation were to better define limits of ISCO treatment and evaluate site stratigraphy
- 46 Points installed to an average depth of 70 ft bgs
- MIP and soil conductivity measurements collected at 0.05 ft vertical interval
- Soil and groundwater confirmation samples collected

MIP Investigation Points

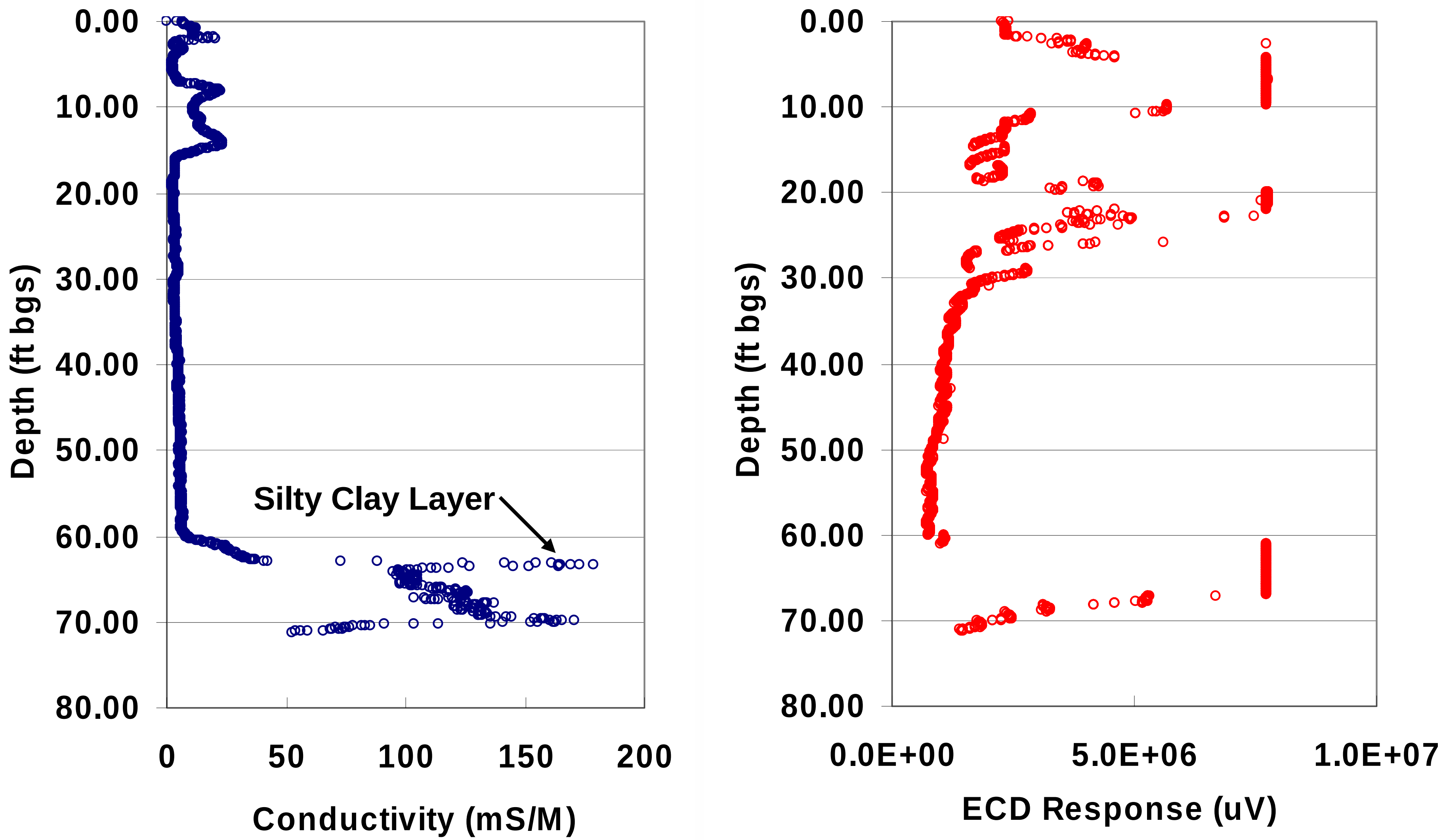


MIP Equipment

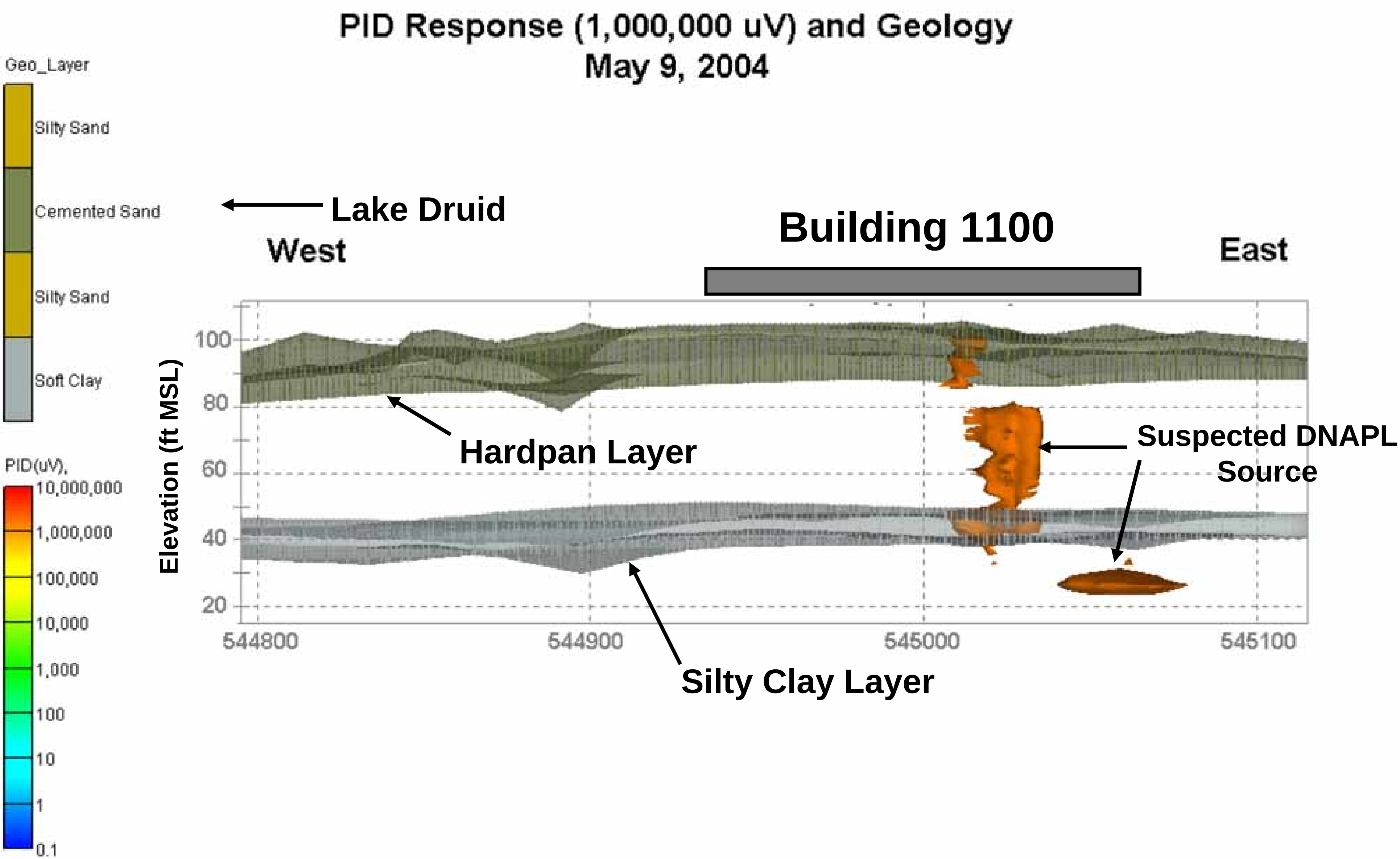
MIP Investigation

Typical MIP Response

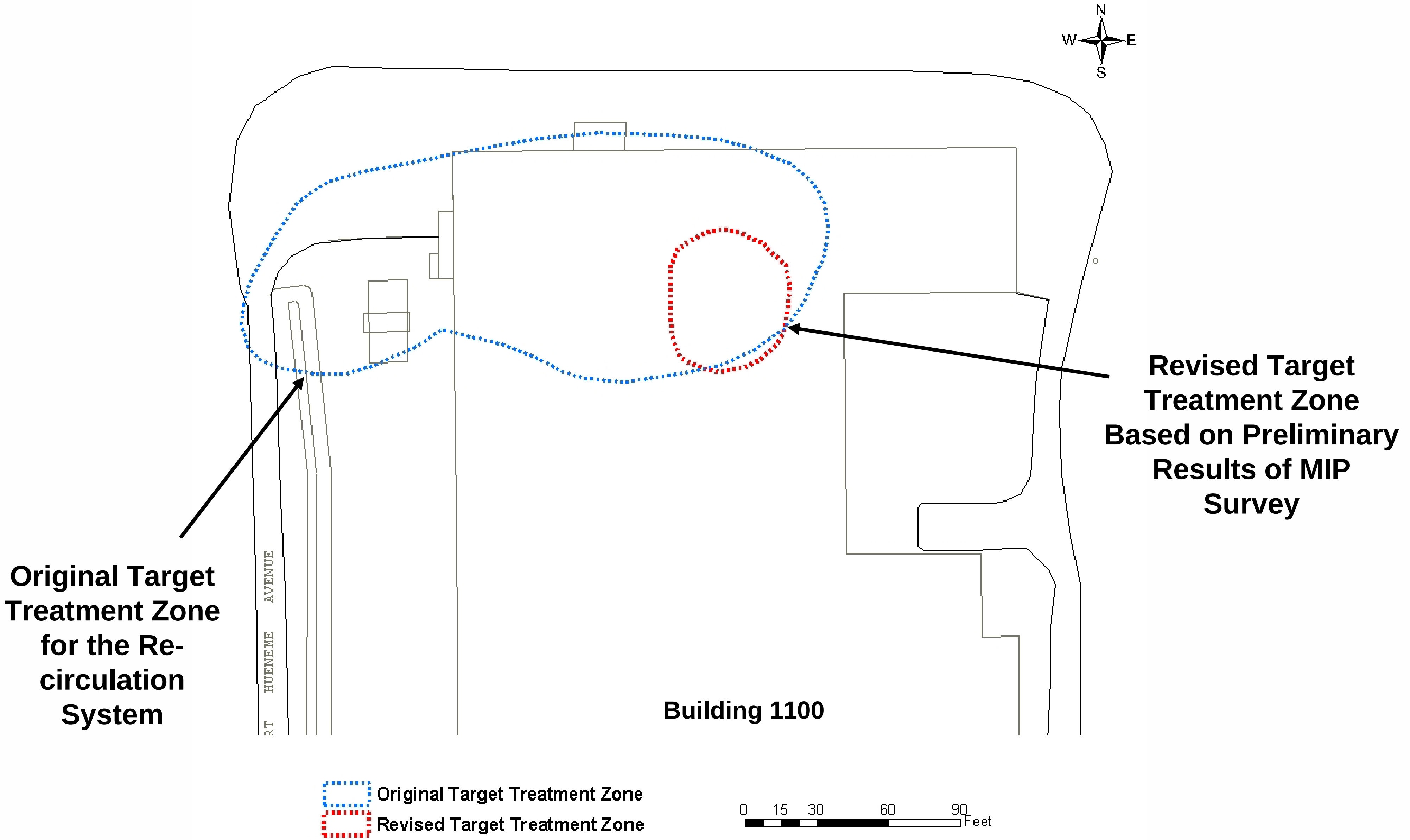
T1-7 in DNAPL Source Area



MIP Results


PID Response (1,000,000 uV) and Geology
May 9, 2004
Geo_Layer
Silty Sand
Cemented Sand
Silty Sand
Soft Clay
PID(uV),
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0.1
Lake Druid
West
Building 1100
East
Elevation (ft MSL)
100
80
60
40
20
544800
544900
545000
545100
Hardpan Layer
Suspected DNAPL Source
Silty Clay Layer

Reduction in Target Treatment Zone



Optimization Alternatives

- **<u>Option 1 – Optimize Re-circulation System</u>**
  - **Optimize existing re-circulation system by reducing the permanganate concentration. Injection well field would be designed based on design simulation using permanganate reaction kinetics.**
- **<u>Option 2 – Permanganate Delivery Using DPT Injection</u>**
  - **Based on smaller target treatment zone, focus delivery of permanganate with use of DPT technology. Option would also include enhanced bioremediation as a polishing tool.**

Summary

- Injection well fouling/formation plugging caused by buildup of manganese dioxide solids resulted in low oxidant loading
- Inaccurate estimation of natural oxidant demand of porous media
  - Oxidant consumed within short distance
  - Higher MnO2 solids generated causing fouling
  - Reduce oxidant concentration to reduce MnO2
- Overestimation of oxidant transport in design model simulations
  - Design simulator did not take into account oxidant reaction kinetics

Summary (Cont.)

- ❑Improved DNAPL characterization will reduce target treatment zone; improve effectiveness and cost efficiency
- ❑Alternate delivery method using DPT technology may be more cost effective

Lessons Learned

- ❑ **Critical design factors:**
  - ➢ **Accurate estimate of SOD**
    - Depends on SOD test method (batch vs. flow through)
  - ➢ **Accurate source zone characterization**
  - ➢ **Selection of appropriate reagent delivery method**
  - ➢ **Account for aquifer geochemistry (e.g high SOD, anaerobic conditions)**
  - ➢ **Design simulators need to include permanganate reaction kinetics**
- ❑ **Perform optimization reviews at all phases**
  - ➢ **Particularly at FS, RD when optimization can be built in**
  - ➢ **Involve specialized technical expertise as appropriate**

Questions?

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