In-Situ Remediation of Dissolved Chlorinated Hydrocarbons Via Enhanced Reductive Dechlorination

-A Rail Yard Case Study

Remediation Technologies Symposium 2012
Fairmont Banff Springs Hotel
Environmental Services Association of Alberta

October 17-19, 2012

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Imagine the result

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Introduction

Petroleum impacts are commonly found at railroad yards and facilities. Releases from chlorinated solvents are not as common, but present an entirely different set of challenges.

- Understand importance of developing accurate CSM for remediation planning
- Present project challenges and solutions for in-situ remediation of chlorinated solvents
- Discuss remediation results following treatment enhancements
- Provide a summary of lessons learned

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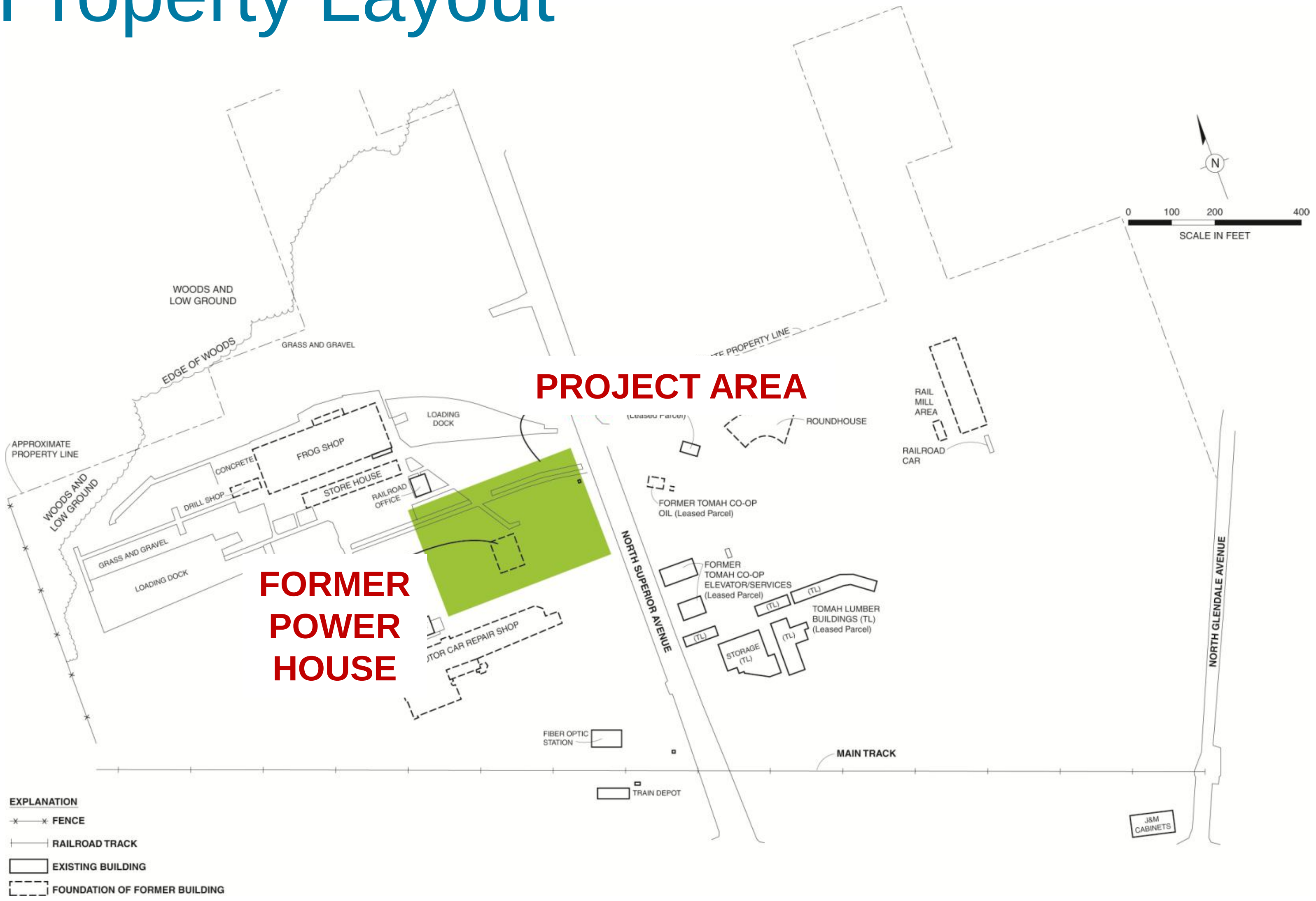
Site History

- 60-acre property developed as rail yard in 1870s
- Historical operations included power house, frog shop, roundhouse, paint shop, motor car repair shop, rail mill, other ancillary buildings
- Majority of buildings demolished 1980s/early 90s

Property Layout

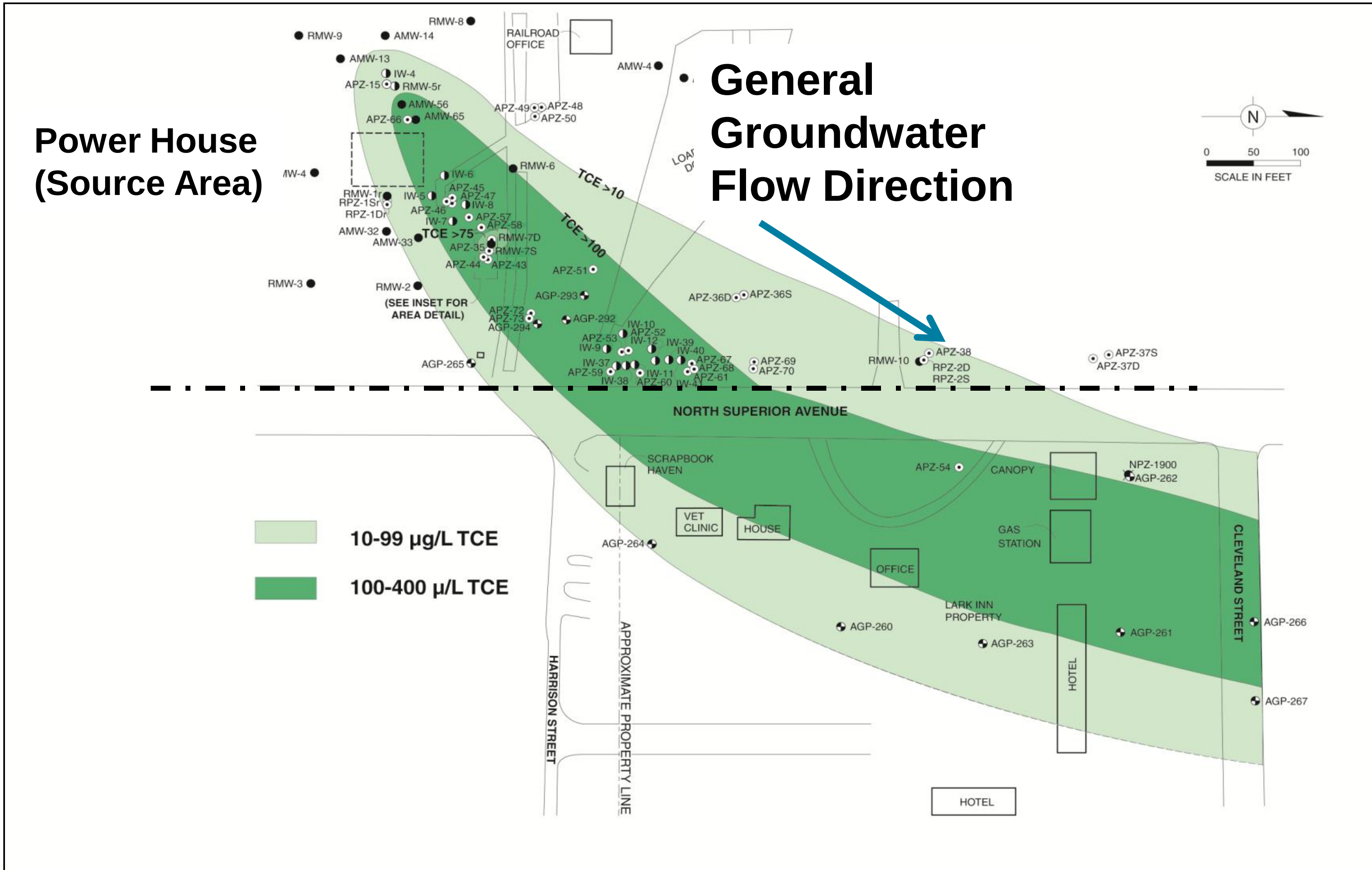


Project Background

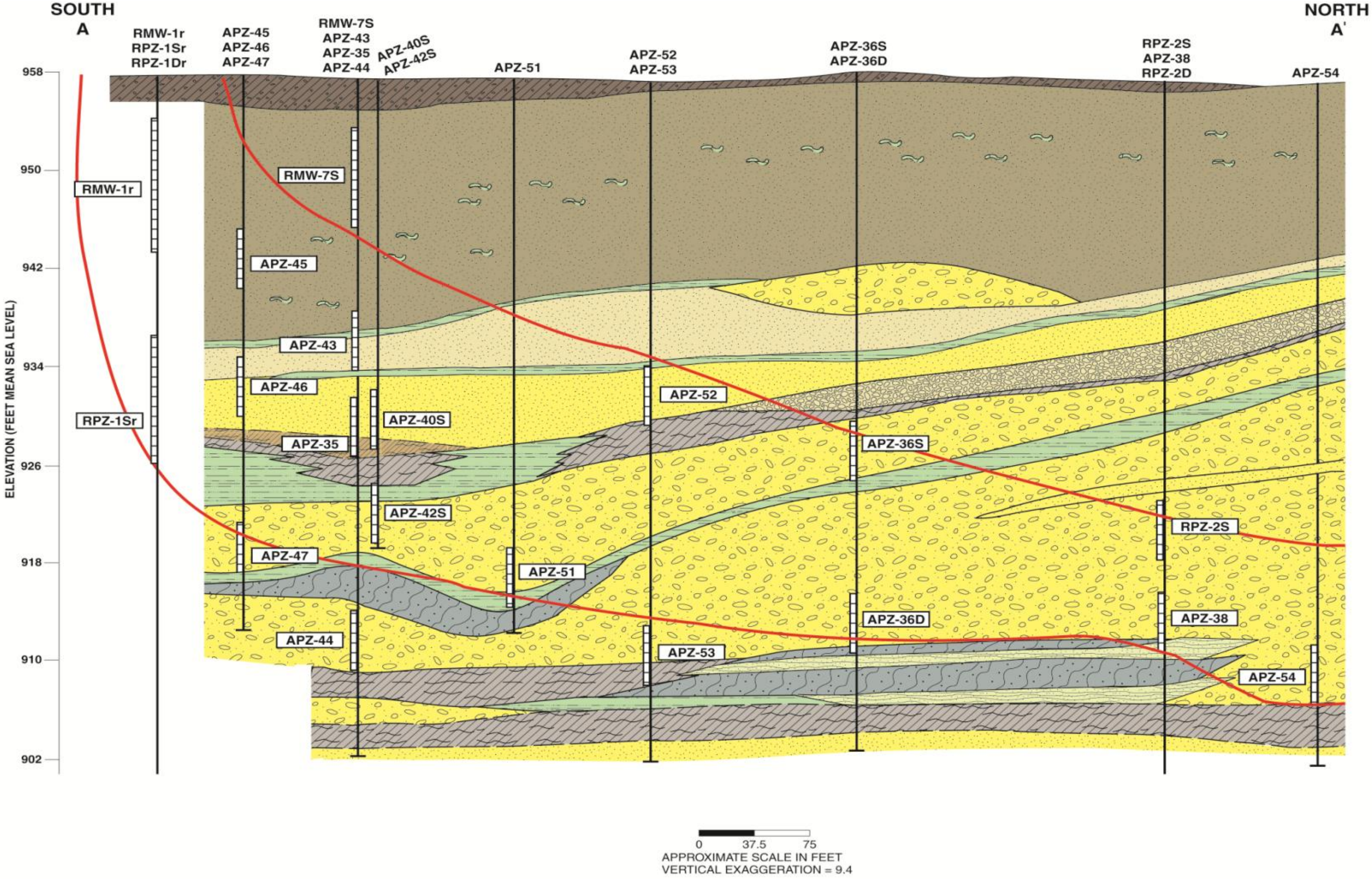
- Initial site characterization completed by others
- Project review indicated TCE detected in soil and groundwater in vicinity of power house; impacts undefined

- ARCADIS conducted subsequent investigations to refine CSM
  - Soil TCE (2-28 mg/kg)
  - Dissolved TCE up to 600 ug/L
  - TCE plume migrating off-site more than 700 ft from source, and 50 ft vertically

Lateral Plume Extent (Pre-remediation)



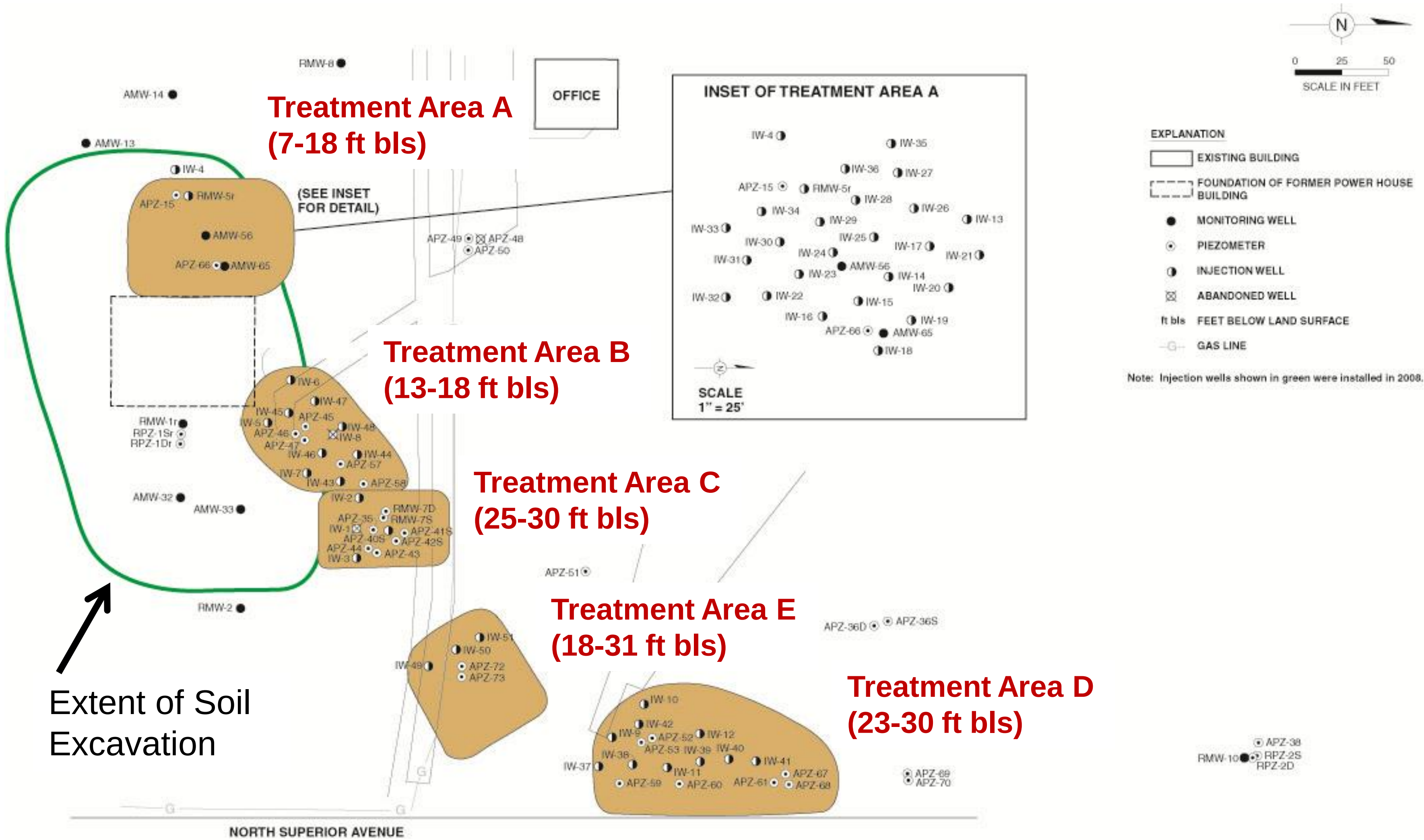
Vertical Plume Extent (Pre-remediation)



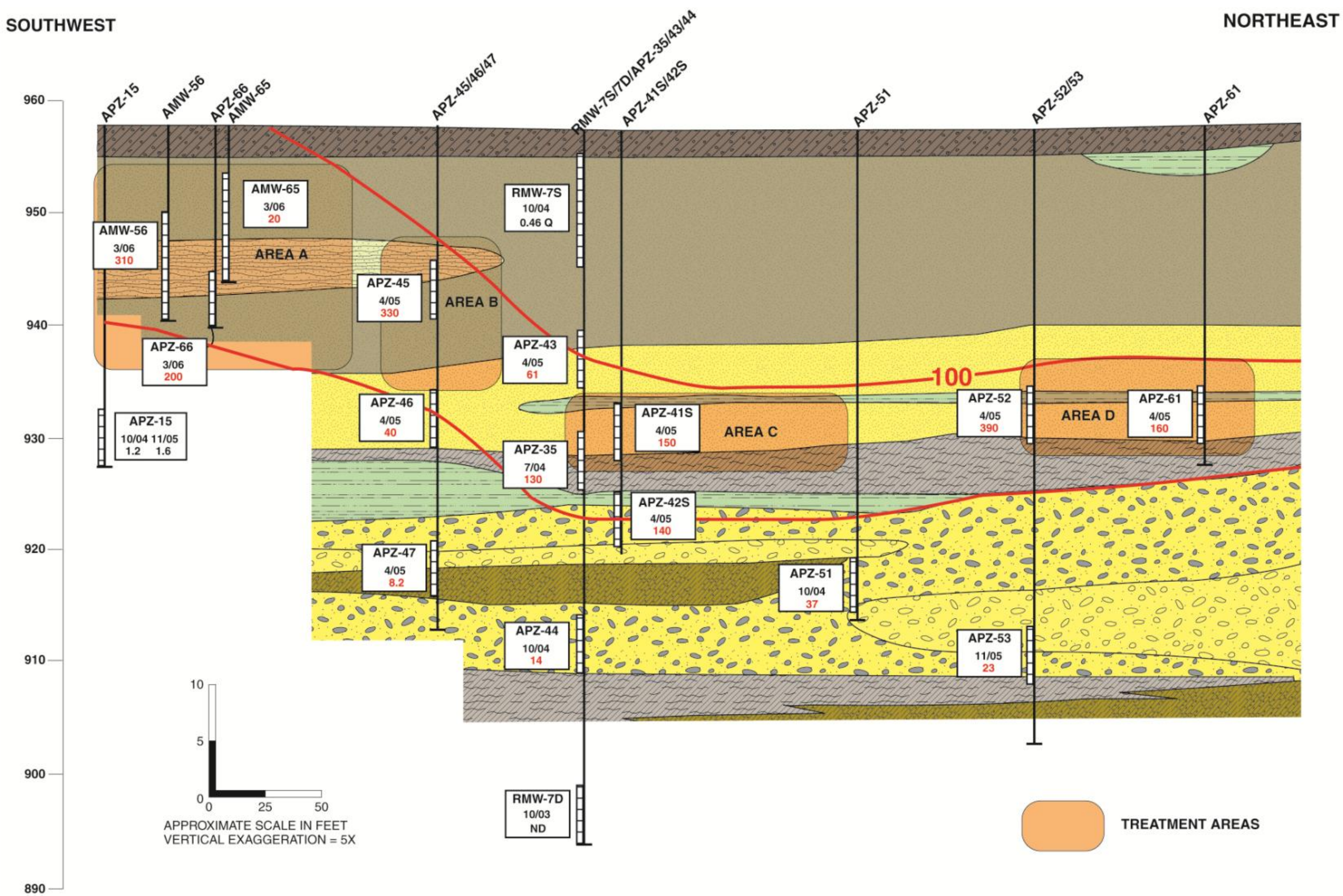
Remediation Strategy & Objectives

- Source Removal - Excavation and off-site disposal of 2,100 tons of TCE-affected soil
- Implement in-situ remediation of TCE-affected groundwater through enhanced reductive dechlorination
- Treat dissolved TCE within source area and at downgradient property boundary (establish clean water fronts)
- Target treatment zones at multiple depths on-site where TCE >100 ug/L

Treatment Areas A Through E



Cross-Section View of Treatment Areas



Treatment Area B

Treatment Area C

Project Challenges

- Solution delivery into subsurface
- Maintaining sufficient carbon loading rates to sustain anaerobic microbial population
- Naturally low pH conditions inhibited microbial growth

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Solution Delivery and Carbon Loading

- Excessive fluid pressure caused daylighting, preferential flow paths through ground or well seal, especially in Areas A, B, and D
  - Reducing injection rates to avoid excess pressure extended injection time/cost
- As the anaerobic microbial population increased following initial injection program, carbon demand from increasing population exceeded carbon loading rates
  - Insufficient carbon loading decreased TCE degradation rates and caused cis-1,2-DCE accumulation
- Bio-fouling of well screens over time reduced injection capacities

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Solution to Carbon Delivery: Modify injection approach/design

Area A

- Shallow water table (<4 ft), daylighting through ground surface at higher volumes
- Installed injection grid across area to facilitate better distribution (per well volume decreased but overall volume increased with grid system)

- Issue related to daylighting effectively addressed

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Areas B and D

- Adapted the injection process to facilitate low-pressure gravity feed systems to address fluid pressure
- Enhanced the injection well network in both areas
- Modified injection wells (4” diameter, SS wire-wrapped screens to increase injection surface area, reduce bio-fouling; neat cement seal)

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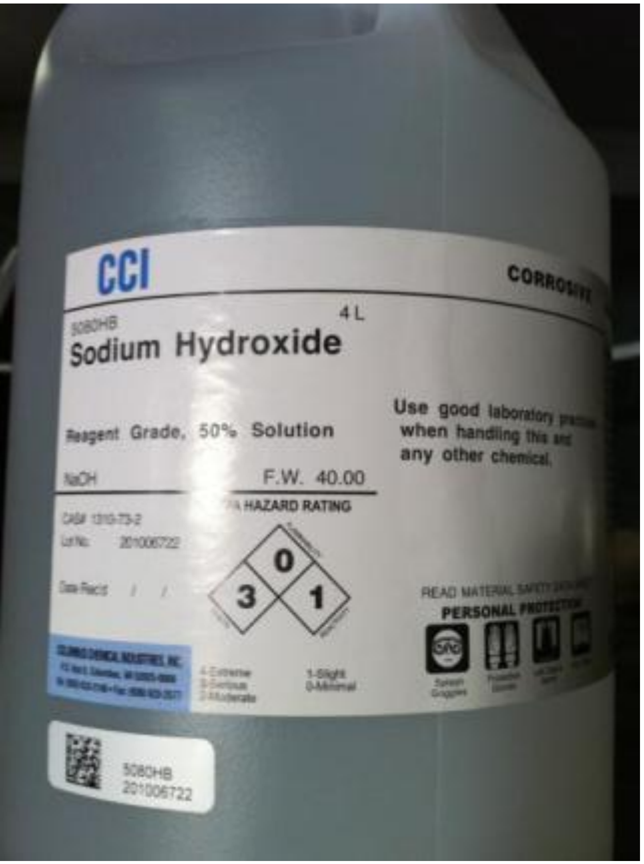
Area B

Constructed elevated pad for gravity feed

Area D

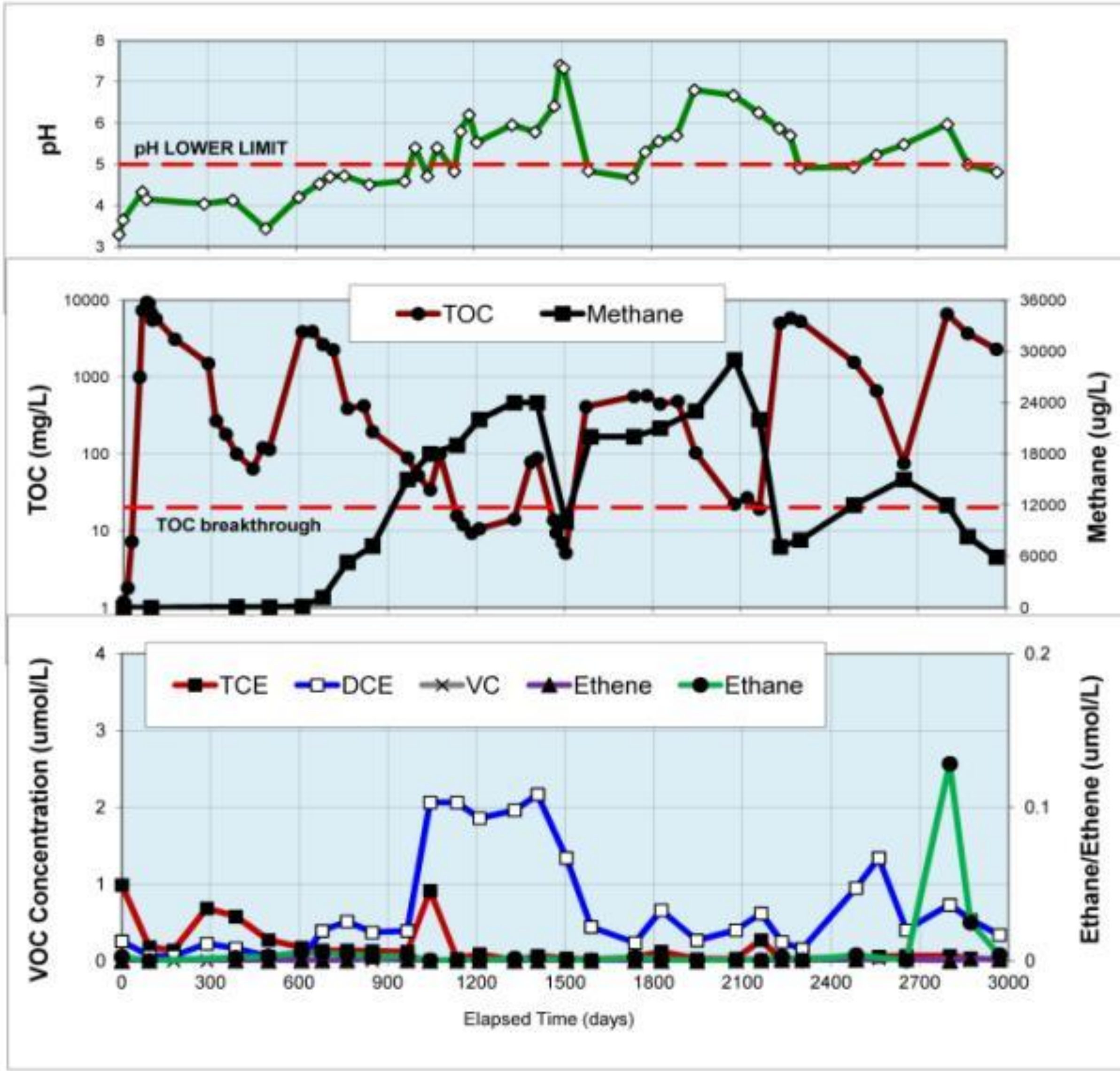
Used existing loading dock for gravity feed



Solution to Low pH Conditions: Adjust pH of Solution

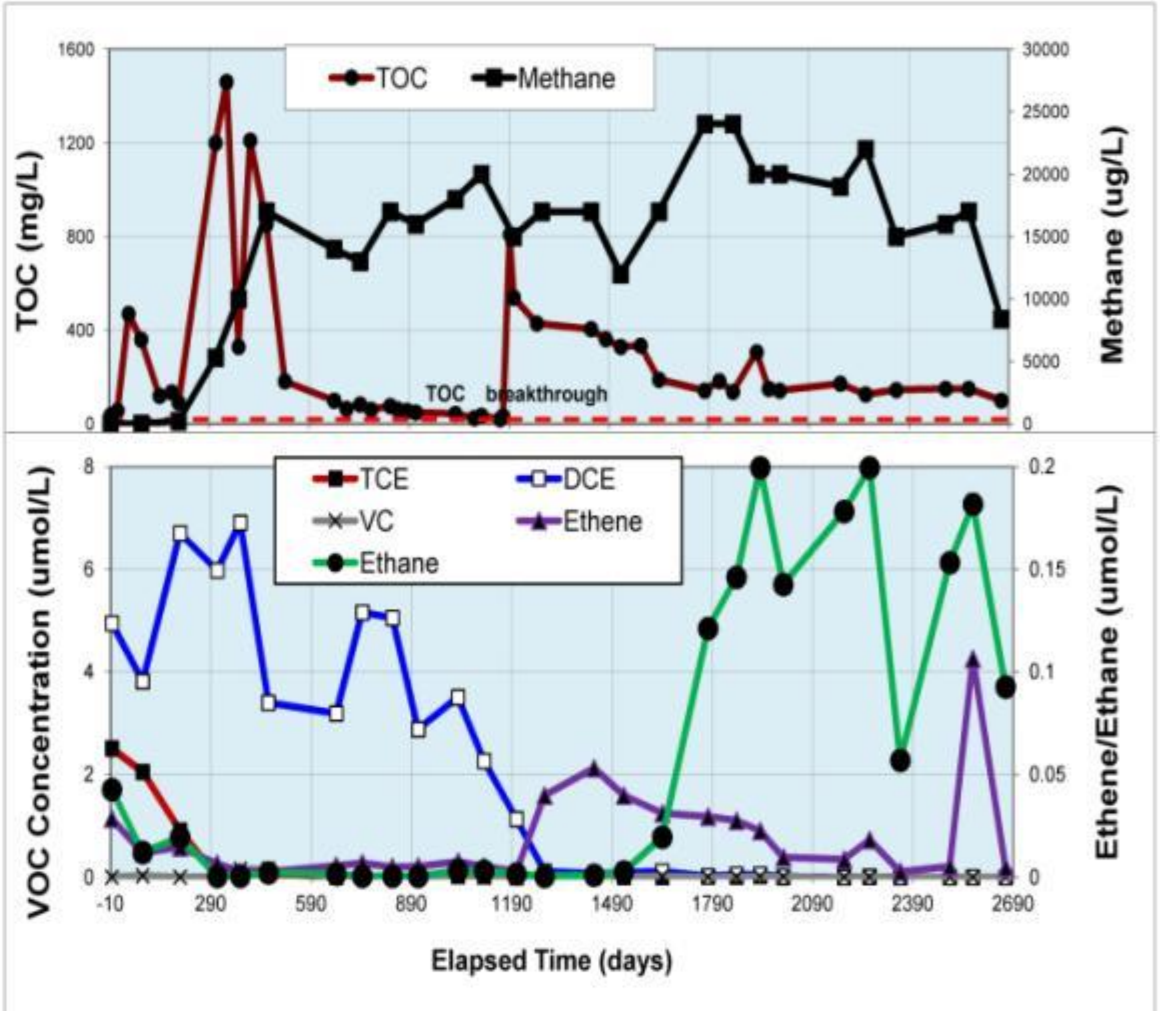
- Baseline groundwater pH in some areas naturally low (~4)
- pH of carbon solution also slightly acidic (~4-5)
- Implemented batch mixing with 50% NaOH
- Field-derived dosing rates to achieve target pH, avoid pH shocking of microbial community
- Target pH range of carbon solution was 7 to 8 s.u.

pH Adjustments: Area C (Well APZ-35)



- pH increased above optimal level (~5)
- Onset of methanogenesis following pH increase
- Reduction in DCE with onset of methanogenesis

Increased Carbon Loading: Area B (APZ-45)



- Anaerobic conditions established (increased methane)
- Degradation dependent on consistent TOC loading
- Reduction in DCE with onset of methanogenesis
- Increase in ethene and ethane indicate degradation process complete

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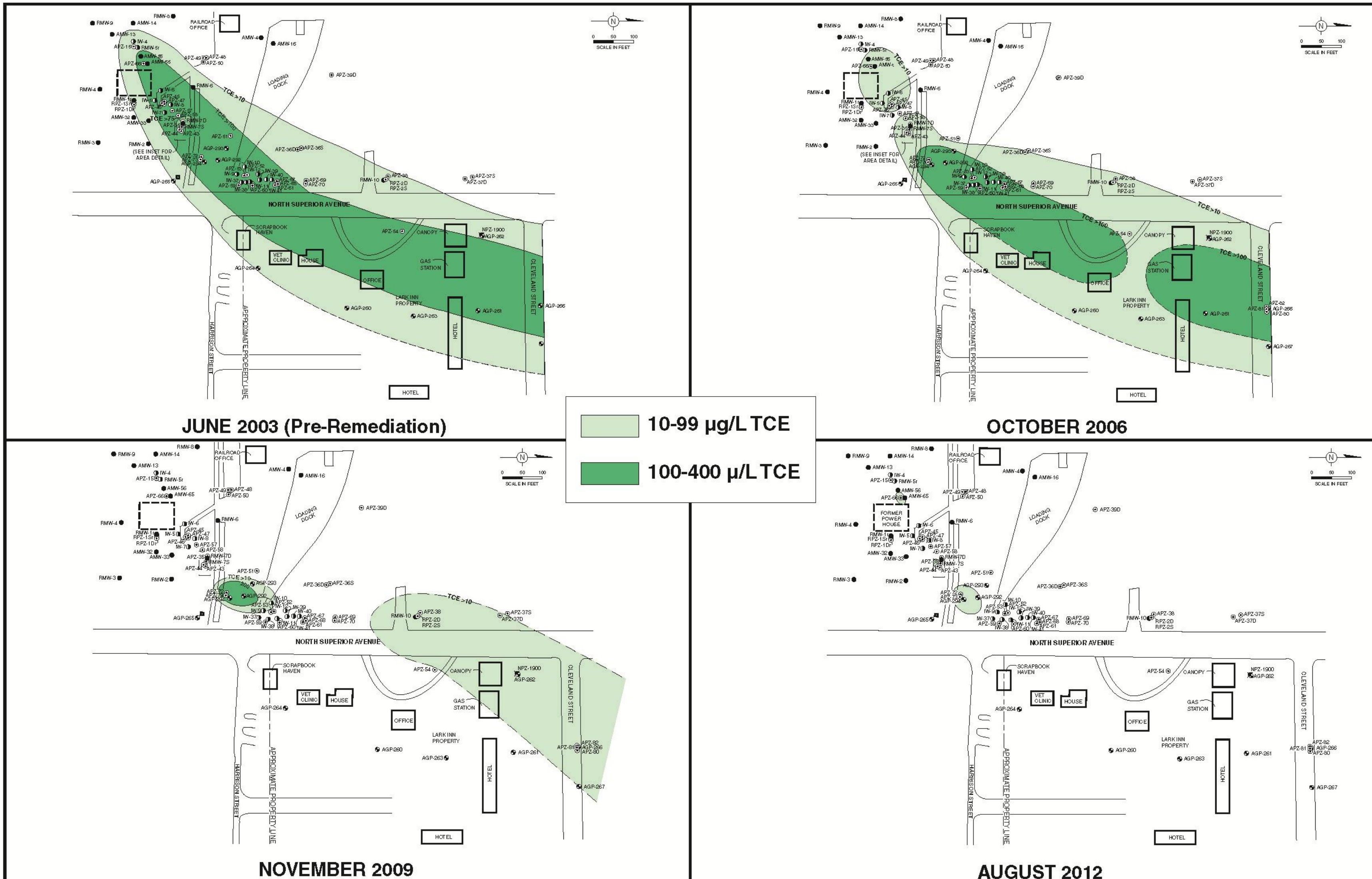
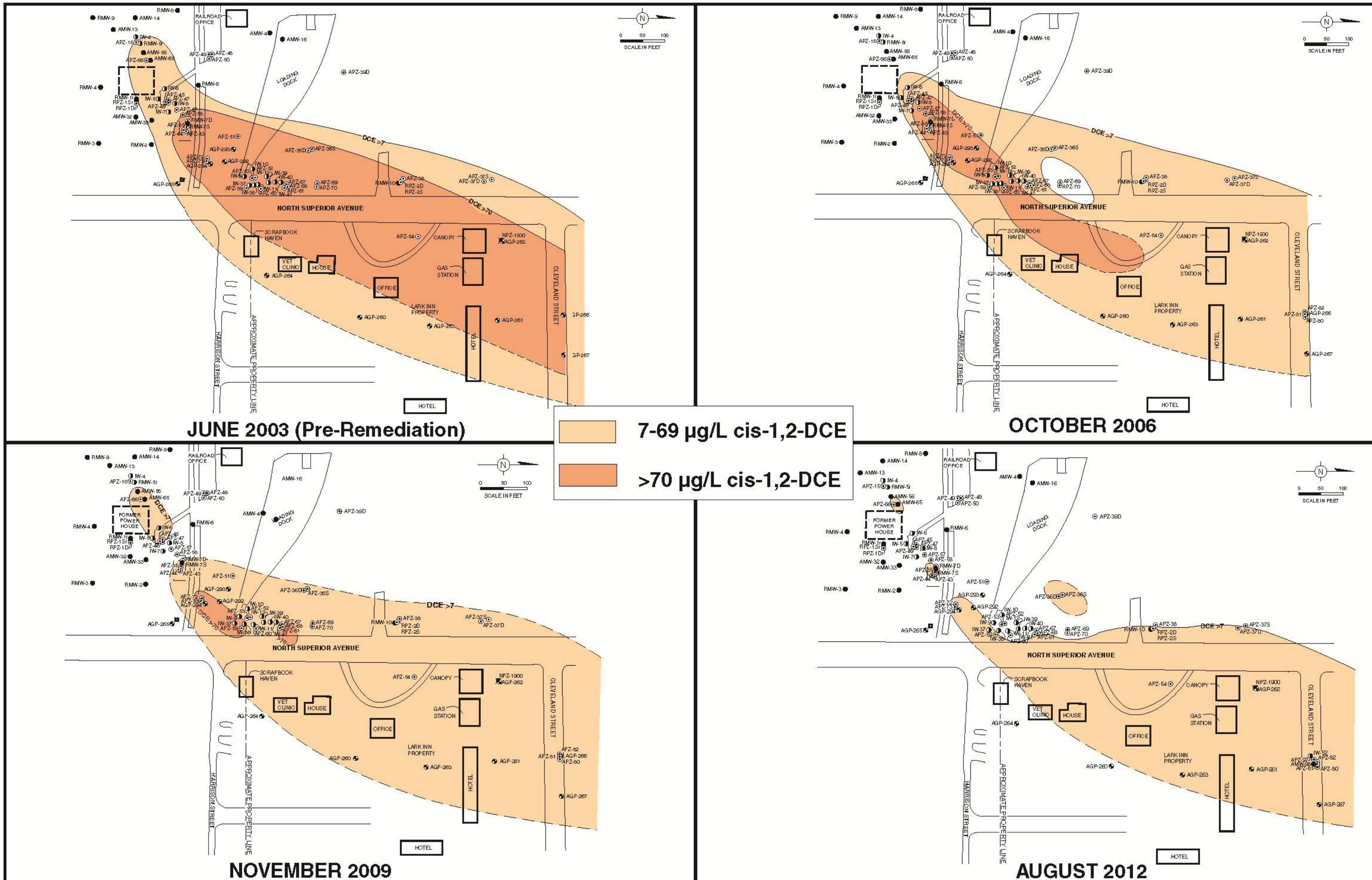
TCE Concentrations Over Time



DCE Concentrations Over Time



Project Accomplishments

- **Dissolved TCE concentrations within treatment areas decreased 95-100%, below state ES (5 ug/L) in most of the areas**
- **TCE concentrations 100 to 400 feet downgradient of treatment areas (on-site and near off-site) decreased below state ES**
- **After system modifications, cis-1,2-DCE concentrations decreased 90 to 100%, currently below state ES (70 ug/L) on-site and near off-site**
- **Ethene production and low vinyl chloride concentrations (generally <5 ug/L) indicate reductive dechlorination process proceeding to completion**

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Summary and Lessons Learned

- Proper site characterization and accurate CSM crucial to success
- Address carbon solution delivery issues through adaptable design, proper injection well design, and regular maintenance program to maintain injection well performance
- Optimize carbon loading rates as remediation progresses to sustain demand from increasing microbial population
- pH adjustments of reagent can address low pH conditions that inhibit microbial growth

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Imagine the result

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