Large Scale Bioremediation Using Multiple Electron Donors

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State Coalition for Remediation of Dry Cleaners (SCRD)

Fall Meeting 2009

San Antonio, Texas

Morning Plenary with EPA Technical Support Project (TSP)

November 17, 2009

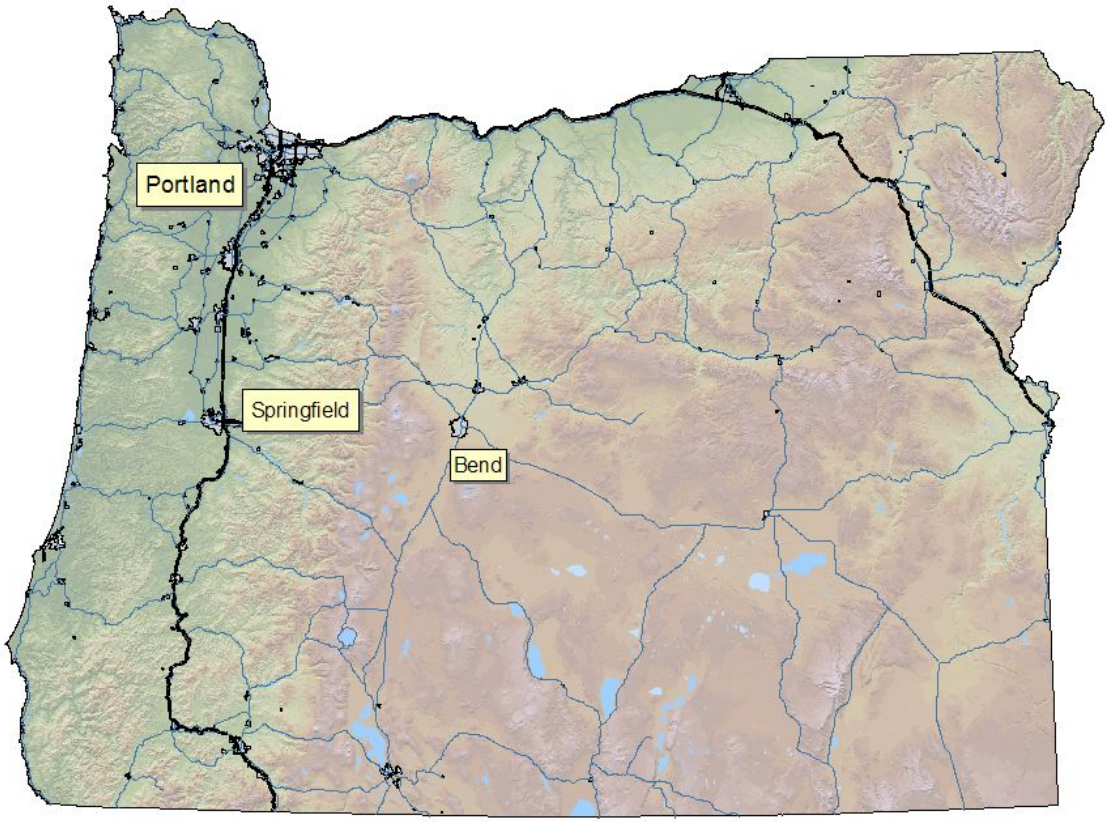
Oregon Dry Cleaner Program

Oregon's flexibility to use "State-Lead" or "Reimbursement "Approaches

- Most Cleanups are done using State Lead approach
- Prioritize sites based on human health risk
- Limited funding to "riskiest" sites
- Consideration to timing (site redevelopment and other opportunities to access source areas)
- Leverage Insurance as possible

Springvilla Drycleaners

Springfield, Oregon



Springvilla Cleaners

Background

- Self Service laundry and dry cleaners
  - 1960s to 2000 (closed in 2000)
- Tetrachloroethylene (PCE) the dry cleaning solvent
- Apparent leak in/around sewer drain connection
- Soil and groundwater contamination
- Groundwater contamination affecting municipal supply aquifer – not in city wells….yet
- Several backyard irrigation wells impacted
- Vacant shopping center space and motivated owner helped facilitate soil cleanup

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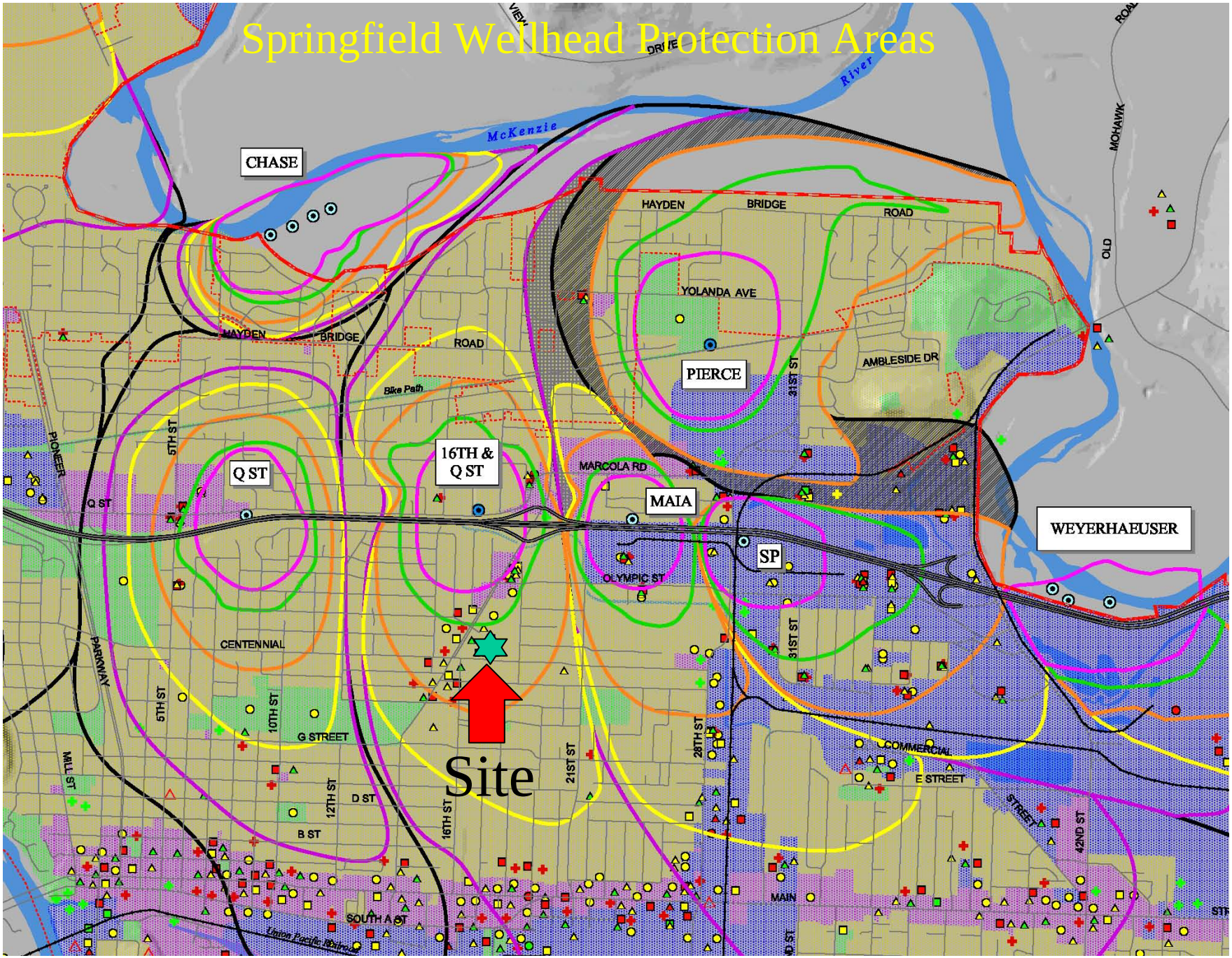
2002 – Prior to Cleanup

Springfield Wellhead Protection Areas



Springvilla Cleaners Site

Note: Base map prepared from a plan provided by Maul Foster & Alongi (from a Groundwater Assessment Report, dated November 21, 2001).

MW-16 Monitoring Well Location and Number

(IN-4s) Injection Location and Number

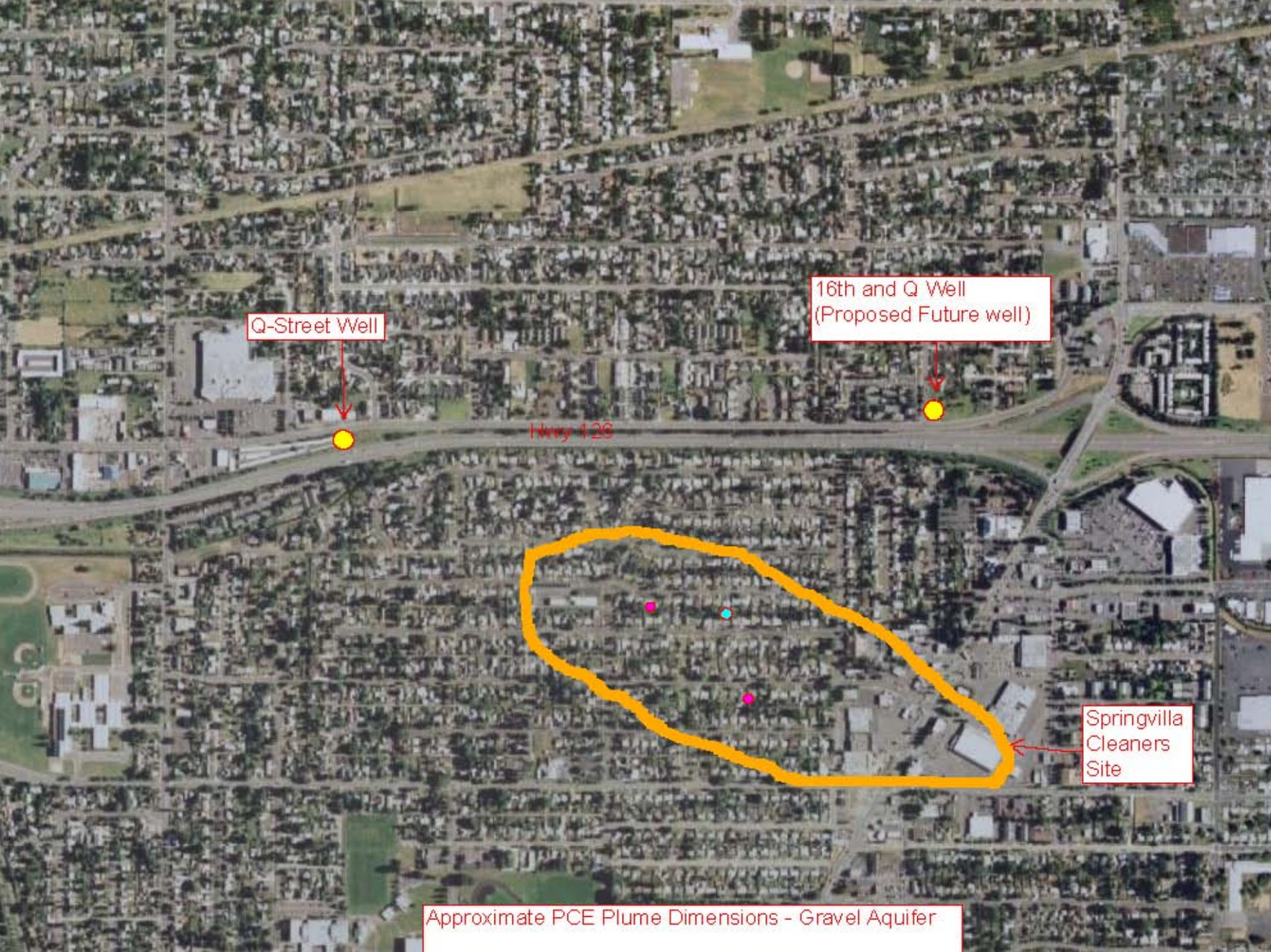
(EX-2s) Extraction Location and Number

Underground Recirculation System Piping

Aboveground Recirculation System Piping

0 100 200

Approximate Scale in Feet


16th and Q Well
(Proposed Future well)
Q-Street Well
Hwy 126
Springvilla
Cleaners
Site
Approximate PCE Plume Dimensions - Gravel Aquifer

Remediation Approaches

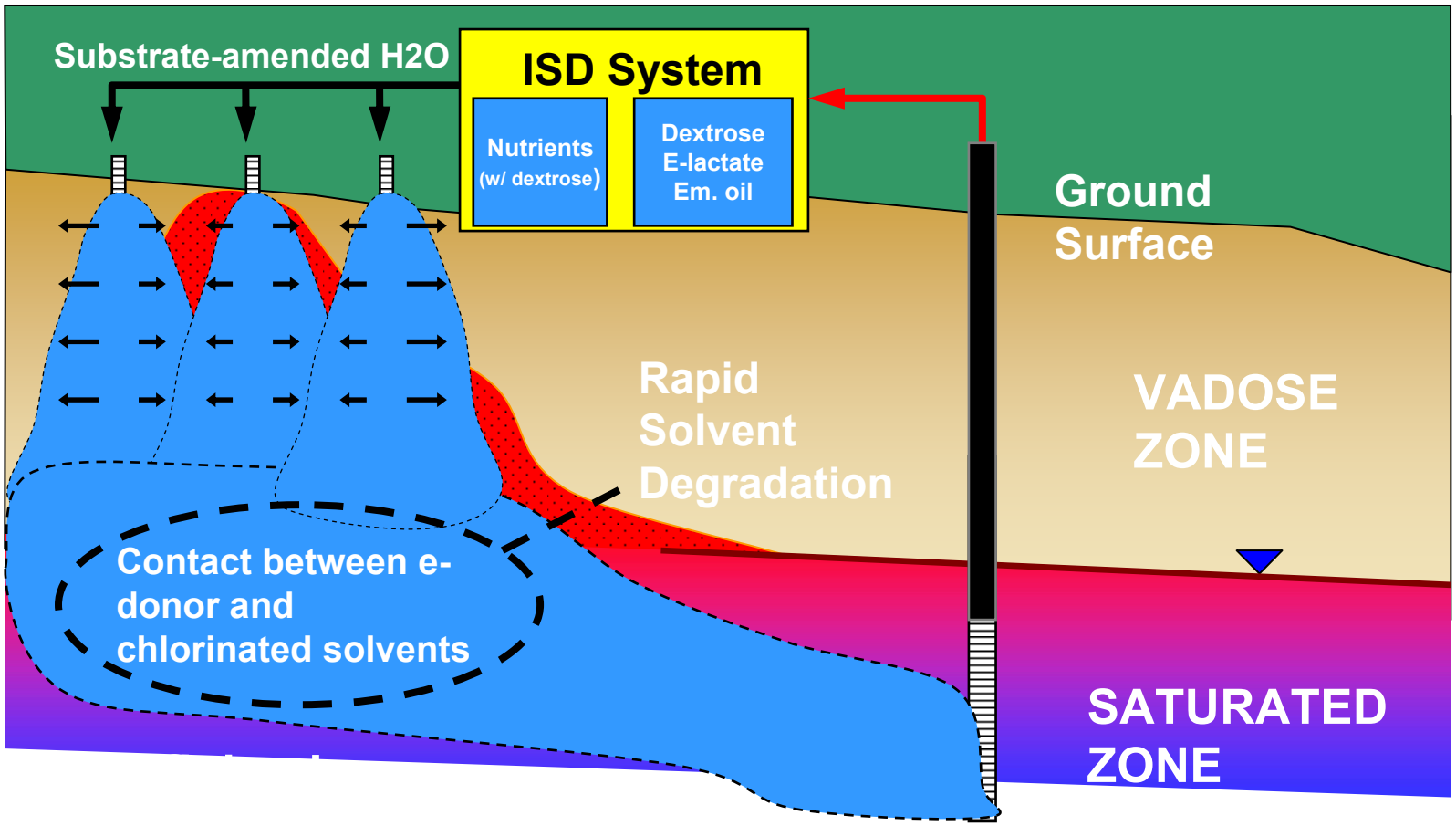
Soil and Groundwater

- Soil Removal in 2004
  - Ex-situ treatment and off-site disposal - 150 cy of soil
  - Install injection piping in open excavation during backfill
  - Install shallow vapor recovery piping in upper portion of excavation (help prevent vapor intrusion)
- Initial Groundwater Treatment – Chemical Oxidation
  - Limited permanganate injections in source area
    - Oct 2004: 1,100 gal 4% sodium permanganate solution
    - Oct 2005: 2,100 gal 4% sodium permanganate solution
- Subsequent Reductive Bioremediation Approach for groundwater

Reductive Bioremediation Approaches for Groundwater

Springvilla Drycleaners

- **Groundwater recirculation system**
  - CarBstrate® = dextrose and nutrients
  - Complex Lactates (Ethyl lactate)
  - LactOil ® (soybean oil emulsion & complex lactates)
  - NewmanZone ® (soybean oil + sodium lactate)
- **Slug Injections**
  - Complex Lactates (Ethyl lactate)
  - LactOil ®
  - NewmanZone ®



- ❑ Effective substrate delivery via 24/7 GW recirculation
- ❑ Substrate added in <u>pulsed</u> injection mode (to help reduce bio-fouling)
- ❑ Highly soluble substrate, plus nutrients, to grow active biomass in pore space
- ❑ Max. microbial activity, ↓ ORP, methanogenic cond., ↑ dissolution

A note about re-injecting contaminated water

RCRA Section 3020(b) Clarified

EPA has interpreted RCRA Section 3020(b)(2) such that contaminated ground water withdrawn from an aquifer can be amended above ground and that the “substantial treatment” can take place either before or after re-injection. The reduction may occur ‘in-situ’ after reinjection of the ground water into the aquifer (that is, within the formation that is the target zone for the injected fluid). “

“The treatment must reasonably be expected to reduce levels of contamination and must be part of a legitimate effort to achieve cleanup of such contamination.”

(From 12/27/2000 EPA Memo)

http://www.clu-in.org/products/regs/memo122700.htm

Underground Injection Control (UIC)

Springvilla Cleaners

- UIC registration required
- Oregon generally “UIC friendly” for remediation projects

Cost Savings by using existing monitoring wells for extraction and injection

- Existing 2-inch monitoring wells utilized
  - 2 shallow for injection
  - 3 deep for extraction
- New 2-inch monitoring wells drilled
  - 3 new shallow injection wells drilled
  - 1 shallow extraction wells drilled
  - 3 new deep injection wells drilled
- Drilling cost: $40,000
- Downsides to using monitoring wells became apparent later…

Recirculation System Layout

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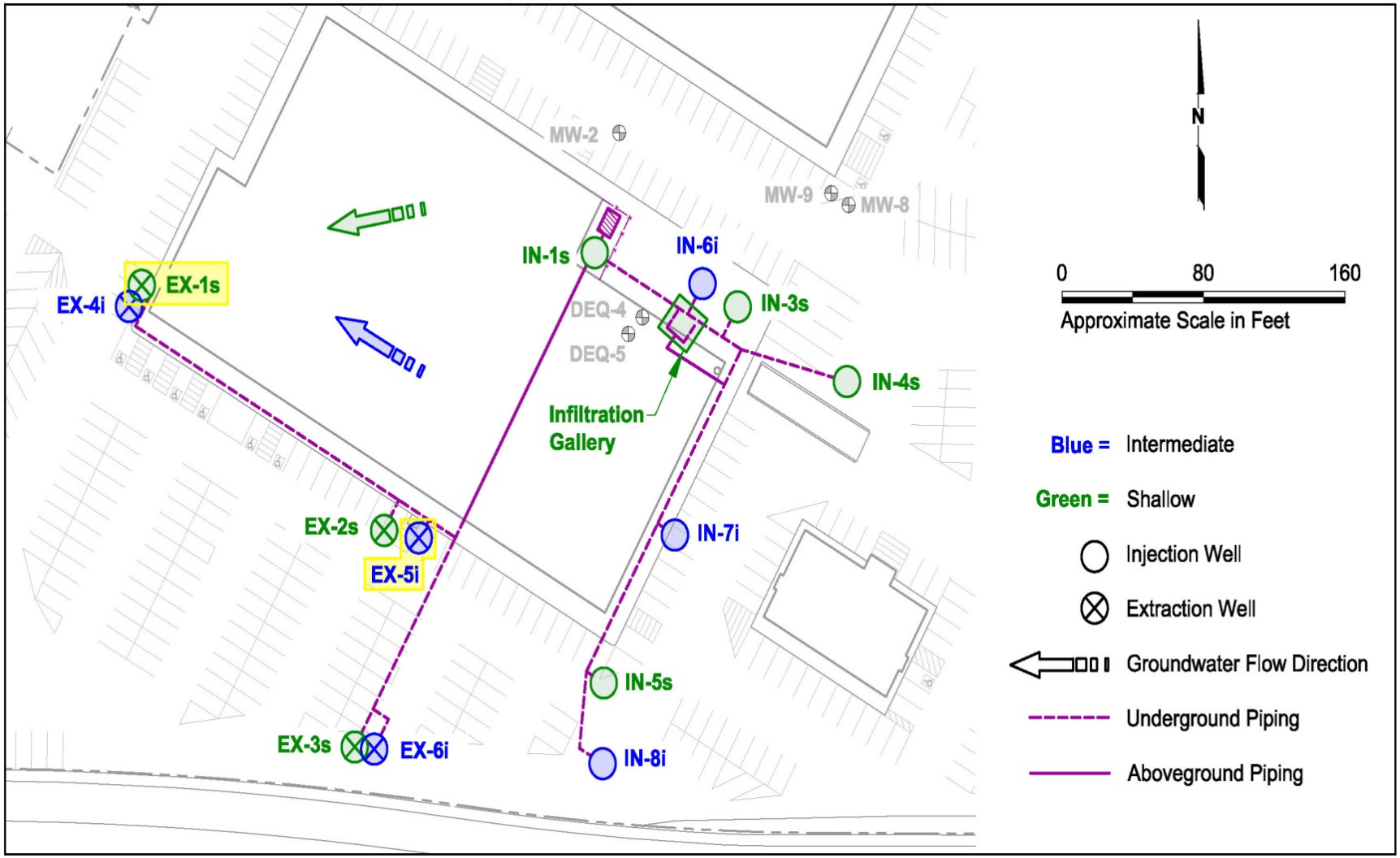



PHARMACY

Permanganate still Lingering Near Source Area We found it.

Drilling Injection well IN-6i

ETEC LLC's In-Situ Delivery (ISD) System

Baseline Concentrations

August 2007 – Shallow and Intermediate Extraction wells

- Shallow Zone 10-25 ft. bgs
  - ORP: +56 to +180 mV
  - DO: approx. 0.4 mg/l
  - PCE: 139 ug/l to 814 ug/l (EX-3s)
  - TCE: 1 ug/l to 64 ug/l (EX-3s)
- Intermediate/Deep Zone 25-70 ft.
  - ORP: + 31 to +121 mV
  - DO: approx. .3 to 3 mg/l
  - PCE: 31 ug/l to 604 ug/l (EX-4i)
  - TCE: 1 ug/l to 7 ug/l (EX-4i)

Dechlorination Process

Nutrients:

N

P

K

Trace Metals

Competing electron acceptors:

O_2

Nitrate NO_3^-

Manganese Mn^{4+}

Ferric Fe^{3+}

Sulfate SO_4^{2-}

Chlorinated hydrocarbons:

PCE

TCE

DCE

VC

Nitrite N_2

Dissolved Mn^{2+}

Ferrous Fe^{2+}

H_2S

Ethene / Ethane

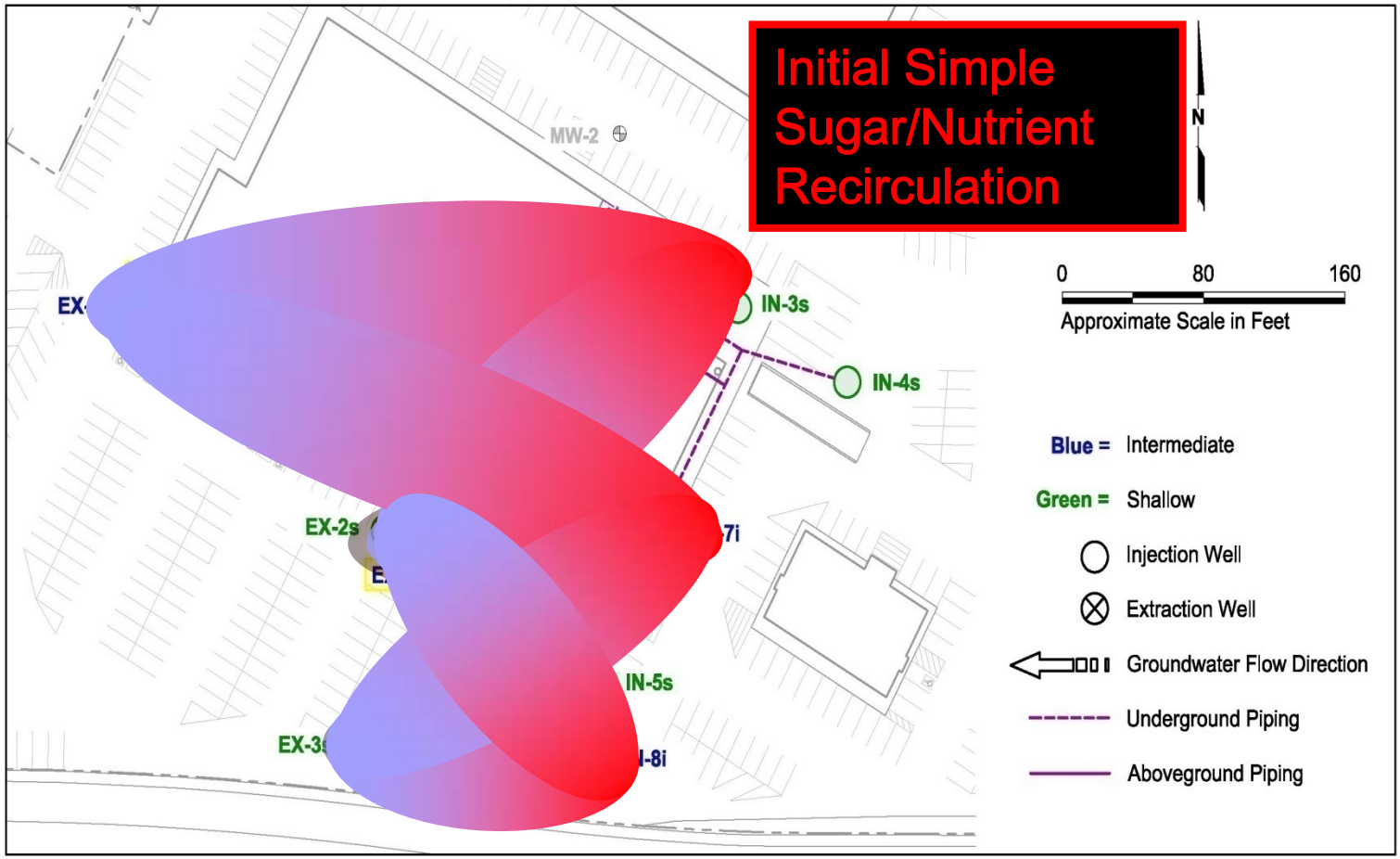
Initial System Operation (Carbstrate/dextrose) Recirculation

September 2007 through mid-February 2008

- Initial amendment rate was 1,200 lbs/month 9/07 thru 1/08
- Feb. 08 begin alternating ethyl lactate (3weeks) carbstrate (3 weeks)
  - 1,200 lbs ethyl lactate/month
  - 750 lbs carbstrate/month

Carbstrate (dextrose)Donor Application

September 2007 until February 2008 (Intermediate zone shown only)



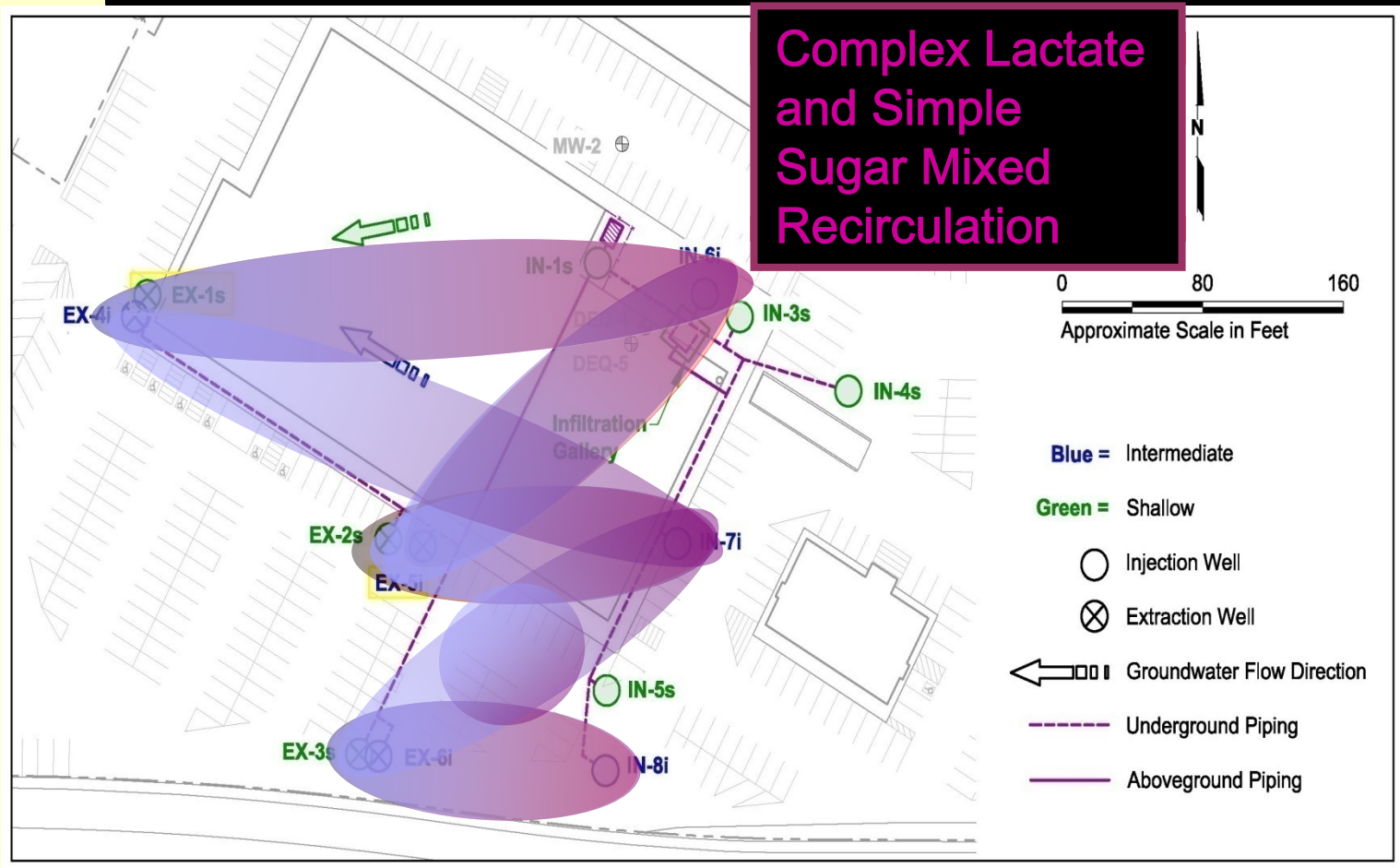
Ethyl lactate introduced and alternated monthly with(Carbstrate/dextrose) Recirculation

February 2008 through January 2009

- To help reduce biofouling of injection wells, ethyl lactate recirculation was alternated with the Carbstrate.
- Ethyl lactate also reacts slower and treats wider area than Carbstrate.
- Ethyl lactate (3weeks) carbstrate (3 weeks)
  - 1,200 lbs ethyl lactate/month
  - 750 lbs carbstrate/month

Carbstrate and Ethy Lactate

Feb 2008 – Jan 2009 (Intermediate zone shown only)



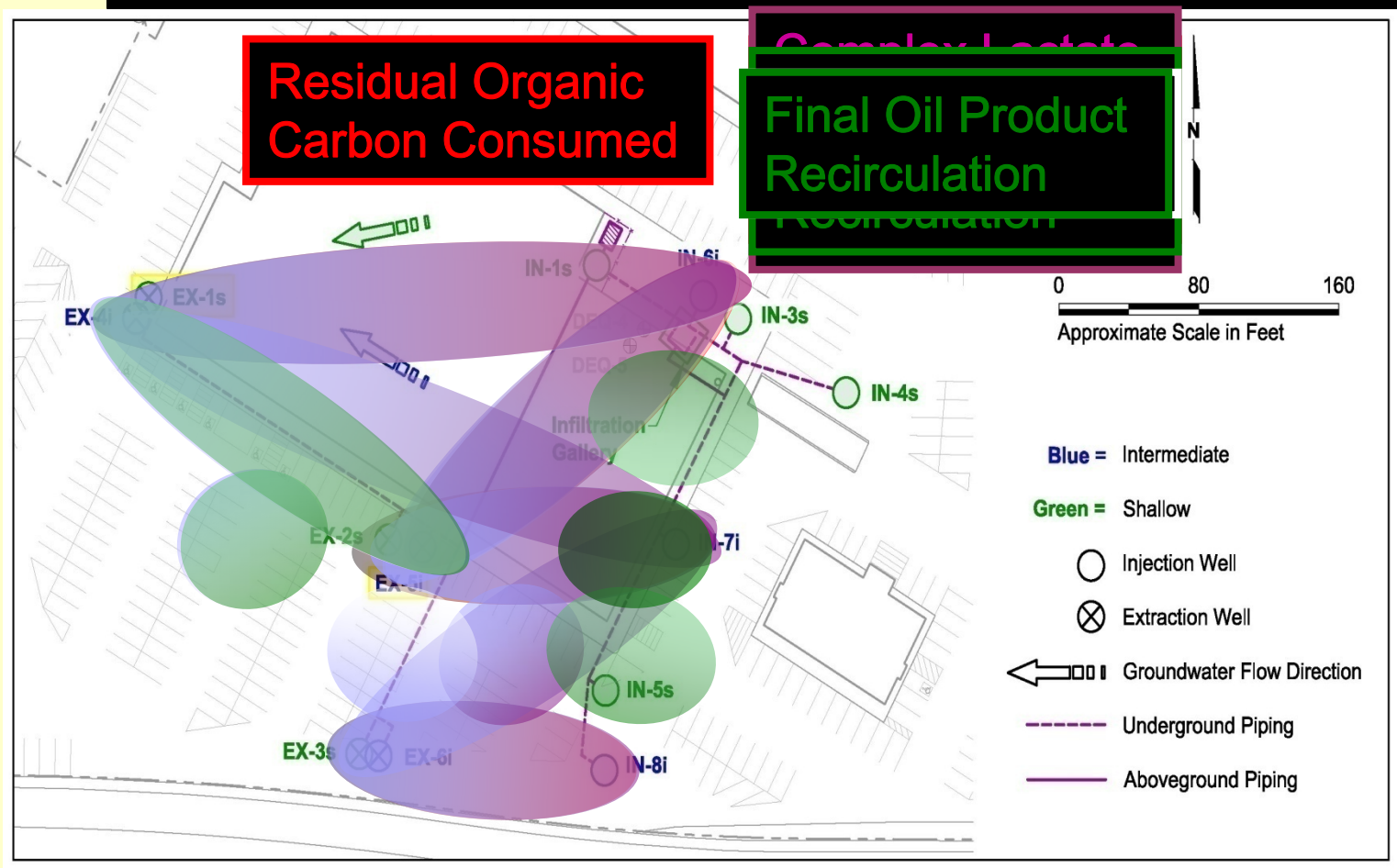
Switch up pumping/injection regimes to mix-up groundwater flow paths
Install LactOil “Biowall”

Jan 2009

- Convert EX-5i to an injection point
- Convert IN-7i to an extraction point
- Stop shallow injections (due to low flows)
- Install/inject LactOil “biowall” north/south
- Distrubute ethyl lactate from EX-5i to distal locations
- Distribute NewmanZone in downgradient wells for long lasting donor

Electron Donor Progression

(Slide courtesy Troy Fowler, Hart Crowser)



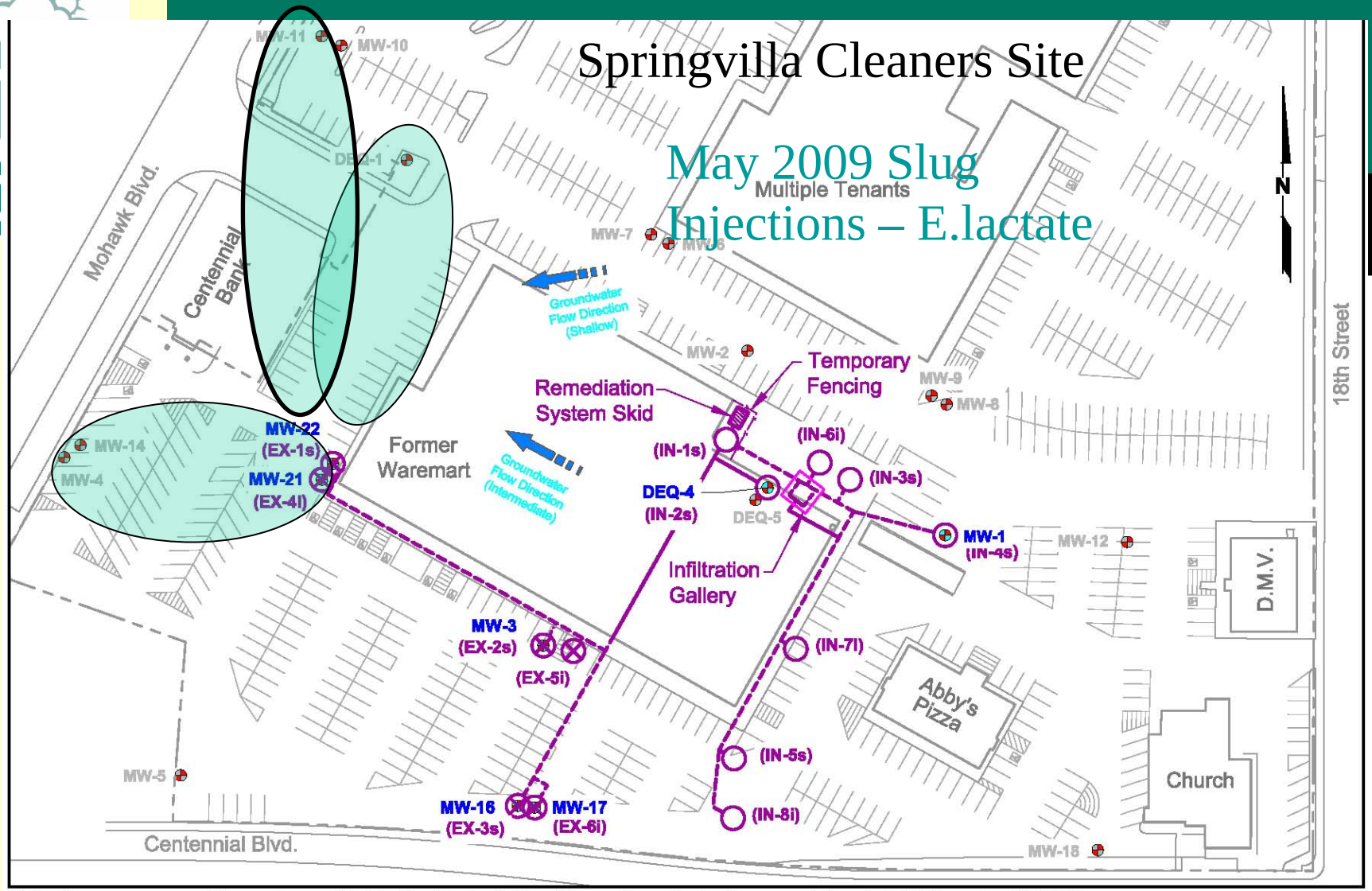
Downgradient Well Slug Injections

Intermediate Wells MW-14, MW-11, DEQ-1

- May 2009
- 15-20 gal ethyl lactate each
- 1 month prior to recirculation system shut-down

Springvilla Cleaners Site

May 2009 Slug Injections – E.lactate



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Underground Recirculation System Piping

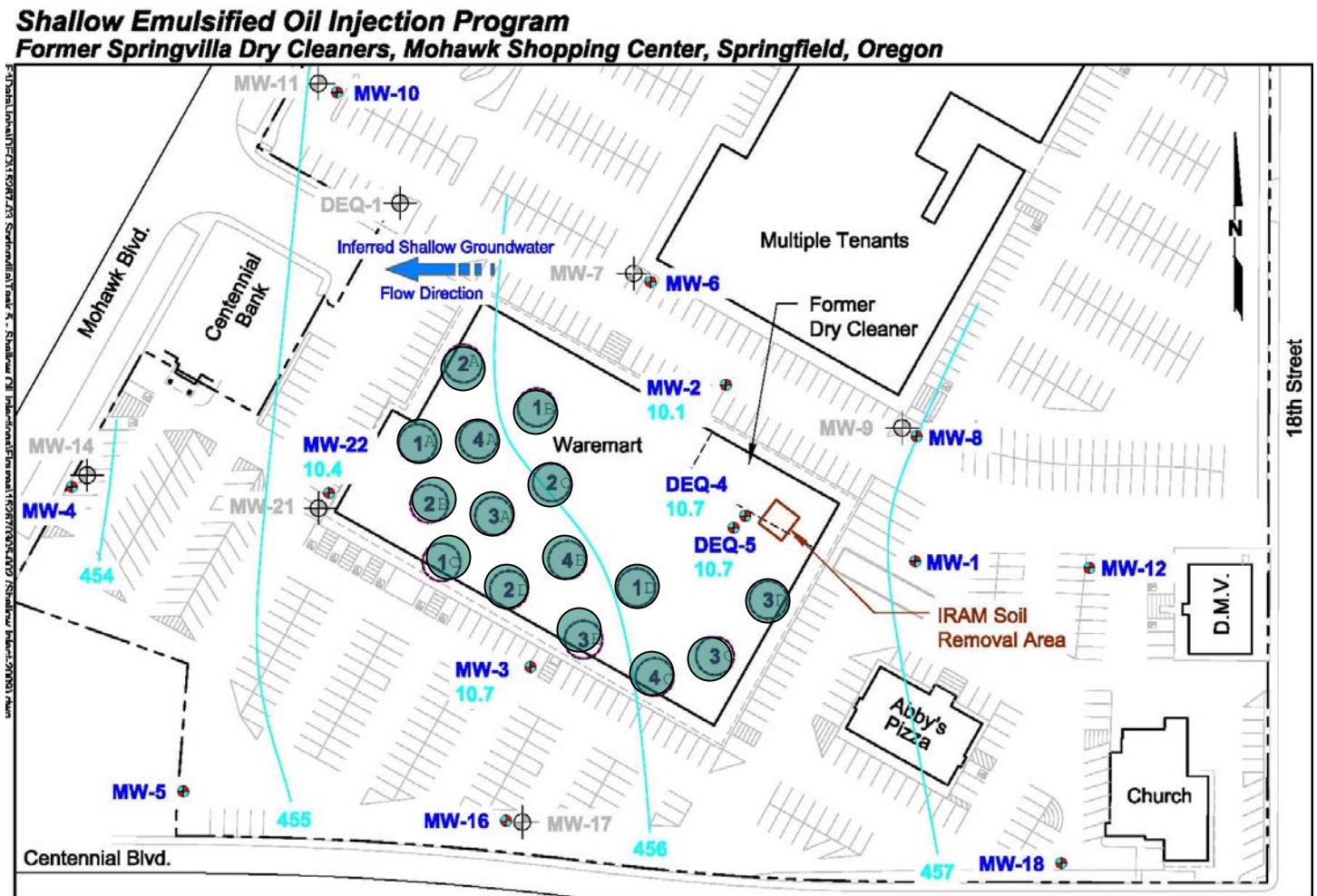
Aboveground Recirculation System Piping

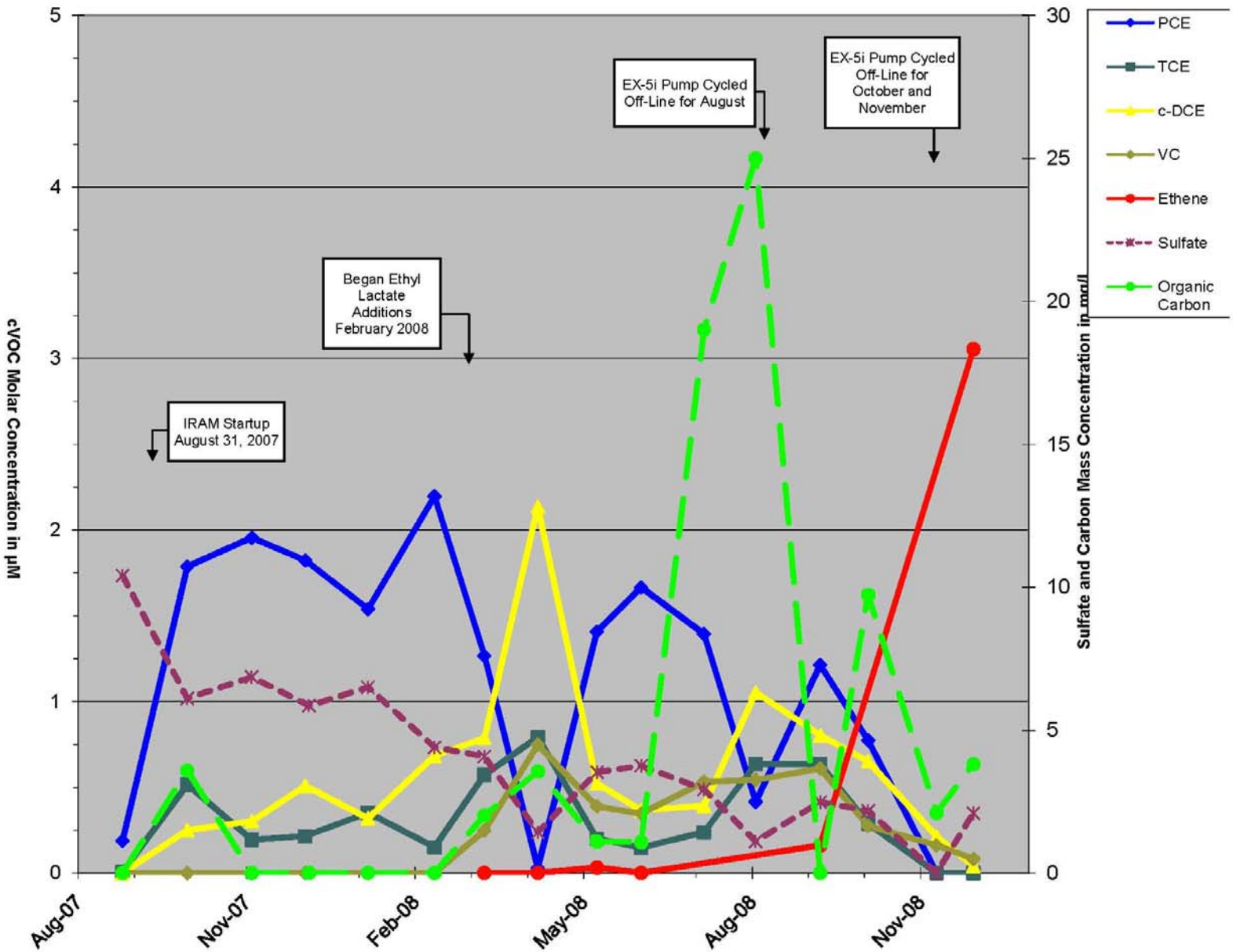
0 100 200

Approximate Scale in Feet

Shallow Emulsified Oil Injections Beneath Building

August 2009




Concentrations in Intermediate Well EX-5i
cVOC Molar Concentration in µM
Sulfate and Carbon Mass Concentration in mg/l
IRAM Startup August 31, 2007
Began Ethyl Lactate Additions February 2008
EX-5i Pump Cycled Off-Line for August
EX-5i Pump Cycled Off-Line for October and November
PCE
TCE
c-DCE
VC
Ethene
Sulfate
Organic Carbon
0
1
2
3
4
5
0
5
10
15
20
25
30
Aug-07
Nov-07
Feb-08
May-08
Aug-08
Nov-08

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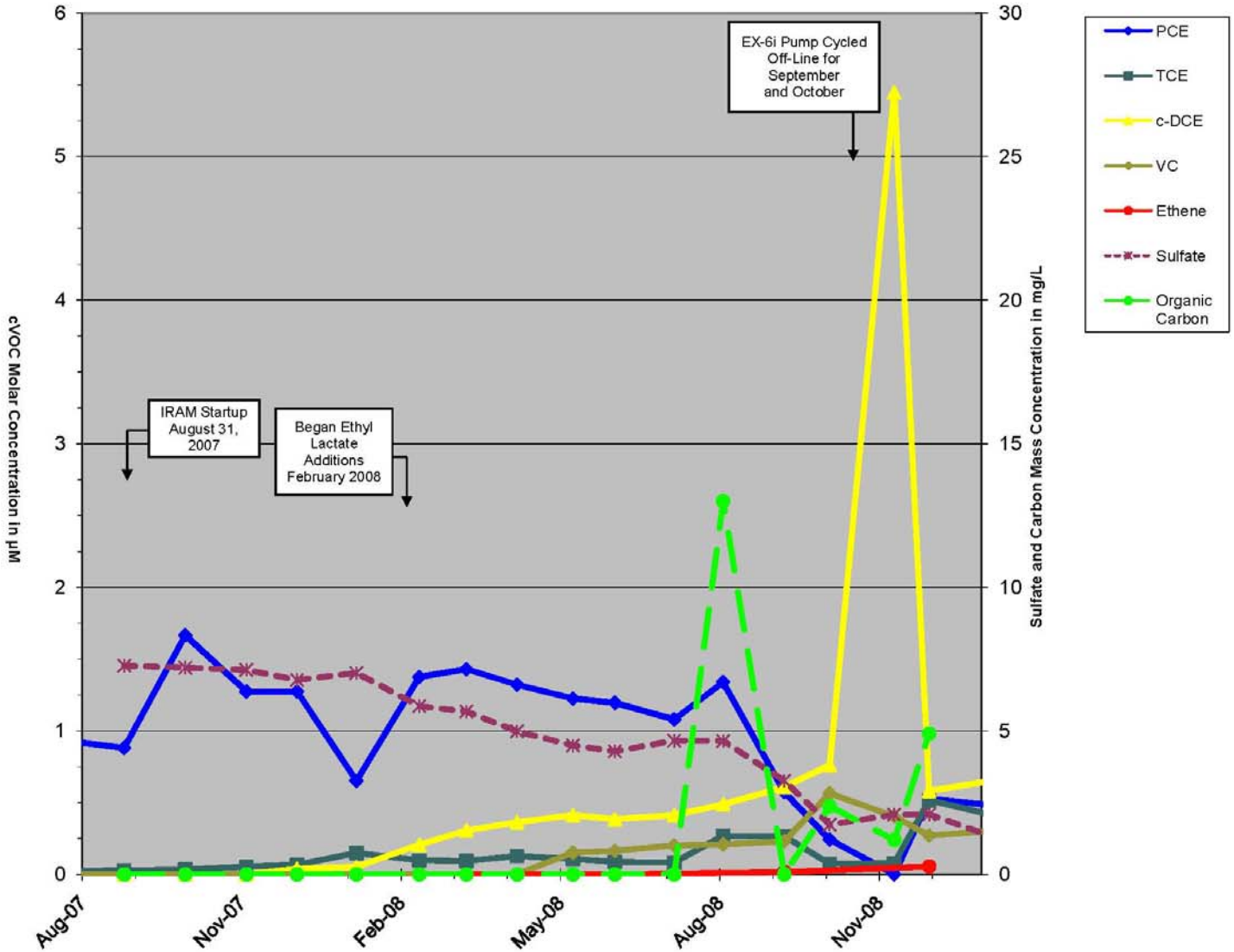
Aboveground Recirculation System Piping

0 100 200

Approximate Scale in Feet

Concentrations in Intermediate Well EX-6i



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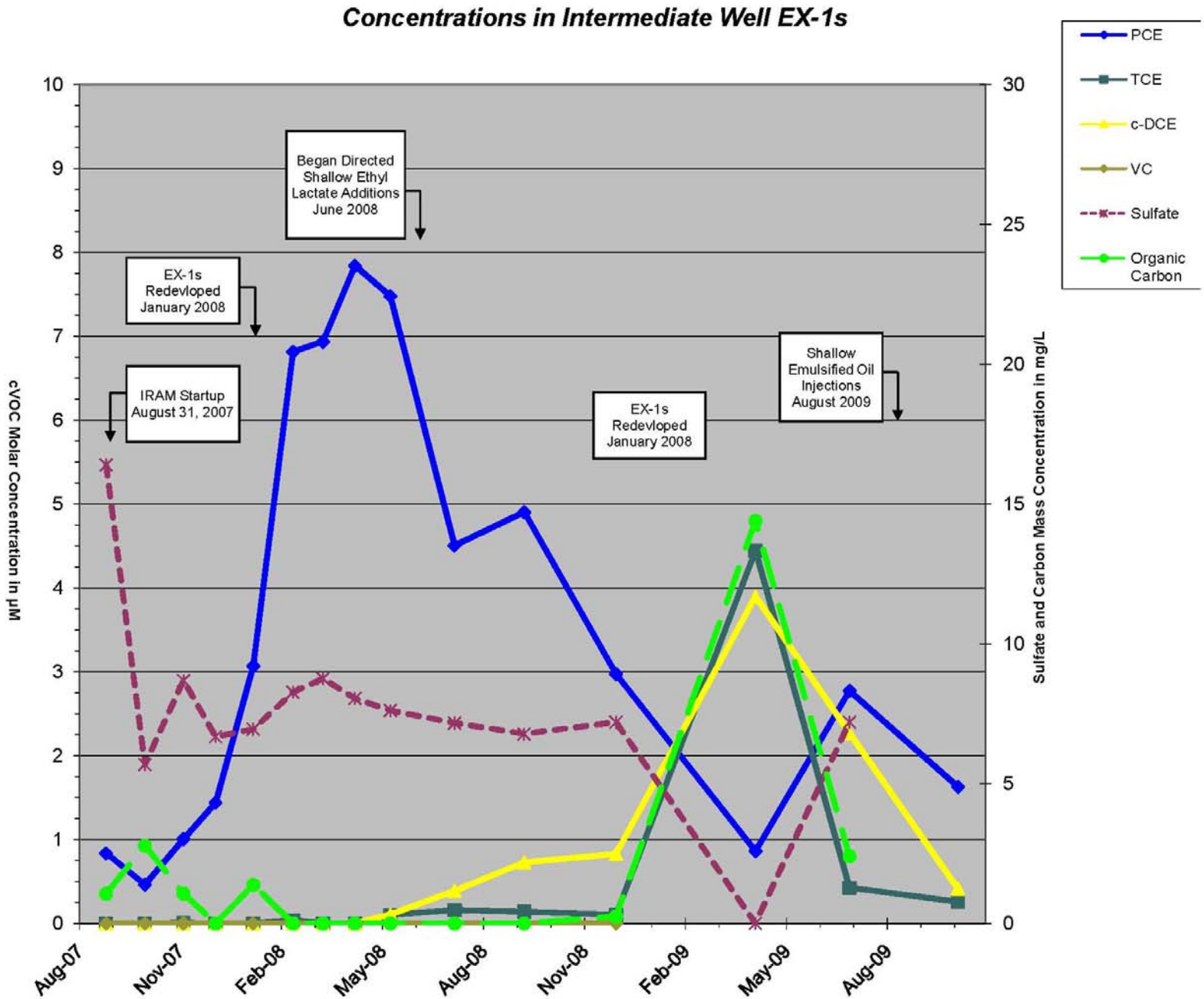
Approximate Scale in Feet


Concentrations in Intermediate Well EX-1s
PCE
TCE
c-DCE
VC
Sulfate
Organic Carbon
Began Directed Shallow Ethyl Lactate Additions June 2008
EX-1s Redevloped January 2008
IRAM Startup August 31, 2007
EX-1s Redevloped January 2008
Shallow Emulsified Oil Injections August 2009
cVOC Molar Concentration in µM
Sulfate and Carbon Mass Concentration in mg/L
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30
Aug-07
Nov-07
Feb-08
May-08
Aug-08
Nov-08
Feb-09
May-09
Aug-09

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Underground Recirculation System Piping

Aboveground Recirculation System Piping

0 100 200

Approximate Scale in Feet

Current Concentrations

October 2009 – Shallow and Intermediate Extraction wells

	Innitial Concentrations	Current
• Shallow Zone 10-25 ft. bgs		
– ORP:	+56 to +180 mV	-138 to -58 mV
– DO:	approx. 0.4 mg/l	0.2 – 1.73
– PCE:	139 ug/l to 814 ug/l (EX-3s)	140 ug/l (EX-1s)
– TCE:	1 ug/l to 64 ug/l (EX-3s)	34 ug/l (EX-1s)
• Intermediate/Deep Zone 25-70 ft.		
– ORP:	+ 31 to +121 mV	-83 to -95 mV
– DO:	approx. 0.3 to 3 mg/l	0.2 to 5 mg/l
– PCE:	31 ug/l to 604 ug/l (EX-4i)	66 ug/l (EX-6i)
– TCE:	1 ug/l to 3.5 ug/l(EX-4i)	31 ug/l (EX-6i)

Remediation Costs

Initial Groundwater Bioremediation (Aug 2007 – Jan 2008)

• New Wells	$40,000
• Piping/trenching/paving	$55,000
• Laboratory Analytical	$11,000
• ETEC System and Monitoring	$31,000
– ISD System Rental $3,500/mo	
– Pump rental	
– O&M Visits	
– Dextrose/nutrients $1.60/pound	
• Consulting Services	$117,000
– Work plans	
– Oversight	
– Sampling	
– Reporting	
TOTAL	$254,000

Remediation Costs

From January 2008 to Jan 2010

- GW Monitoring $60,000
- System O&M $180,000
- Reporting $20,000
- Oil Probe Inj. $35,000
- Jan 08-June 2010 $295,000

- **Project Total Aug 2007-Jan 2010**
  - **$549,000**

Current Status

Springvilla Cleaners

- Performance groundwater monitoring
- Monitored Natural Attenuation
- Vapor Intrusion Assessment – near downgradient receptors
- Insurance archaeology complete
  - Following up on several policies
  - Will attempt cost recovery

Questions?

Springvilla Cleaners

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