Field Application of Passive Treatment of Chlorinated Solvents using Novel Sustained-Release Oxidant Technologies

Remtech - October 18, 2013

D. Grant Walsom, B.A.Sc., P.Eng., QP
Partner
XCG Consultants Ltd.

Pamela J. Dugan, Ph.D, P.G.
Technical Development Manager
Carus Corporation

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Outline

- Technology Development
- History of the Site and the Issue
- Decision Criteria
- Cost Review
- Barrier Design
- Field Installation
- Monitoring Effectiveness
- Summary

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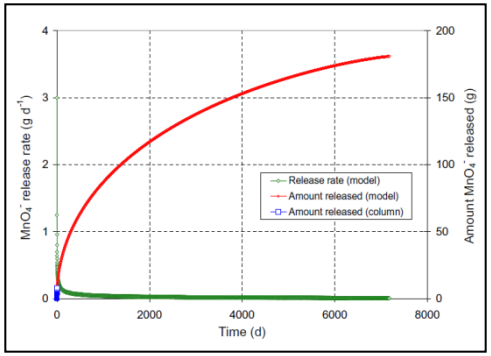
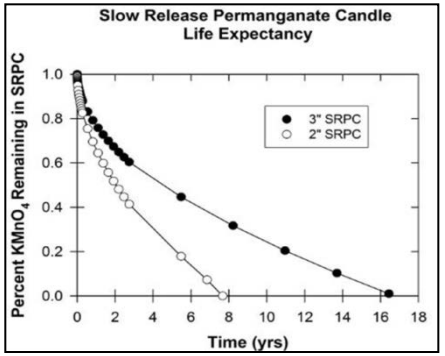
Technology Development – Sustained-Release (SR) Oxidants

- Promising slow-release permanganate and persulfate modeling, lab, pilot-scale field studies (e.g., Ohio State University, Clemson, University of Nebraska, Colorado School of Mines)





- Variety of reactive materials are possible
  - Oxidants, bio-amendments, oxygen release compounds, activators, chelating agents

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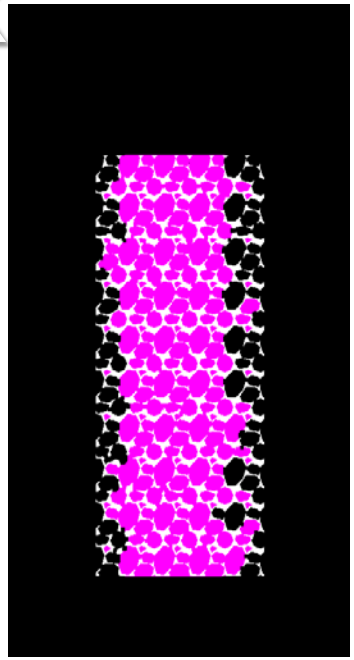
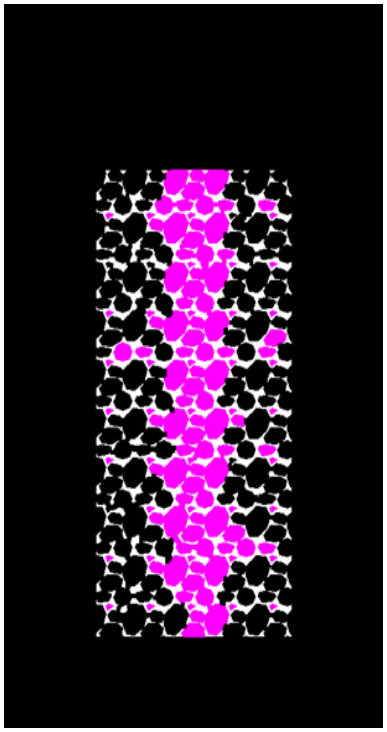
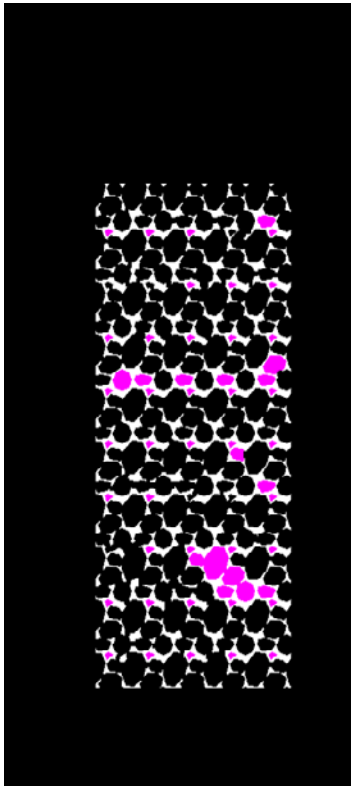
Oxidant Release from Wax







- This is why we see an initial spike of permanganate in early time…
- And a significantly slower and lower release of permanganate at later times

- Newly created void spaces expose permanganate solids for dissolution and diffusion
- Process occurs radially from the exterior of the cylinder to the inner core

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Technology Development – SR Oxidants

- Sustained-release permanganate is a $KMnO_4$-based product dispersed in a solid paraffin wax matrix (~80% w/w) RemOx® SR ISCO Reagent




- Sustained-release persulfate is a $NaS2O_8$-based product dispersed in a solid paraffin wax matrix (~80% w/w)

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SR Technology - Versatility in Form

- Solid product formed as cylinder, chipped for trench/barrier applications, or small pellets/pastilles for hydro-fracturing into low permeability media:
  - 1.35 or 2.5 inch diameter
  - 18 inches long
  - DPT emplacement, well installation, hydro-fracturing

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SR Technology – Versatility in Application

- Current Emplacement Methods:
  - Direct push technology
  - Holders in existing wells
    - Hydro-fracturing being investigated

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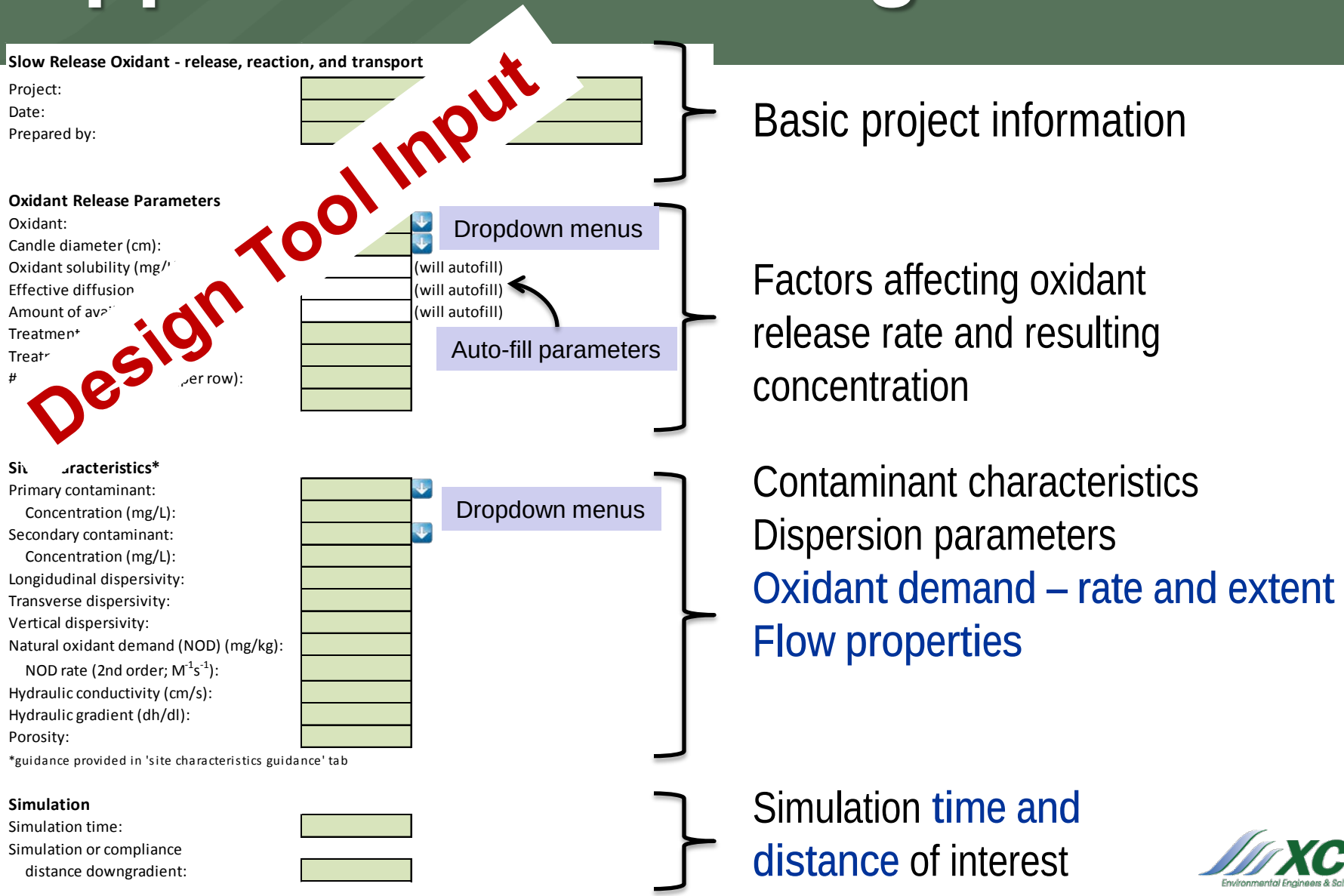
Approach – SR Design Tool



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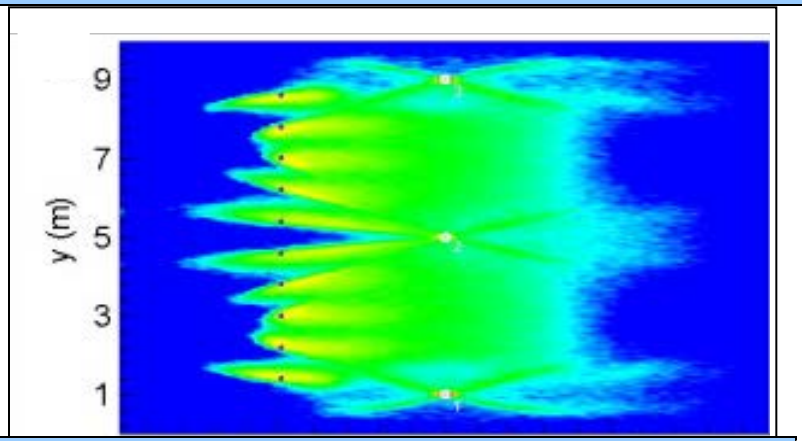
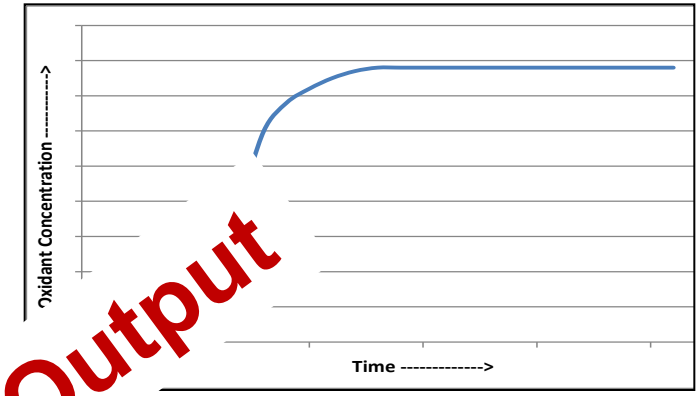
Approach – SR Design Tool

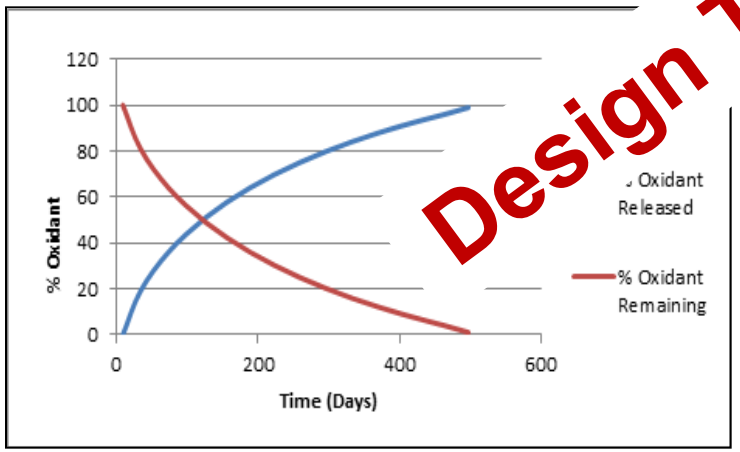
Oxidant concentrations vs. distance at a given time



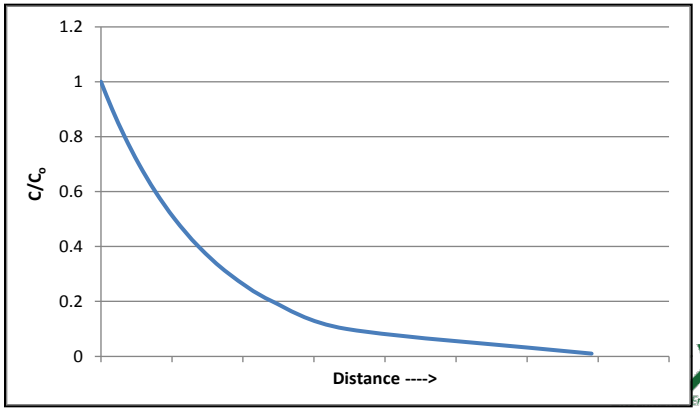
Oxidant concentrations at a given point over time



Oxidant release from cylinders



Contaminant concentrations vs. distance at a given time



History of the Site and the Issue

- Historical Industrial Site in Hamilton, Ontario
- Developed circa 1925
- Close to the Harbour
- Geology is fill over silty-clay down to clay material
- Historical use of chlorinated solvents:
  - PCE, TCE → c-DCE and VC in groundwater
- Difficult Remediation – Complicated Ownership

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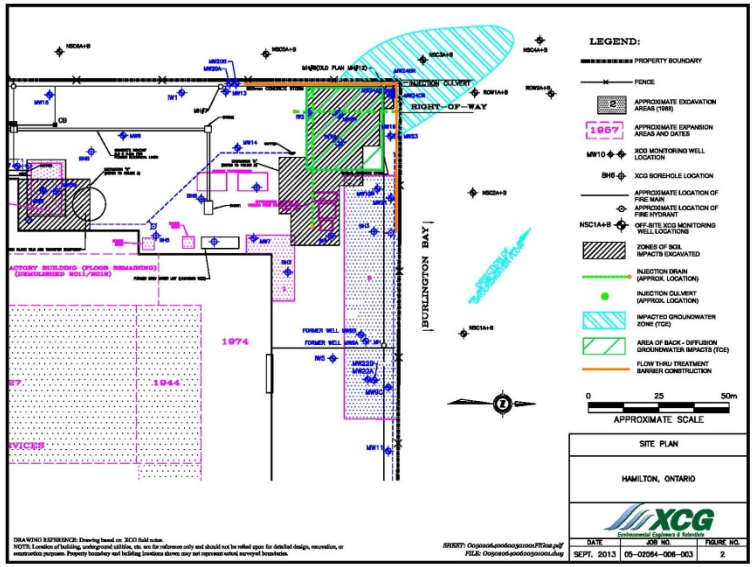
History of the Site and the Issue

- Off-site Groundwater Impacts …
  - Higher concentrations
  - Near saturation levels



- Remediation Stages … excavation of soil impacts
- Back-Diffusion of impacted groundwater following excavation and hydraulic re-equilibration

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History of the Site and the Issue

- Off-site Owner non-co-operative
- Edge of property, high-volume storm sewers

- Client needs to move on …
- How to cost-efficiently and technically sound prevent back-diffusion

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Decision Criteria

- Ease of Application – Difficult location/situation
- Known Technology – want to be sure it works
- Low Operation & Maintenance
- Overall Cost
- Remtech 2012 … RemOx SR Presentation

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Cost Review

- Cost Analyses – Total of $163,500:
  - Cylinders (per cylinder $250) = $120,000
  - Direct Push Installation & Locates = $23,500
  - Engineering/Consulting/Oversight = $12,500
  - Monitoring and Analytical = $7,500

- Other barriers cost minimum of $500,000 (in 2002)
  - ZVI, funnel and gate, barrier with pump/treat

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Field Installation

- First Site Application in Canada
- December 2012 – use budget before end of year
- Installed 476 cylinders in 119 boreholes over 8 days
- Straight-forward installation – health and safety

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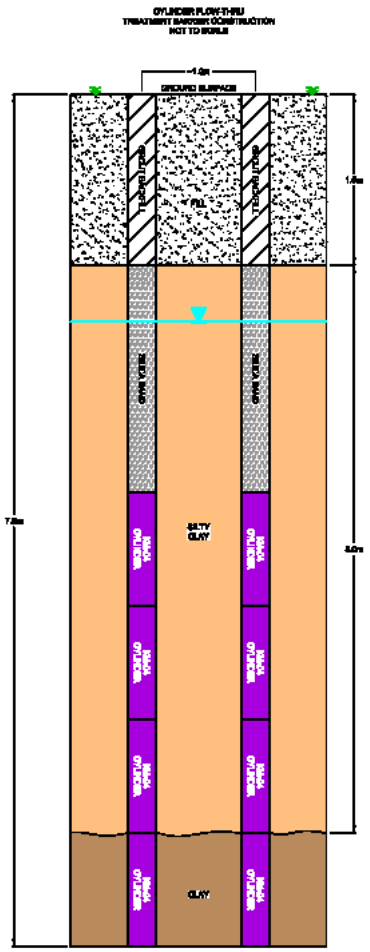
Barrier Design

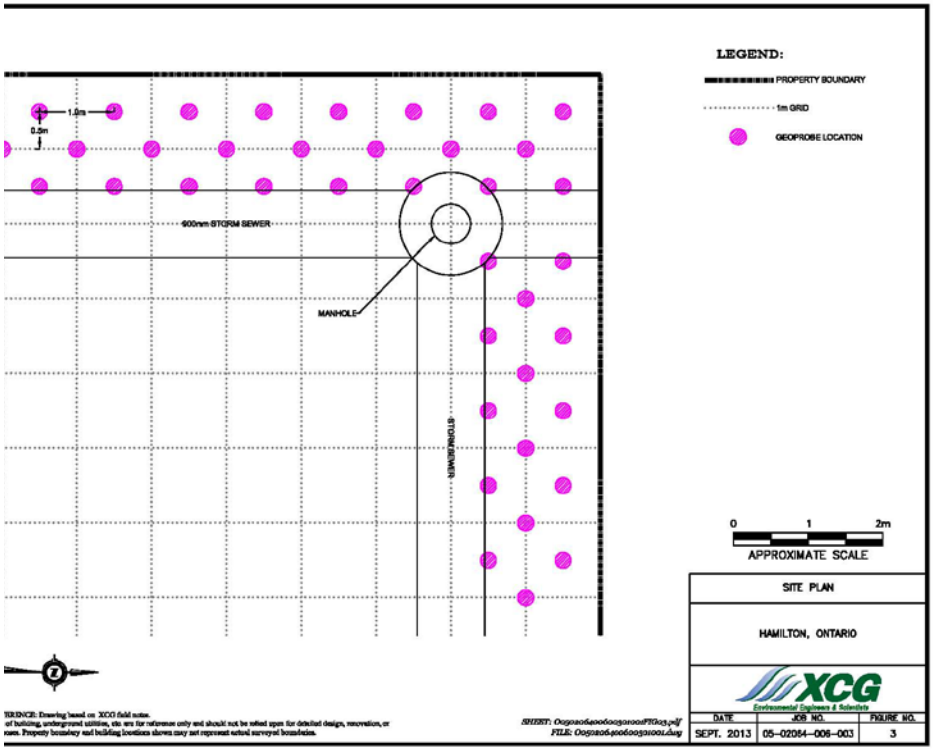
10^{-3} m/s

10^{-5} m/s

10^{-7} m/s

10^{-9} m/s





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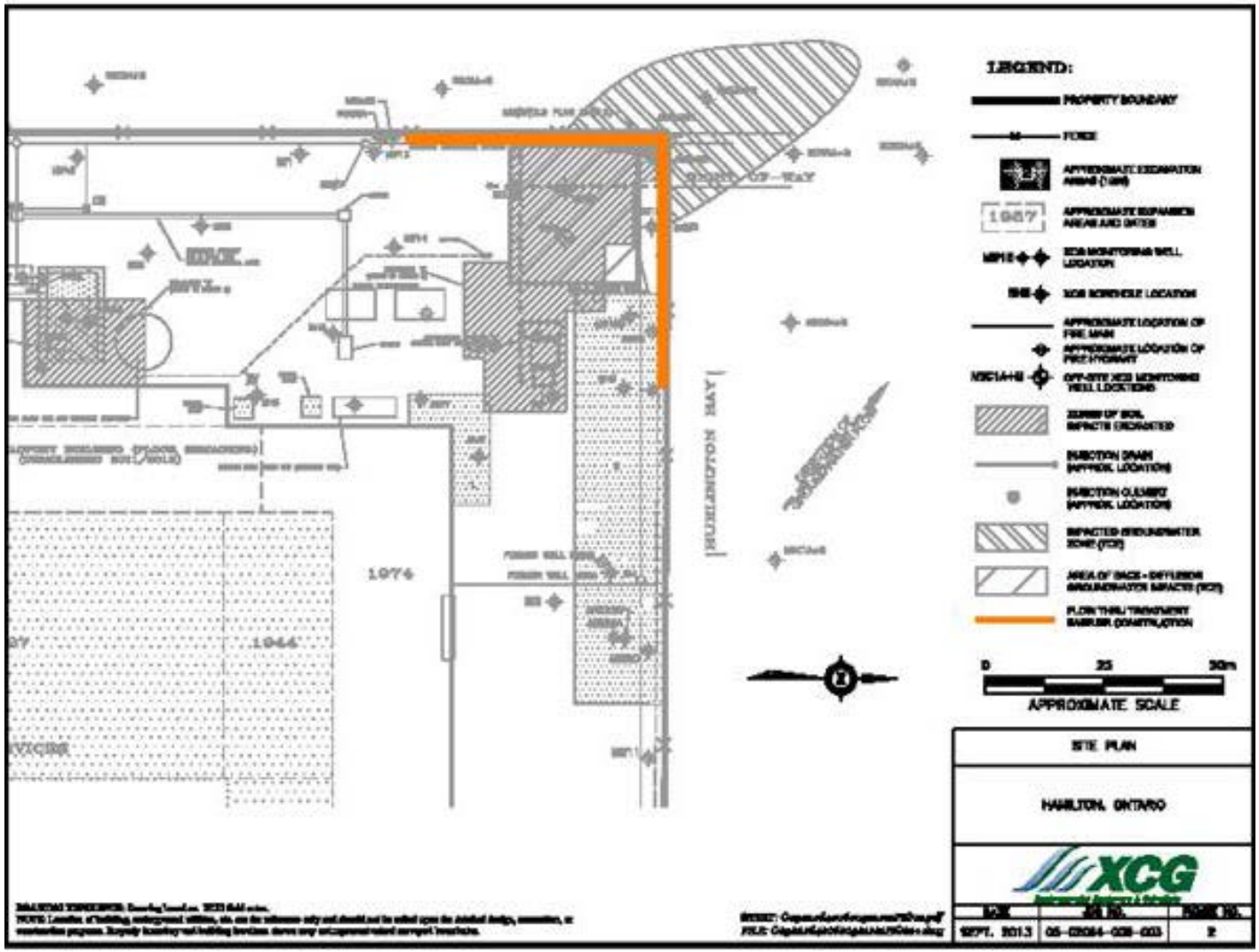
Barrier Design



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Field Installation

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Field Installation

- Two Drills supplied by Strata Soil
- Along Corner of property
- Close proximity of neighbouring plant

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Field Installation

- Direct-Push
- Cylinder installed through drill rods
- Easy installation

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Monitoring Effectiveness

- Installed … now what?
- Client needs assurance that effective
- Monitoring indicators in groundwater – electrical conductivity
- Eventual concentration decrease

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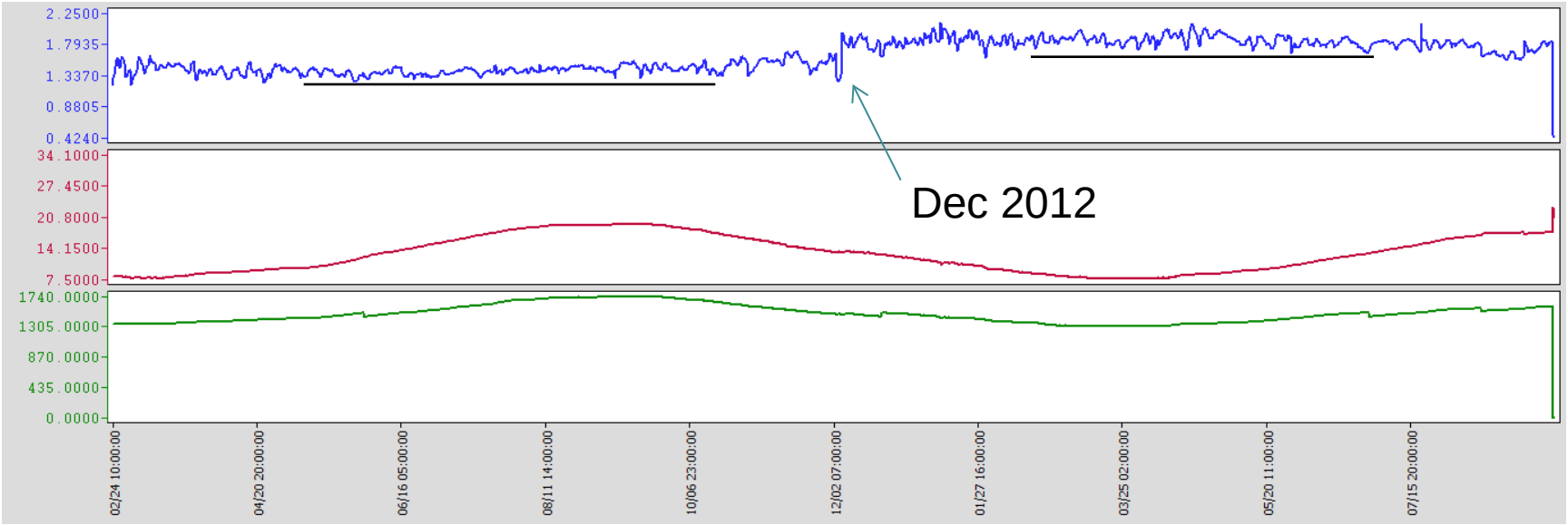
Monitoring Effectiveness

- Location MW20B – observed an almost immediate increase in electrical conductivity (distance ~ 1.5m)



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Monitoring Effectiveness

- Down-gradient showing increases in electrical conductivity with time (pre vs. post installation):
  - Location NSC5A (avg. of 0.32 up to 4.44 mS/cm)
  - Location NSC5B (avg. of 0.87 up to 2.21 mS/cm)
  - Location NSC3A (avg. of 1.94 up to 3.11 mS/cm)
  - Location ROW1B (avg. of 3.34 up to 4.53 mS/cm)
  - Within the area of the Barrier – increases of 18 - 54% since 2005
- Recall hydraulic conductivity ... 10^{-5} m/s to 10^{-9} m/s
  - velocity from 93 m/yr (fill) down to 0.015 m/yr (clay)

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Monitoring Effectiveness

- Is conductivity enough of an indicator?
  - Monitored ORP as well.
- Stronger indicators together ...
  - Know that Positive ORP values > 100 mV indicate favorable oxidizing conditions.
  - Negative ORP values indicate reducing conditions.
- We have created a zone of favourable ORP conditions (positive ORP or approaching).

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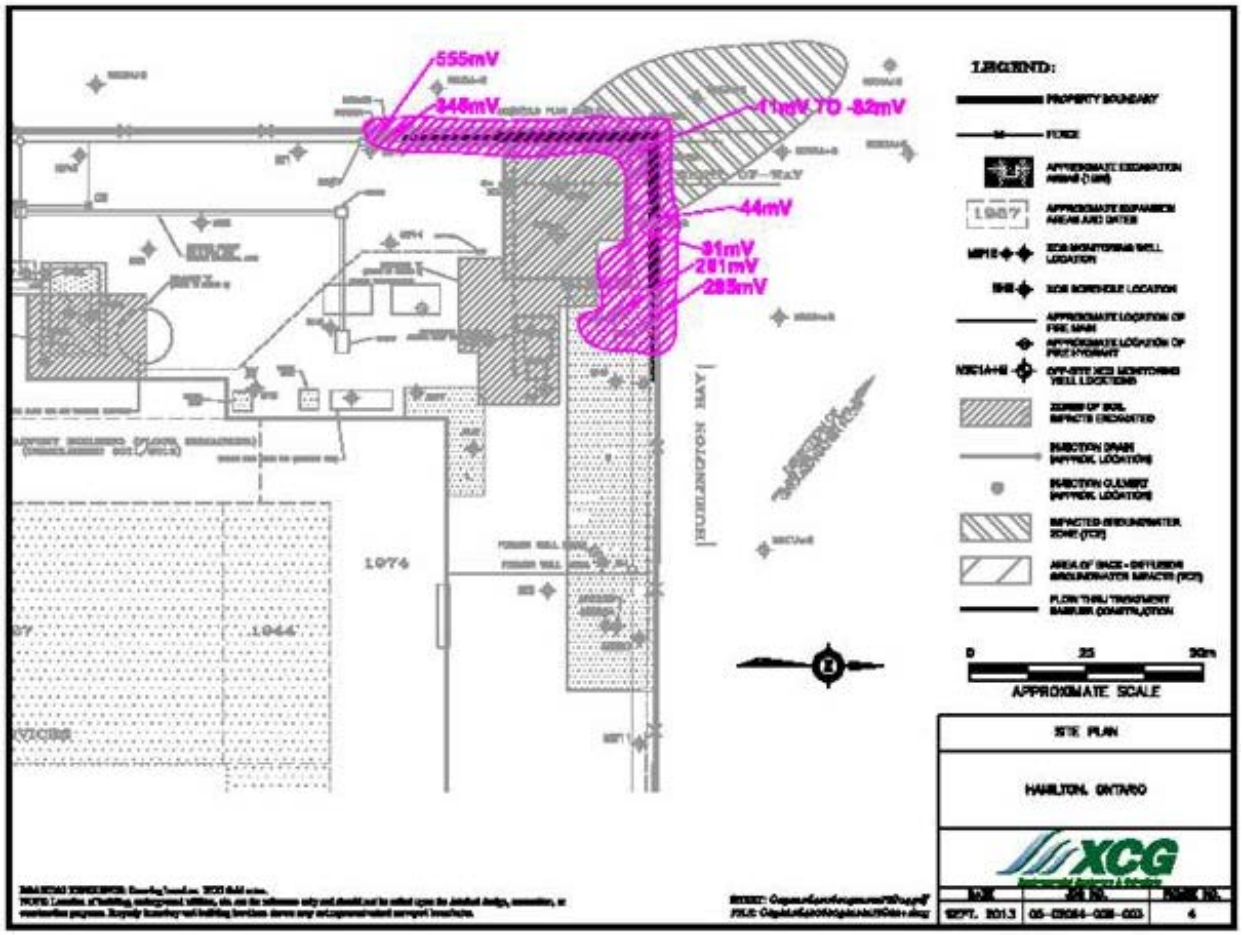
Monitoring Effectiveness

	Location	ORP
upgradient	MW7R	-133
	MW8R	-32
	MW14R	-154
barrier treatment zone	MW12R	261
	MW13	-51
	MW20A	555
	MW20B	345
	MW21	285
	MW23	-44
	MW19	31
	MW24AR	-82
	MW24BR	-11
	MW24CR	-49
downgradient	NSC3A	-104
	NSC3B	-102
	NSC4A	164
	NSC4B	187
	NSC5A	105
	ROW1B	-117

Plume Core



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Monitoring Effectiveness

- Indicators aside ... We have oxidizing conditions and decreasing VOCs concentrations.
- Impacts of TCE ... c-DCE and vinyl chloride:
  - MW24B
  - MW24C
- At these locations we also have:
  - Slight increases in electrical conductivity observed
  - ORP values rising – indicating Oxidation Zone

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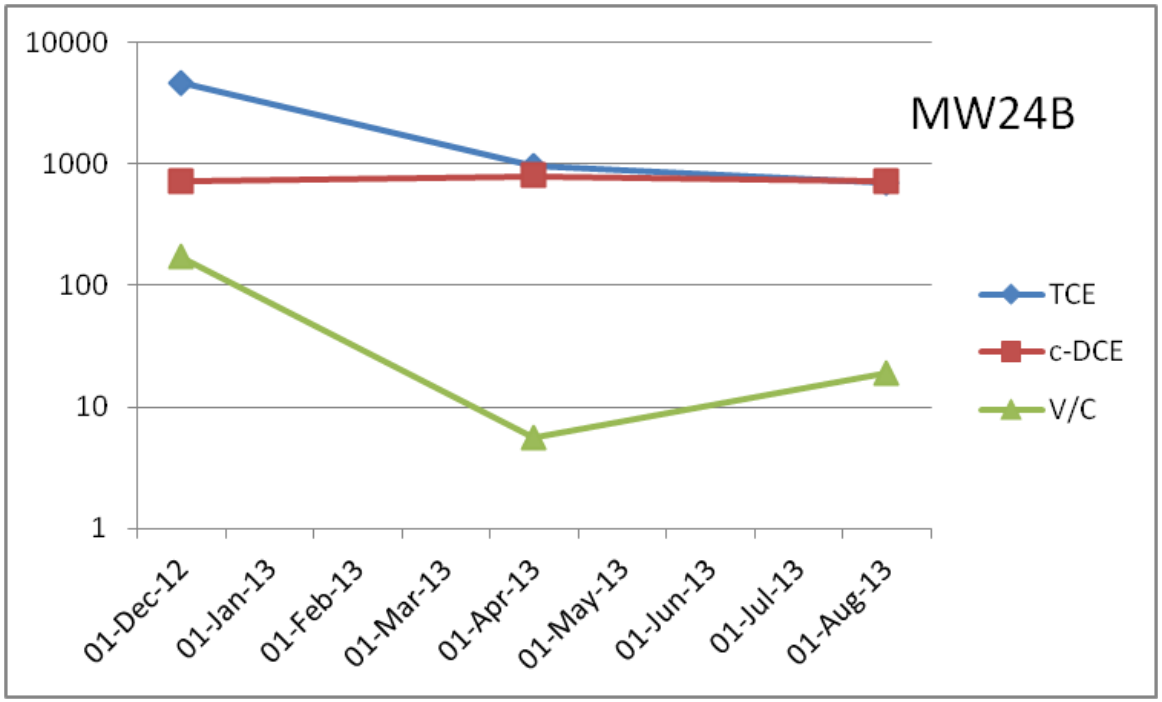
Monitoring Effectiveness

MW24B installed at 5.5 metres below ground surface, located within 1.0 metre of the barrier

MW24B	06-Dec-12	15-Apr-13	12-Aug-13
c-DCE	710	790	720
PCE	0	0	0
TCE	4600	950	700
V/C	170	5.6	19



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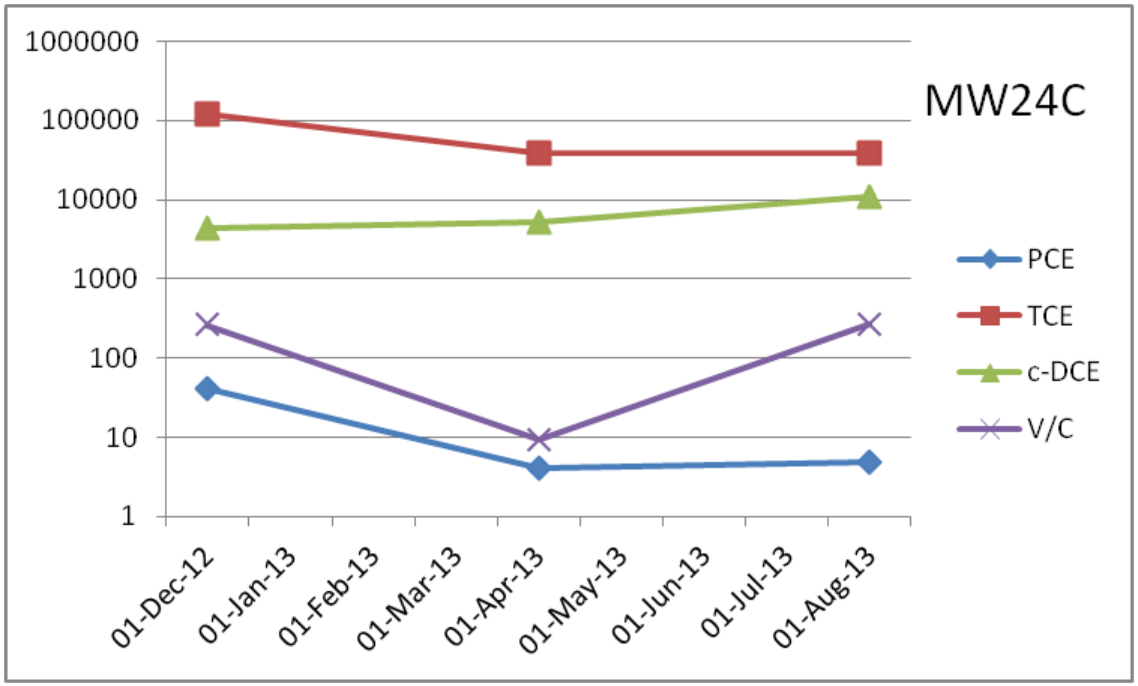
Monitoring Effectiveness

MW24C installed at
8 metres below ground
surface, located within
1.0 metre of the barrier

MW24C	06-Dec-12	15-Apr-13	12-Aug-13
c-DCE	4400	5100	11000
PCE	41	4	4.9
TCE	120000	39000	38000
V/C	260	9.2	270



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Summary ... SUCCESS!

- New twist on a known technology – $KMnO_4$
  - First Canadian Application
- Application ease for this difficult location/situation:
  - Sewers, property boundaries
  - Low hydraulic conductivities and velocity
- Early Indications of success:
  - ↑ Electrical conductivity
  - Creating a favourable ORP zone

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Summary … SUCCESS!

- Oxidation occurring in nearby wells:
  - Close proximity – low groundwater velocity
- Client is pleased with Cost/Benefit:
  - Much lower cost than others … $ to treatment vs. construction
- Technology has fit well with overall remediation plan and exit strategy:
  - Remediation to meet RA targets … move to RSC

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Closing

- Questions?
- Thank you for Attending!

D. Grant Walsom, B.A.Sc., P.Eng., QP
Partner
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www.xcg.com

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