Monitored Natural Attenuation for Oil and Gas Sites

Consortium for Research
on Natural Attenuation
(CORONA)
March 2005

James Armstrong

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Steering Committee

- **Chairman**
  - *Mr. Brent Moore, Devon Canada Corp.*
- **Principal Investigator**
  - *Dr. Kevin Biggar, University of Alberta*
- **Project Manager**
  - *Mr. James Armstrong, Komex International, U of A*
- **Committee**
  - *Mr. Scott Hiller, ConocoPhillips Canada*
  - *Dr. Cathy Laureshen, COURSE*
  - *Mr. Paul Bacchus, Environment Canada*
  - *Mr. Norman Sawatsky, Alberta Environment*
- **External Technical Review**
  - *Dr. Ryan Dupont, Utah State University*

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Researchers

- **University of Alberta**
  - *Drs. Biggar, Foght, Guigard, Deutsch, Mendoza*
- **Research Partners**
  - *Kim McLeish / Dr. Cathy Ryan, Angus Chu (U of C)*
  - *Stephanie Anderson / Dr. Larry Bentley (U of C)*
  - *Dr. Dale Van Stempvoort (NWRI)*
  - *Chad Petersmeyer / Dr. Uli Mayer (UBC)*
- **Technical Support:**
  - *Komex International Ltd., Maxxam Analytics*

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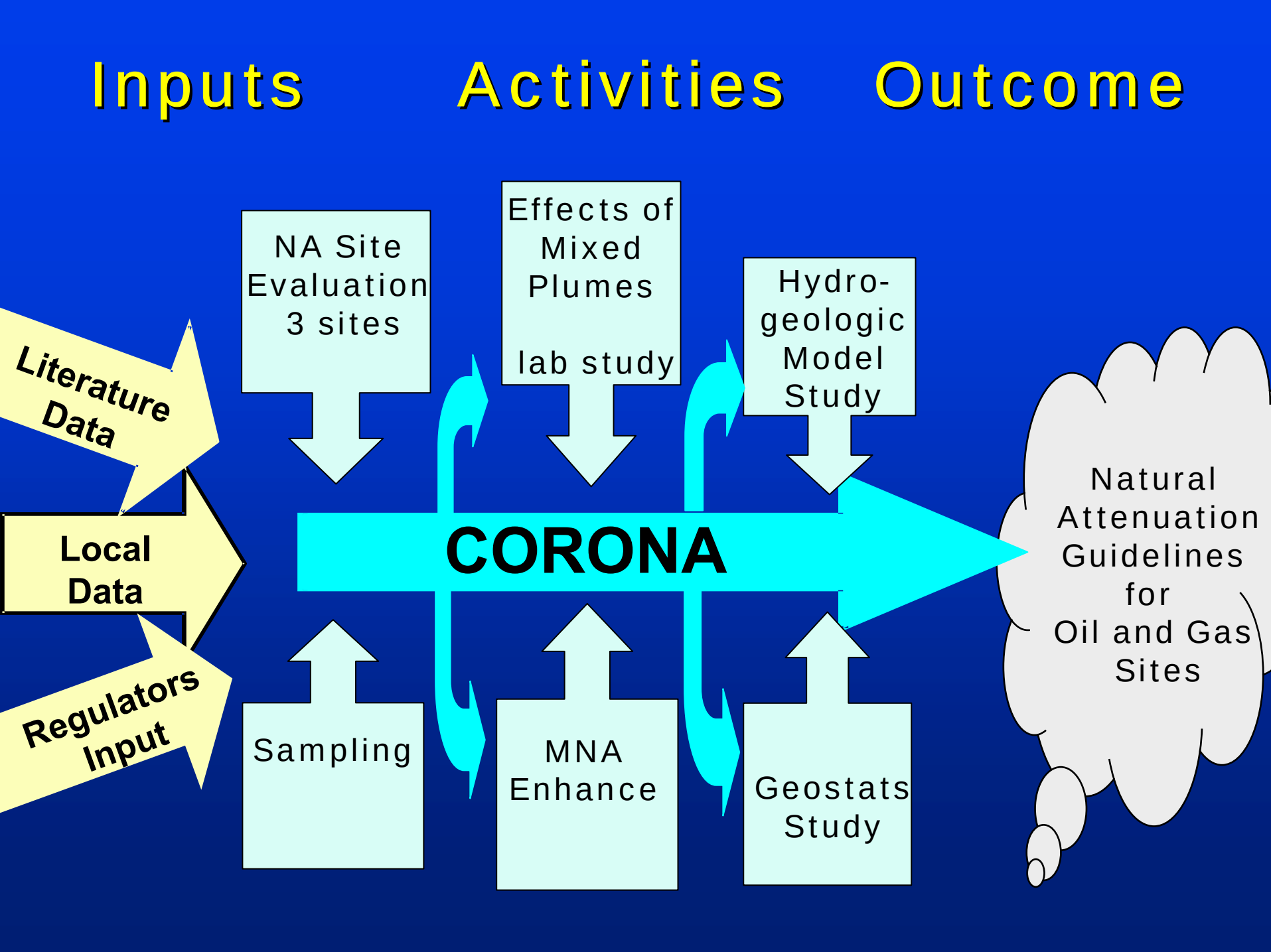
Inputs
Activities
Outcome
Literature Data
Local Data
Regulators Input
NA Site Evaluation 3 sites
Effects of Mixed Plumes
lab study
Hydro-geologic Model Study
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Sampling
MNA Enhance
Geostats Study
Natural Attenuation Guidelines for Oil and Gas Sites

Objectives

- Sampling/monitoring protocol
- Interpret/model data & variability
- Inhibition effects (salt)
- Bio-enhancement potential

➢ Assess/predict MNA effectiveness

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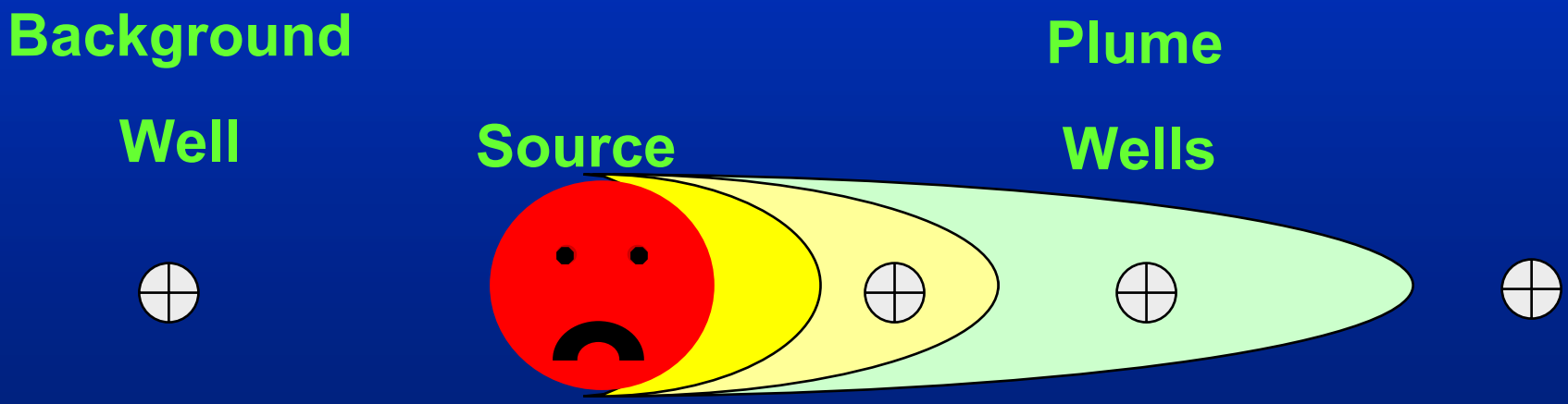
Input

- **Monitoring to support MNA?**
  - *decreasing hydrocarbon concentrations*
  - *characteristic geochemical patterns*



Lower oxygen, nitrate, sulfate

higher iron, manganese, methane

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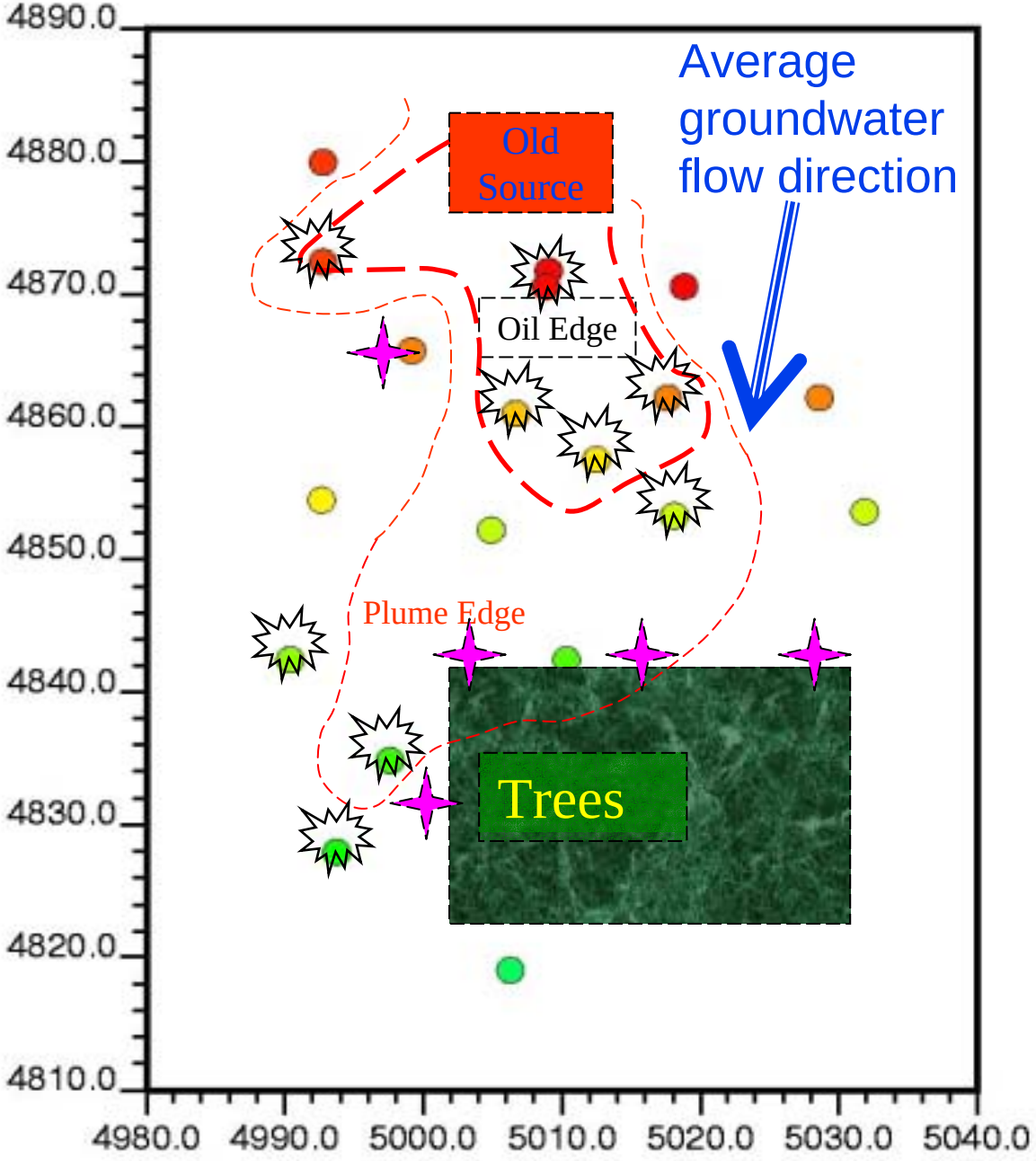
Site 1



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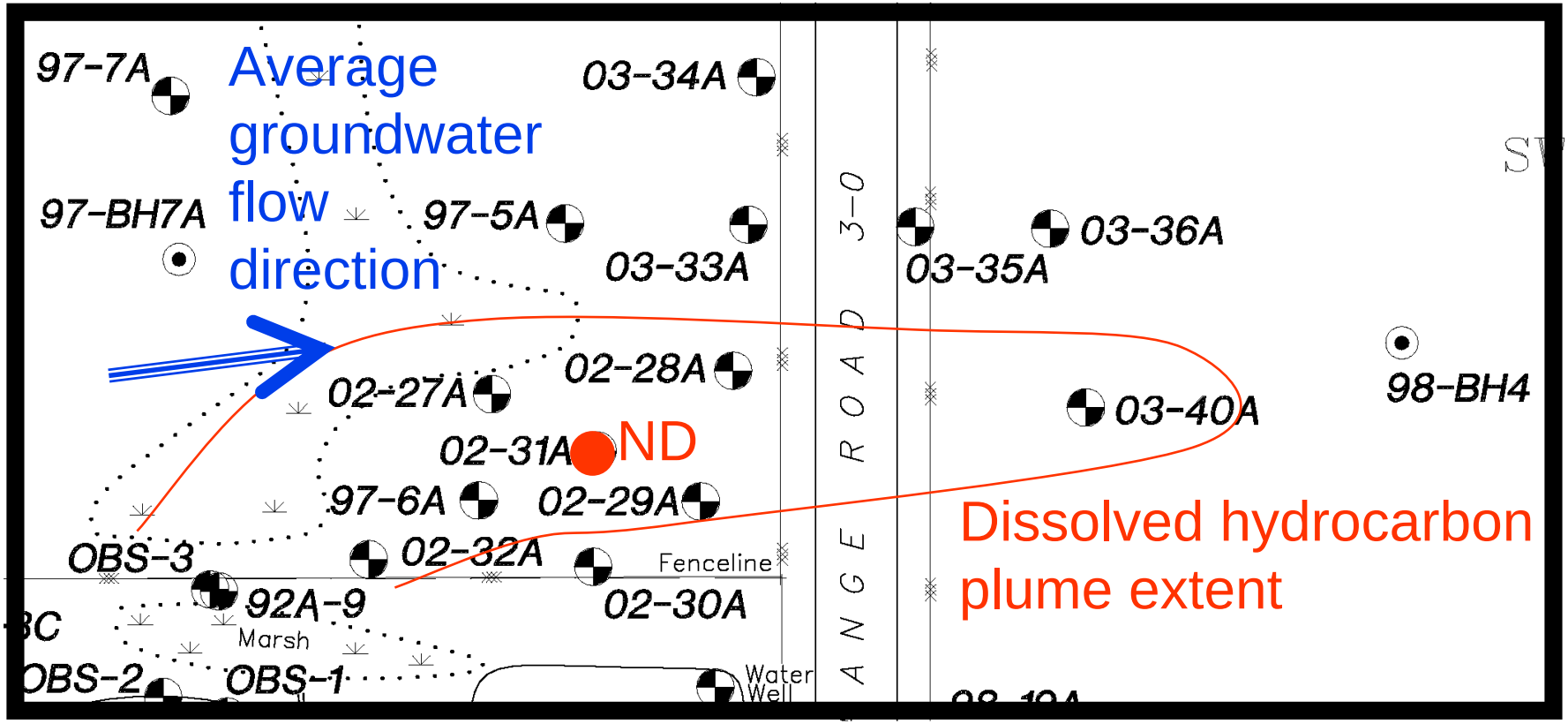
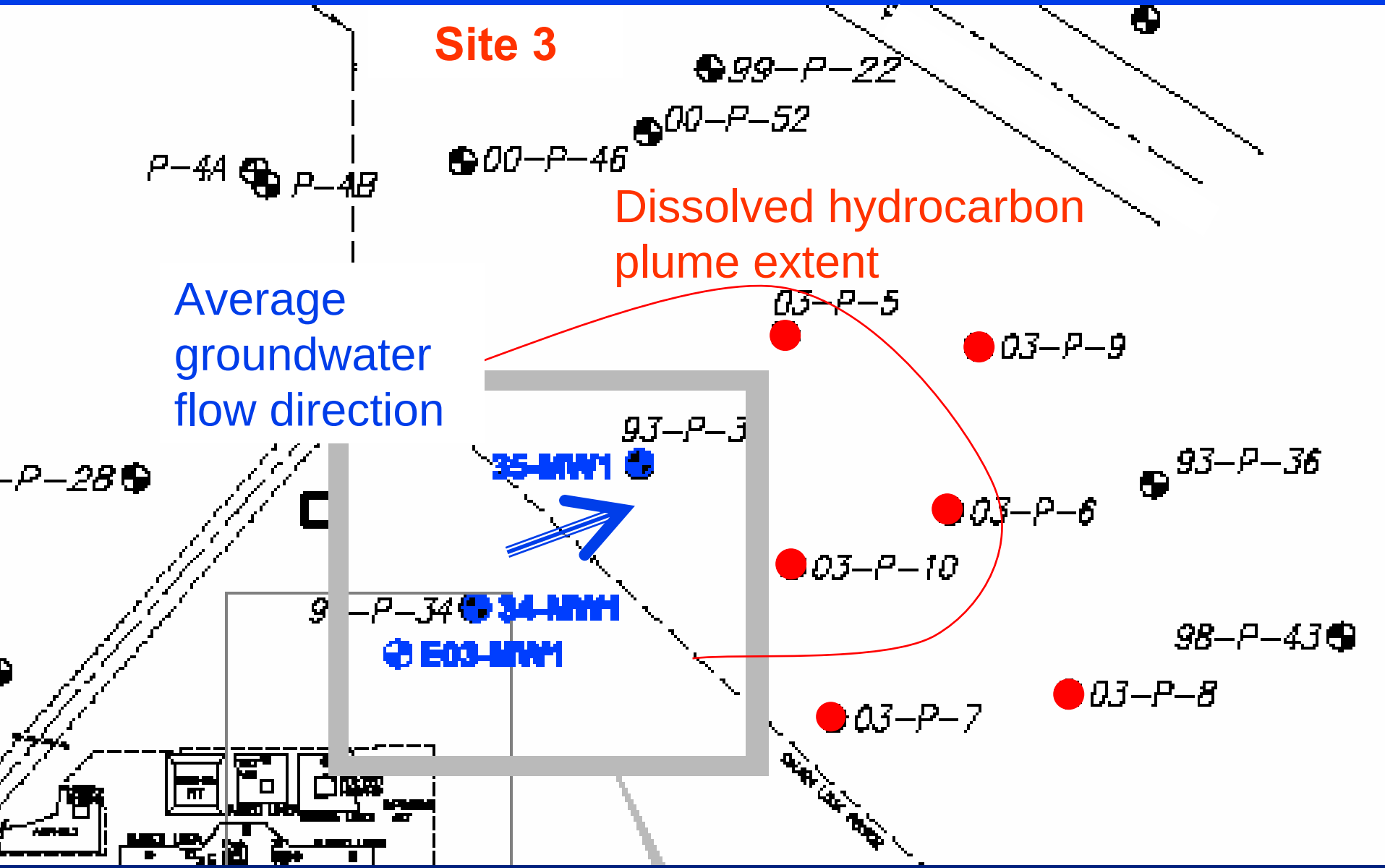
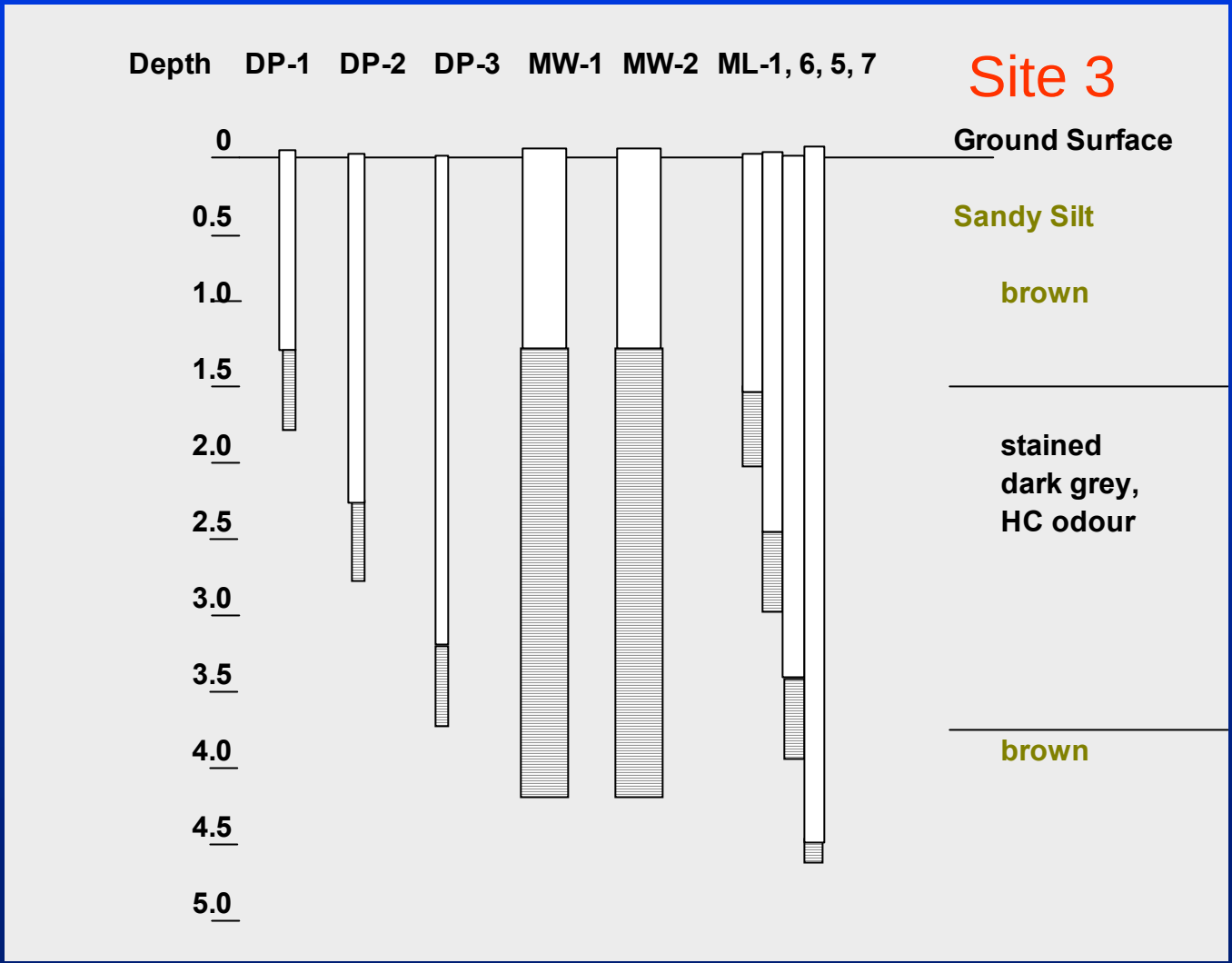
Site 2


97-7A
Average groundwater flow direction
03-34A
97-BH7A
97-5A
03-33A
03-36A
03-35A
98-BH4
02-28A
02-27A
03-40A
02-31A
ND
97-6A
02-29A
Dissolved hydrocarbon plume extent
OBS-3
02-32A
Fenceline
92A-9
02-30A
Marsh
OBS-2
OBS-1
Water Well
ANGE ROAD 3-0

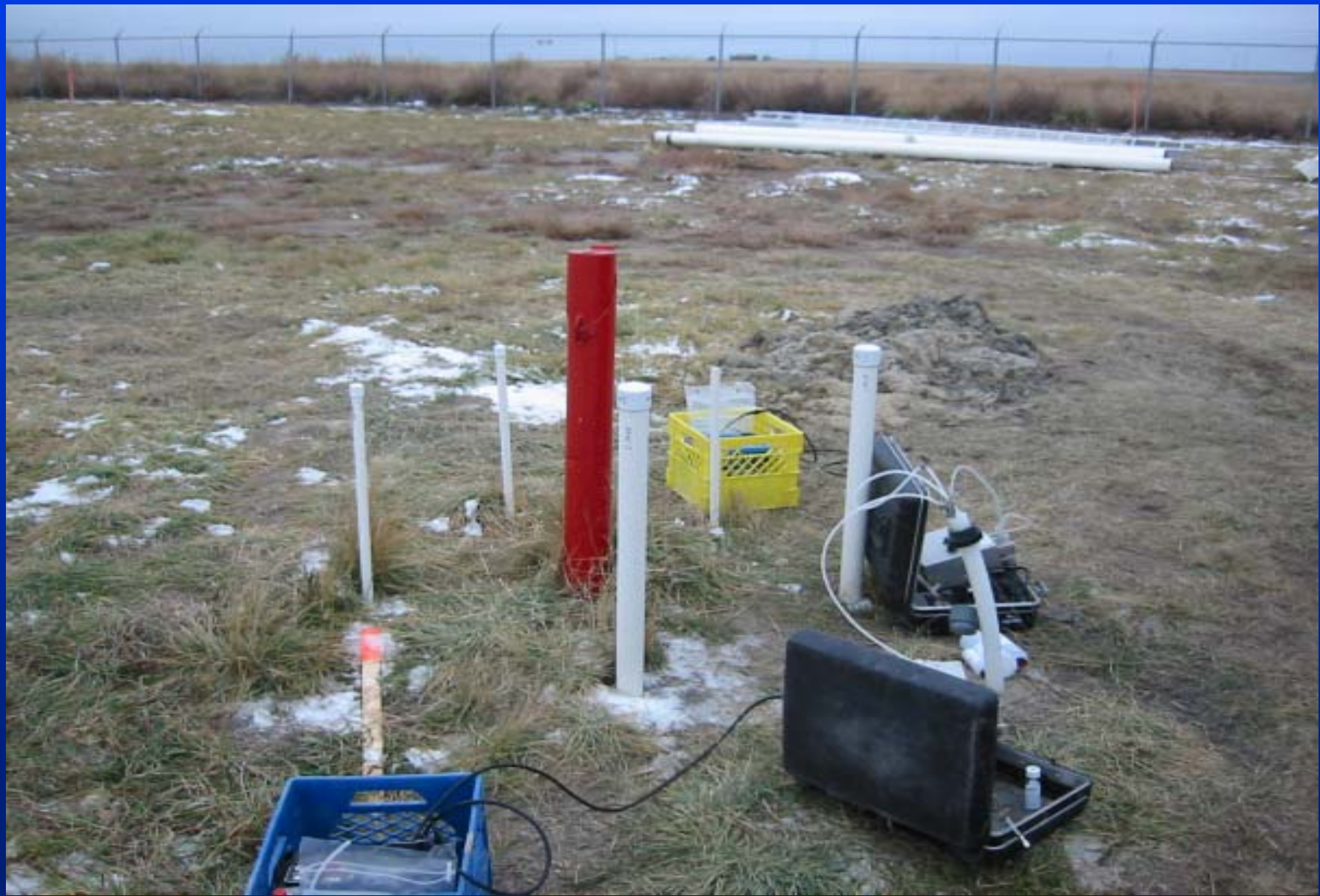
Site 3


99-P-22
00-P-52
00-P-46
P-4A
P-4B
Dissolved hydrocarbon plume extent
Average groundwater flow direction
03-P-5
03-P-9
93-P-3
93-P-36
03-P-6
03-P-10
98-P-43
03-P-8
03-P-7

Typical Well Cluster



Research Well Cluster



Soil Staining Variation

Conventional Approach

- Develop site model (phased, monitoring)
- Track changes over time
- Remove source(s)
- Explain / model the data
- Predict expected response
- Regulatory acceptance

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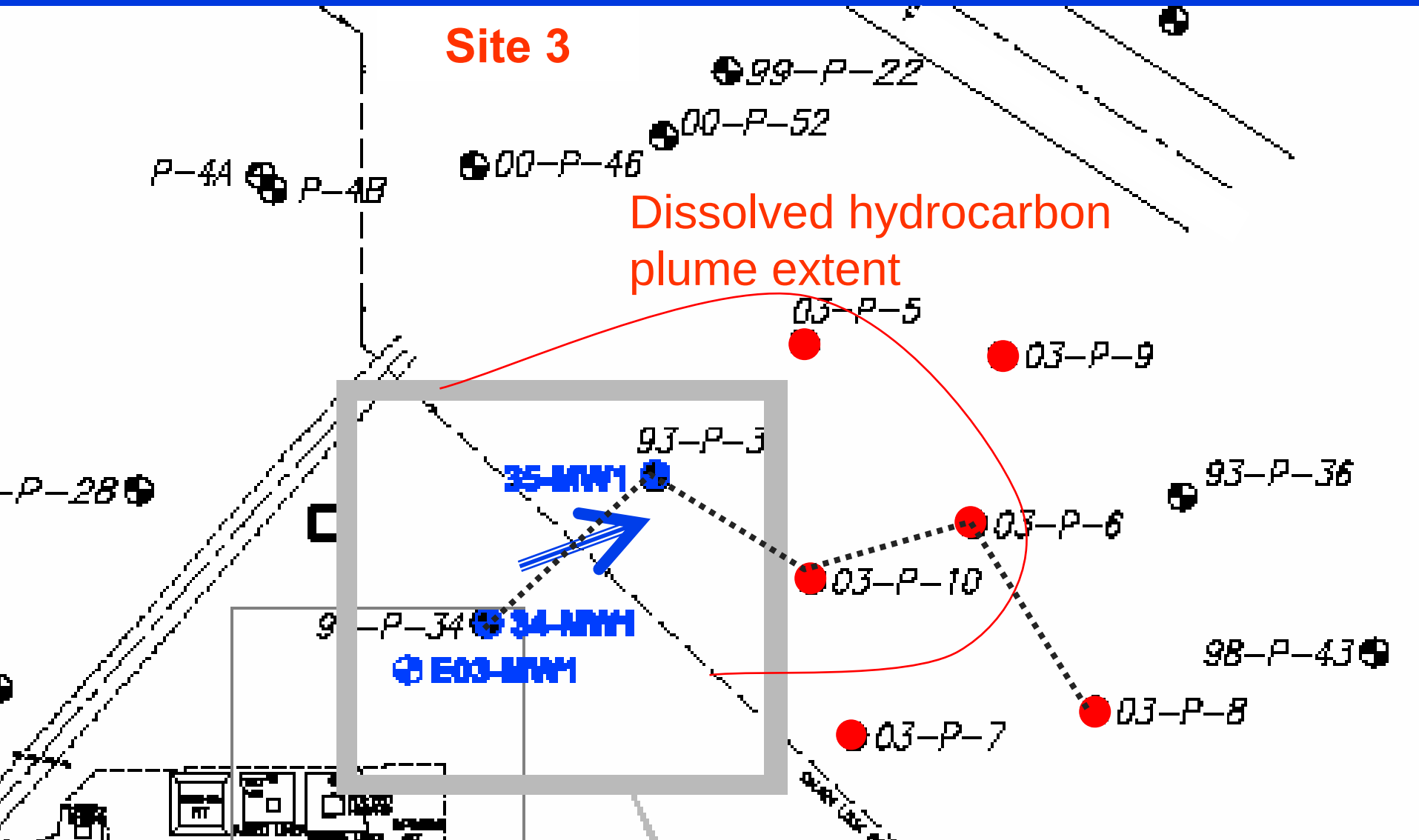
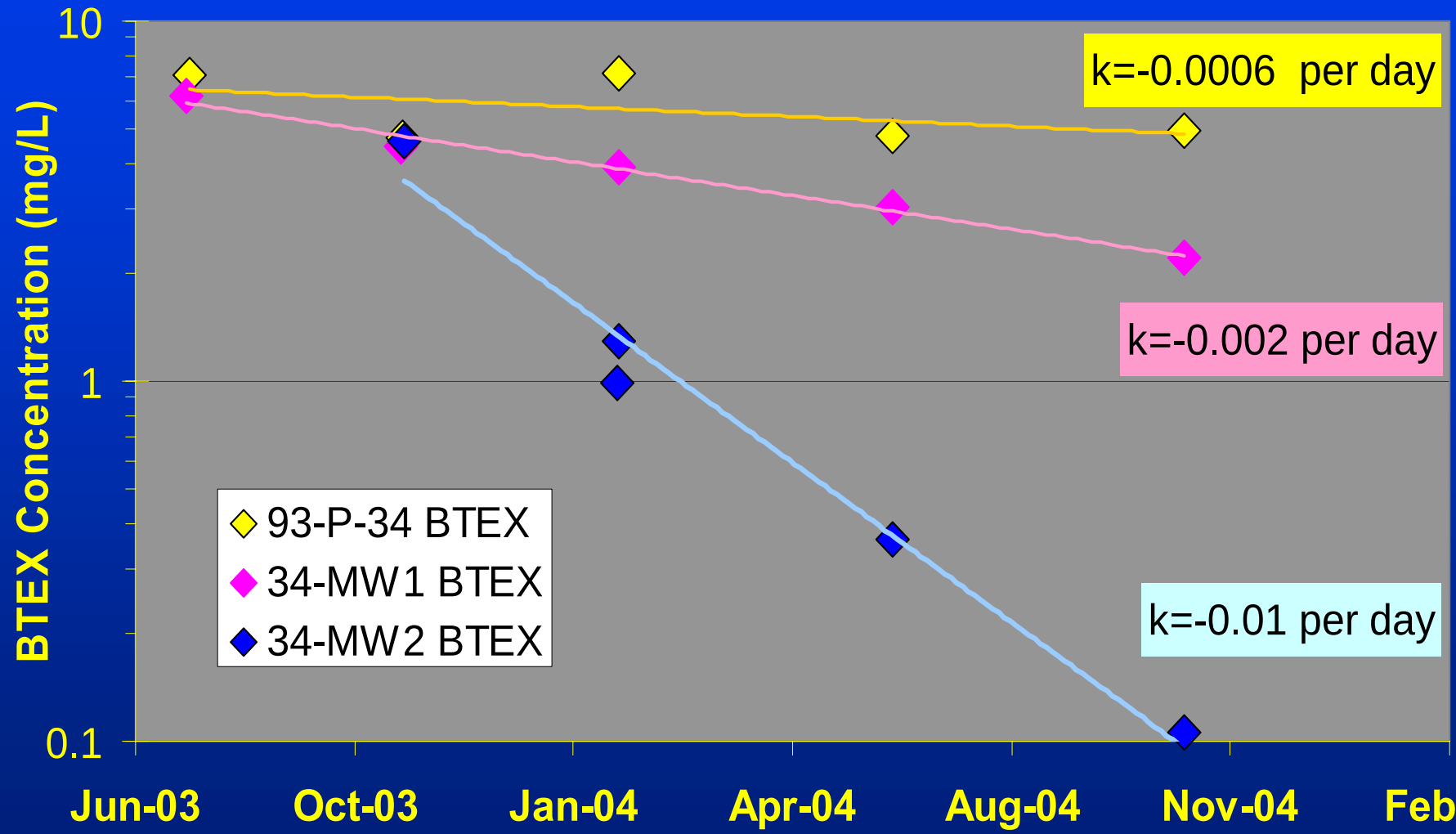
Sampling (outcome)

- **Variability – Understand and deal with it**
- **Variability sources:**
  - ***Analytical***
  - ***Protocol: technique, personnel, purging***
  - ***Well construction***
  - ***Seasonality***
  - ***Spatial (vertical and lateral)***

Research Area



Variability: one location



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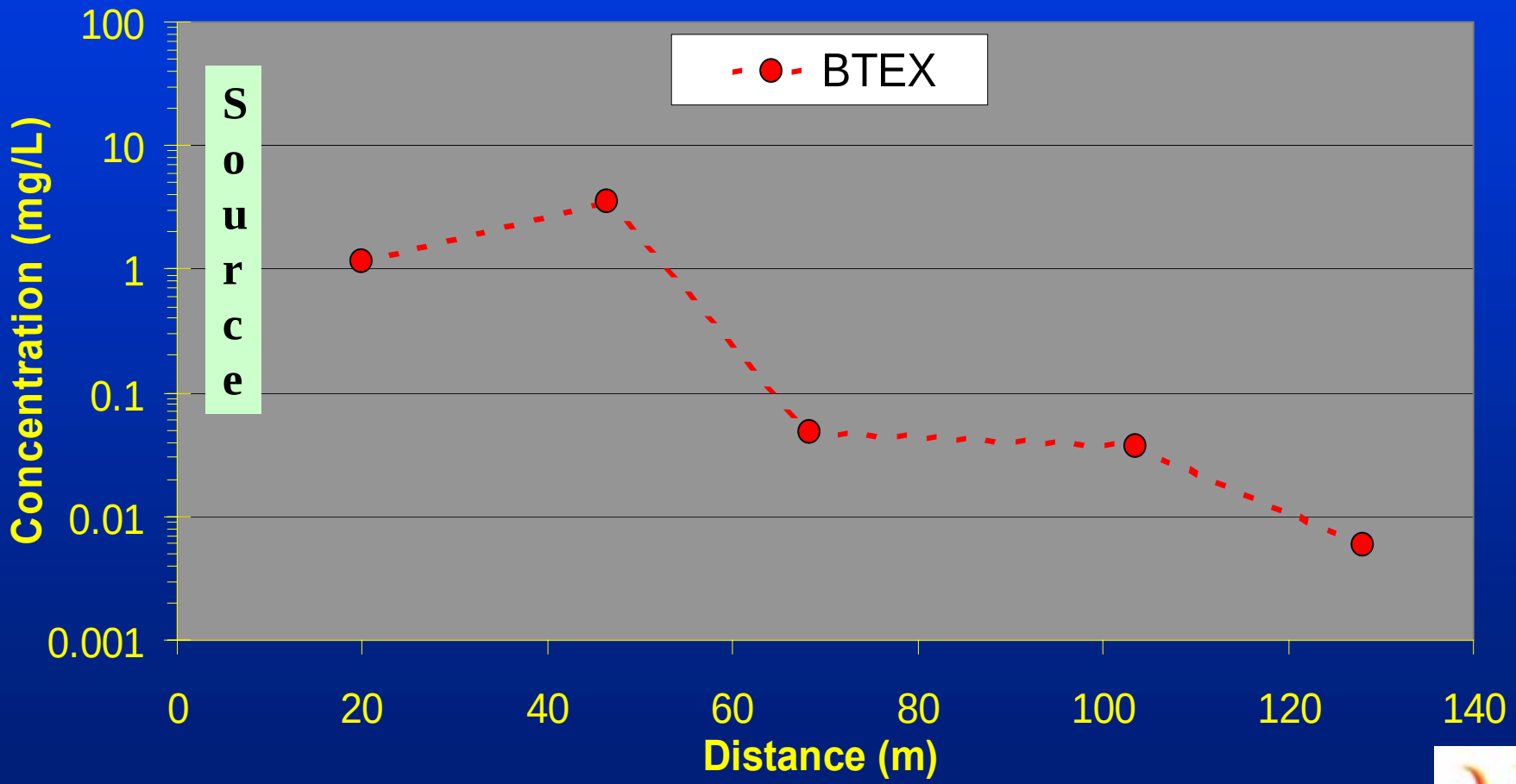
Spatial Trend



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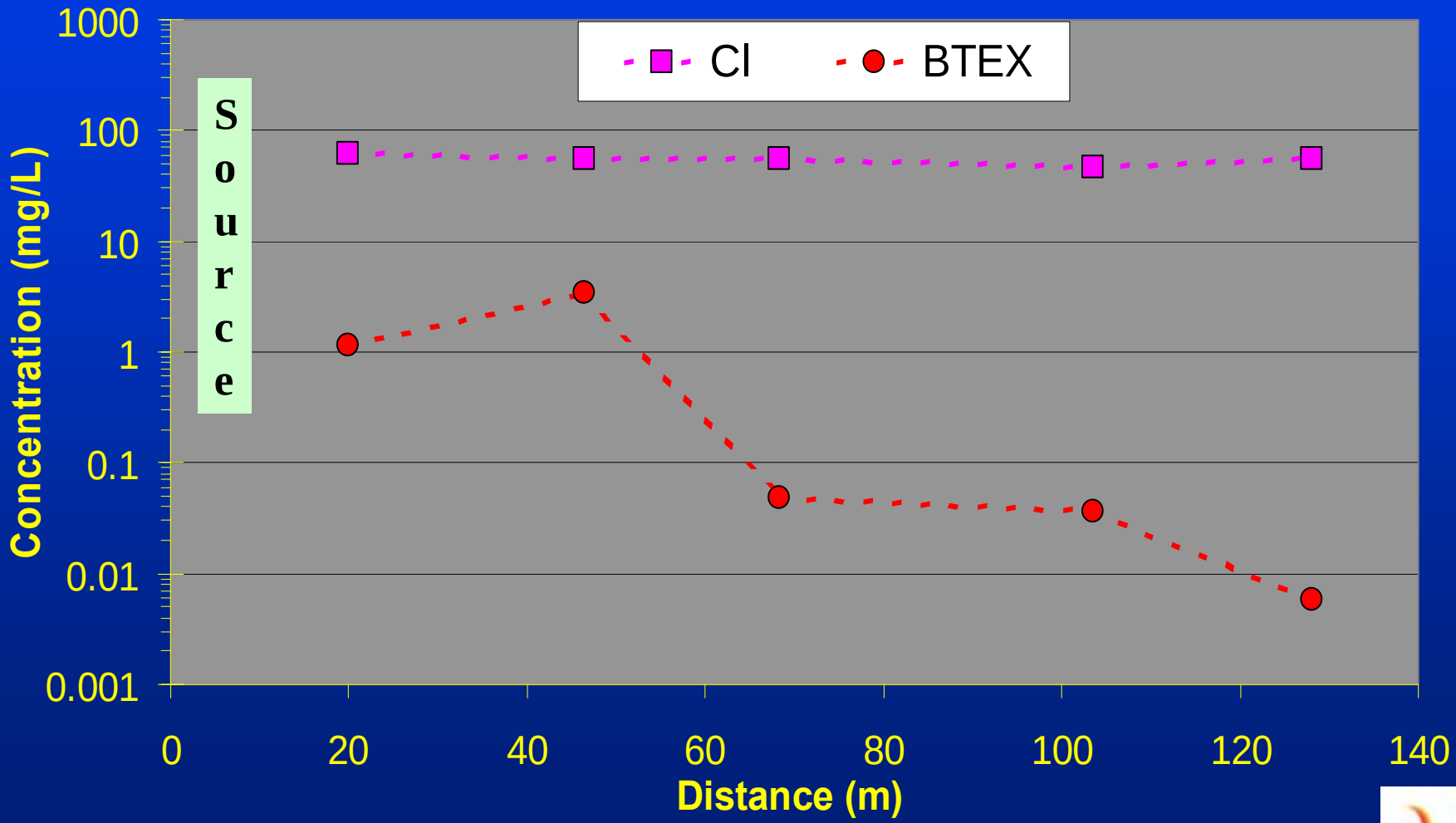
Spatial Trend



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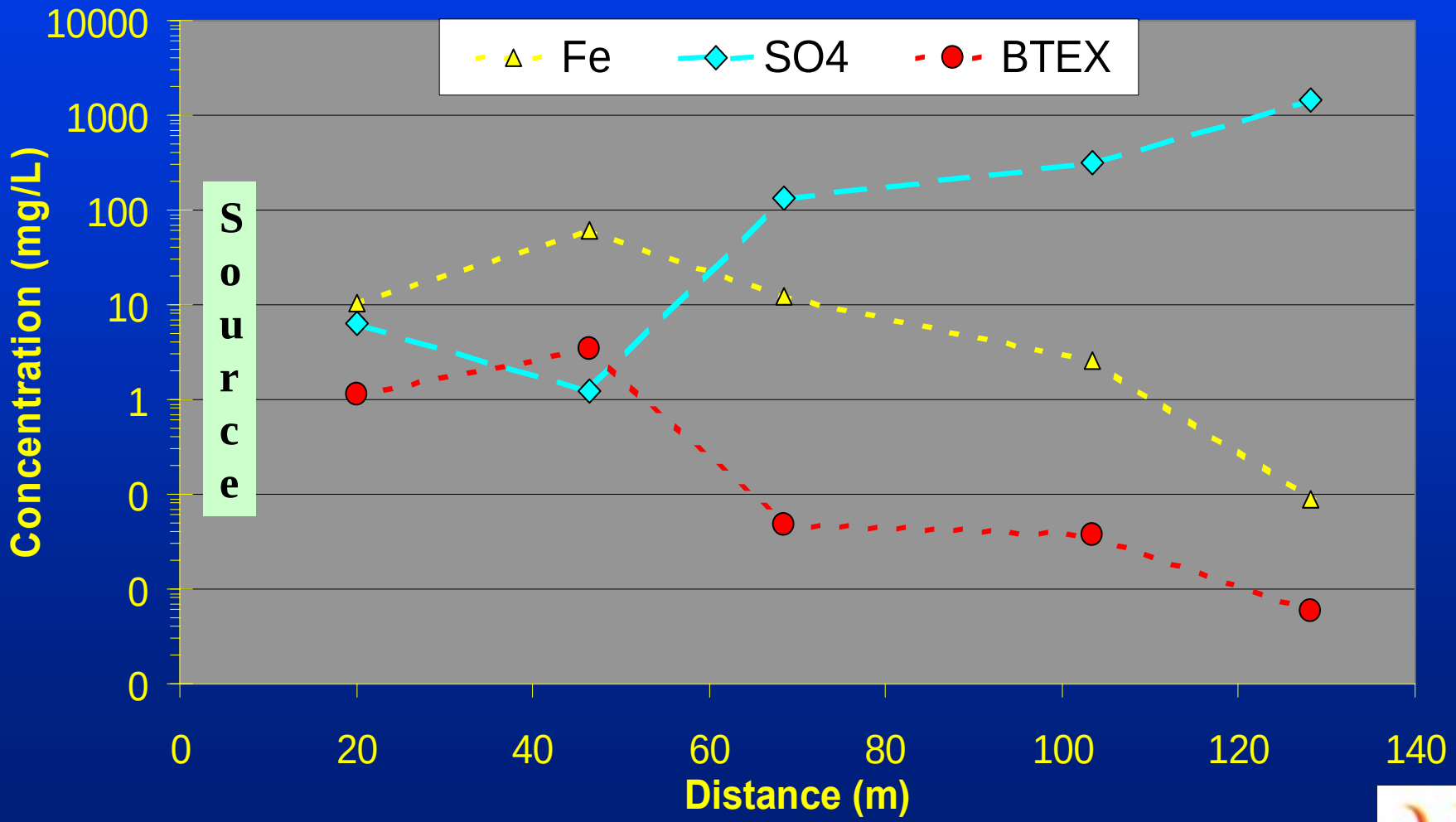
Spatial Trend



Lab Study in progress

1. **Effects of salt as a co-contaminant:**

   Microcosm (start with aerobic-biometer)

   Identify salt concentration effects

2. **Enhancement approaches:**

   - *Design and set up mesocosms*
   - *Establish metabolite analyses to:*

     confirm biodegradation

     identify enhancement effects

     help verify monitoring data

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Salt Impact Lab Study

Effect of NaCl on aerobic biodegradation at 10°C & 25 °C

dissolved model hydrocarbons, based on Site 1

^{14}C-hexadecane or ^{14}C-phenanthrene

Site 1 data:

- **Low salt (≤ 1% NaCl): no effect or slightly stimulatory**
- **High salt (2.5% - 5% NaCl): delays or inhibits biodegradation but does not stop it.**

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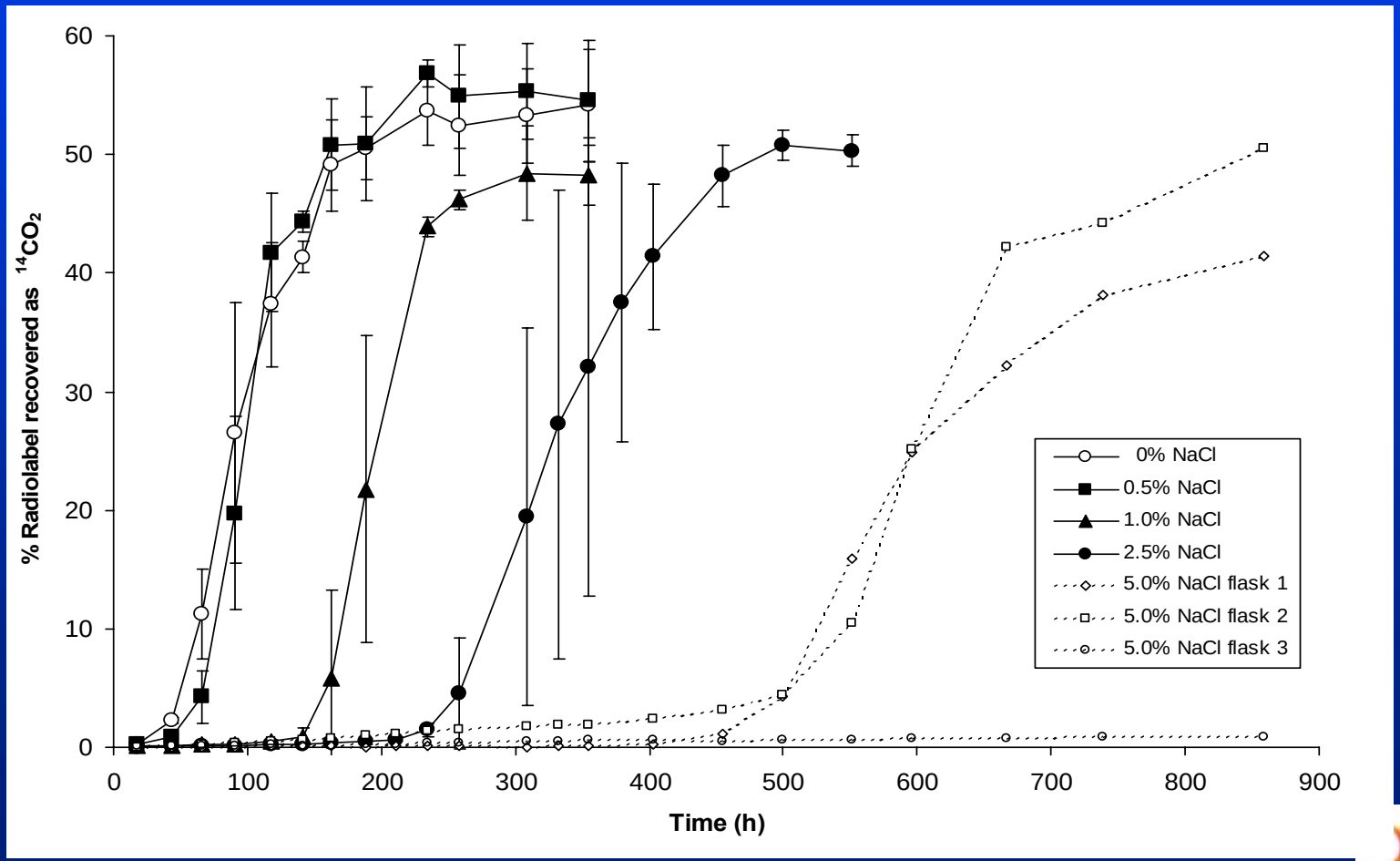
Biodeg'n of Phenanthrene (vary NaCl)



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Metabolites (Dr. Foght)

Intermediary biodegradation compounds

- Direct evidence of biodegradation
- Time Zero samples:
  - *metabolites already present (1 month equilibration)*
- Currently doing 6 month samples

Metabolite Detection (t=0)

Parent compound	Metabolites from	Site 1	Site 3
Alkanes	C3, C4	-	-
	C5, C6	✓	-
	C7, C8, C9	✓	✓
	C10, C11	-	✓
Aromatics	Monoaromatics	-	✓
	Naphthalenes	✓	-

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Enumeration (Dr. Foght)

Microbial type	Site 1	Site 3
Aerobic	1,000	10,000
Nitrate RB	100,000	10,000
Iron RB	100,000	10,000
Sulphate RB	10	100
Methanogens	BDL	1,000

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MNA Enhancement

Objective: enhance anaerobic biodegradation by adding electron acceptor and nutrients

Laboratory study re-started in 2004

- Experiment matrix (each in duplicates)
  - Anaerobic conditions maintained
  - Microbial activity observed

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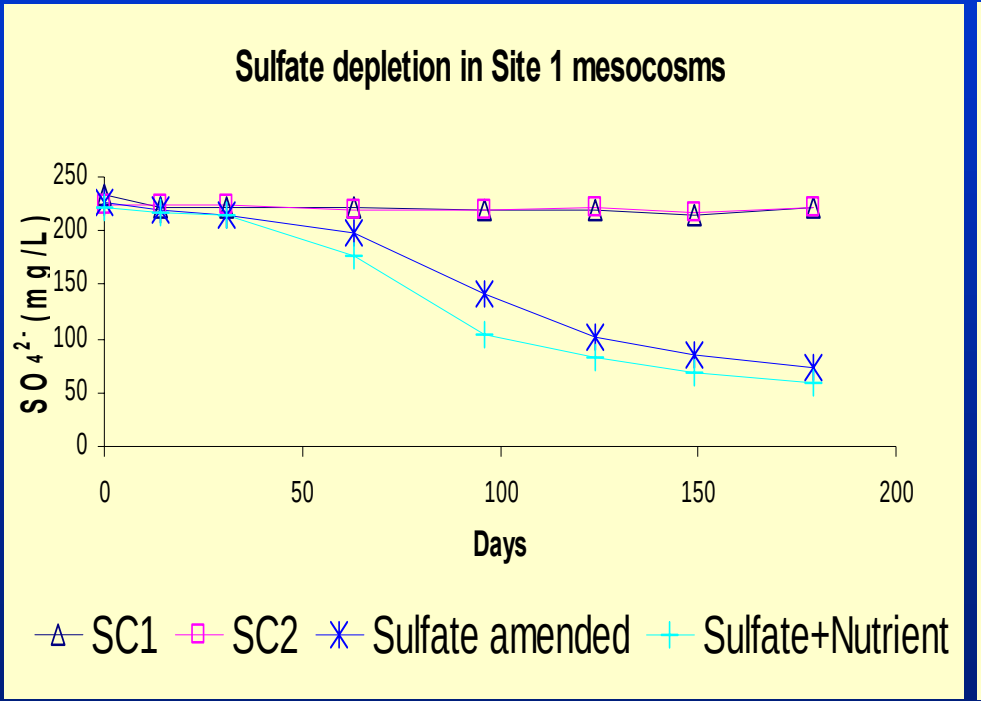
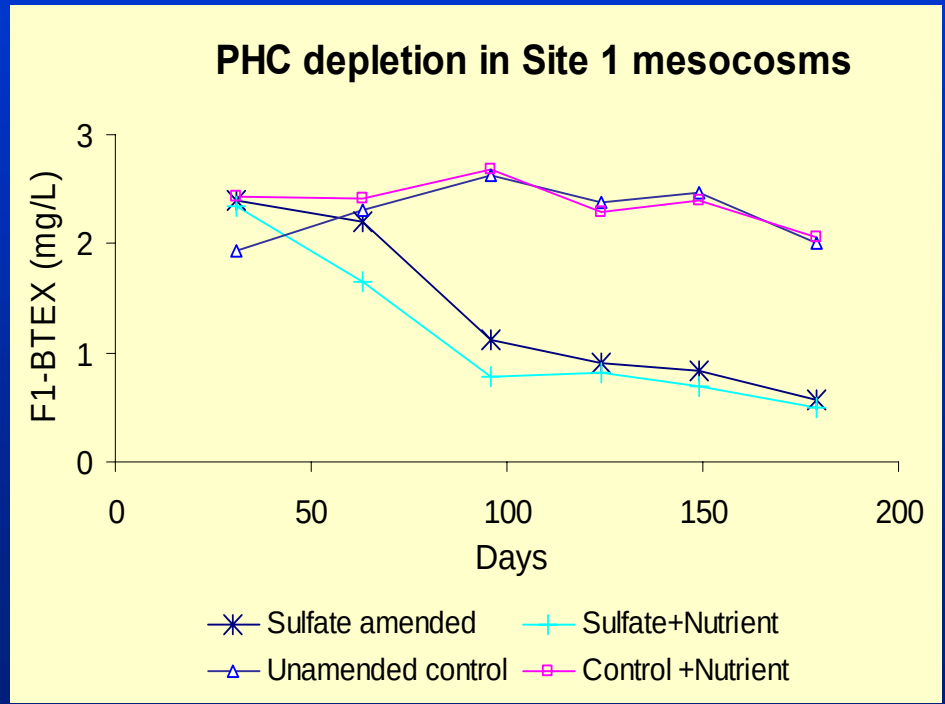
Mesocosms

Nitrate only	Nitrate+nutrients	Unamended control
Sulfate only	Sulfate+nutrients	Sterile control
Nutrients only		

MNA Enhancement

- Depletion of TEAs and enhanced biodegradation of PHCs in some mesocosms





MNA Modelling

Geostatistical approach started in 2004

- *Effects of parameters:*
  - uncertainty
  - sensitivity
- *Value of additional data*
- *Value of effort to reduce uncertainty*

MNA Modelling

Deterministic approach to start in 2005

- *Utility of existing models*
- *Use geostatistical results for uncertainty*
- *Identify data needs: site characterization*

Guidelines

- Steering Committee started development
- Draft in preparation for internal review

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Conclusions

- **Natural attenuation is occurring at all 3 sites:**
  - *Geochemical indicator patterns*
  - *Metabolites present*
  - *Microbes present*
- **Variability in rates and processes**
- **Numerous uncertainty sources**

Implications

- **Site characterization is key for MNA**
- **Sampling:**
  - ***Be consistent***
  - ***Variability can confound understanding***
- **Risk management strategy**
  - ***Longterm***
  - ***Not a quick remediation option***

Partnerships

- **NWRI (Dr. Dale van Stempvoort)**
- **U of C (Kim McLeish):**
  - ***Dissolved gas system working well***
  - ***Strong evidence of biodegradation activity***
- **UBC (Chad Petersmeyer):**
  - ***Site 3 soil extractions underway***
  - ***Scanning electron microscopy (SEM)***
  - ***Clear sulfide enrichment in stained zone***

Funding Partners

- **Industry**
  - *Devon Canada, ConocoPhillips*
  - *Canadian Association of Petroleum Producers*
  - *Komex International, Maxxam Analytics*
- **Government**
  - *Environment Canada – PERD*
  - *NSERC*
  - *Coordination of University Research for Synergy and Effectiveness (COURSE) – Gov't of Alberta*
  - *Alberta Environment*