100-D Area Biostimulation Treatability Test

July 2008 Status

PNNL-SA-61817

MJ Truex (PI)
VR Vermeul (TL)
JS Fruchter (PM)

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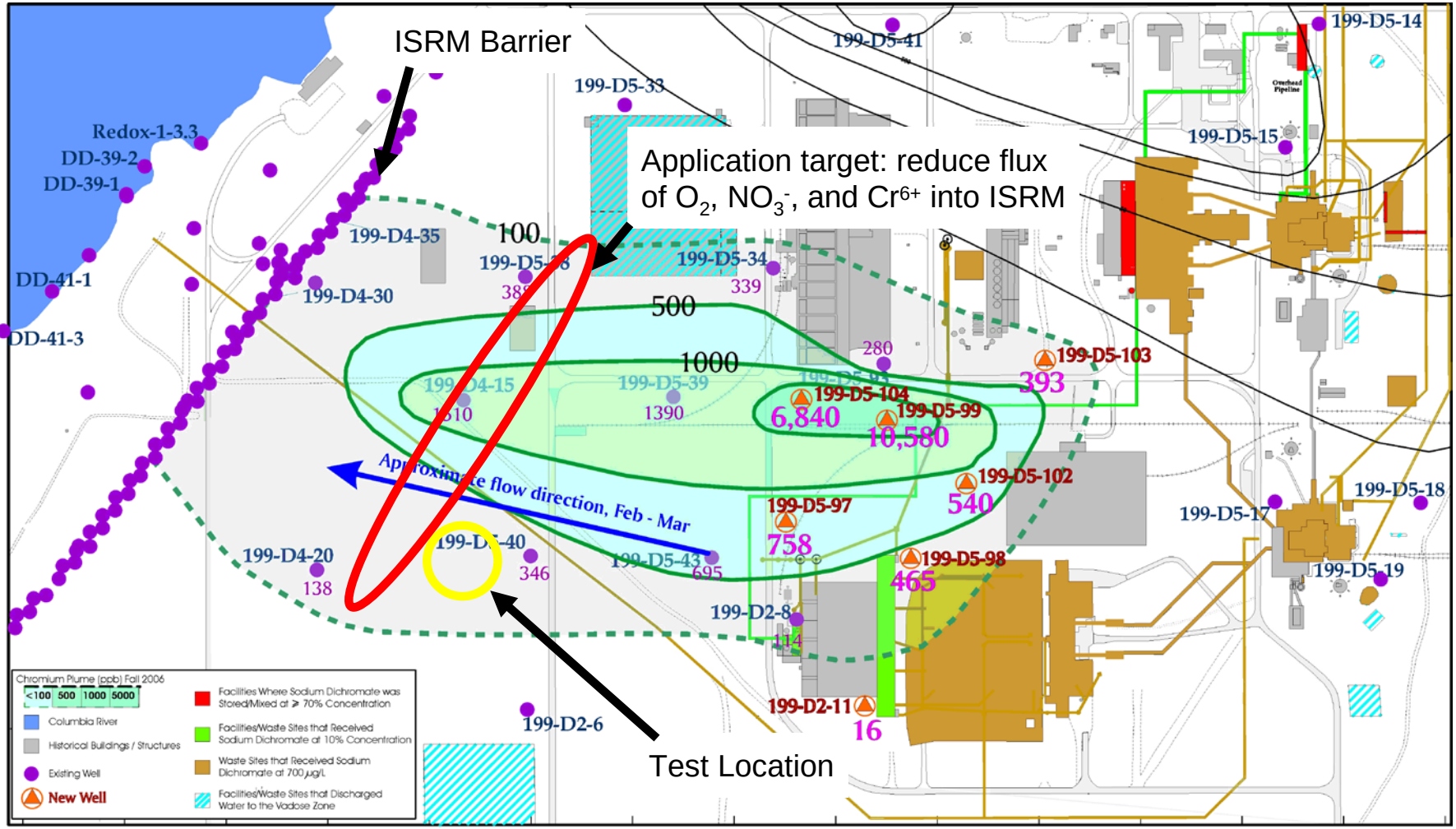
100D Biostimulation Concept



Hexavalent chromium values in parts per billion (ug/L)

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Overview

- Two approaches for a biobarrier
  - Soluble Substrate (e.g., molasses)
    - inject soluble substrate
    - build biomass, reduce iron
    - barrier reduces influx until biomass is decayed
    - repeat substrate injection
  - Immiscible substrate (e.g., vegetable oil)
    - inject immiscible substrate
    - substrate slowly dissolves and reduces influx until substrate is gone
    - repeat substrate injection

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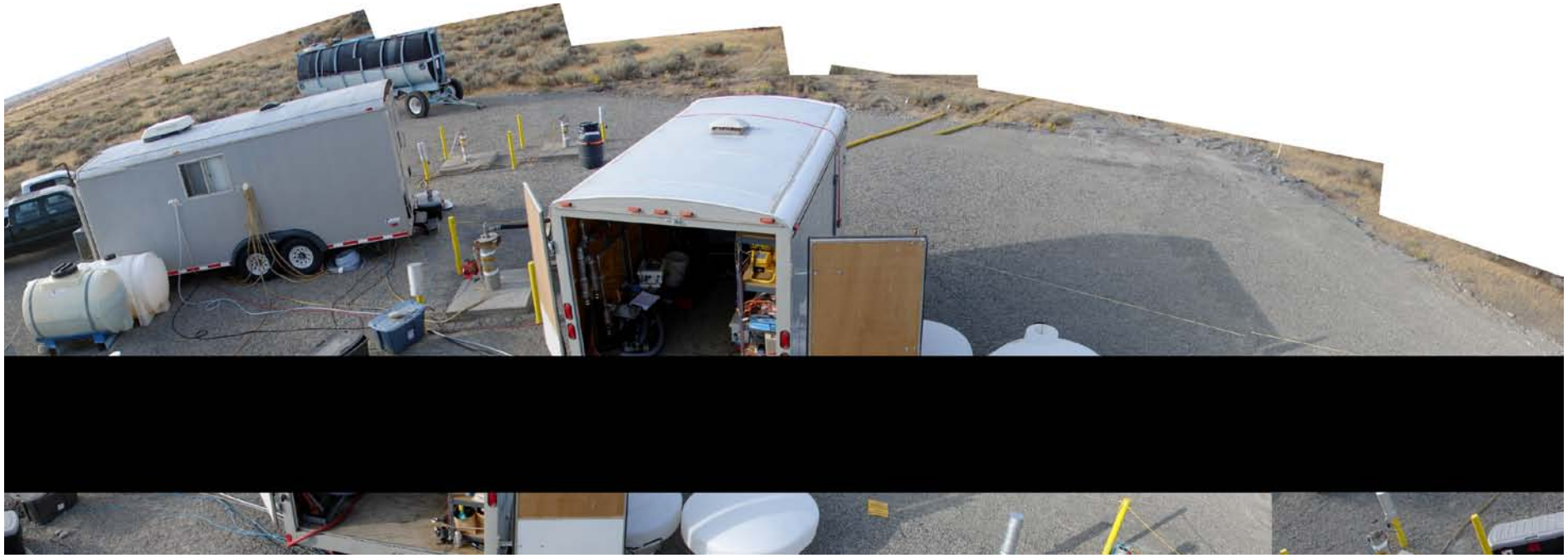
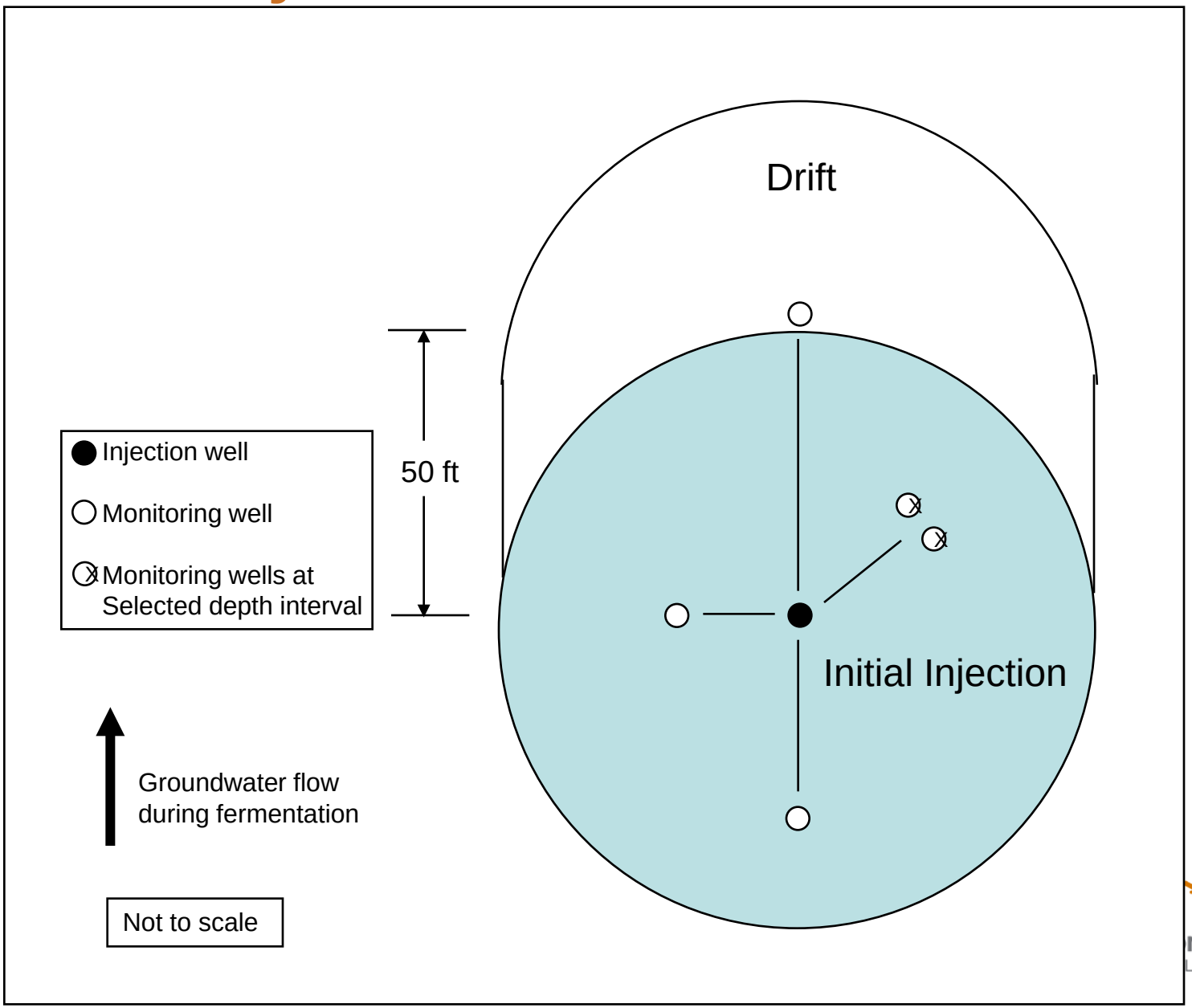
Project Status – Soluble Substrate

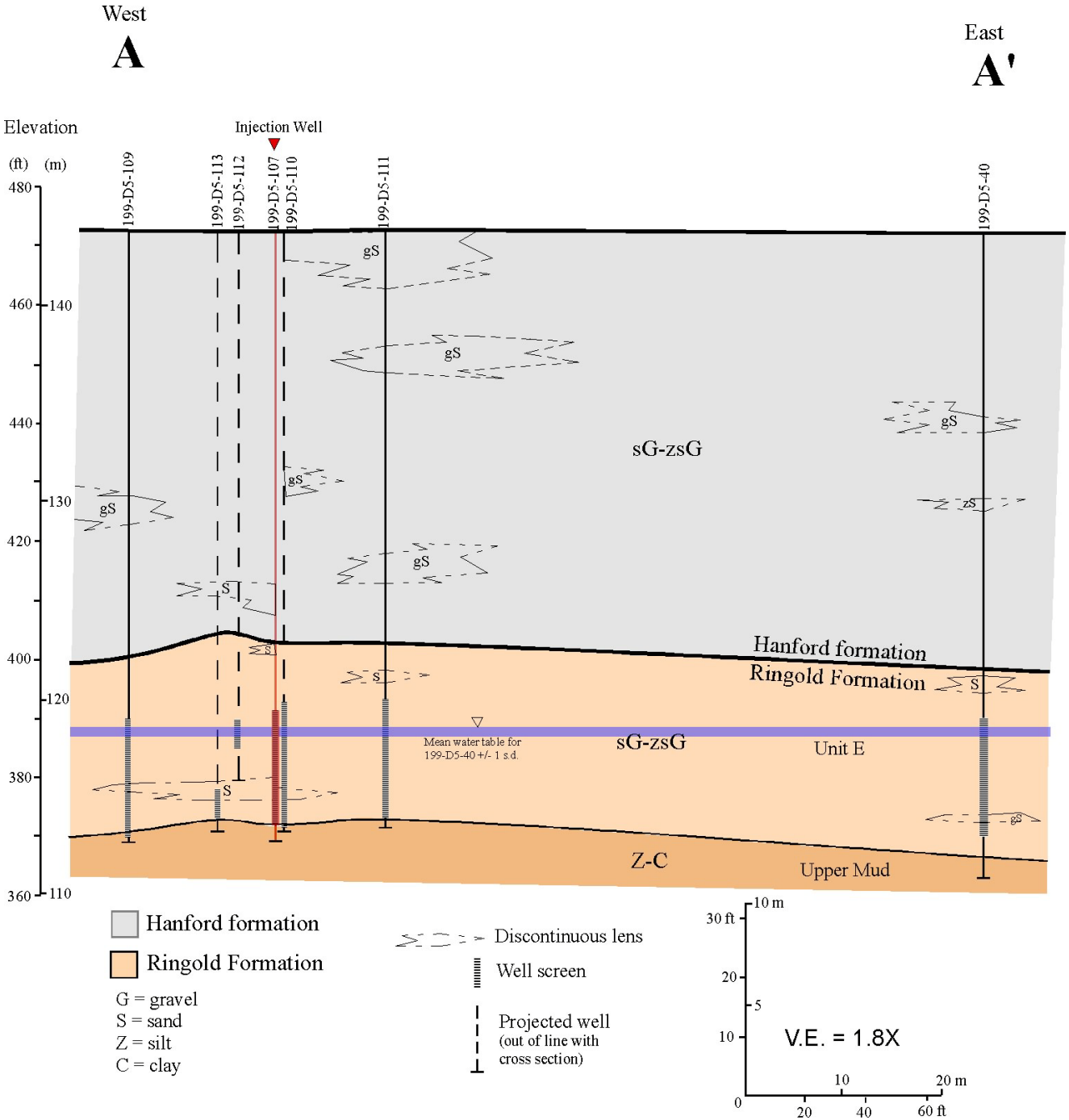


- Successful substrate injection
- Reducing conditions being maintained in test cell (9 months)
- Collecting samples to collaborate with LBNL science program
  - geophysical survey, microbial community, chromium isotope analysis
- Continuing performance monitoring

Test Cell Layout



Test Site



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Injection Objectives and Results

- Determine the effective radius of injection
  - Result: A radius of injection of about 15 m from the injection well for a labile substrate is obtainable. It is unlikely that a radius greater than 20 m could be obtained due to the rapid initiation of microbial reactions and associated biomass buildup near the injection well.
- Evaluate the uniformity of substrate distribution
  - Result: Uniformity of substrate injection is, as expected, dependent on formational heterogeneities within and beyond the targeted treatment zone. Subsequent microbial activity has been observed at all locations.
- Identify operational needs for injection
  - Result: Relatively simple operations with use of process water and substrate supply in a tanker truck were demonstrated during the injection. Initial injection pressure increase, most likely due to molasses accumulation on the injection well screen, occurred but could be mitigated.

Substrate Injection

- Average injection flow rate (water and all solutes) of approximately 33 gpm
- Average molasses injection flow rate of approximately 1.1 gpm
- Approximately 157,000 gallons of water injected
- Approximately 5100 gallons of molasses injected
- Average molasses concentration during injection was 44 g/L
- Injection duration of 3.25 days
- Based on the injected volume, estimated aquifer properties (6.1 m thick with a porosity of 0.15), and an idealized radial geometry, the nominal injection radius was about 15 m

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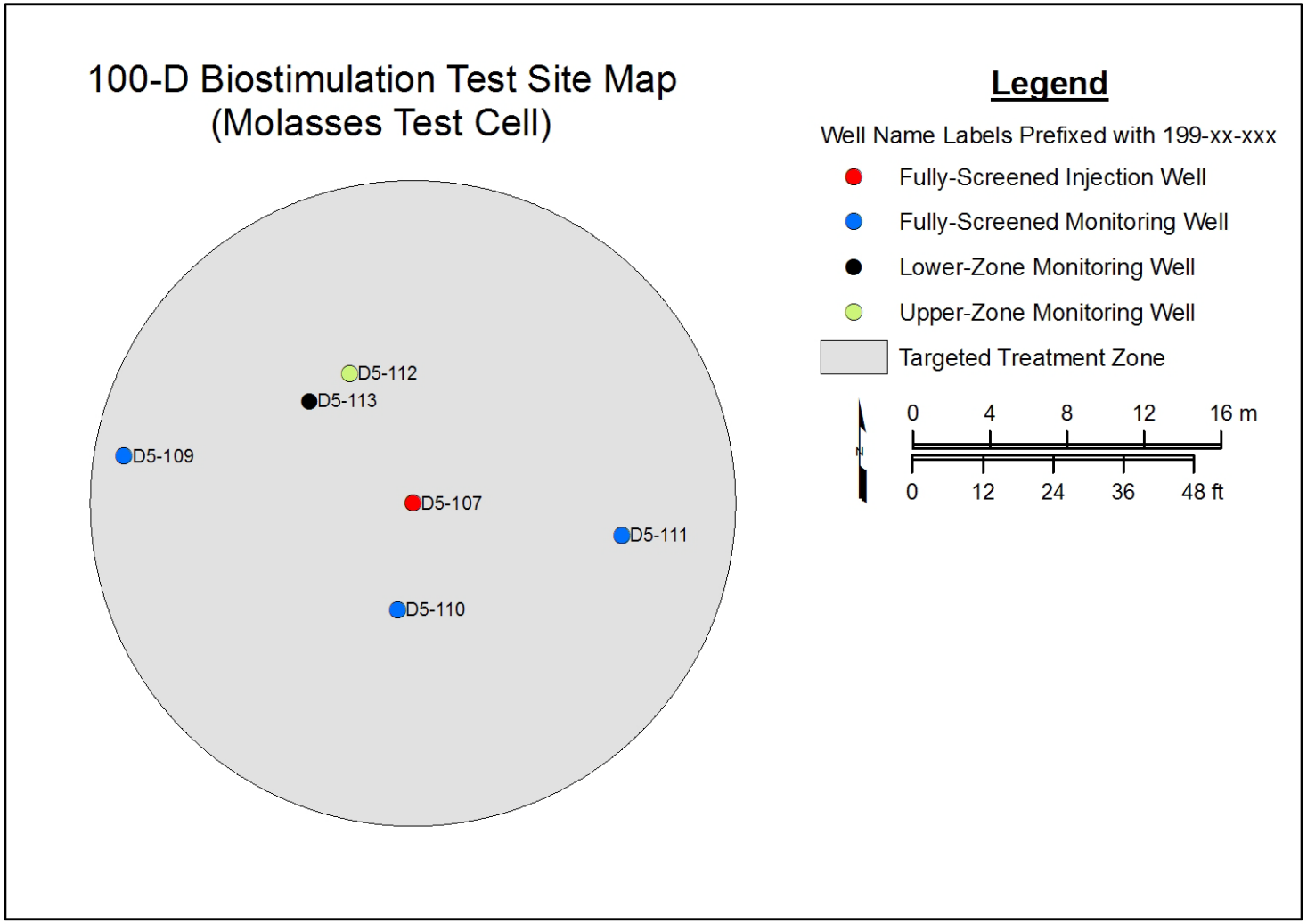
Test Site



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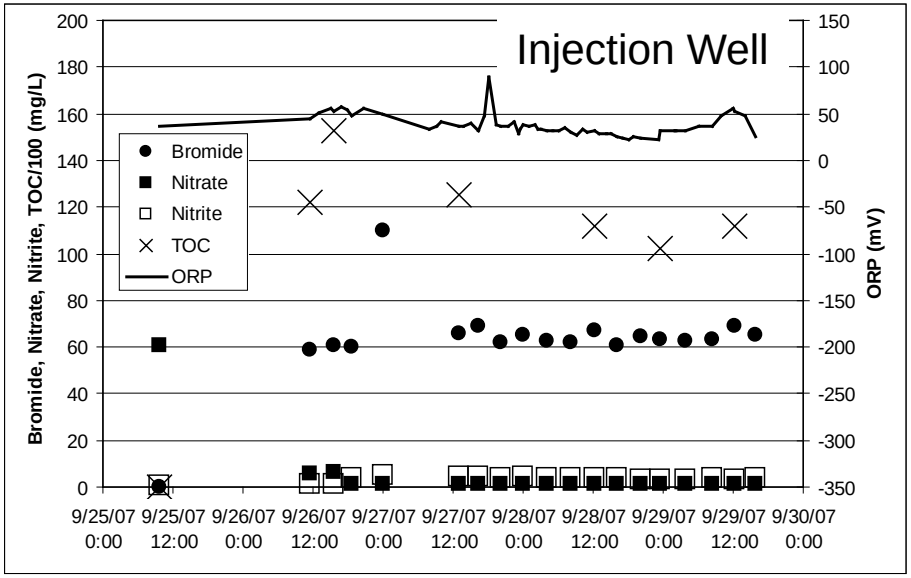
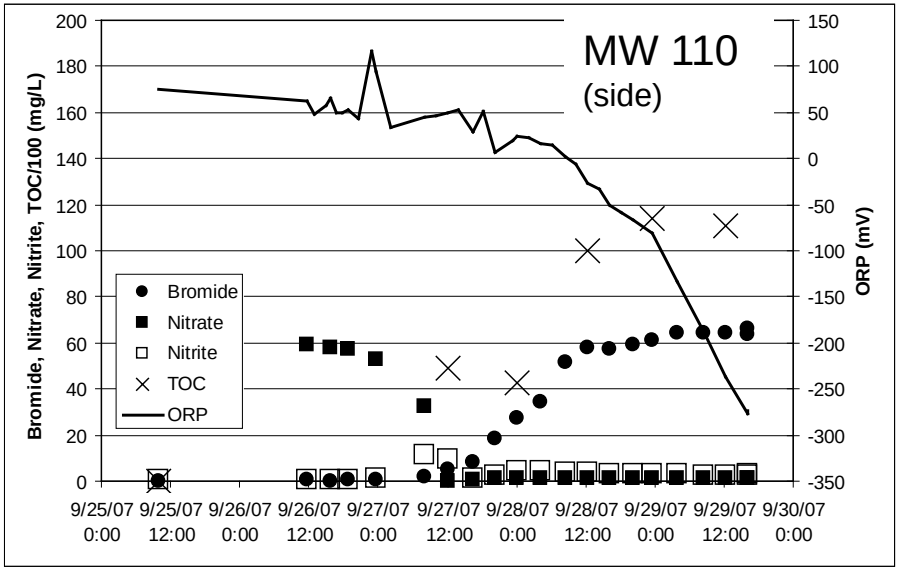
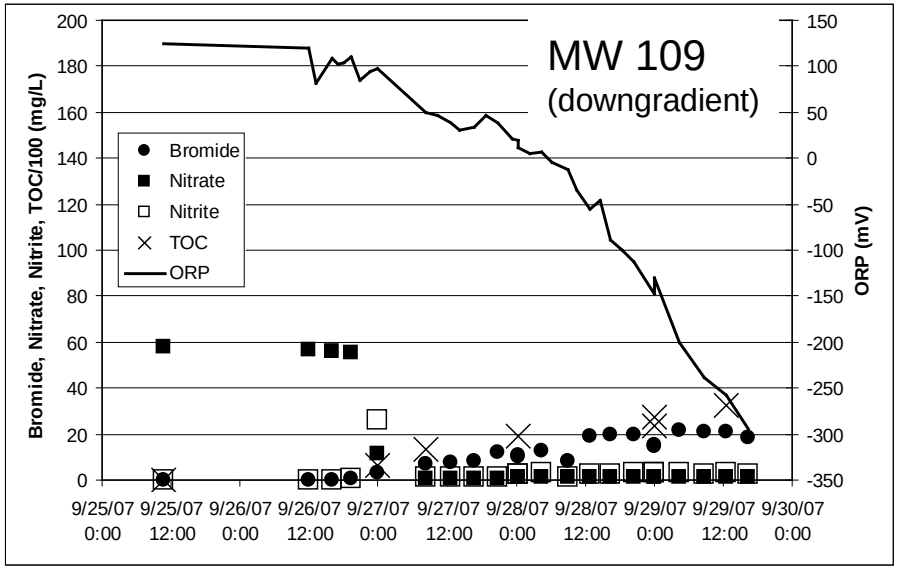
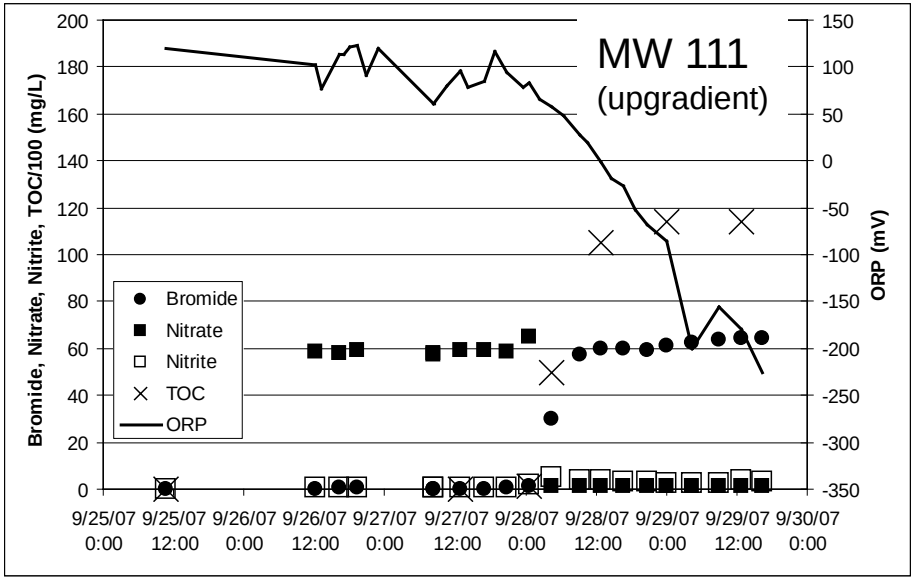
Substrate Injection

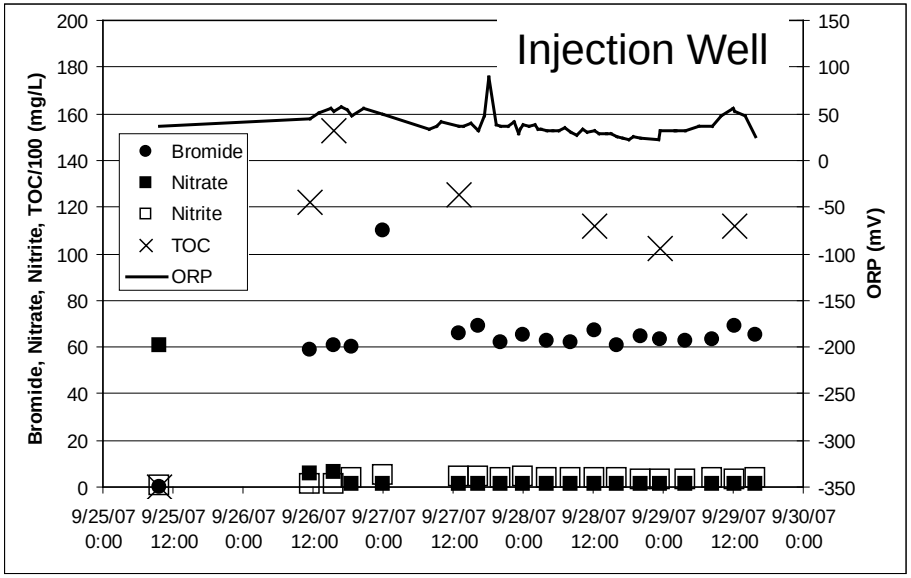


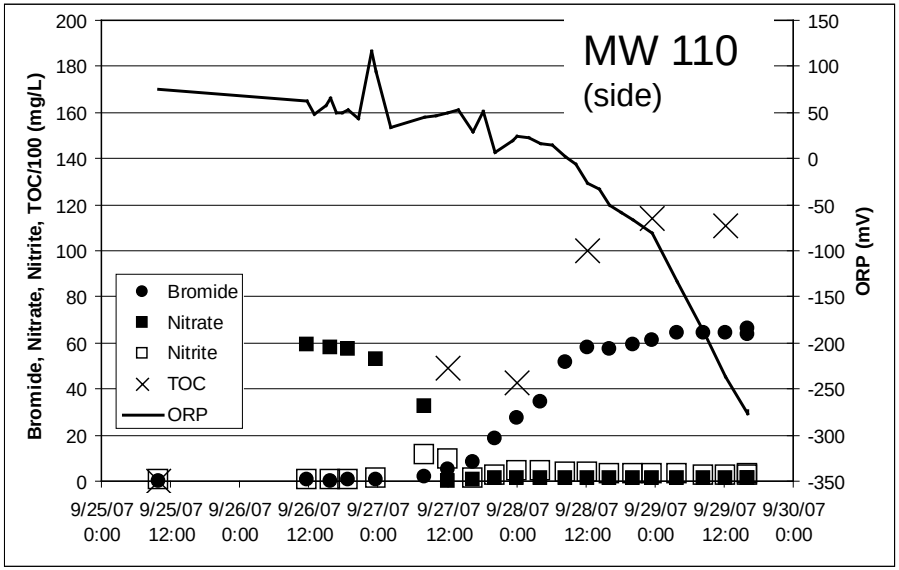


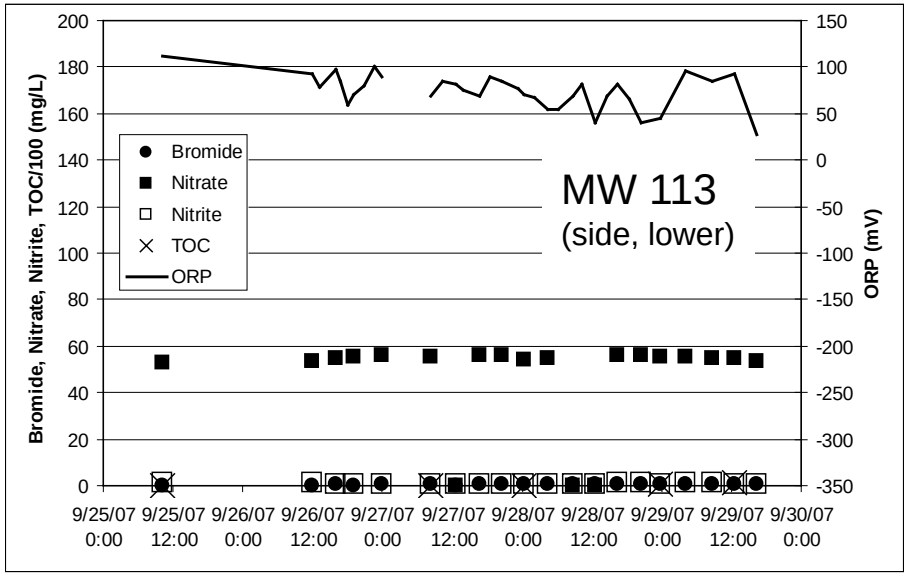


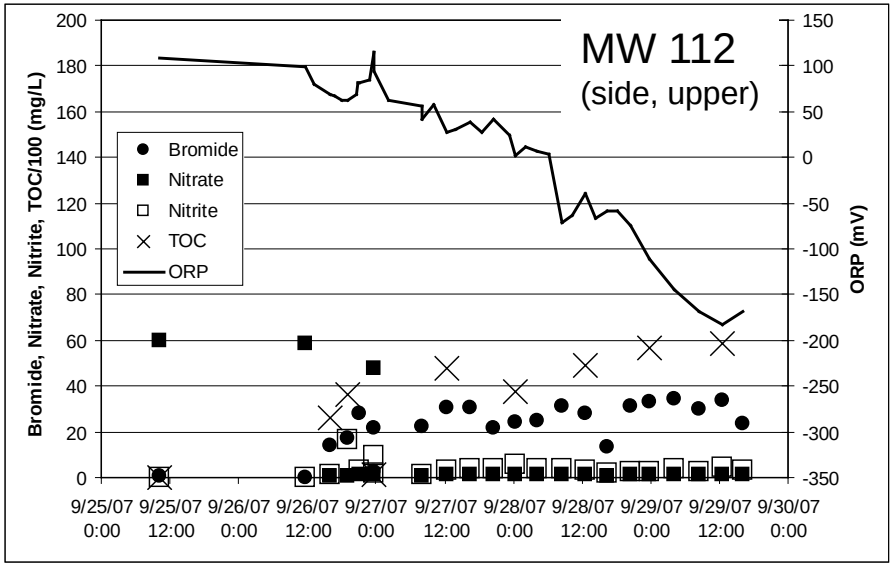


Substrate Injection





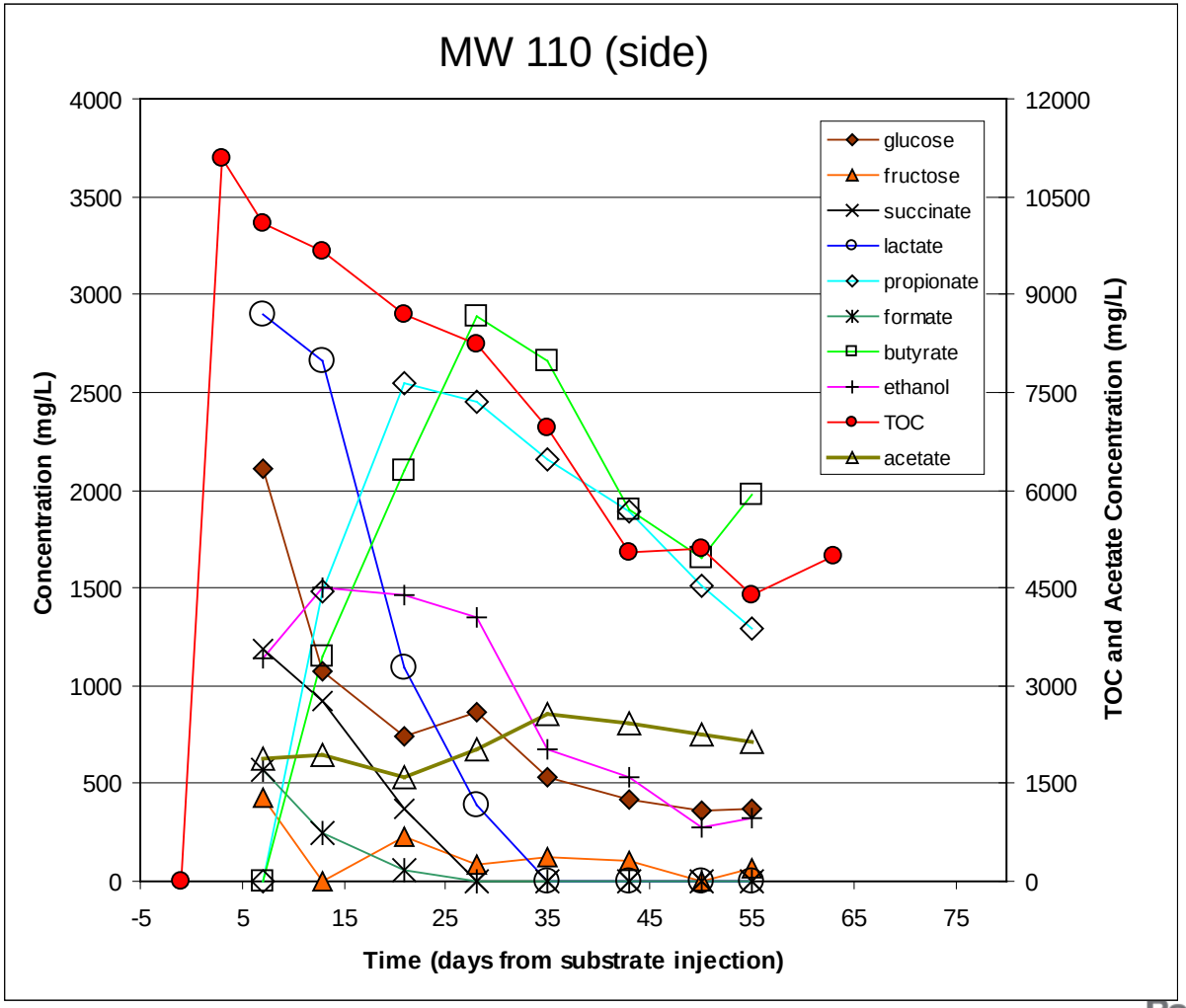




Substrate Distribution

Well	Total Organic Carbon (g/L)
199-D5-107 (Injection well)	11
199-D5-109	3.2
199-D5-110	11
199-D5-111	11
199-D5-112	6
199-D5-113	0.1 (rising to 1.5 shortly after injection terminated)

Substrate Fermentation



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Process/Performance Monitoring Objectives and Results

- Induce fermentation reactions and reducing conditions and grow biomass
  - Result: Process monitoring data show that fermentation reactions and associated reducing conditions occurred at all of the monitoring locations and persisted for up to 9 months.
- Minimize permeability changes due to biomass increases
  - Result: Semi-quantitative estimates of permeability reduction based on single-well slug testing in site monitoring wells indicate an average K decrease of ~ 20% (range → +9% to -65%). Still assessing heterogeneity in the permeability distribution.
- Quantify the ability to obtain and maintain low oxygen and nitrate/nitrite concentrations (limit primary electron acceptor flux) and determine longevity of treatment
  - Result: Low oxygen, nitrate, and nitrite concentrations have been maintained over the duration of the process monitoring phase. Low concentrations still maintained through 9 months.

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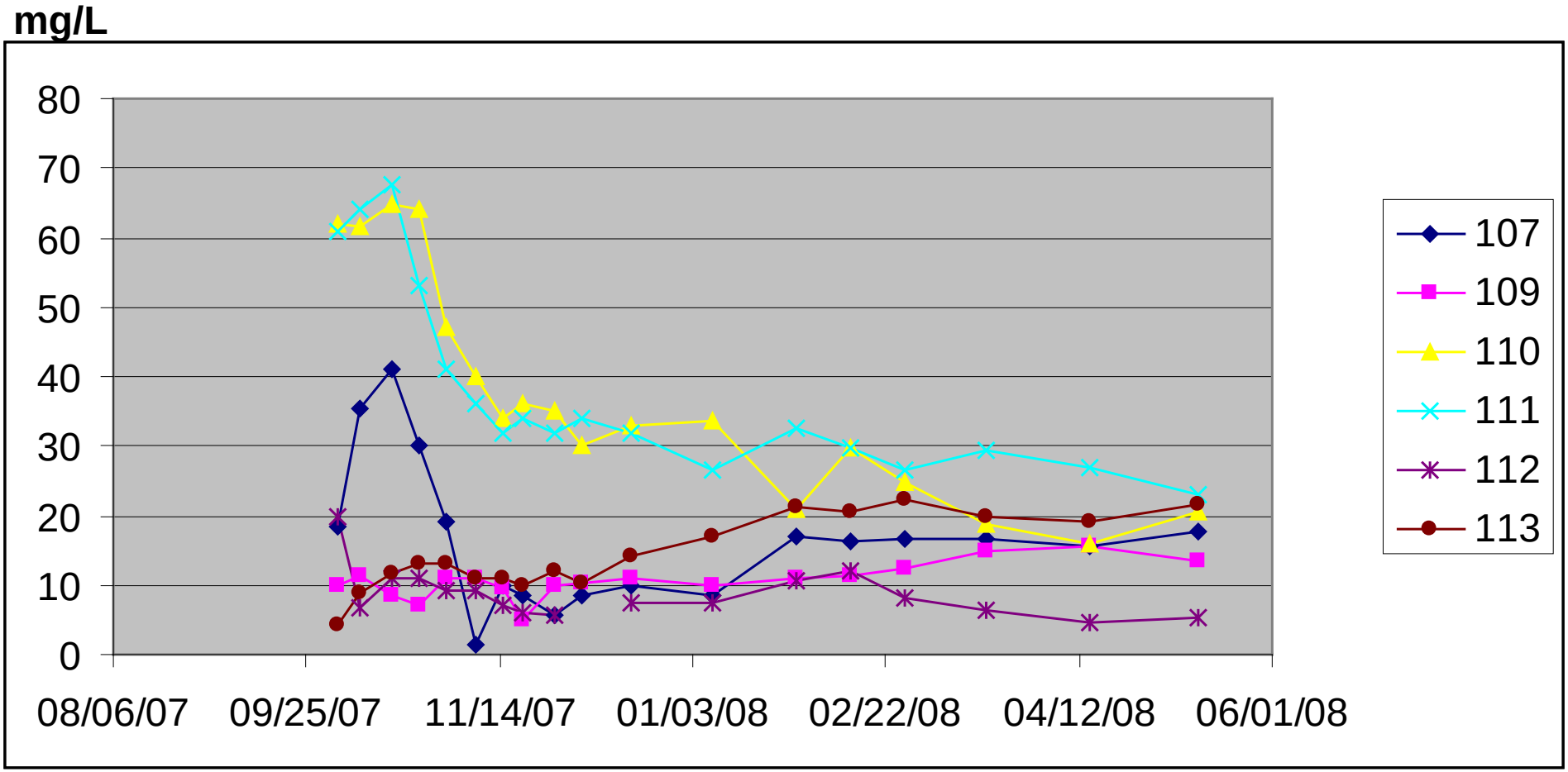
Process/Performance Monitoring Objectives and Results

- Quantify the ability to obtain and maintain low chromate concentrations (augment chromate treatment) and determine longevity of treatment
  - Result: Low chromate concentrations were maintained through most of the process monitoring phase. After about 50 days, the chromate concentration at the monitoring locations increased. Chromate concentrations are variable but generally less than about 30% of upgradient concentration through 9 months.
- Compile information for full scale design considering the injection process, biobarrier performance, hydrogeology, and electron flux information at 100D
  - Result: An assessment of full scale design considerations will be provided after data from the performance monitoring phase has been collected and analyzed.

Performance Monitoring Status - Bromide



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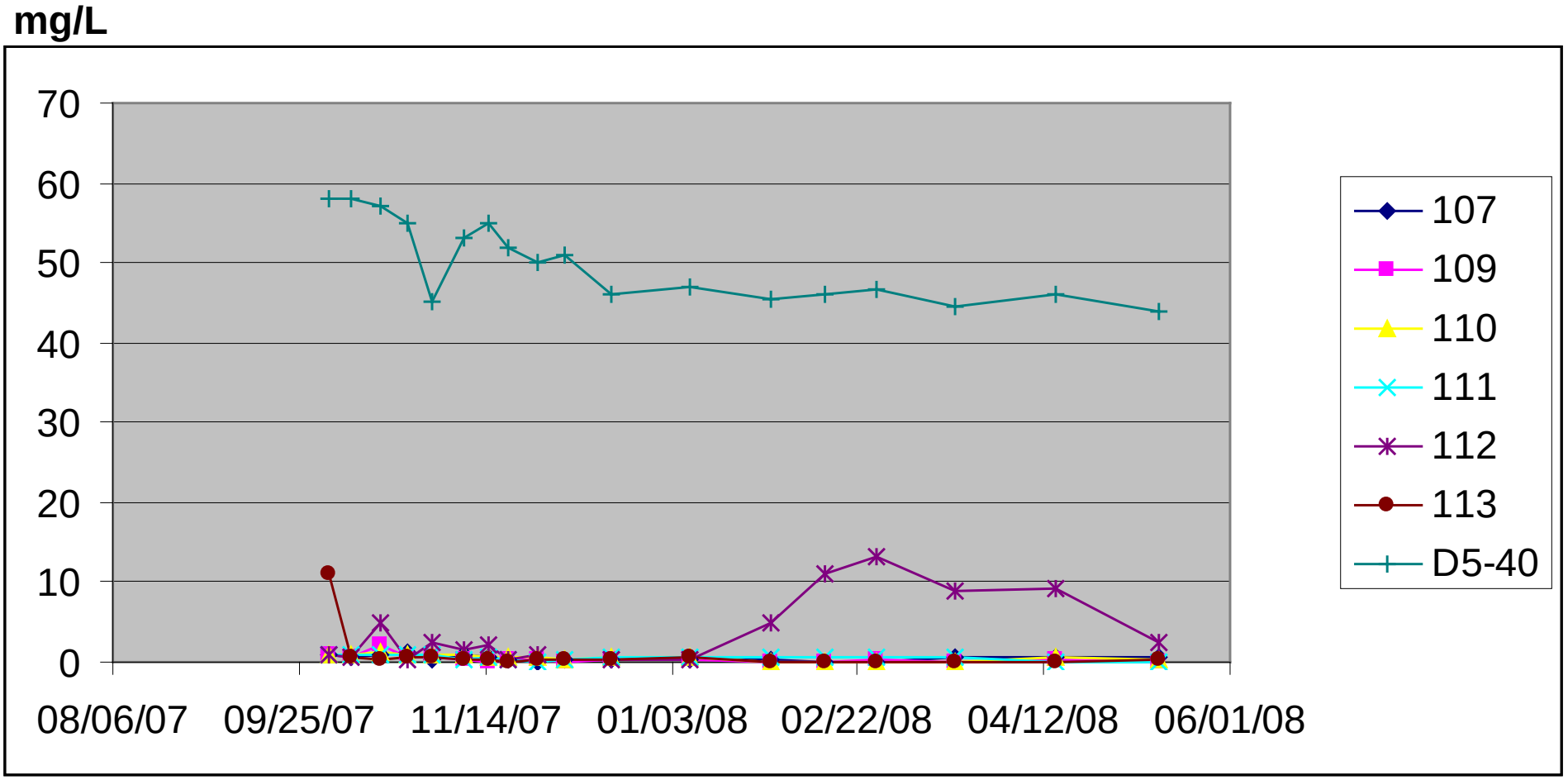
Performance Monitoring Status - Nitrate



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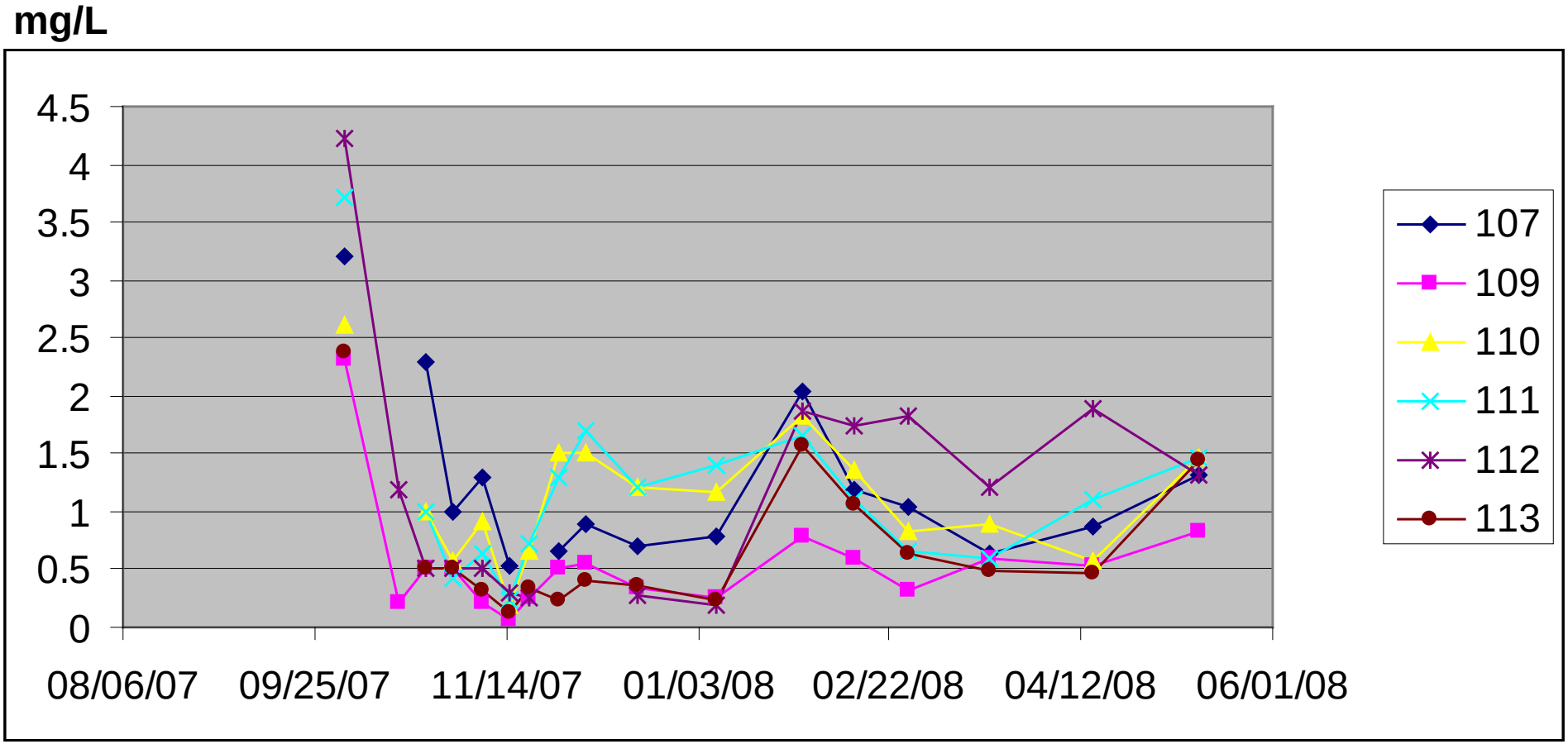
Performance Monitoring Status - Nitrite



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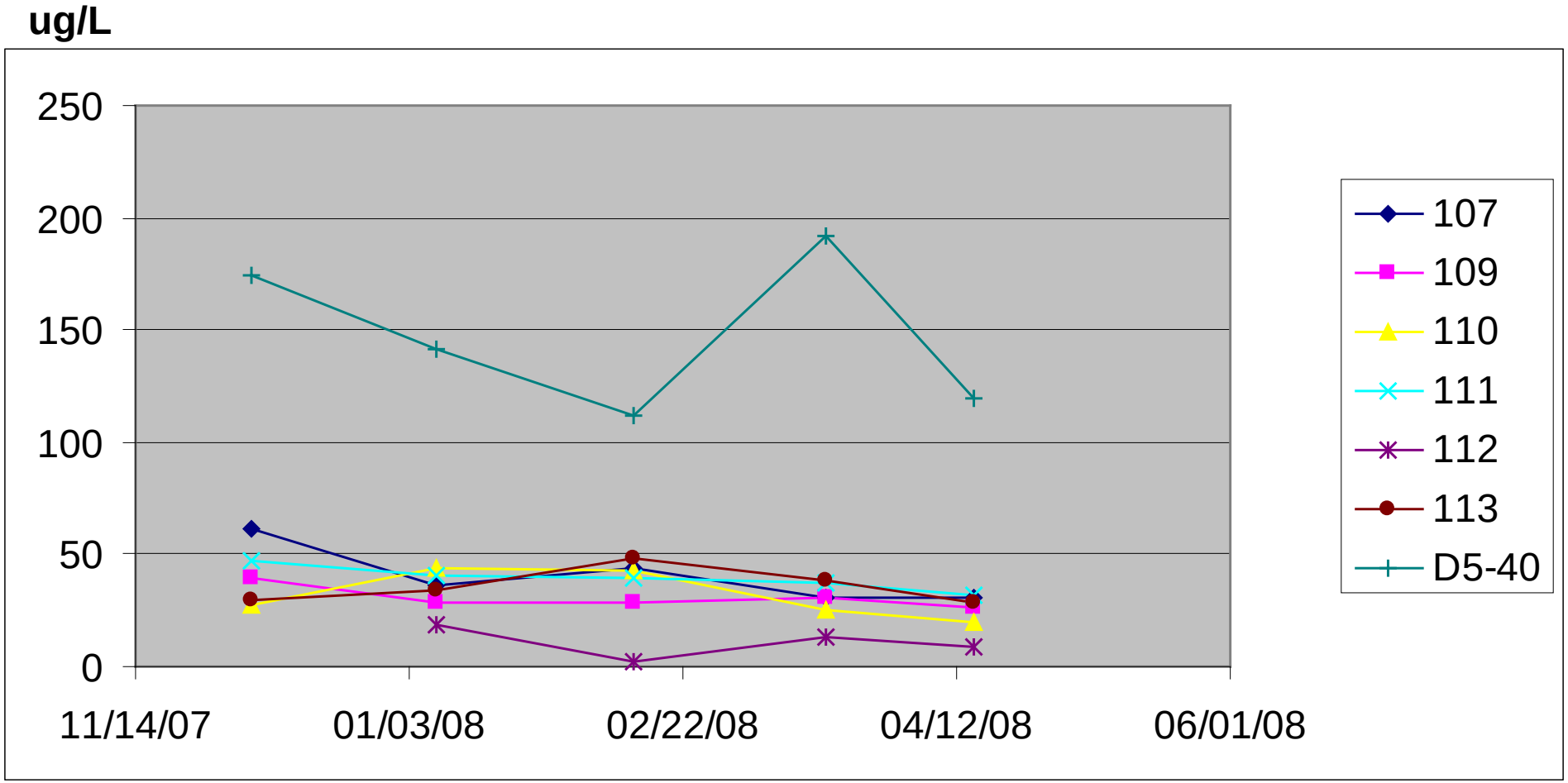
Performance Monitoring Status - Chromium



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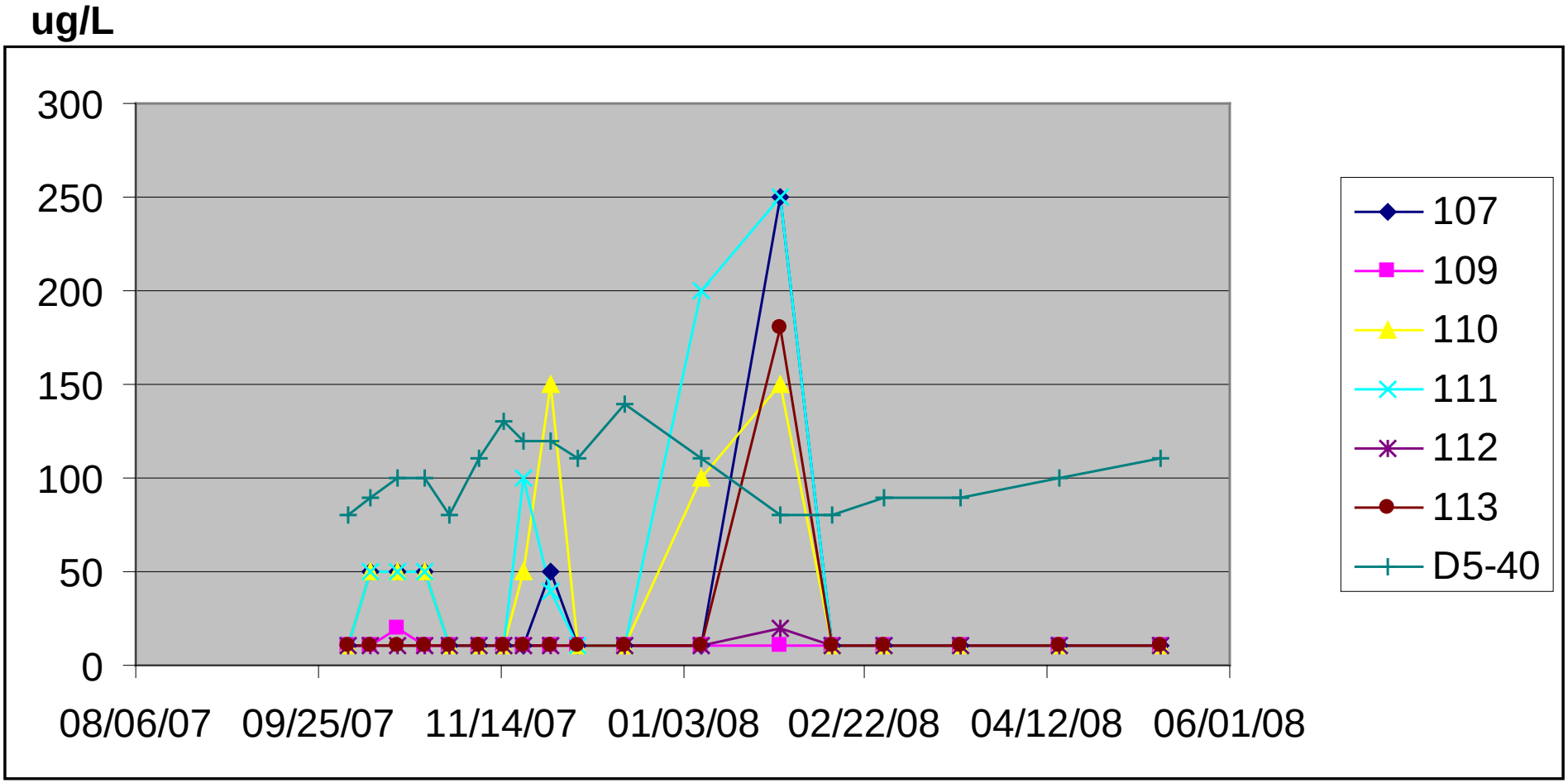
Performance Monitoring Status - Chromate



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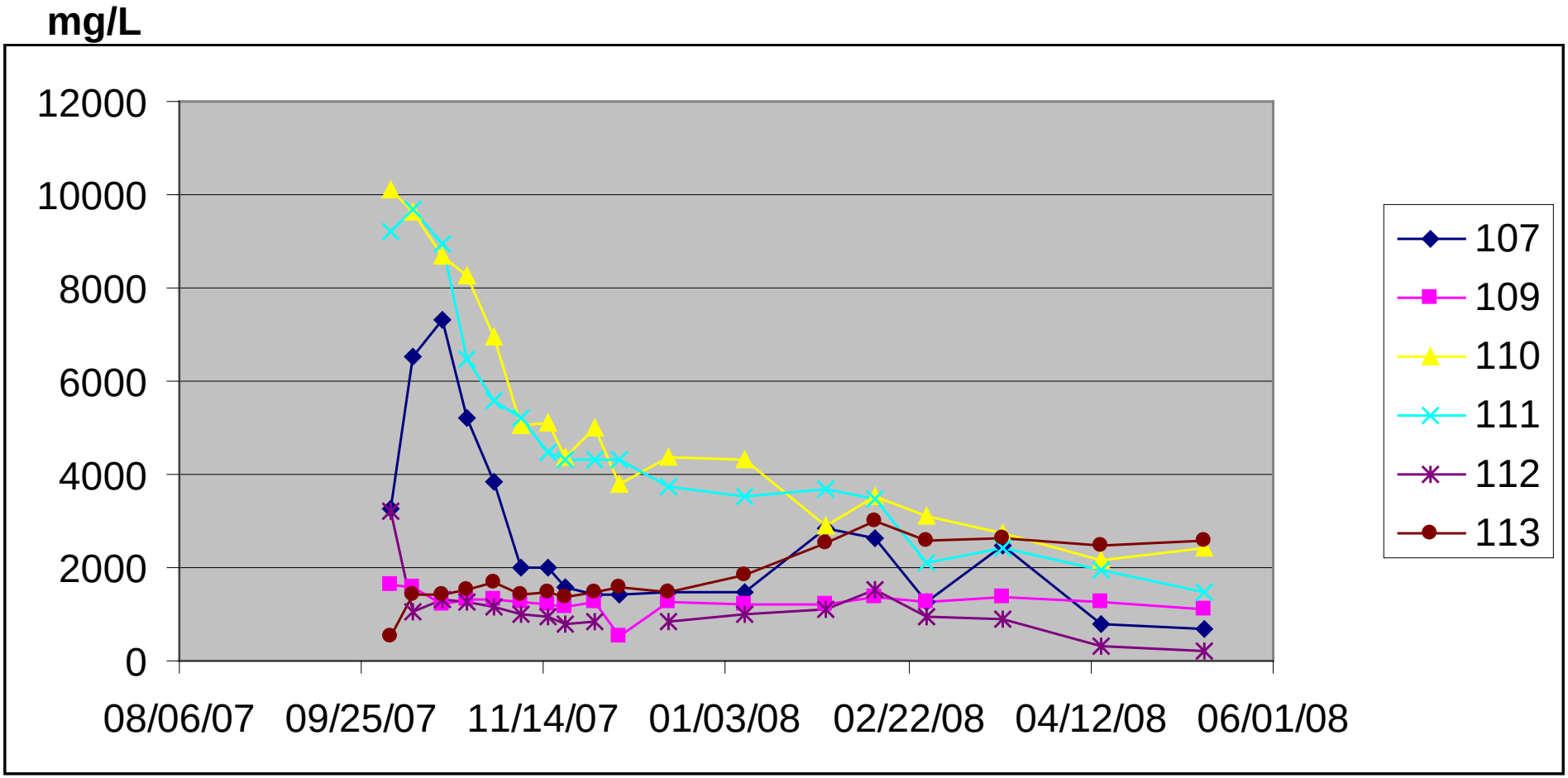
Performance Monitoring Status - TOC



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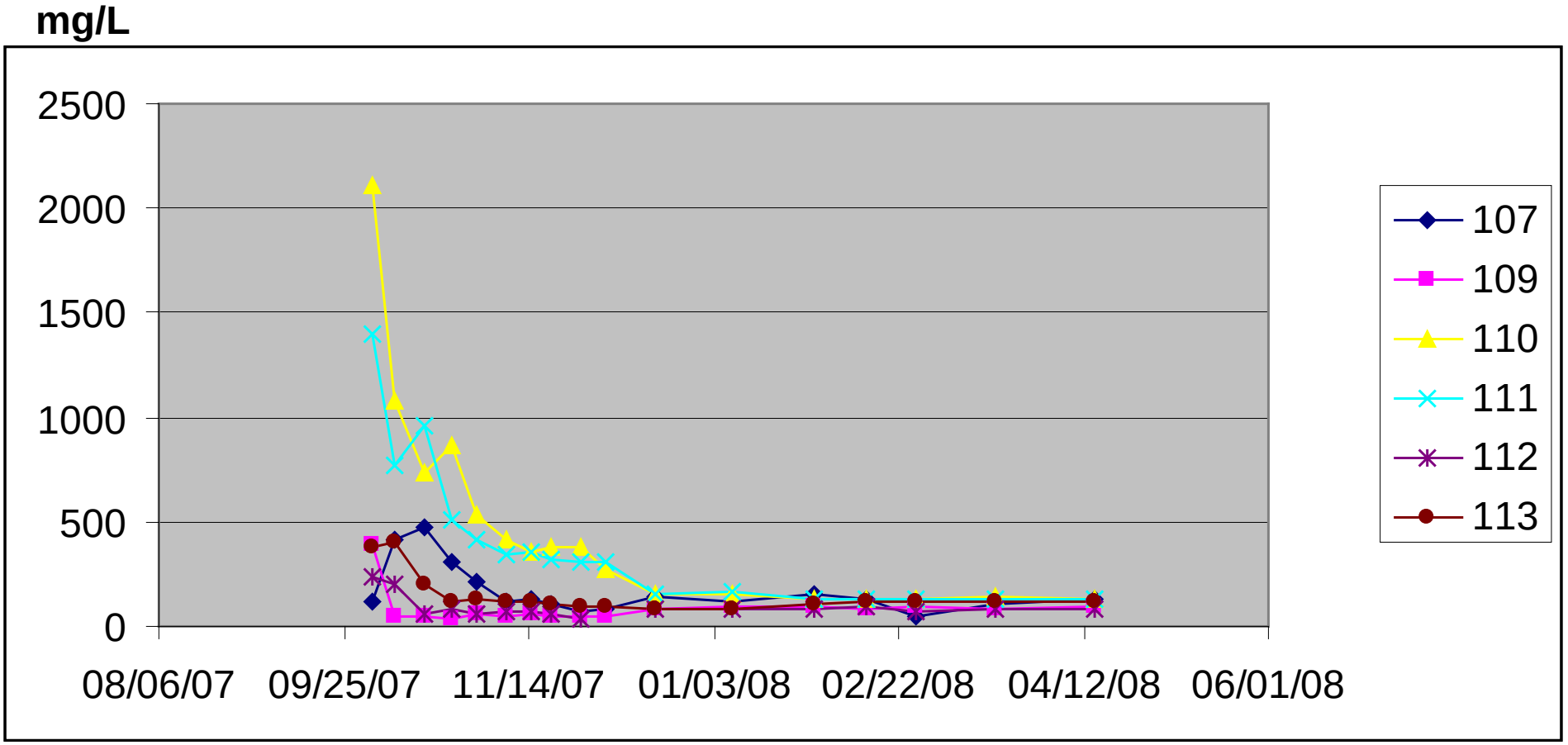
Performance Monitoring Status - Glucose



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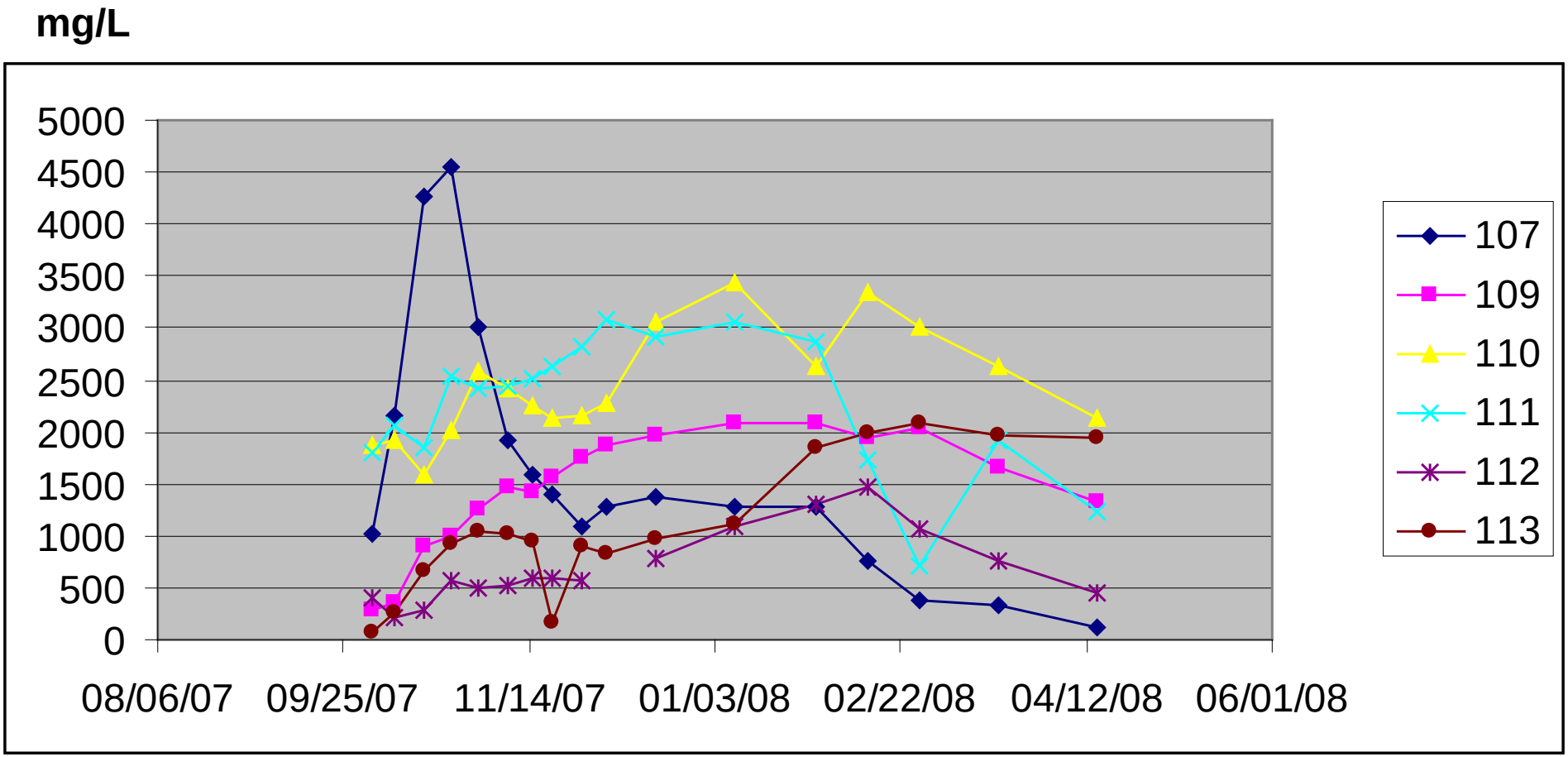
Performance Monitoring Status - Acetate



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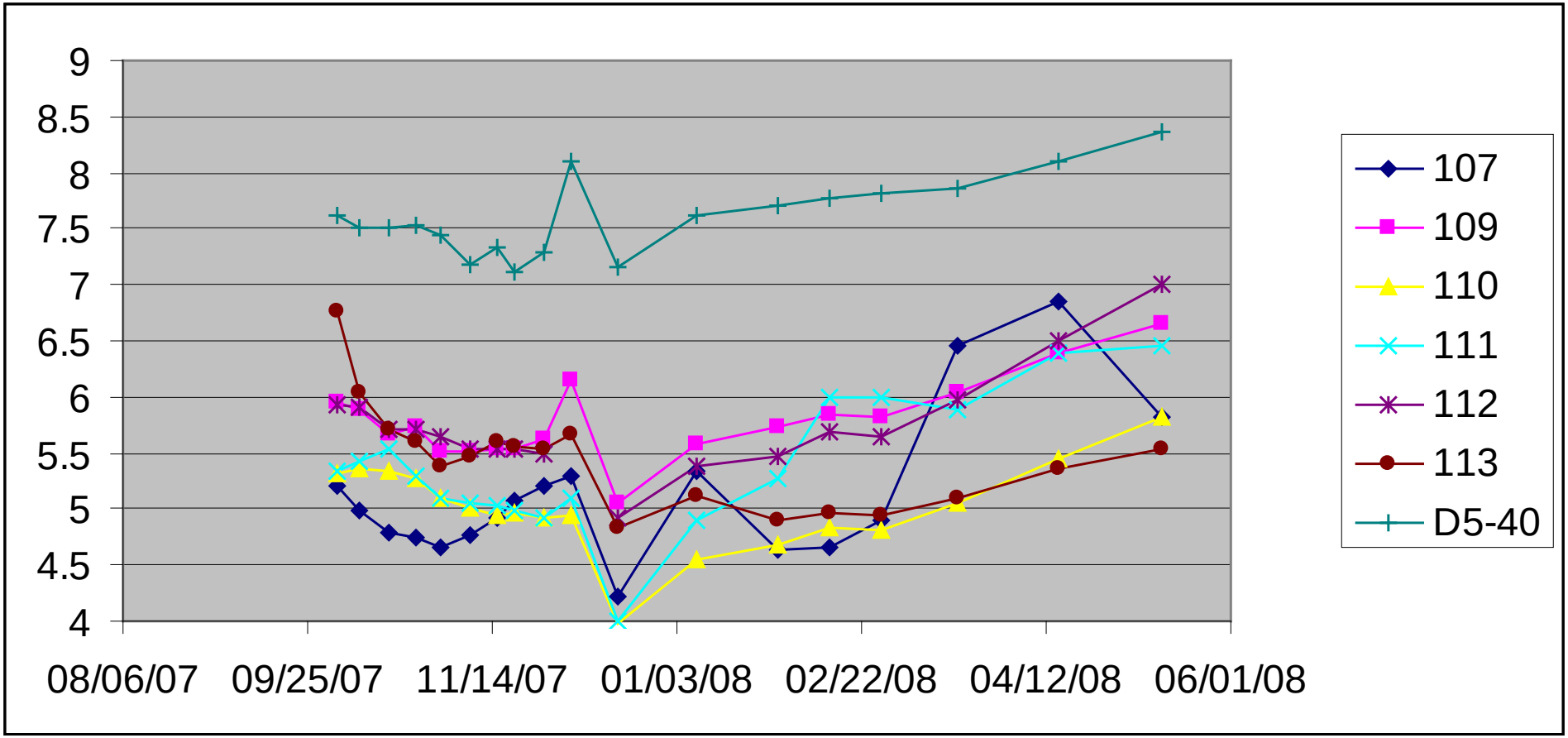
Performance Monitoring Status - pH



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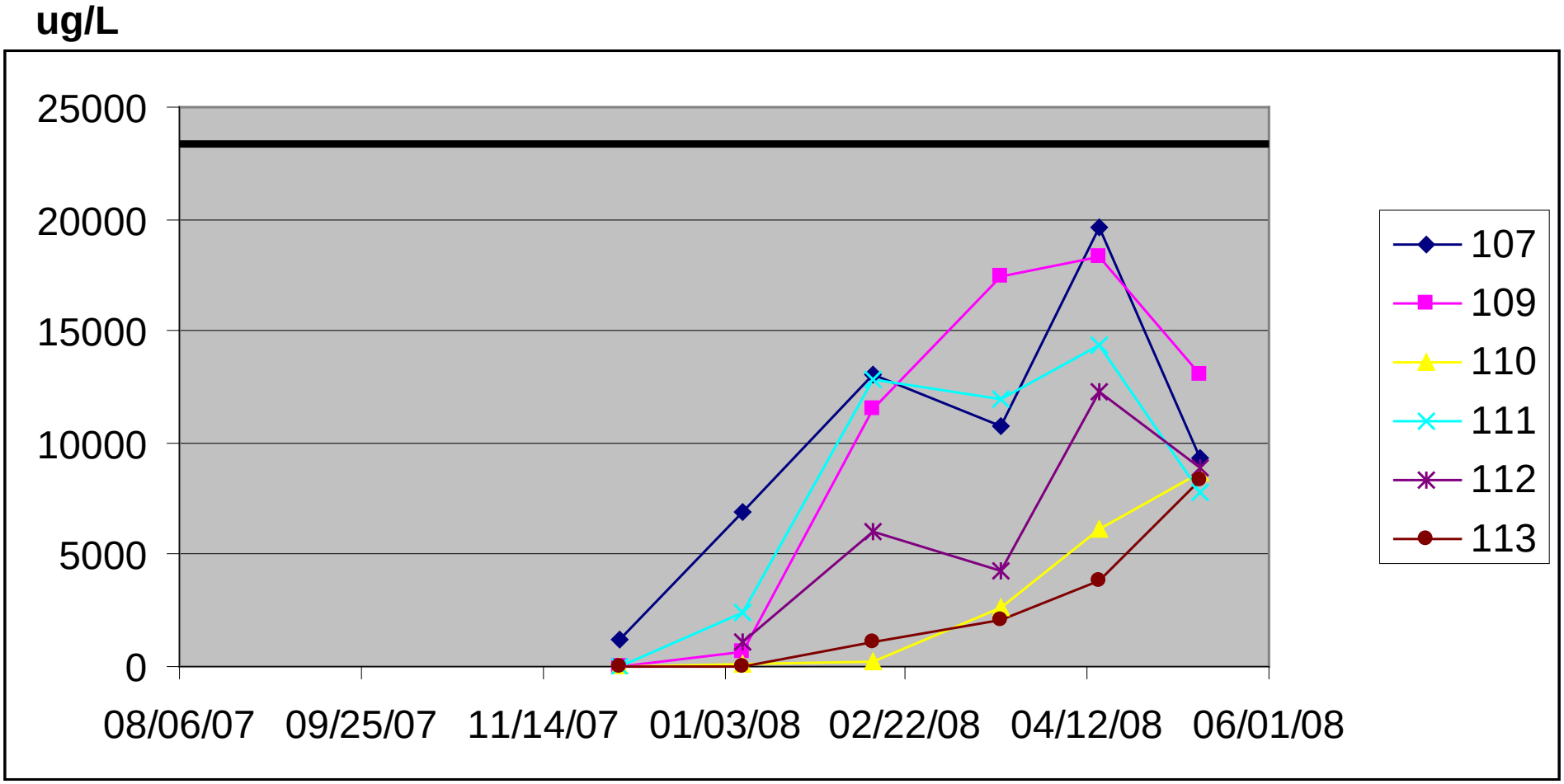
Performance Monitoring Status - Methane



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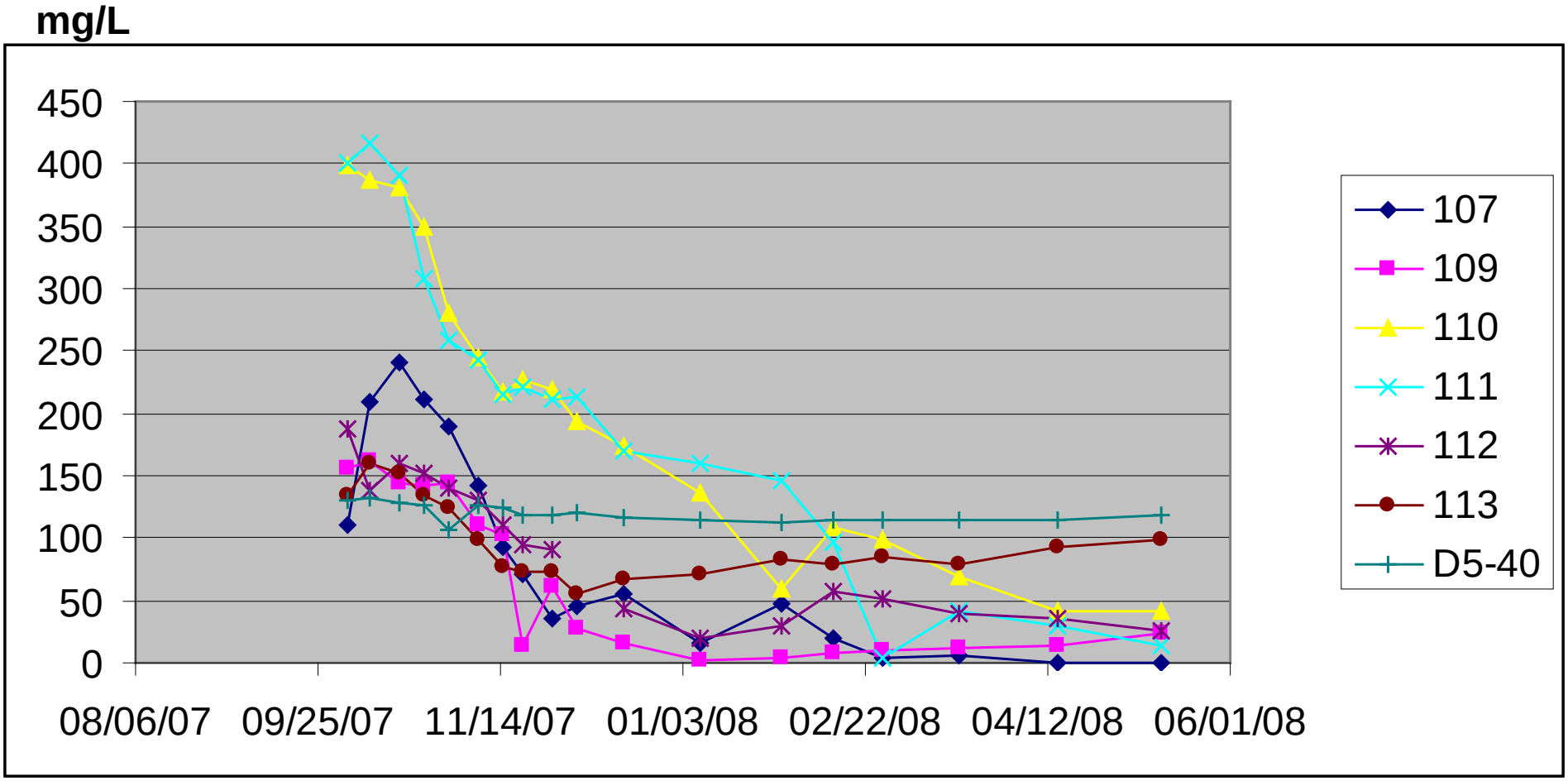
Performance Monitoring Status - Sulfate



Iron concentrations 50-130 mg/L in test site wells

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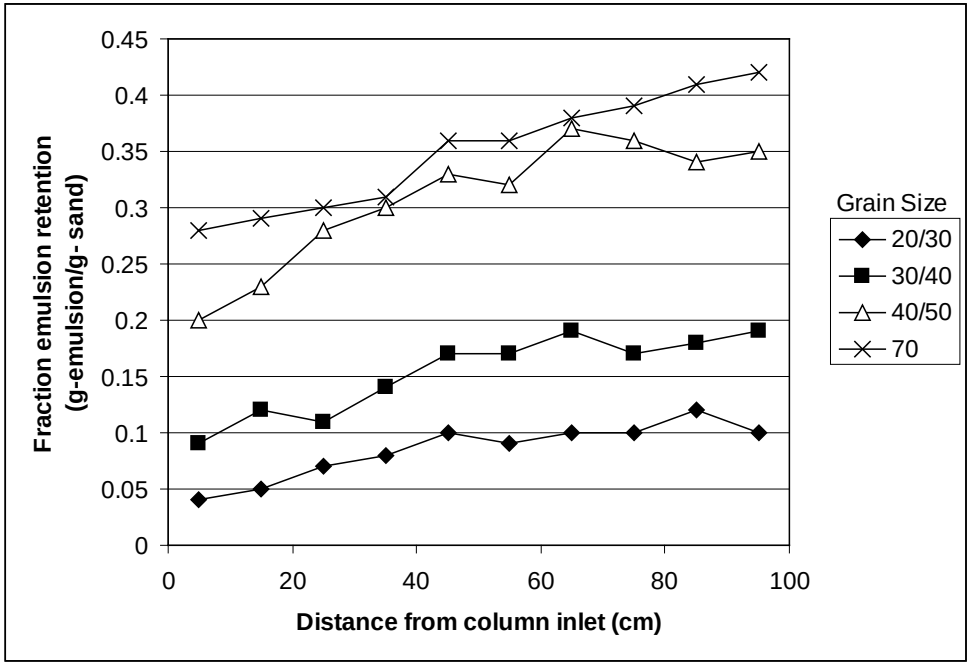
Performance Monitoring Observations

- Fermentation extended longer than expected
  - pH effect?
  - Contribution of low permeability zones?
  - Substrate injected to larger radius in high permeability zones?
- Maintenance of reduced conditions is relatively consistent compared to large variation in initial injection distribution
- Nitrate reduction with minimal nitrite production
- Chromate reduction down to about 40 ppb
  - Presence of other electron acceptors?
- Sulfate reduction and methane production initiated after about 4 months
- Monitoring over next year to provide data on how biomass decay can support maintenance of reducing conditions

Project Status – Immiscible Substrate

- Immiscible substrate design completed
- Emulsion transport experiments completed
  - Established emulsion transport and retention as function of concentration and porous media particle size



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Project Status – Immiscible Substrate

- Immiscible substrate injection planned August/September
  - EOS 598 emulsified vegetable oil
  - Quality assurance for droplet size distribution
  - 1500 gallons in 24,000 gallons water (6%)
  - Chase with 25,000+ gallons water
  - Total injection radius 7 m
- Monitoring Plan
  - Turbidity, bromide, TOC during injection primary monitor for breakthrough
  - Performance monitoring every 2 months
  - LBNL geophysical survey
  - Hydraulic testing

Path Forward

	FY08												FY09											
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Project Management																								
Design Analysis																								
Well Installation																								
Laboratory Testing																								
Injection Design																								
Soluble Substrate Field Test Injections																								
Soluble Substrate Performance Monitoring																								
Immiscible Substrate Field Test Injections																								
Immiscible Substrate Performance Monitoring																								
Soluble Substrate Data Analysis and Report																								
Soluble Substrate Interim Data Report																								
Immiscible Substrate Data Analysis and Report																								

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Earned Value Report

Polyphosphate	FYTD (K)
BCWS	$1,627
BCWP	$1,622
ACWP	$1,622
SV	--
CV	--

- No significant schedule variance
- No significant cost variance

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