Results from a Bench Scale Passive Treatment System Designed for Removing Sulfate at a Site on Vancouver Island, BC

Presented by,
Eric Blumenstein, PE, Golder Associates Inc.

Golder Associates

Presentation Overview

- Site Location / Background
- Desires / Needs of Site
- Traditional Sulfate Removal Technologies
- Biological Sulfate Removal
- Bench Testing Construction (March 2011)
- Bench Testing Results (Summer 2011)
- Consideration for Demonstration System Design
- Demonstration System Design Overview
- Path Forward

Site Location / Background / Needs

- Underground coal mine (not hard rock)
- Active workings
- Inactive workings
- Seep into freshwater lake
- Mining influenced water:
  - Sulfate
  - Iron
  - Arsenic
- Desire for:
  - Low long-term operating and maintenance costs
  - Operate in cool weather
  - Fit on available land

Golder Associates

SULFATE REMOVAL TECHNOLOGIES

Traditional Sulfate Removal Technologies

- Reverse Osmosis (RO) Membrane Filtration:
  - Proven technology
  - Capital cost
  - Operating and maintenance cost
    - Labor
    - Chemicals
    - Power
    - Equipment maintenance
  - Brine production / disposal

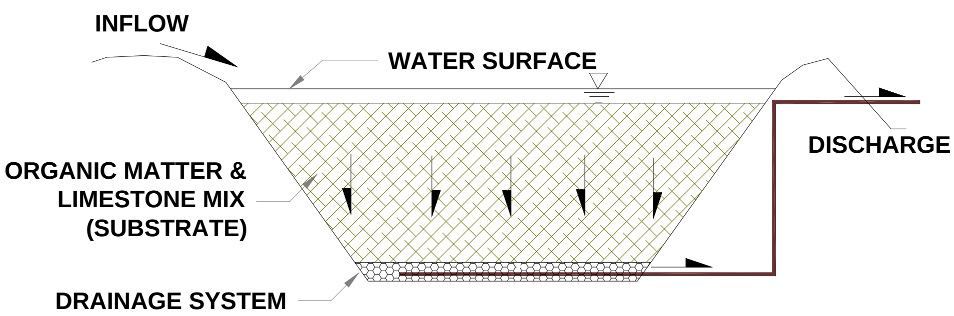
Traditional Sulfate Removal Technologies

- Chemical Precipitation
  - Barium chloride
  - Lime
  - Proven technology
  - Capital cost
  - Operating and maintenance cost
    - Labor
    - Chemicals
    - Power
    - Equipment maintenance
  - Sludge production / disposal

Golder Associates

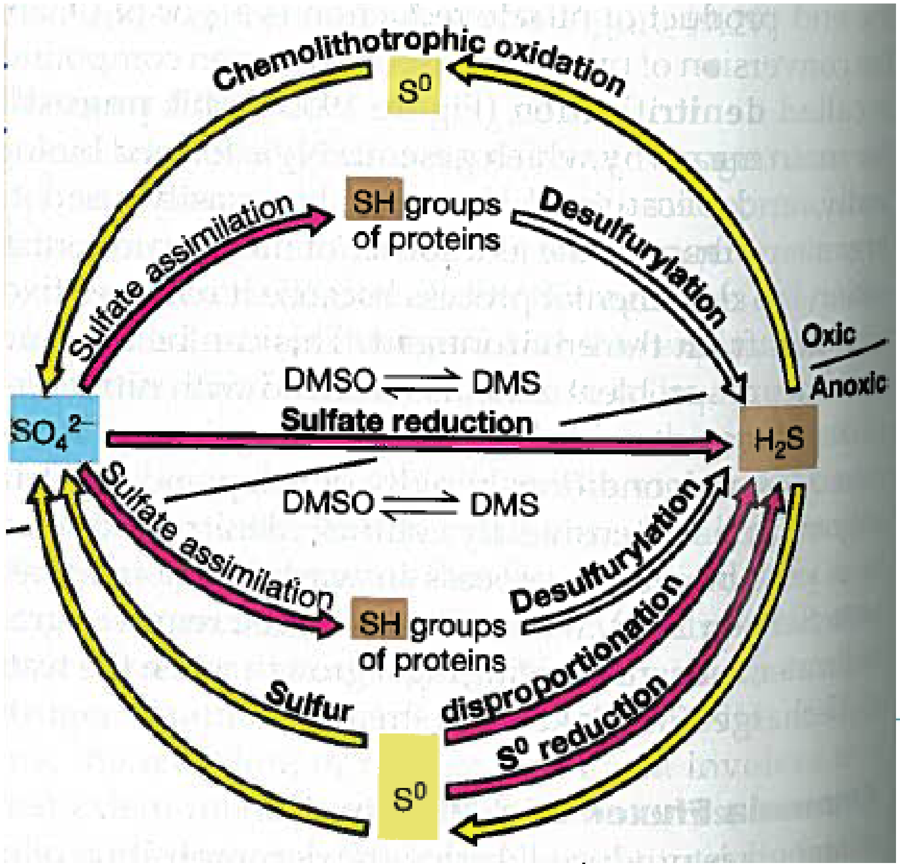
Potential New Sulfate Removal Technology

- Biological sulfate removal:
  - Active or passive
  - Not a new concept
  - Biochemical reactors (BCR):
    - Sulfate reducing bioreactors (SRBR)
    - Succesive alkalinity producing systems (SAPS)
    - Reducing alkalinity producing sytsems (RAPS)
  - Limitations:
    - Sulfate reduction is limited by carbon availability
    - Need to sequester reduced sulfate



Potential New Sulfate Removal Technology

- Sulfate biologically reduced to sulfide:
  - Some sulfide forms metal precipitates (metal sulfides)
  - Some adsorbs to surface area on substrate
  - Some sulfide leaves the BCR as sulfide anion or hydrogen sulfide



Brock Biology of Microorganisms, 10th Edition

- Excess sulfide in BCR effluent can:
  - Cause health and safety issue and
  - Convert back to sulfate upon leaving cell and being re-oxidized

Golder Associates

Potential New Sulfate Removal Technology

- Options for “sequestering” excess sulfide:
  - Harvest reduced sulfate in BCR effluent (difficult to design and extensive O&M)
  - Add source of sacrificial iron (sulfide anion binds to iron cation and form iron sulfide precipitate):
    - Add iron prior to BCR
    - Mix iron into BCR substrate
    - Add iron to BCR effluent

BENCH SCALE BIOCHEMICAL REACTOR CONSTRUCTION

March 2011

Golder Associates

Bench Scale Design / Construction

CELL MIXTURES ON AN AS RECEIVED BASIS					
Material	**Cell 1**	**Cell 2**	**Cell 3**	**Cell 4**	**Cell 5**
Wood Chips	74.7%	59.7%	53.7%	50.7%	74.7%
Sawdust	0%	15%	0%	0%	0%
Hay	10%	10%	10%	10%	10%
Limestone Chips	15%	15%	10%	7%	15%
Natural Iron Ore	0%	0%	0%	32%	0%
Hedin Iron	0%	0%	26%	0%	0%
Animal Manure (Inoculum)	0.3%	0.3%	0.3%	0.3%	0.3%
Total	100%	100%	100%	100%	100%
Logic	Baseline 1 Woodchips	Baseline 2 Woodchips + Sawdust	Hedin Iron $Fe(OH_3)$	Natural Iron Ore 40% Iron	Baseline 1 Woodchips

Golder Associates

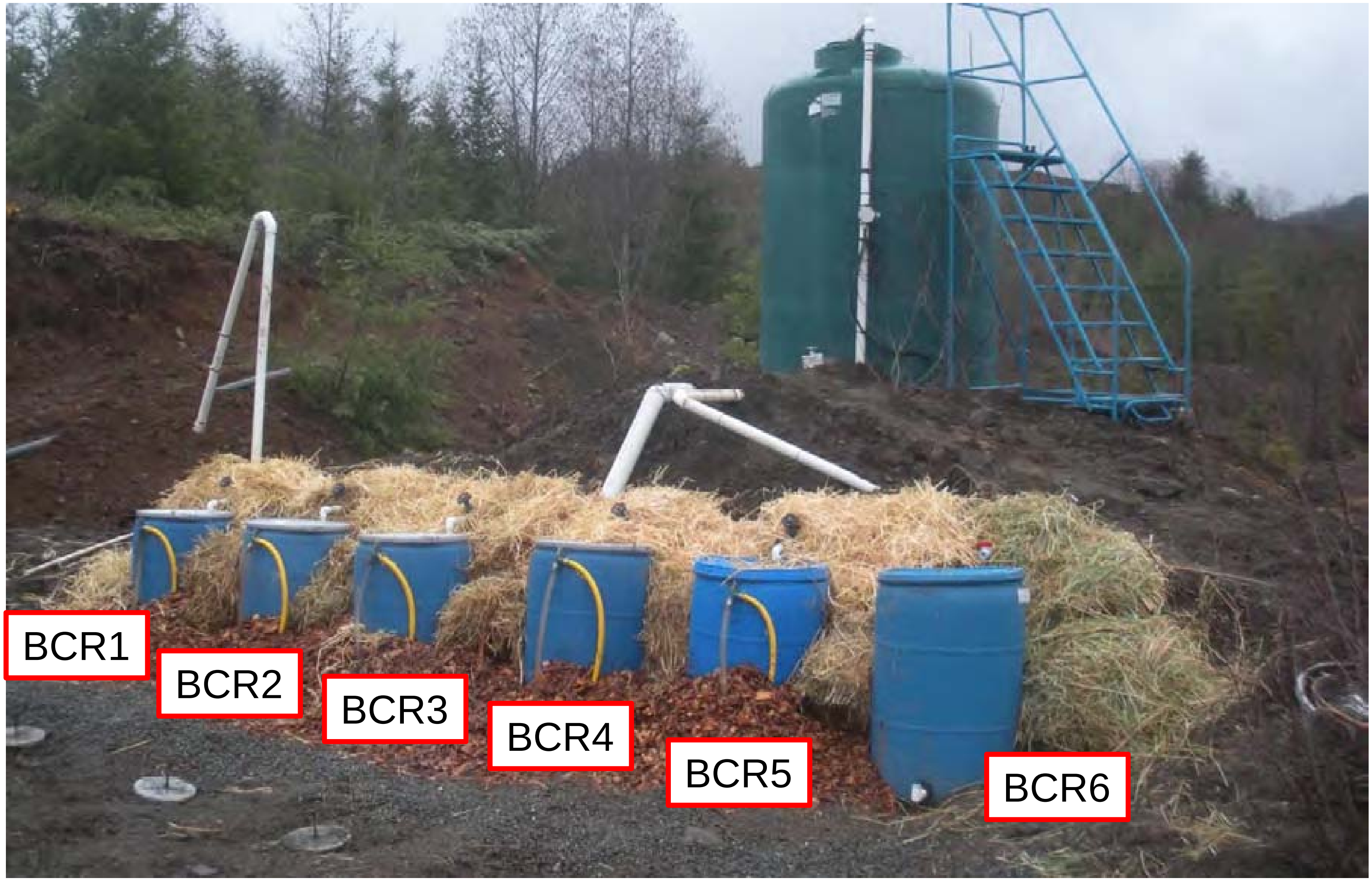
Bench Scale Design / Construction

Golder Associates

Bench Scale Design / Construction

Bench Scale Design / Construction

Bench Scale Design / Construction



BENCH SCALE BIOCHEMICAL REACTOR RESULTS

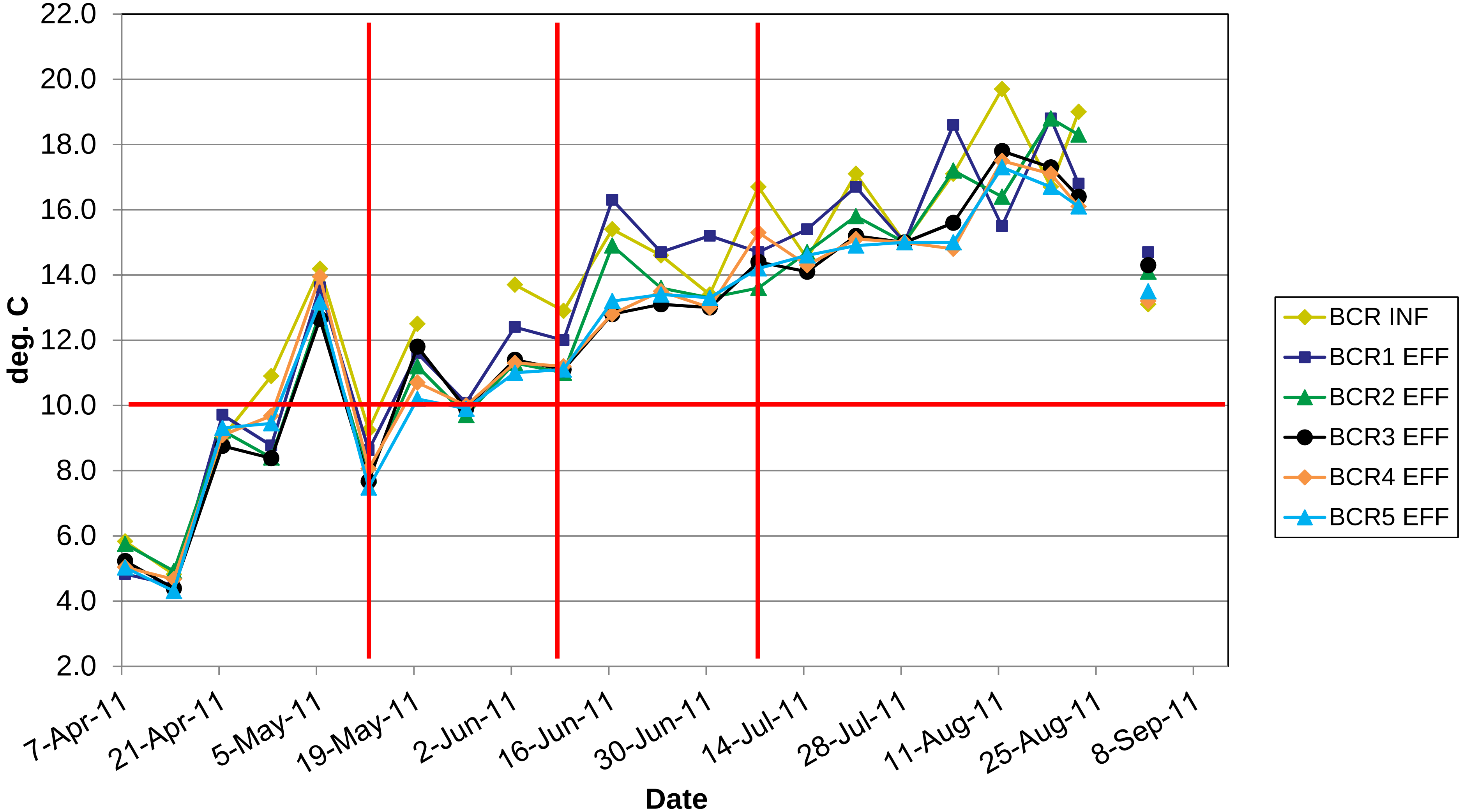
March – September 2011

Golder Associates

Bench Scale Testing Periods

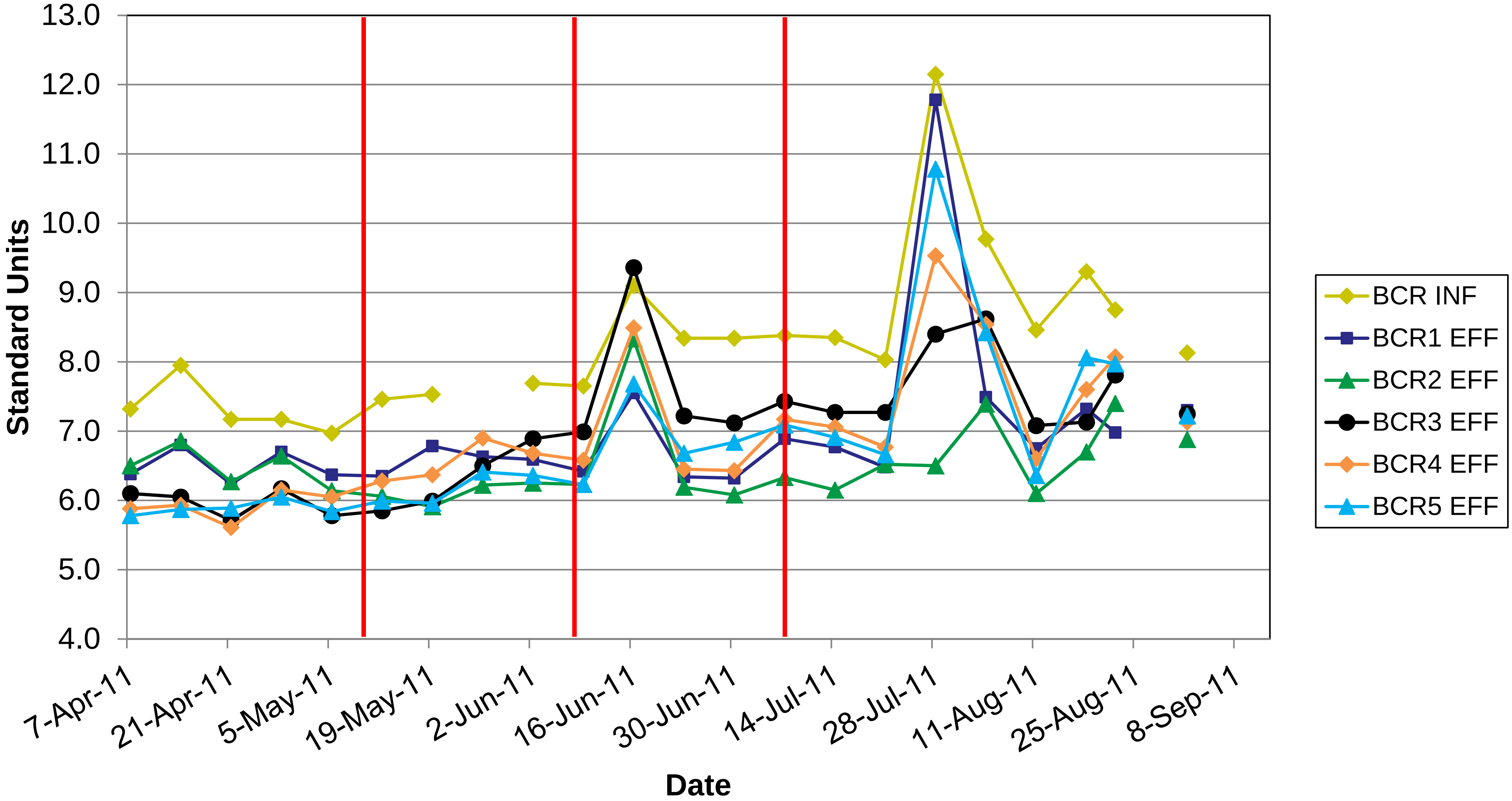
- Initial Incubation Period (31 March – 6 April)
- Primary Start-up Period (7 April – 12 May)
- Second Incubation Period (13 May – 8 June)
- Second Start-up Period (9 June – approximately 7 July)
- Steady-State Operations (approximately 7 July – 1 September)

Bench Scale Results – Temperature



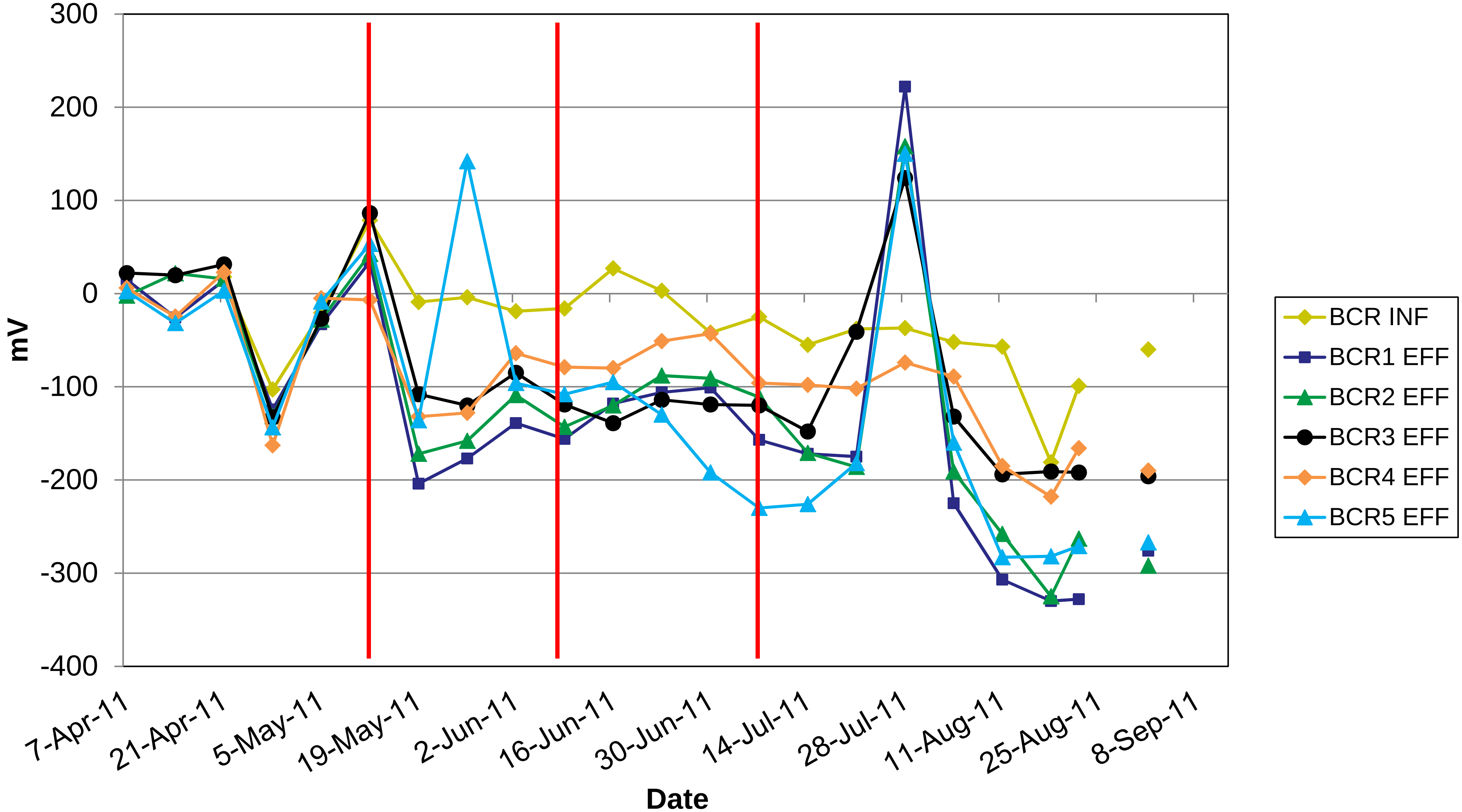
Golder Associates

Bench Scale Results – pH



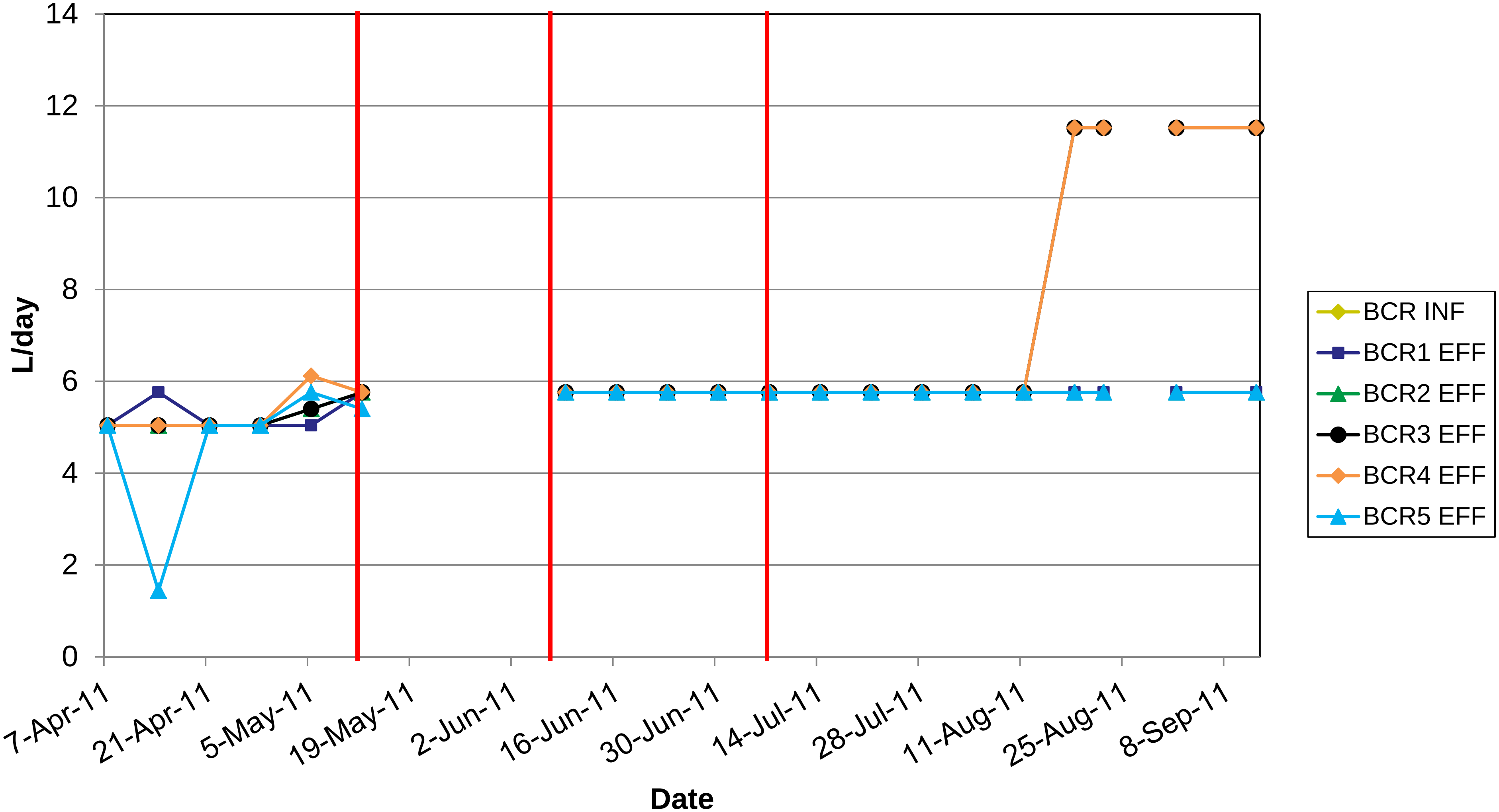
Golder Associates

Bench Scale Results – ORP

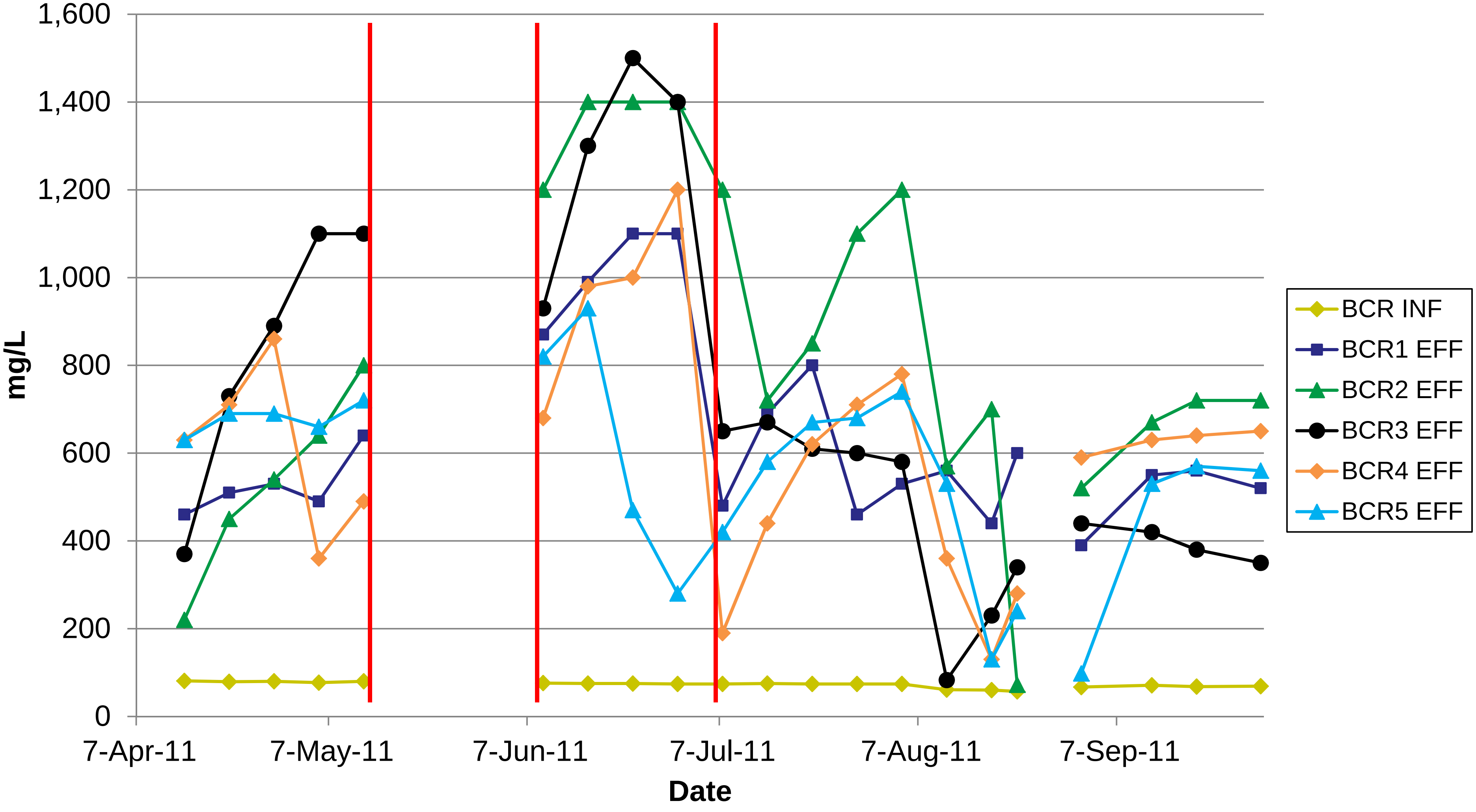


Golder Associates

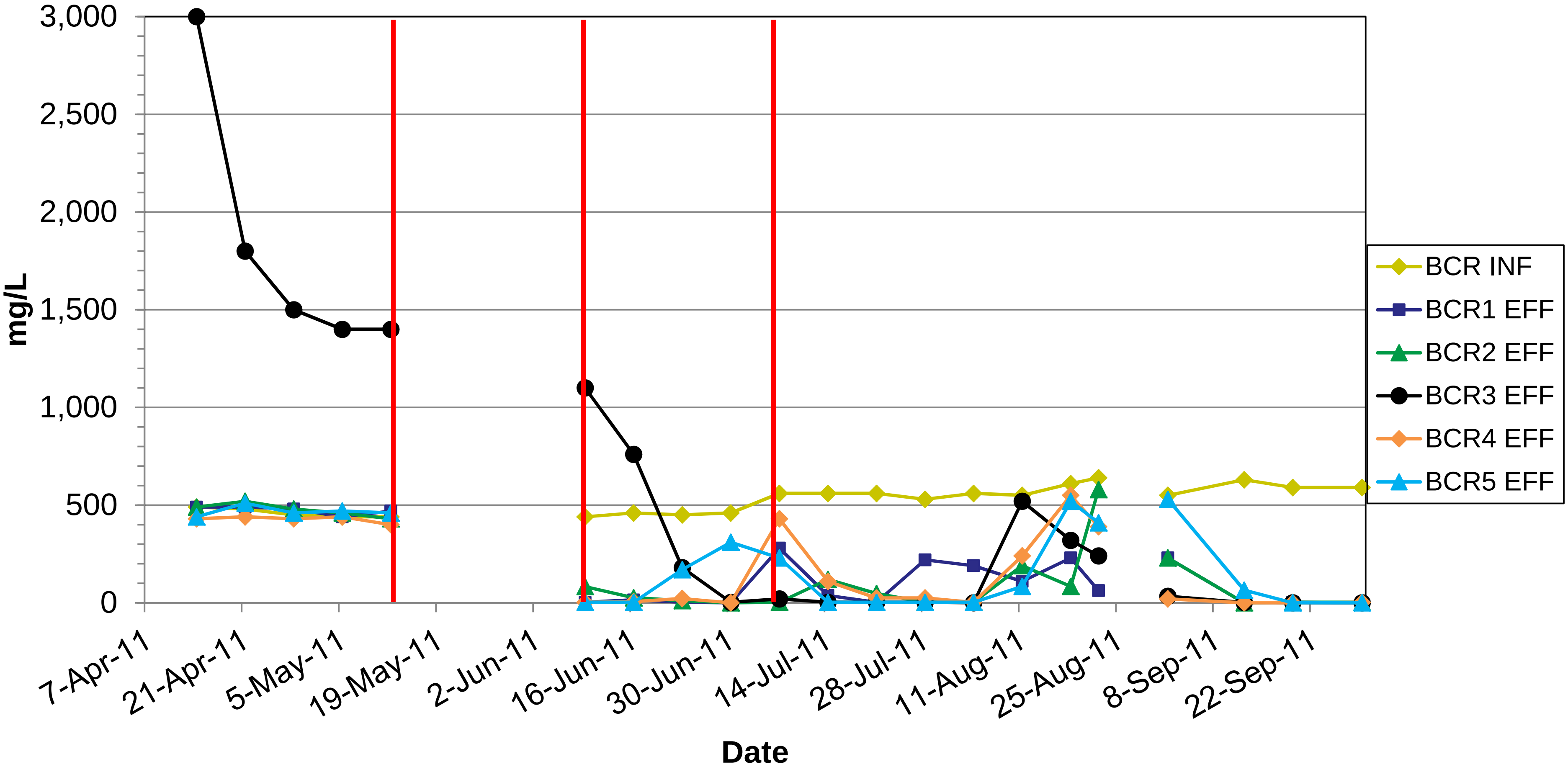
Bench Scale Results – Flow Rate



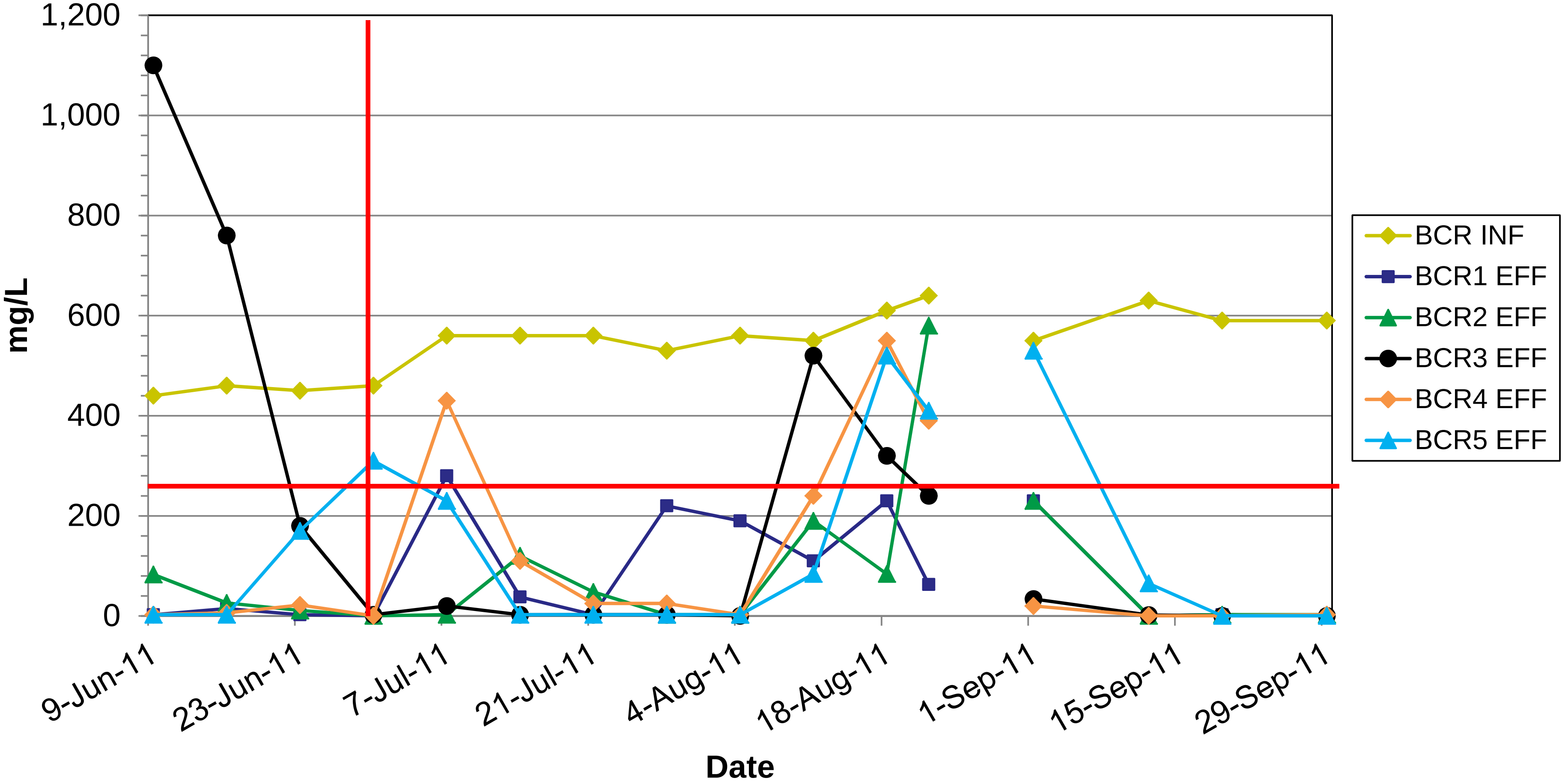
Bench Scale Results – Alkalinity



Bench Scale Results – Sulfate (full test)

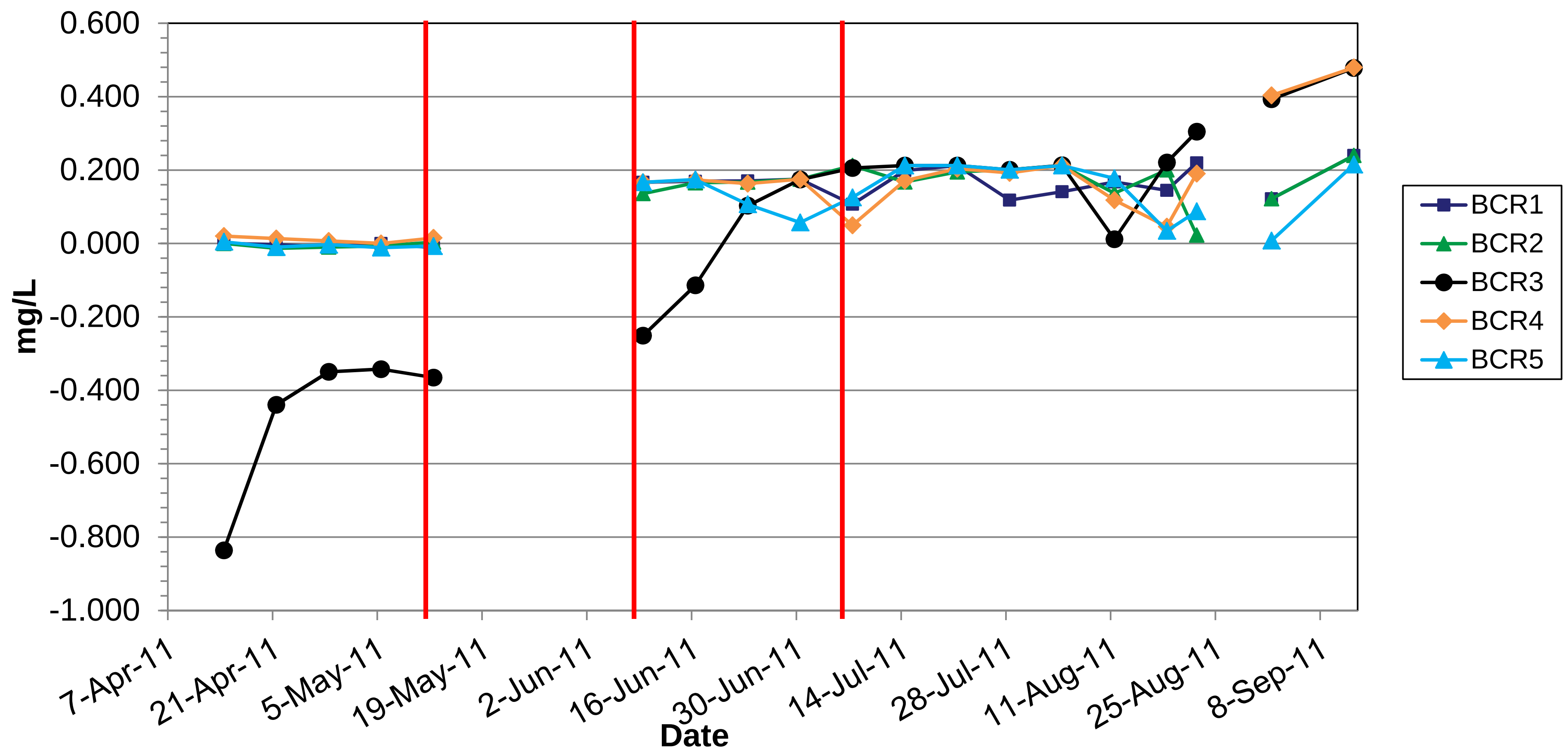


Bench Scale Results – Sulfate (steady state)



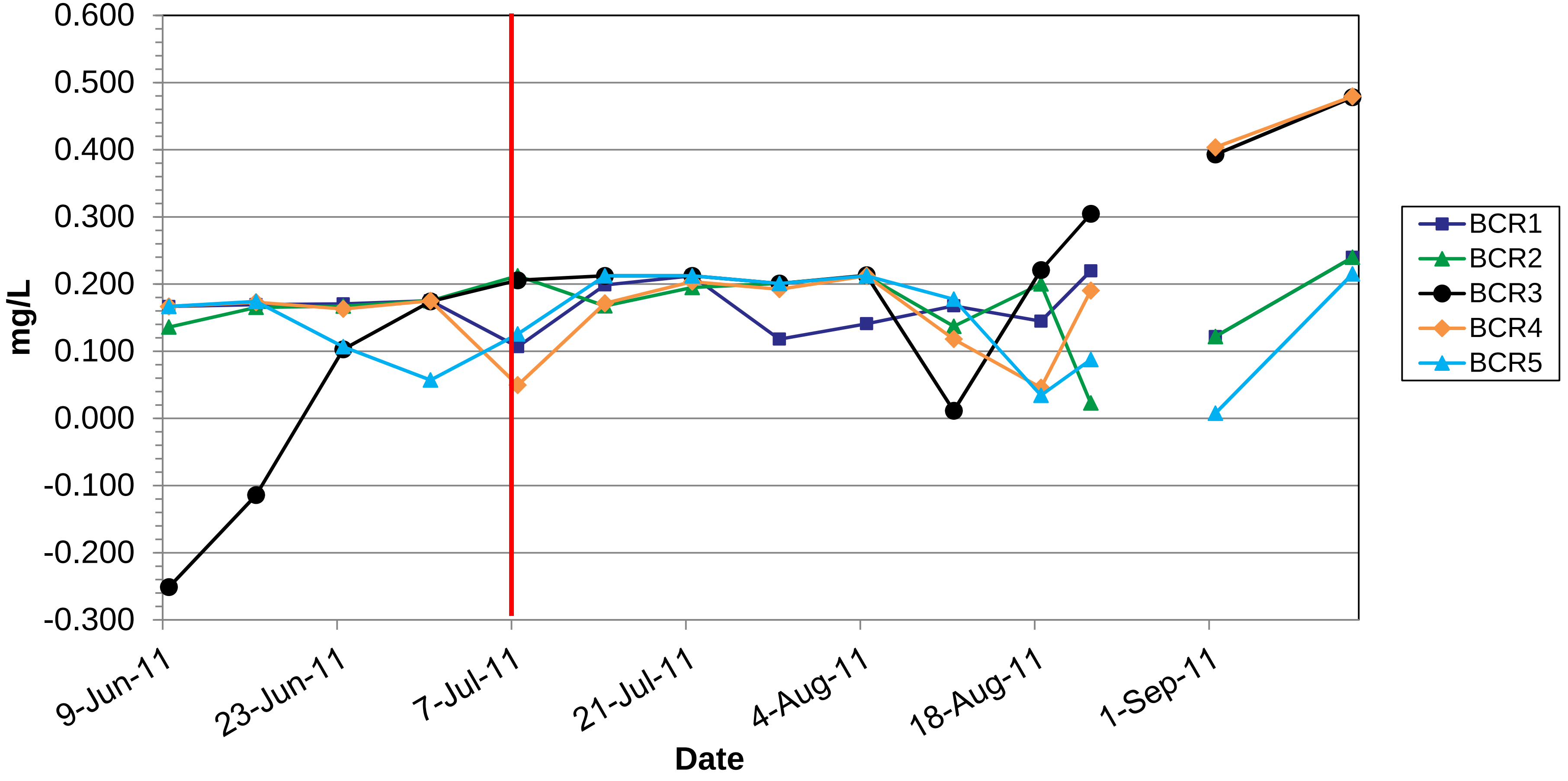
Golder Associates

Bench Scale Results – Sulfate Reduction (full)

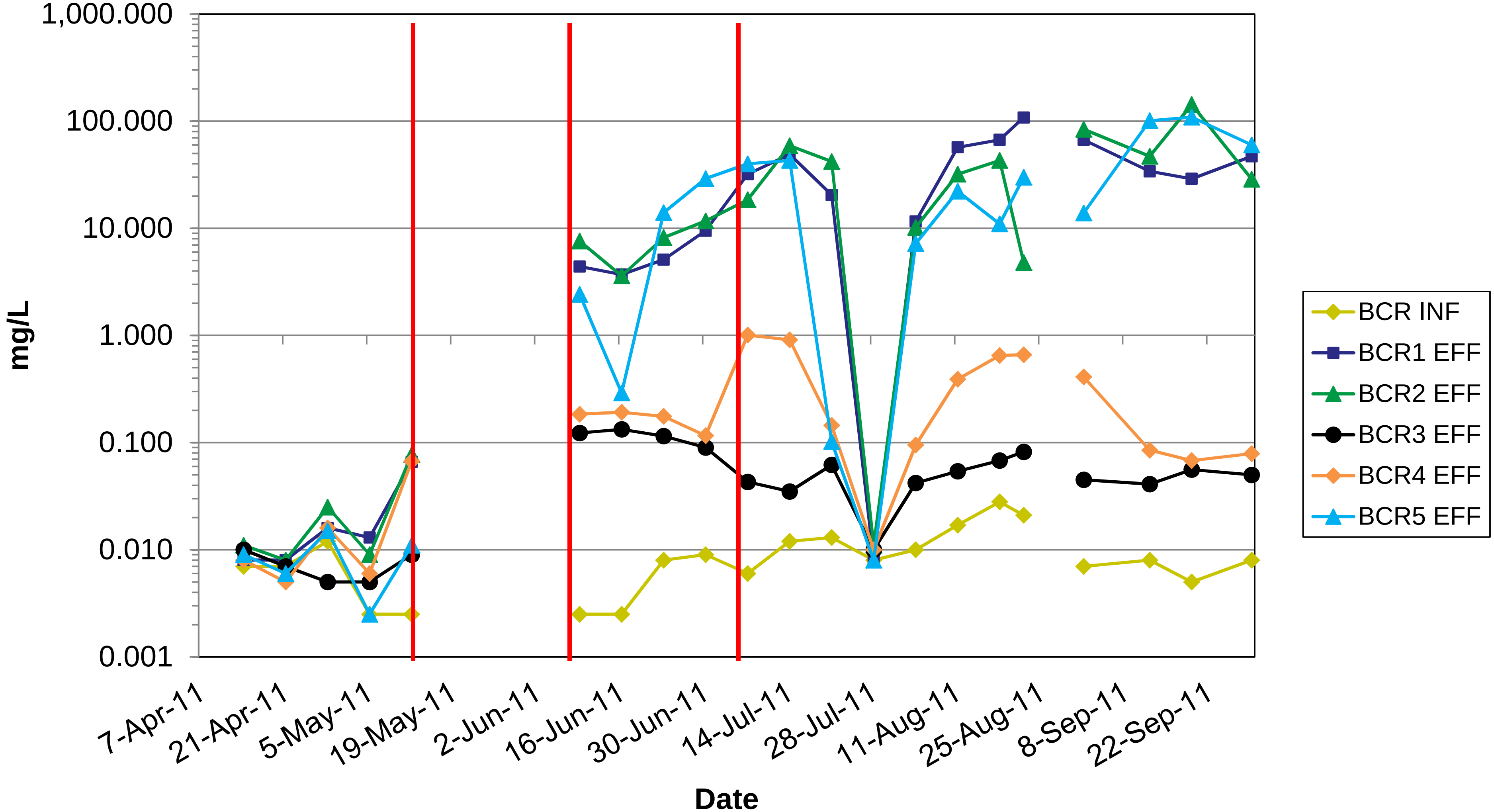


Golder Associates

Bench Scale Results – Sulfate Reduction (steady state)

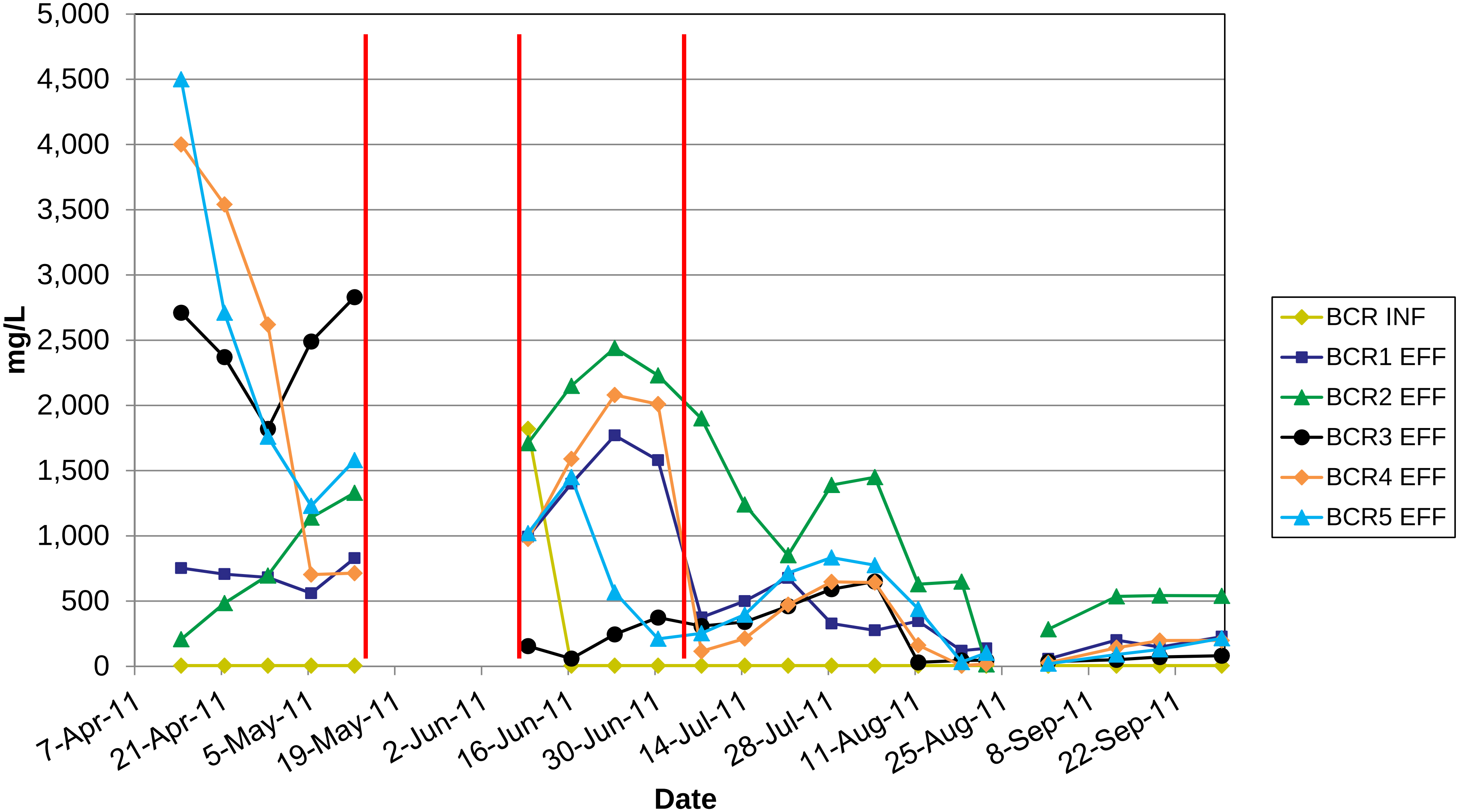


Bench Scale Results – Sulfide

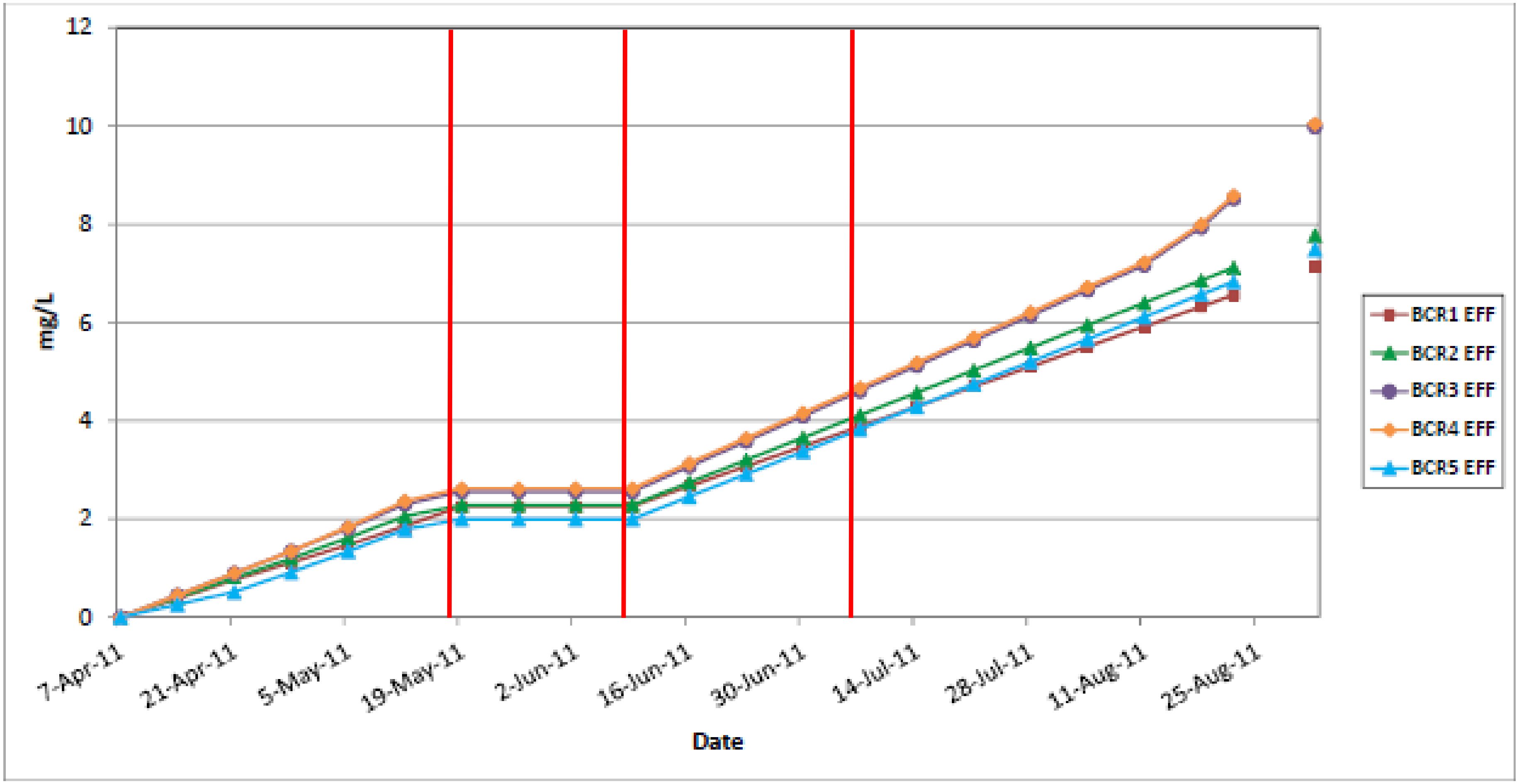


Golder Associates

Bench Scale Results – Biochemical Oxygen Demand (BOD)

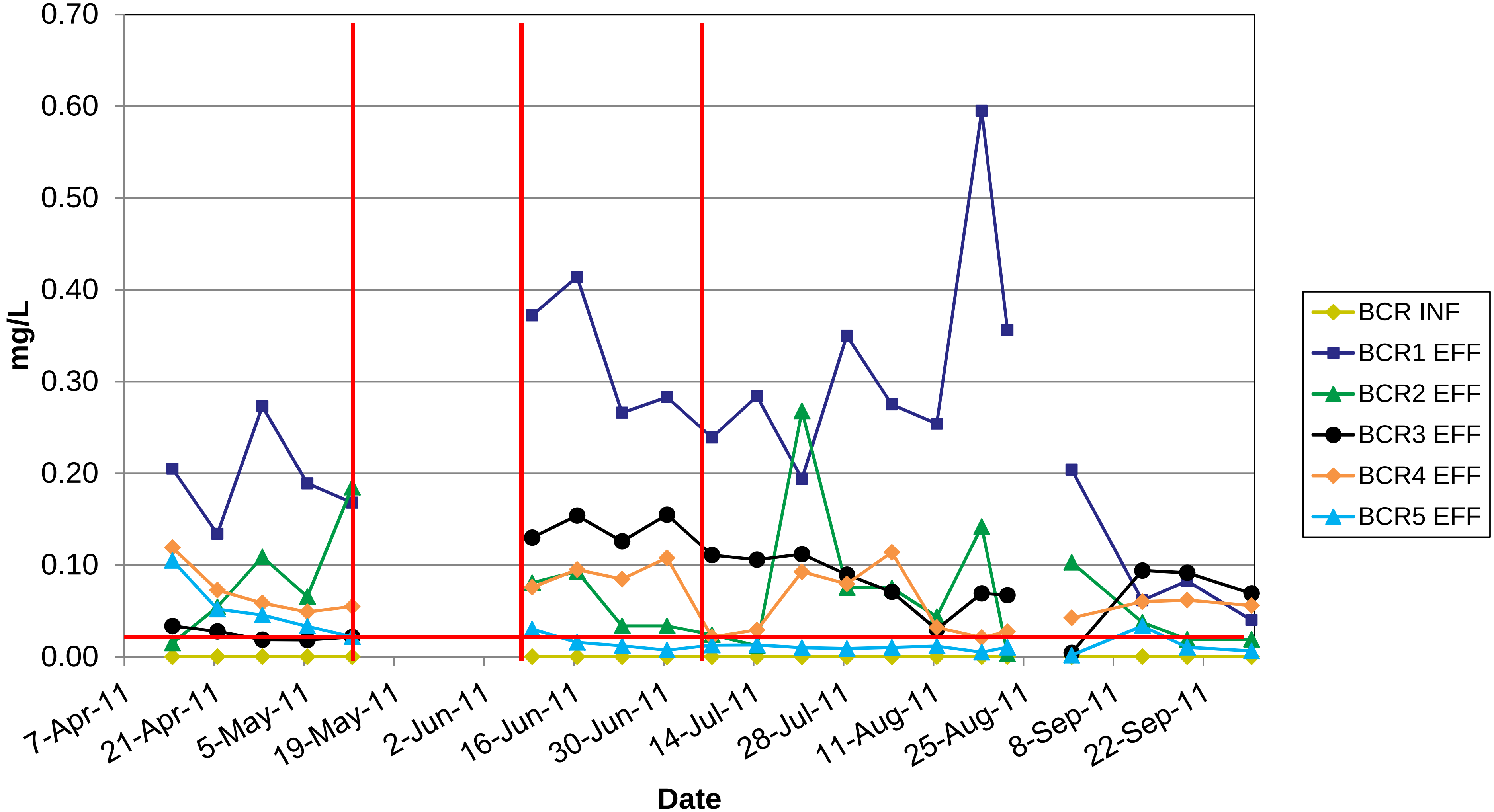


Bench Scale Results – Pore Volumes Treated

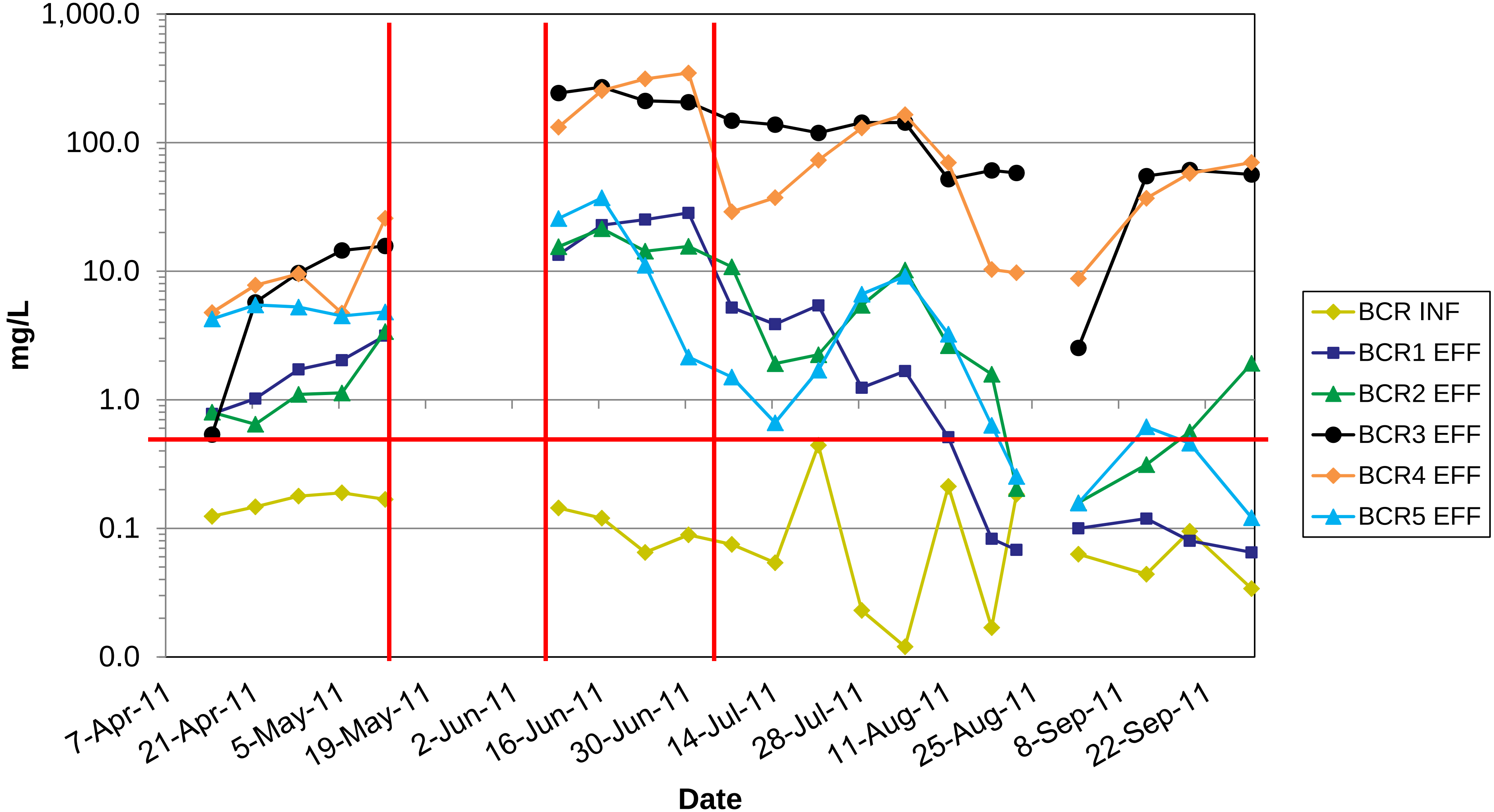


Golder Associates

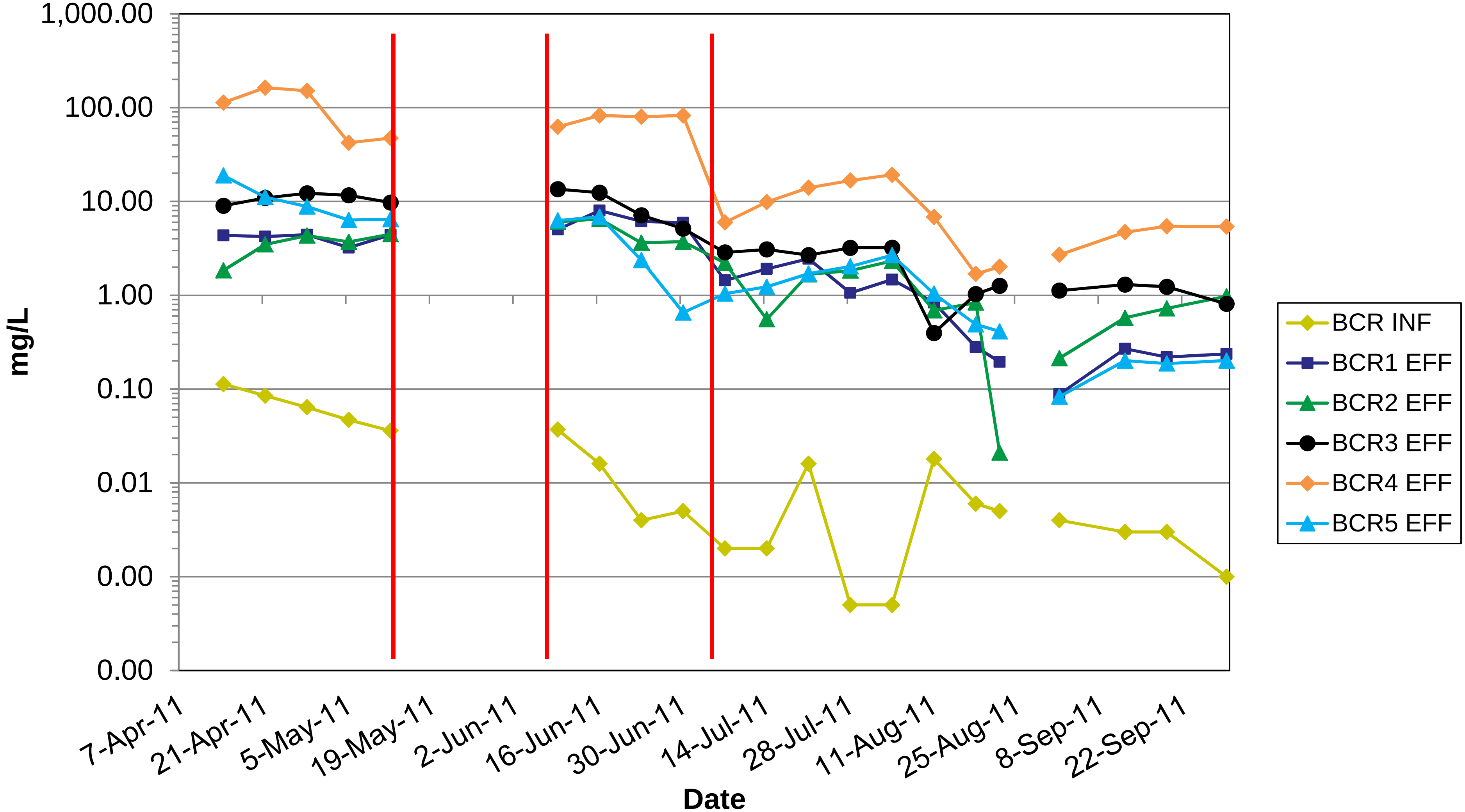
Bench Scale Results – Arsenic



Bench Scale Results – Iron



Bench Scale Results – Manganese



Golder Associates

Bench Testing Conclusions

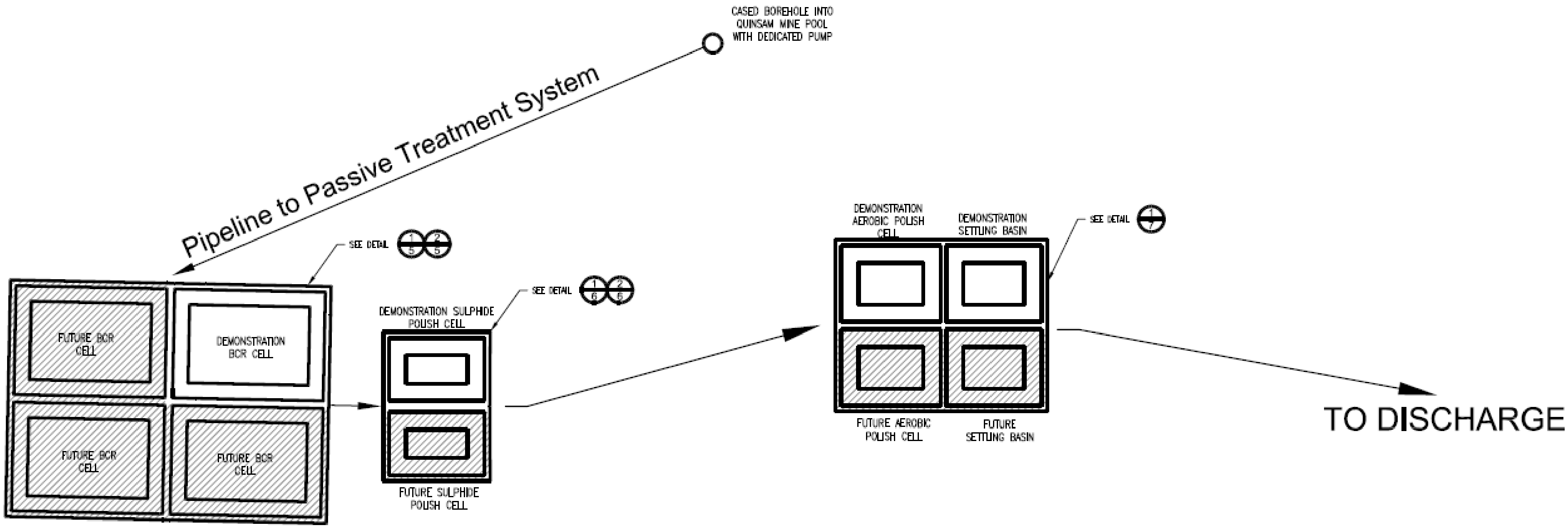
- Each of the five BCR cells demonstrated that sulfate can be removed to the levels desired (>50% removal)
- Each of the five BCR cells demonstrated sulfate removal at the maximum possible rate (0.20 mol/m_3/day)
- When flow rate sent to BCR3 and BCR4 was doubled, sulfate removal also doubled (0.40 mol/m_3/day)
- While BCR3 and BCR4 provided acceptable sulfide sequestration in situ, iron levels dropped throughout testing, leading to concerns about iron longevity (6 months – 3 years)
- Because of a variety of nuisance parameters present in BCR effluent (BOD, TOC, arsenic, manganese, etc.), it is necessary to include an aerobic polishing step in a demonstration/full-scale system
- Arsenic and manganese levels may increase in BCR cell, another reason why an aerobic polishing step is required
- Maximum operational flexibility must be included (bypass piping)

Golder Associates

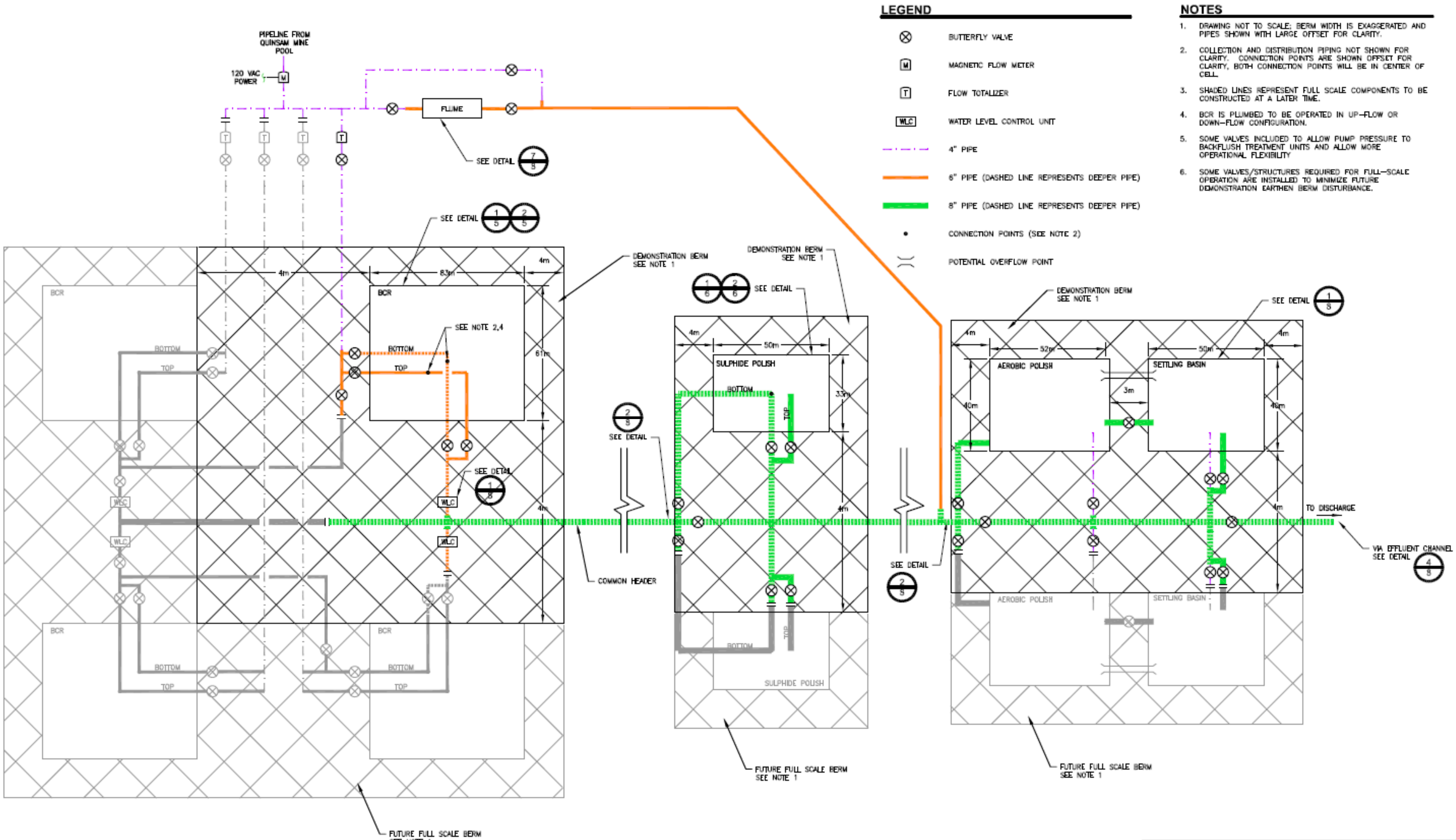
DEMONSTRATION SYSTEM DESIGN

Fall 2011

Demonstration System – Flow Schematic

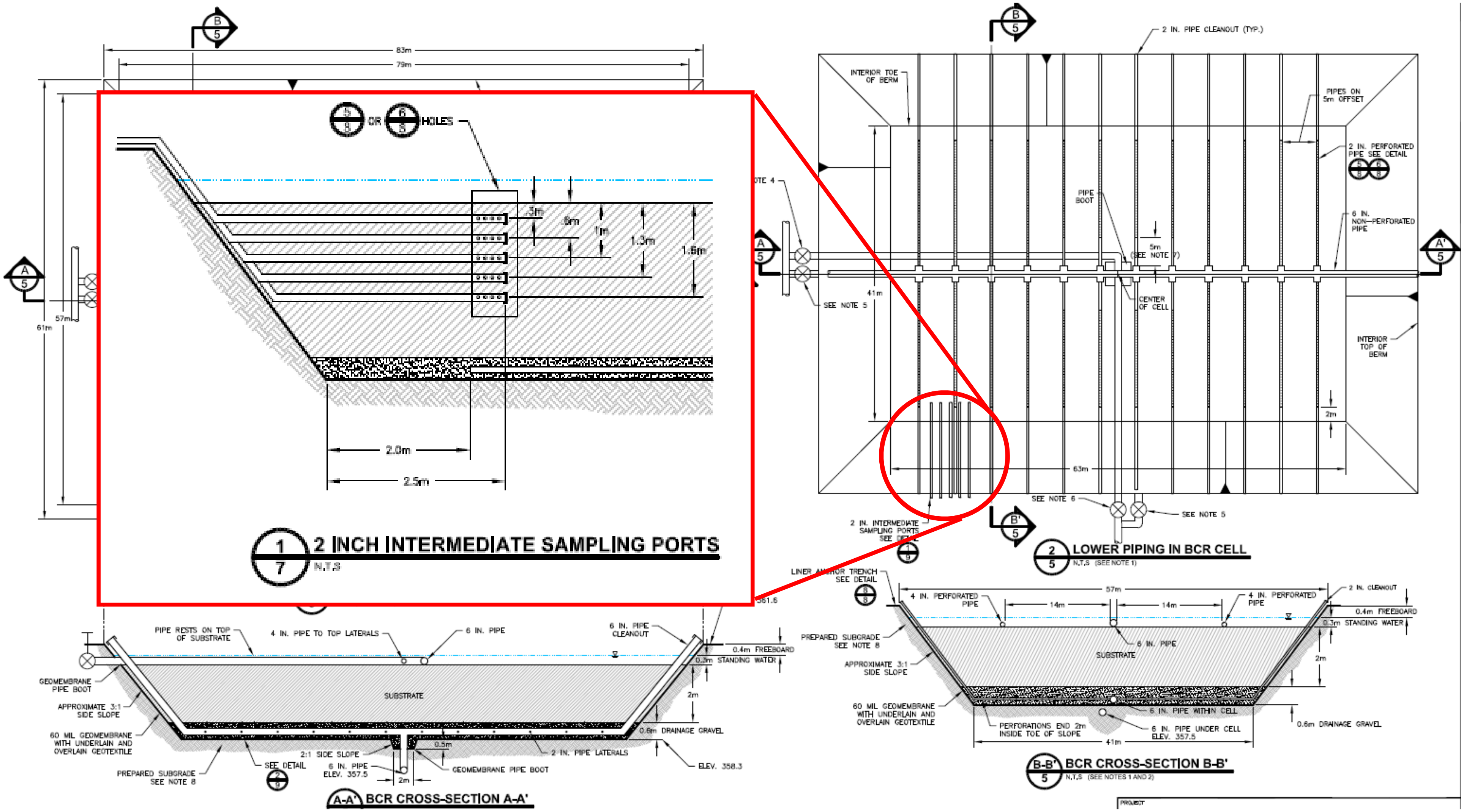


Demonstration System – General Piping Arrangement

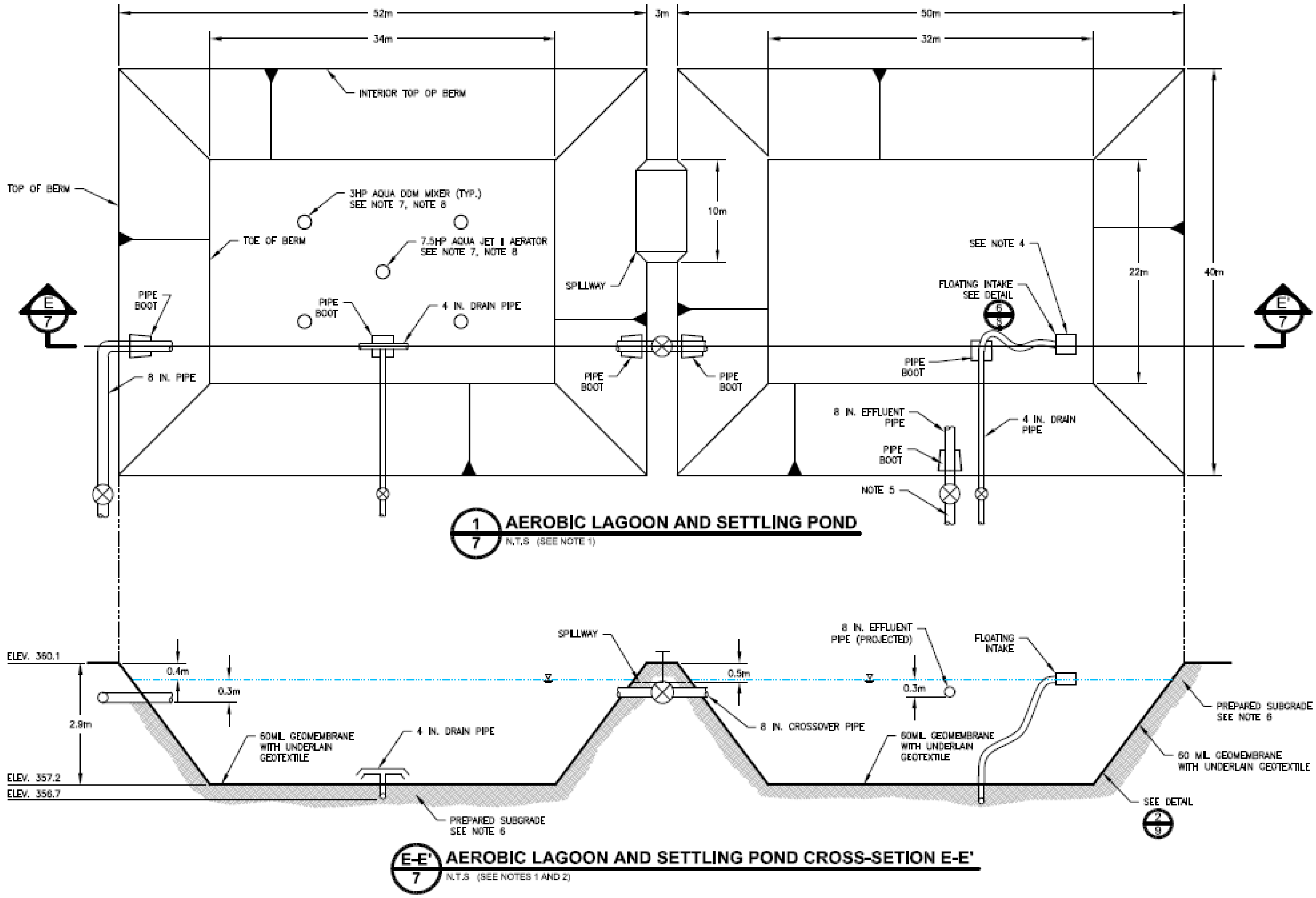


Golder Associates

Demonstration System – BCR Cell



Demonstration System – Aerobic Polishing System

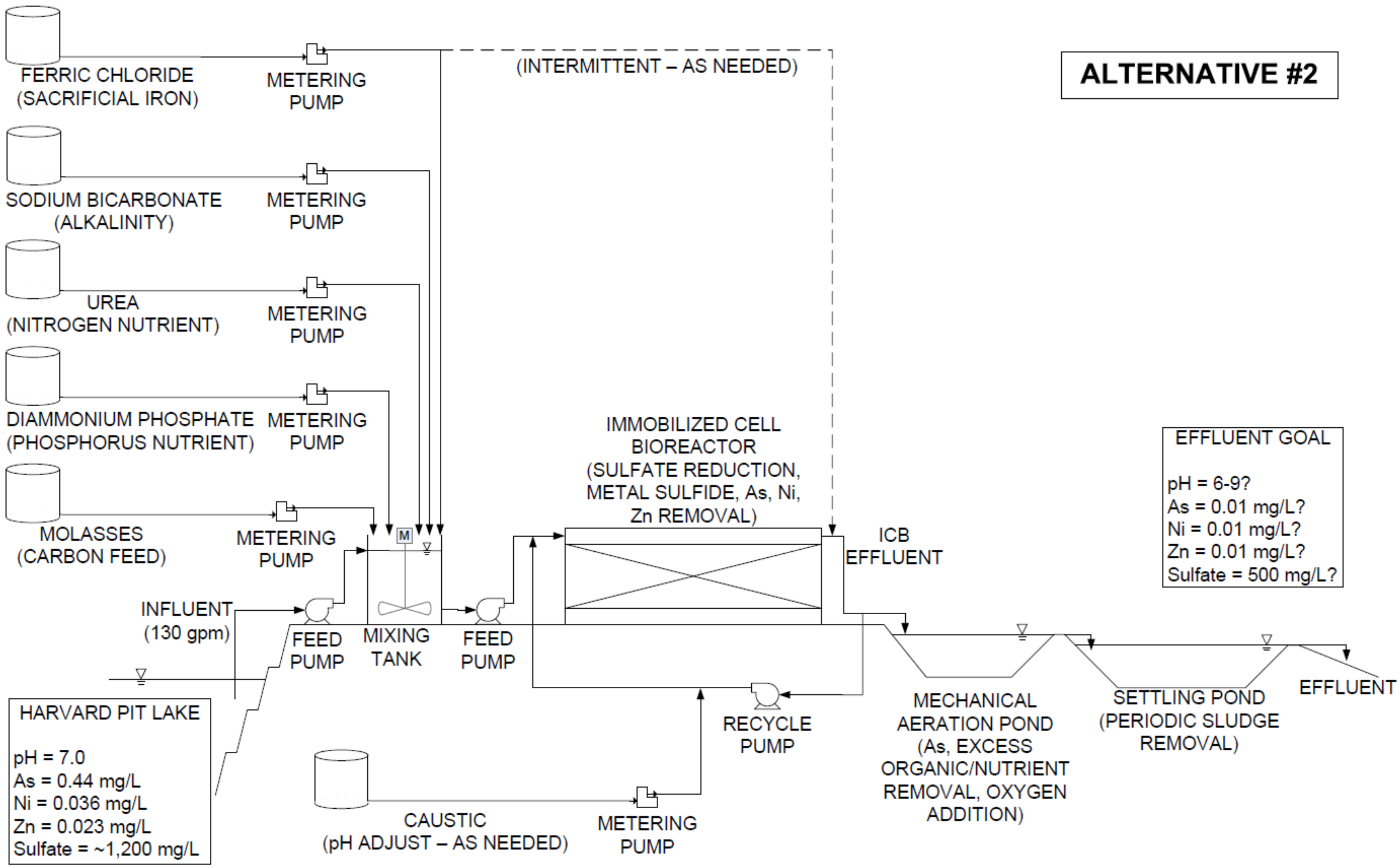


Golder Associates

Demonstration System – Path Forward

- Construction to begin in late April, complete in June
- Incubation for two weeks during June
- Begin minimum of one year demonstration testing period
- Move forward to full-scale system (incorporating demonstration system)
- Looking into testing / developing biological sulfate reduction process:
  - Fully passive system (no pumping, passive aeration)
  - Hybrid system (minimal power and O&M requirement)
  - Fully active system (ICB fixed-film media with carbon/nutrient dosing)

Future of Biological Sulfate Removal



Golder Associates

THANK YOU!
Co-author Jim Gusek

eblumenstein@golder.com

Golder Associates