The Construction and Initial Results of a Demonstration Passive Treatment System for Removing Sulfate at a Site on Vancouver Island, BC

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Presentation Overview

- Site Location / Background / Desires
- Traditional Sulfate Removal Technologies
- Biological Sulfate Removal
- Bench Testing (Summer 2011)
- Demonstration System
  - Design (Winter 2011-2012)
  - Construction (Summer 2012)
  - Preliminary Results (October 2012 – May 2013)
- Path Forward

Site Location / Background / Needs

- Underground coal mine
- 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

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

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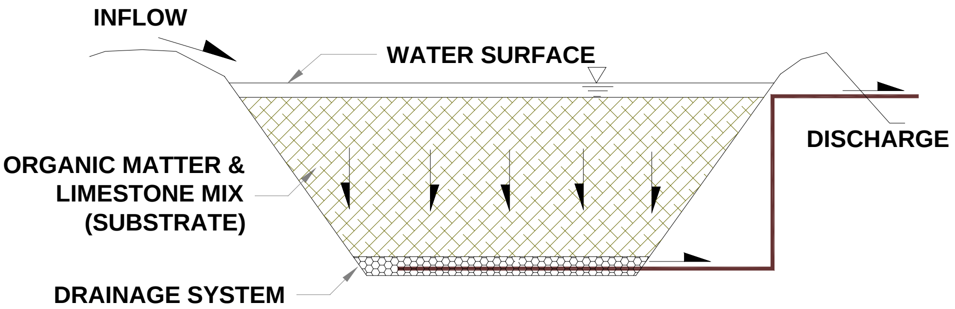
Traditional Sulfate Removal Technologies

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

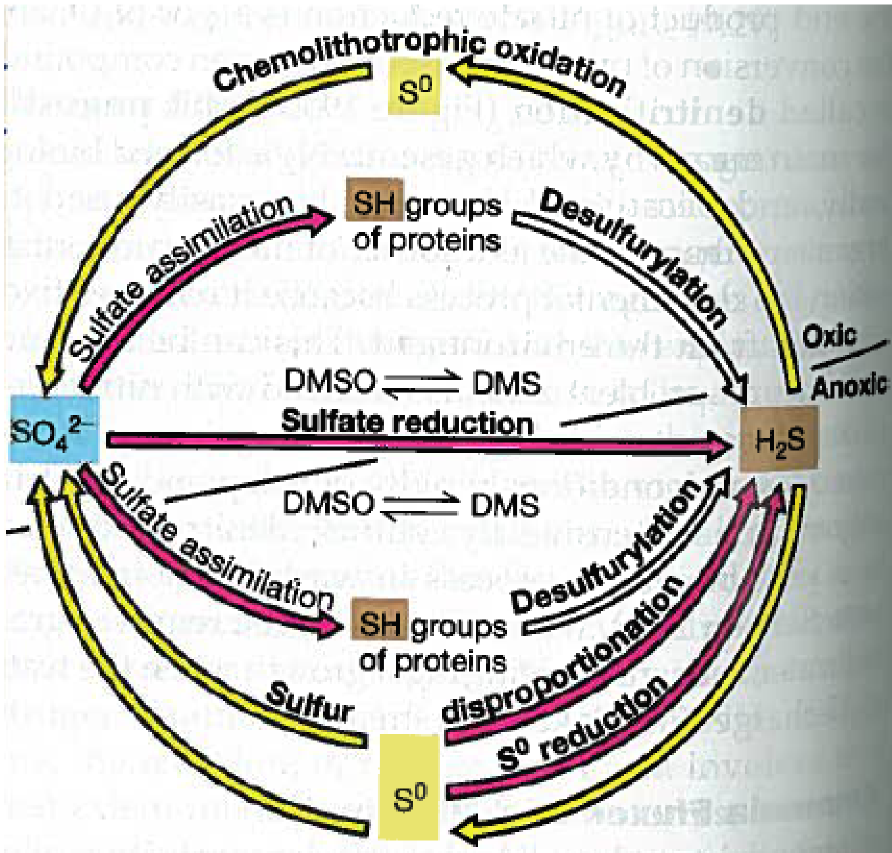
Potential New Sulfate Removal Technology

- 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 (sulfide)



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 (offgas as hydrogen sulfide)
  - Convert to elemental sulfur upon being re-oxidized
  - Convert back to sulfate upon leaving cell and being re-oxidized

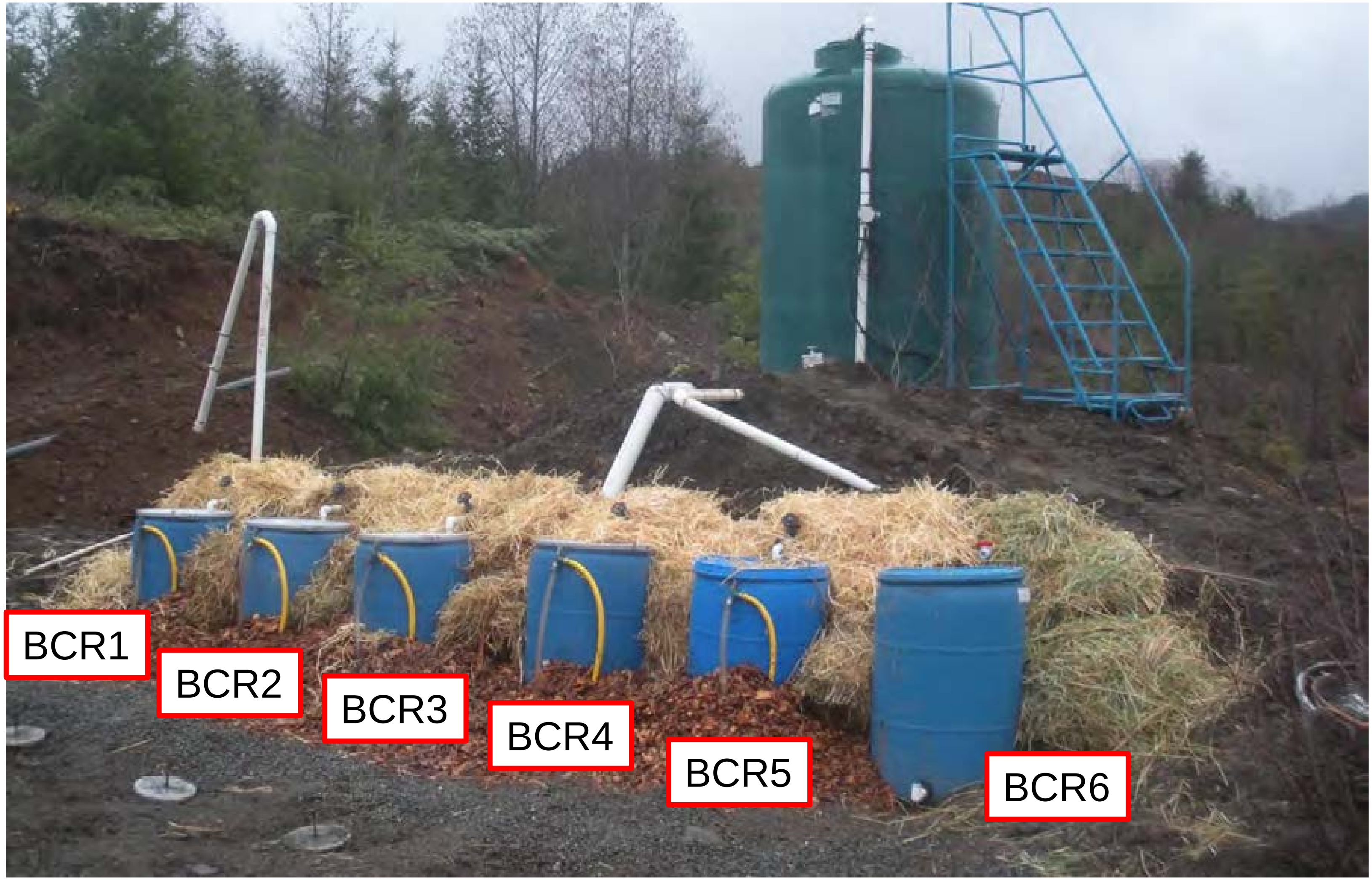
Potential New Sulfate Removal Technology

- Options for "sequestering" excess sulfide:
  - Harvest reduced sulfate in BCR effluent
    - After aeration as elemental sulfur
    - Can be difficult to design and require more continual O&M
    - Mechanical rake/collection equipment
  - 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

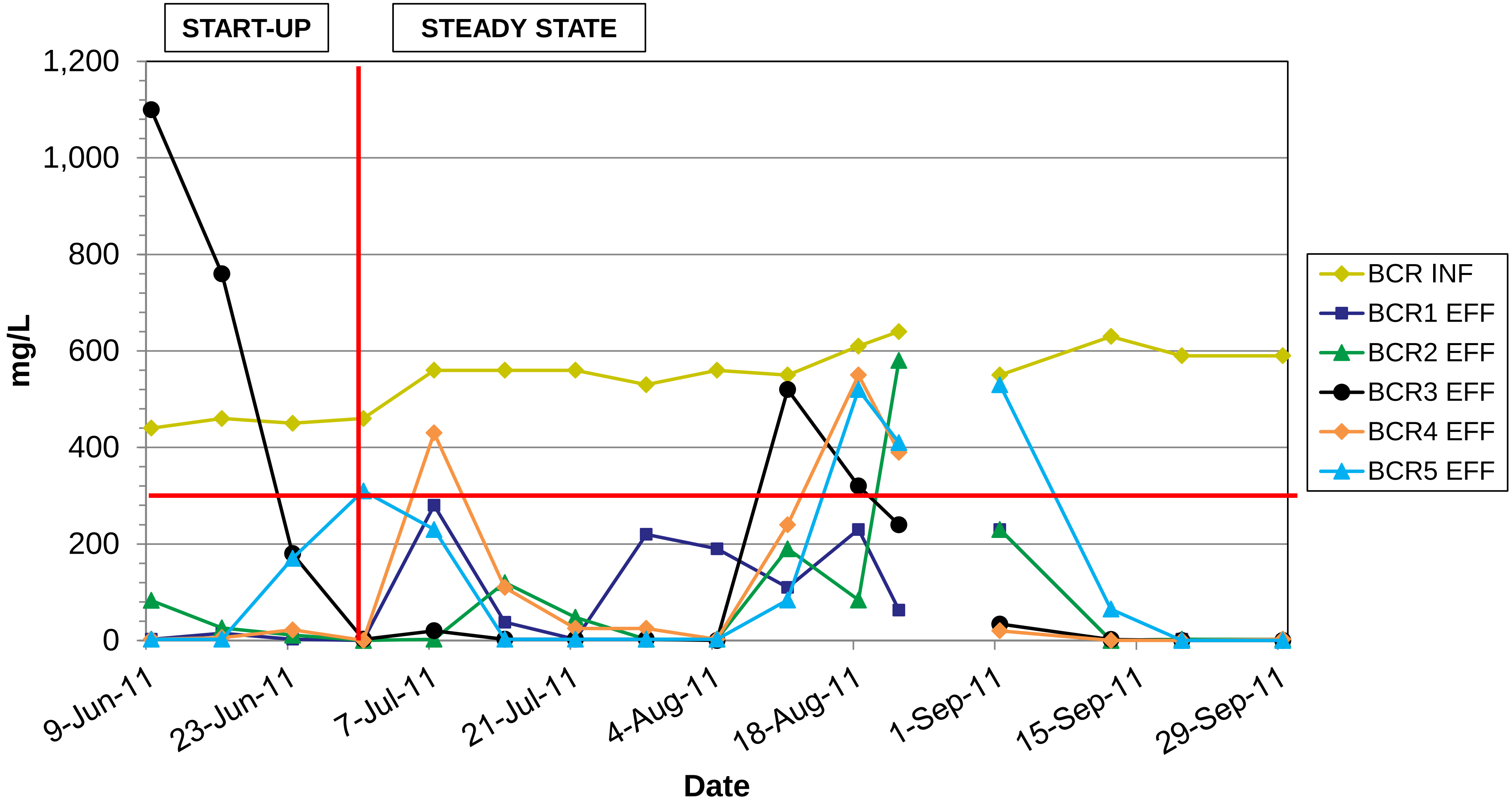
BENCH SCALE BIOCHEMICAL REACTOR

Summer 2011

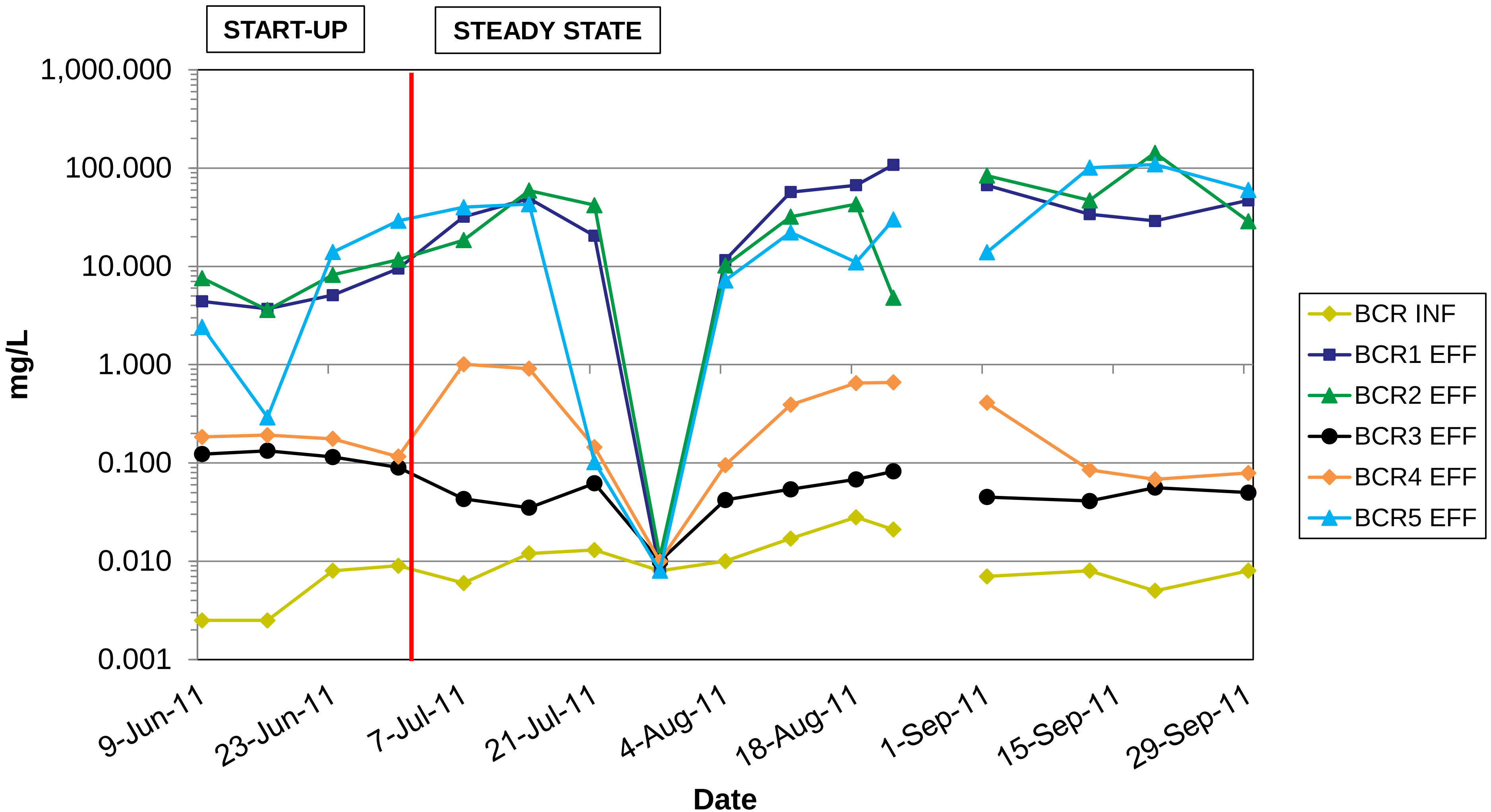
Bench Scale Design / Construction



Bench Scale Results – Sulfate



Bench Scale Results – Sulfide



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Bench Testing Conclusions

- Each of the five BCR cells demonstrated that sulfate can be removed to the levels desired (>50% removal)
- While the BCR cells with iron sacrificial iron mixed in to substrate provided acceptable sulfide sequestration in situ, iron levels dropped throughout testing, leading to concerns about iron longevity (6 mo-3 yrs)
- 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)

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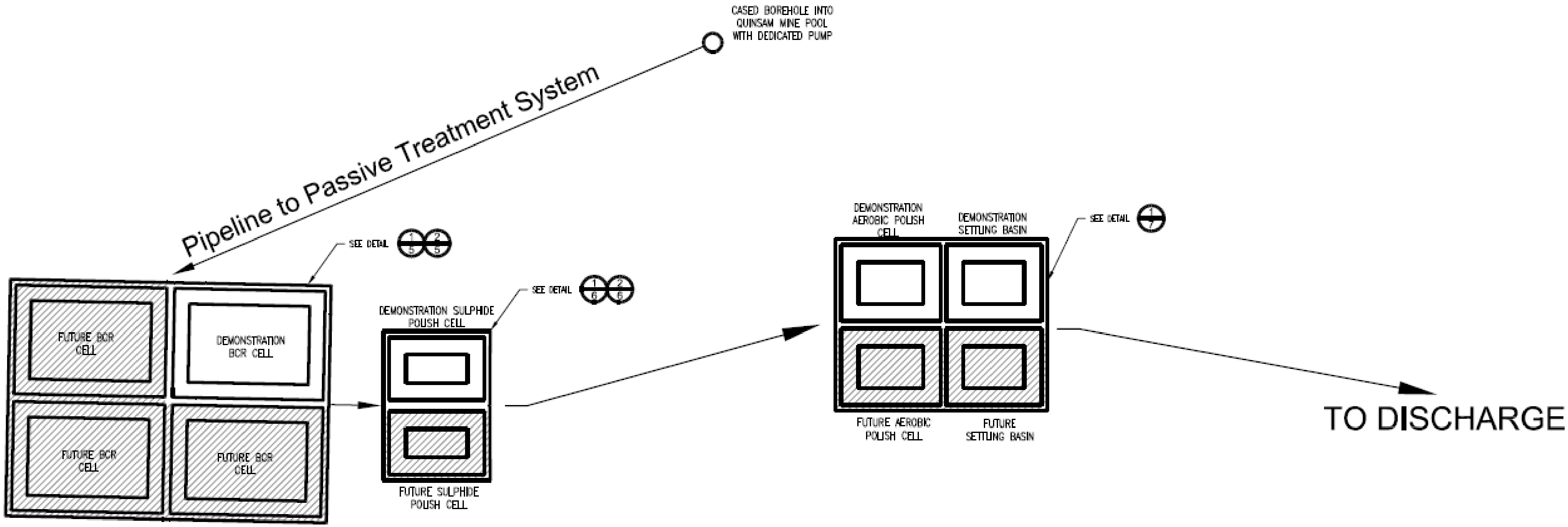
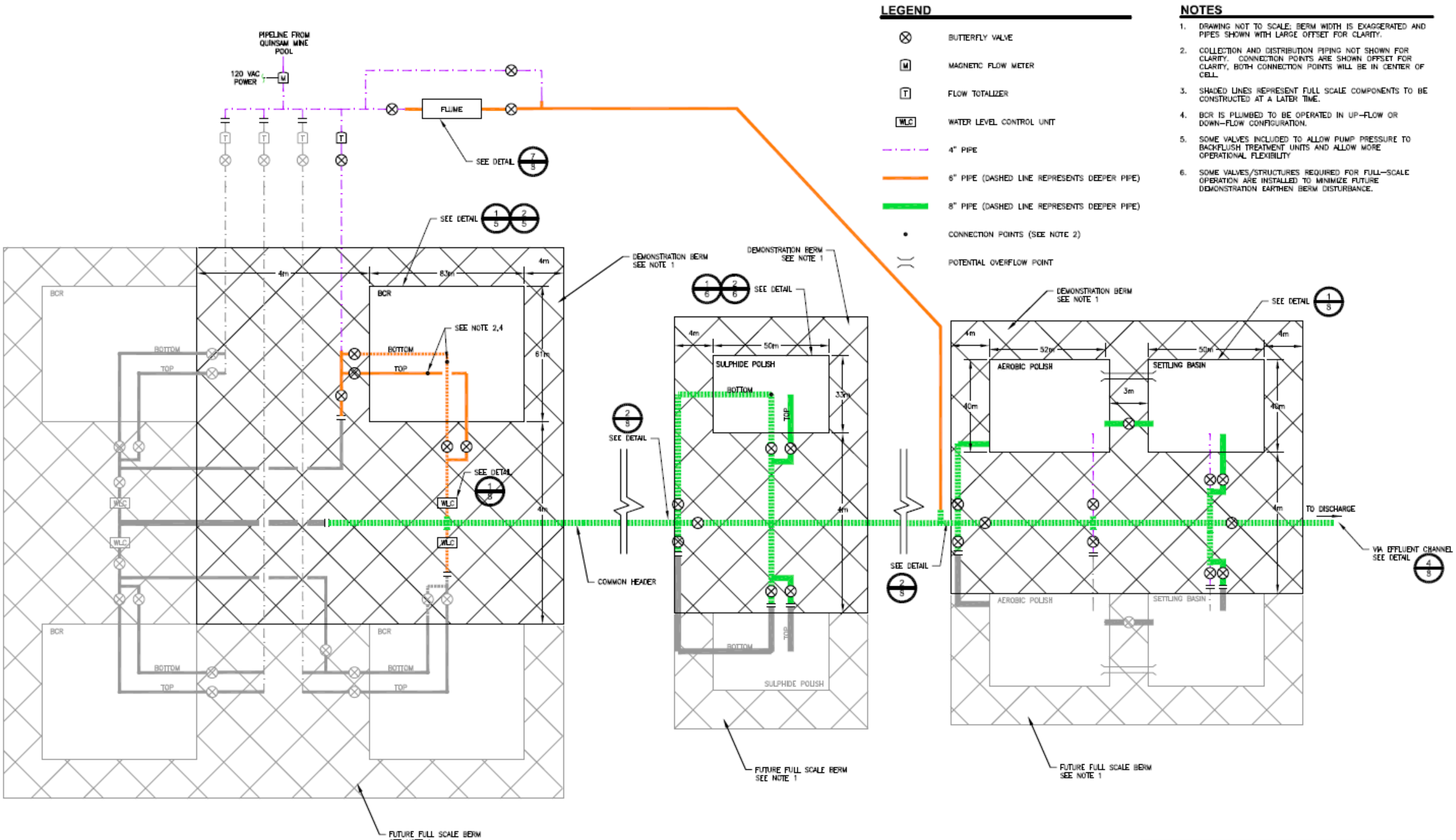
DEMONSTRATION SYSTEM DESIGN

Fall 2011

Demonstration System –
Flow Schematic



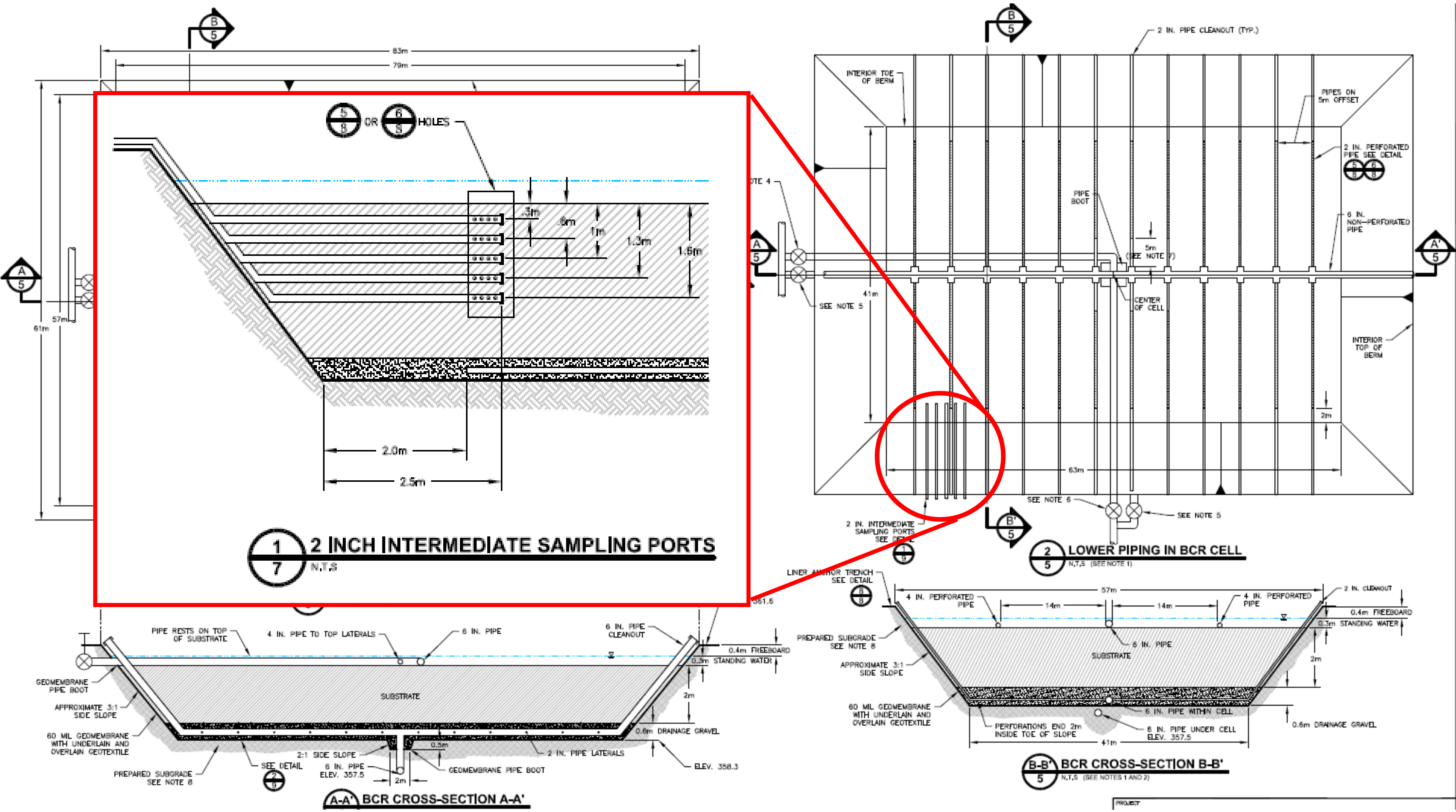
Demonstration System – General Piping Arrangement



NOTES

1. DRAWING NOT TO SCALE; BERM WIDTH IS EXAGGERATED AND PIPES SHOWN WITH LARGE OFFSET FOR CLARITY.
2. COLLECTION AND DISTRIBUTION PIPING NOT SHOWN FOR CLARITY. CONNECTION POINTS ARE SHOWN OFFSET FOR CLARITY, BOTH CONNECTION POINTS WILL BE IN CENTER OF CELL.
3. SHADED LINES REPRESENT FULL SCALE COMPONENTS TO BE CONSTRUCTED AT A LATER TIME.
4. BCR IS PLUMBED TO BE OPERATED IN UP–FLOW OR DOWN–FLOW CONFIGURATION.
5. SOME VALVES INCLUDED TO ALLOW PUMP PRESSURE TO BACKFLUSH TREATMENT UNITS AND ALLOW MORE OPERATIONAL FLEXIBILITY
6. SOME VALVES/STRUCTURES REQUIRED FOR FULL–SCALE OPERATION ARE INSTALLED TO MINIMIZE FUTURE DEMONSTRATION EARTHEN BERM DISTURBANCE.

Demonstration System – BCR Cell



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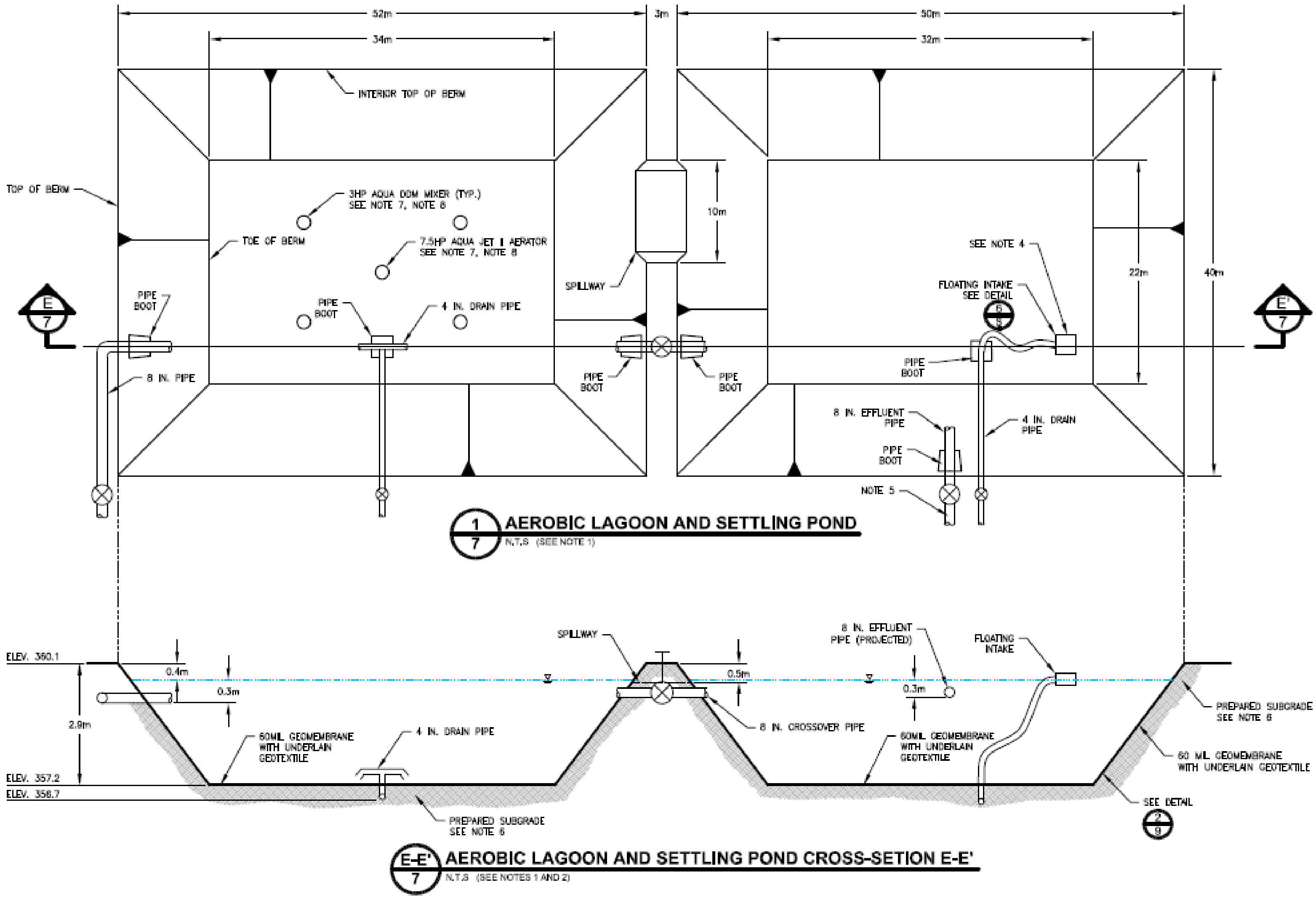
Demonstration System – Aerobic Polishing System



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DEMONSTRATION SYSTEM CONSTRUCTION

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Demonstration System Construction – Feed Pump / Piping

Demonstration System Construction – Unexpected Delays / Bedrock Blasting

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Demonstration System Construction – Bypass and Effluent Piping

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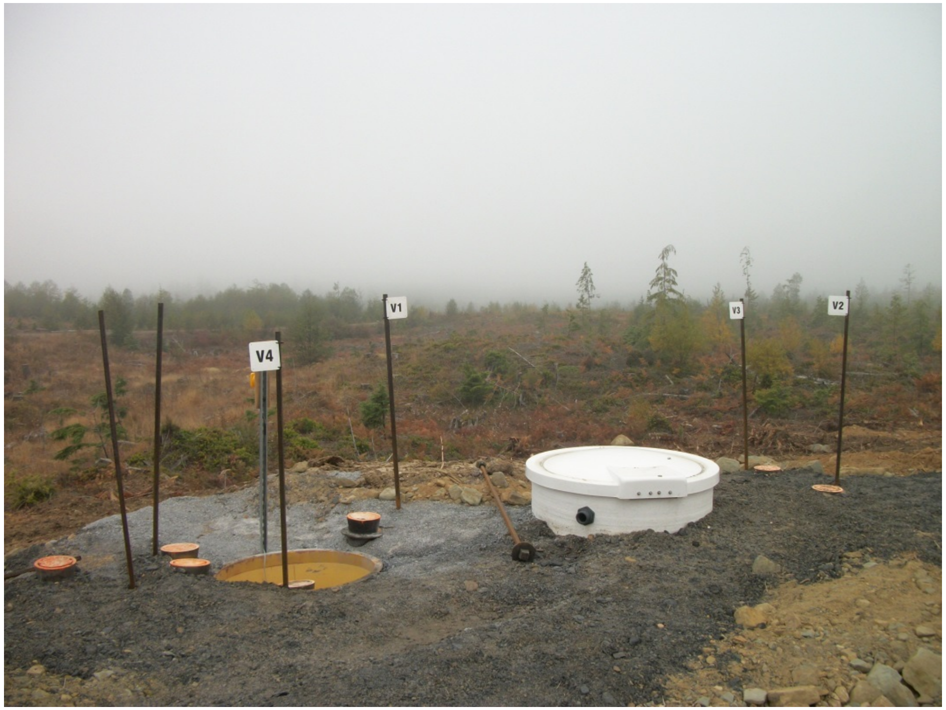
Demonstration System Construction – BCR Cell

Demonstration System Construction – BCR Cell

Demonstration System Construction – BCR Cell



Demonstration System Construction – BCR Cell

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Demonstration System Construction – Sulfide Polish Cell

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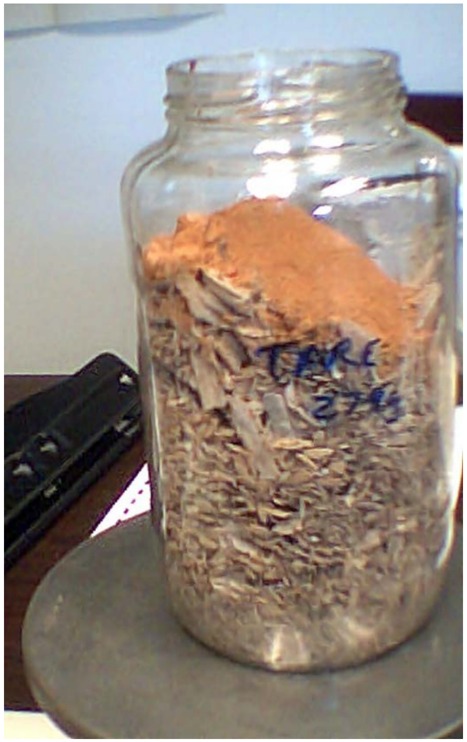

Demonstration System Construction – Sulfide Polish Cell

Demonstration System Construction – Aerobic Polish Cell and Settling Pond

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Demonstration System Construction – Aerobic Polish Cell and Settling Pond

Demonstration System Construction – Aerobic Polish Cell and Settling Pond

Demonstration System Construction – Effluent Channel

DEMONSTRATION SYSTEM PRELIMINARY OPERATION

October 2012 – May 2013

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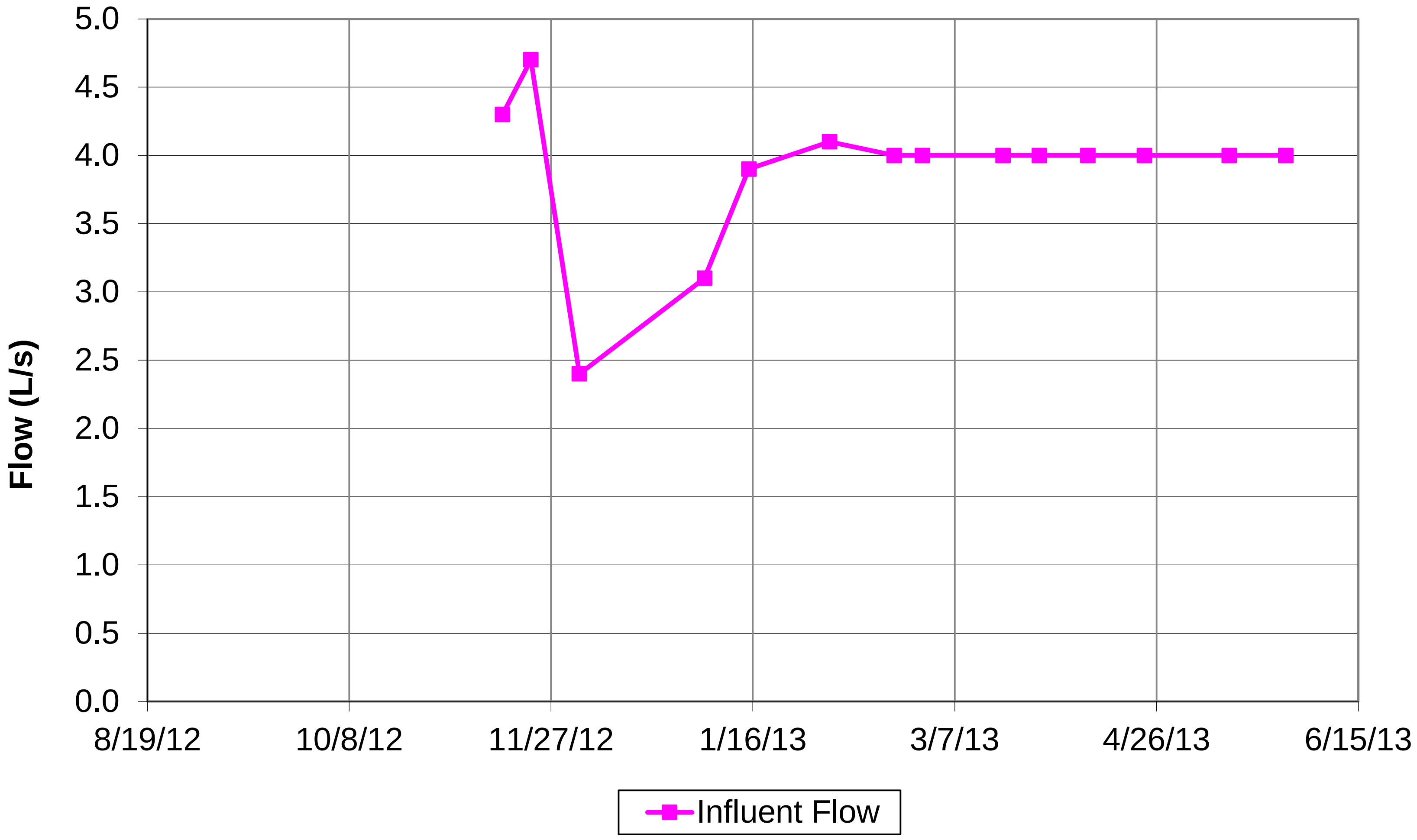
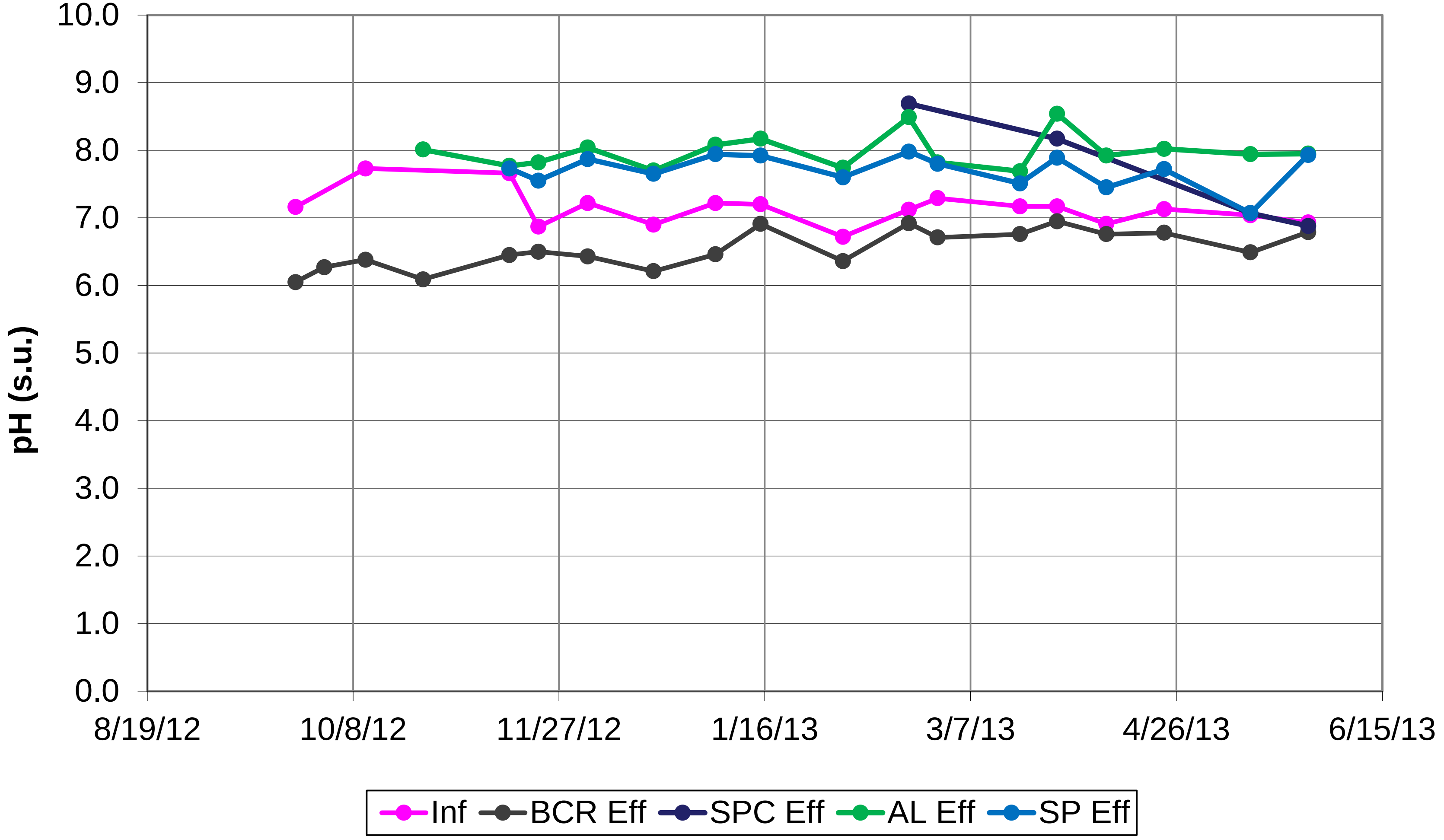
Demonstration System Preliminary Operation – Flow Rate (L/sec)



Demonstration System Preliminary Operation – pH (standard units)



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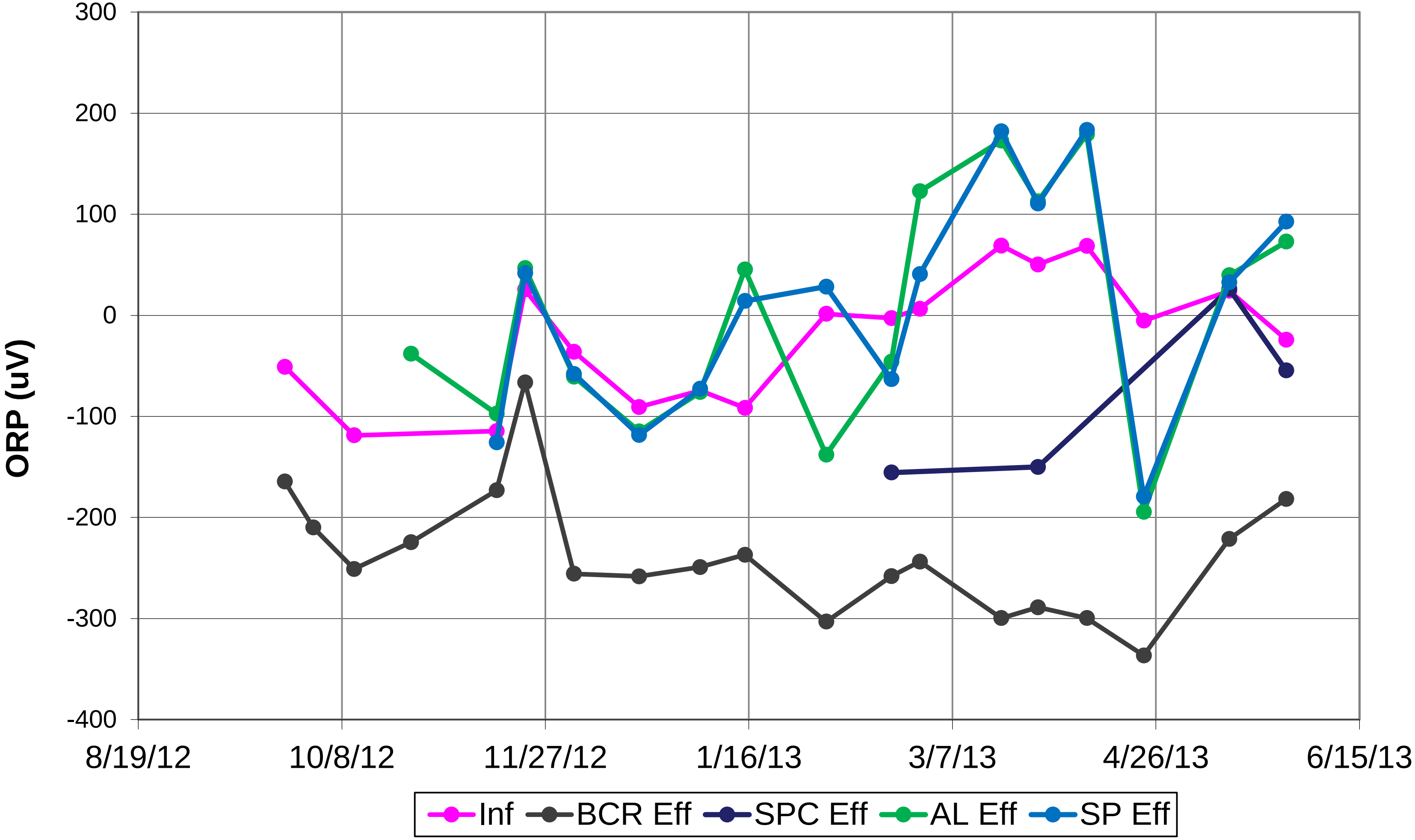
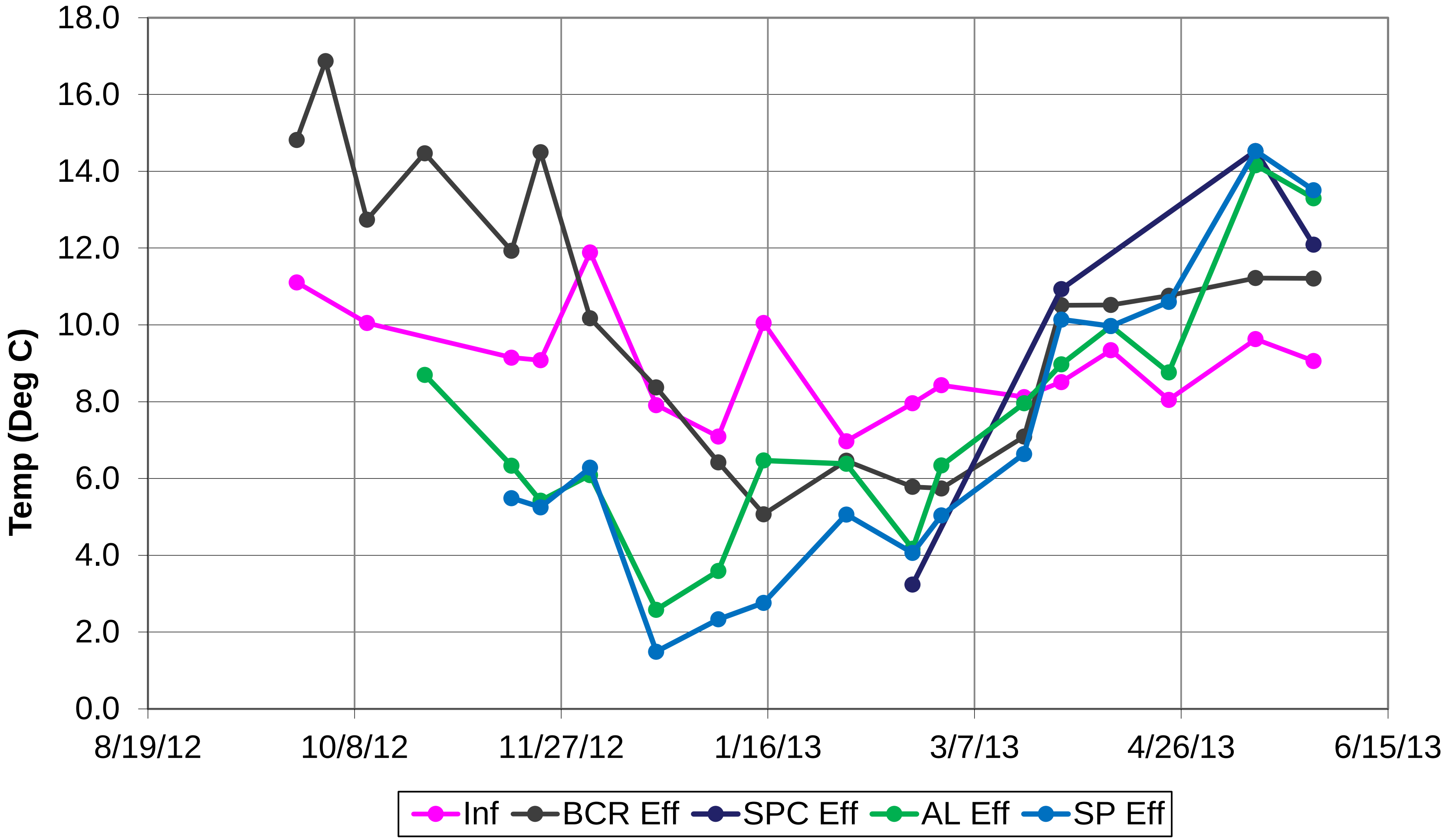
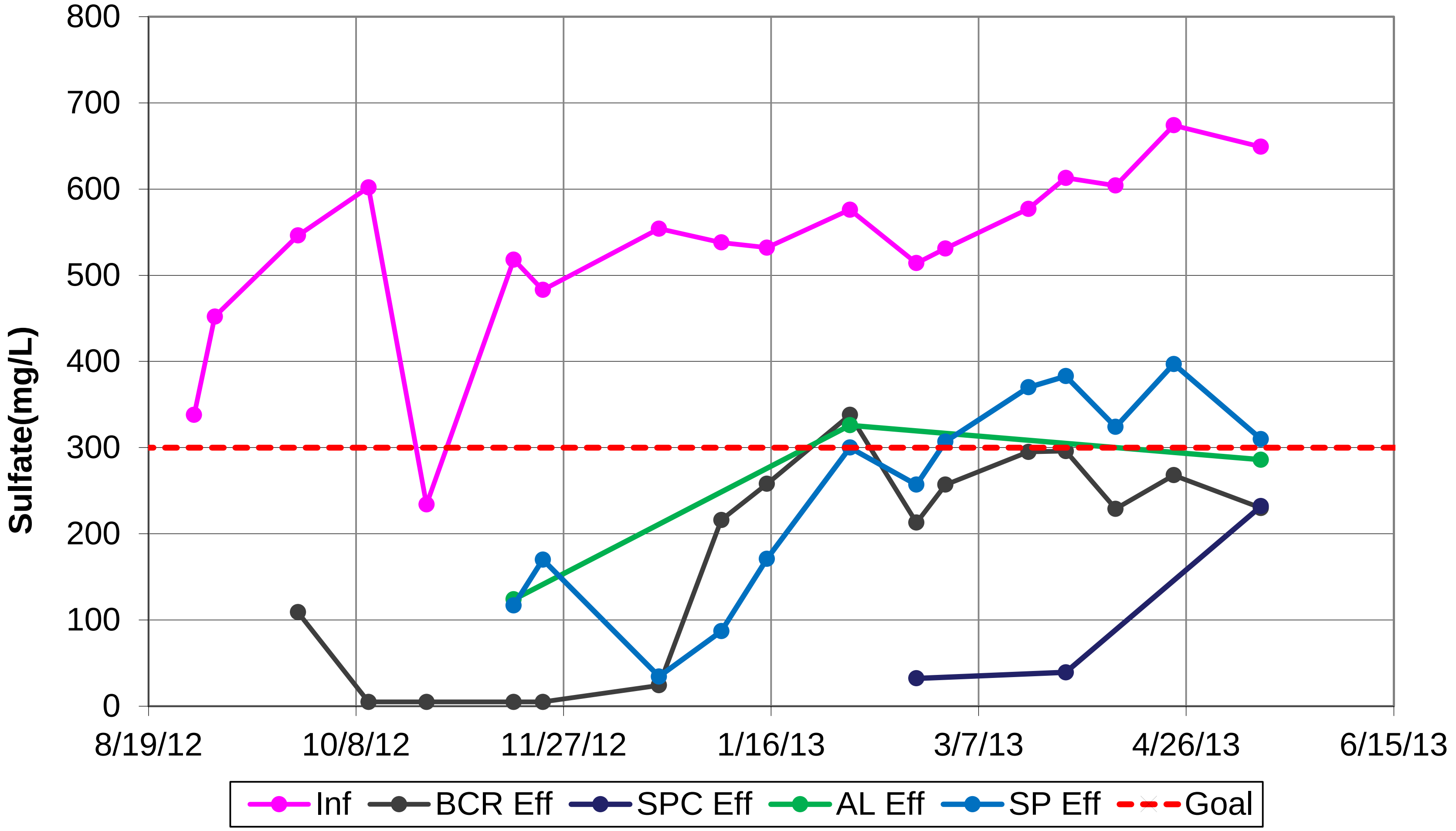
Demonstration System Preliminary Operation – Oxidation Reduction Potential (mV)



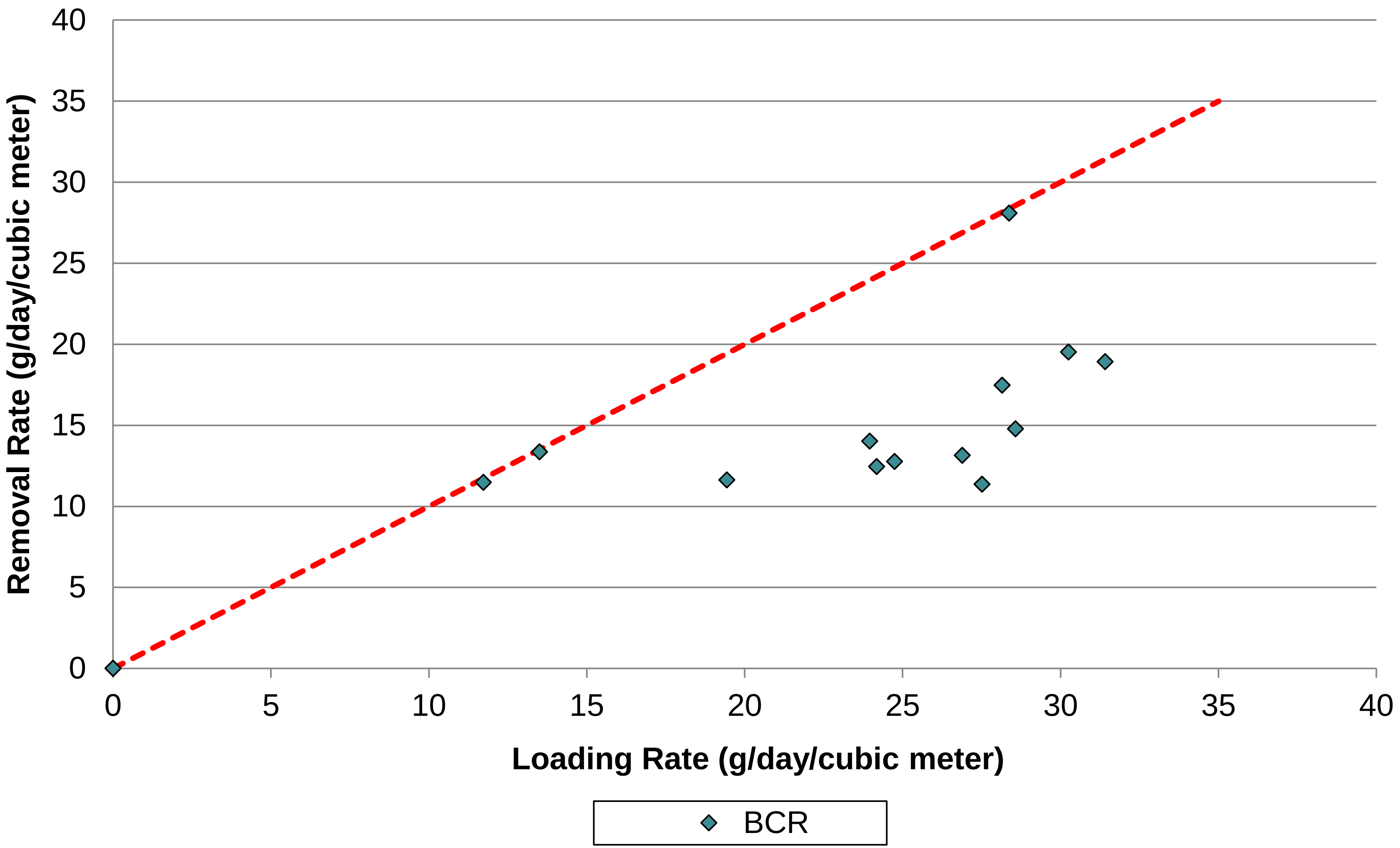
Demonstration System Preliminary Operation – Temperature (degrees Celsius)



Demonstration System Preliminary Operation – Sulfate (mg/L)



Demonstration System Preliminary Operation – Sulfate Loading and Removal Rate (g/m^3/day)



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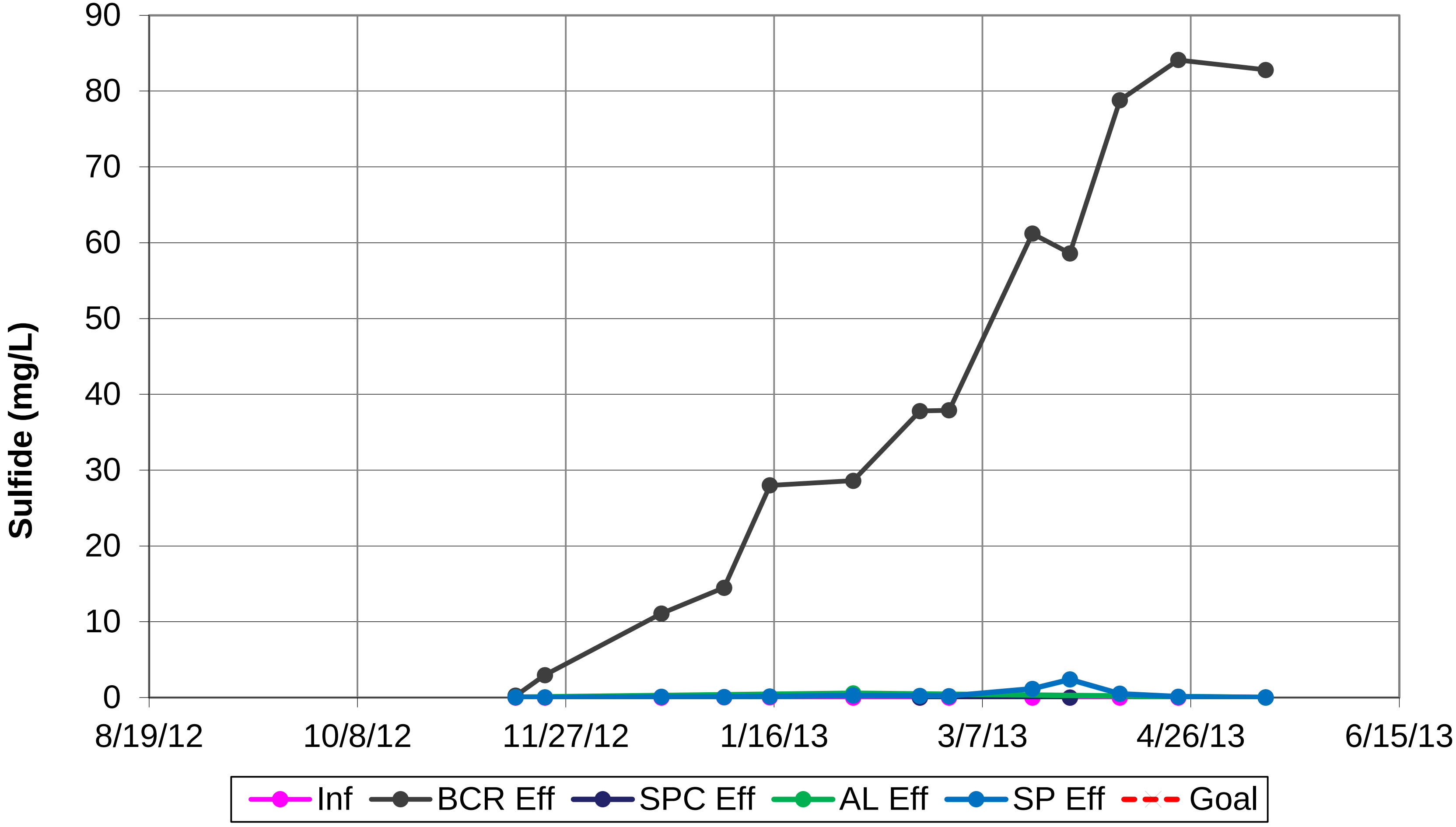
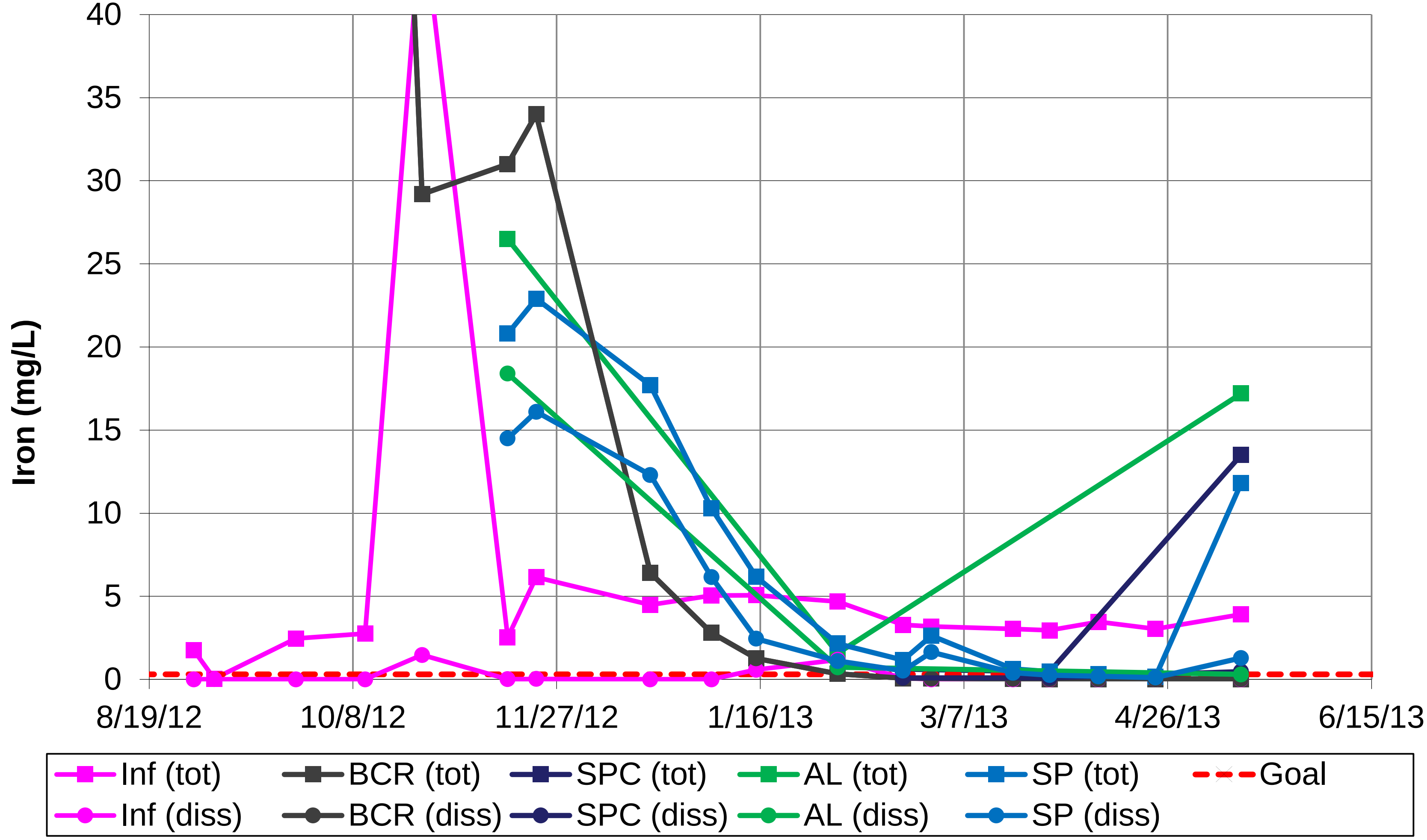
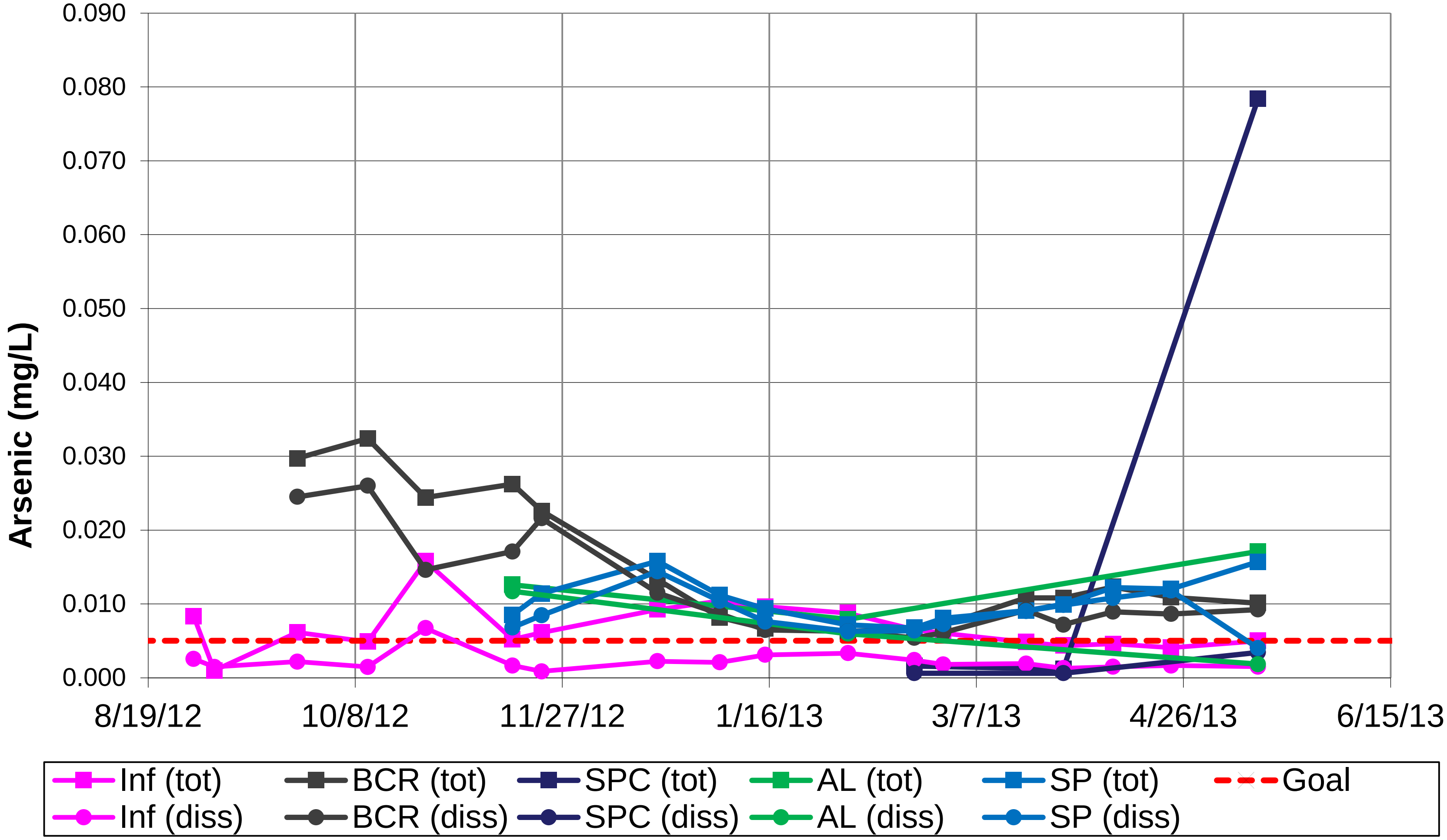
Demonstration System Preliminary Operation – Sulfide (mg/L)



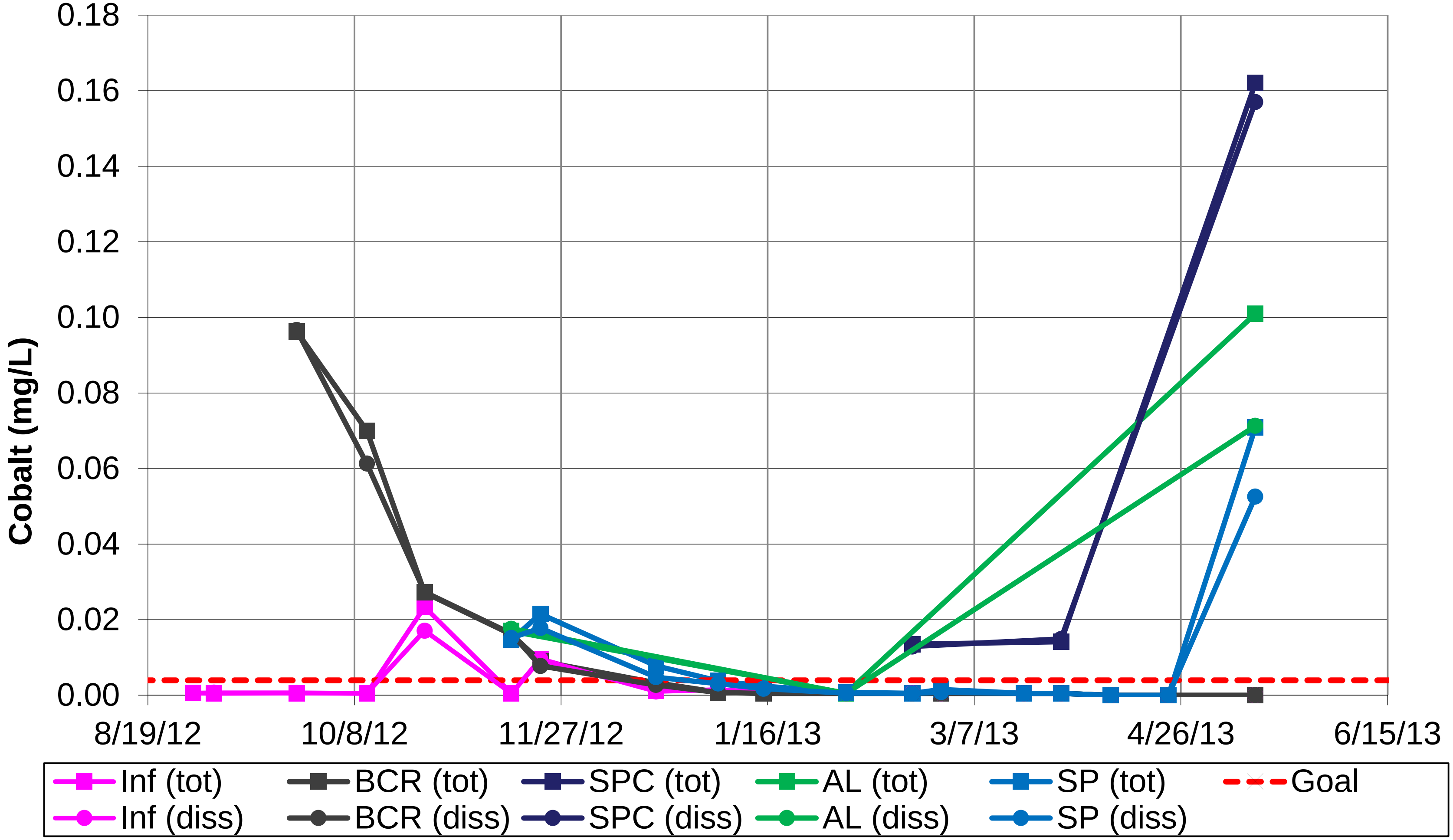
Demonstration System Preliminary Operation – Iron (mg/L)



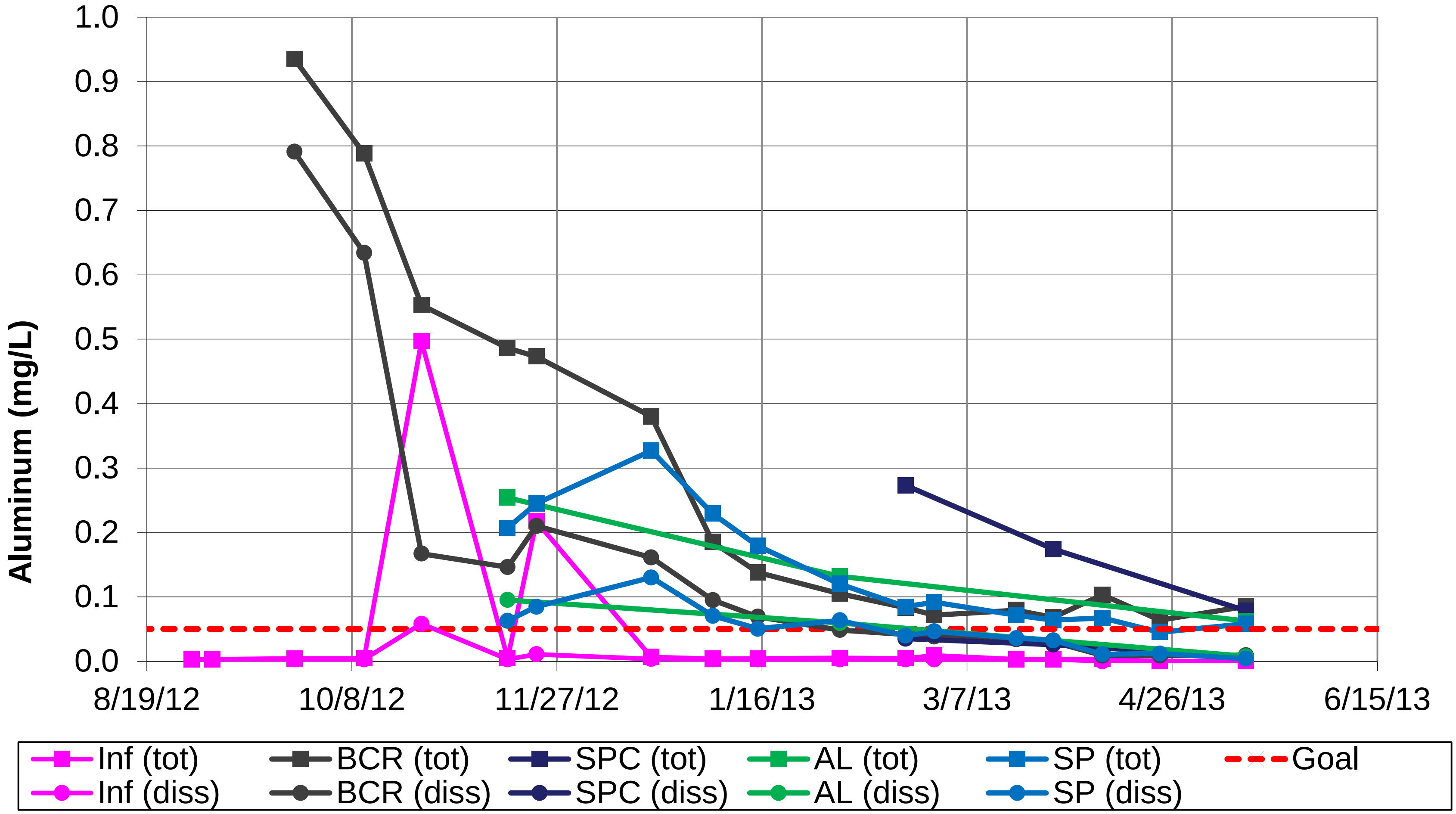
Demonstration System Preliminary Operation – Arsenic (mg/L)



Demonstration System Preliminary Operation – Cobalt (mg/L)



Demonstration System Preliminary Operation – Aluminum (mg/L)



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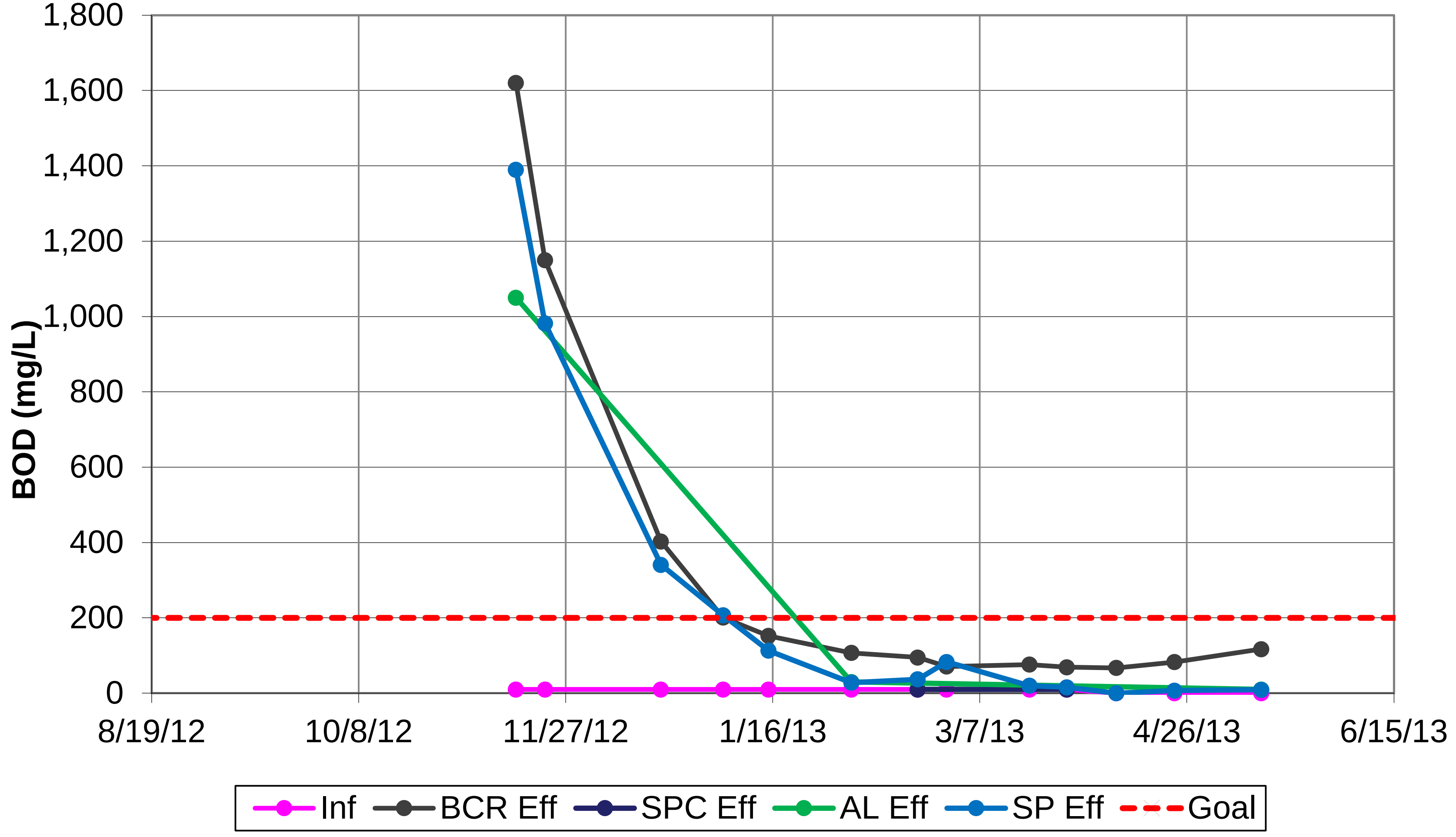
Demonstration System Preliminary Operation – Biochemical Oxygen Demand (mg/L)



Path Forward – Part 1

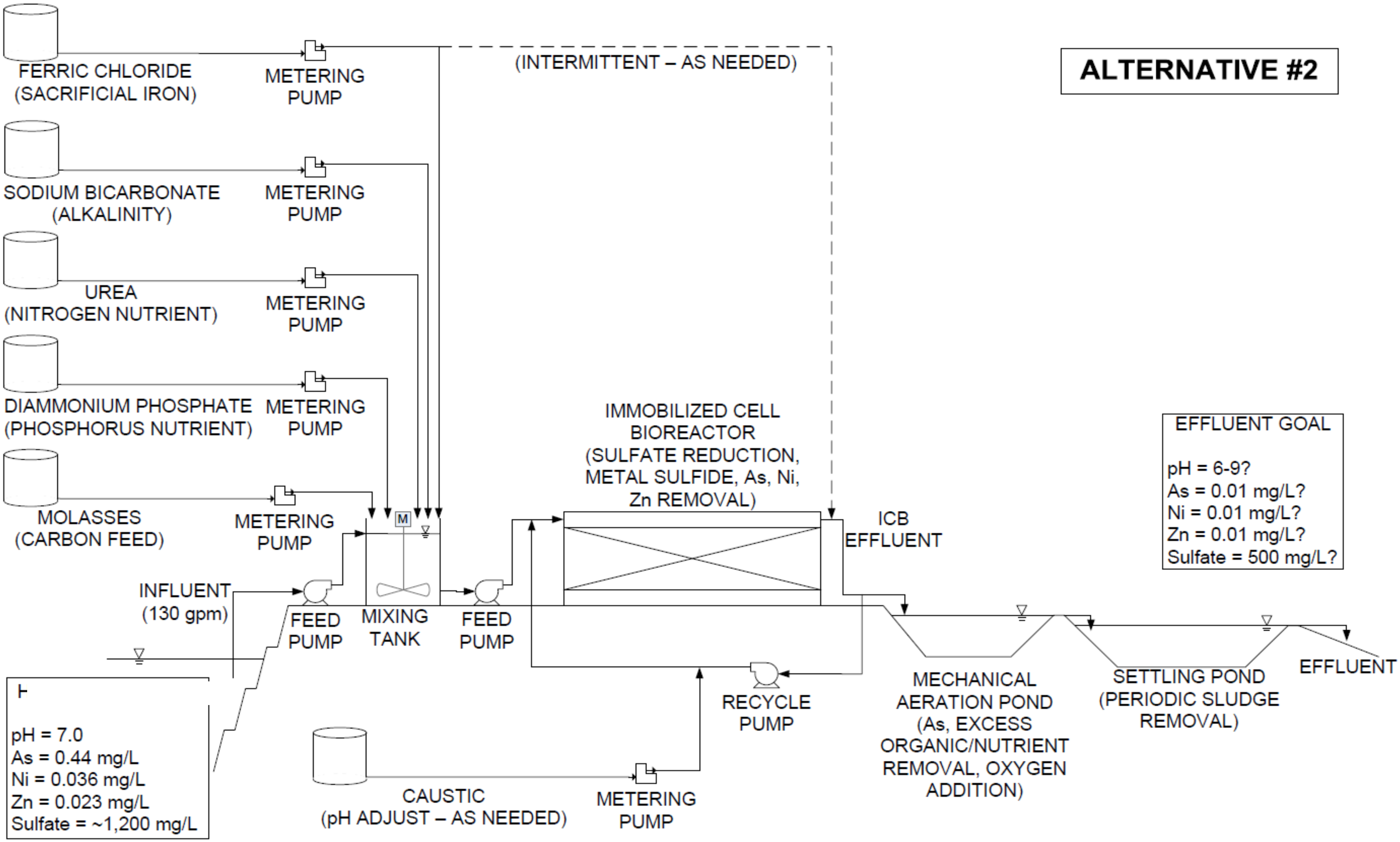
- Allow demonstration system to operate through end of 2013
- Monitor data as SPC flush completes and adjust operation as necessary
  - Potentially bypass a portion of the flow around the BCR
  - Potentially bypass a portion of the flow around the SPC
  - Adjust flow rate and resulting hydraulic retention time
- Use data from demonstration system to design full scale system
- Construct full scale system in summer 2014 or summer 2015

Path Forward – Part 2

- Operate system indefinitely
  - Drop water level in underground workings to dry up seep
  - Continue operations to maintain low water level in workings
  - Replace BCR substrate as-needed (10-20 yrs)
  - Replace SPC substrate as-needed (5-10 yrs)
  - Remove sludge from AL as-needed (5-7 yrs)

- Look for additional sites to implement/fine tune biological sulfate removal
  - 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)

Potential Future of Biological Sulfate Removal



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THANK YOU!

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