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Tulsequah Chief Passive Bioreactor

17th Annual BC-MEND ML/ARD Workshop

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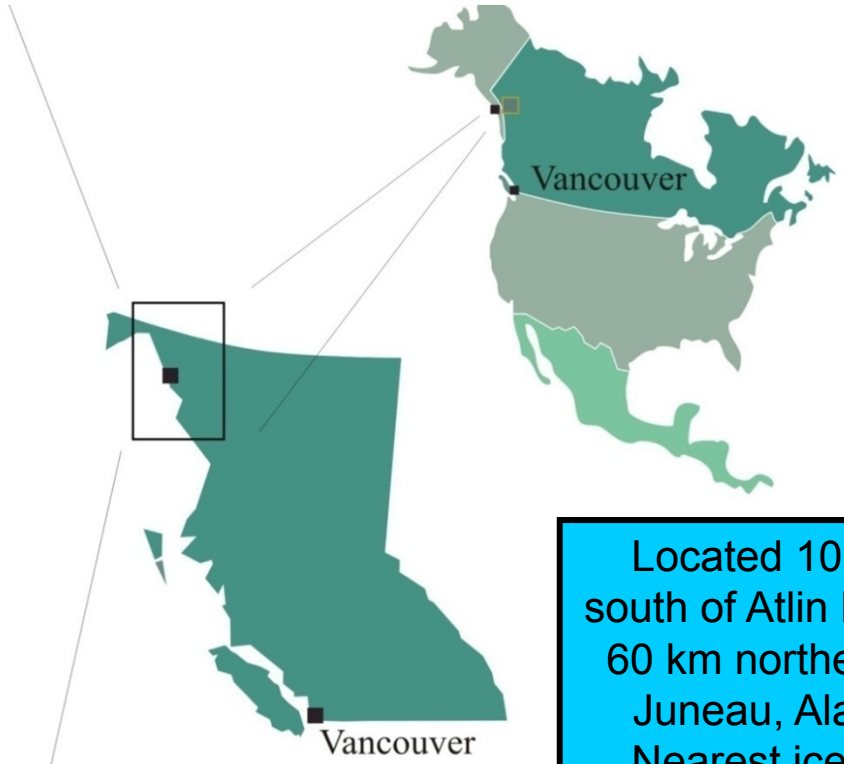
Tulsequah Chief Passive Bioreactor

- Site History and Characteristics
- Laboratory and Field Studies
- Passive Bioreactor
- Conclusions

Project Location



Located 100 km south of Atlin BC and 60 km northeast of Juneau, Alaska. Nearest ice-free concentrate port is Skagway, Alaska.

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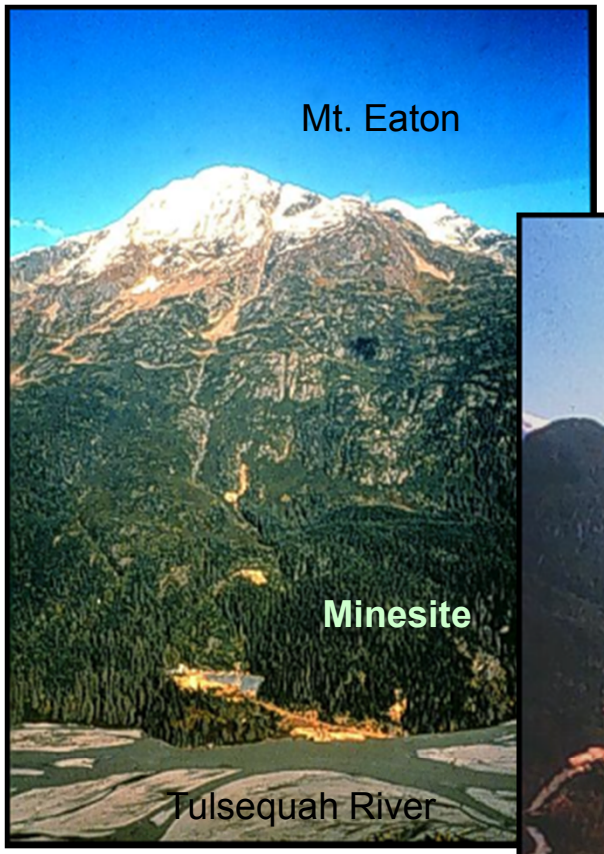
Tulsequah Chief Mine Site



LOOKING EAST

LOOKING NORTH

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Early Project History

- Tulsequah Chief occurrence discovered in 1925.
- Polaris-Taku Mine produced from 1937 to 1951.
- Tulsequah Chief mined from 1951 to 1957 by Cominco Ltd.

- Ore from Tulsequah Chief trucked across the valley to Polaris-Taku for milling.
- Ore concentrate then barged out during summer months on Taku River.
- 580,256 tonnes was mined from Tulsequah Chief at a rate of 480 tonnes per day.

Former Tulsequah town site at Polaris-Taku mine

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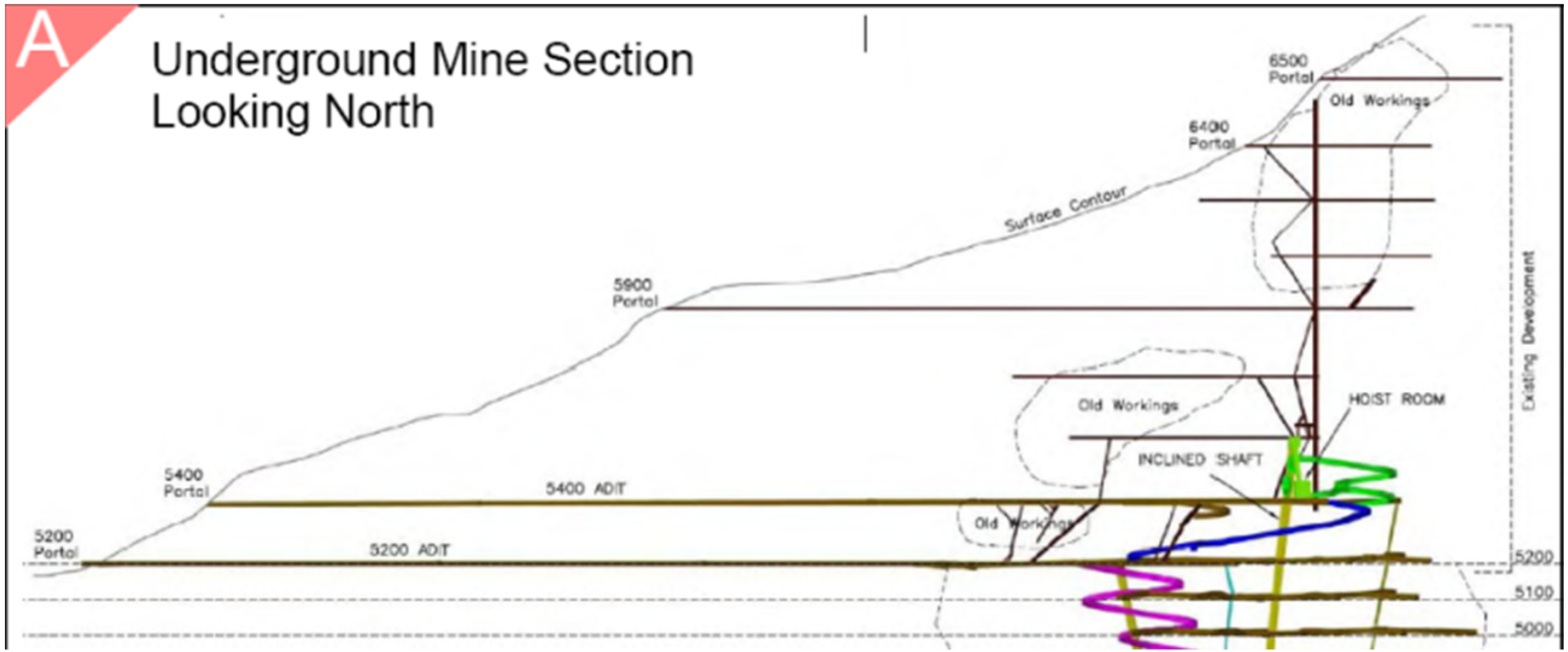
Historic Workings



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Mine Workings – 5200 level drift

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Historic Water Quality

- Portal discharge water is a combination of acidic adit water and neutral groundwater
- Average acidic adit water quality is approximately an order of magnitude worse than portal drainage

Parameter	Acid Water	5200 Portal
pH	2.8	3.1
Al	76	14
Cd	1.5	0.3
Cu	126	16
Fe	320	42
Zn	335	64

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Recent Project History

- EC applied an Inspector's Direction on July 12, 2002 requiring the treatment of discharge from the site.
- Redfern began investigating water treatment options in 2003 and commissioned a limestone/SRB-bioreactor in 2005.
- In July 2005, the *CEAA* screening amendment process concluded that the project was unlikely to produce any significant environmental impacts and could proceed to the permitting stage.
- Redfern raised funds to start development in 2007 but was forced in to receivership in 2009.
- Chieftain Metals acquired the property in 2010.

Laboratory Studies

- Treatment system needed to address many site challenges
  - System must be simple
    - construction cannot require heavy materials or equipment
  - Operation will be unattended, especially for 3-6 months during winter
  - Temperature is an important factor
  - High metal concentrations will produce substantial sludge volume
- Focussed efforts on limestone-SRB treatment concept
  - Limestone bed will neutralize acidity and remove Al, Fe
  - SRB cell will produce sulfide to remove rest of metals (Cd, Cu, Pb, Zn)
- Laboratory designed to produce proof-of-concept

Laboratory Studies

- Initial column study with limestone and wood chips
  - Limestone neutralized acid water within 6 hours
  - Wood chip decomposition did not support SRB activity at 8ºC
  - Did not address metal removal

- Evaluated synthetic plastics to support SRB activity
  - Plastics tested included polybutylene, polycaprolactone, polyhydrobutyrate
  - Added plastics in serum bottles
  - Inoculated with Tulsequah bugs
  - Measured HS^- production at 8 and 26ºC

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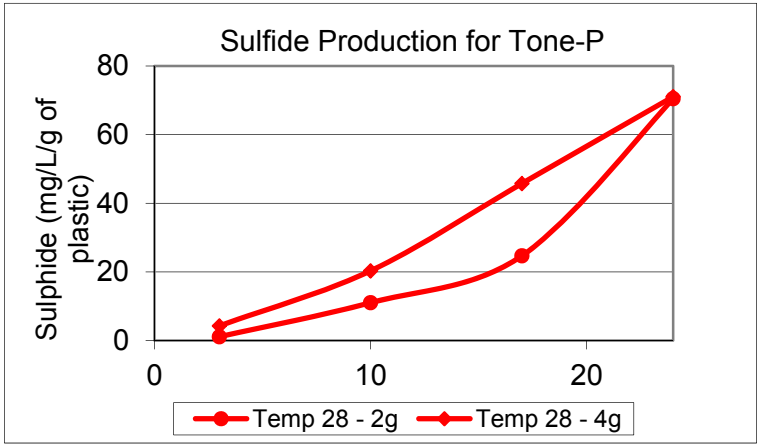
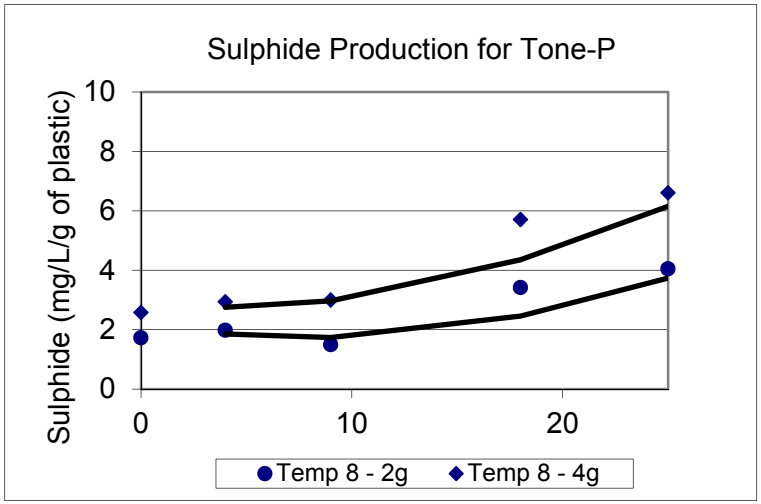
Laboratory Studies

- Sulfide production from plastics
  - Plastics were tested at 8 and 26ºC
  - Sulfide production slow, but possible at 8ºC
- Rate of production compared with mulch/ethylene glycol
  - Plastic: 0.011 mg HS^-/5g/d
  - Mulch/EG: 0.78 mg HS^-/5g/d
- Mulch/Ethylene glycol is superior





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Pilot-scale Bioreactor Study

Evaluated limestone-SRB concept at mine site

- Identified space inside the 5200 level adit for bioreactor
  - Test at ambient (6-7ºC) temperature
  - ARD can be piped passively to bioreactor
- Developed a 4-cell vertical flow reactor in a 10 m^3 crib
- Formulated limestone-SRB medium
  - Located source of limestone near mine site
- Isolated and grew SRB culture from site
- Obtained wood chipper to produce mulch

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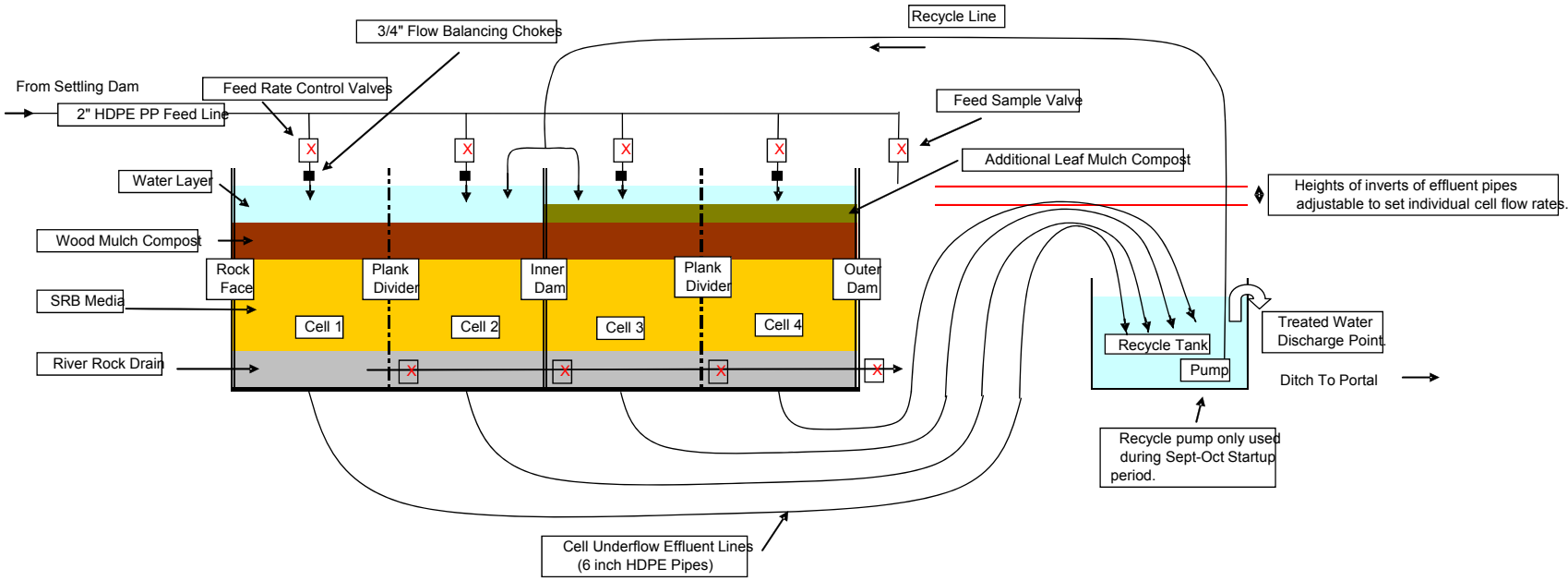
Pilot-scale Bioreactor Study

Schematic of Pilot Plant Design



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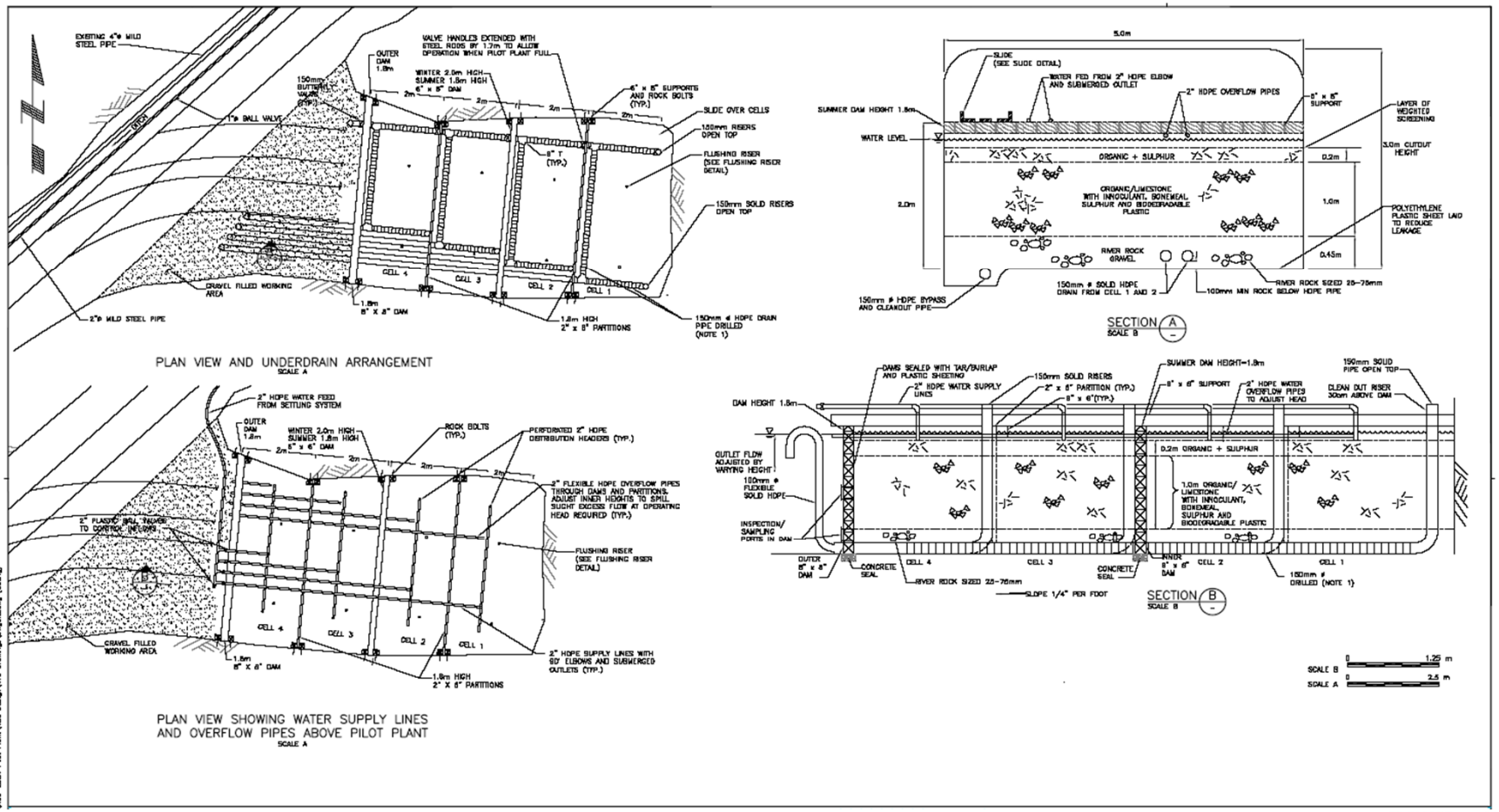
Pilot-scale Bioreactor Study

As Built, Pilot Water Treatment Plant



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Pilot-scale Bioreactor Study

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Pilot-Scale Bioreactor

Pilot-scale Bioreactor Trial

- ARD fed at ~ 0.25 L/s
- Temperature, flow, and pH monitored daily
- Later, DO/ORP monitored as additional parameter
- Samples taken weekly from inflow/effluent for metal concentrations
- Later, monitor for hydrogen sulfide

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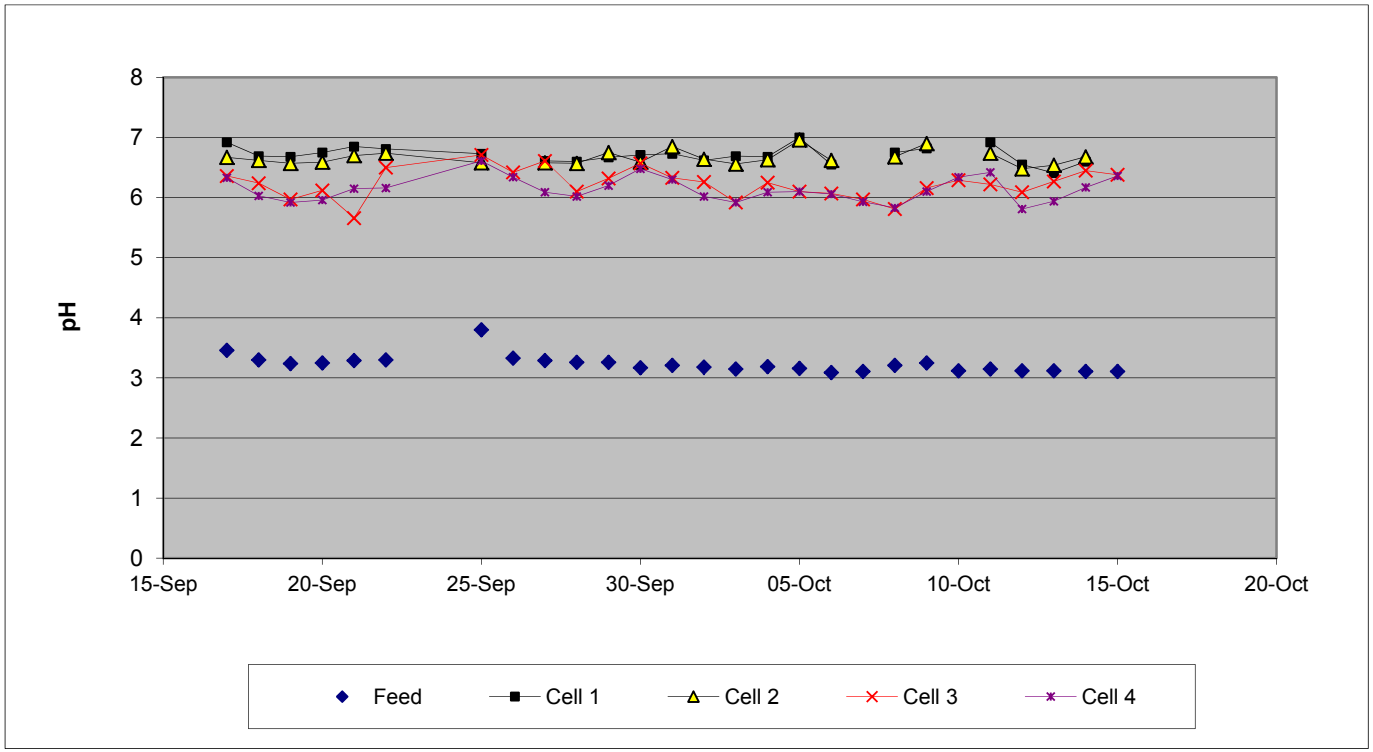
Pilot-scale Bioreactor Trial – Results



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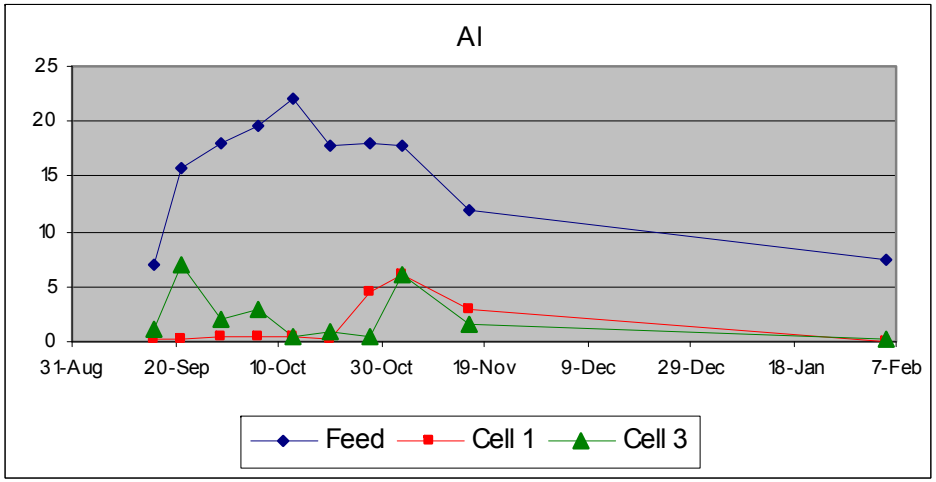
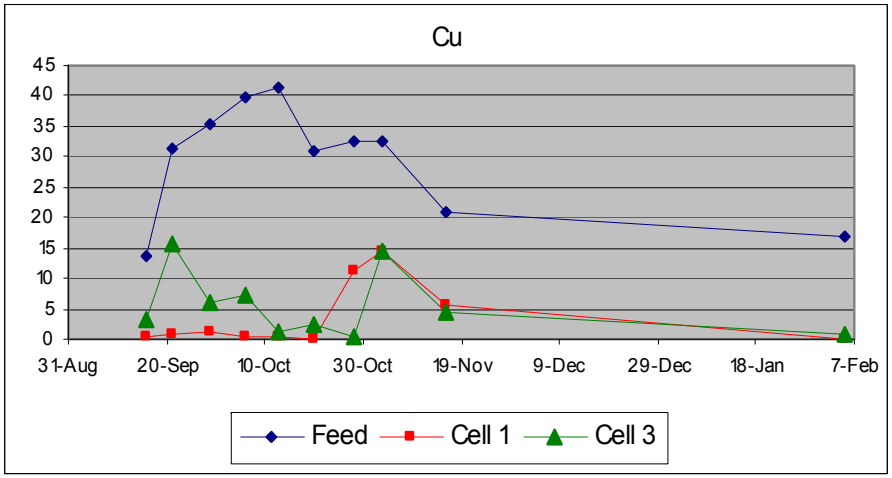
Pilot-Scale Bioreactor

Pilot-scale Bioreactor Trial – Al, Cd and Cu

- Aluminum removed by >90%
- Copper is removed by 80%





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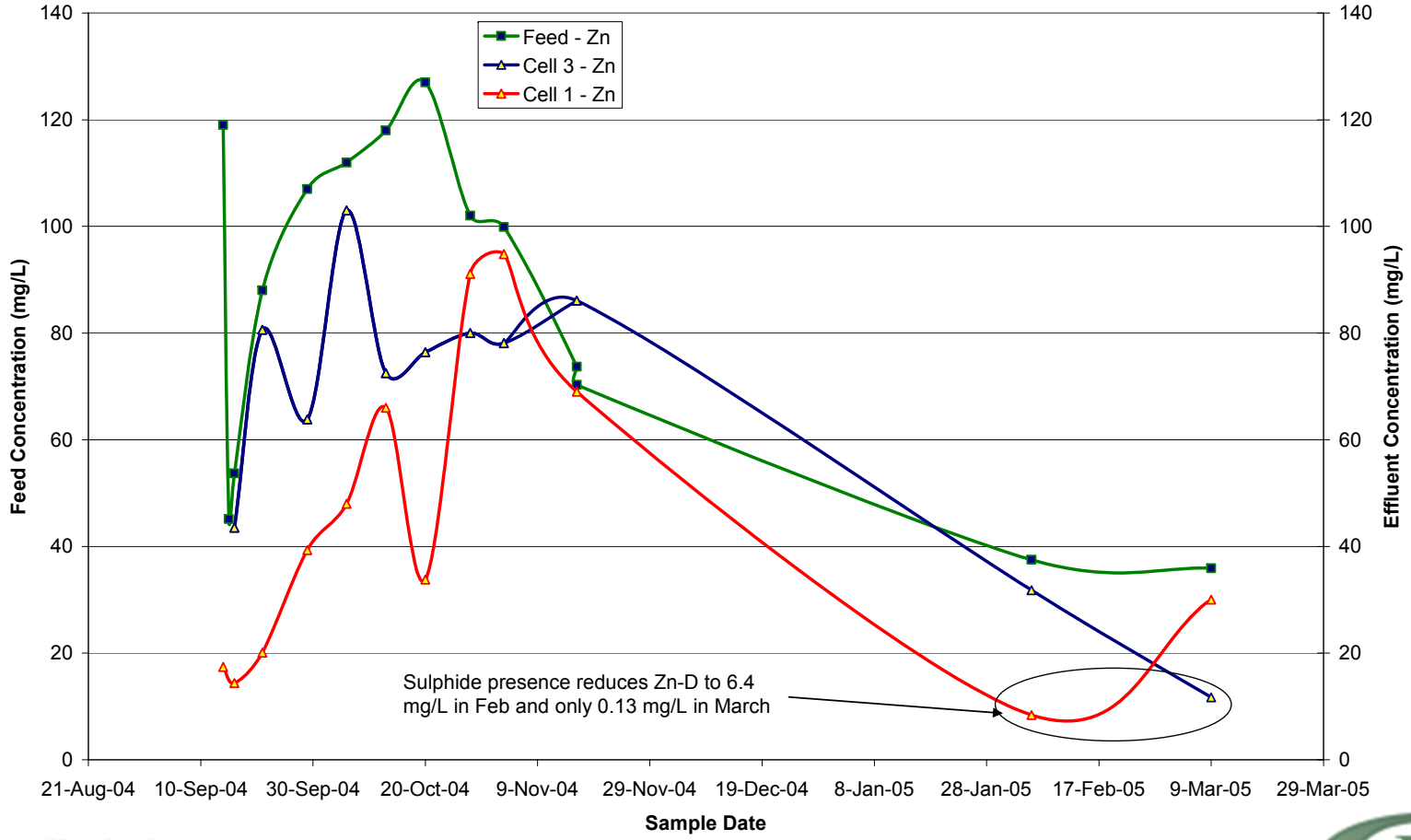
Pilot-Scale Bioreactor

Zinc

Pilot Plant Performance Monitoring
Figure 5 - Zinc in Feed, Cell 1 and Cell 3 Effluent



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Pilot-scale Bioreactor Trial – Underdrain inspection

Pilot-Scale Bioreactor

Pilot-scale Bioreactor Trial – Sludge Accumulation

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Pilot-Scale Bioreactor

Pilot-scale Bioreactor Trial – Bioreactor deconstruction

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Pilot-scale Bioreactor Trial – Bioreactor deconstruction

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Pilot-scale Bioreactor Trial – Bioreactor deconstruction

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Pilot-scale Bioreactor Trial – Bioreactor deconstruction

Sludge Composition (g/kg)

Sample	Al	Cd	Ca	Cu	Fe	Mg	Pb	Zn
Washed sludge	48.0	0.438	24.2	26.3	81.7	12.9	0.256	54.0
Underdrain Sludge	51.8	0.434	11.7	29.0	68.5	6.01	0.321	137

Scale up

Key Factors:

- Hydraulics
- Residence time
- Iron control

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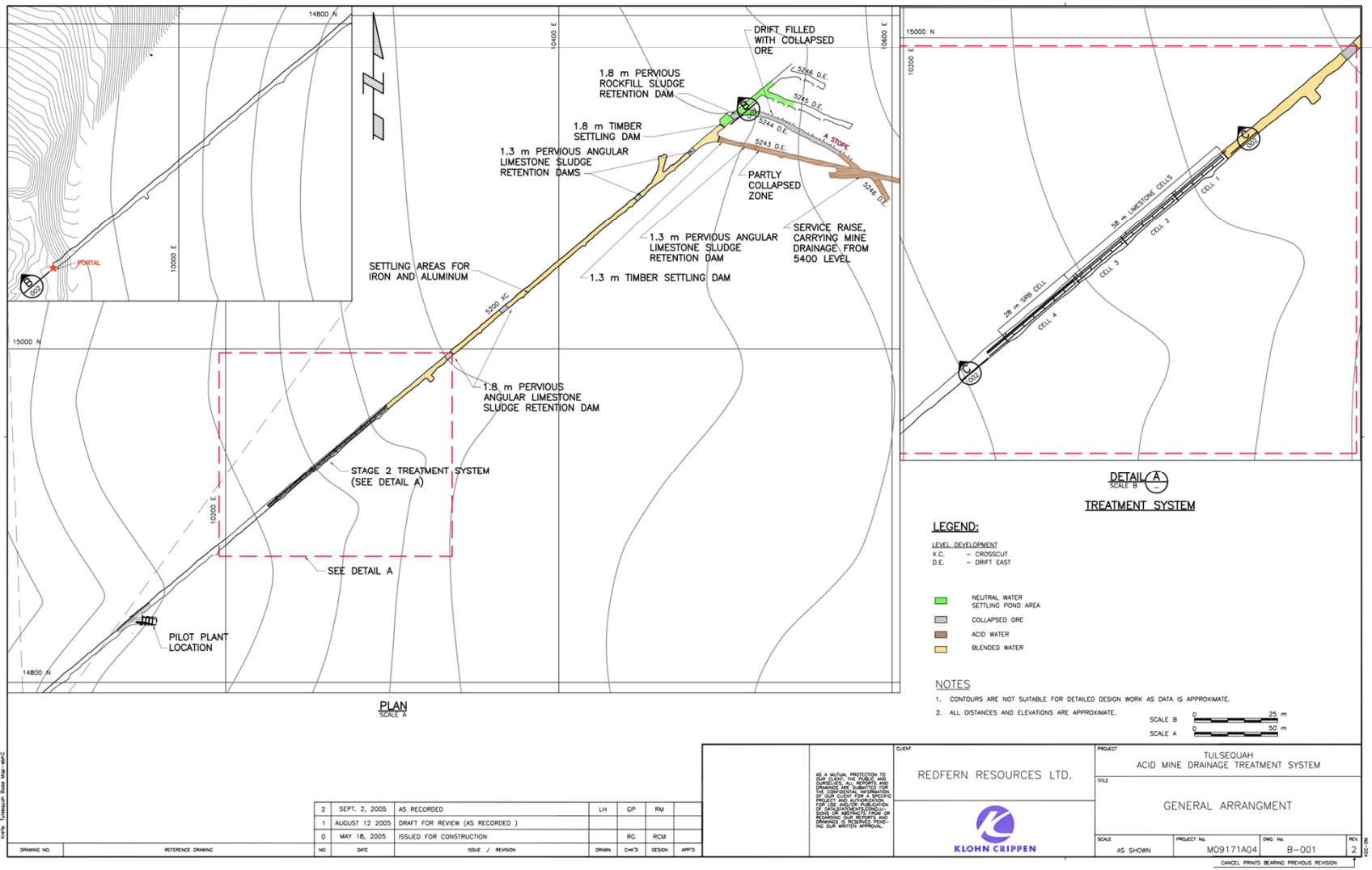
5200 Level Plan



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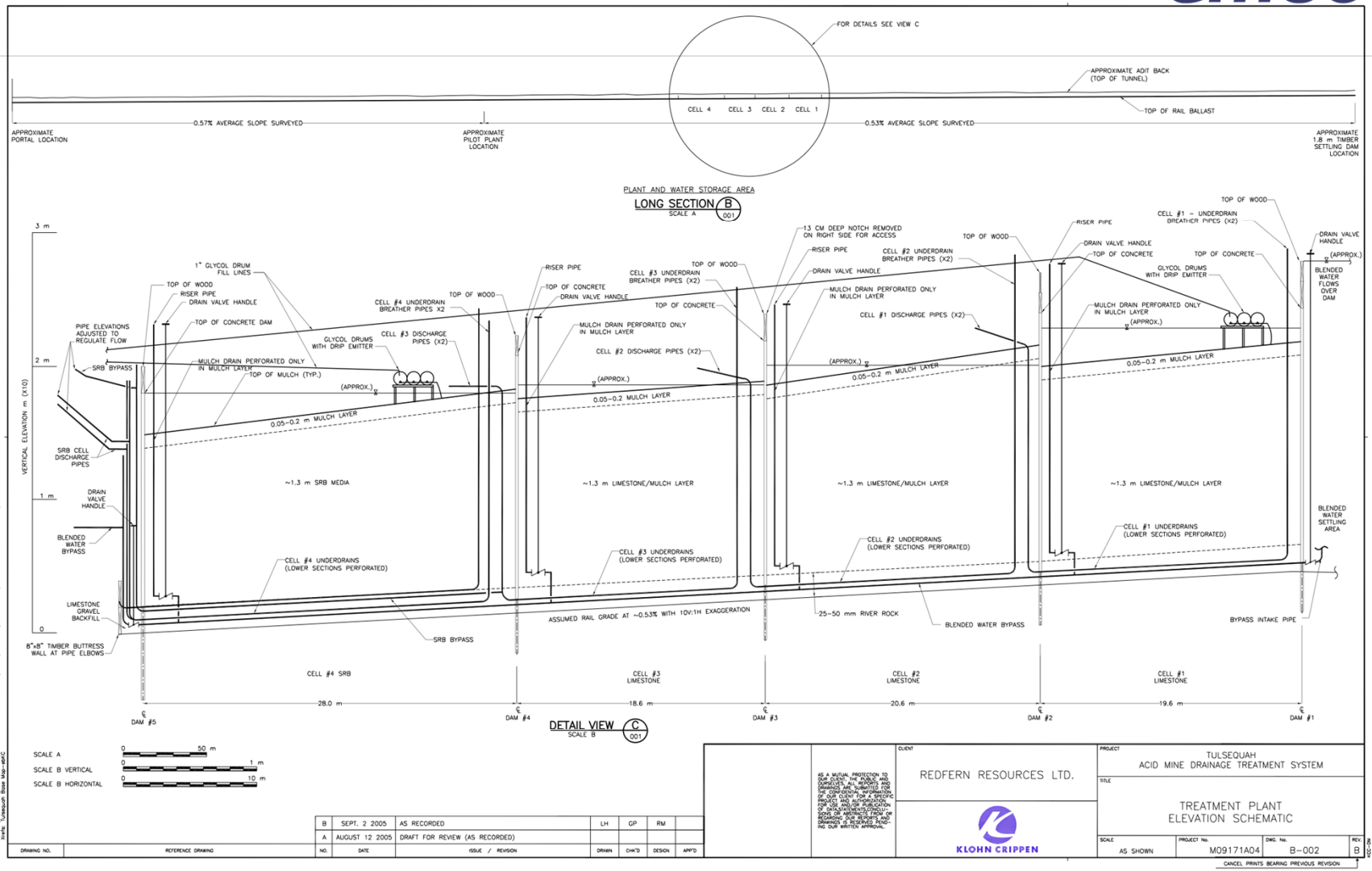
Design – Long Section showing Drain System



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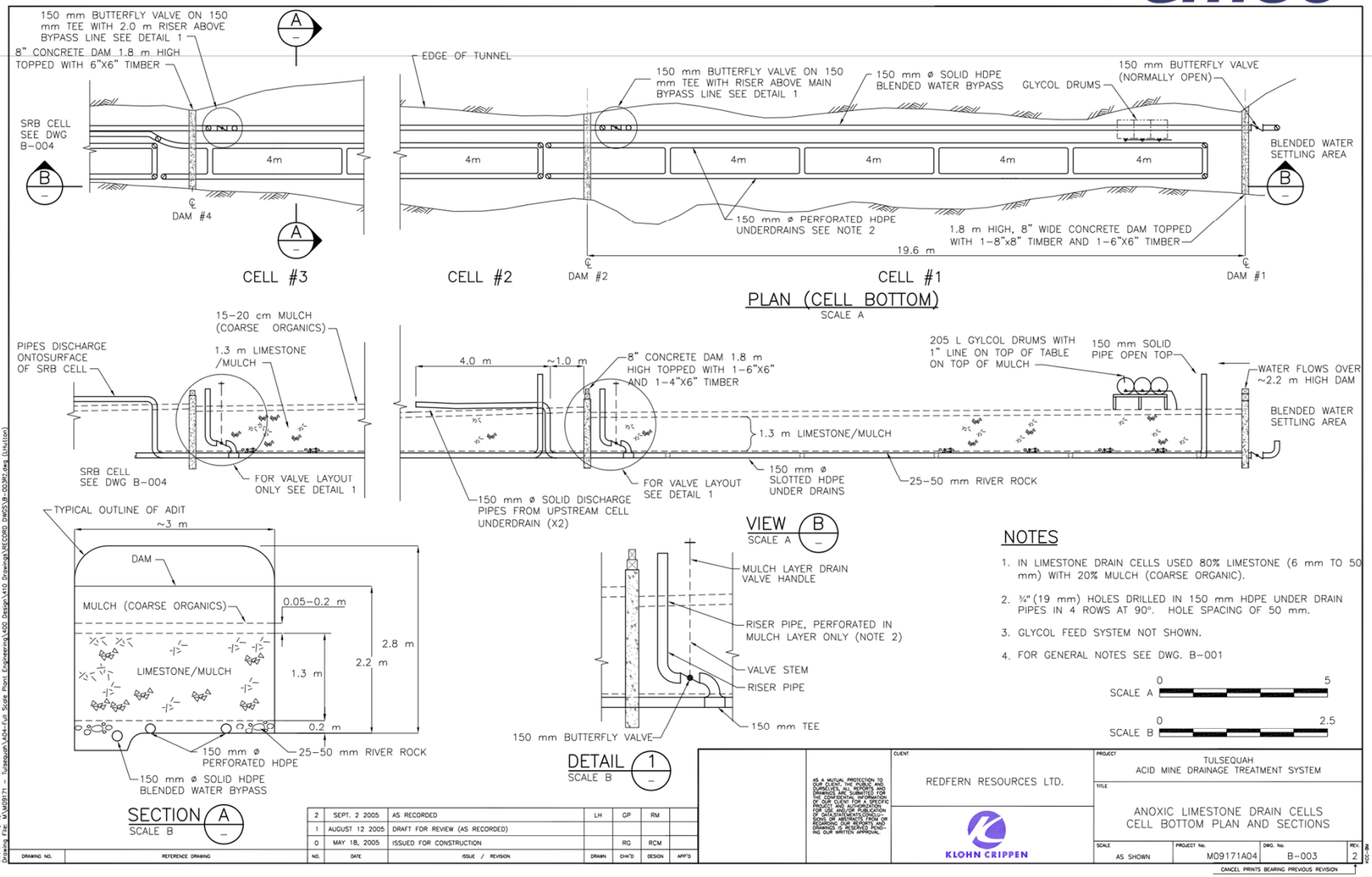
Design – Fill Materials



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Construction

- Install and close margo plugs
- Develop end dump car
- Place limestone berms

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Construction

- Concrete forming and pouring for end walls

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Construction

- Installing underdrain pipes and risers
- Placing drain rock

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Operations – NaOH Pre-treatment

- Prepared 25% NaOH drip solution
- Used metering pump powered by 80 W microhydro

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Operations and Monitoring

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Operations - Flow Control and Monitoring

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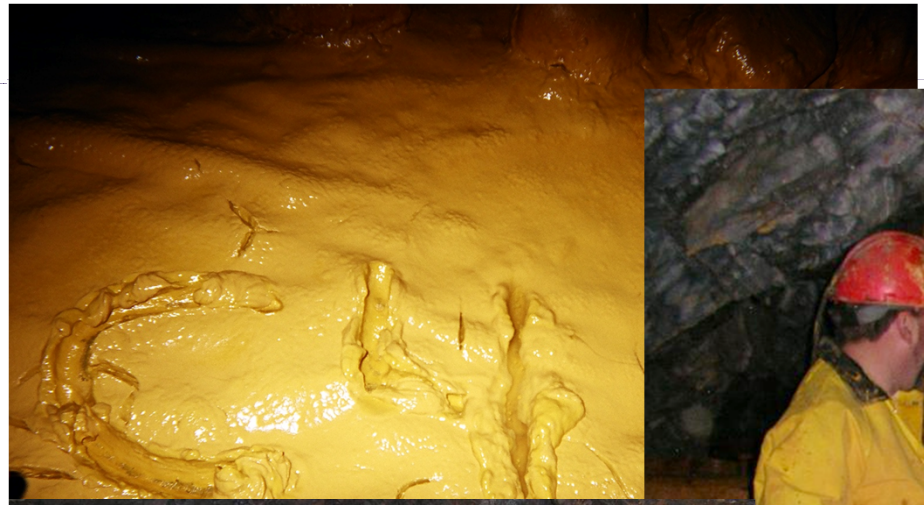
Maintenance – “Dirty Jobs” winner



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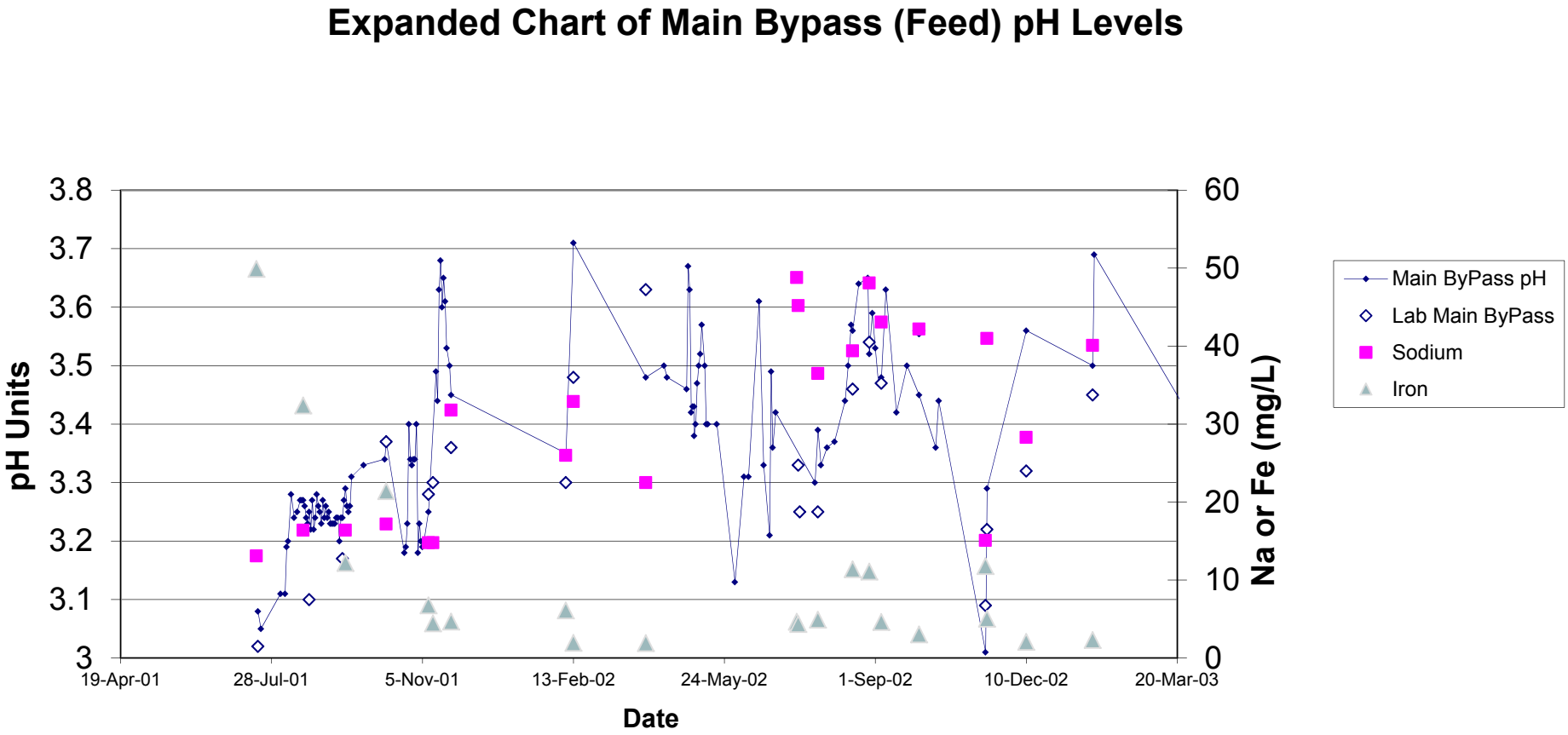
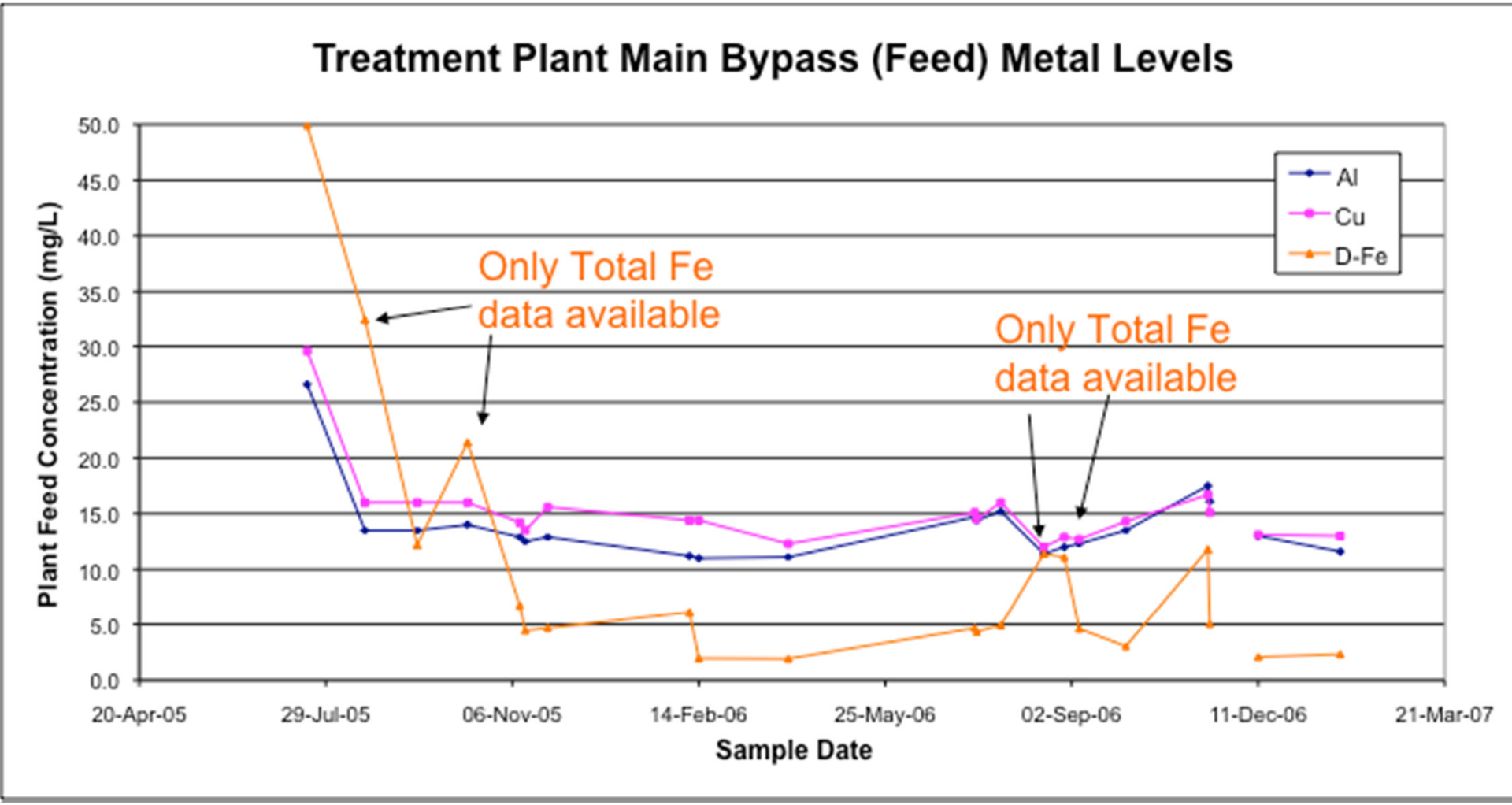
Results – Pre-treatment pH and Fe



Results – Pre-treatment Metals



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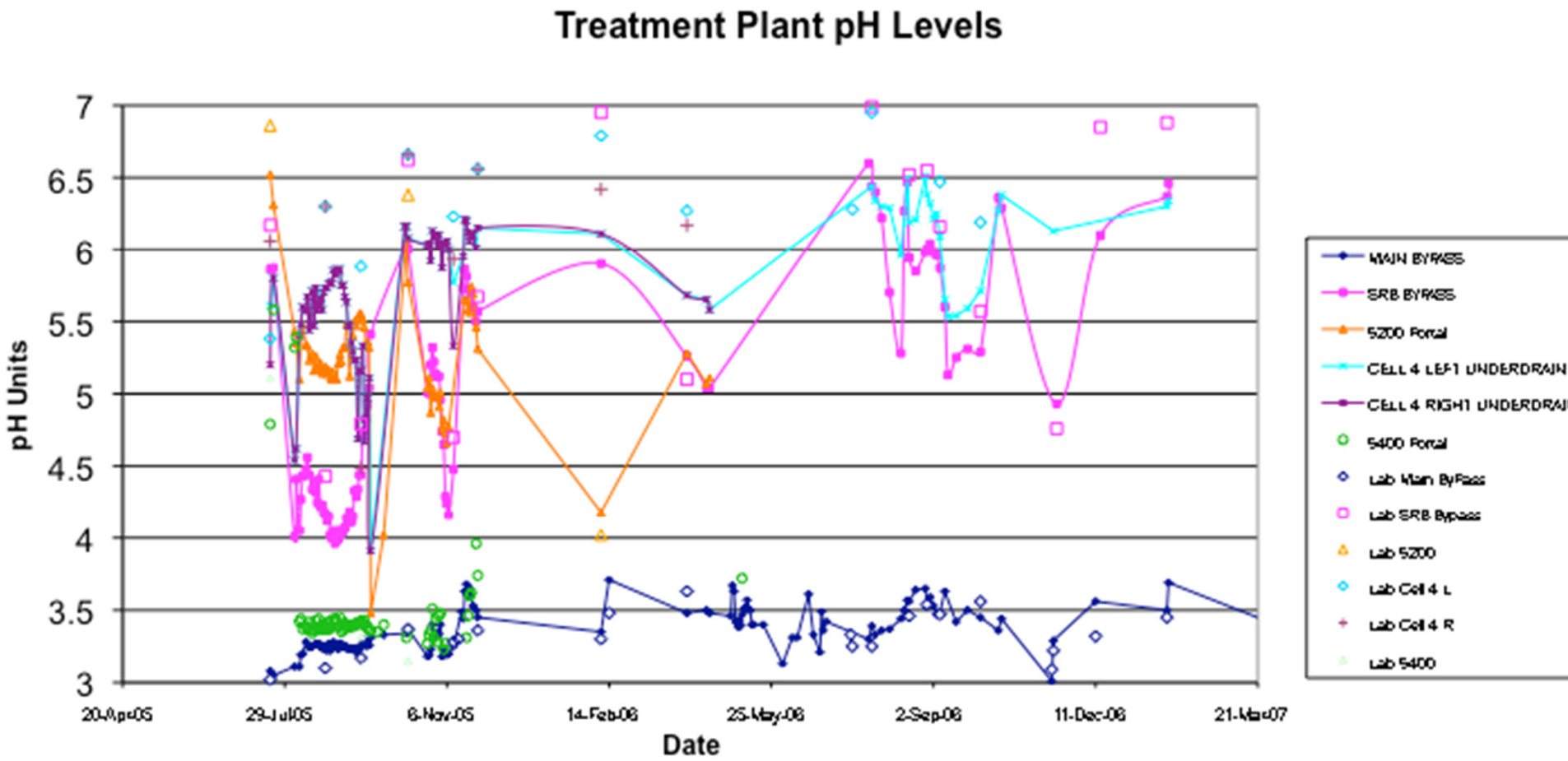
Results – Treated pH



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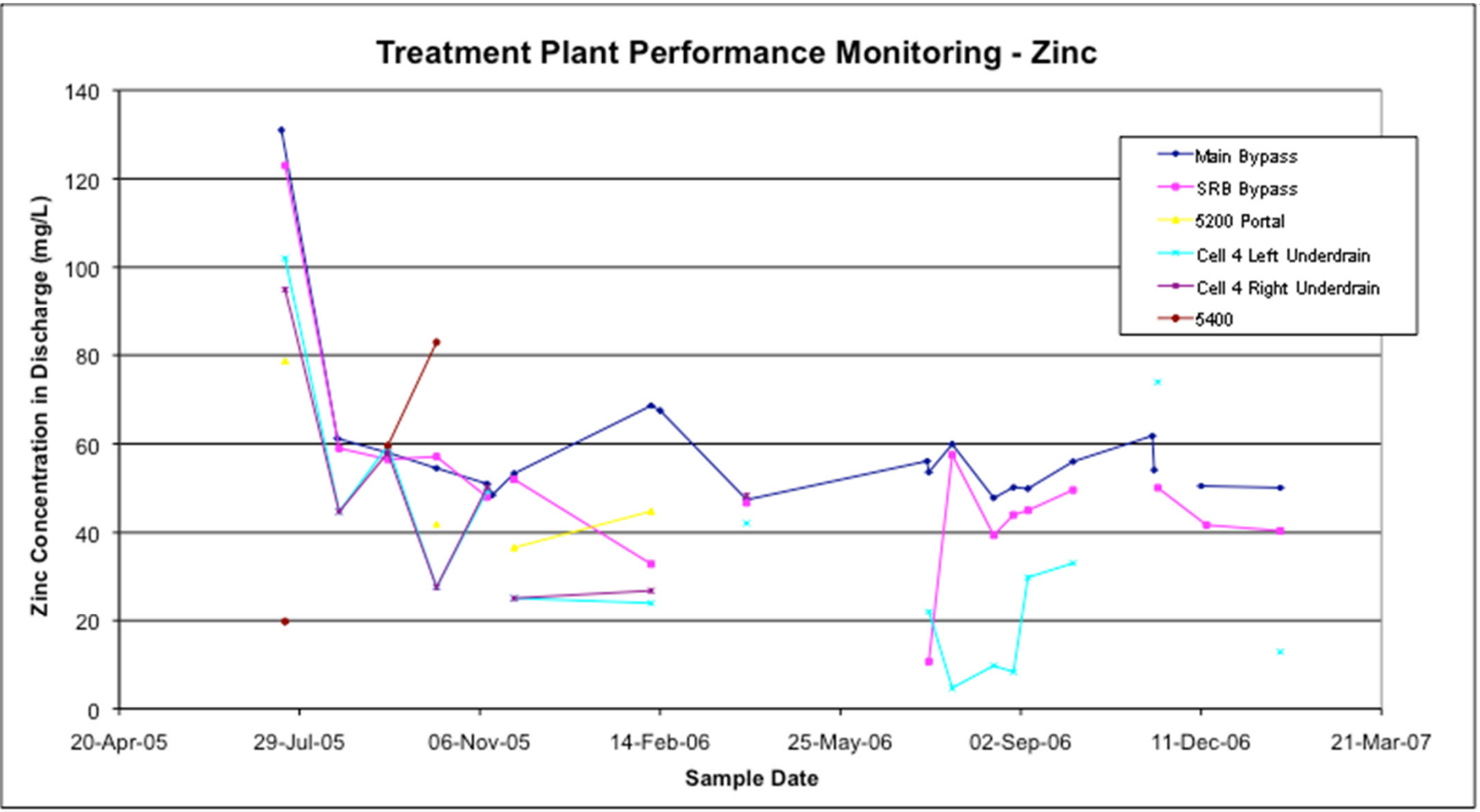
Results – SRB Zn



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Conclusions

- Succeeded in achieving unattended metals removal with a passive system while exploration proceeded
- The system operated without major maintenance for over 1 year
- SRB performance was demonstrated

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