Brewery Creek Mine

From Assessment and Permitting through Production, Closure, and Reclamation

A Post Closure Analysis of a Northern Heap Leach Mine

Presentation Outline

- Mine Overview and History
- Assessment and Regulatory Processes
- Study Components
  - Leach Pad and Pond Design and Leakage Rates
  - Solution Management
  - Heap Detoxification
  - Heap Leach Soil Cover
  - Revegetation
  - Receiving Water Quality and Stream Sediment Impacts
  - Security costs
- Conclusions

Brewery Creek Mine Highlights

- Open pit, oxide deposits
- Conventional cyanide heap leach gold mine
- 10 small open pits
- Active mining operations 1996 – 2000. Total of 9.5 mt ore mined and 14.7 mt overburden
- Planned for 15 mt ore over 8 years
- Discrepancy due primarily to depressed markets
- Production of ~280,000 ounces Au to date
- Reclamation, ongoing water management, monitoring, 2002-present

Mine Facilities

- Office/Maintenance Area
- Open Pits
- Heap Leach
- Carbon adsorption/desorption/recovery facility (ADR Plant)
- Process ponds
- Overflow pond


View during active mine operations - 1999
Kokanee/Golden/Lucky
Moosehead
Fosters
Canadian
Blue
Pacific
Administration/Camp/Shop
Laura Creek
Leach Pad
Process Facilities

Brewery Creek Mine History

- First staked in 1987
- Construction began in 1995
- Production ran from 1996-2000
- Mining ceased Sept 2000
- Leaching of the heap ceased December 2001
- Active heap detox completed in 2nd and 3rd quarters of 2002
- Reclamation on-going

Type A Water Licence History

- Water Licence QZ94-003 issued August 1995, replaced by QZ96-007 issued in August 1997;
- 7 Amendment Applications:
  - May 1999 - QZ98-032, extend the DRP submission date;
  - June 1999 - QZ98-038, revise leach pad liner design;
  - October 1999 - QZ98-038, revise pad cushion specifications;
  - June 2002 - QZ01-050, leach pad land application system;
  - November 2002 - QZ02-056, revise security payment;
  - March 2004 – QZ03-060, site specific selenium criteria, and
  - March 2005 – QZ03-062, closure standards

Assessment History

- First screened under Environmental Assessment and Review Process Guidelines Order (EARP)
- Subsequent Water Licence amendments reviewed under:
  - –Canadian Environmental Assessment Act (CEAA),
  - –Yukon's Environmental Assessment Act (EAA), and
  - – Yukon Environmental and Socio-economic Assessment Act (YESAA)

Leach Pad and Pond Design and Leakage Rates

- Liners installed for the heap, process ponds and overflow pond
- Leak Detection Recovery System installed for heap and process ponds
- Different system for each

Heap Liners:

- a 0.6 to 1 m of crushed ore as a cushion layer:
- a primary composite layer of 40 mil PVC geomembrane and 300mm of compacted silt;
- a geotextile filter and separation layer;
- a LDRS layer of 300mm of gravel; and
- a secondary composite layer of 30 mil PVC and 300mm of compacted silt

Leach Pad and Pond Design and Leakage Rates

- Installation errors in process ponds resulted in water in a diversion ditch bypassing the liner during freshet
- A broken seal in 2000 resulted in high volumes of water in process pond LDRS
- Testing confirmed it wasn't process water
- When back calculated to remove these volumes leakage rates were lower than anticipated

Leach Pad and Pond Design and Leakage Rates

Lessons Learned:

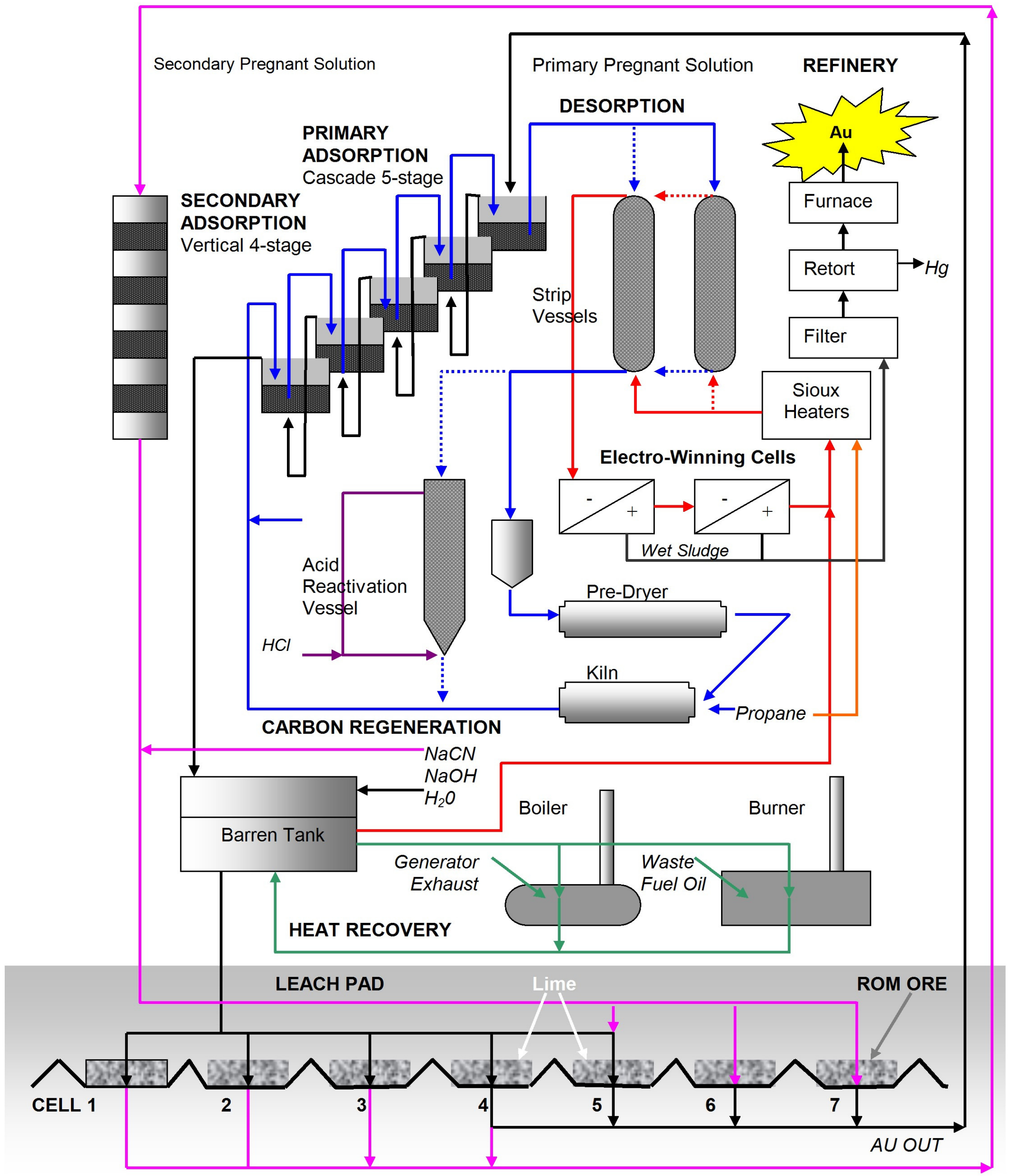
Emphasis on care during installation of liners

Liner and LDRS were effective

Solution Management – Heap Application

- Lower than expected recovery rates
- A second application circuit of the process water to the heap was added to increase solution concentrations

Figure 2 Heap Solution Process Flow Sheet

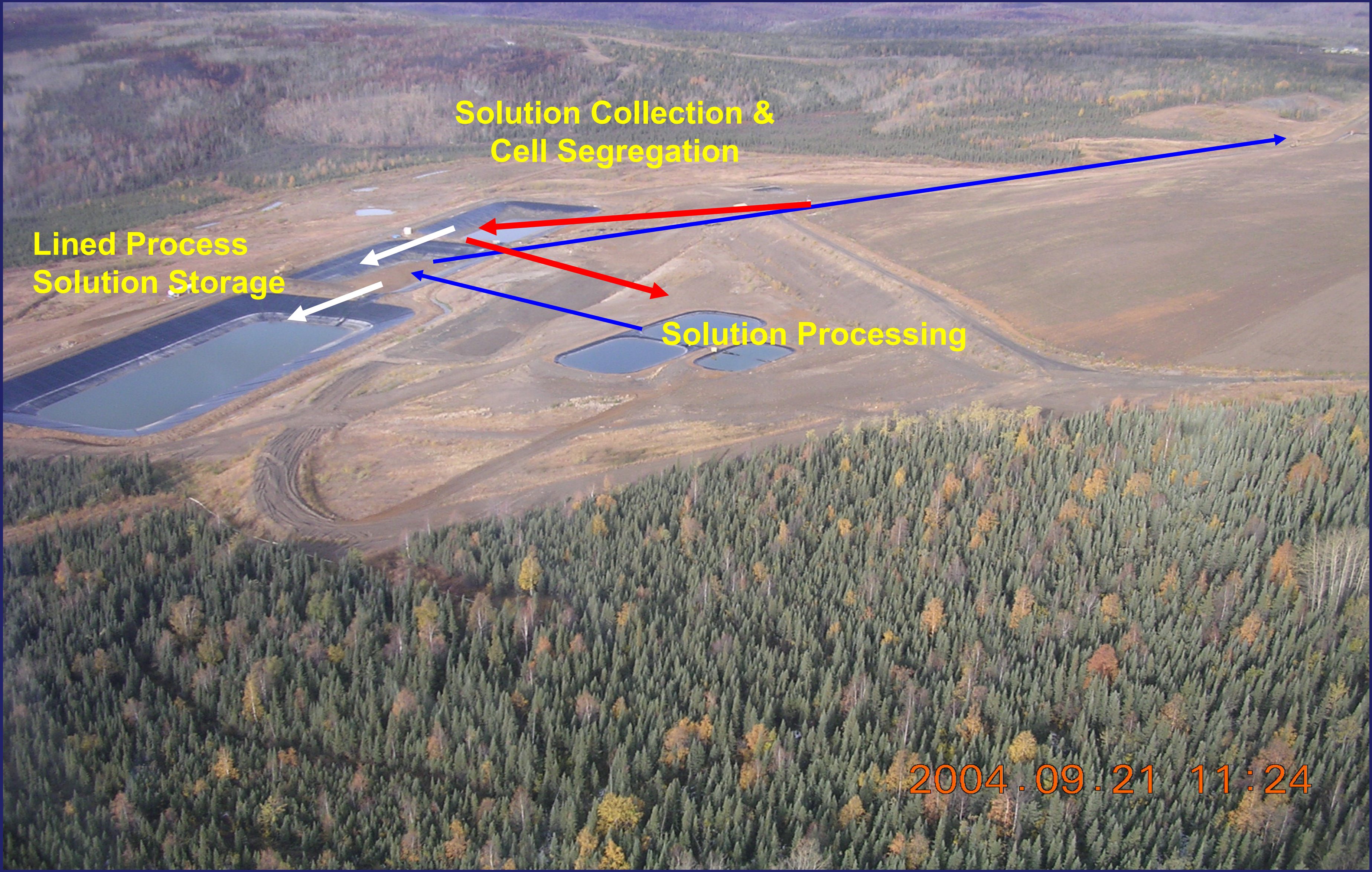


Solution Management – Process Ponds

- Initial plan was for pregnant and barren ponds to be used as storage prior to and after processing through the ADR plant

- Process water would then be recycled from barren pond and reapplied to heap

Solution Management Overview (Proposed)

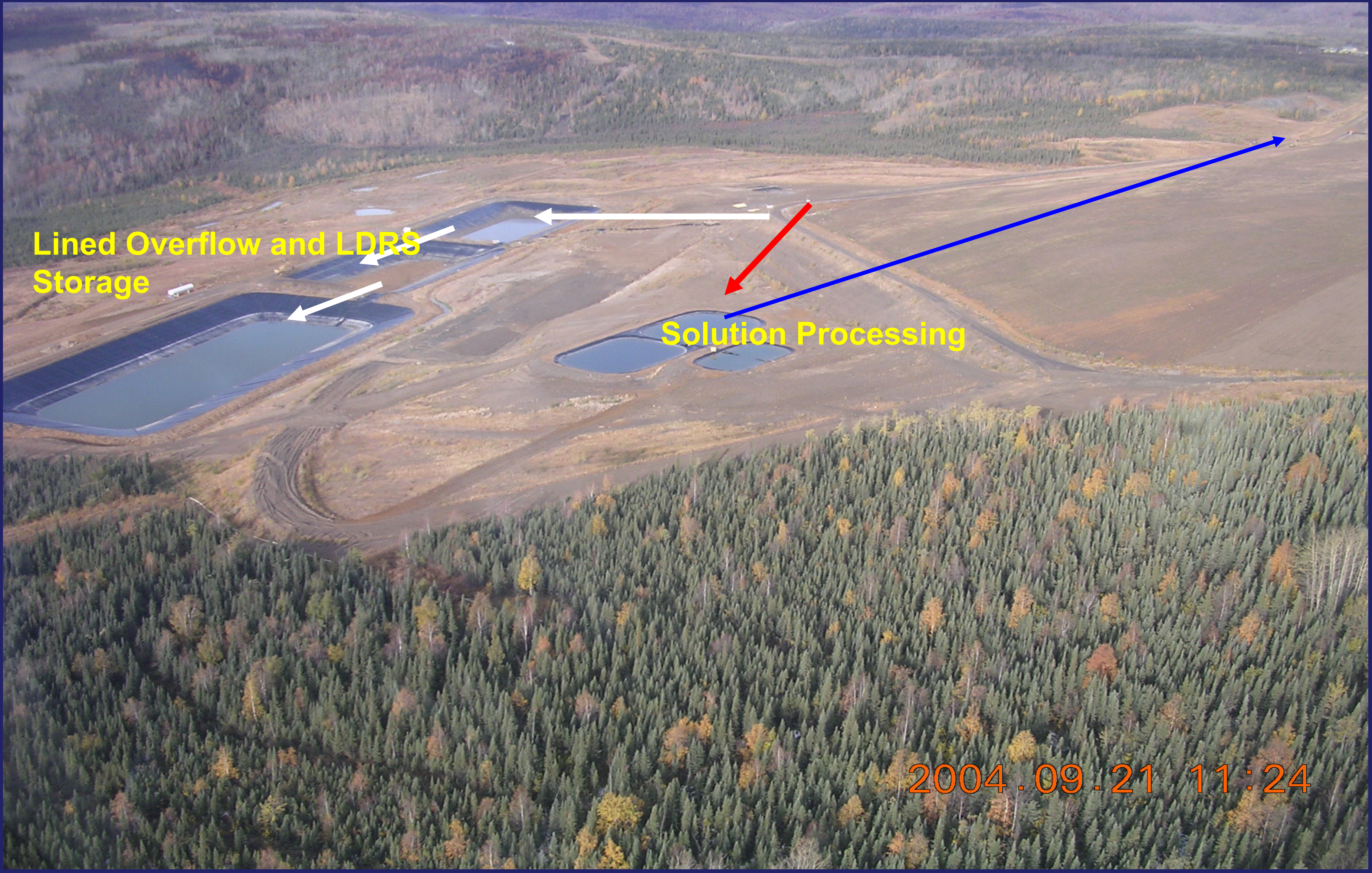


ACCESS

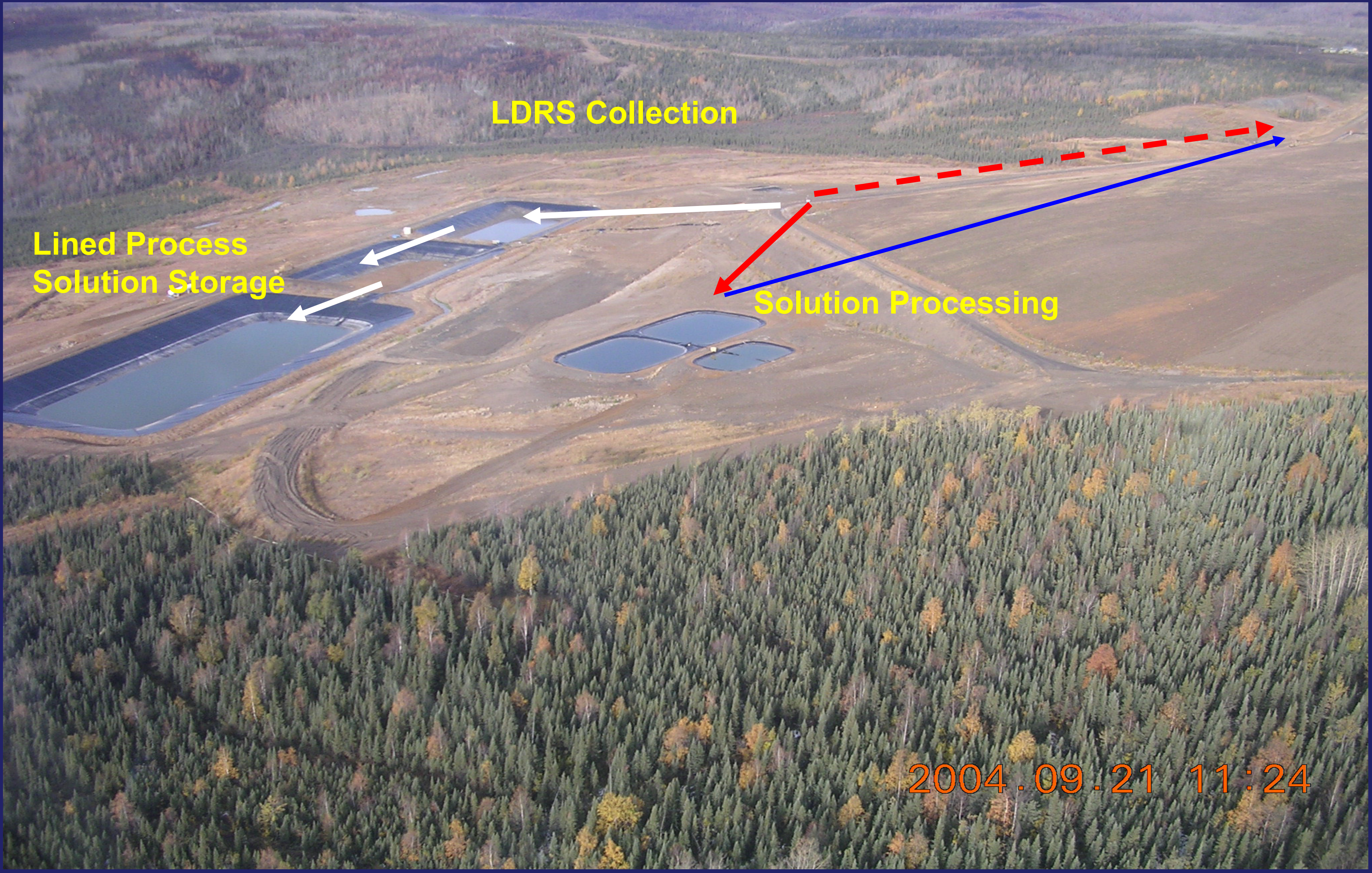
Solution Management – Process Ponds

Concerns over the process ponds freezing and low solution temperatures throughout the system resulted in a pumping system to bypass the process ponds

Solution Management Overview (Direct Pumpback)



Solution Management Overview (Direct Pumpback Second Circuit)



Solution Management – Solution Temperatures

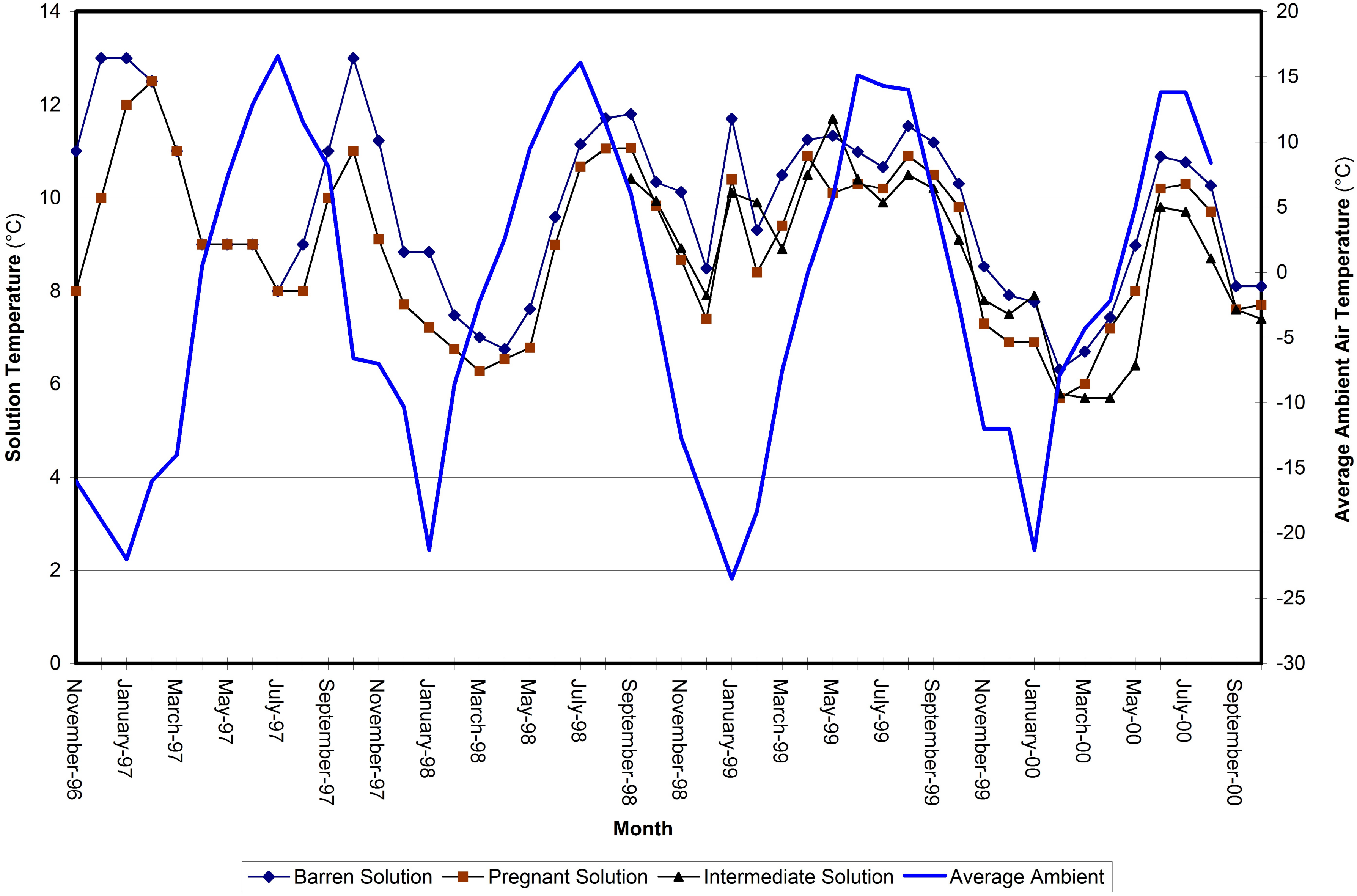
- Concerns during assessment that the solution could freeze within the heap over the winter
- Extensive temperature monitoring of the solution at every stage of the process was required

Solution Management – Solution Temperatures

Lessons learned:

- Temperatures stayed within a much tighter range than anticipated
- No real threat of freezing in the heap

Figure 3: Leach Pad Solution and Ambient Temperatures



Solution Management – Overflow Ponds

- Initial planning called for two overflow ponds for complete drawdown of the heap and 100 year peak precipitation event
- To be phased in as required over the life of the mine
- The information to calculate these was a relatively short duration baseline climatic data

Solution Management – Overflow Ponds

Lessons learned:

- Requirements were significantly less than anticipated
- Second overflow pond determined redundant due to expanded baseline weather data and reduced mine size and life

Heap Detoxification

- Reactive free cyanide is the driving force for instability in the heap.
- The destruction of reactive free cyanide remaining in the heap removes the driving force for mobilization of metals

Heap Detoxification

Initial planning called for fresh water rinsing

Various methods researched and tested for heap detox:

- natural degradation through continued recirculation,
- cyanide destruction with strong oxidizers such as hydrogen peroxide, and
- detoxification through biological processes

Heap Detoxification

Biological processes

- With the in-situ bacteria detoxification process, a supply of nutrients consisting of sugars, alcohols, fats and proteins was designed and mixed based on the specific nature and level of contaminants in the Brewery Creek process solution

Heap Detoxification

Heap cyanide destruction and metals stabilization

Heap draindown and effluent solution release

Secondary contingency measures

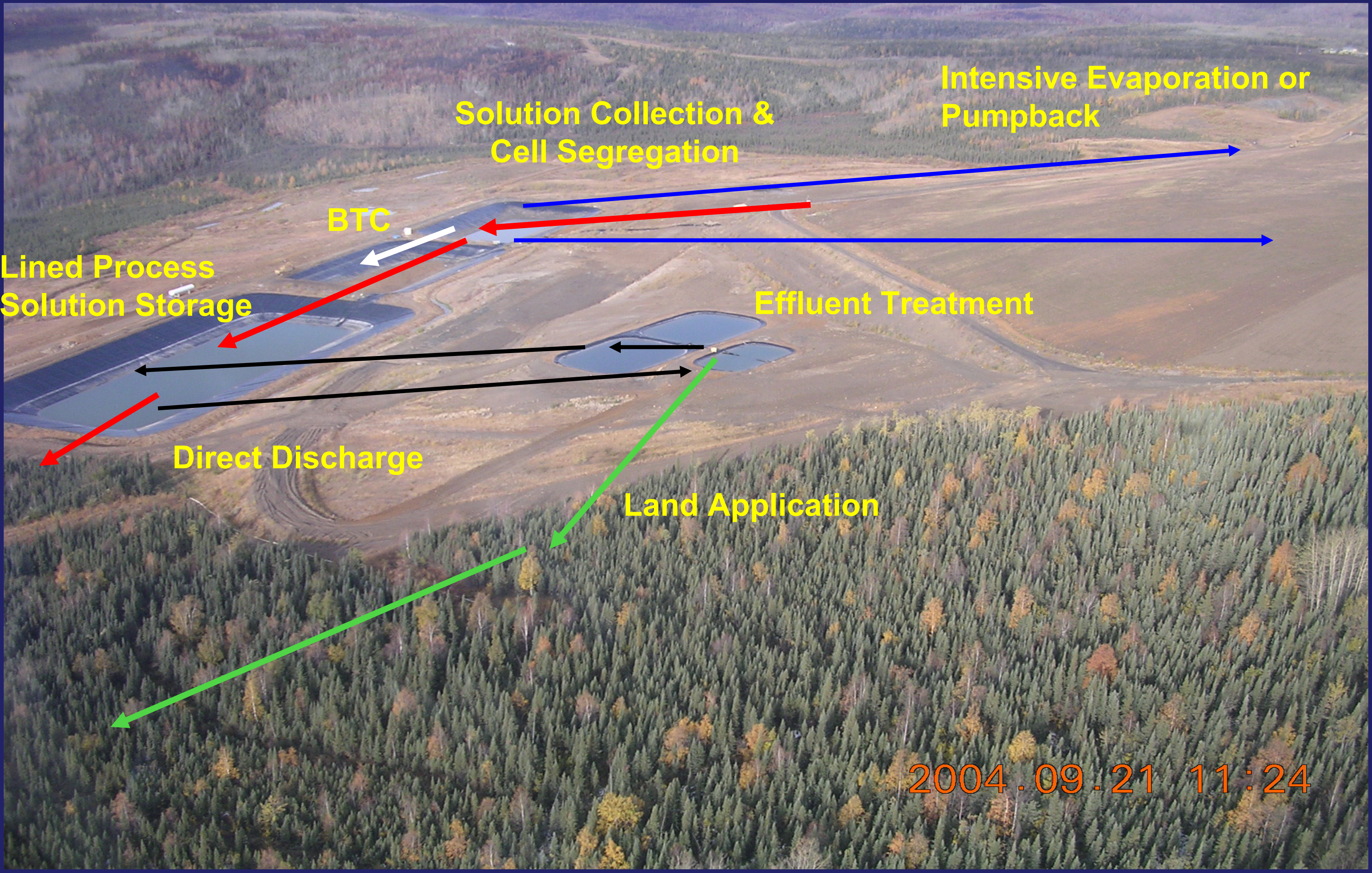
- Heap pumpback
- Solution containment
- Biological Treatment Cell
- Effluent Treatment and Land Application
- Intensive Evaporation
- Monitoring

Biological Treatment Cell – Contingency Measure

Chemical Treatment System – Contingency Measure

Land Application System – Contingency Measure

Heap Water Management Overview and Contingency Measures



Heap Detoxification

Lessons learned:

- Biological reduction of cyanide required far less time for the detox process than was anticipated
- Biological reduction resulted in significantly less solution requiring treatment
- Biological reduction has been proven to be successful in a cyanide heap leach in northern climates

Heap Leach Soil Cover

In 2003, the heap leach pad was recontoured, 80,000 m3 of growth media applied and the area revegetated.

The objective of the cover was:

- to reduce the infiltration of precipitation runoff into the heap so that the volume of effluent requiring further passive secondary treatment and/or release to the environment is likewise reduced.
- provides an environment for successful natural revegetation

Heap Leach Soil Cover

- The design for soil cover over the heap estimated an annual infiltration rate of 24%.
- All of the secondary contingency measures and long-term release volumes had been estimated using a 30% infiltration factor

Year	Calculated infiltration (%)
2004	21.5
2005	24.1
2006	27.3
2007	27.1

Detoxified, Soil Cover & Revegetated Heap

Heap Leach Pad – Final Reclamation

Revegetation

- The seeded species are not intended to be sustainable in the long-term, as these species should eventually give way to native successional species.
- Most of the grasses seeded since 2003 are species naturally occurring in the Yukon, but at the time of seeding Yukon-produced seeds were not available in the necessary amounts

Revegetation

- Neither of the non-native species proved significantly effective and both were quickly replaced by indigenous species
- At the time of the 2008 Vegetation Assessment many native plant species were observed to be colonizing most reclaimed areas
- Willows and Alaska birch were observed naturally recolonizing at a number of sites

Revegetation

Lessons Learned:

- Natural revegetation at this latitude is a slow process.
- Further seeding with grasses will do little to hasten this process, and may even hinder it.
- Disturbance to the soil after initial seeding could delay the revegetation process, and the resulting formation of a too dense ground cover may inhibit the colonizing of the area by indigenous species.


Recontouring


Growth Medium

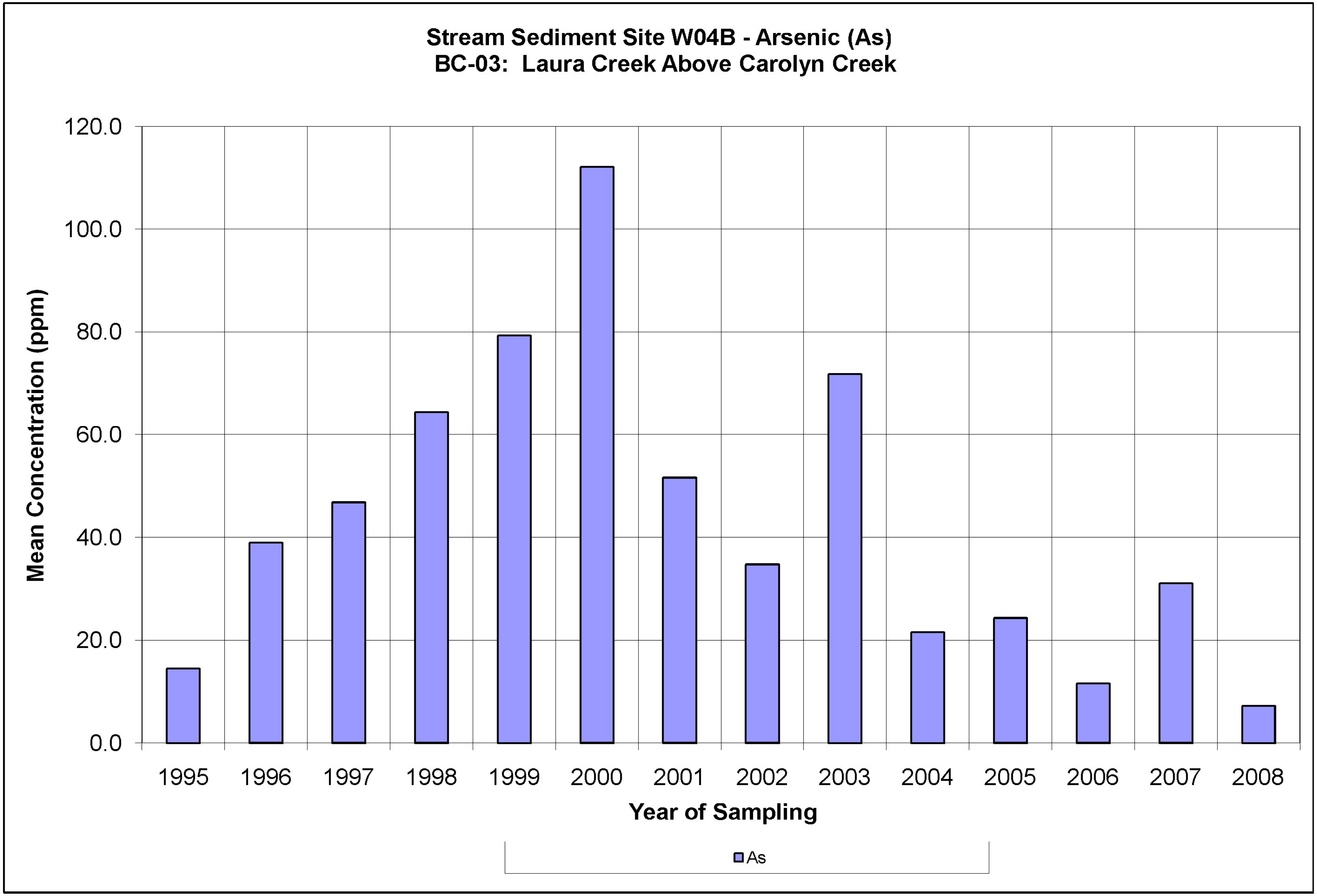

Revegetation

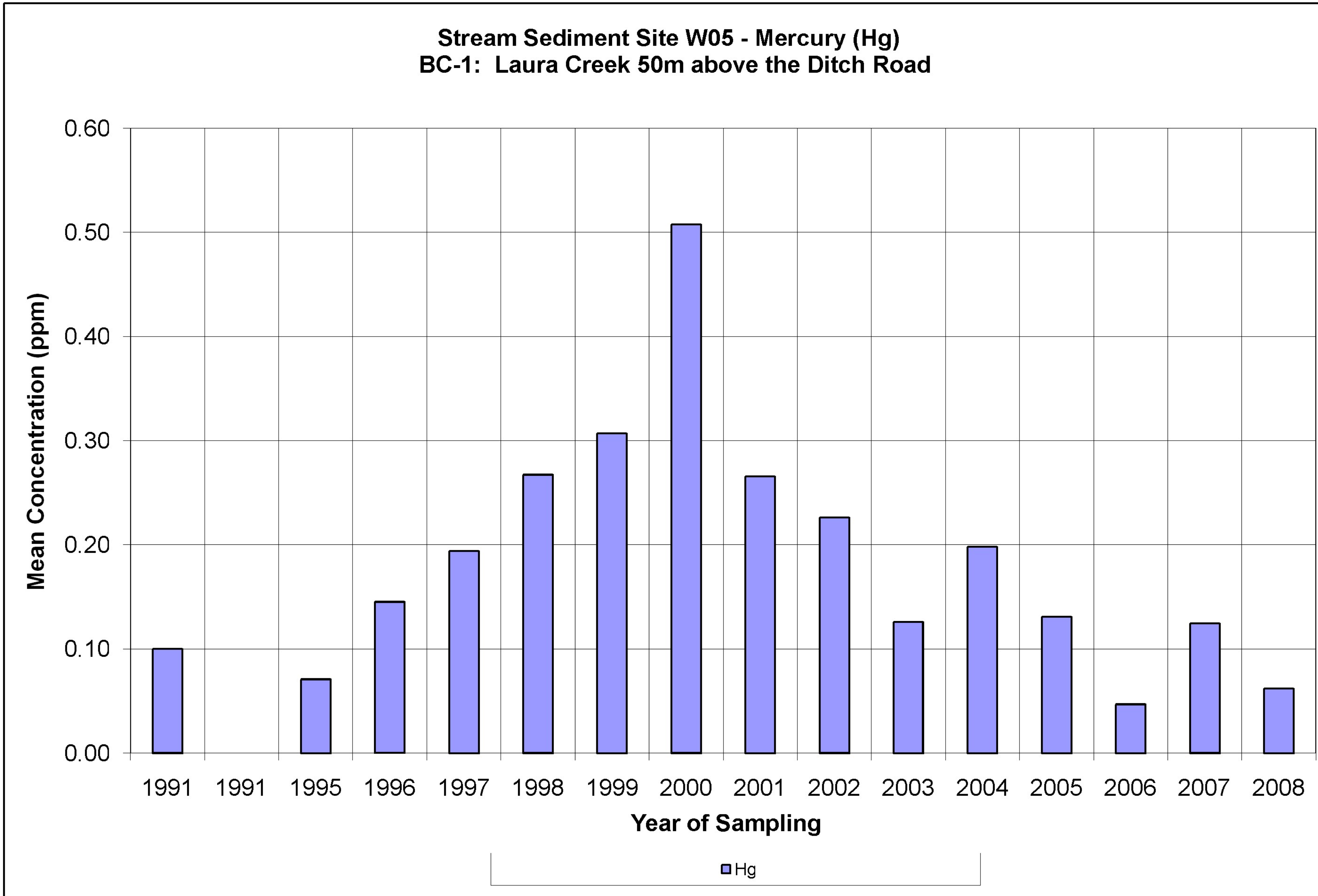
North Golden Pit Concurrent Reclamation

Receiving Water Quality and Stream Sediment Impacts

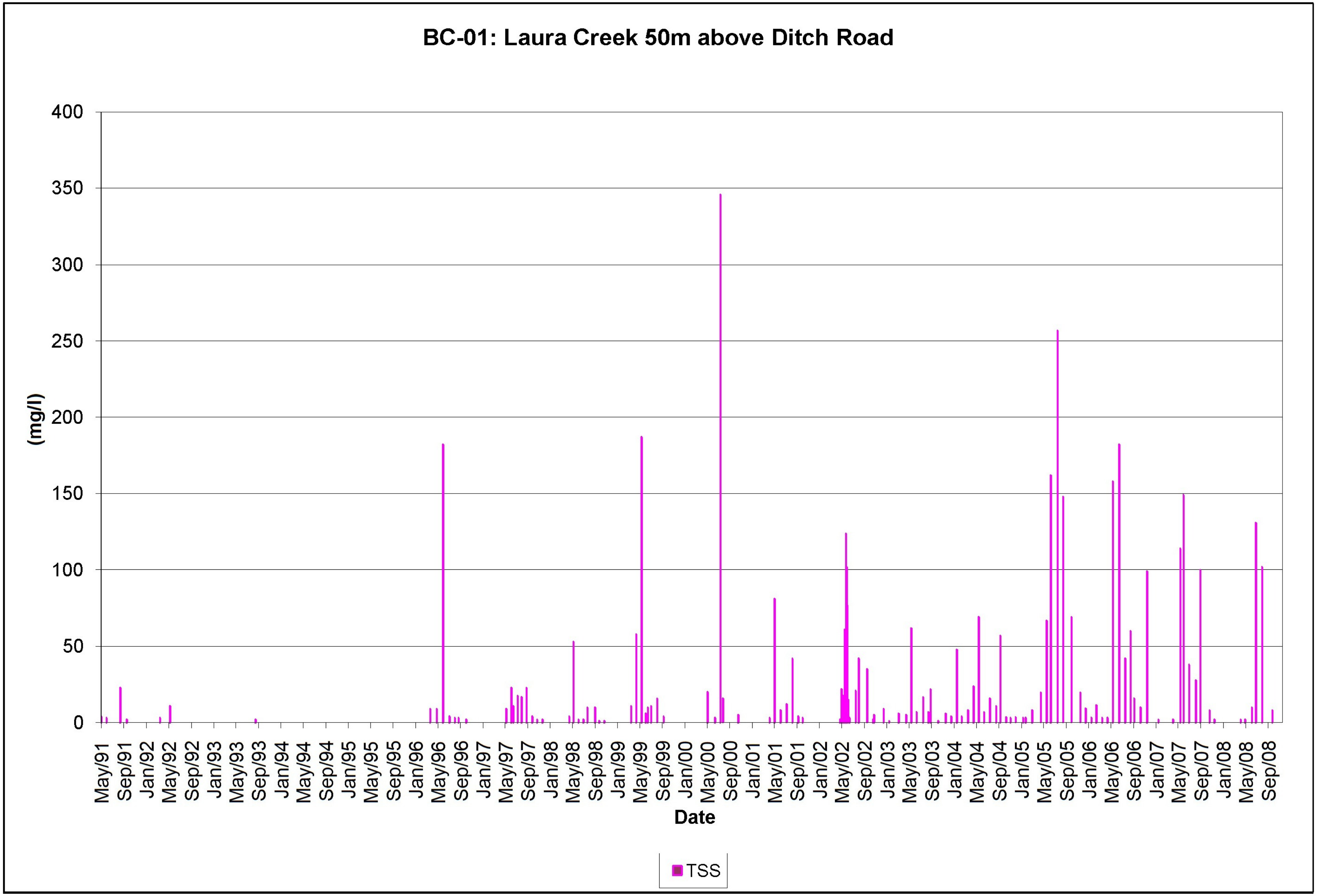
- Water quality sampling downstream provides a snapshot of the conditions
- Sediment sampling describes long-term trends

2 stations immediately downstream of the mine chosen as examples as they provide the clearest trends


Stream Sediment Site W04B - Arsenic (As)
BC-03: Laura Creek Above Carolyn Creek
Mean Concentration (ppm)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year of Sampling
As



Stream Sediment Site W05 - Mercury (Hg)
BC-1: Laura Creek 50m above the Ditch Road
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Mean Concentration (ppm)
1991
1991
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year of Sampling
Hg



BC-01: Laura Creek 50m above Ditch Road
400
350
300
250
200
150
100
50
0
(mg/l)
May/91
Sep/91
Jan/92
May/92
Sep/92
Jan/93
May/93
Sep/93
Jan/94
May/94
Sep/94
Jan/95
May/95
Sep/95
Jan/96
May/96
Sep/96
Jan/97
May/97
Sep/97
Jan/98
May/98
Sep/98
Jan/99
May/99
Sep/99
Jan/00
May/00
Sep/00
Jan/01
May/01
Sep/01
Jan/02
May/02
Sep/02
Jan/03
May/03
Sep/03
Jan/04
May/04
Sep/04
Jan/05
May/05
Sep/05
Jan/06
May/06
Sep/06
Jan/07
May/07
Sep/07
Jan/08
May/08
Sep/08
Date
TSS

Receiving Water Quality and Stream Sediment Impacts

- Obvious trending upwards of Hg and As during production, trending downwards post-closure
- Forest fire in 2005 resulted in TSS and ammonia spikes

Lesson Learned:

- The mine had some impacts to the surface water quality
- Some ability for natural renovation of surface waters

Security Costs

Comparison of a contemporary mine:

- Mt Nansen – smaller deposit and a smaller proposed mine but relative security bond was much less
- $974 500 compared to a bond of $8 709 000 for Brewery Creek

Security Costs

- Brewery Creek is a mine that has seen a high level of reclamation work (that is still on-going) and thus has regained a portion of the security bond
- Mt Nansen is currently classified as a Type II Abandoned Mine

Security Costs

- Some of the high level of reclamation work undertaken can be attributed to the very high, at the time, bond and some to the will of the company to undertake the reclamation work

- One problem has been a lack of agreed upon reclamation benchmarks for the repayment of the bond

Security Costs

Lessons Learned:

- Will of the company and bonding levels that will promote reclamation are both important
- Clearly defining methods and benchmarks for assessing effectiveness of reclamation
- Allowing innovative reclamation techniques may speed process up

Conclusion

Many lessons have been provided by Brewery Creek at each stage of the process; from planning through assessment construction, production, closure, and reclamation.

A post closure analysis of any mine can provide invaluable information that can be used for operational, assessment, and regulatory purposes by government, First Nations, industry, and the general public.