Addressing the Challenges of Major Mine Reclamation in British Columbia

Mine Reclamation and Closure Workshop
Yellowknife, February 1-3, 2005

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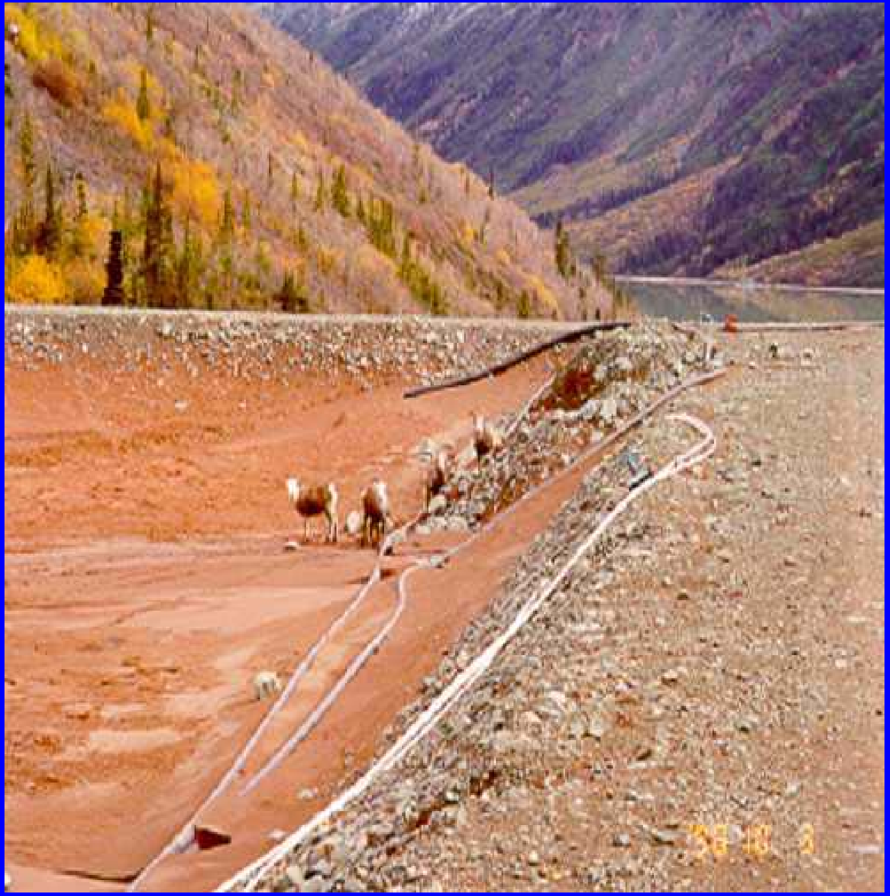
Presentation is based on my previous work in British Columbia:

- Setting regulatory conditions and criteria, and writing guidelines.
- Reviewing mine proposals, and reclamation and mine closure plans.
- Enabling mines meet regulatory conditions
- Various research, technology transfer and education initiatives

Like any other project, with reclamation it is important to keep the objectives in mind. This is especially important with reclamation because there ‘s a hierarchy of objectives and because reclamation can be so complex.

Primary goal in reclamation is to prevent impacts to ecological and human health (environmental protection).

1. downstream or down gradient resources.
2. animals, fish and people using the site.



Secondary goals are to:

3. minimize the liability (reduce cost and risks of future failure);
4. post-mining site productivity.

Various Regulatory Tools to Ensure Objectives Acheived

General Requirements:

- Env. Ass requirements;
- Health, safety and reclamation code; and
- Reclamation permit
- Waste Management permit

1. For downstream and down gradient resources:
   - Discharge limits and concentrations in water and sediments
   - Geotechnical criteria for dam, dump and mine safety
   - Studies of ecosystem health (EEM)

2. For animals, fish and people using the site:
   - Forms of ecological and human health risk assessment.
3. Minimize the liability (reduce cost and future risks of failure):
   - Conditions in Mines Act Permit
   - Risk assessment
   - Annual submission of reclamation costs
   - Financial security
   - Progressive reclamation where possible required
4. Post-mining site productivity
   - Site-specific criteria that post-mining site productivity except pit equal pre-mining site productivity
   - Baseline data required in EA
   - Conditions in Mines Act Permit for soil salvage and research program (if required).

Reclamation actions include:

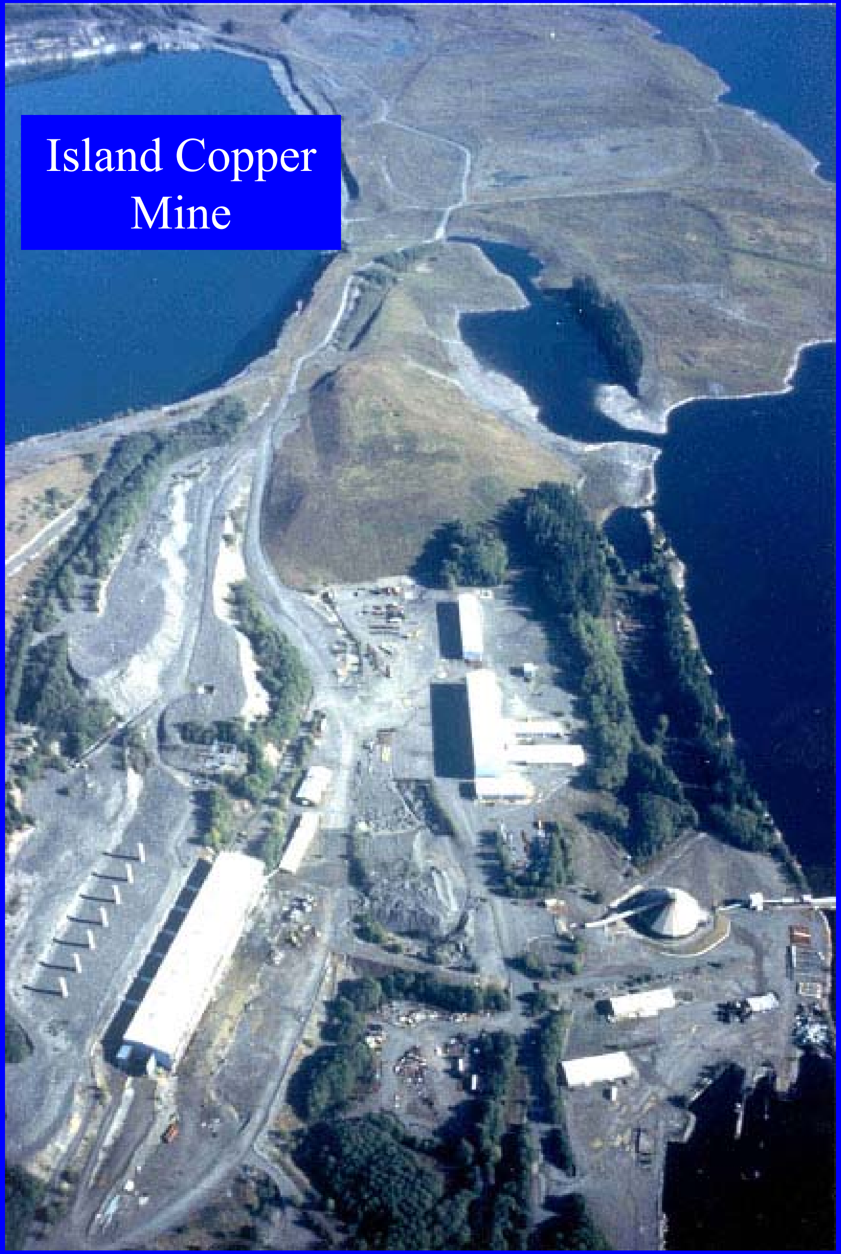
- Treatment (removal) of structures and equipment
- Disposal of toxic chemicals (e.g., process or lab chemicals)
- Prevent access into or onto unstable mine workings
- Stabilize land forms – dumps, impoundments, tailings, etc… - geotechnically stable and limited wind and water erosion
- Ensure adequate discharge quality and loadings (prediction and mitigation of metal leaching and ARD)
- Soil covers to prevent significant ecological impacts to biota using site
- Where possible, reclamation to land-use equal to pre-mining productivity (or capability)
- Monitoring, maintenance and repair
- Studies plus contingency plans to fill information gaps

For example

- Treatment (removal) of buildings, other structures and equipment
  - Removal
  - Convert to other use

- Removal of toxic chemicals (e.g., process or lab chemicals)

- No health impacts to people and ecology of reclaimed facilities (ecological and human health study)



Unique Properties of a Mine

- Mining dramatically changes the local landscape
- Best land use might differ from that prior to mining

A Mine is a Waste Storage Facility

- Most of the products of mining - waste rock and tailings - remain on the site after mining.
- The large volumes usually make waste movement prohibitively expensive.
- Disposal procedure and location can have a large impact on reclamation results. Consequently, mine plan must consider needs of the reclamation plan.

- Relatively small on-site footprint
- Potentially large remediation costs or off-site impacts

Road access is potentially a very large footprint

Important considerations

- Will road be required after mining
- Who can use it
- Reclamation and environmental requirements should be part of construction plan (e.g., save topsoil)

Reclamation Best Management Practices (BMP) consist of the tools and processes for developing the required site-specific understanding and subsequent plans.

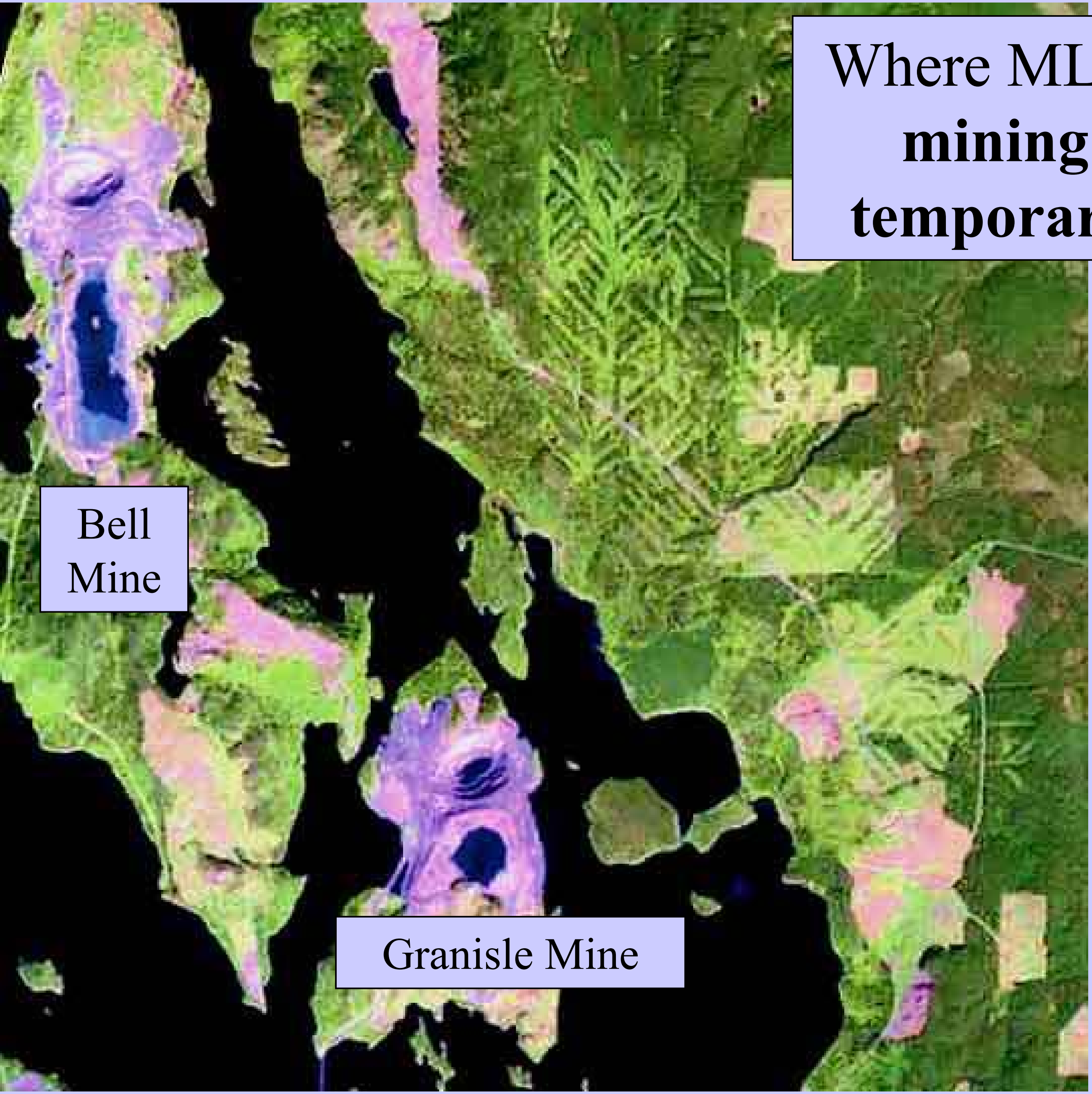
Challenge: Developing the required understanding may cost $100,000s and take years to develop. While this may seem onerous, the costs are minimal compared to the costs when problems are not addressed at the appropriate phase of the mine life or impacts occur.

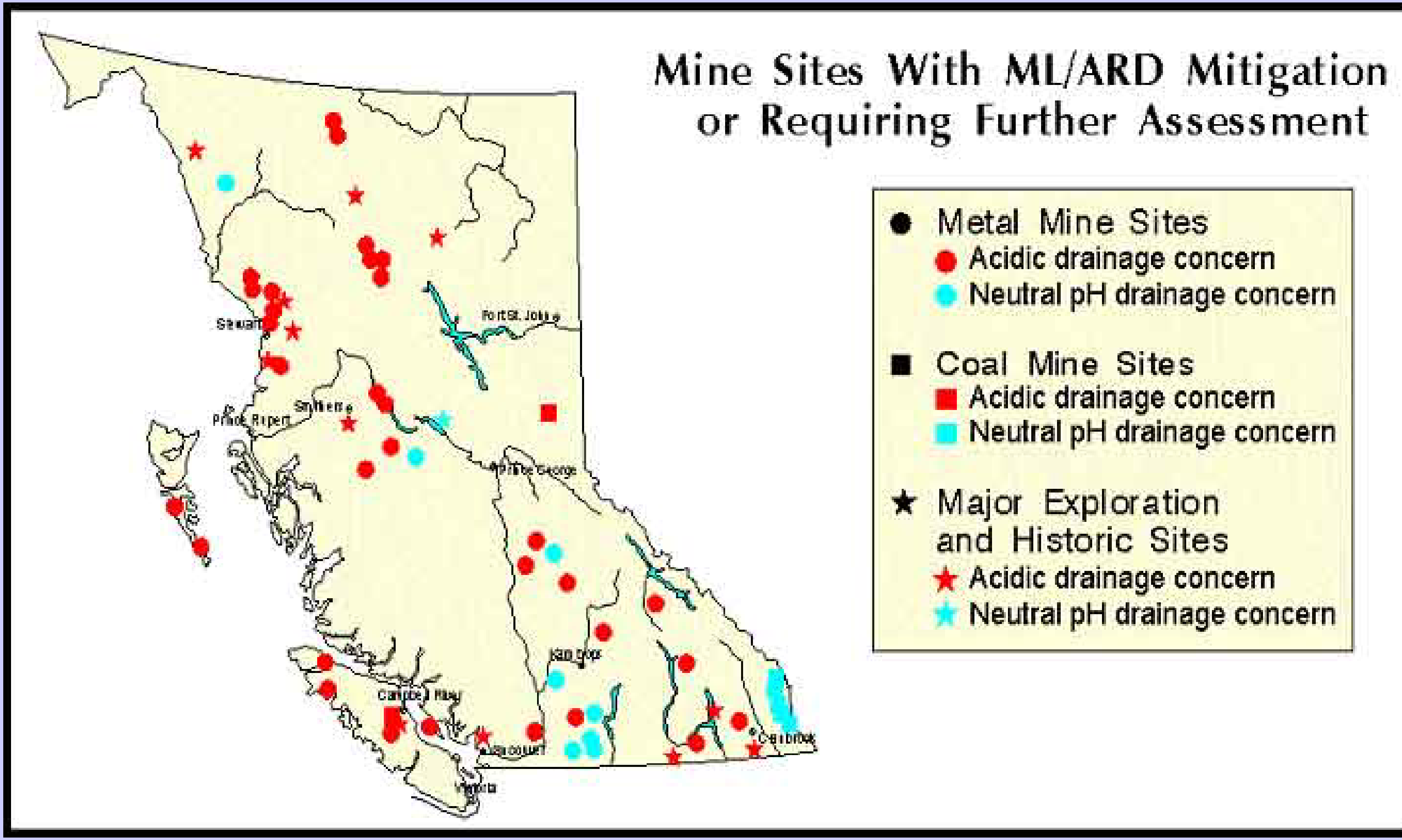
A comprehensive understanding of the site is needed to identify both opportunities and constraints. For example, steep terrain and high snow fall create erosion and maintenance problems. They may also lead to fish-free lakes and large dilution.

Challenge: Long-Term Performance

Many components of the reclaimed mine site must perform <u>indefinitely</u>. This is especially true of structures constructed for water management and mitigation of ML/ARD.

Where ML/ARD is a concern, **mining is usually not a temporary use of the land**.





There are more than 60 major mines in B.C. with a potential for significant ML/ARD. 80% are closed.

Challenge: Limit Liability and Risk

- Recognition of long-term costs and risks is leading mines to use underwater disposal rather than soil covers or drainage treatment as primary means of preventing significant metal leaching or ARD.
- This has increased the number of water-holding dams, which have geotechnical risks.



Eskay Creek has avoided the geotechnical risks associated with a dam by flooding its wastes in two lakes.

In addition to fish-free lakes and large dilution:

- sediment curtains reduce suspended solids and
- treatment of mine drainage prior to disposal.

Positive EEM results immediately downstream.

Challenge: Pro-Active Resolution of Problems

Reclamation needs to be designed and operated in a manner that allows **pro-active detection and resolution of problems**. This requires:

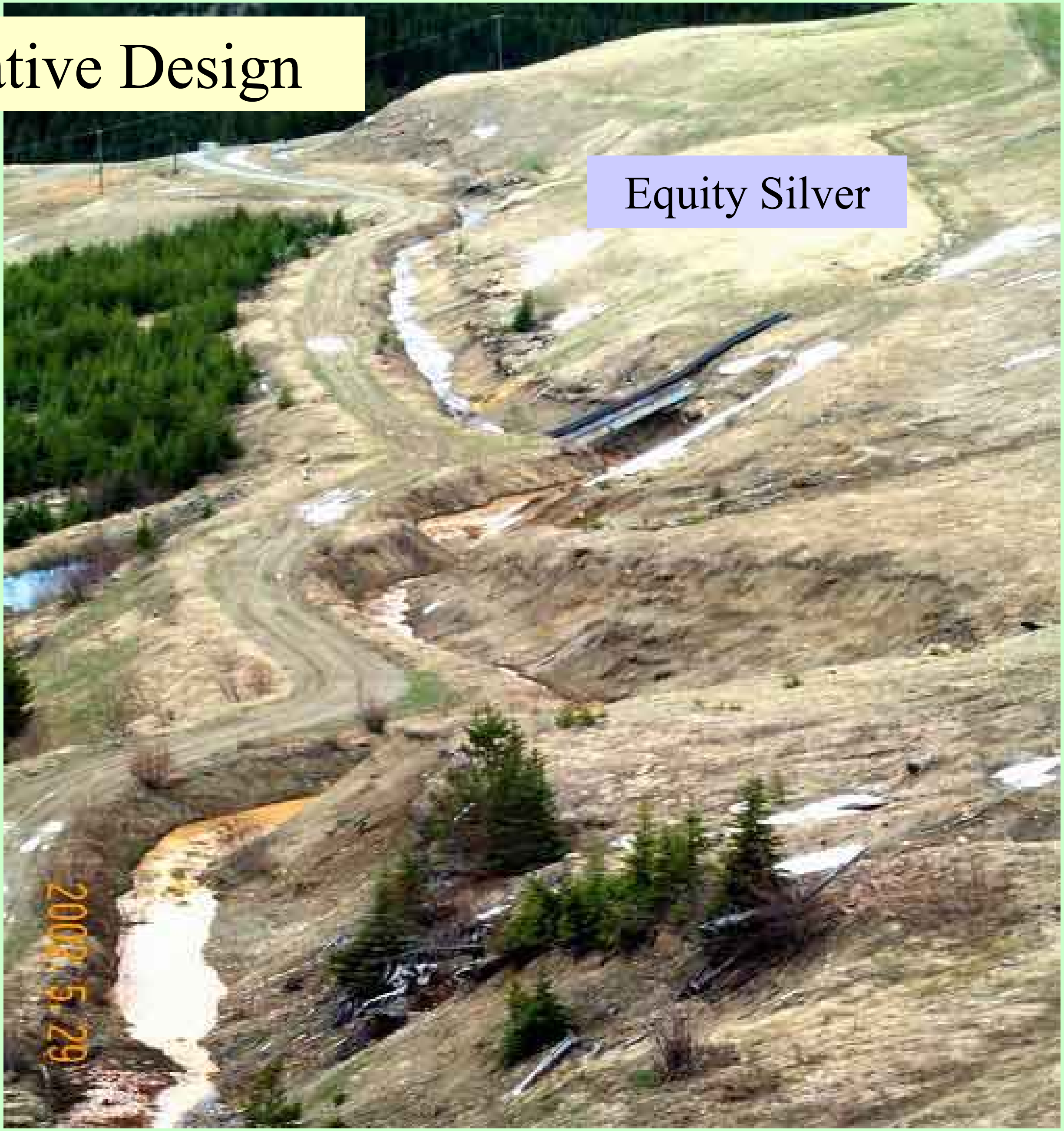
- conservative design;
- ability to handle future geochemistry, hydrology, ecology, etc.;
- monitoring. maintenance* & contingency plans ; and
- financial resources to conduct the above.

*including repair and replacement

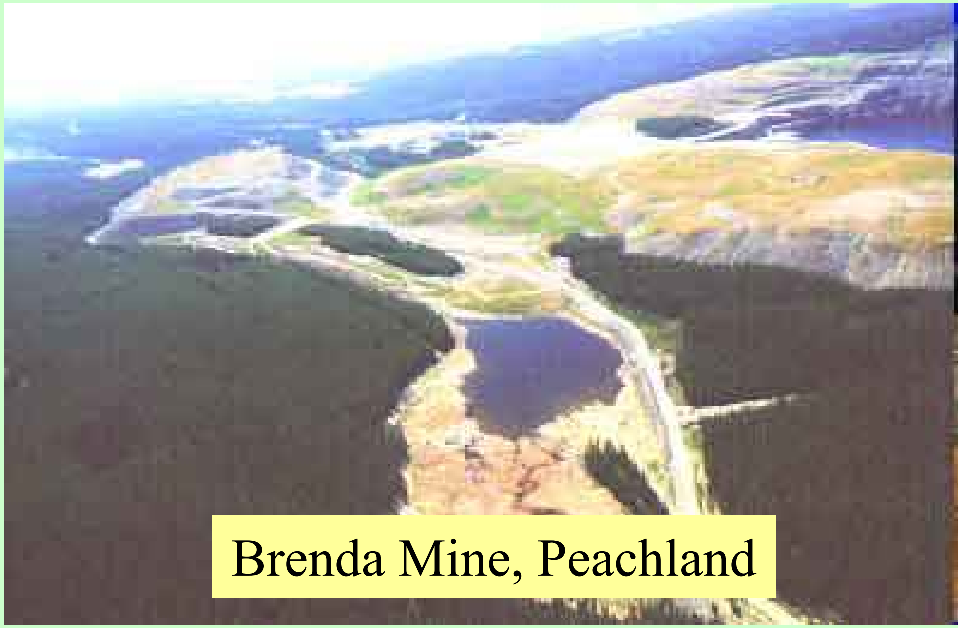
Challenge: Conservative Design

Ability to predict magnitude of extreme weather events has been a problem at some sites.

Equity Silver has discharged untreated ARD twice in the last seven years because it underestimated the possible size of its runoff.

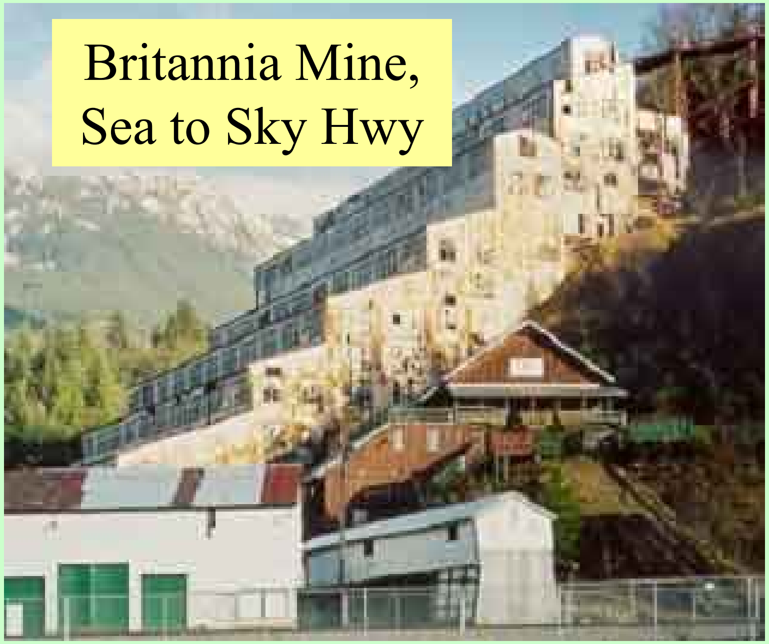


The first step in pro-active detection is recognizing the potential failure mechanisms. Decreased performance of the cover system may also result from damage to drainage systems, through ditch scouring, overtopping or damage when snow, ice and other debris are removed.


Brenda Mine, Peachland


Equity Silver, Houston

Failure to pro-actively plan in advance for ML/ARD can result in capital closure costs that often exceed $10s of millions, with operating costs up to $2 million per year.


Britannia Mine, Sea to Sky Hwy

Faro

Summitville

The public pays the $100s of millions if the company goes bankrupt,. To avoid these costs, reclamation must be planned and mines operated and decommissioned in a manner that allows for effective problem detection and mitigation, and exercise caution if there is a high degree of uncertainty.

Best way to limit reclamation costs and risks is to consider reclamation prior to mining. BC now has four mines where ML/ARD considered since inception (e.g., Huckleberry and Kemess).

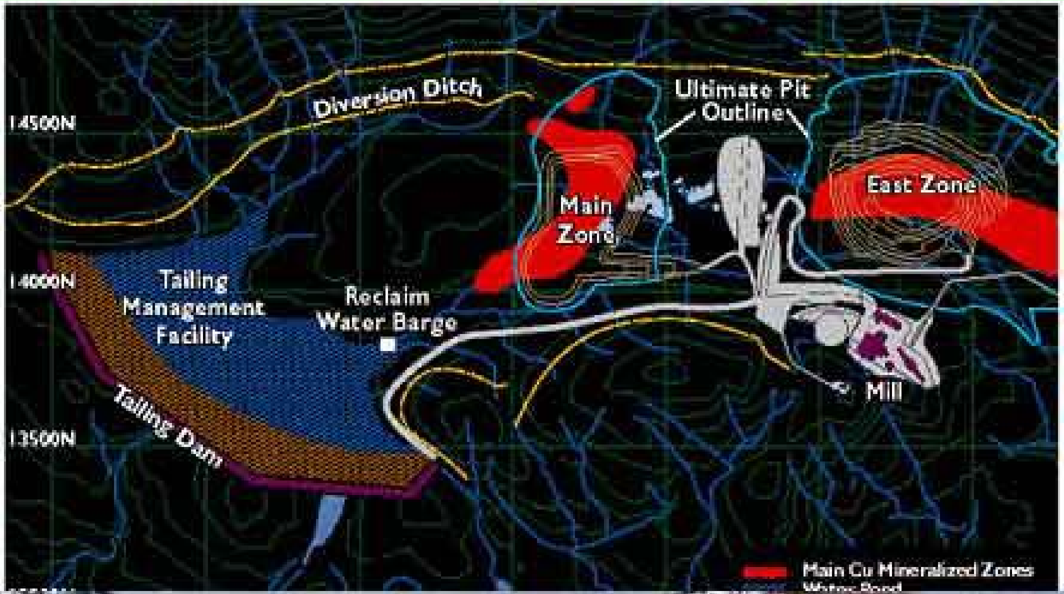
Huckle

e

Huckleberry Mine

Consideration of reclamation prior to mining, led Huckleberry to the use the Main Zone Pit waste rock to construct the tailings dam and put the East Zone Pit waste into the Main Zone pit.

This greatly reduced the footprint of the mine and the size of the dam.



Many reclamation issues resolved using information from pre-mine baseline studies

- Water quality / sediments
- Hydrology (Surface)
- Groundwater
- Fisheries / Stream Biota
- ML/ARD – rock characterization
- Soils
- Vegetation
- Wildlife
- Air Quality
- Noise
- Geotechnical testwork
- Alternative facility locations
- Socio-economic

A soil survey is conducted to determine soil capability and what materials should be salvaged for use in reclamation. A soil survey also provides information on soil handling requirements, drainage management and erosion control.

Important to determine post-mining land use objectives prior to mining so requirements can be included in the mine plan. Land use should be compatible with:

- surrounding land use;
- environmental conditions;
- mine plan; and
- community objectives.

Need to show:

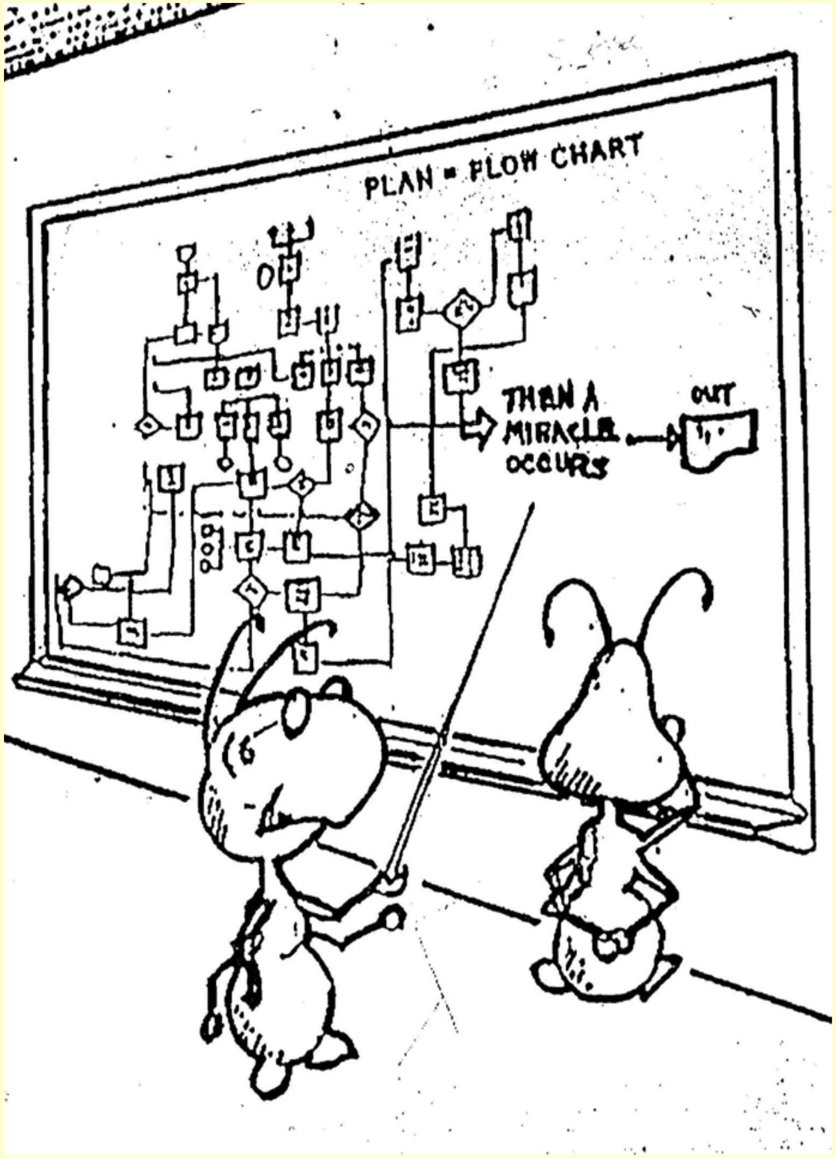
- how reclamation objectives will be achieved;
- what criteria will be used to measure success; and
- any uncertainty and how it will be addressed.

Challenge: Lack long-term experience with many features of a reclaimed site (e.g., soil covers, frost depth, etc...)

- Much of our understanding of soil covers comes from small scale trials, computer simulations, and micro-scale monitoring.

- Limited information on long-term performance and departures from the ideal, such as permafrost and durability.

- This results in uncertainty about durability, repair and replacement costs, and triggers to initiate that work.



Closure costs for the cover shown previously -

Present Maintenance Costs:

- $1,000 per year to remove woody shrubs
- $1,000s/yr for pre-freshet ice removal from ditches

Projected Future Maintenance Costs:

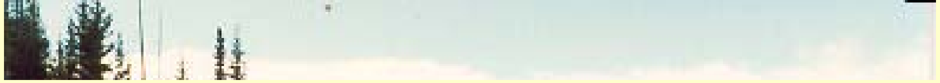
- $250,000 in year 10
- $100,000 in year 20 and every 10 years thereafter (2030, 2040, etc.,)

Need more long-term operating experience in order to assess whether projected future costs are accurate.

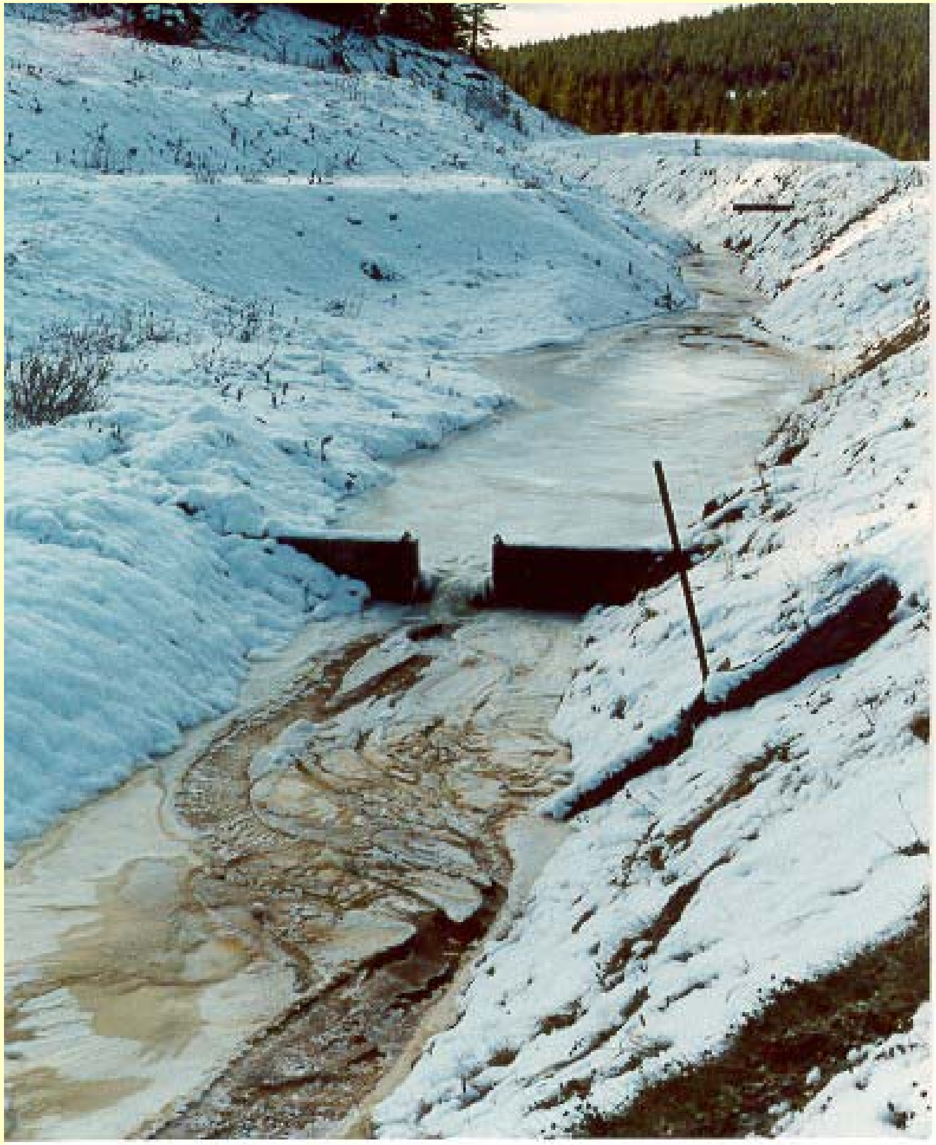
In the past, monitoring was primarily required to detect impacts. In pro-active modern mine reclamation, monitoring must also:

- provide early warning of potential problems (e.g., detect a reduction in design capacity),
- inform corrective measures (e.g., direct maintenance), and
- allow adaptive management or implementation of contingency plans.

Reclamation without monitoring and maintenance is equivalent to driving a car without a wind shield or a fuel gauge, or checking the oil.



Maintenance and monitoring are required even for simple water management features.



Maintenance Plan for a 'Ditch'

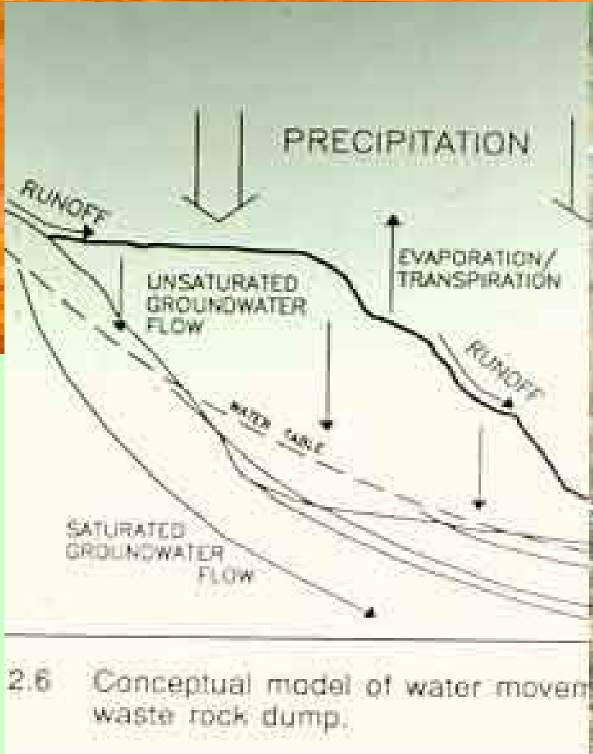
Includes:

- removal of invading woody species,
- repair erosion,
- removal of vegetative debris and sediment, and
- removal of ice from ditches prior to freshet

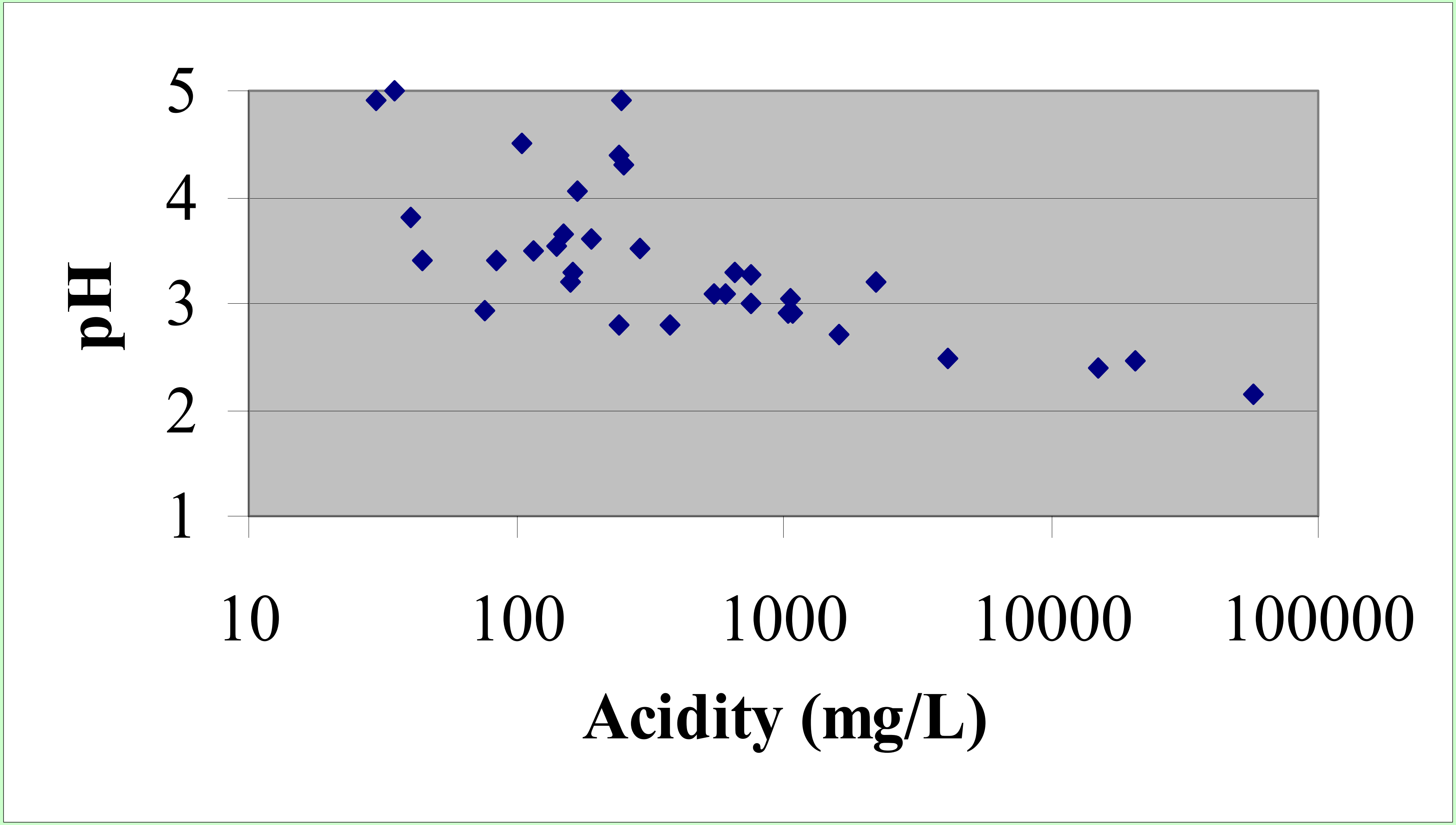
Challenge: Many Key Properties and Processes are in a State of Flux

Mining dramatically alters landscape – e.g., chemistry of wastes, height of water table and biological communities.

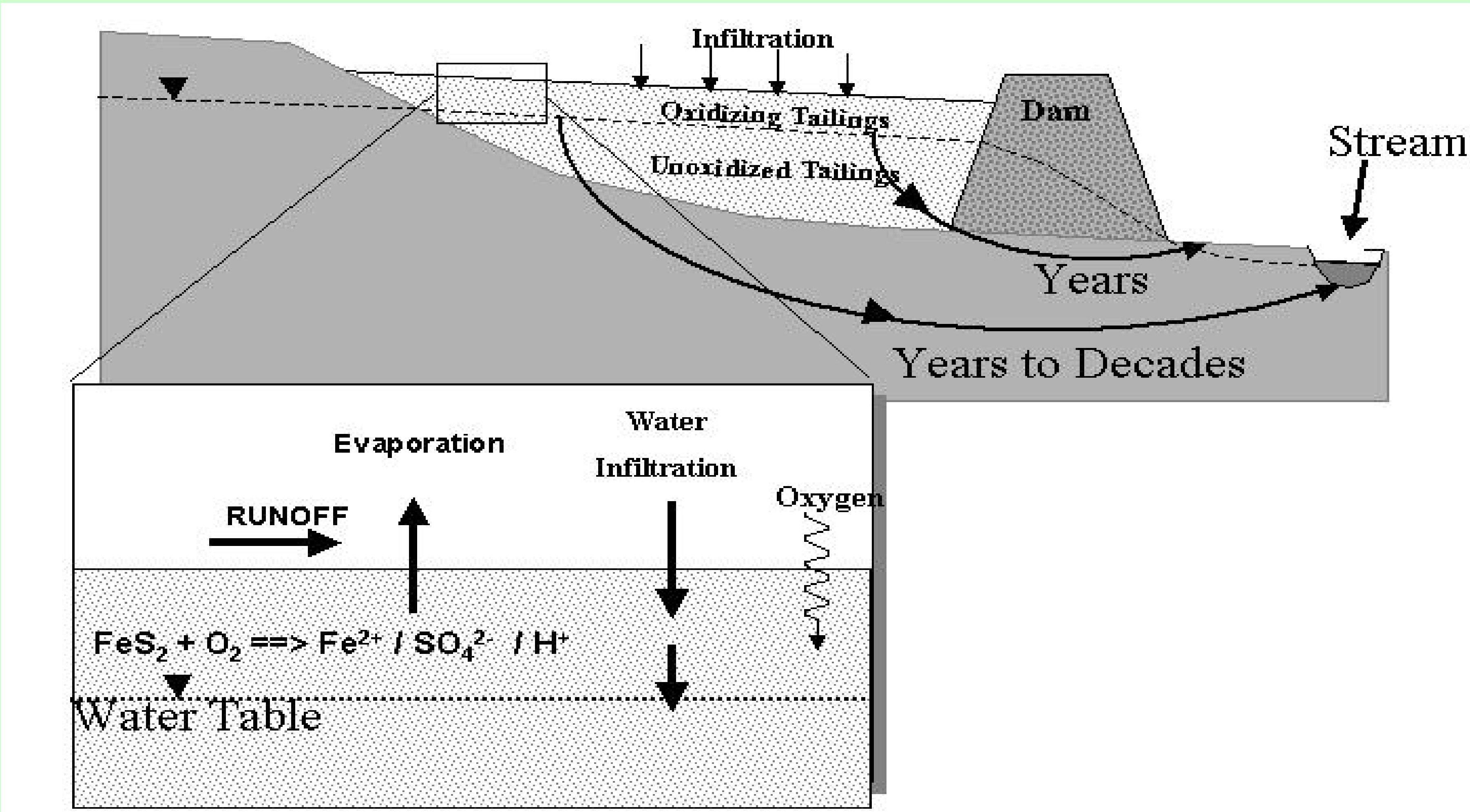
Groundwater rebound following mining can significantly increase leaching and collection and treatment costs.



Changes in rock weathering, which greatly increase concentrations of acidity and metals, may take decades.



Contaminants entrained in groundwater may take years to reach sensitive resources. To avoid groundwater issues, dump potentially problematic wastes on impermeable materials.



Presently the main way to measure changes in weathering and drainage chemistry is by monitoring seeps.

Post-mining changes in land use may alter exposure and how results are interpreted.

At Mine Site #1:

- Most sensitive downstream species are fish.
- Discharge must meet Mo limit of 15 or 30 mg/L.

At Mine Site #2:

- Drainage used as drinking water by children.
- Discharge must meet Mo limit of 0.25 mg/L.
- Treatment required to meet this objective costs $1.5 million/yr.

A common concern is whether metal uptake is a concern. There are various tests. For wildlife, EEM and population studies are used to assess impacts.

Measures taken to protect reclamation from wildlife include:

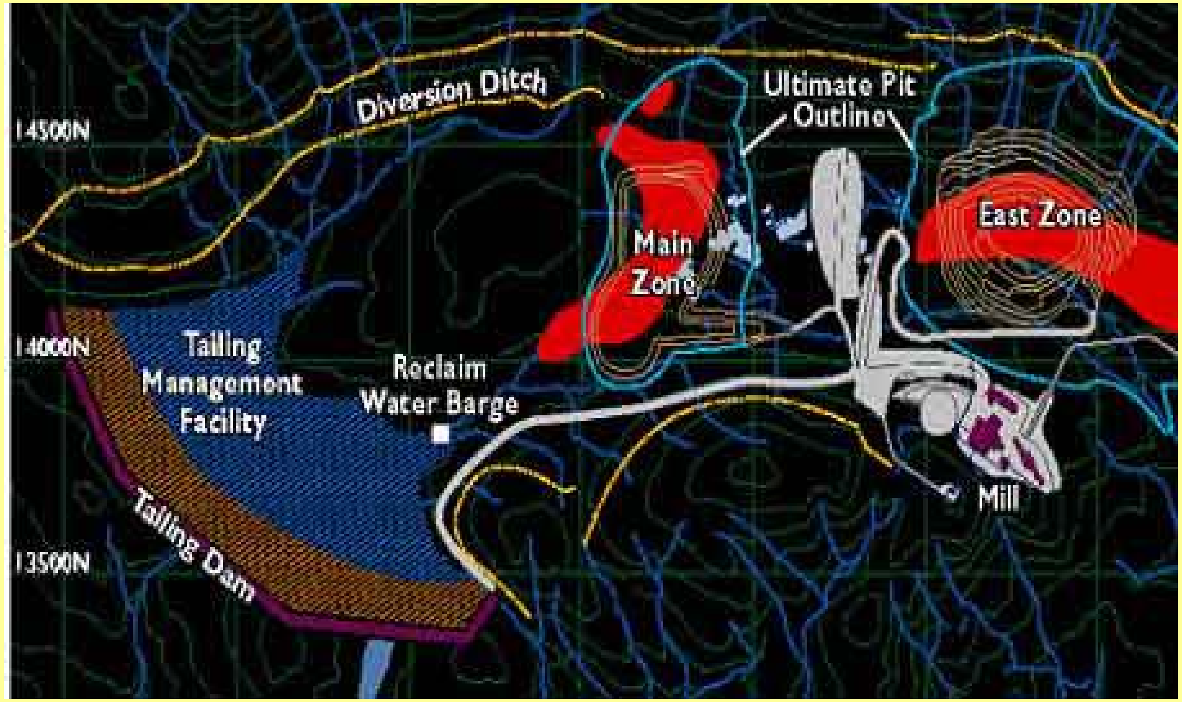
- put boulders in areas of flow to prevent beaver dams and
- make buildings and pipes inedible for porcupines.

Challenge: Predicting Whether there will be Significant Metal Leaching or ARD

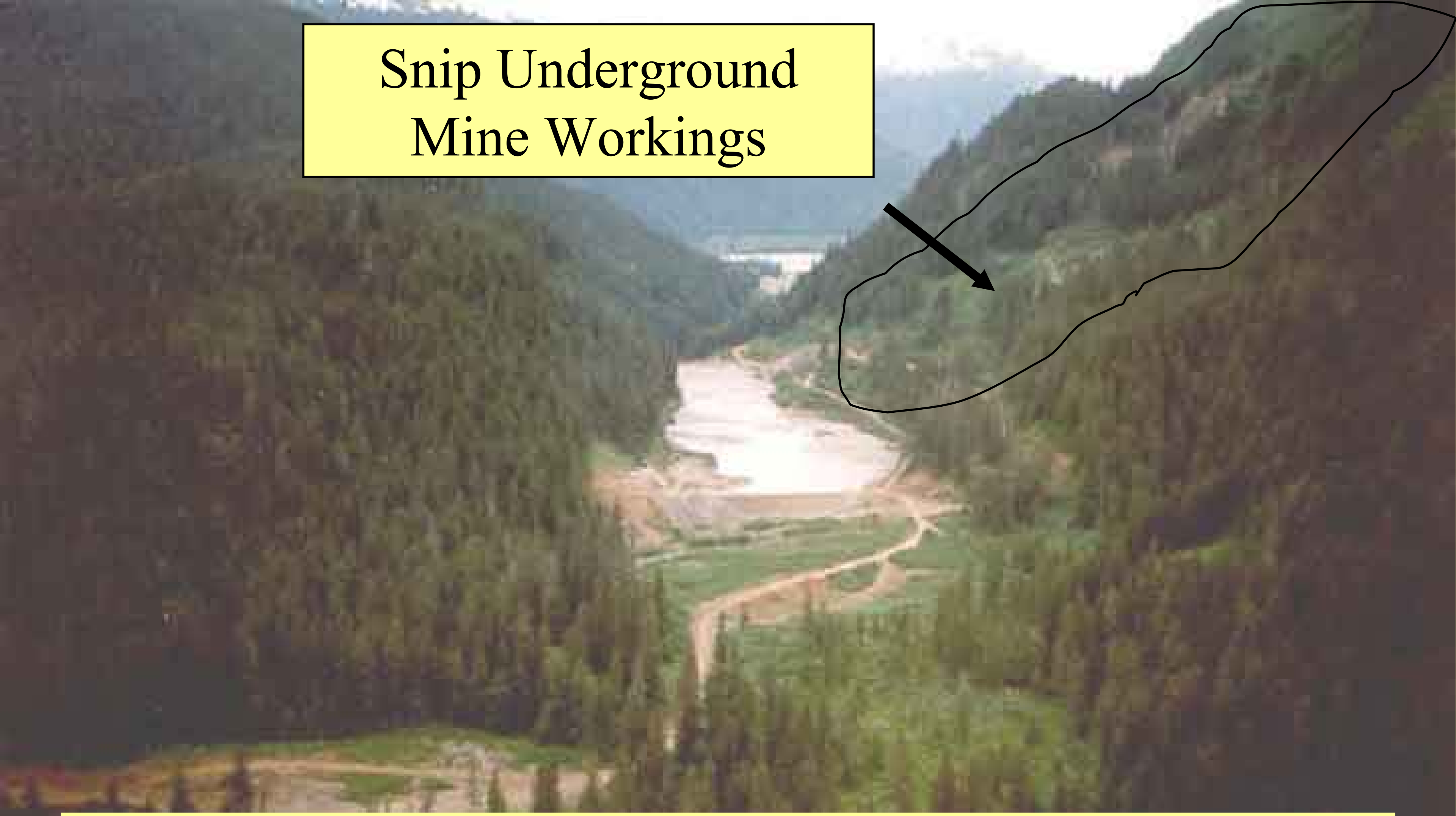
Full metal leaching and ARD requirements are uncertain at over 40 major mines in British Columbia due to uncertainty about magnitude of metal loading and whether it will have a significant environmental impact.

Studies being conducted to address these short-comings. Extensive research is ongoing in south east coal fields to determine if there are impacts from selenium.

Not all issues can be resolved prior to mining. Huckleberry has been working on mitigation plan for East Zone pit and plant site since it opened 7 years ago.

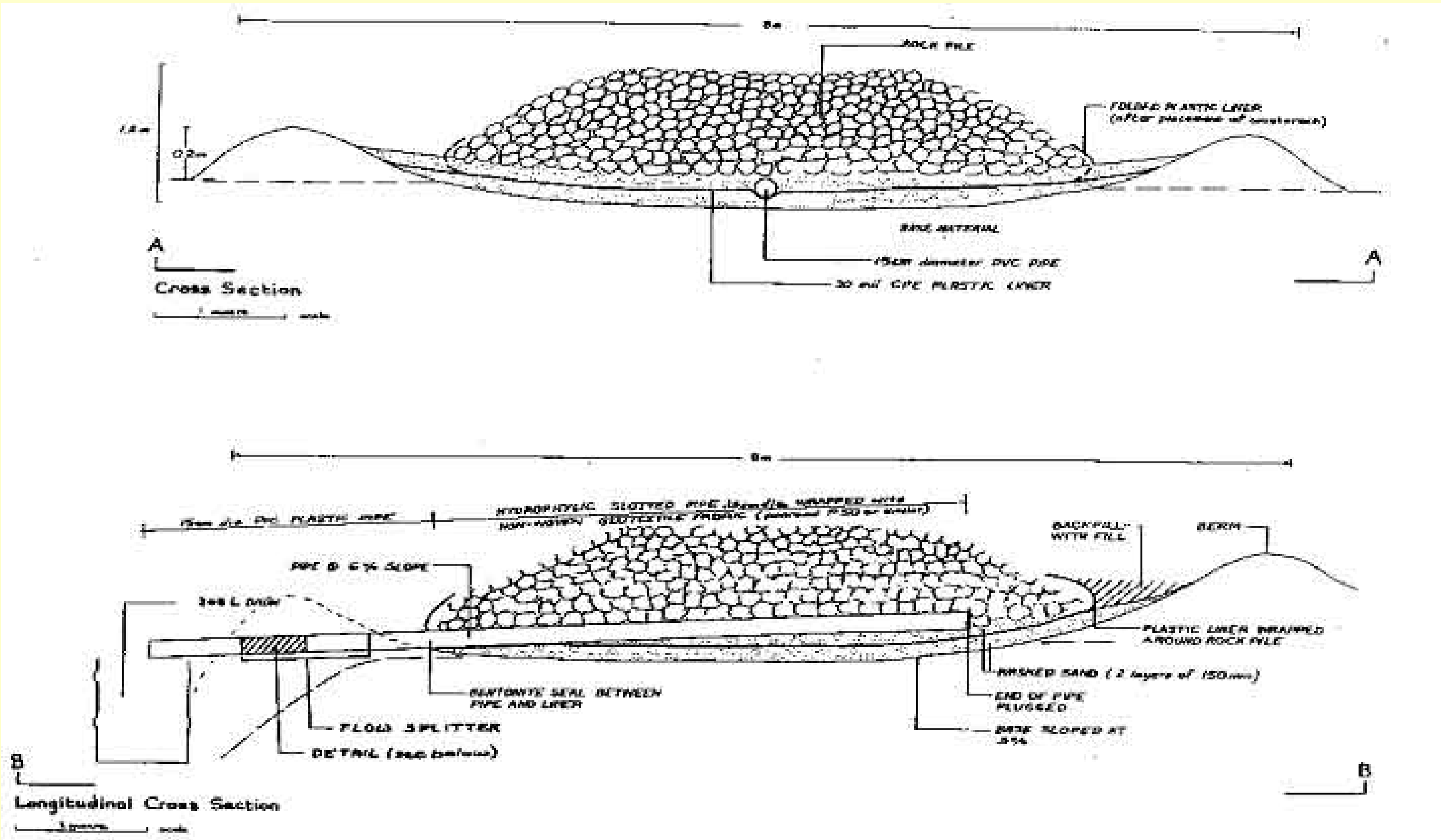


Snip Underground Mine Workings



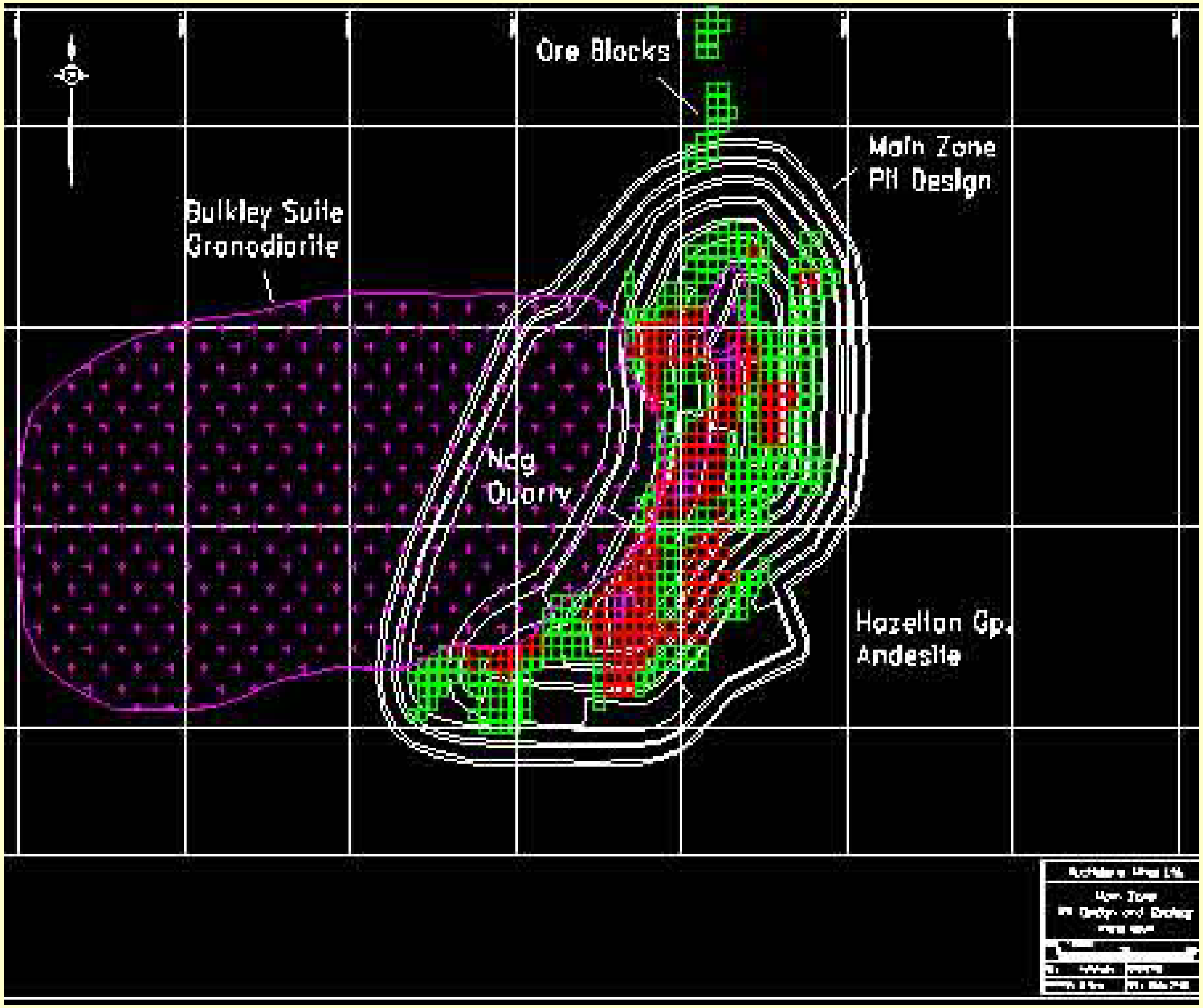
Snip was unable to predict whether future drainage from underground will require treatment. Liability may increase by $10 of millions if this is the case. Decommissioning of a remote site can make monitoring and additional test work difficult.

Significant differences exist between laboratory and field (e.g., cold temperature impact on carbonate dissolution). Field test pads are being installed to study effects.



An important part of reclamation is verifying metal leaching and ARD predictions.

Follow-up monitoring to check pre-mine predictions of waste composition is as important as for ore grades.



It is also important to check pre-mine predictions of weathering and drainage quality and loadings.

Reclamation Research

Most BC mines conduct research to determine best revegetation strategy, species selection and compatibility with amendments or different parts of their site.

Syncrude.

Reclamation can involve a variety of productive post-mine ecosystems, each appropriate to the local area and to the post-mine landforms created by mining.

Challenges For Practitioners

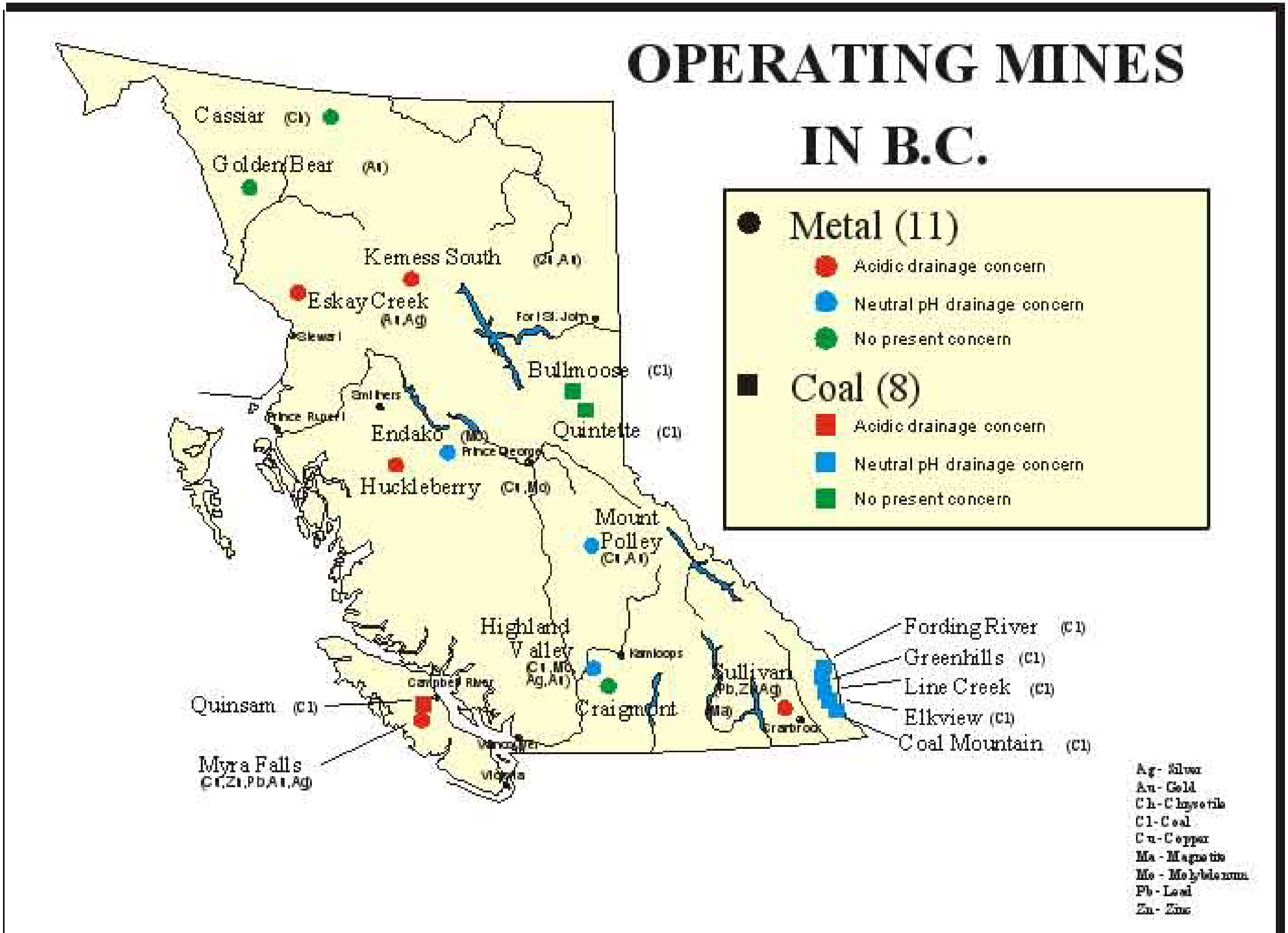
- Knowledge of a large number of technical disciplines required, in addition to technology-specific information and experience. One individual cannot do it all.
- Relatively new field and there is a continual need to upgrade knowledge.
- Complex issues, with many influential factors, interactions and potential changes, something might be overlooked.
- Corporate memory, very important for complex sites, is lost with frequent staff changes in government and industry. High turn in mine staff when mine closes.
- Mine review is hard work. Often strong financial and political pressure.

Dealing with Uncertainty

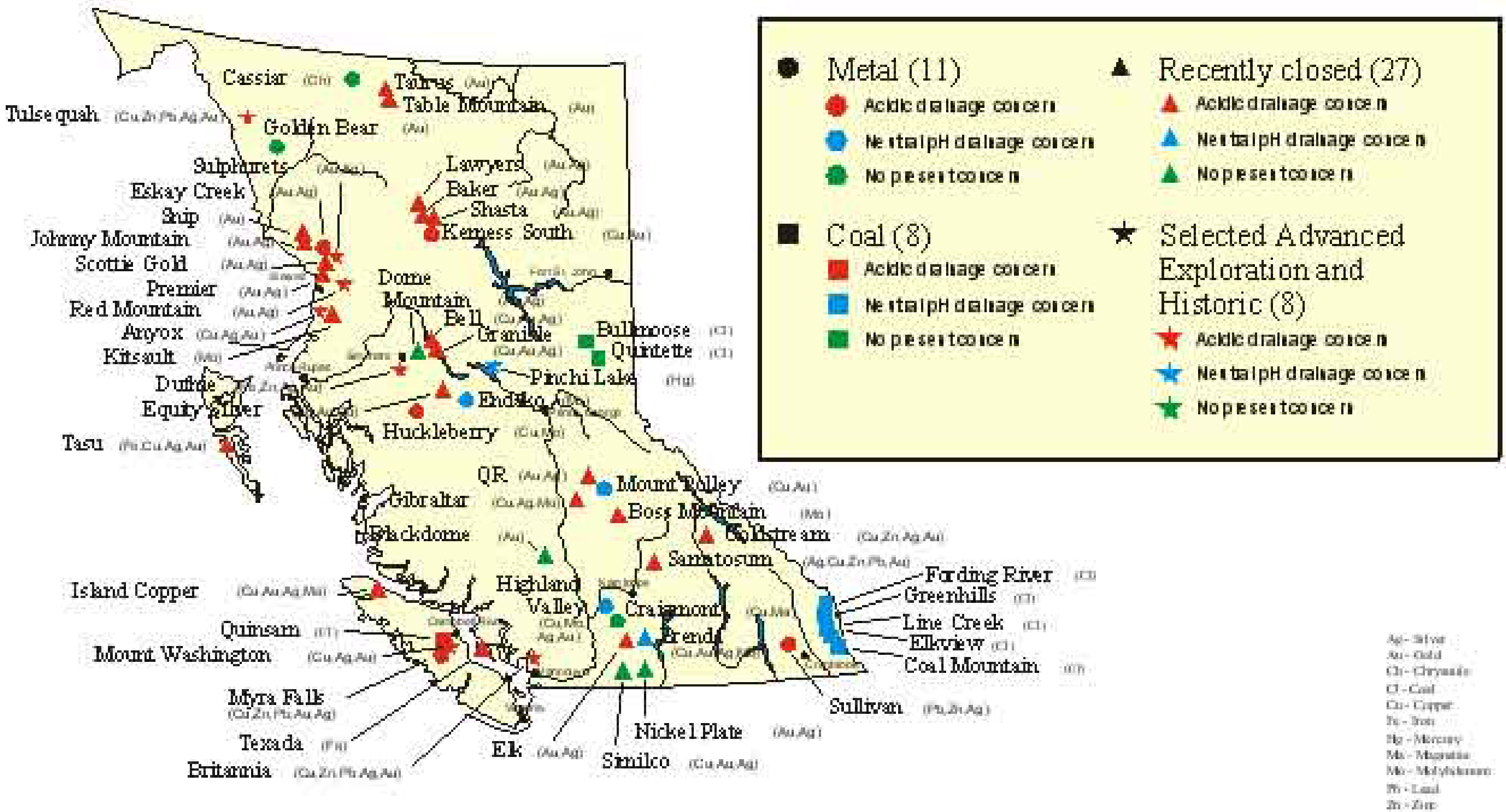
- As a result of limited operating experience and the large number of properties and processes, all mines have some uncertainty. Need to recognize issues and conduct studies to reduce costs and risks.
- Contingency plans and adaptive management are often the most cost-effective means of dealing with uncertainty. Timing and degree of preparation must depend on the risk, when potential events of concern may occur and the resources required.

Cumulative increase in number of mine sites

Mines with ML/ARD Concerns in BC	Number	Cumulative #
Historic	10	10
Closed 1970-1990	18	28
Recently Closed	20	48
Operating	12	60


OPERATING MINES IN B.C.
Metal (11)
Acidic drainage concern
Neutral pH drainage concern
No present concern
Coal (8)
Acidic drainage concern
Neutral pH drainage concern
No present concern
Cassiar
Golden Bear
Kemess South
Eskay Creek
Stewart
Fort St. John
Bullmoose (Cl)
Smithers
Prince Rupert
Endako
Prince George
Quintette (Cl)
Huckleberry
Mount Polley
Highland Valley
Kamloops
Campbell River
Quinsam (Cl)
Craigmont
Sullivan
Cranbrook
Fording River (Cl)
Greenhills (Cl)
Line Creek (Cl)
Elkview (Cl)
Coal Mountain (Cl)
Myra Falls
Vancouver
Victoria
Ag - Silver
Au - Gold
Ch - Chrysotile
Cl - Coal
Cu - Copper
Ma - Magnetite
Mo - Molybdenum
Pb - Lead
Zn - Zinc

OPERATING AND RECENTLY CLOSED MINES IN B.C.



Government and Regulation

- Reclamation plan required prior to mining, updated periodically (e.g., every 5 years) or prior to significant changes to mine (e.g., expansion or closure) or site conditions (e.g., forest fire).
- Regular review to ensure plans, information and financial resources are sufficient.
- Must provide guidance with regards to overall objectives and what constitutes an acceptable plan and acceptable reclamation.
- Increasing number of meetings result in less resources for doing technical reviews and follow-up.
- Where a number of agencies are involved, need to clarify who is responsible for different technical issues.

Strategies of British Columbia mining community to improve its own reclamation practices:

- Develop Provincial Policy, Guidelines, Glossary and Methods Manual to Support Regulation.
  - Clarify process and information requirements
  - Permits constructive criticism
- Use guidance created by others (e.g., MAC tailings guide).
- Annual workshops review of site-specific results, challenges with different practices and regulatory practices.
- Participate in national & international research groups.
- Create a constructive environment for sharing ideas and experiences

Conclusion

Significant challenges still exist in reclamation as a result of:

– the complexity of mines and mines sites;
– the large information requirements;
– the potentially high costs; and
– our limited experience.

To address these issues and other environmental issues, the northern mining sector needs to:

1. use the experience of other jurisdictions as a general guide, taking care to check its applicability to northern conditions;
2. conduct studies to better understand waste deposition, and associated weathering and leaching under northern conditions;
3. adopt a constructive, cooperative approach to information sharing and discussing the results; and
4. have contingency plans or use caution in the absence of the required understanding.

Pinchi Lake Hg Mine

Although our understanding is far from complete, this approach should ensure cost-effective, environmentally safe, future reclamation practices.

Worst Images of Closed Mines

- Historic practices have been poor
- Widely perceived as environmental "spoiler"

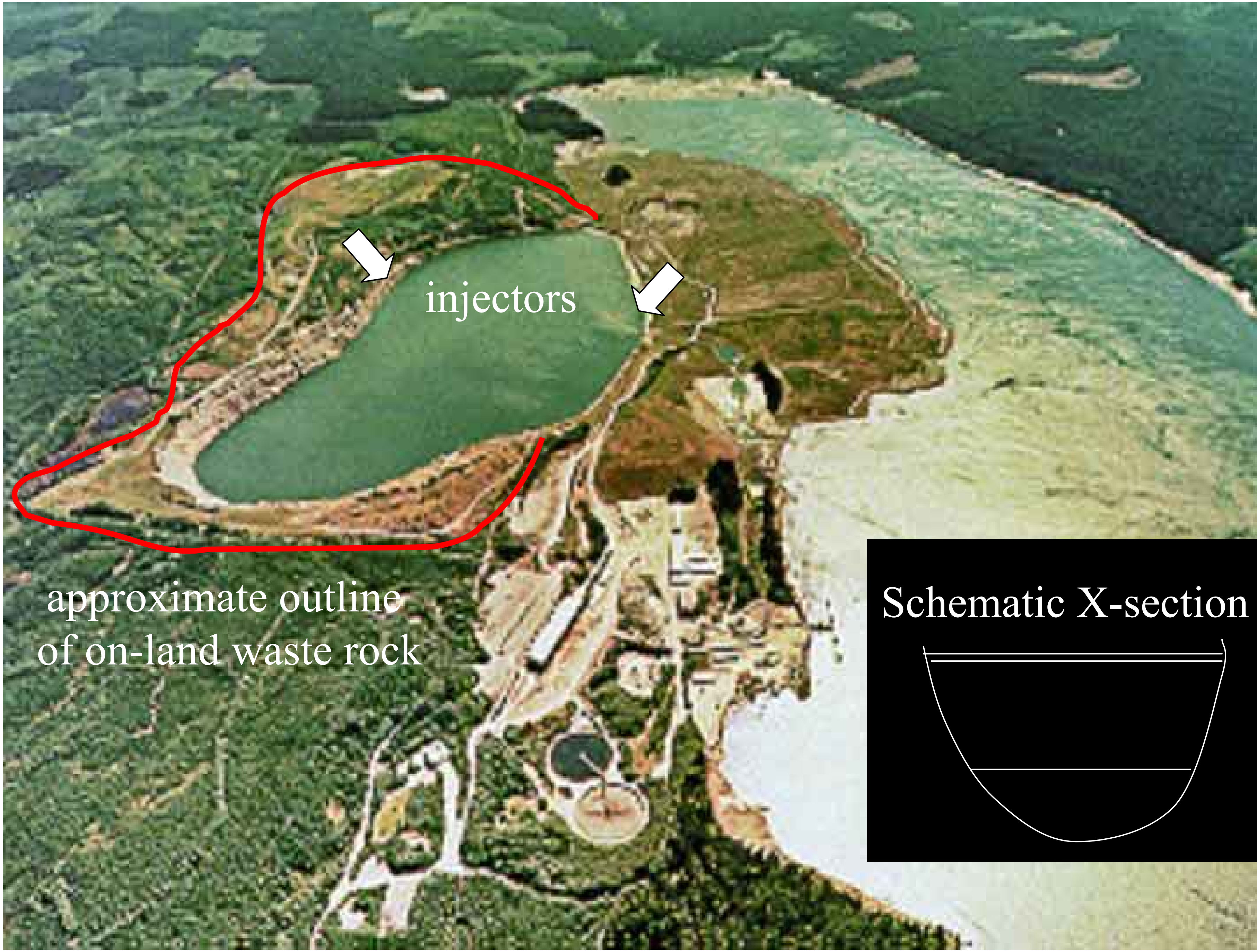
Duthie Mine, Smithers
In 1980s

Improved site reclamation practices in British Columbia over last 10 years


Duthie Mine, Smithers
2004

Mines Components

- Waste Rock Dumps
- Tailings
- Open Pits
- Underground Workings
- Ore Stock Piles
- Low Grade Ore Stock Piles
- Treatment Sludge
- Roads
- Dams
- Cycloned Tailings (backfill)
- Backfilled Tailings Paste
- Cemented Backfill
- Mixture of the above


injectors
approximate outline
of on-land waste rock
Schematic X-section

Acknowledgements

- Mike Aziz, Equity Silver Mine
- Stephen Day, SRK
- Glenda Ferris
- Mark Freberg, Highland Valley Copper
- Doug Johnson, Huckleberry Mine
- Walter Kuit & Bruce Donald, TeckCominco
- Peri Mehling, Mehling Environmental
- Kevin Morin, MDAG
- Marlin Murphy, Eskay Creek Mine