D.6. The Risks Associated with Uplands Disposal of PAG Wastes

by
Peri Mehling
Mehling Environmental Management Inc.

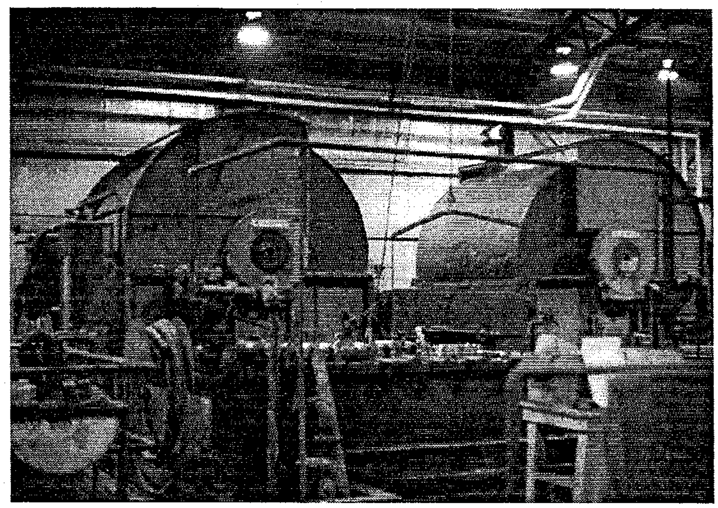
The Risks Associated with Uplands Disposal of PAG Wastes

Peri Mehling
MEHLING ENVIRONMENTAL MANAGEMENT INC.

How to deal with PAG wastes

Some alternatives ...

De-pyritize



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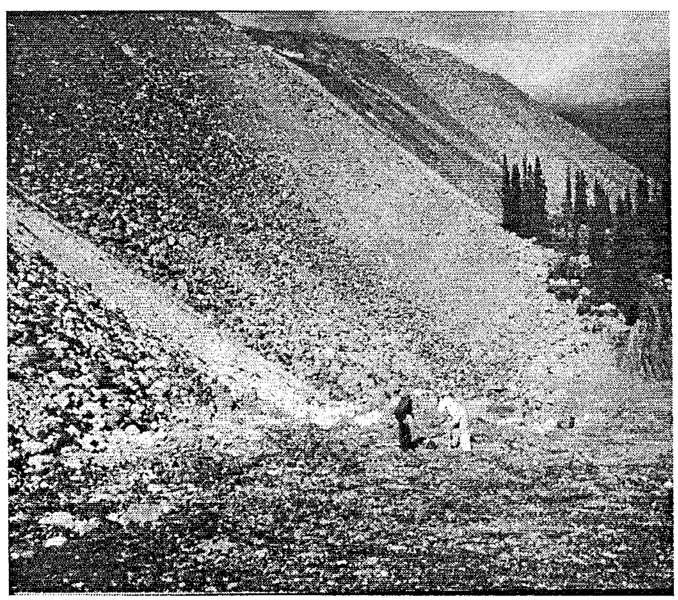
Blend



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Cover

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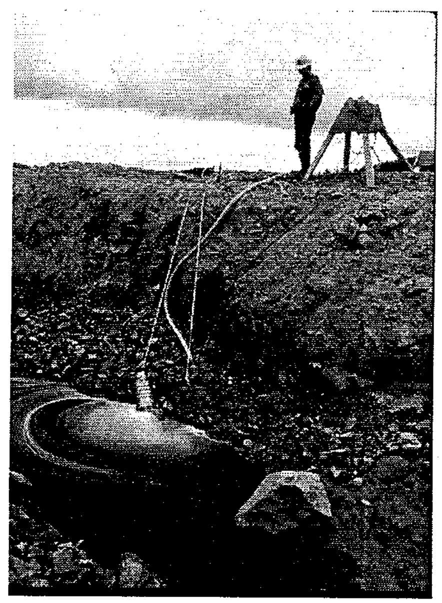
Collect and ...



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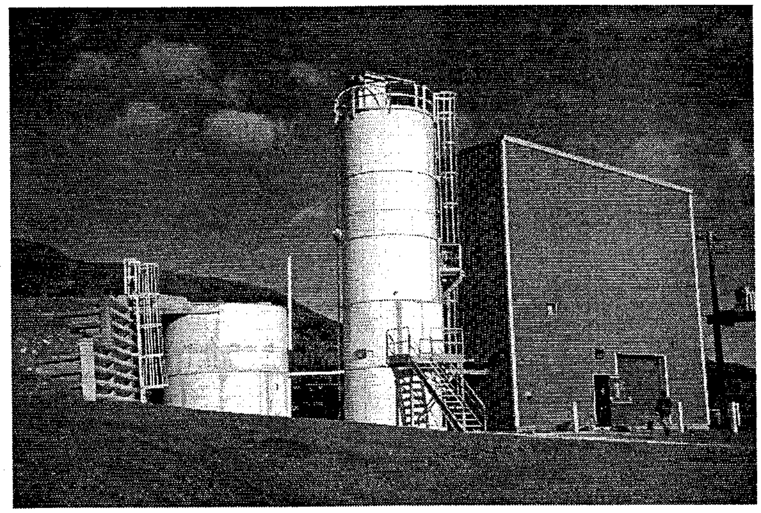
Treat



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Flood

- geochemically successful
- inhibits ARD

However...

- its success promotes its overuse as a preventive mitigation method

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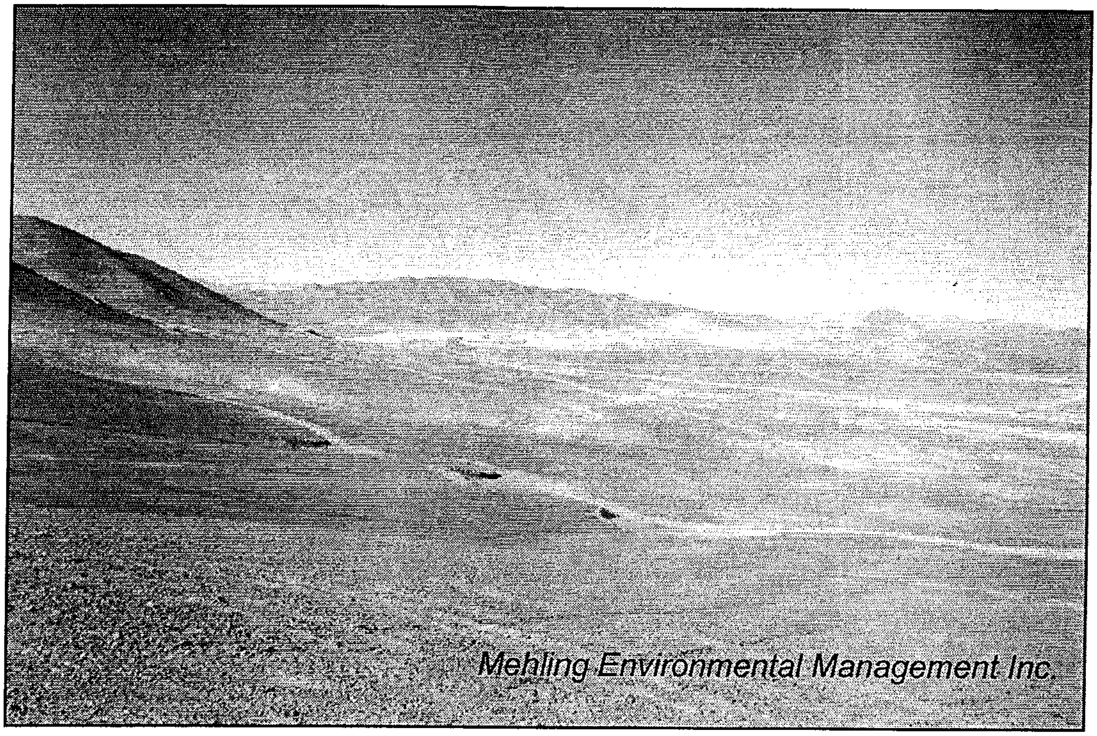

Limitations

- Doesn't work everywhere
- Doesn't work well as a retrofit, especially where there are upstream constructed dams
- Flooding exacerbates some issues which are already a concern for impoundment integrity

Considerations for Disposal of Wastes in Flooded Upland Impoundments

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Construction Materials

- low permeability core for dams
- granular materials for toe drains and upstream riprap

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Foundation Conditions

- low permeability
- not adversely effected by continued seepage and additional flows

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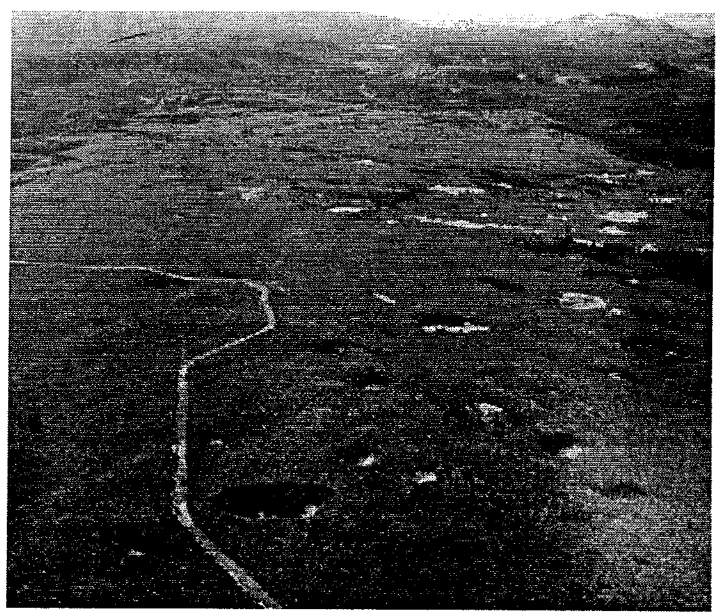
Karst



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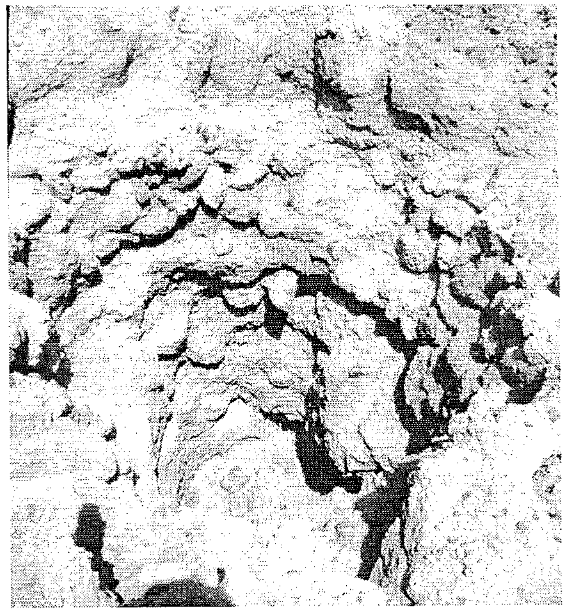
Karst



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Water Management

- Water Balance
  - hard to predict based on limited data at mine sites
  - too much or too little is more critical (wet/dry years)
  - need to handle variability, storm events

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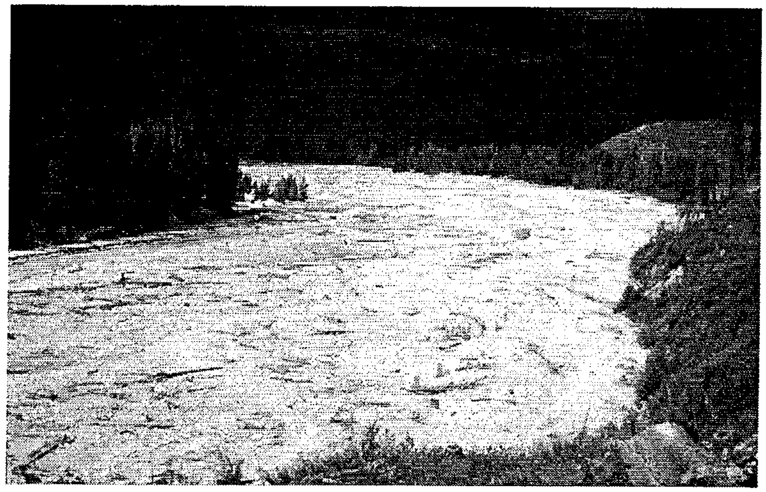
Natural Hazards



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Dam Stability

- 40% of tailings dam failures are due to:
  - overtopping
  - seepage
  - liquifaction
- More water - greater vulnerability

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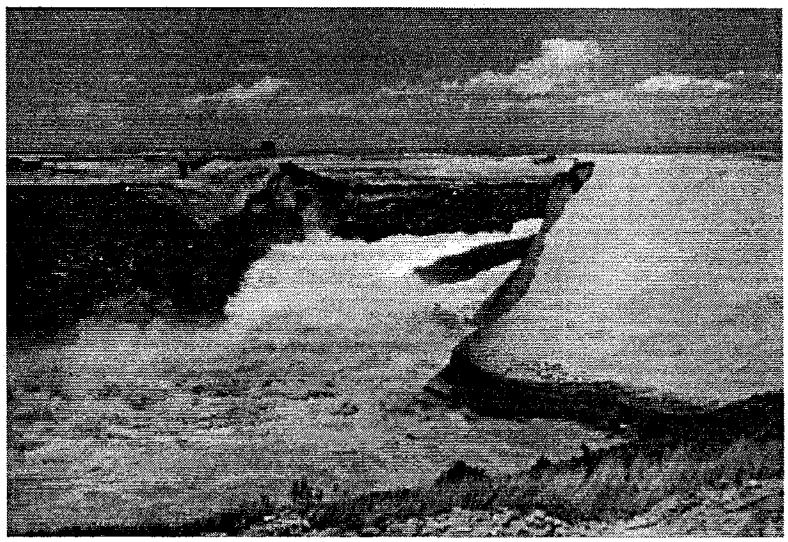
Piping



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Seepage

- loss of seepage increased with water cover
  - difficulty in predicting long term seepage quality
  - long term recovery and potential treatment of seepage

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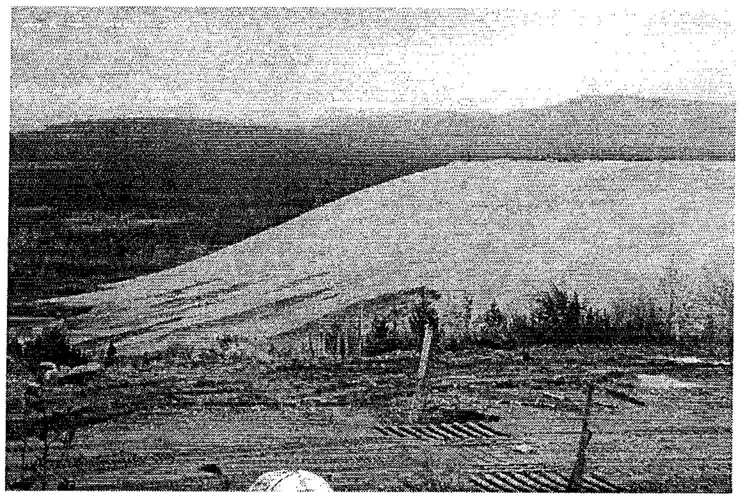
Seepage control



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Maintenance

- continued concern for stability issues
  - overtopping
  - beaver dams
  - spillway

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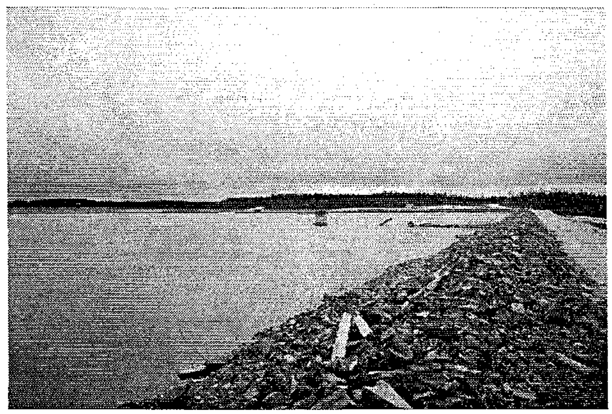
Flooded Impoundments

- increased geotechnical concerns
- perpetual maintenance



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Flooded Impoundments

- Doesn't work everywhere
- Site specific
- Must conduct thorough prediction work before selecting appropriate mitigation measure

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Flooded Impoundments

Flooded facilities
= 'pending or ponded risk',
'deferred risk'

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Lake Disposal

- Nature has minimized stability problems
- often cited as a temporary use which implies:
  - lake will discharge clean water after disposal has ended
  - ecology around lake will return to productive use

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Lake Disposal - Issues

- number of lakes
- value of lakes
- geochemical control of ARD
- unknown ecological effects

The consequences are not fully known.

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Recommendations

Mining community must work together to

- support basic research in the biology and ecology of lakes or man made water bodies that hold waste
- quantify long term consequences
- develop detailed information at existing sites to assist the application at future sites

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D.7. Underwater Disposal of Sulphide-Rich Tailings in Lakes: Why or Why Not?

by
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University of British Columbia

and
Lorax Environmental

Underwater Disposal of Tailings in Lakes: Why or Why Not?

Thomas F. Pedersen
Earth and Ocean Sciences
University of British Columbia

and
Lorax Environmental, Vancouver

Why Store Tailings Under Water?

Concentration of O_2 in air is 210,000 ppmv, whereas in water it is sparsely soluble: ~8 ppm by weight.

The molecular diffusion of oxygen in water is some four orders of magnitude slower than in air.

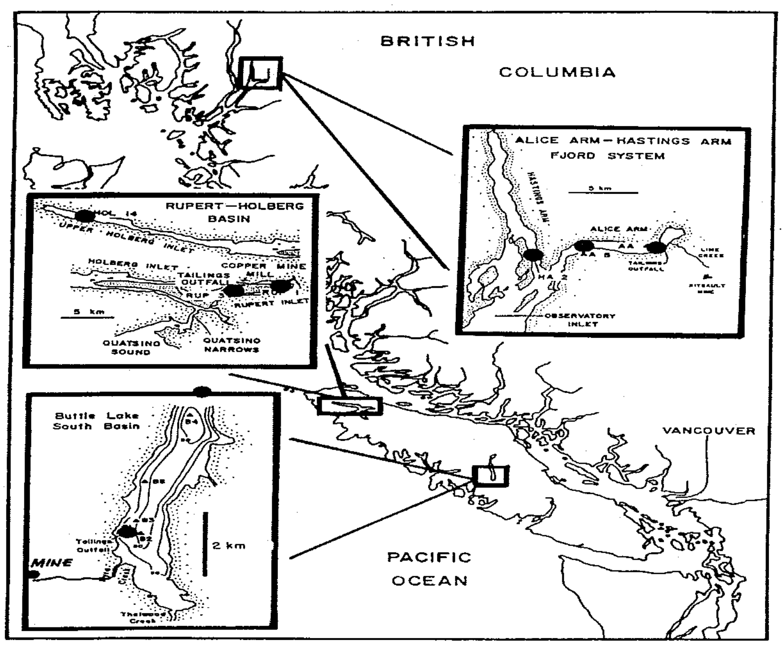
The Case For Lakes...

Sulphide-rich tailings submerged in natural lakes do not release significant amounts of metals, during disposal or after.

Submerged tailings in lakes are covered eventually (quickly?) by an anoxic veneer of natural sediments.

Biological uptake of metals from tailings on (deep) lake floors is not significant.

Benthic recolonization is rapid (based on marine experience).

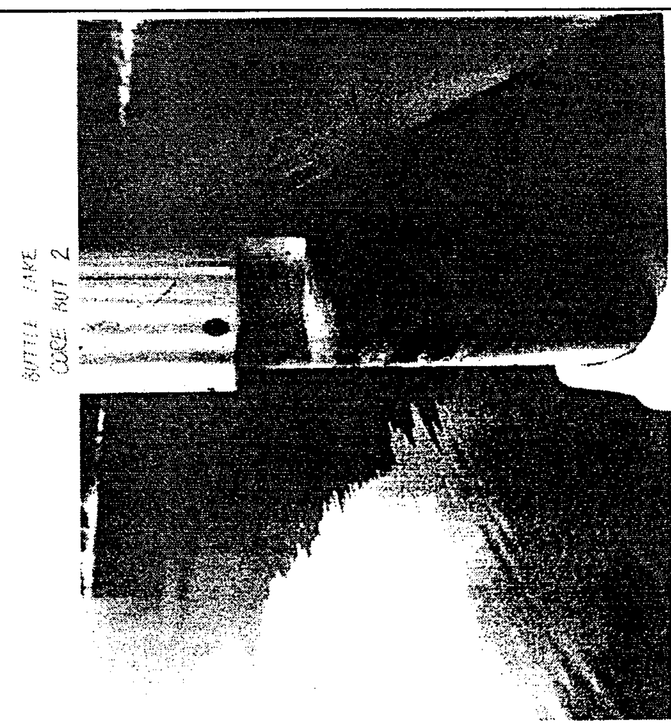


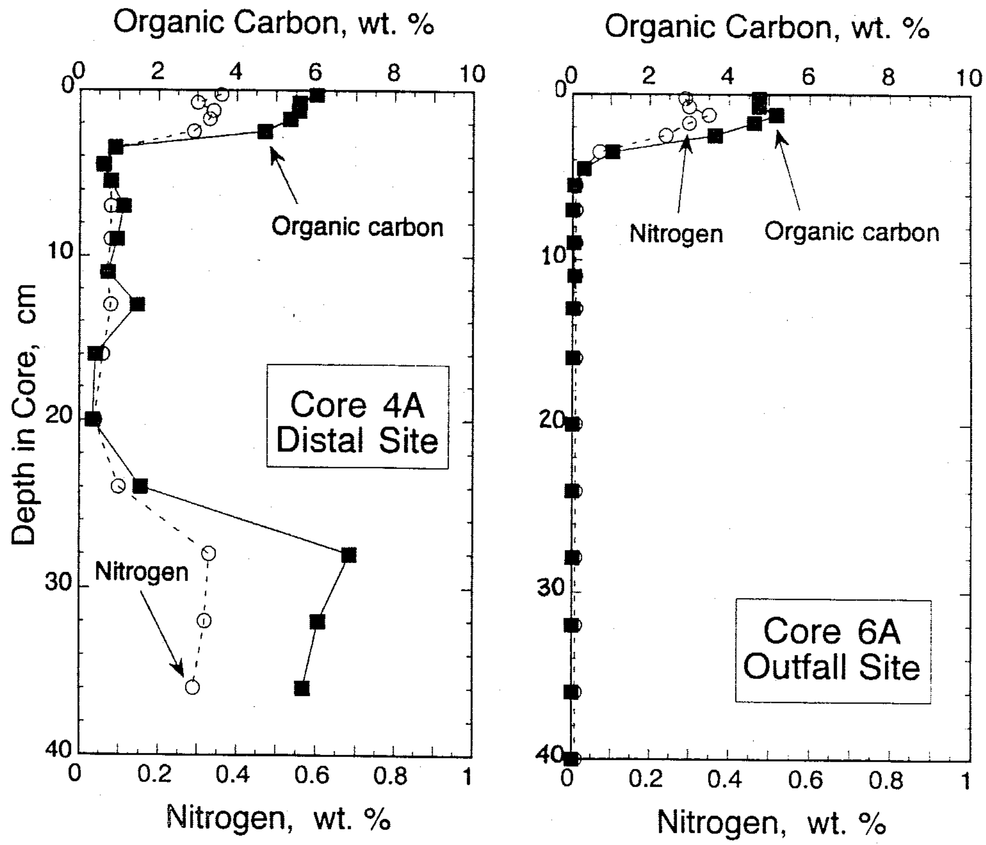
Buttle Lake, Vancouver Island, B.C.

Deep, oligotrophic.

Pyrite, Zn-, Cu- and Pb-rich tailings discharged to the South Basin from 1967-1984 via a submerged outfall

ARD from a waste-rock dump near the mine flowed into the lake from the early 70's to about 1983.

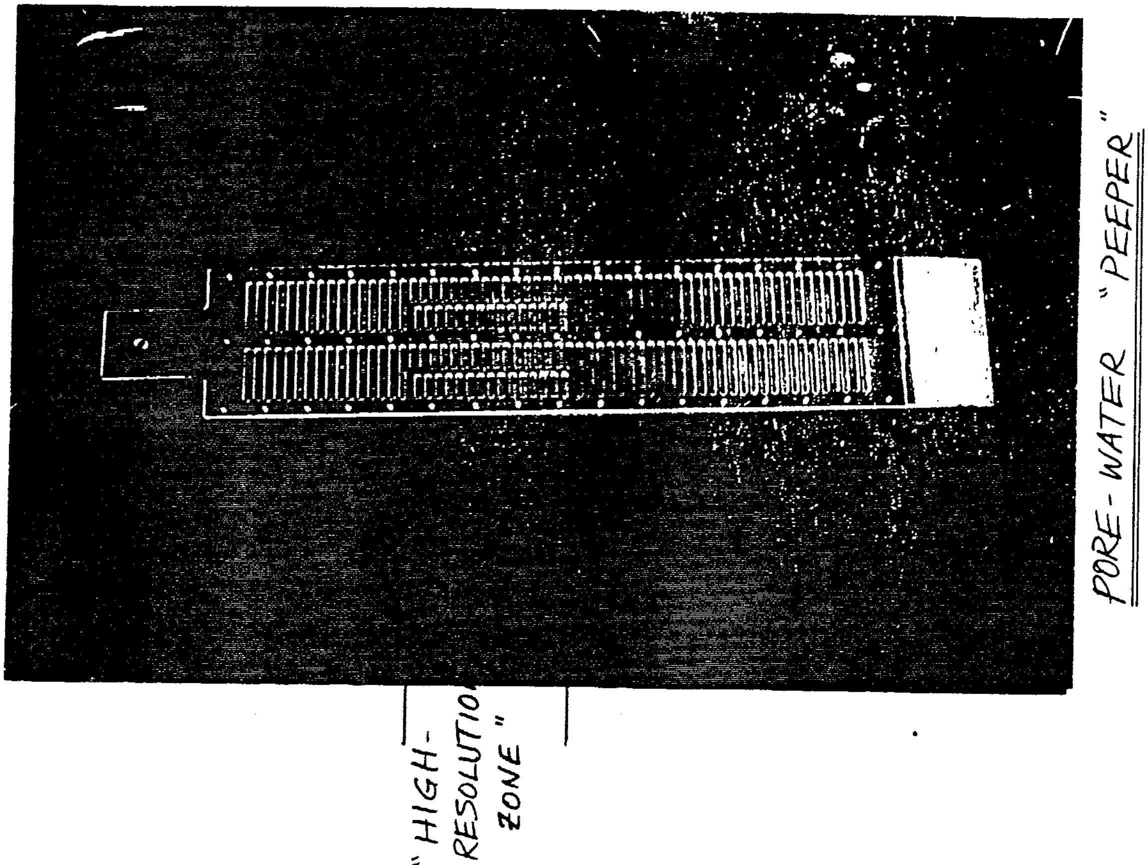


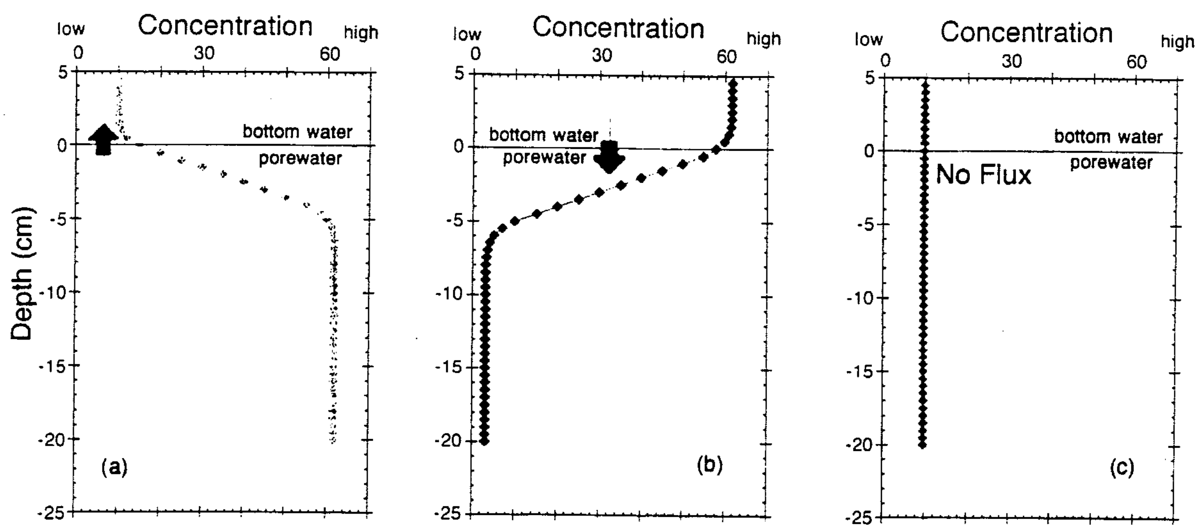


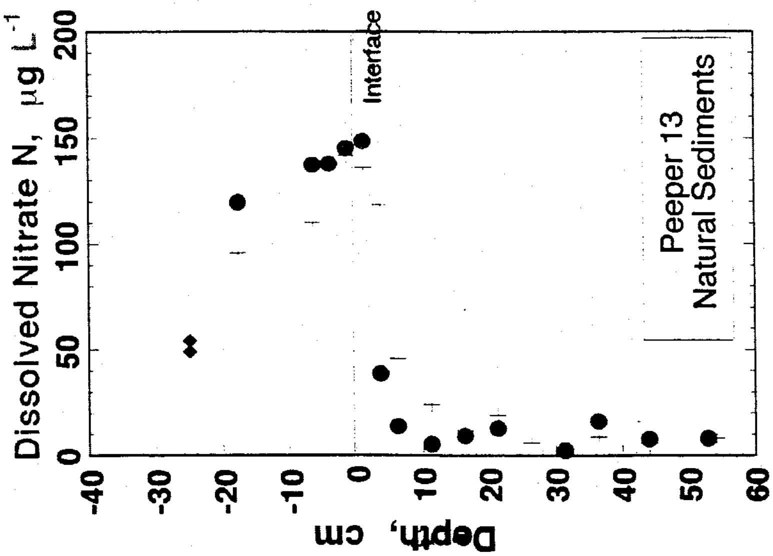
Oxidation Reactions in Sediments

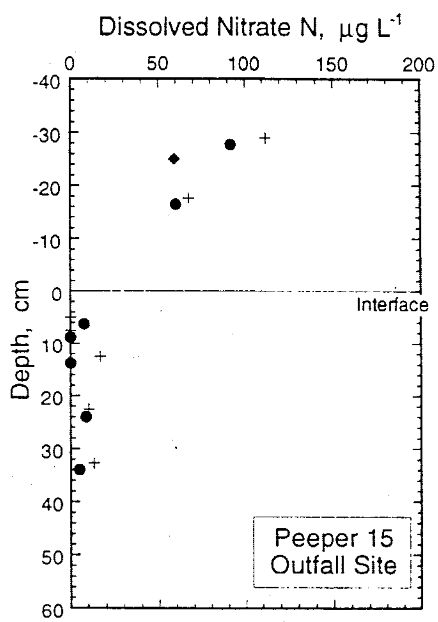
The degradation of organic matter by bacteria drives a suite of oxidation reactions, in which the following oxidants are consumed, quasi-sequentially:

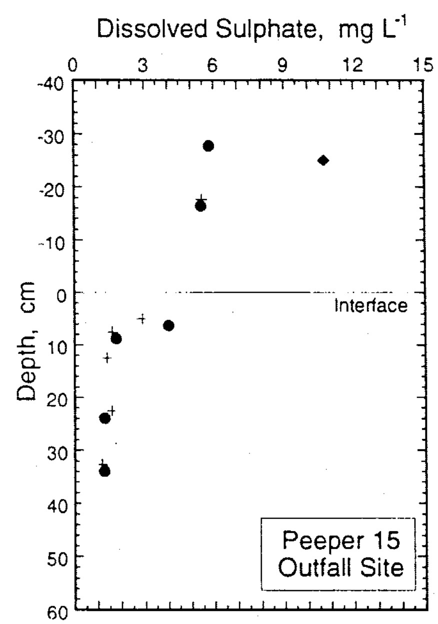
Oxidant	*Product*
O_2 (aq)	CO_2(aq)
NO_3^-(aq)	N_2(g)
MnO_2(s)	Mn^{2+}(aq)
FeOOH(s)	Fe^{2+}(aq)
SO_4^{2-}(aq)	H_2S(aq)

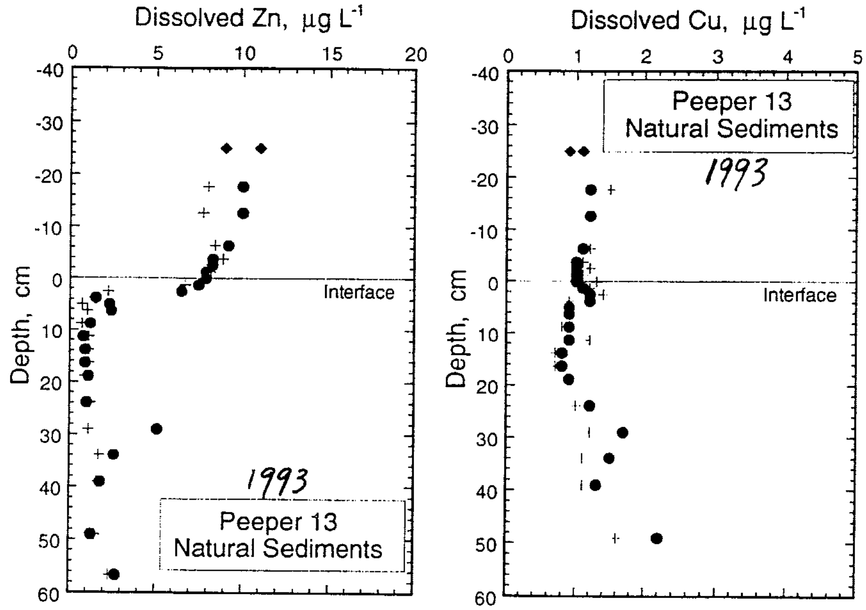

PORE-WATER "PEEPER"
"HIGH-RESOLUTION ZONE"

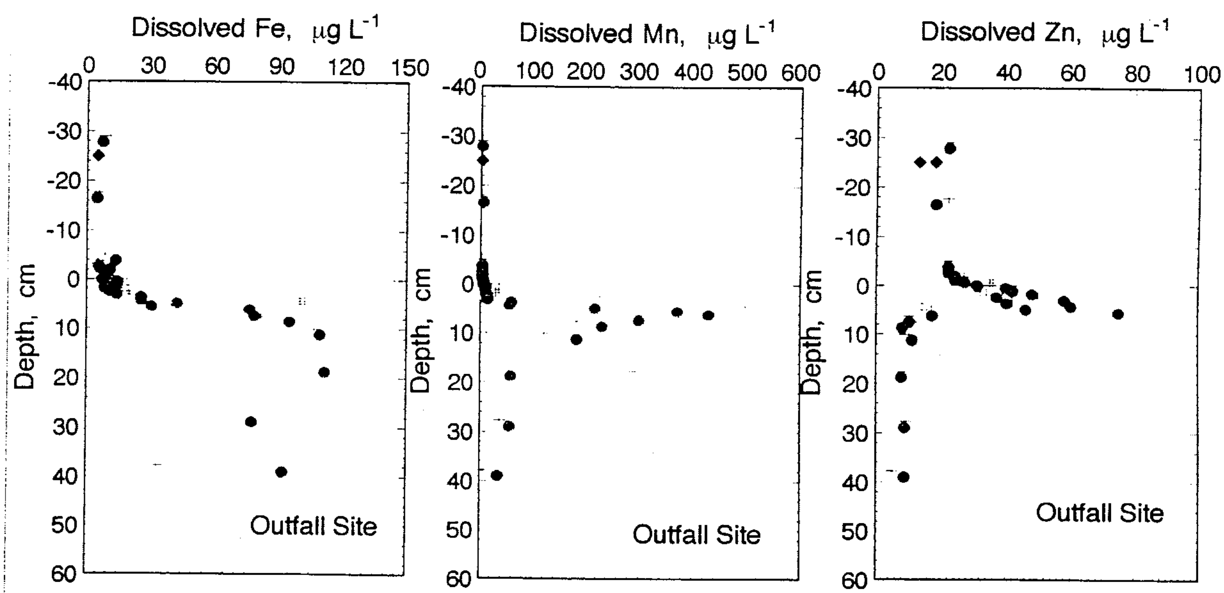

Concentration
low
high
0
30
60
Depth (cm)
bottom water
porewater
No Flux
(a)
(b)
(c)
5
0
-5
-10
-15
-20
-25


Dissolved Nitrate N, µg L-1
Depth, cm
Interface
Peeper 13
Natural Sediments


Dissolved Nitrate N, µg L-1
Depth, cm
Interface
Peeper 15
Outfall Site


Dissolved Sulphate, mg L-1
Depth, cm
Interface
Peeper 15
Outfall Site


Dissolved Zn, µg L-1
0 5 10 15 20
-40 -30 -20 -10 0 10 20 30 40 50 60
Depth, cm
Interface
1993
Peeper 13
Natural Sediments
Dissolved Cu, µg L-1
0 1 2 3 4 5
-40 -30 -20 -10 0 10 20 30 40 50 60
Depth, cm
Peeper 13
Natural Sediments
1993
Interface


Dissolved Fe, µg L-1
0 30 60 90 120 150
-40 -30 -20 -10 0 10 20 30 40 50 60
Depth, cm
Outfall Site
Dissolved Mn, µg L-1
0 100 200 300 400 500 600
-40 -30 -20 -10 0 10 20 30 40 50 60
Depth, cm
Outfall Site
Dissolved Zn, µg L-1
0 20 40 60 80 100
-40 -30 -20 -10 0 10 20 30 40 50 60
Depth, cm
Outfall Site

Island Copper, Vancouver Island

1971-1996, open-pit copper and molybdenum mine

30,000 to 60,000 tonnes per day of ore processed

All tailings discharged to adjacent Rupert Inlet via submerged outfall (25m deep)

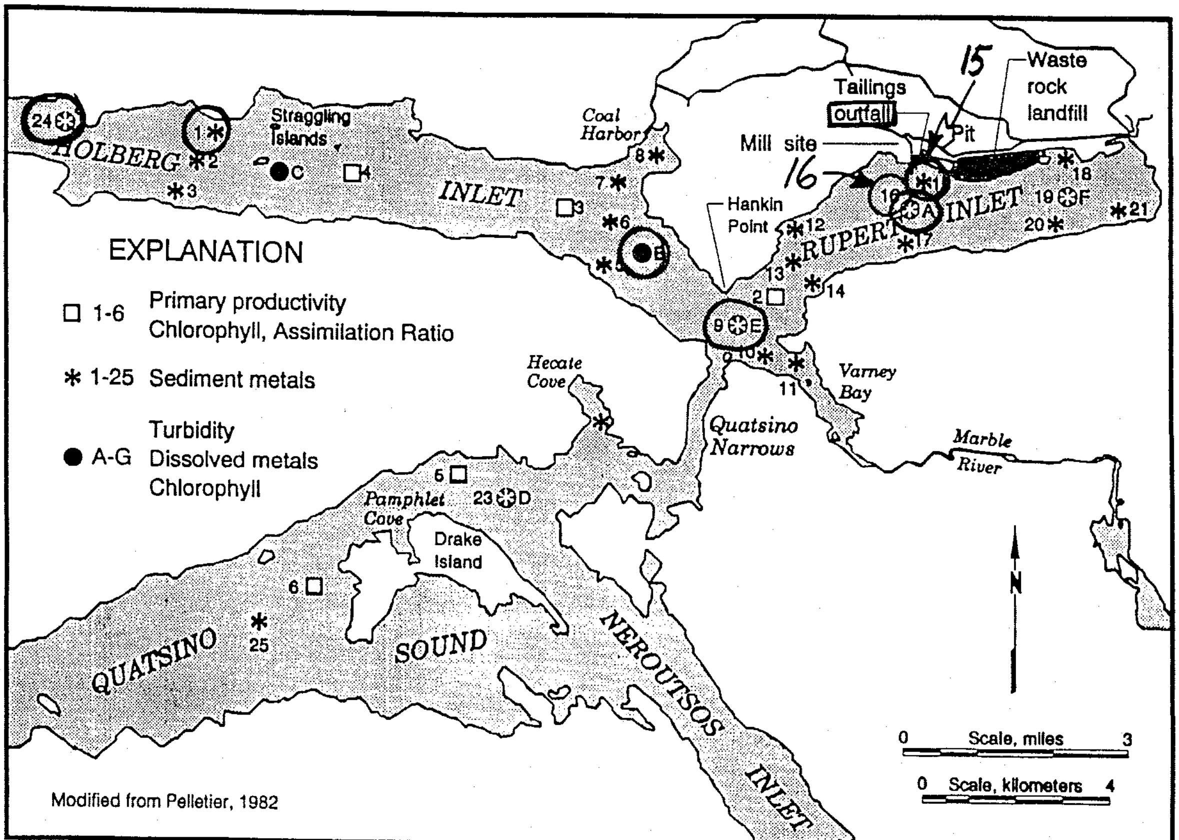
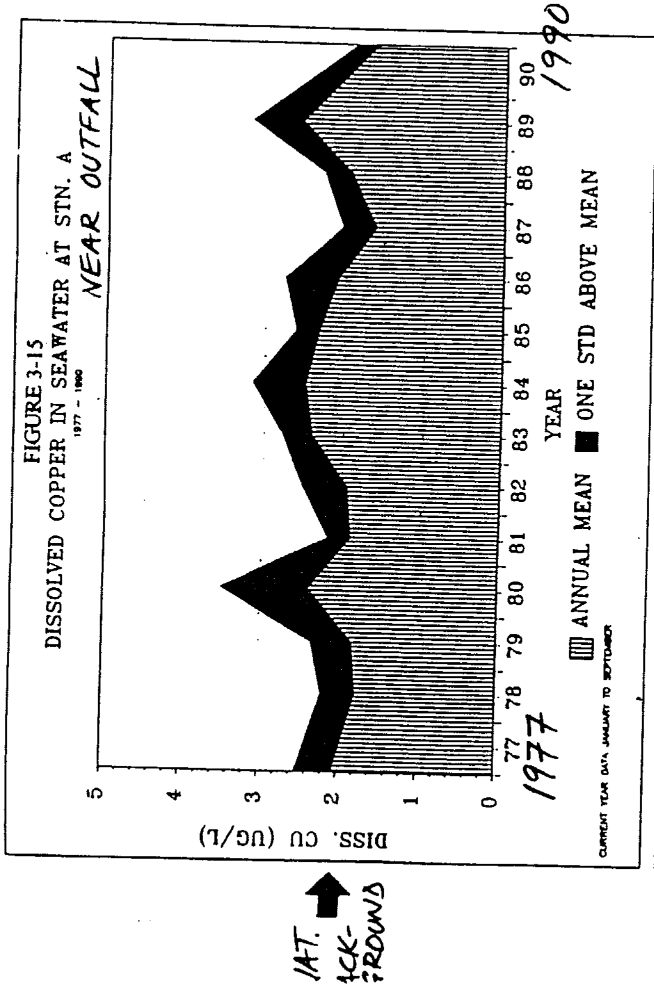
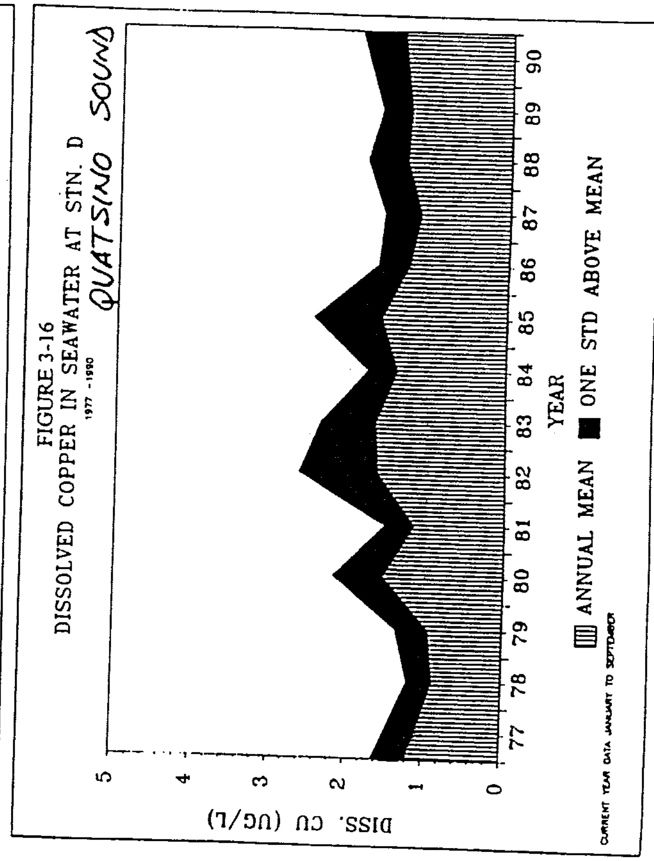


Figure 3.13 - Rupert Inlet and adjacent fjords with selected monitoring stations.





The Case For Lakes...

Sulphide-rich tailings submerged in natural lakes do not release significant amounts of metals, during disposal or after.

Submerged tailings in lakes are covered eventually (quickly?) by an anoxic veneer of natural sediments.

Biological uptake of metals from tailings on (deep) lake floors is not significant.

Benthic recolonization is rapid (based on marine experience).

Dissolved zinc levels and metallothionein in trout livers, Campbell River watershed, 1980-1981

(from Roch et al., Can. J. Fish. Aquatic Sci. 39, 1596-1601, 1982)

Location	Dissolved zinc ($\mu g\ L^{-1}$)	Metallothionein (nmol g-1)
Southern Buttle Lake	170	269
Upper Campbell Lake	60	164
John Hart Dam	50	94
Upper Quinsam	<5	58

DOWNSTREAM →

The Case For Lakes...

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Recolonization, Rupert Inlet

Data courtesy Derek Ellis, U. Victoria

Station	# species	#organisms, per m^2
15	4	426
16	8	640

Station	# species	#organisms, per m^2
15	28(59)	4,826 (13,420)
16	25	4,566

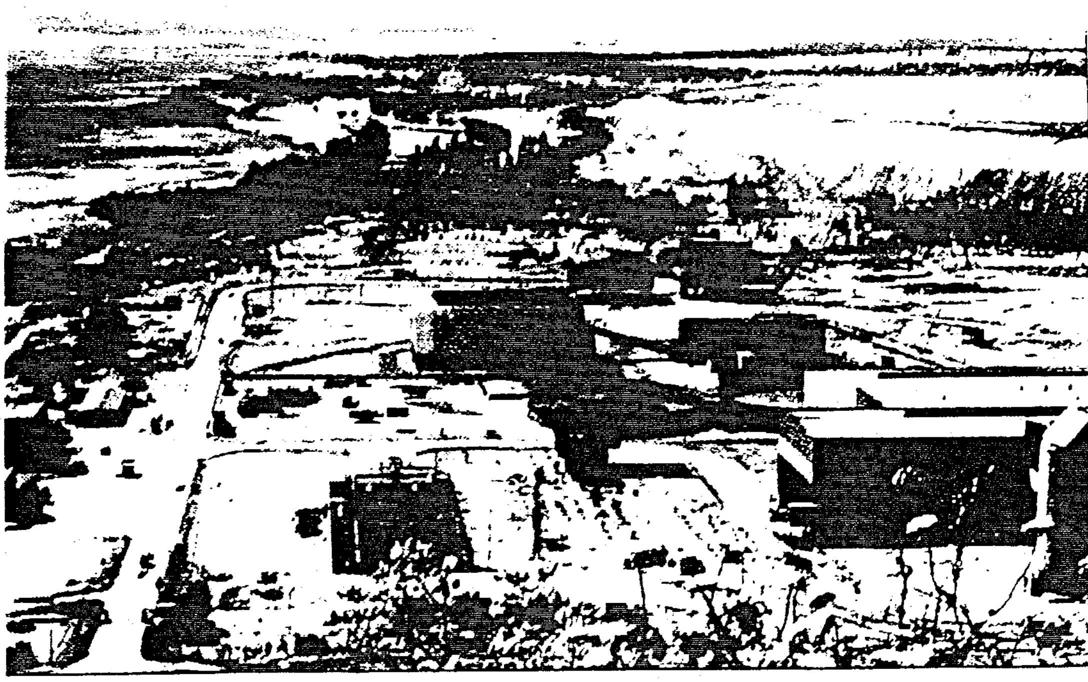
Caveats and Concerns

- Not all types of tailings are chemically suitable for submergence in lakes:
  - *Molybdenite-bearing ore*
  - *Previously-oxidized deposits*
- Benthic obliteration
- Bioaccumulation in shallow sediments accessible to animals

Why not put tailings on land?

- Acid rock drainage
- Perpetual stewardship
- Aesthetics
- Habitat degradation
- Scale of pond footprints
- Water balance issues
- Seismic hazards
- Engineering deficiencies

LOS FRAILES, SOUTHERN SPAIN



supernatant liquid is treated and recycled

pH 2-4

High Zn^{2+} Cu^{2+} Pb^{2+} Fe^{2+}

APRIL, 1998:

~4 M m^3 LIQUID, ~1 M m^3 SOLIDS RELEASED

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Conclusions and Implications

Not all types of mine waste are suitable for subaqueous disposal in lakes. Oxidized wastes, for example, are poor candidates for submerged storage.

The best available science allows us to conclude that subaqueous disposal in lakes, if properly conducted, can be an environmentally sound and permanent disposal option.