Information and Design Requirements for Dry Covers

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Bill Price
Mining and Mineral Sciences Lab.,
Natural Resources Canada

Performance Objective of a Dry Cover

- reduce infiltration of water or oxygen through the surface sufficiently to achieve a ‘significant’ reduction in contaminant loading

A significant reduction in loading could:

- Permit direct discharge
- Reduce overall mitigation costs (e.g., reduces $ for treatment)
- Reduce off site impacts (less-regulated site)

- The performance objective for oxygen reducing cover is to prevent or significantly reduce sulphide oxidation
- The performance objective for drainage reducing **cover** is to reduce the volume component of contaminant loading

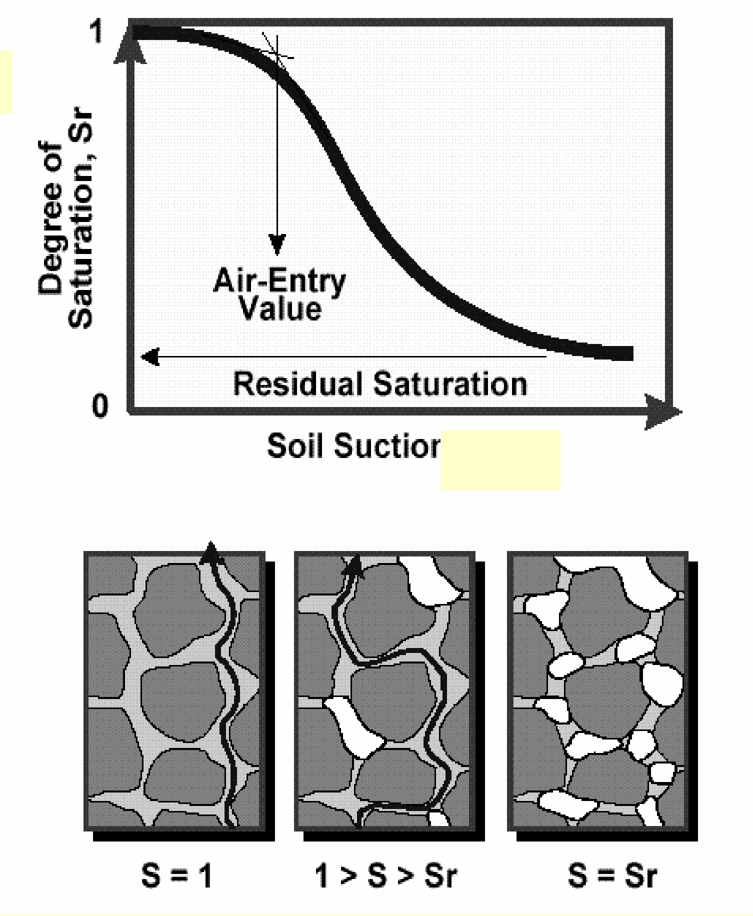
Many covers are intended for both purposes.

Cover Materials

Most commonly clayey soil or geotextile or some combination. Also organic covers and some new ideas (e.g., permanganate)

Cover mechanisms for reducing O_2 and H_2O infiltration are well understood, many references to contributing factors and predicted performance

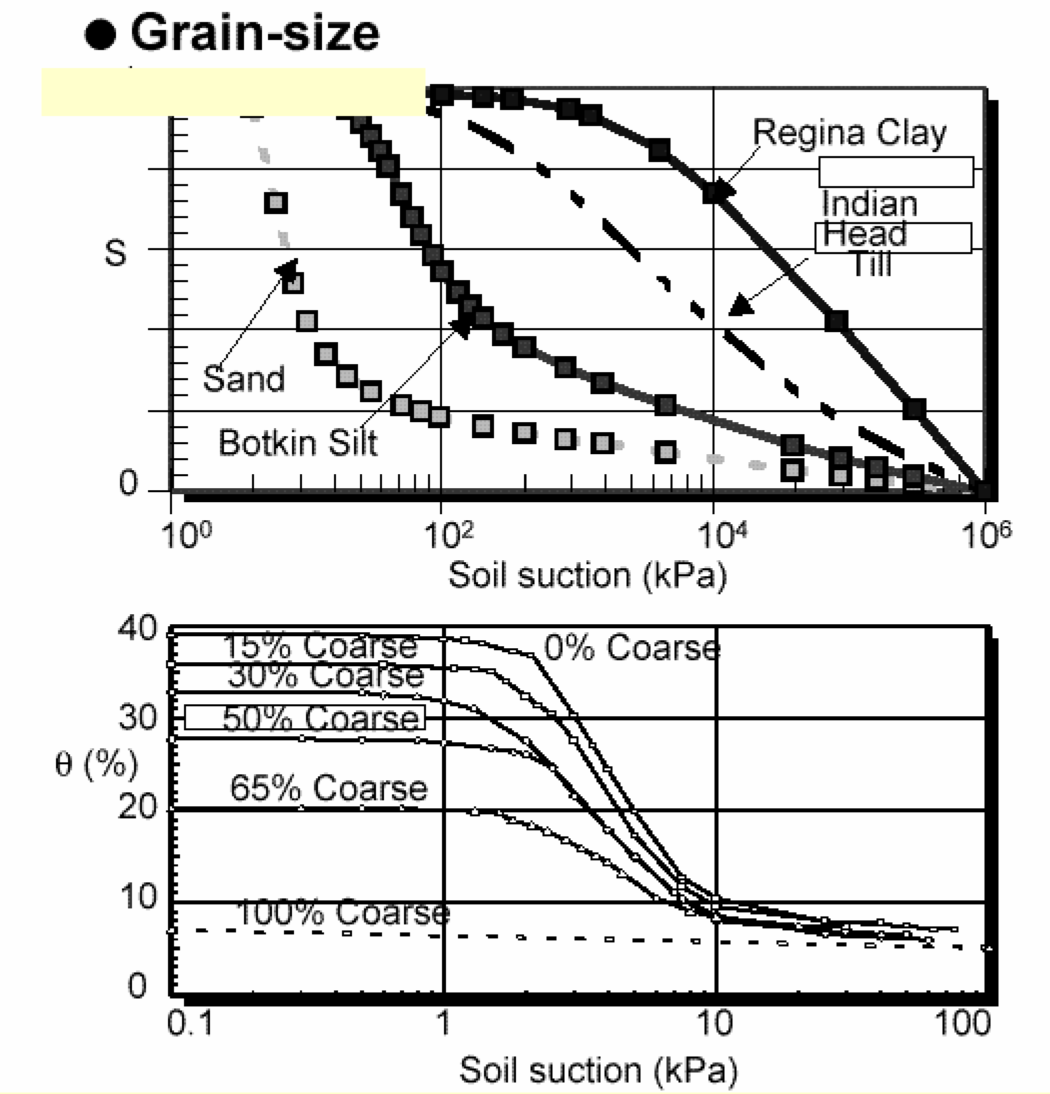
E.g., Diffusion of oxygen through covers described by Fick's Laws. Flux of oxygen is proportional to the oxygen gradient and the effective diffusion coefficient (D) of the cover. The value of "D" is controlled by the degree of saturation.



Example of Evaluation of Factors Contributing to Performance of Soil Covers for Oxygen Control

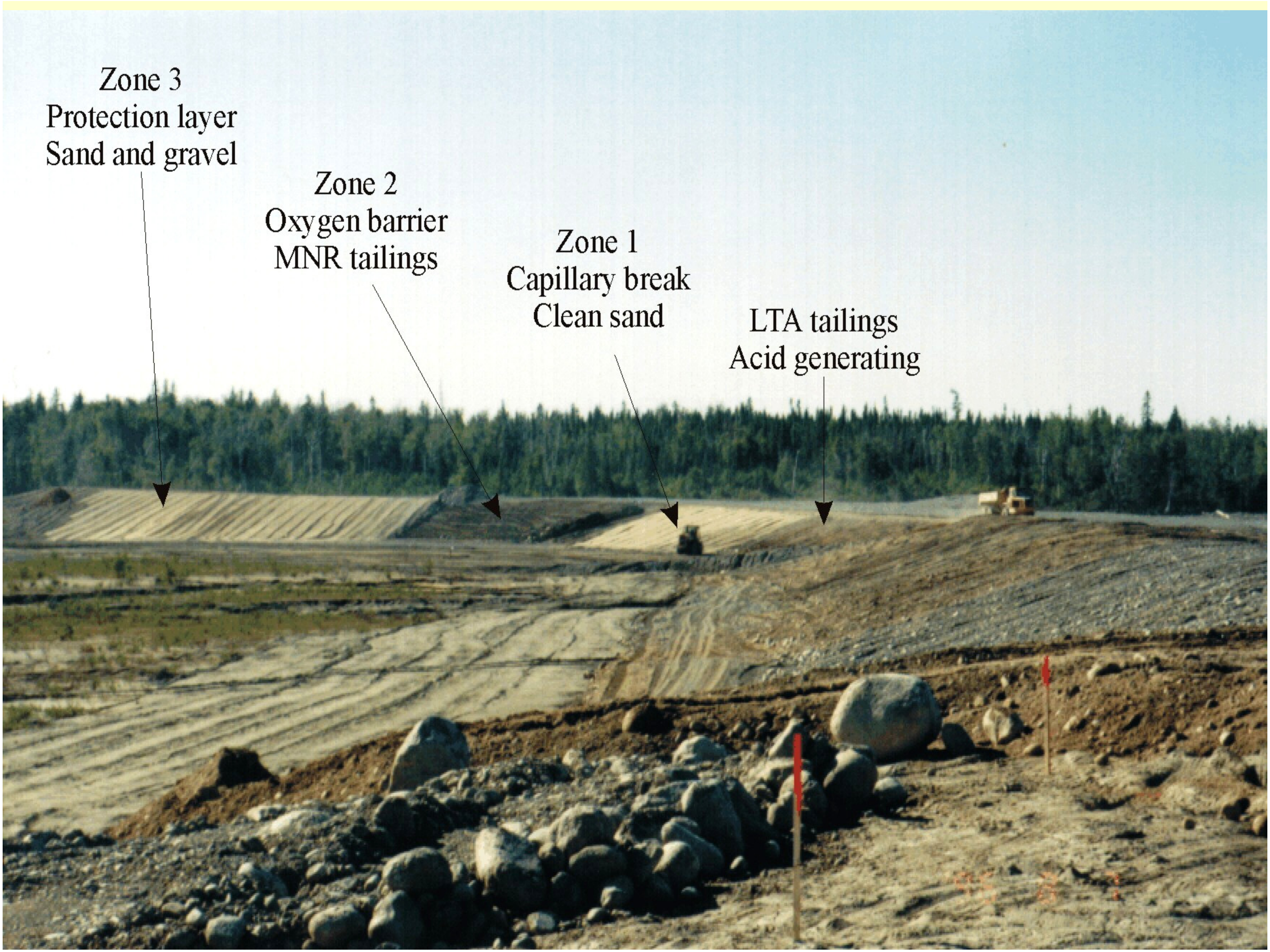
Moisture retention is a function of grain size

Fine grained materials retain high degrees of moisture



Components of a Dry Cover

- Low conductivity material to reduce O_2 and H_2O infiltration (e.g., compact clay or geotextile)
- Surface
  - conduct excess water off the cover
  - protect low conductivity layer
  - support plant growth and increase evapotranspiration
- Bottom
  - may contribute to the impedance of infiltration
  - prevent contamination of biota on surface.

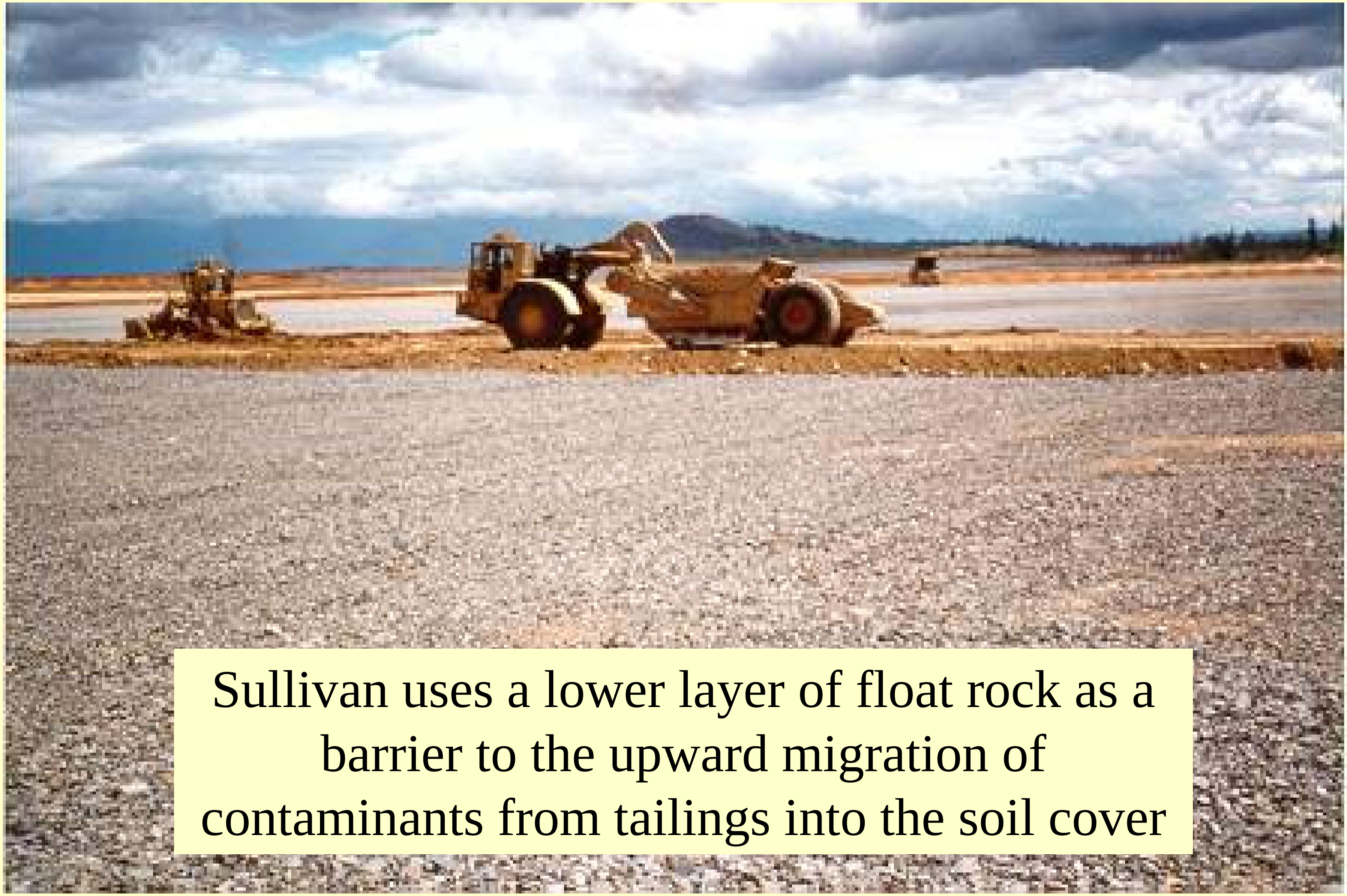

Zone 3
Protection layer
Sand and gravel
Zone 2
Oxygen barrier
MNR tailings
Zone 1
Capillary break
Clean sand
LTA tailings
Acid generating

Cover Design and Construction

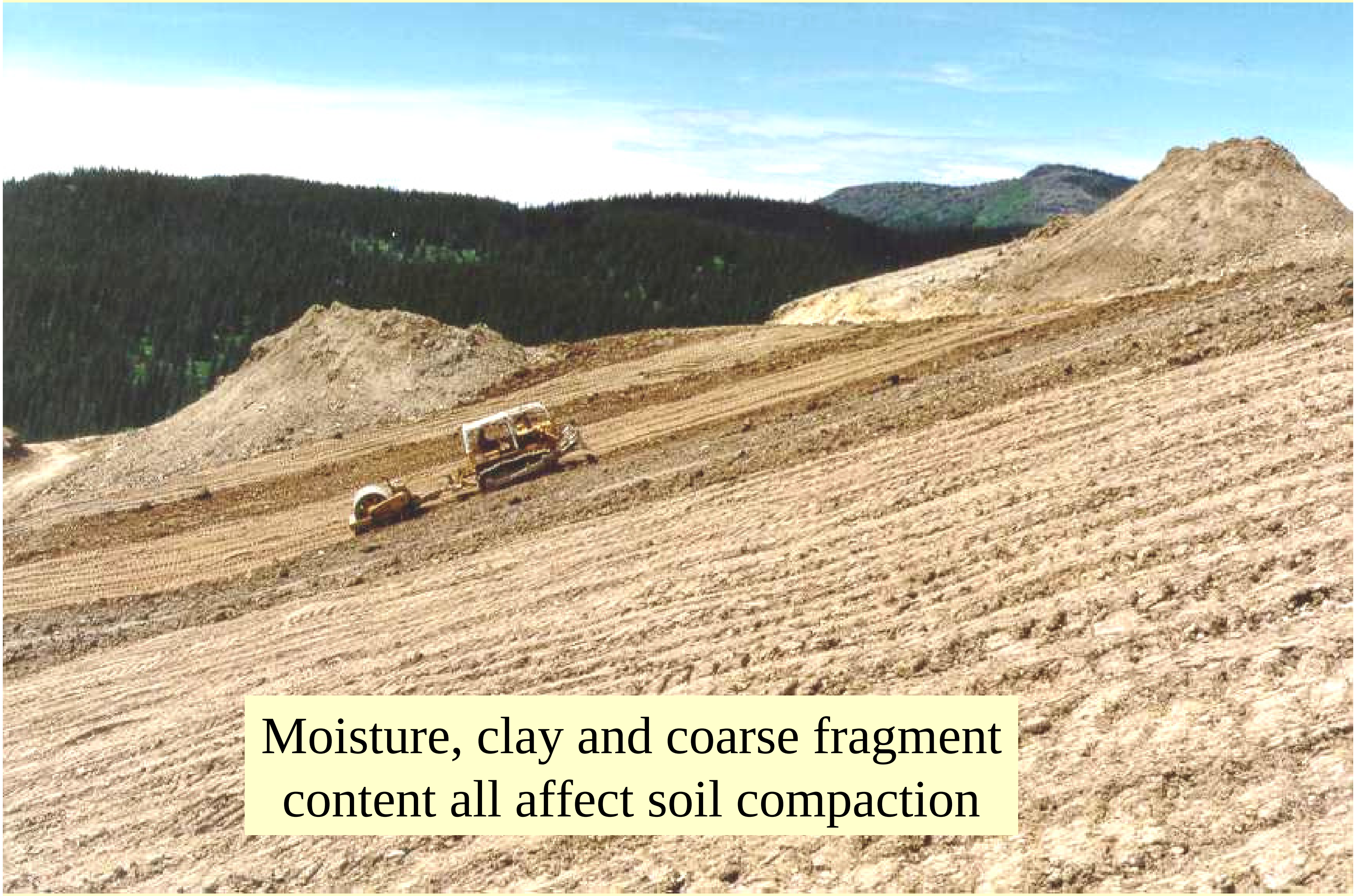
Need:

- cost-effective source of cover materials;
- engineered design, which should include the following;
  - detailed materials testing;
  - site preparation;
  - QA/QC during construction;
  - vegetation management plan;
  - drainage management plan; and
  - plans for monitoring, maintenance, repair and if required replacement and supplemental mitigation.

Site preparation may include resloping angle of repose waste rock dumps prior to cover construction. Some regrading may also be required to remove drainage from covered tailings



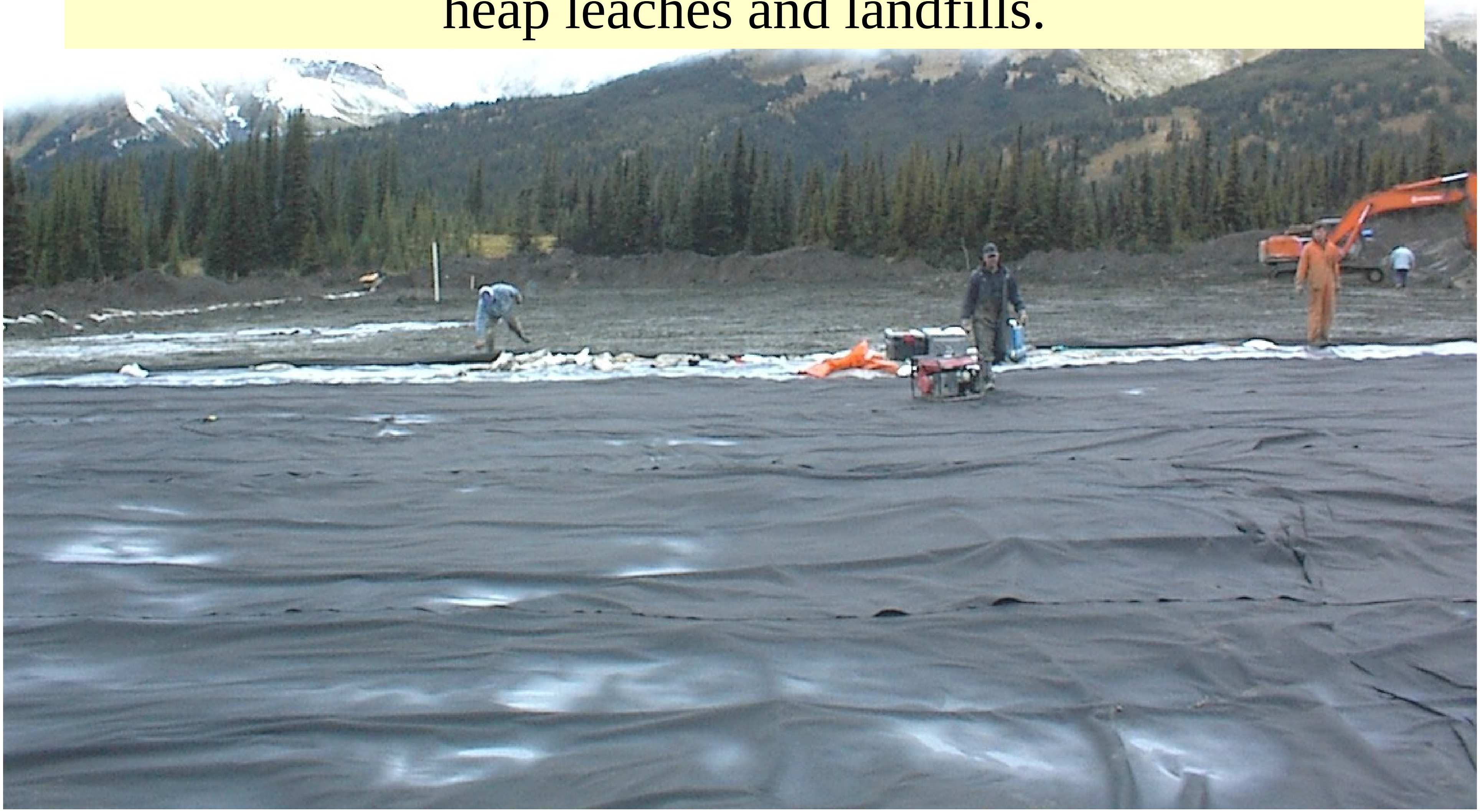
Sullivan uses a lower layer of float rock as a barrier to the upward migration of contaminants from tailings into the soil cover



Moisture, clay and coarse fragment content all affect soil compaction

With massive quantities and machinery involved, detailed QA/QC is needed to ensure required soil quality and depth of different layers.

Construction requirements are also very important for geotextile covers. Lots of data on construction requirements available from use of geotextile liners by heap leaches and landfills.



Species Use in Cover Revegetation

- Advantages of herbaceous species are that they make it easier to identify surface deformation, and provide better erosion control and a barrier to native invasion than woody species.
- Tree-throw by woody species may damage cover.
- Root growth by both woody and herbaceous plant species can damage compacted soil layer if at times of the year this layer becomes the only source of water and nutrients.

Vegetation Management

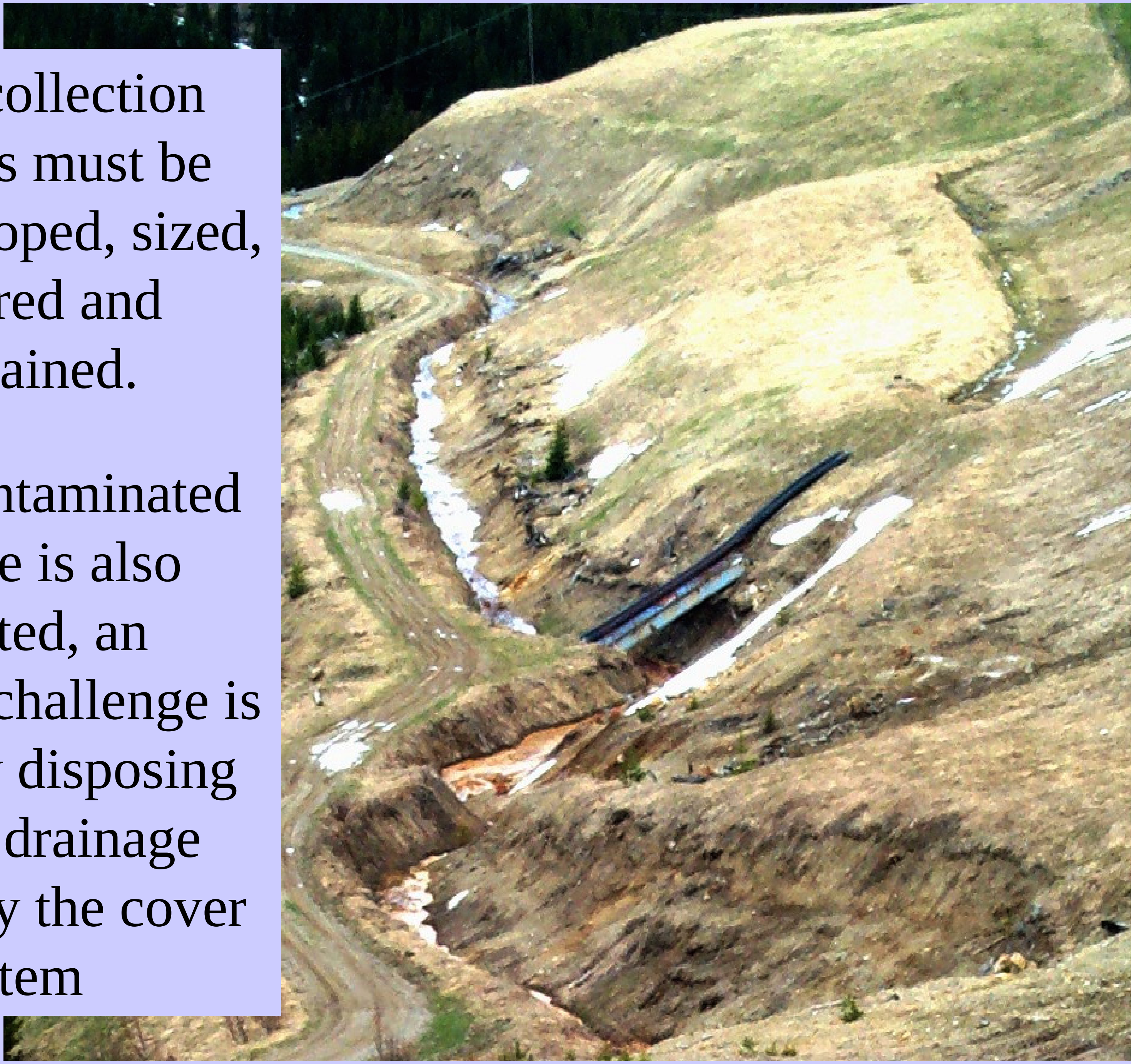
- Removal of woody species from cover
- Repair areas of erosion, disease, etc.
- Likely need to reseed, fertilize and/or lime to keep herbaceous cover healthy and competitive

Drainage Plan for Cover

Adequate slope and frequency of ditches are required to prevent increased infiltration due to ponding. Open ditches less likely to plug than drains or culverts.

Runoff collection structures must be properly sloped, sized, armoured and maintained.

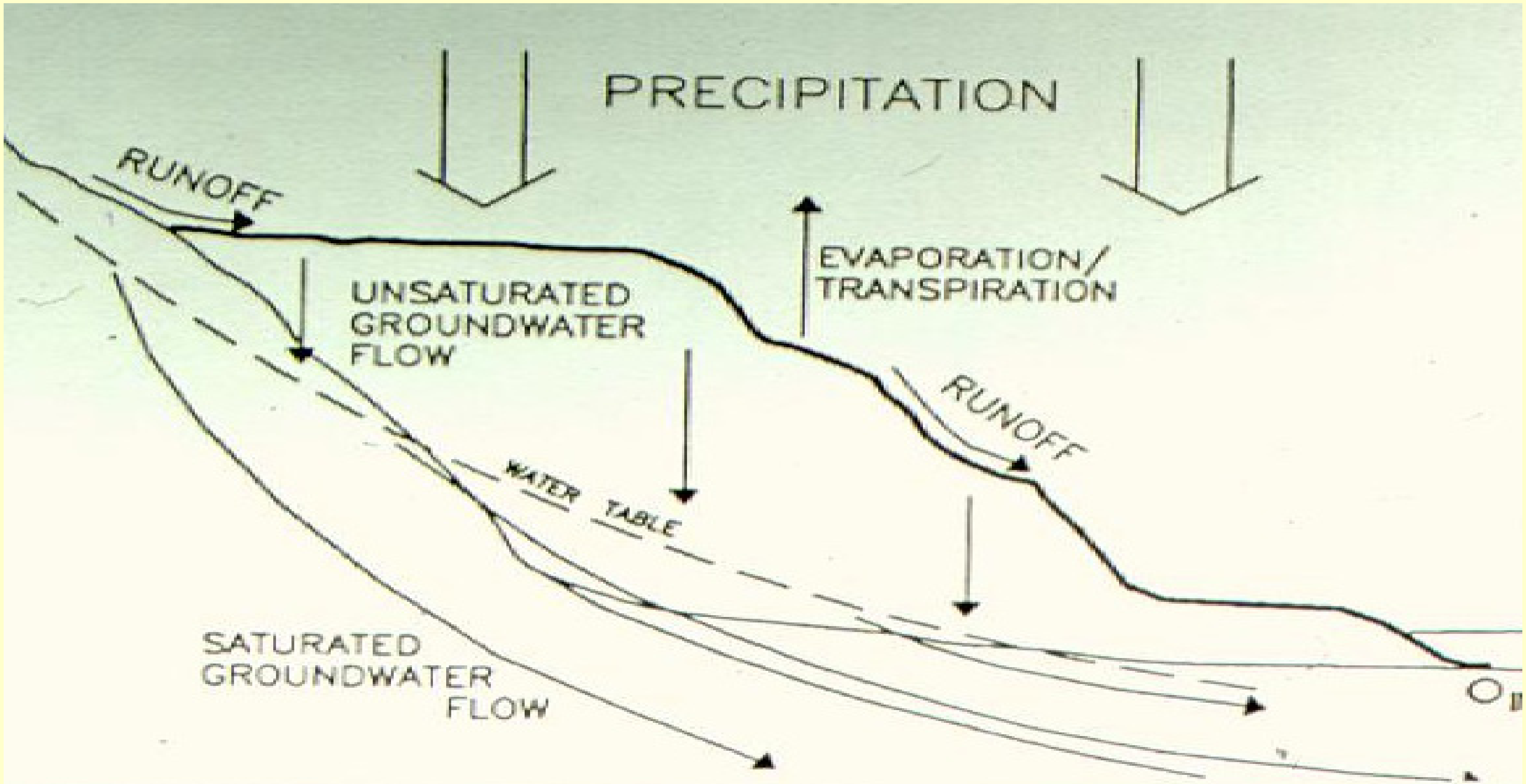
Where contaminated drainage is also collected, an additional challenge is separately disposing of clean drainage diverted by the cover system



Overall Performance of Cover System

Reduction in drainage and oxygen depends on:

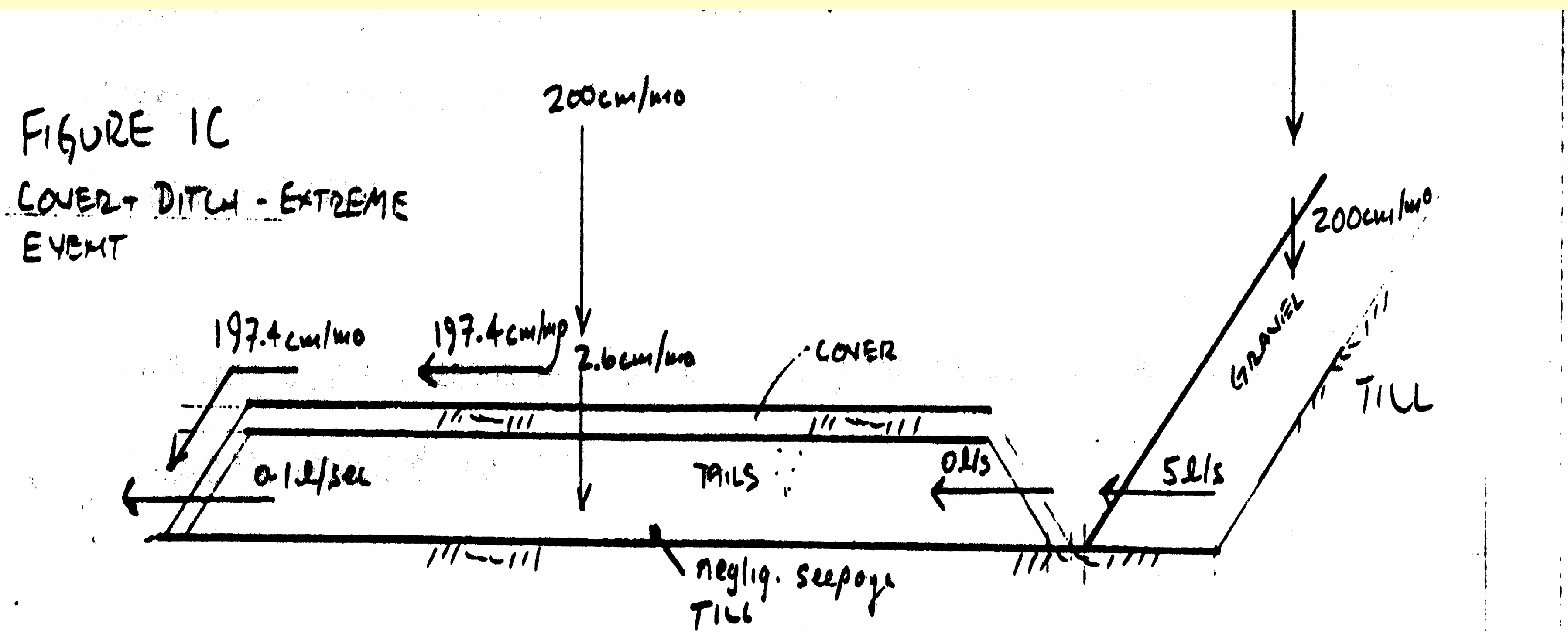
1. cover effectiveness in preventing surface infiltration; and
2. amount of water or oxygen infiltrating through subsurface.



Ideal situation for drainage is if the waste is on a height of land with no groundwater inputs, as is the case with this tailings impoundment in Quebec.

Cirque placed a liner underneath and above to totally encapsulate the 24,000 m^3 pile of waste rock

More commonly subsurface inputs are significant and a 'dry cover system' must incorporate measures such as upslope barrier walls and ditches to reduce subsurface inputs



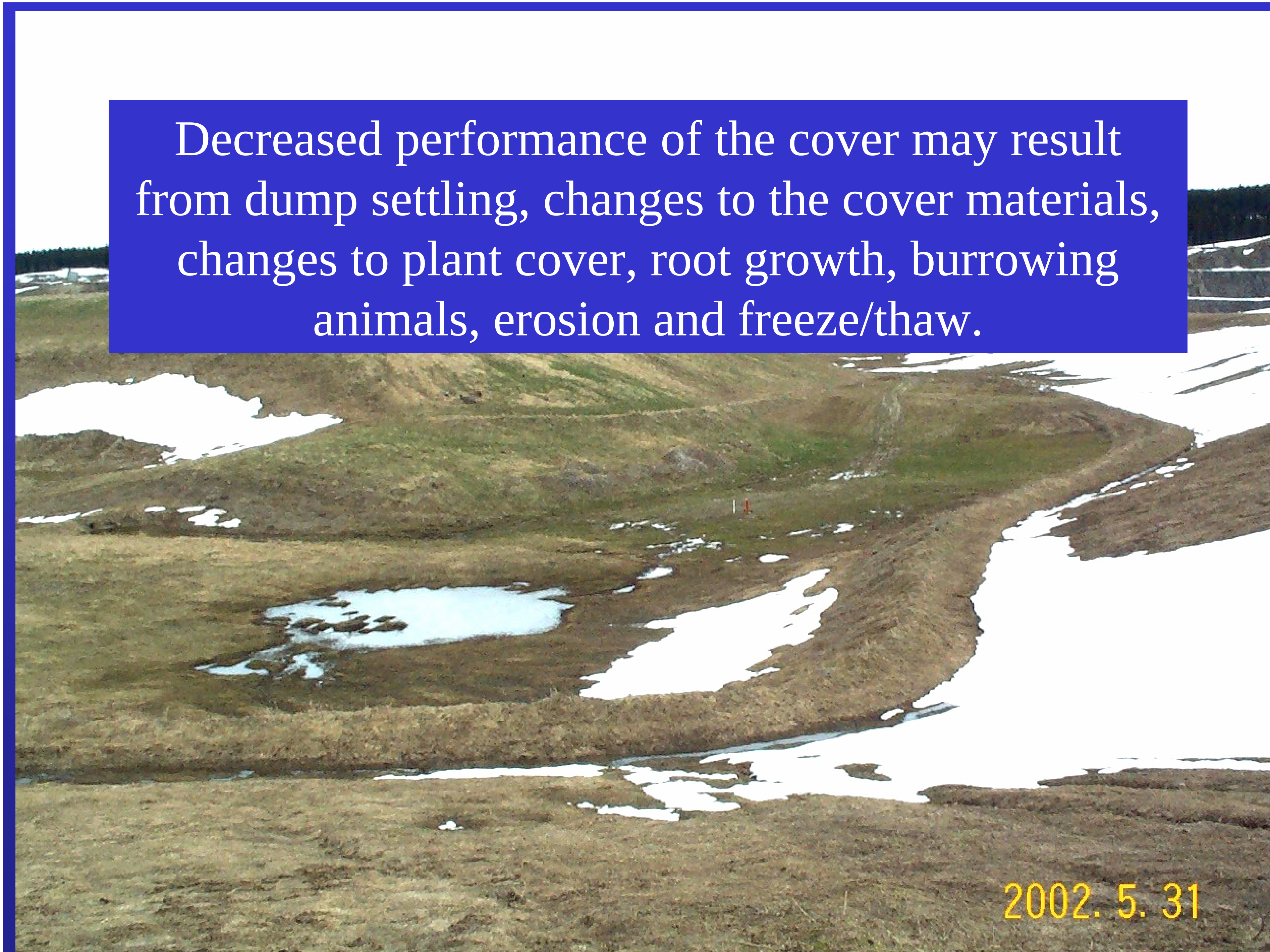
Long-Term Performance

Cover systems needs to be designed, operated and financed in a manner that allows pro-active detection and resolution of problems prior to significant environmental impact. This requires:

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

*including repair and replacement

Decreased performance of the cover may result from dump settling, changes to the cover materials, changes to plant cover, root growth, burrowing animals, erosion and freeze/thaw.

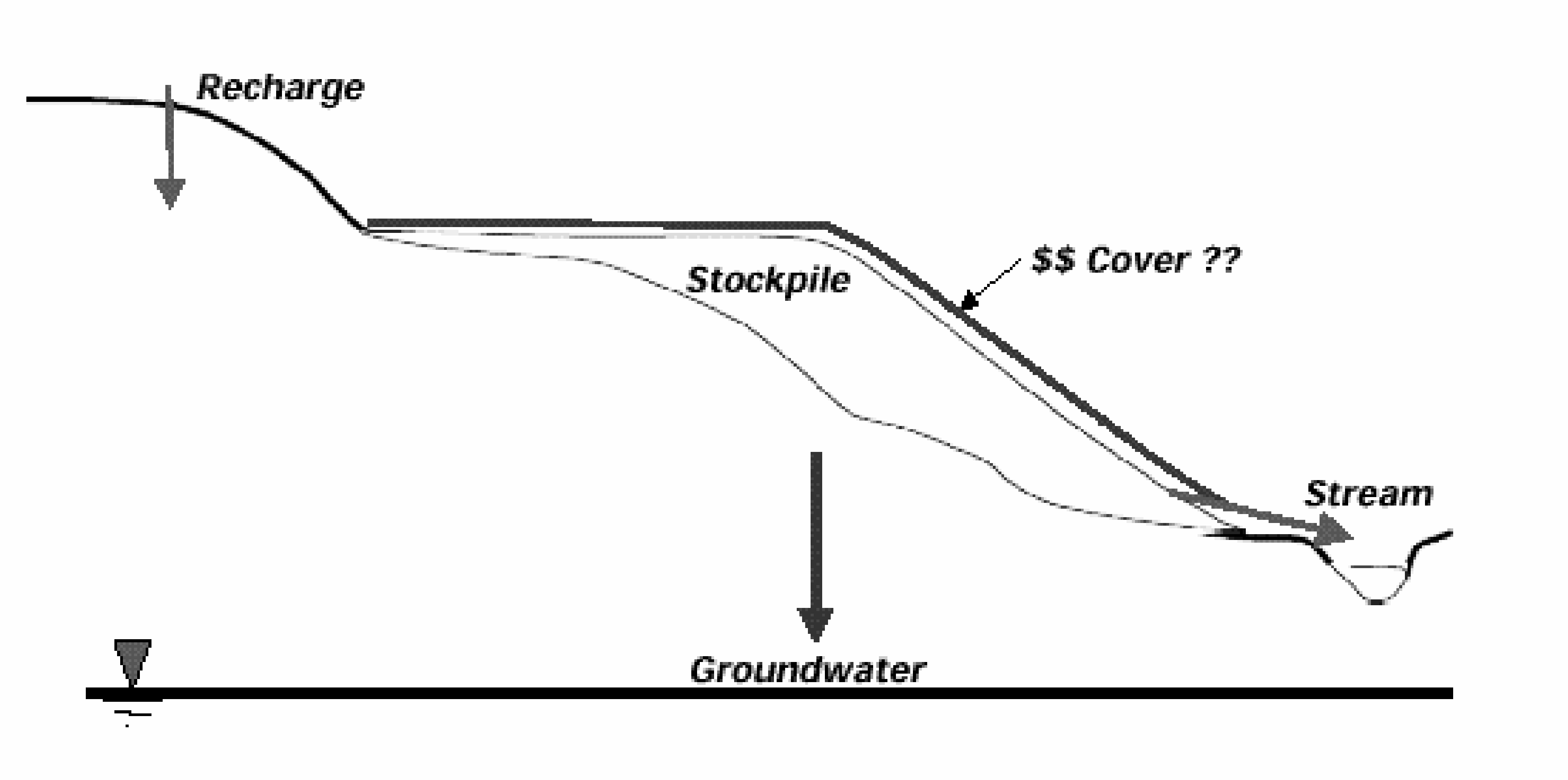


- Dump settling may result from chemical and physical weathering or melting of snow and ice within the dump.
- Changes to the cover material may result from soil development (pedogenesis) or degradation of geotextile.
- Changes to plant cover include decreased growth due to fire, insects and disease, plant succession, and root growth into low conductivity material.

Decreased performance of the cover system may also result from damage to drainage diversion and collection systems, through ditch scouring, overtopping or damage when snow, ice and other debris are removed.

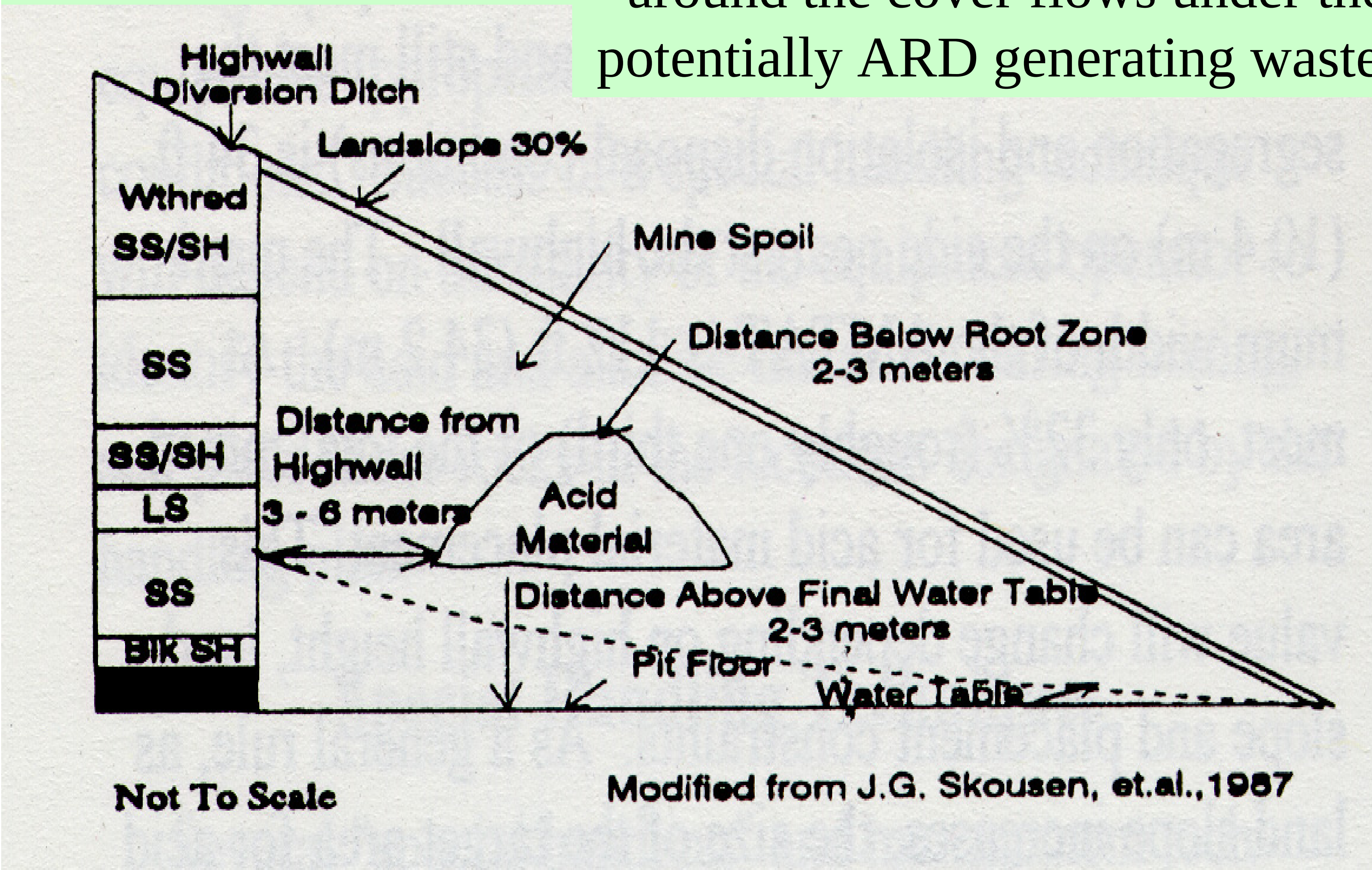
Conservative Cover System Design

Has the durability and capacity to achieve operational objectives during and after extreme climate or seismic events.

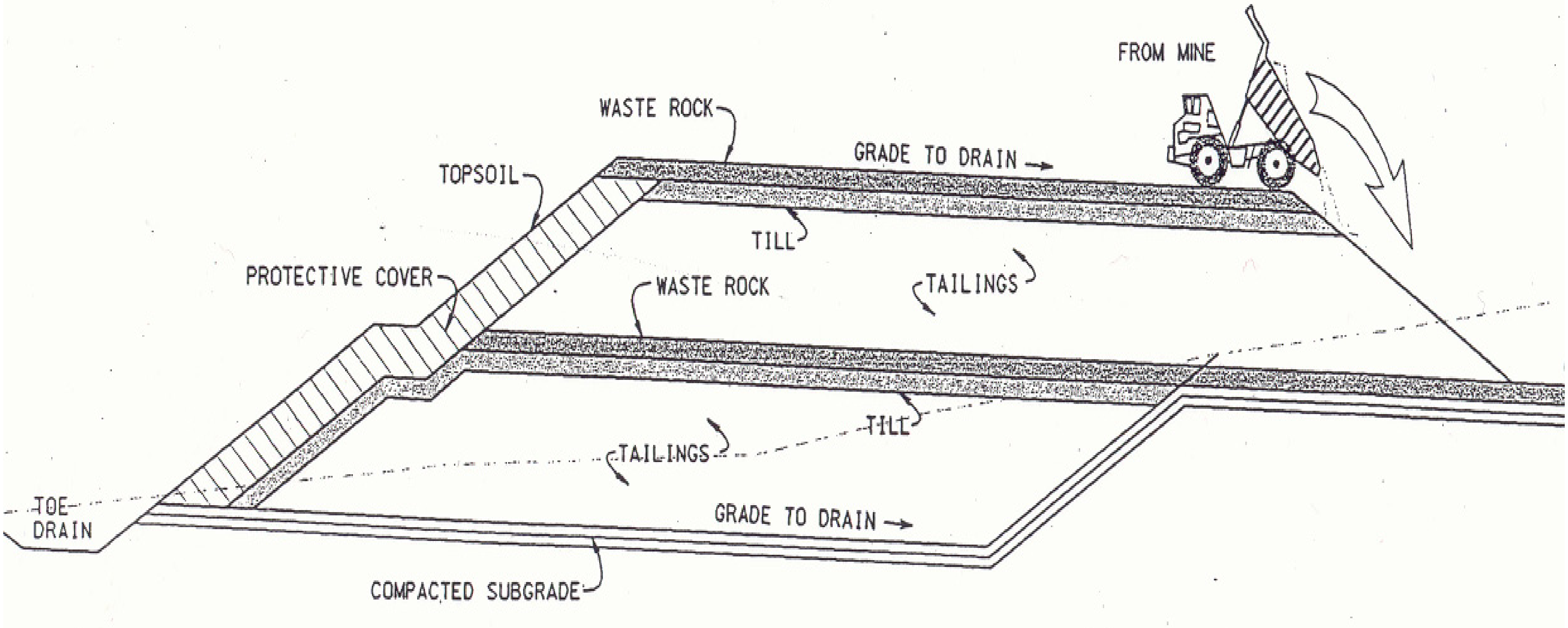


Depth of Cover: At Waihi Mine in New Zealand, cover is 2.5 m deep, with 50 cm topsoil, 50 cm loose subsoil and 1.5 m compacted clayey soil

Extra Drainage Capacity: Waste backfilled so drainage through or around the cover flows under the potentially ARD generating wastes.



In this design, a deep soil cover, extra drainage and placement of tailings in cells are all included to minimize the impacts of a local failure.

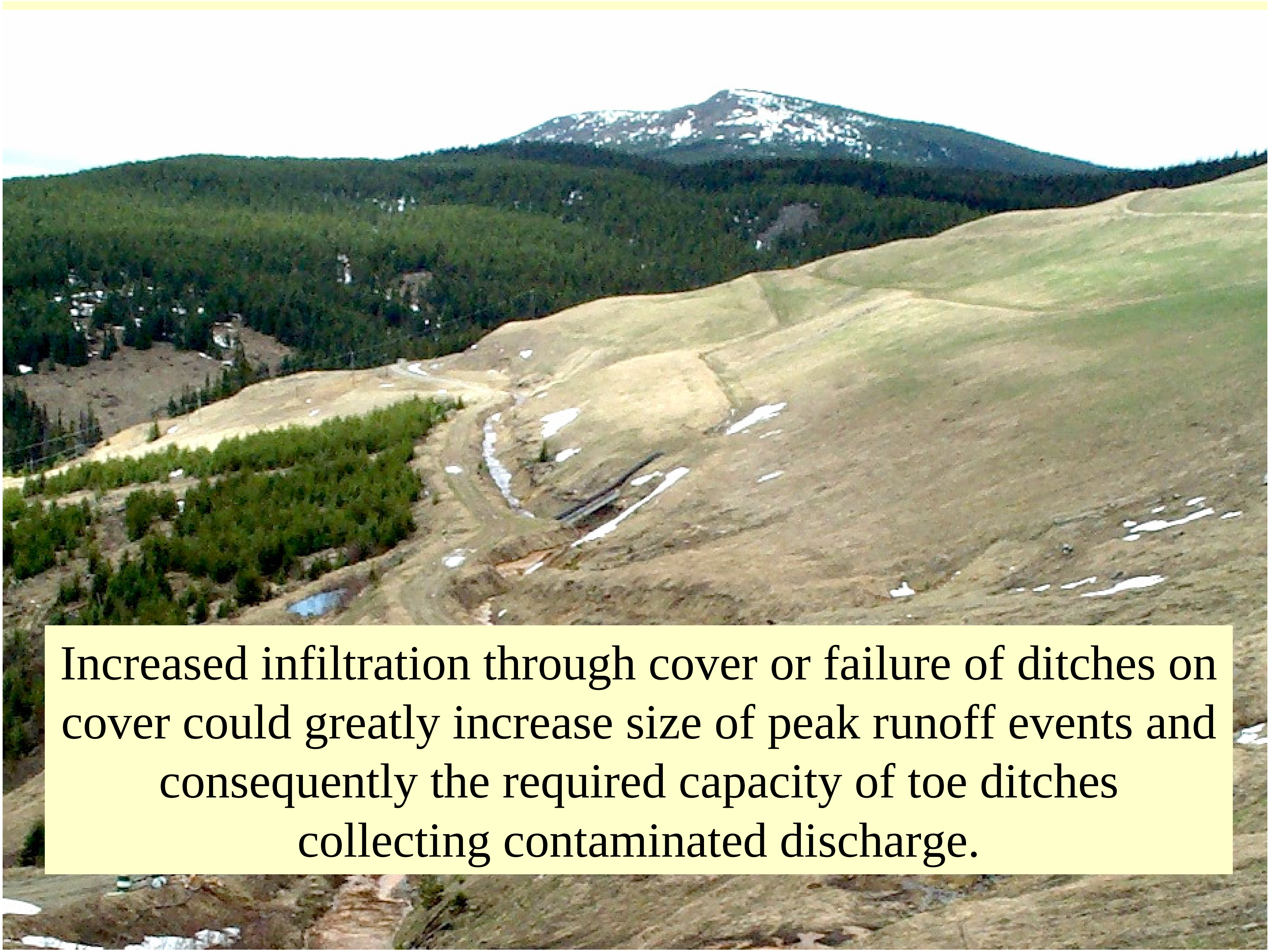


DRY TAILINGS SECTION
(SECTION LOCATION SHOWN ON FIGURE 3)

Supplemental Mitigation

Must be aware of dependence of primary mitigation measures on performance of cover system.

Sizing of collection system, treatment plant and financing may all assume some minimal cover performance.



Increased infiltration through cover or failure of ditches on cover could greatly increase size of peak runoff events and consequently the required capacity of toe ditches collecting contaminated discharge.

Maintenance Plan for ‘Cover System’

Includes:

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

Monitoring Plan for Cover System

Key aspect of the work to sustain the design capacity :

- provide early warning of potential problems
- inform corrective measures
- allow timely implementation of contingency plans

Micro-Scale Monitoring

Typical measurements include cover moisture content and H_2O infiltration. These results can be misleading if:

- equipment installation impacts surrounding cover (e.g., lysimeter);
- lack monitoring in areas of concern (e.g., ponding, lower slopes, collection ditches);
- do not detect local features with wider implications such as settlement fractures.

Macro-Scale Monitoring of Cover

Includes visual observations of cover appearance and drainage, and measuring precipitation and snow accumulation, and the resulting water quality and flow.

- Equity and Sullivan monitor height of water table and groundwater quality.
- Lack of information regarding groundwater inputs is a major impediment in calculating a water balance and evaluating cover performance.

- Where groundwater inputs are uncertain, comparison of runoff volumes with volume of incident precipitation + snow pack is perhaps the best indicator of overall cover performance.
- Changes in local runoff may prove to be a good tool for indicating when and approximately where repairs are required.

Sites presently do not continuously monitor cover runoff and therefore cannot measure runoff .

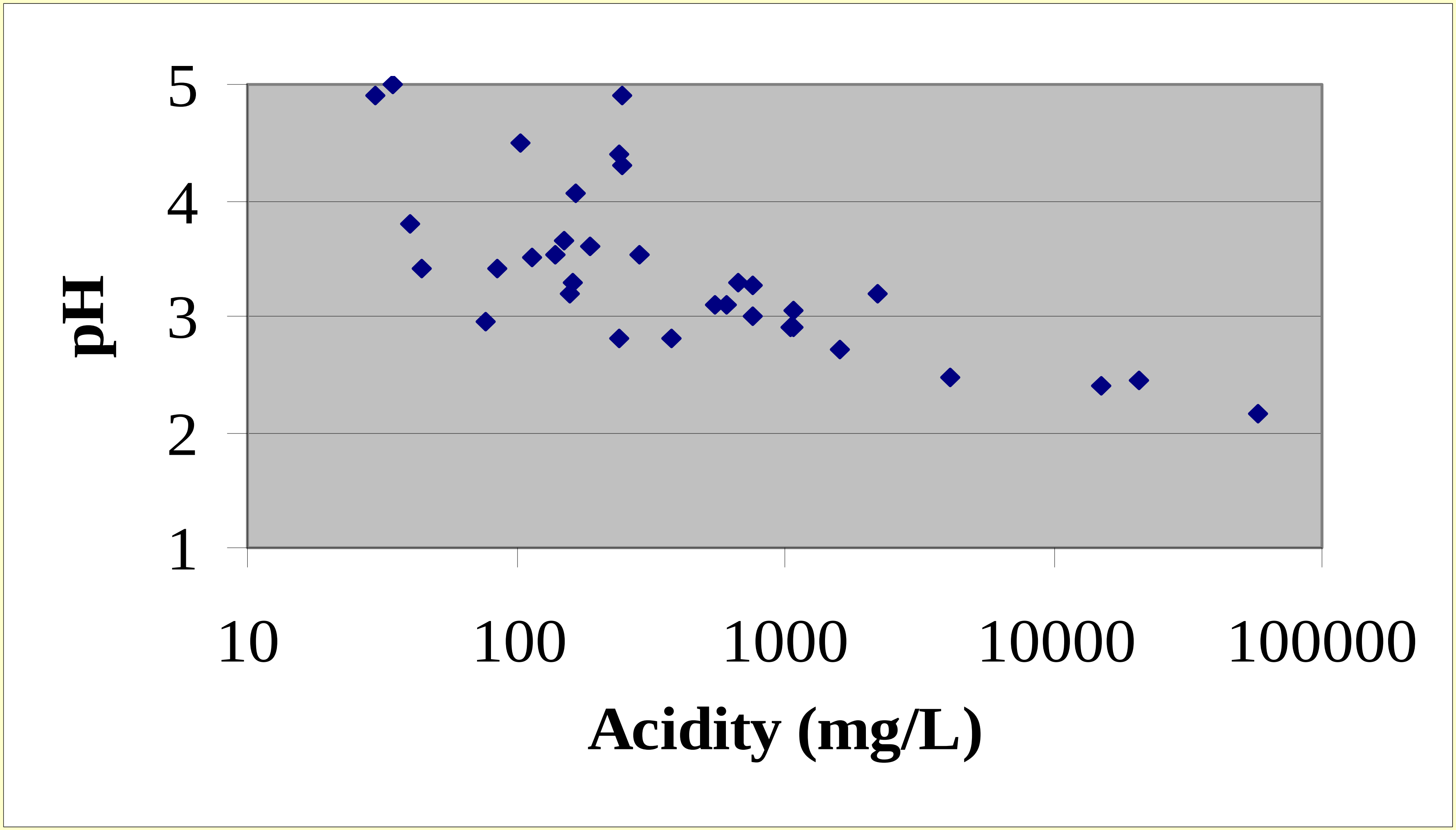
Challenges in continuous monitoring of runoff include a large number of monitoring locations, snow cover at critical times of the year, potential for exposed water to freeze, lack of power, and wide fluctuations in flow.

The Waste Beneath the Cover

Performance of the cover system also depends on the geochemistry and hydrogeology of the waste beneath the cover. Usually overlooked by cover design and researchers.

- Groundwater rebound following mining may greatly increase subsurface drainage inputs.
- Conversely, measures that lower the water table may significantly increase subsurface oxygen entry

Changes in weathering and drainage chemistry of the waste may increase concentrations of acidity and metals sufficiently to increase overall loadings.



Monitoring beneath the cover commonly limited to temperature and oxygen. These parameters provide useful data. However, drainage chemistry may deteriorate decrease in both temperature and oxygen.

- Studies indicate that O_2 concentration must be < 2% to reduce rate of sulphide oxidation
  - Need large decrease in O_2 to reduce sulphide oxidation.
- Studies also indicate that rate of sulphide oxidation is typically >> rate of trace metal leaching
  - Need large decrease in sulphide oxidation to reduce accumulation of trace metals

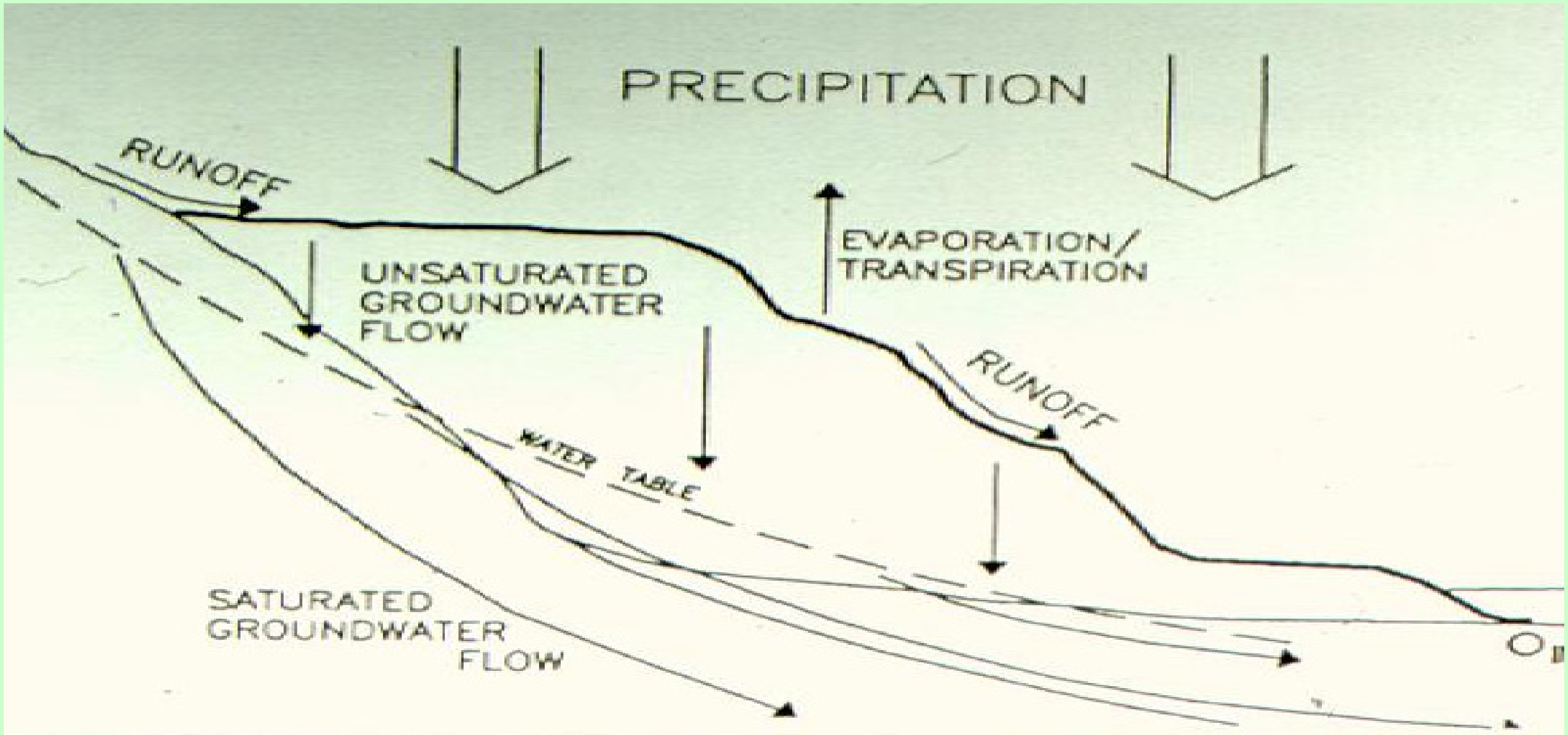
Presently the main way to measure changes in drainage chemistry is by monitoring seeps. In seep monitoring, it is important to monitor when and where new seeps occur.

Also important to monitor frequently and measure discharge rate. Changes in seep chemistry may result from changes in flow or drainage sources rather than dump weathering.

A risk in using dry covers that needs to be considered in cover system design

If the cover reduces leaching but does not reduce sulphide oxidation, there will be a greater accumulation of weathering products in the underlying waste compared to an uncovered dump.

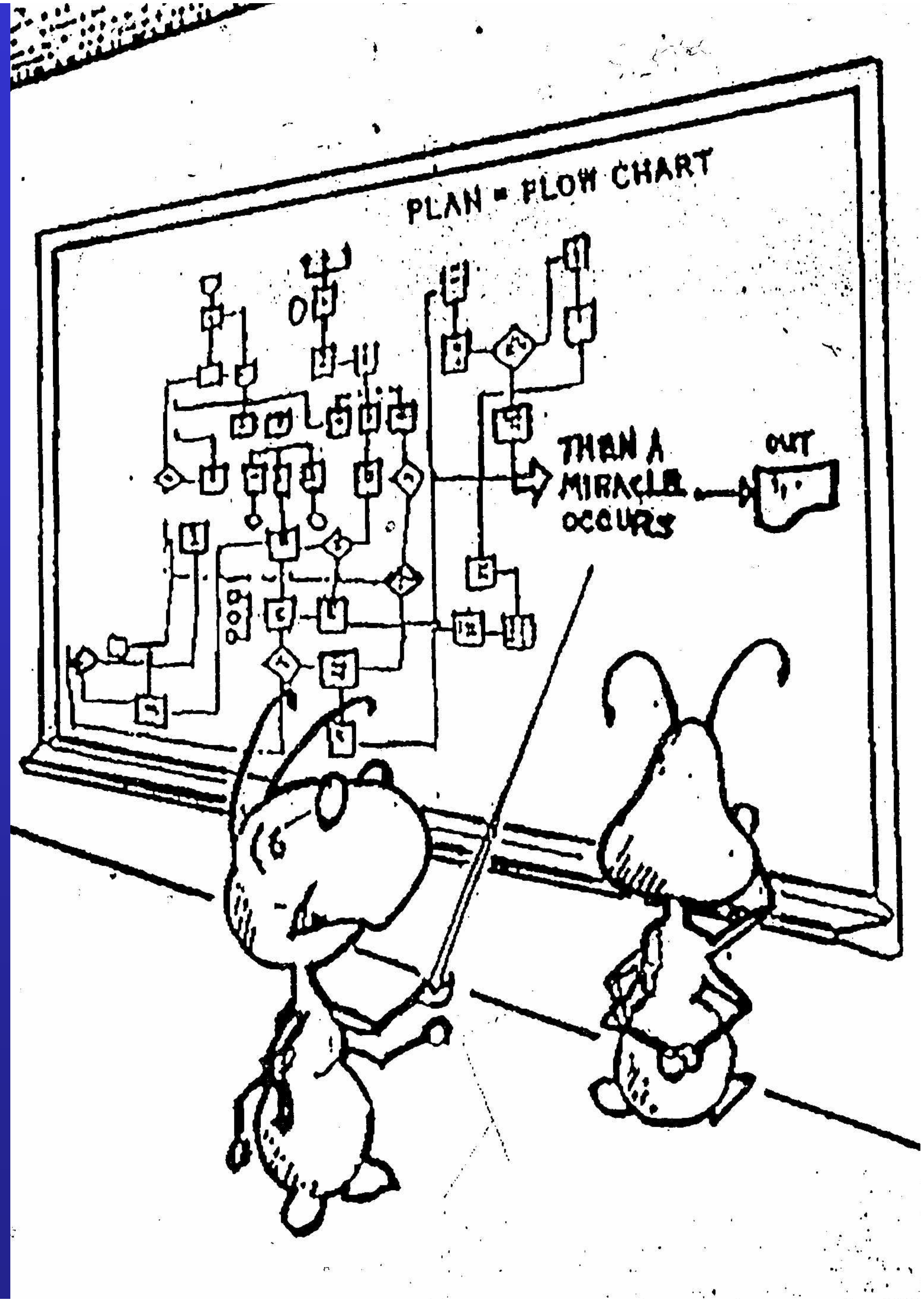
The accumulation of soluble weathering products increases the likelihood of potential environmental consequences should the dump cover break. It could also potentially result in increased loadings compared to an uncovered dump during large runoff events.



Outstanding Information Requirements

- Much of the cover work has been done on small scale trials, computer simulations, and micro-scale monitoring. As a result mechanisms of cover performance are well understood, with many references to the contributing factors and theoretical performance.
- Far less information is available on real cover performance, departures from the ideal, such as permafrost, and cover durability.

Associated with the uncertainty about durability is significant uncertainty about how to pro-actively repair covers, repair and replacement costs, and triggers to initiate that work.

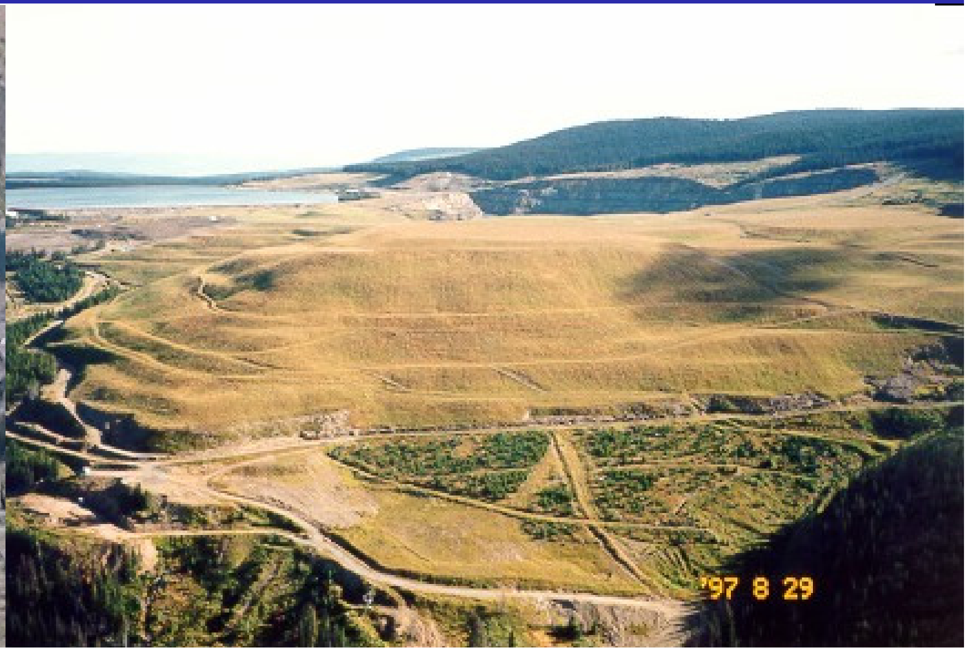


Future work needs to address ways to monitor local cover and ditch performance, the performance of the waste beneath the cover and the risks where weathering products accumulate underneath the cover.

Conclusions

The three most commonly used ML/ARD mitigation strategies are underwater disposal, collect and treat drainage, and **dry cover systems**.

All three have strengths and weaknesses.



The selection of the best mitigation strategy for a particular site should be based on a site-specific assessment of which strategy creates the least liability and environmental risk.

For dry covers, this includes having a realistic view of the breadth and depth of the information, design and maintenance requirements; and your ability to collect the necessary information and answer the required questions in a pro-active manner.

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