C.1 An Overview of Dry Cover System Applications in Canada and Around the World

Mike O'Kane

O'Kane Consultants Inc.

Outline

An Overview of Dry Cover System Applications in Canada and Around the World

Mike O'Kane, P.Eng.

1:00 PM, Wednesday, November 29, 2000

Presented at the

7th ANNUAL BC METAL LEACHING/ARD WORKSHOP

November 29 and 30, 2000
Simon Fraser University at Harbour Centre
Room 1900 - 515 West Hastings Street
Vancouver, BC

This presentation will include discussion on:

- the scope of the conceptual system;
- purpose of dry cover systems;
- key theoretical cover system concepts;
- general dry cover system design objectives;
- factors influencing dry cover system design objectives; and
- sustainable performance of dry cover systems.

General examples, as well as site specific case studies from around the world, will be used to illustrate the specific presentation topics. However, the focus of the presentation will be on the final presentation topic, that is, on sustainable performance of dry cover systems.

Scope of the Conceptual System

The basis for this presentation will be the scope of the conceptual cover system, which includes:

- the performance of the dry cover on a relatively horizontal surface;
- the performance of the dry cover on a sloping surface;
- the internal hydraulic and geochemical performance of the waste material; and
- the influence of basal flow as a result of placing the waste material on a valley wall and/or historic surface water path.

Specific examples from sites around the world will be used to illustrate the importance of utilizing an integrated approach, as outlined above, for developing a dry cover system design. In general, the first item is well understood and addressed during the design of dry covers. However, there are a number of subtle design issues, which are not widely appreciated, and will be addressed during the presentation. The second and fourth tems will significantly influence the metal loading released from the waste material. For example, some documented case studies of "cover system failures" are in fact a result of the cover system being designed for a horizontal surface while being constructed on a sloping surface. The performance of a dry cover on a sloping surface can be much different as compared to a horizontal surface and the difference in performance relates to site climate conditions, the slope length and angle, and the material properties. Numerous other documented "cover system failures" can be attributed to the influence of basal flow resulting from placing the waste on valley walls, basins, groundwater discharge features, and historic surface water paths. In these cases, the release of acidic drainage from the waste storage facility following cover placement was not due to incident precipitation on the surface, but rather sub-surface basal flow leaching oxidation products from the storage facility.

Purpose of Dry Cover Systems

The purpose of a dry cover system is to minimize further degradation of the receiving environment. In addition, the dry cover system provides a medium for establishing a sustainable vegetation cover that is consistent with the current and final land use of the area. Minimizing further degradation (i.e. ensuring long-term cover system performance) requires long-term control of surface runoff and seepage water. The former issue illustrates the importance of a site surface water management system that maintains integrity for extreme snowmelt and rainfall events.

Key Theoretical Concepts

It is fundamental that a dry cover system be design as an unsaturated system exposed to the atmosphere, whose performance is a direct function of site specific climate conditions. The presentation will discuss the importance of this aspect with respect to properly designing a dry cover system as well as for addressing cover system longevity. Key theoretical concepts will be presented, although not discussed in great detail because other presenters will provide the required detail. The key concepts include:

- the soil water characteristic curve;
- the hydraulic conductivity function;
- the capillary barrier;
- the relationship between effective oxygen diffusion and the degree of saturation; and
- the development of a geochemical source term for the underlying waste.

Dry Cover System Design Objectives

The two principle design objectives of dry cover system are:

- to function as an oxygen ingress barrier; and
- to function as a water infiltration barrier.

The presentation will use case studies to demonstrate how and where these design objectives are being implemented. Additional design objectives that will be discussed in the context of the case studies include:

- control of consolidation and differential settlement;
- oxygen consumption (i.e. organic cover materials);
- reaction inhibition (i.e. incorporate limestone at the surface, which does not prevent oxidation but will control the rate of oxidation); and
- control of upward capillary movement of process water constituents/oxidation products.

Factors Influencing Dry Cover System Design Objectives

The factors that influence dry cover system design objectives will be discussed in the context of general examples and site specific case studies. These factors are:

- site specific climate conditions;
- reactivity of the waste;
- type of waste (i.e. tailings, waste rock, and/or co-disposal);
- hydrogeological setting; and
- basal flow.

Sustainable Performance of Dry Cover Systems

Figure 1 is a conceptual illustration of processes controlling long-term cover system performance. The mining community, in general, is gaining confidence with the tools and technology for predicting "constructed" cover system performance. In addition, prediction of long-term performance with respect to the physical processes shown in Figure 1 can generally be achieved using quantitative tools and methodologies (both empirical and theoretically based). However, there is little research and initiative in the "cover system design community" for addressing the chemical and biological processes influencing long-term cover system performance. Anecdotal and site specific evidence are being developed on these influence these two processes have on long-term cover system performance. However, at best these factors can

only be addressed from a qualitative perspective, with respect to their influence on long-term performance. In general, there is significantly less confidence among the mining community that the current state-of-the-art cover system design properly accounts for these latter processes affecting long-term performance.

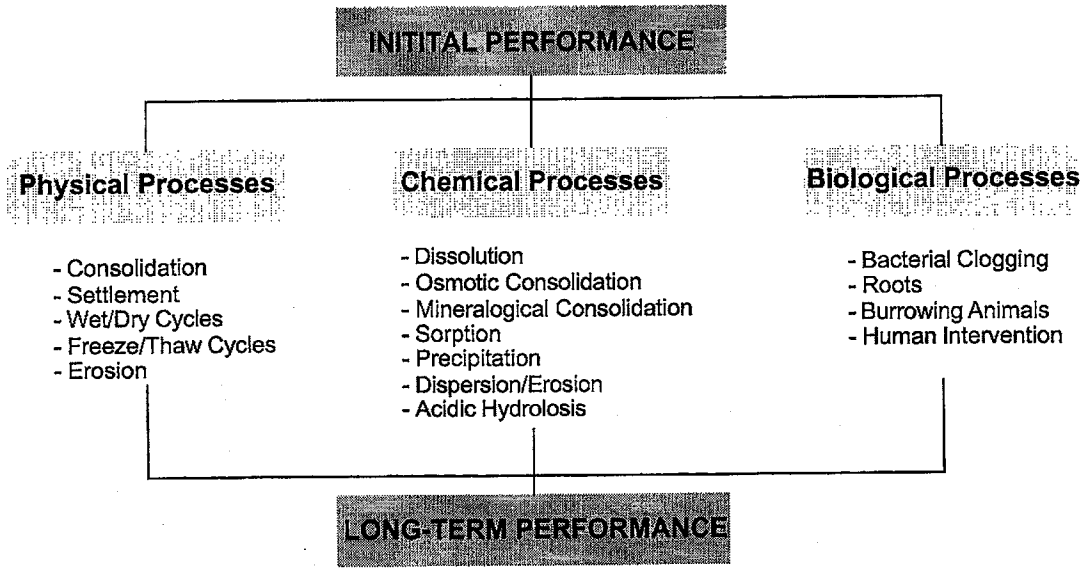


Figure 1 Conceptual illustration of processes affecting long-term performance.

7th Annual BC Metal Leaching / ARD Workshop

An Overview of Dry Cover System Applications in Canada and Around the World

M. O'Kane, P.Eng.
O'Kane Consultants Inc.

November 29, 2000

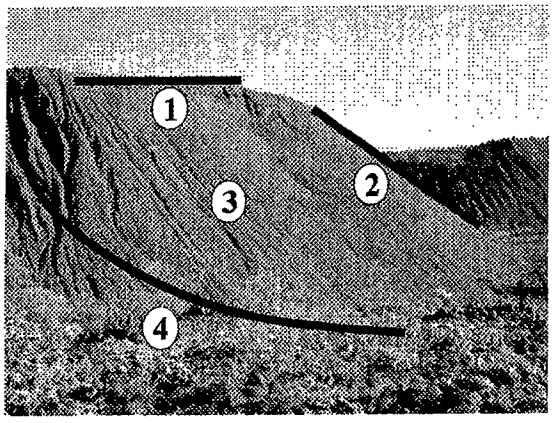
O'Kane Consultants Inc.
Vancouver and Saskatoon, Canada
Brisbane, Australia

Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

O'Kane Consultants Inc.

Scope of the Conceptual System



1. *Performance on a horizontal surface*
2. *Performance on a sloped surface*
3. *Internal gas, moisture, and contaminant transport/storage*

4. *Contribution of flow from valley wall, groundwater recharge, and historic surface water paths*

Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

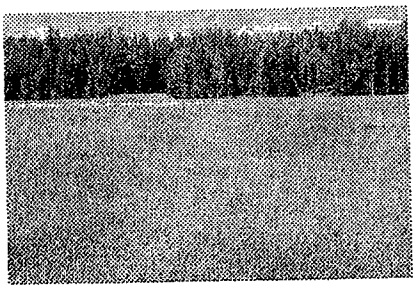
www.okane-consultants.com

O'Kane Consultants Inc.

An Overview of Dry Cover System Applications in Canada and Around the World

Purpose of Cover Systems

Minimize Further Degradation of the Receiving Environment



Medium for Establishing Sustainable Vegetation

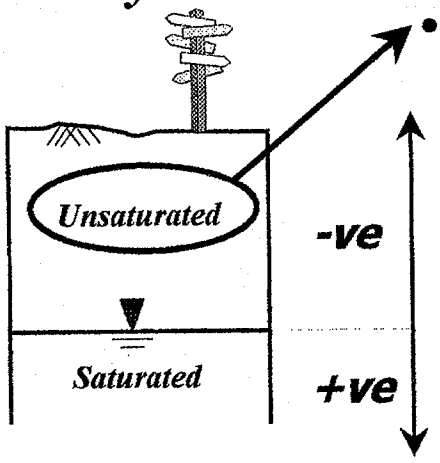
Transpiration Rates and LAI of Native Species

O'Kane Consultants Inc.

Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

Key Theoretical Concepts



- *By Definition a Dry Cover System is an Unsaturated System*
  - *air, "water", solids*
  - *4th phase*

Negative Pore Water Pressure

Positive Pore Water Pressure

SWCC, k-function, S% vs. O_2, C-B concept

O'Kane Consultants Inc.

Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

An Overview of Dry Cover System Applications in Canada and Around the World

Dry Cover System Objectives

- *Control ingress of oxygen to underlying waste*
- *Control water infiltration*

"BLANKET OF WATER"

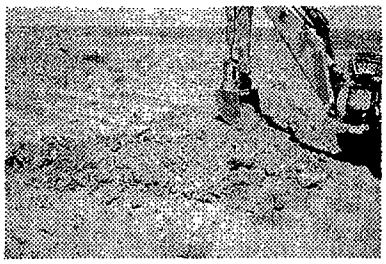
Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

O'Kane Consultants Inc.

Dry Cover System Objectives

- *Controlling Factors that Define the Cover System Objectives*
  - *Climate conditions (wet, dry, seasonal patterns)*
  - *Reactivity of the waste (barren, PAG, PAG w/ buffering, neutral drainage)*
  - *Type of waste material (tailings, waste rock)*
  - *Hydrogeologic setting*
  - *Basal inflow conditions*

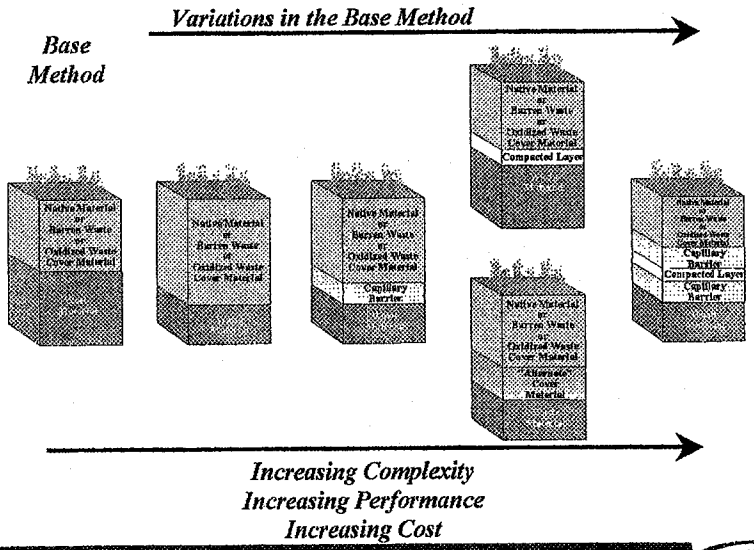


Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

O'Kane Consultants Inc.

Cover System Alternatives

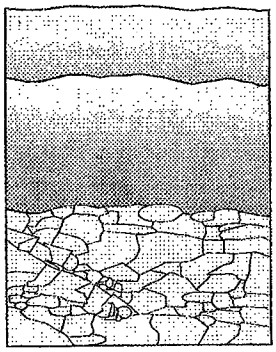


Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

O'Kane Consultants Inc.

1-D Design

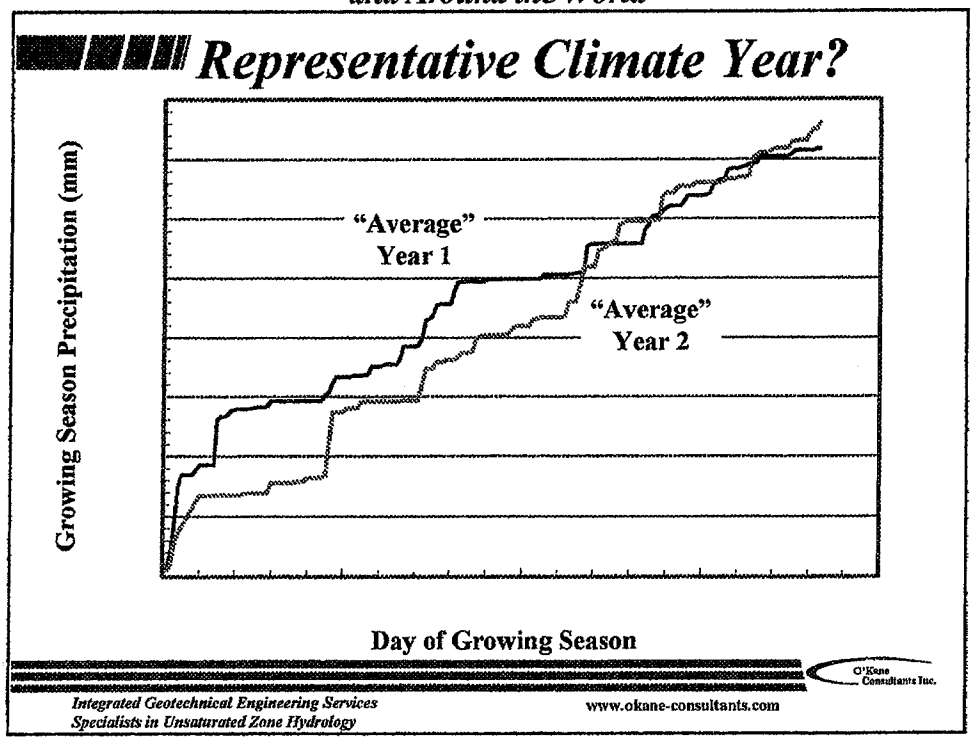


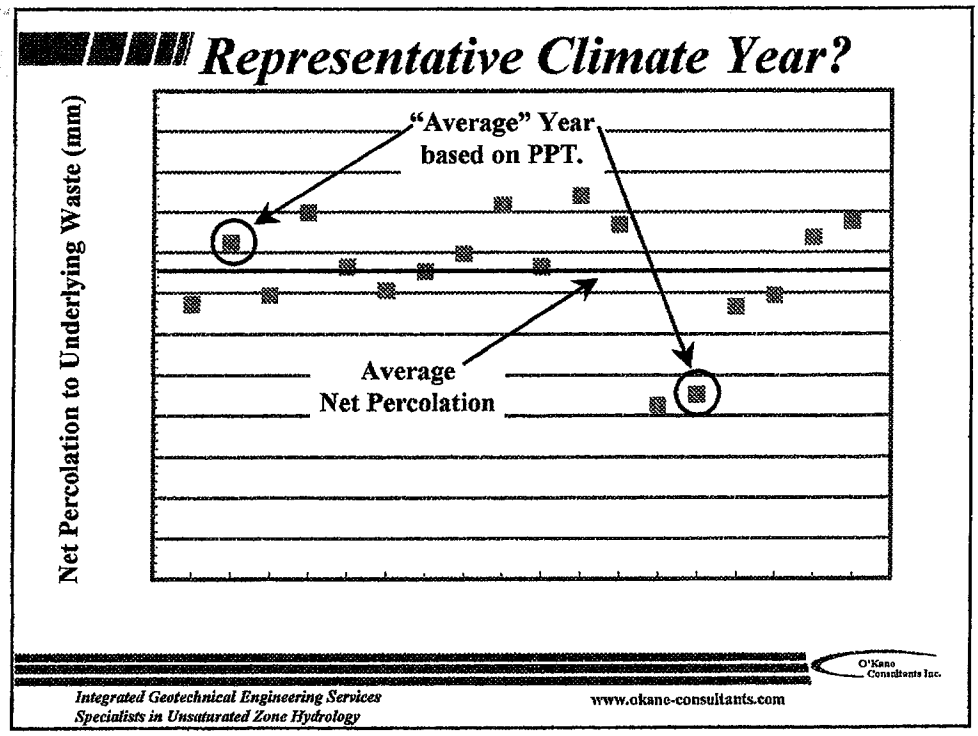
- *Confidence with respect to the technology*
- *Subtle design issues not fully appreciated*
  - *Much greater appreciation for site climate conditions*
  - *Many "wet" sites, hot dry summers*

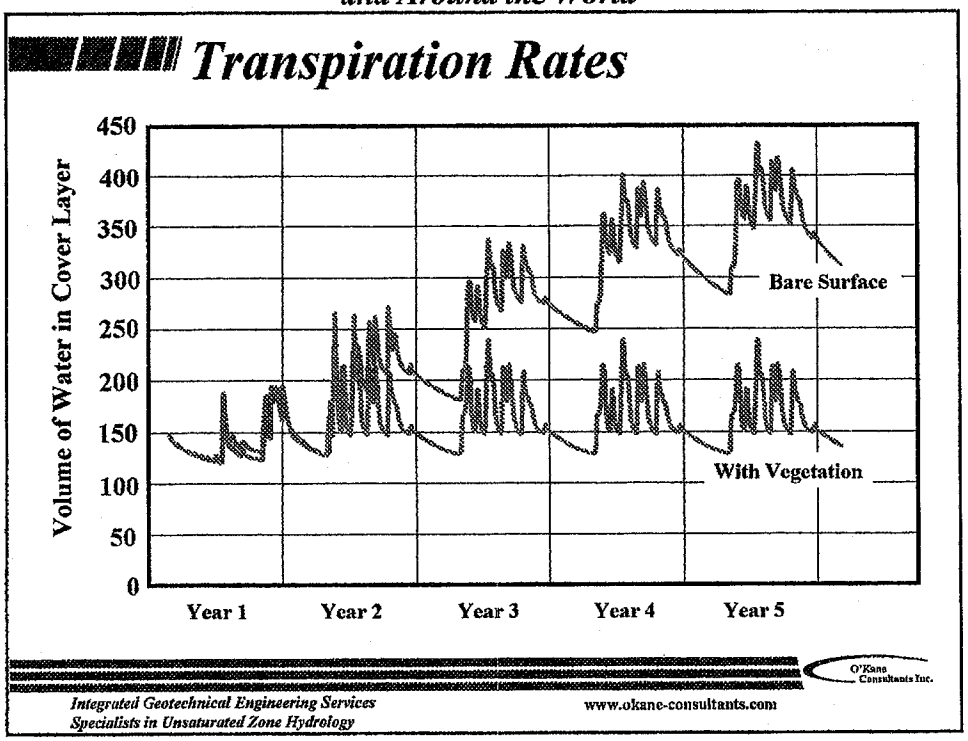
Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

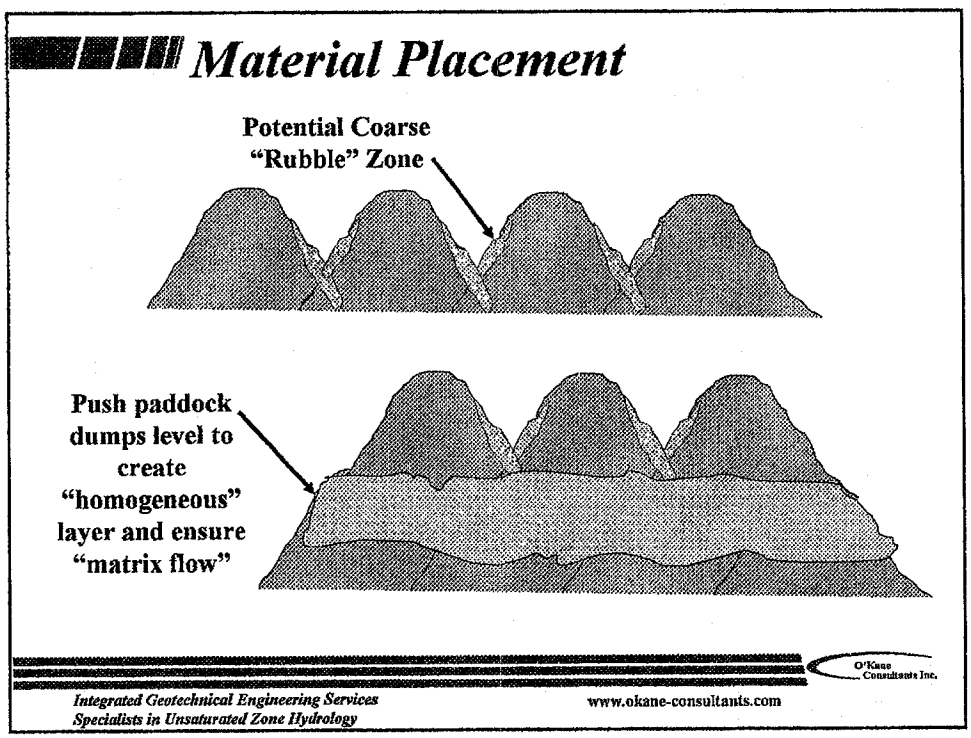
www.okane-consultants.com

O'Kane Consultants Inc.


Representative Climate Year?
Growing Season Precipitation (mm)
"Average" Year 1
"Average" Year 2
Day of Growing Season
Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology
www.okane-consultants.com
O'Kane Consultants Inc.


Representative Climate Year?
Net Percolation to Underlying Waste (mm)
"Average" Year based on PPT.
Average Net Percolation
Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology
www.okane-consultants.com
O'Kane Consultants Inc.


Transpiration Rates
Volume of Water in Cover Layer
450
400
350
300
250
200
150
100
50
0
Year 1
Year 2
Year 3
Year 4
Year 5
Bare Surface
With Vegetation
O'Kane Consultants Inc.
Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology
www.okane-consultants.com


Material Placement
Potential Coarse "Rubble" Zone
Push paddock dumps level to create "homogeneous" layer and ensure "matrix flow"
O'Kane Consultants Inc.
Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology
www.okane-consultants.com

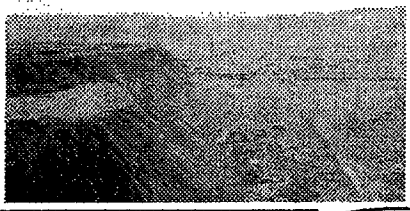
Sloped Surfaces

(Gatzweiler and Marksi, 1996)

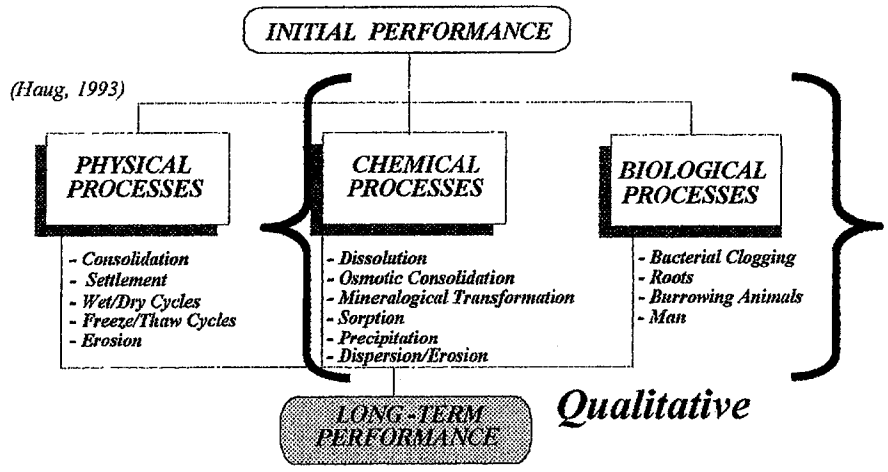
- *Waste rock storage facilities have sloping surfaces*
- *Influence of slope on hydraulic performance of cover system is typically ignored during design and monitoring*
- *Not Entirely Intuitive*

- *All sites require design, construction, and monitoring of covers on a sloped surface*

CB Performance?



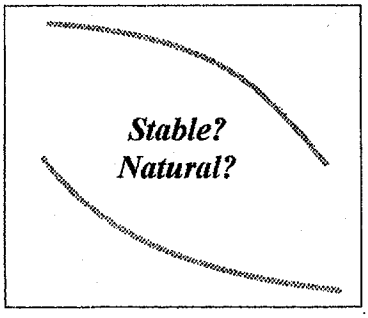
Sustainable Performance



Qualitative

Sustainable Performance

- *Block Modelling of Waste and Control Using GPS System*
- *Transpiration Rates*
- *Longevity of Cover System*
- *Importance of Performance Monitoring*
- *Integration with Operations*
- *Landform Evolution*
  - *Fine textured material on slopes*
  - *Source?*

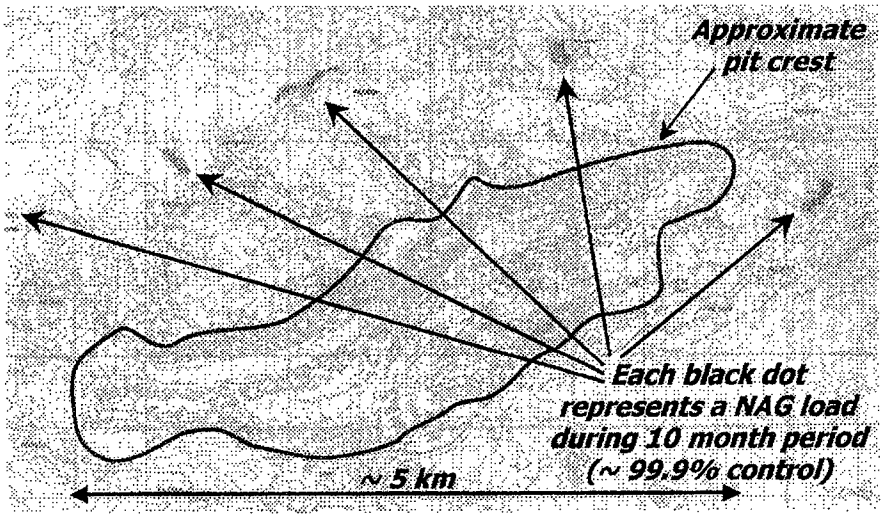


Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

O'Kane Consultants Inc.

Block Modelling

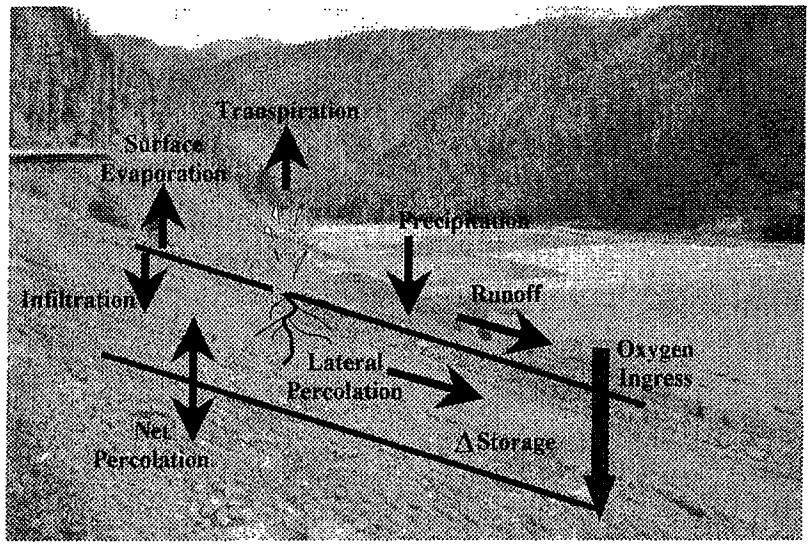


Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

O'Kane Consultants Inc.

Performance Monitoring



Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

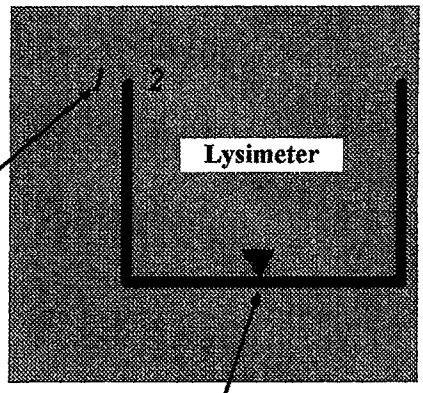
www.okane-consultants.com

O'Kane Consultants Inc.

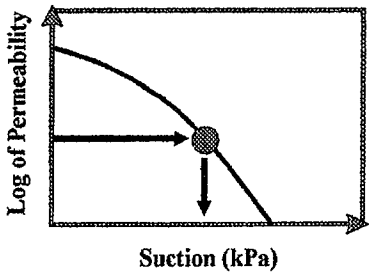
Performance Monitoring

- *Key component of monitoring program*
- *In general lysimeters for monitoring flux from base of cover systems are poorly designed and installed*
- *Soil science literature*

Lysimeter Design



$H_1 = H_2$



Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com

O'Kane Consultants Inc.

An Overview of Dry Cover System Applications in Canada and Around the World

Key Points

- *Increased appreciation for addressing site climate conditions*
- *Subtle design issues need further consideration*
- *"Preferred" alternatives are a function of the particular mining region*
- *Increased confidence with the ability to construct full scale dry cover systems*
- *However, potential biological and chemical processes that impact cover system longevity require further research*
- *In general, the European mining community is moving towards quantifying the impact of these processes*
- *Simple!*
- *Performance Monitoring!! "Snapshot in Time"*

O'Kane Consultants Inc.

Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

www.okane-consultants.com