# 3.5. MODELING ACIDIC DRAINAGE FROM WASTE ROCK PILES

**Daryl Hockley**
**Steffen Robertson & Kirsten (Canada) Inc.**

# MODELING ACIDIC DRAINAGE FROM WASTE ROCK PILES

*Daryl Hockley*

*Tracy Delaney*

*Jason Smolensky*

*Steffen Robertson & Kirsten (Canada) Inc.*

SRK

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# Objectives

*"critical review and discussion of mathematical models of acidic drainage from waste rock piles ..."*

*"emphasis on engineering models ..."*

*"reference to ... physical and conceptual modelling"*

# Topics covered in Report (and Presentation)

*Terminology*

*Process - specific models*

*Engineering models*

*Recommendations*

# Terminology

*"... discussions about modeling are often confused by imprecise or inconsistent terminology"*

conceptual vs. physical vs. mathematical models

empirical vs. mechanistic

deterministic vs. stochastic

comprehensive vs. process specific

engineering models

# Process - Specific Models

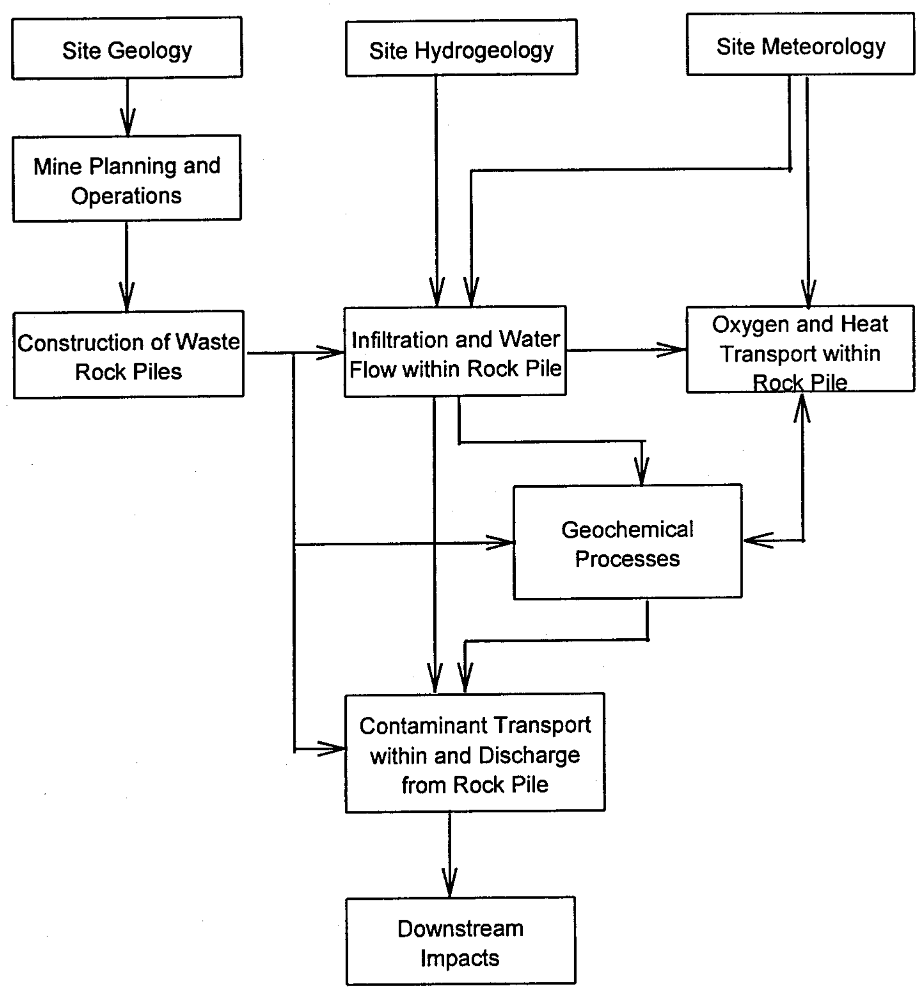
*"models of individual processes,*

*or groups of coupled processes,*

*that contribute to, influence or are influenced by*

*acidic drainage in waste rock"*

# Process - Specific Models



# Process - Specific Models

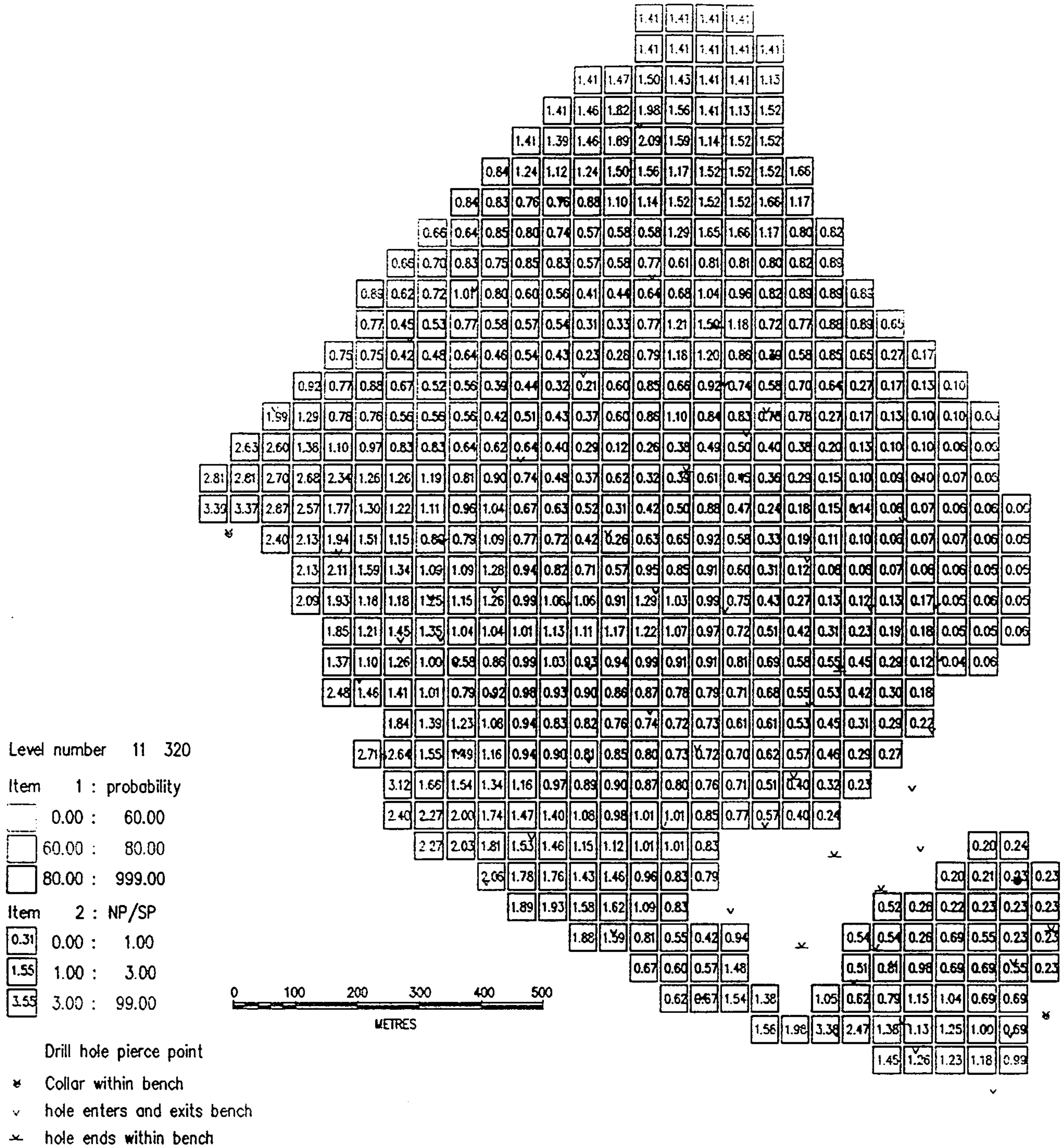
## External processes and variables

- *site geology & mine planning*
- *site hydrogeology*
- *site meteorology*

# Process - Specific Models

## Construction of waste rock piles

- *pile geometry*
- *distribution of material*
- *mixing of material during construction*
- *effects on physical characteristics*

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Consulting Engineers

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ARD MODELLING OF WASTE ROCK PILES

NP: AP RATIOS FROM ORDINARY KRIGING–ABSETZERHALDE LEVEL 300

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| S1202P9 | SEPT.,1995 | | 3.4 |

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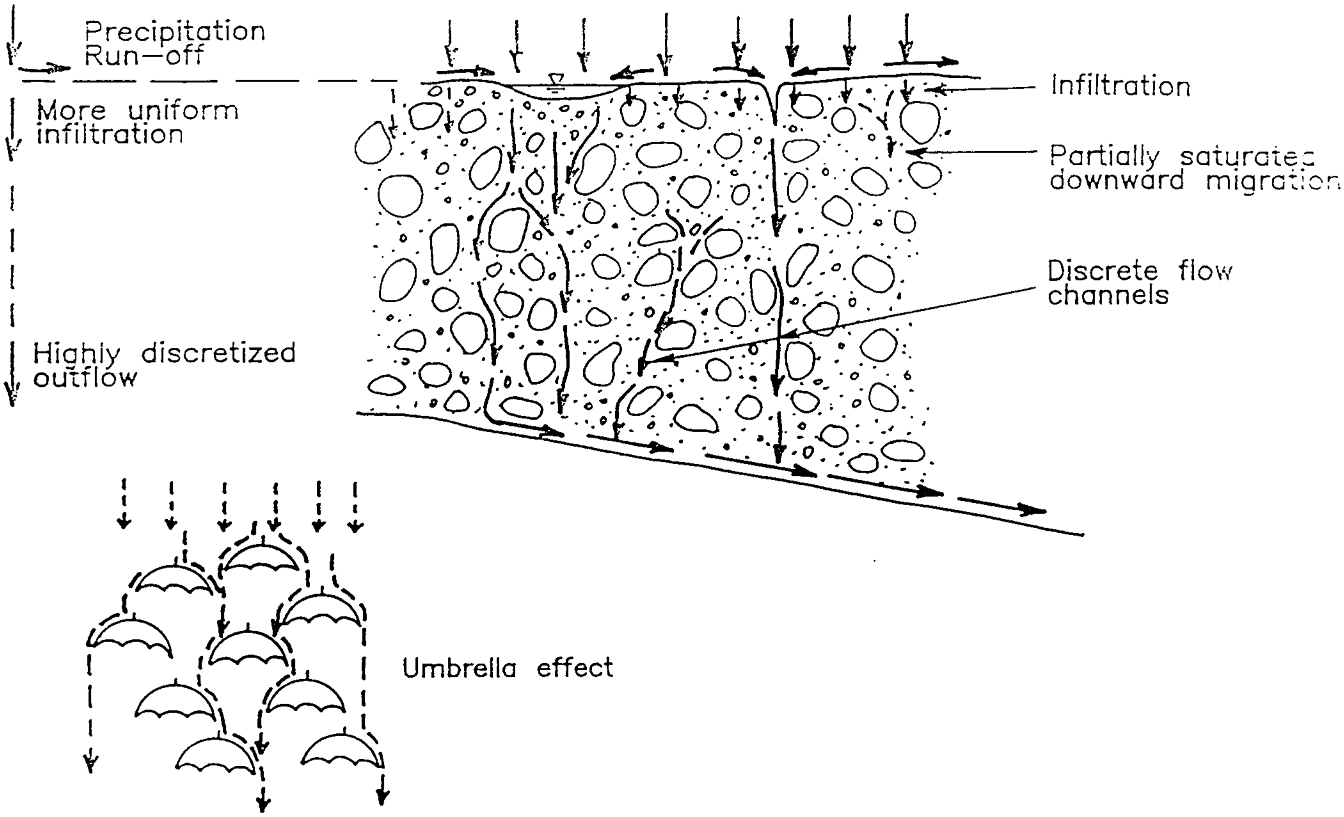
# Process - Specific Models

## Infiltration and water flow within waste rock piles

- *infiltration*
- *unsaturated flow*
- *channel flow*
- *saturated flow*

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MECHANISMS OF CHANNELING IN WASTE ROCK

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# Process - Specific Models

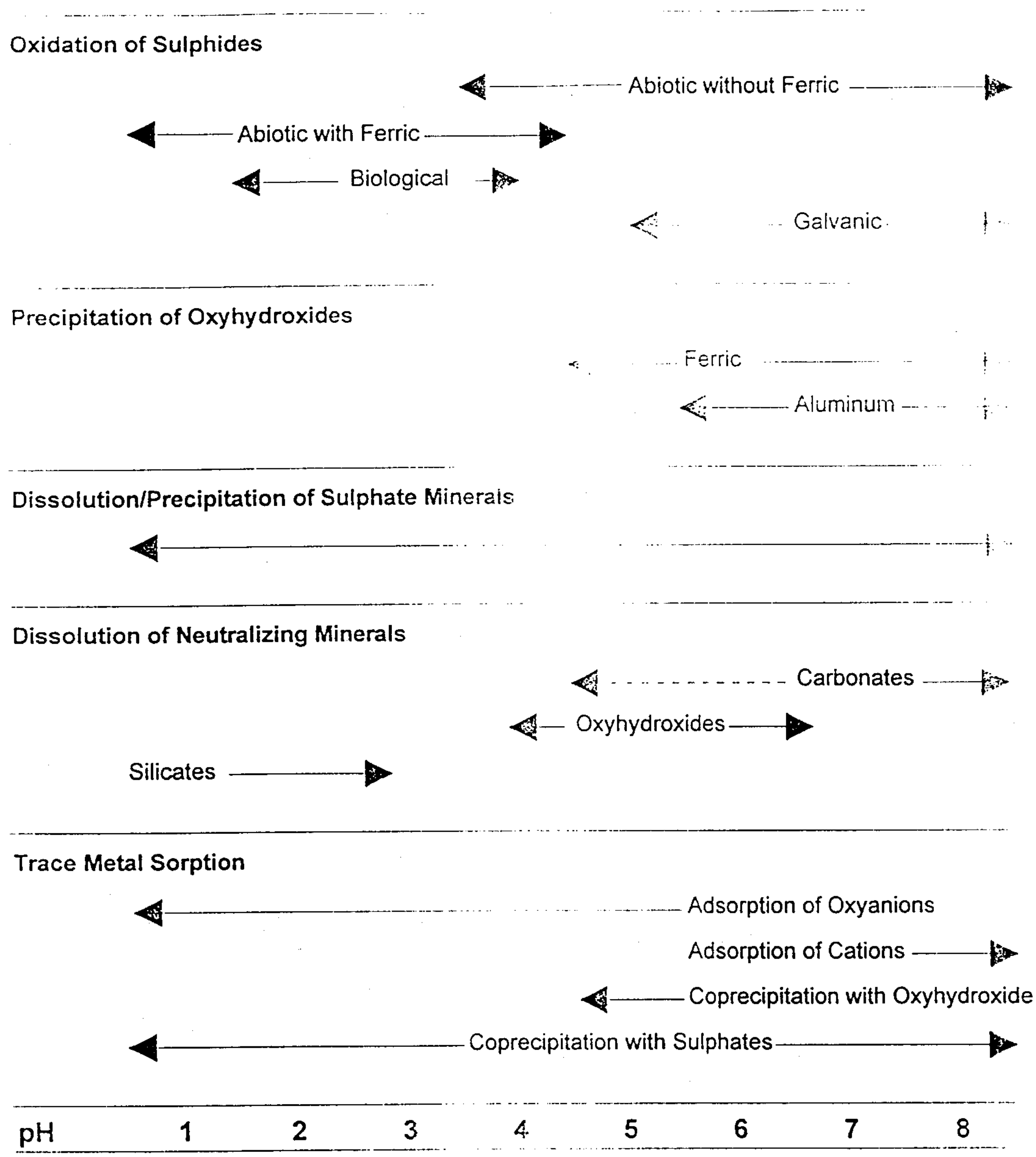
## Oxygen and heat transport

- *advection*
- *thermal convection*
- *air phase diffusion*

# Process - Specific Models

## Geochemical processes

- *oxidation of sulphide minerals*
- *dissolution of carbonates, hydroxides, silicates*
- *precipitation of oxy-hydroxides*
- *precipitation and dissolution of sulphates*
- *co-precipitation, ion exchange, sorption*

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GEOCHEMICAL PROCESSES vs. pH

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| --- | --- | --- | --- |
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# Process - Specific Models

**Contaminant transport within waste rock piles**

**Downstream impacts**

**Remediation measures**

- *covers*
- *geochemical controls*
- *collection and treatment*

# Engineering Models

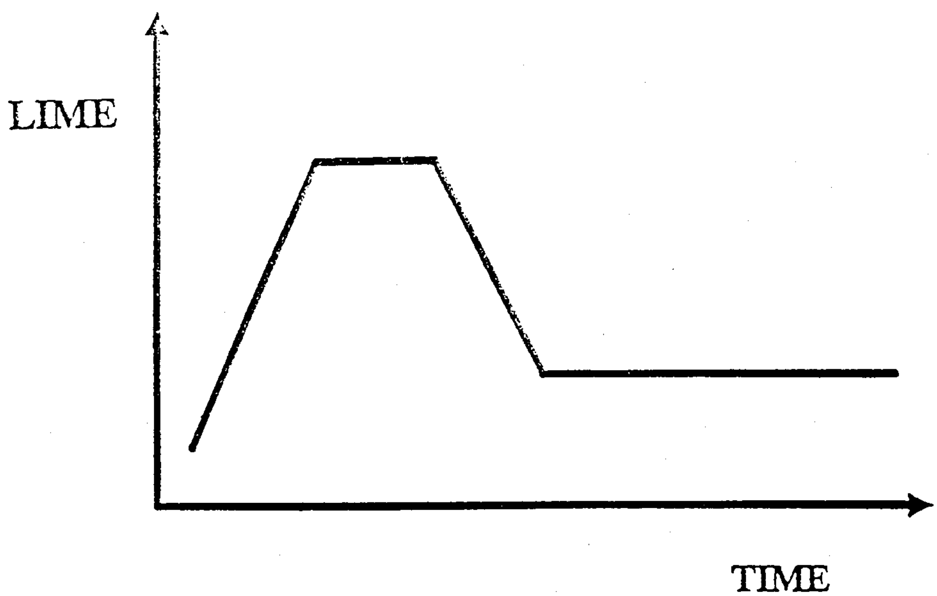
*"models that are intended to support practical decisions about real systems"*

# Engineering Models

## Empirical models

*Equity Silver Technical Committee (1991)*

*AMD Time - Ziemkiewicz (1994)*

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THE LIME CONSUMPTION CURVE USED BY THE TECHNICAL COMMITTEE MODEL

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FILE REF:FIG-4-1

# Engineering Models

## Semi-empirical models

*Morin & Hutt (1994)*

*QROCK - SRK (1993)*

*ACIDROCK - Senes (1991)*

*FIDHELM - ANSTO (1994)*

*TOUGH AMD - (Gelinas et al. 1994)*

# Input Parameters for FIDHELM Simulations

| Parameter | Values | Type * |
|---|---|---|
| **ambient temperature (°C)** | **3** | **M** |
| intrinsic air density (kg/m$^3$) | 1.2 | C |
| acceleration due to gravity (m/s$^2$) | 9.8 | C |
| **air permeability (m$^2$)** | **$2.9 \times 10^{-9}$, $10^{-8}$** | **M** |
| viscosity of air (kg/(m.s)) | $1.9 \times 10^{-5}$ | C |
| thermal coefficient of volume expansion (K$^{-1}$) | $3.47 \times 10^{-3}$ | C |
| oxygen diffusion coefficient of oxygen in air (m$^2$/s) | $2.26 \times 10^{-5}$ | C |
| **parameter in particle oxidation model (m$^3$/(kg.s))** | **$1.354 \times 10^{-9}$** | **E** |
| **bulk density of solid (kg/m$^3$)** | **2200** | **M** |
| **specific heat of solid (m$^2$/(s$^2$ .K))** | **866** | **E** |
| specific heat of air (m2/(s2 .K)) | $1.06 \times 10^{3}$ | C |
| **thermal diffusivity (m$^2$/s)** | **$5.0 \times 10^{-7}$** | **M** |
| heat of oxidation reacton per mass of reactant oxidised (J/kg) | $2.2 \times 10^{-7}$ | C |

SRK

| Parameter | Values | Type * |
|---|---|---|
| mass fraction of oxygen in air | 0.22 | C |
| mass of oxygen used per mass of reactant in oxidation reaction | 1.746 | C |
| **solid volume fraction** | **0.763** | **M** |
| **density of reactant ($kg/m^3$)** | **118** | **M** |
| **maximum intrinsic oxidation rate ($kg (O_2)/m^3/s$)** | **$10^{-9}, 10^{-8}, 10^{-7}$** | **E** |
| **infiltration rate (m/y)** | **1.134** | **M** |
| viscosity of water (kg/m s) | 0.001 | C |
| intrinsic water density ($kg/m^3$) | 1000 | C |
| specific heat of water ($m^2/(s^2 .K)$) | $4.184 \times 10^3$ | C |
| **temperature at which micro-organisms cease to be effective as catalysts (°C)** | **50** | **E** |
| **temperature above which the micro-organism catalytic activity diminishes** | **40** | **E** |
| **tortuosity factor** | **0.59** | **M** |
| **radius of pile (m)** | **34** | **M** |
| **height of pile (m)** | **6.7** | **M** |
| **side slope angle of heap (radians)** | **0.245** | **M** |

# Conclusions

## Process - Specific Models

- *surprising number & diversity*
- *some processes well understood & modeled*
- *other (important) processes neglected*
- *current approach is "bottom up"*

# Conclusions

## Engineering Models

- *all are at least partly empirical*
- *empirical models are more transparent*
- *poor documentation*
- *lack of consideration of uncertainty*
- *lack of validation*
- *"bottom up"*

# Recommendations

- *limitations of ARD models need to be better communicated to industry and regulators*
- *strong "bottom up" work should be complimented by a "top down" approach*
- *appropriate combination of mathematical and physical models needs more attention*