NSERC/COSIA Industrial Research Chair in Oil Sands Tailings Geotechnique

Stochastic Simulation of Tailings Consolidation Process

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NSERC CRSNG

Agenda

- Background
- Introduction to Causal Loop Diagrams (CLD)
- Re-interpretation of Consolidation using CLD
- Stochastic Setup
- Concluding Remarks

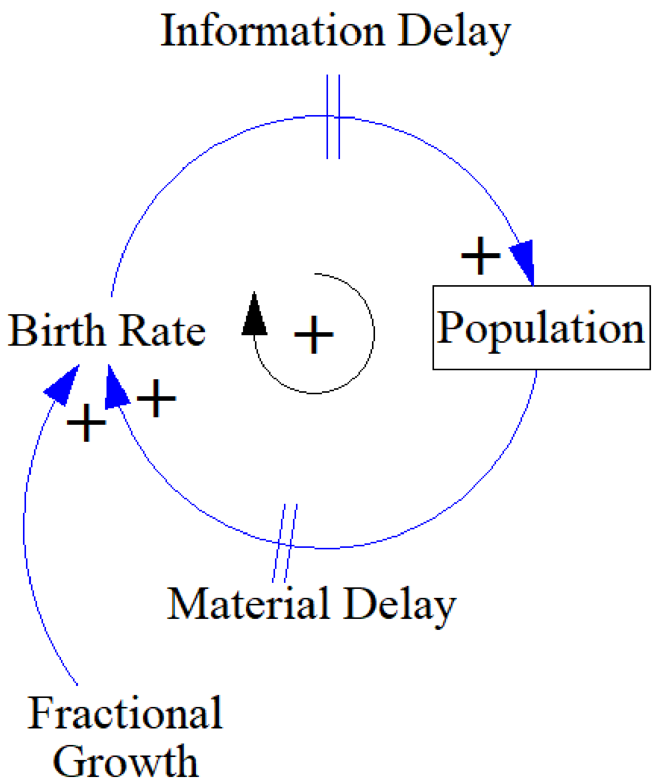
Background

Why Care About Tailings Consolidation ?

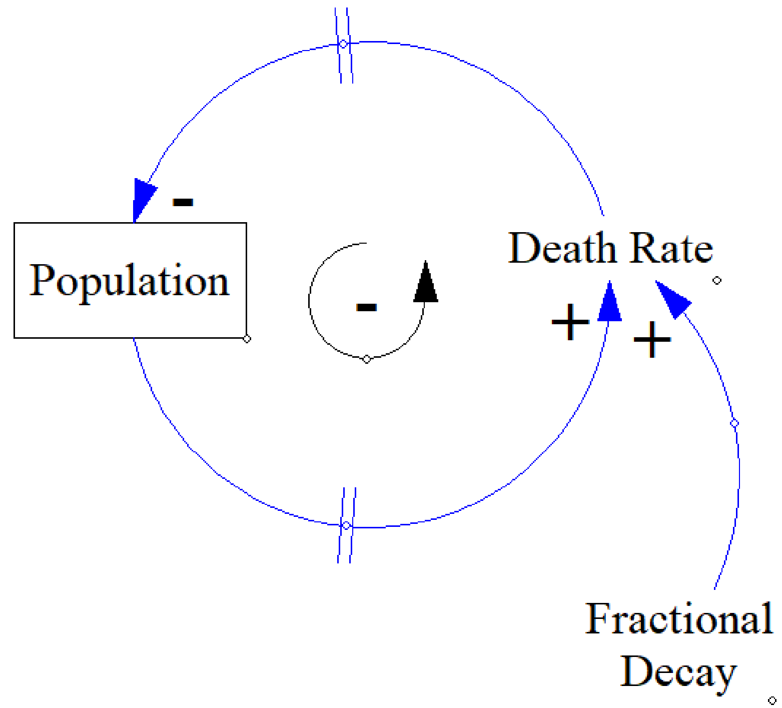
- Reclamation Schedule and Cost
- Regulatory Pressure
- Long-Term Ecological Impact

Causal Loop Diagram (CLD)

Positive Feedback = Reinforcing



Negative Feedback = Balancing



Rate = Fraction (% per time step) * Population

Stock (t) = Stock(t0)+$\int_{t_0}^{t}[Inflow(s) - Outflow(s)]ds$

Finite Difference Method (Cargill, 1982)

Governing Equation:

$$\left\{\gamma_c \beta(e) + \frac{\partial}{\partial z}[\alpha(e)]\right\}\frac{\partial e}{\partial z} + \alpha(e)\frac{\partial^2 e}{\partial z^2} + \gamma_w \frac{\partial e}{\partial t} = 0$$

$$\alpha(e) = \frac{k(e)}{1+e}\frac{d\sigma'}{de} \qquad \beta(e) = \frac{d}{de}\left[\frac{k(e)}{1+e}\right]$$

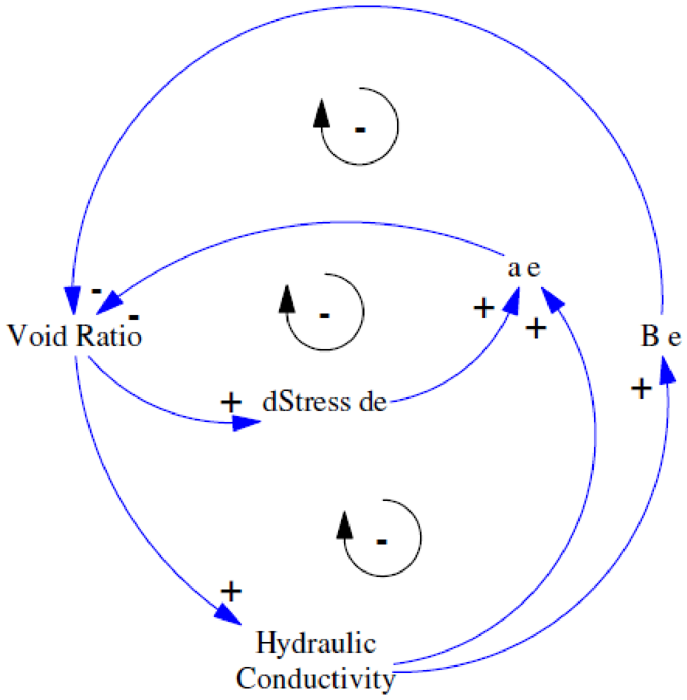
Solution:

$$e_{i,j+1} = e_{i,j} - \frac{\tau}{\gamma_w}\left(\left\{\gamma_c \beta(e_{i,j}) + \left[\frac{\alpha(e_{i+1,j}) - \alpha(e_{i-1,j})}{2\delta}\right]\right\}\left[\frac{e_{i+1,j} - e_{i-1,j}}{2\delta}\right] + \alpha(e_{i,j})\left[\frac{e_{i+1,j} - 2e_{i,j} + e_{i-1,j}}{\delta^2}\right]\right)$$

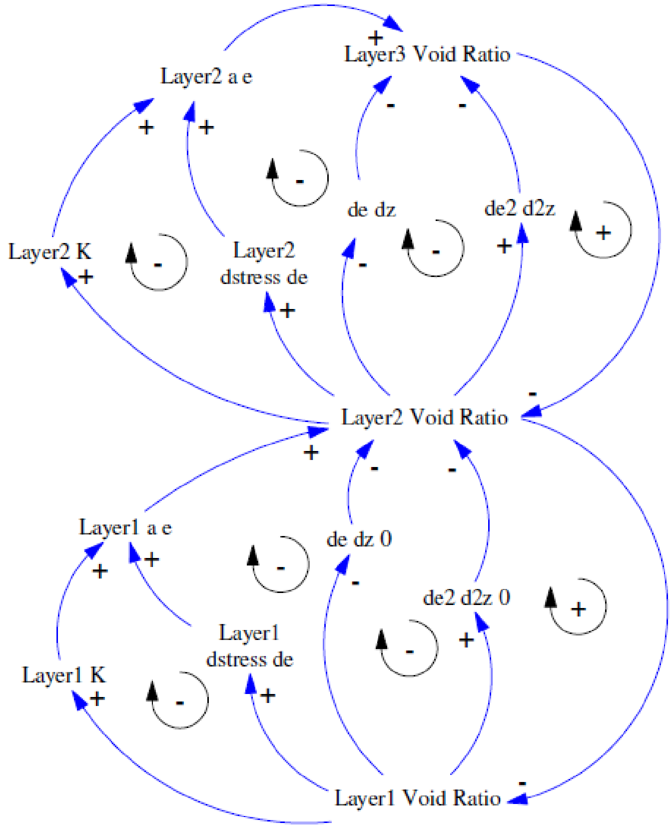
Re-interpretation of Cargill (1982)

9 Negative Feedback Loops and 2 Positive Feedback Loops

Temporal Feedback

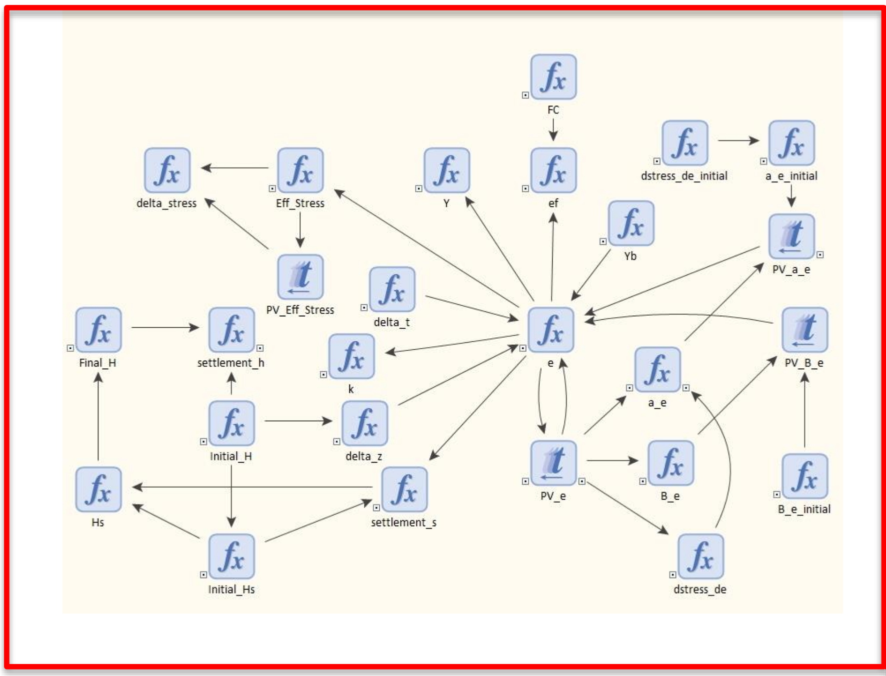


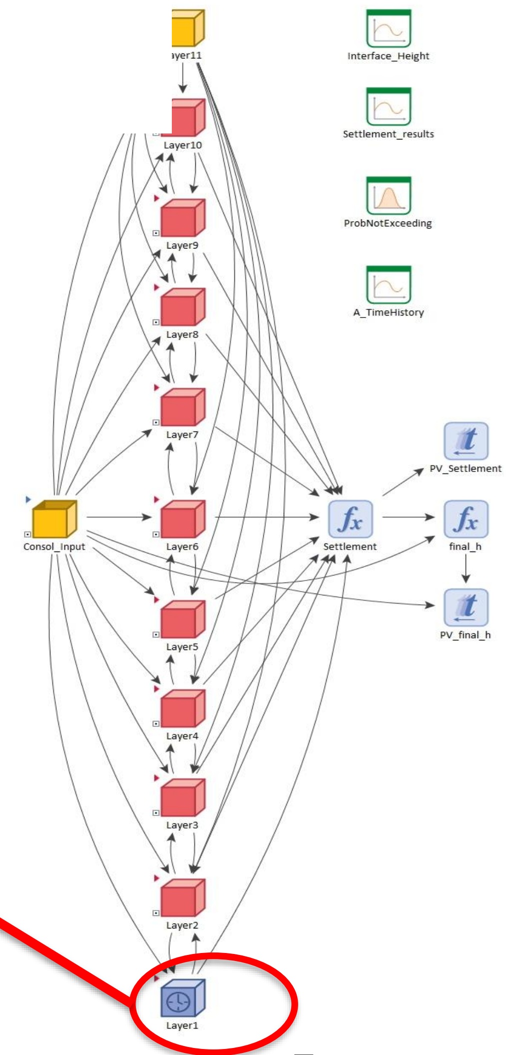
Spatial Feedback



Methodology

Key Stochastic Input: Compressibility and Hydraulic Conductivity Fitting Parameters

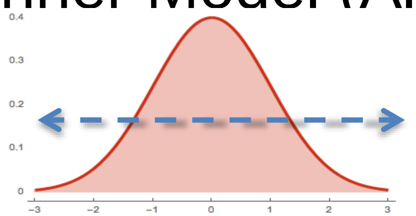




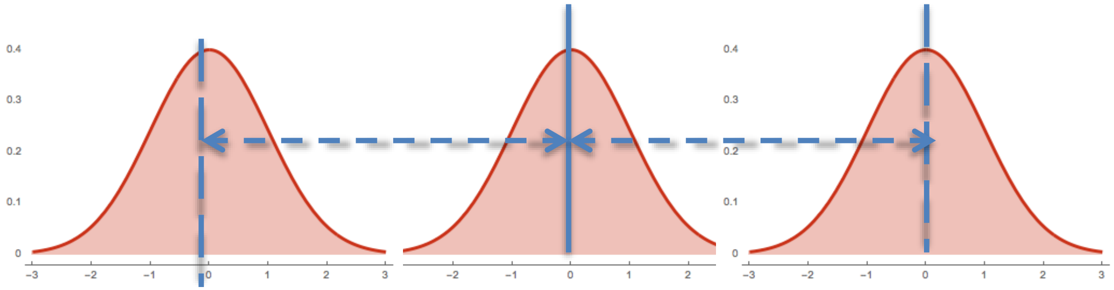
Stochastic Model Setup

- Aleatory Uncertainty (“Inherent” Randomness)
- Epistemic Uncertainty (Lack of Knowledge)

- **Nested** Monte Carlo (Distribution of Distribution)
- Dynamic Inner Model (Aleatory)

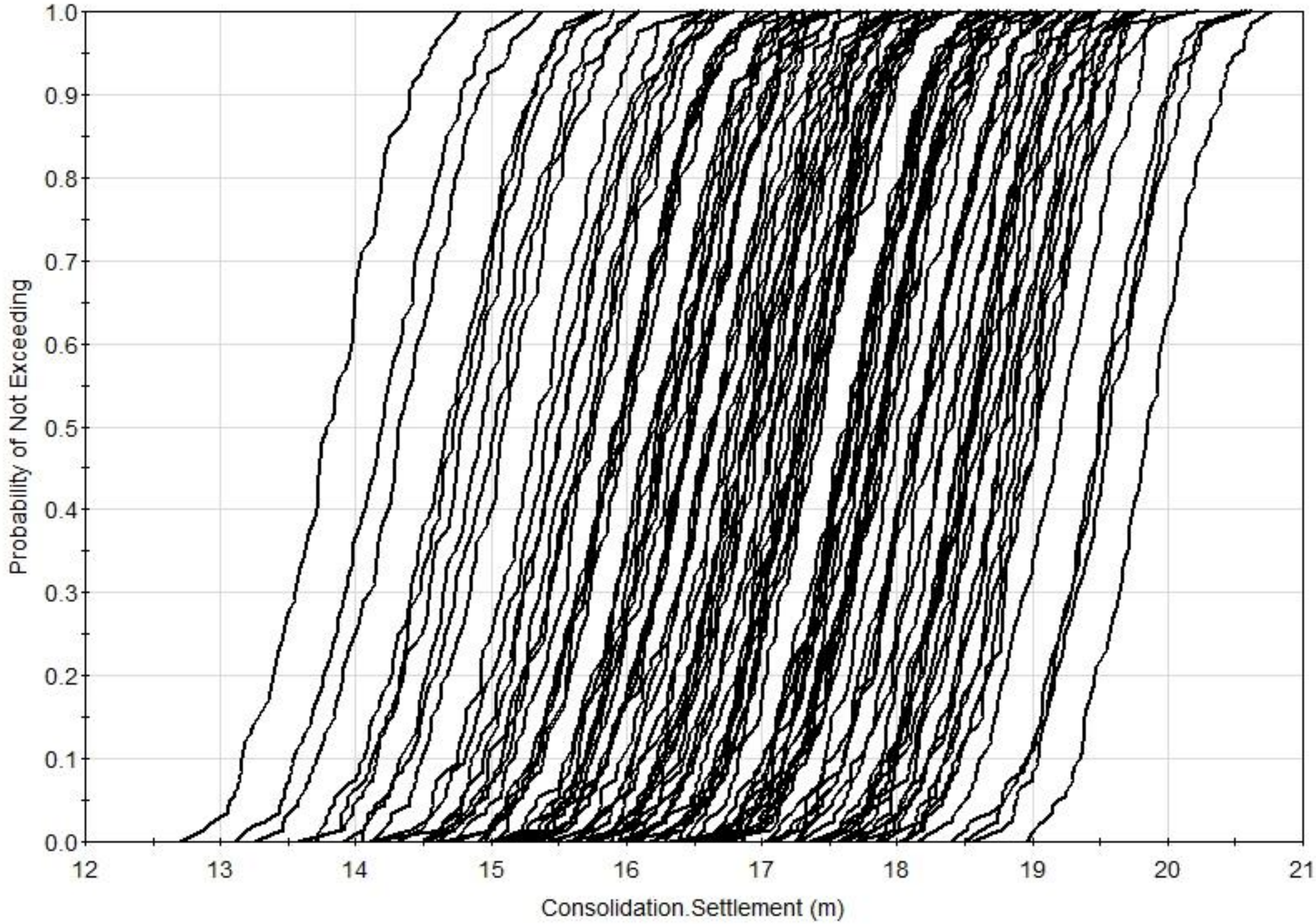


- Static Outer Model (Epistemic)

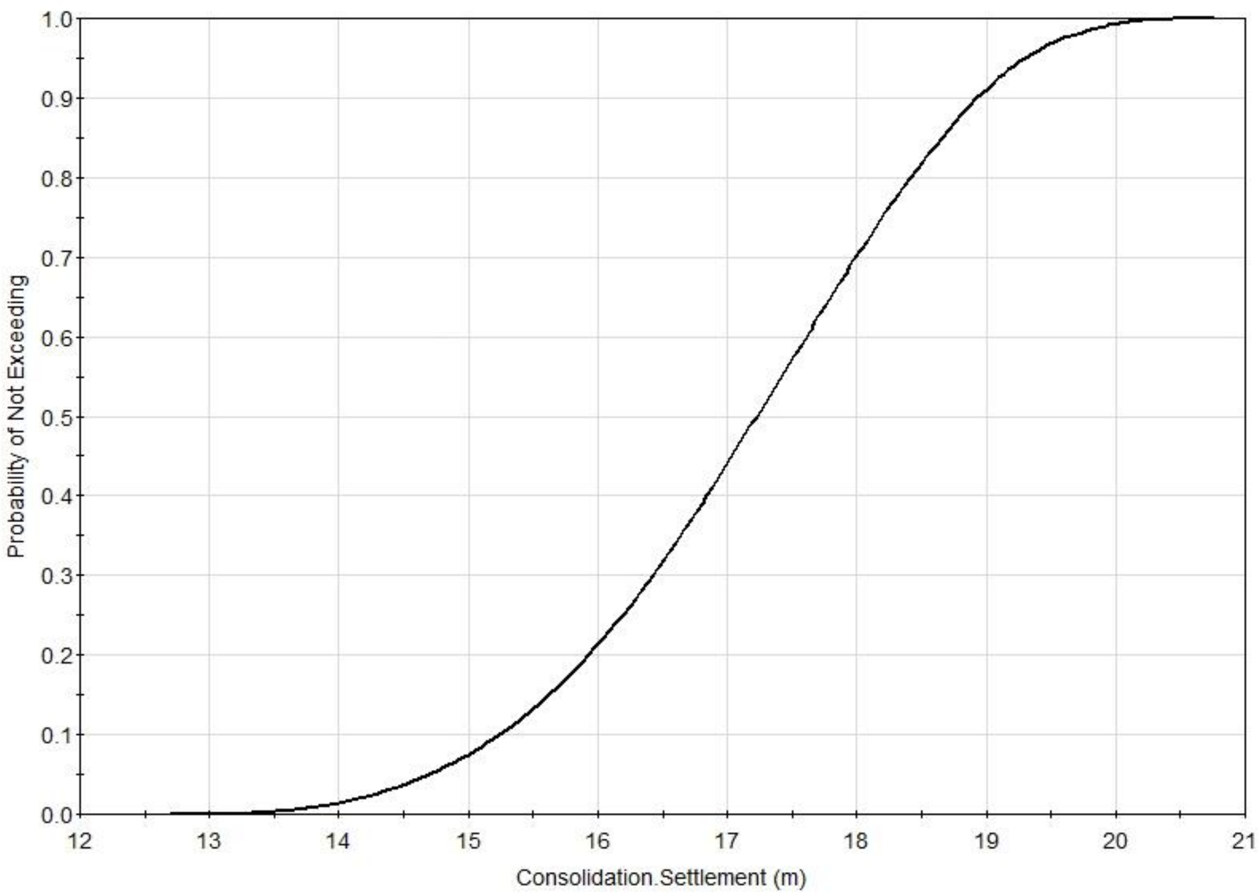


Stochastic Model Setup

100 X 100 Realizations = 10,000 Monte Carlo runs



Stochastic Model Setup



Concluding Remarks

- Simplicity is found in complexity using Causal Loop Diagrams (CLD).
- CLD coupled with Monte Carlo techniques can be a useful qualitative and quantitative tool in Risk Management Modeling
- Separation of Aleatory and Epistemic uncertainties (nested Monte Carlo) demands intensive computing power

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