System Dynamics Approach to Tailings Management Simulation

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Agenda

- **Introduction**: System Dynamics and Causal Loop Diagrams (CLD)
- **Case Study**: 1D Self-Weight Consolidation of Tailings
- **Concluding Remarks**

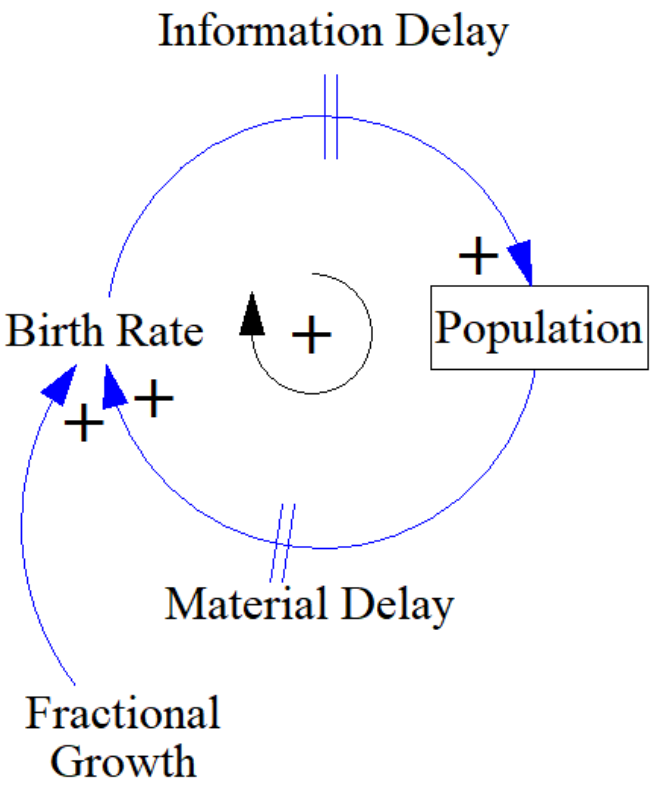
What is System Dynamics ?

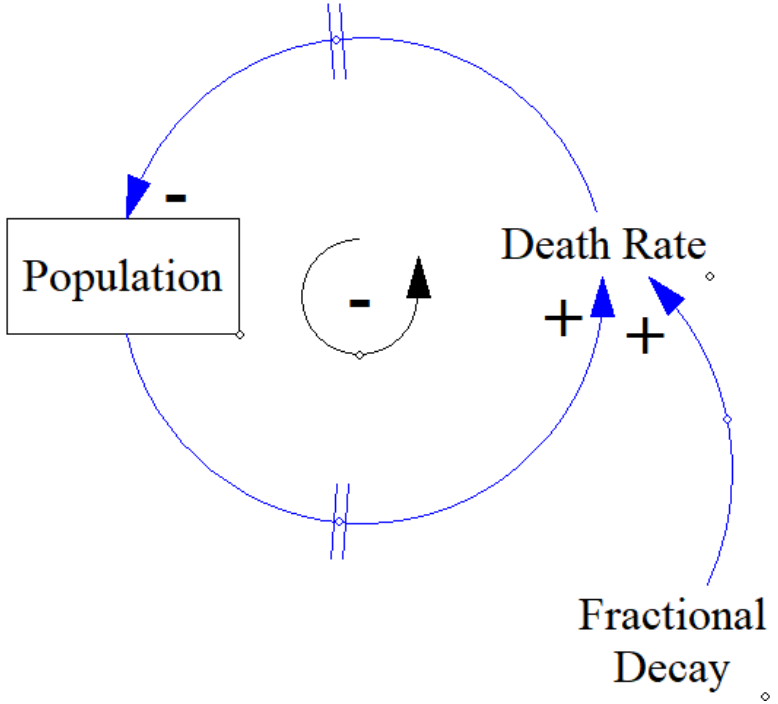
- Developed by Jay Forrester at MIT's Sloan Business School in the 50s:

  To model complex inter-relationships between elements within a system or multiple systems.

- Applications in Public Health, Management Consulting, Water Resource Management, Public Policy, International Relations, Defense and Securities etc.

A Simple Example of Causal Loop Diagrams

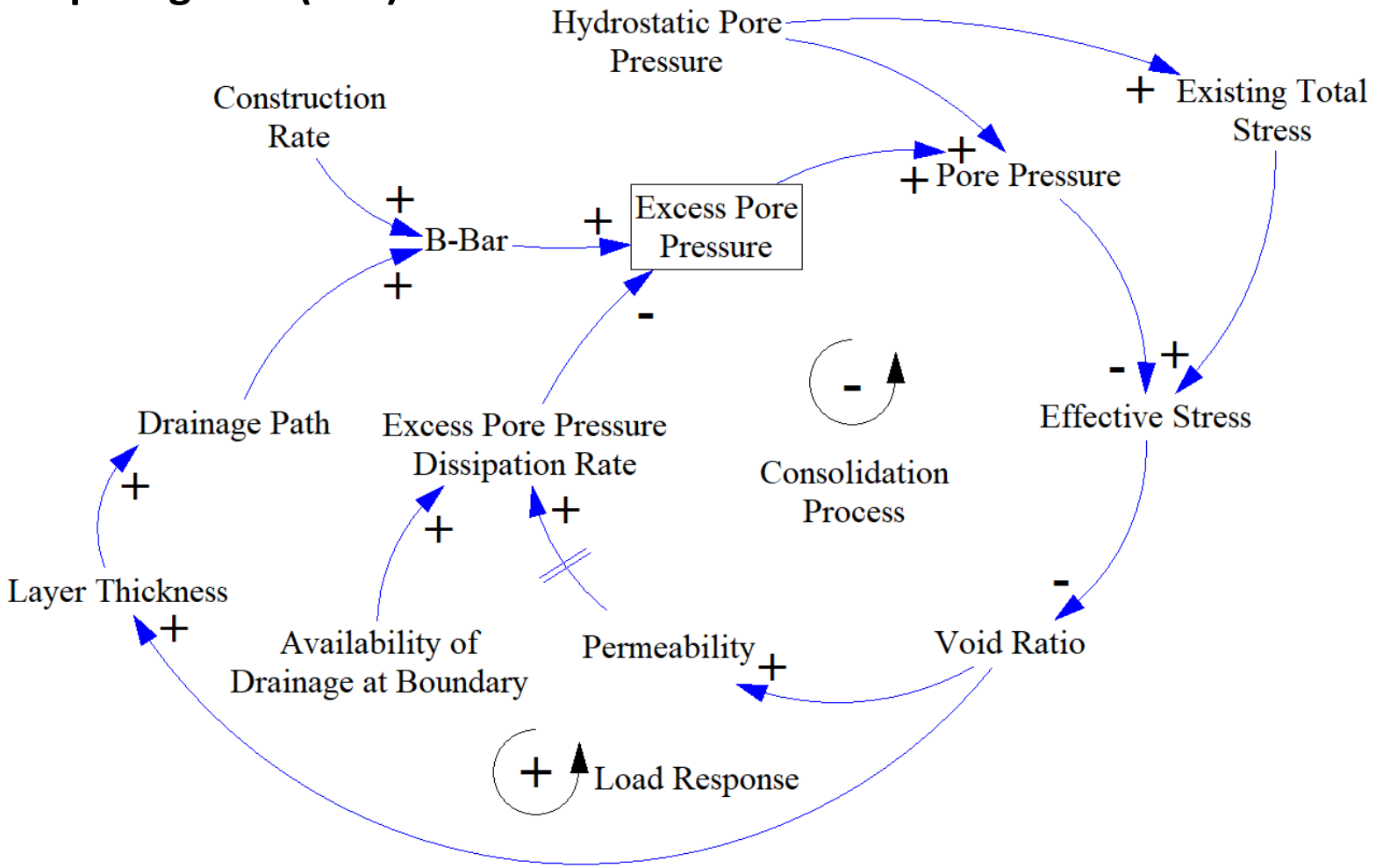




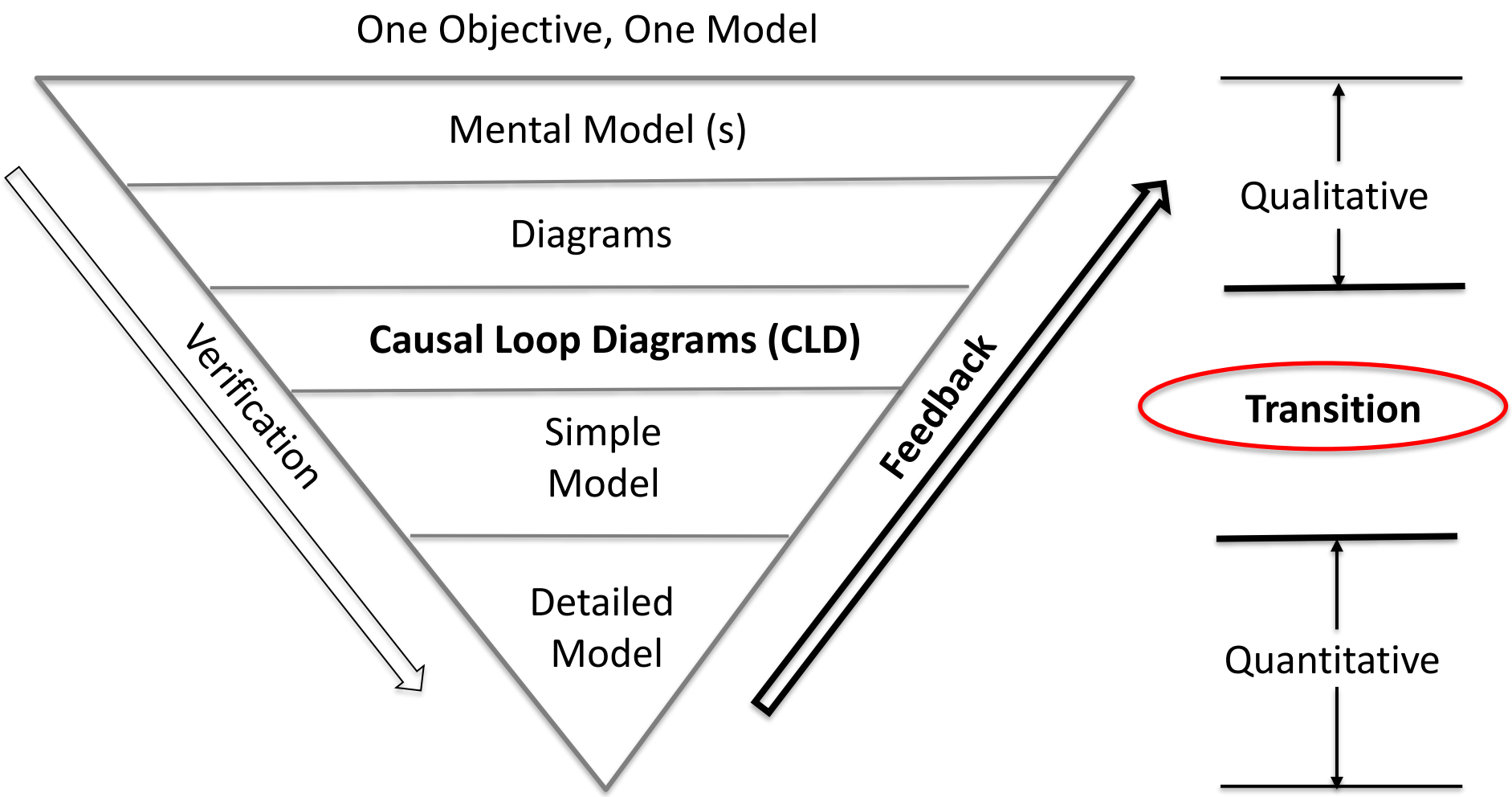
Modified from Sternman, 2000

Top-Down Interpretation of Consolidation

Causal Loop Diagrams (CLD)



System Dynamics Modelling Process



1D Self-Weight Consolidation of Tailings

A Bottom-Up Re-Interpretation using System Dynamics and Causal Loop Diagrams

Case Study

Solution to Differential Equations

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

De-compose

De-compose

Temporal Components

B_e a_e Void_Ratio

dStress_de

Hydraulic_Conductivity

Spatial Components

de_dz d2e_dz2

Neighbour_Void_Ratio

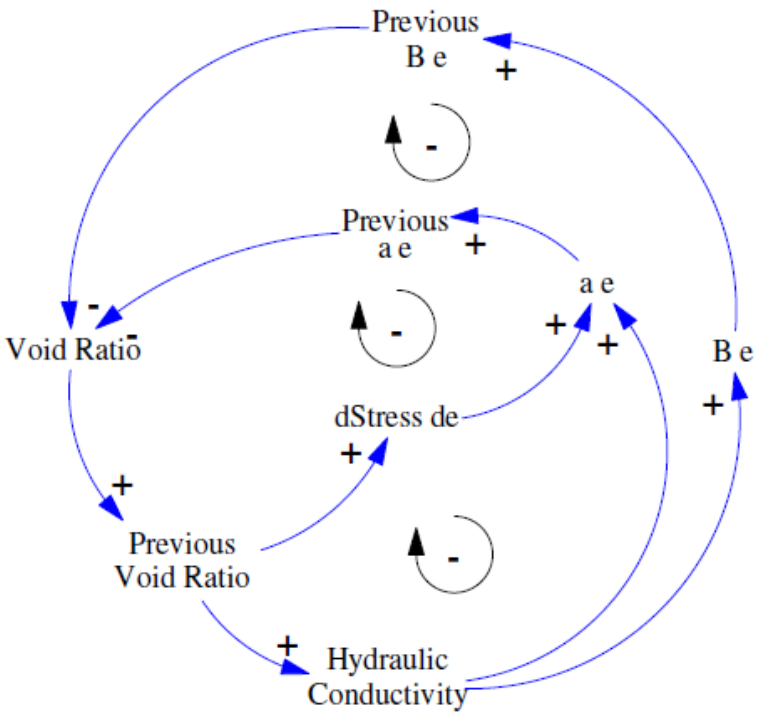
Neighbour_a_e

Neighbour_dStress_de

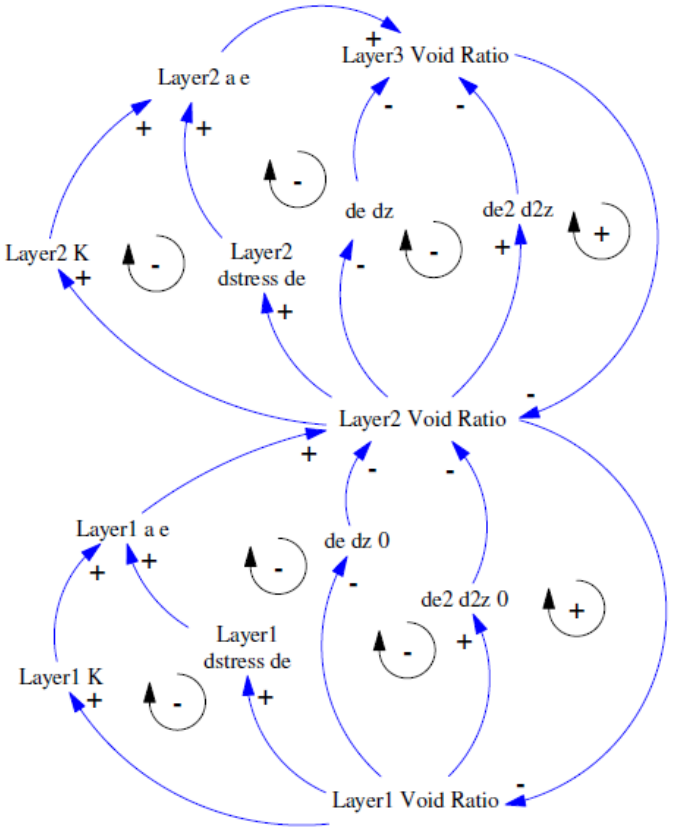
Case Study

What kind of narrative and conclusion can we make by just looking at those CLDs?

Temporal Feedback

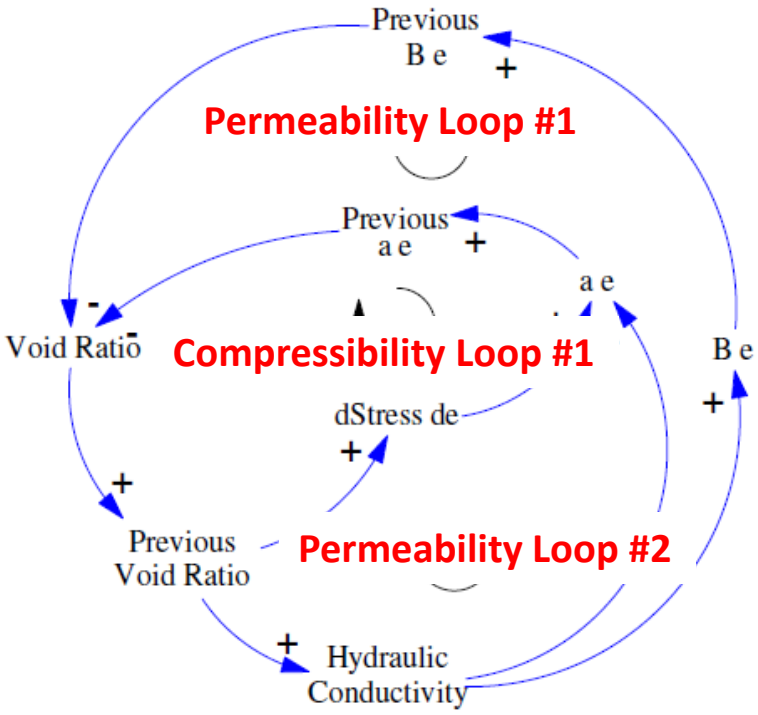


Spatial Feedback

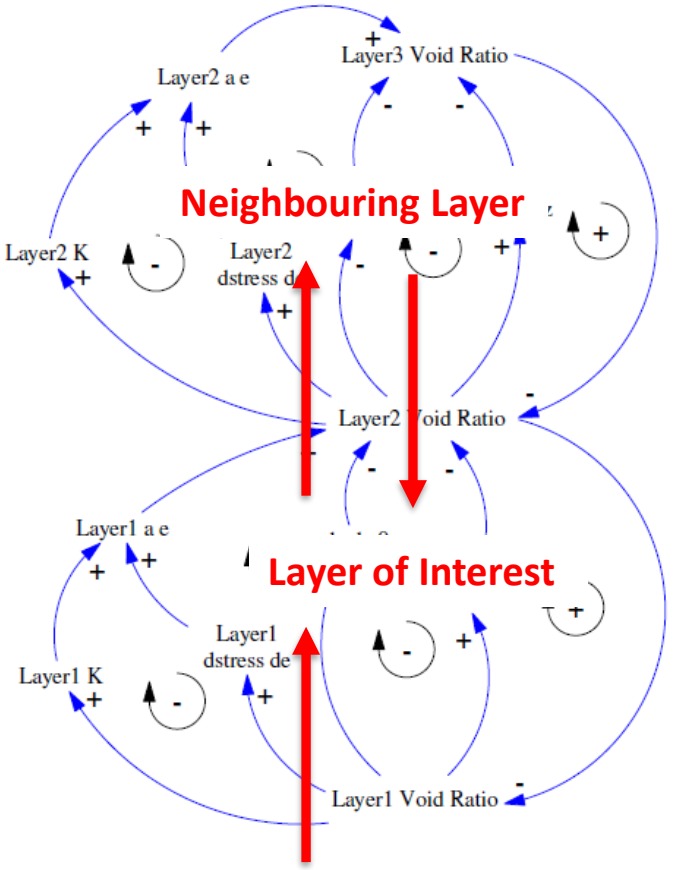


Case Study

Temporal Feedback

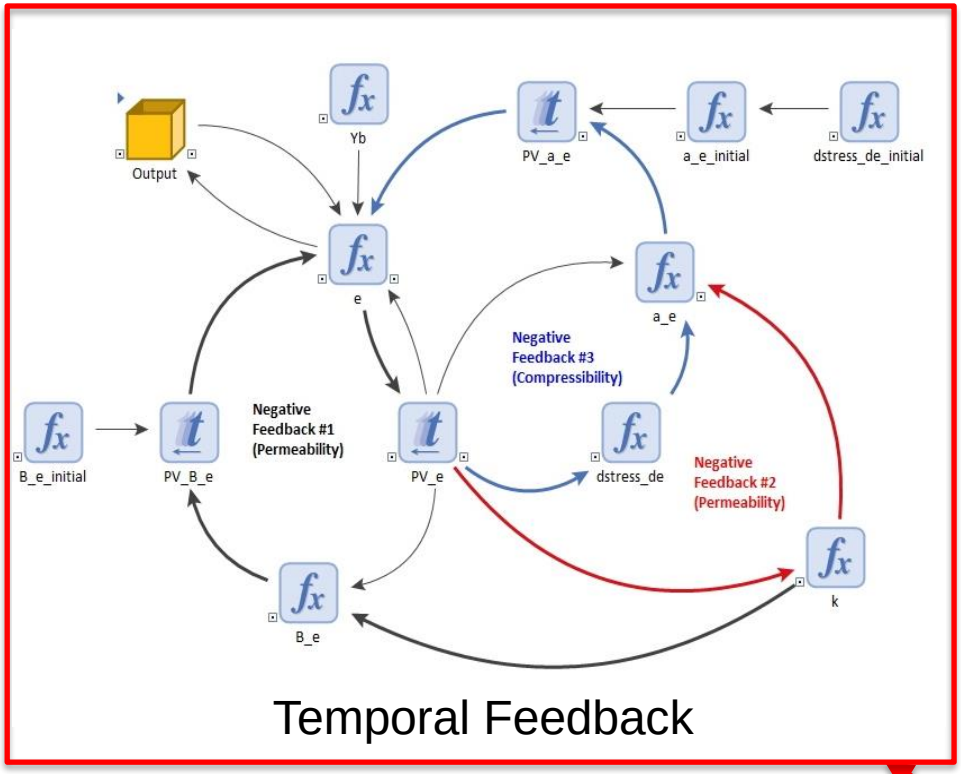


Spatial Feedback

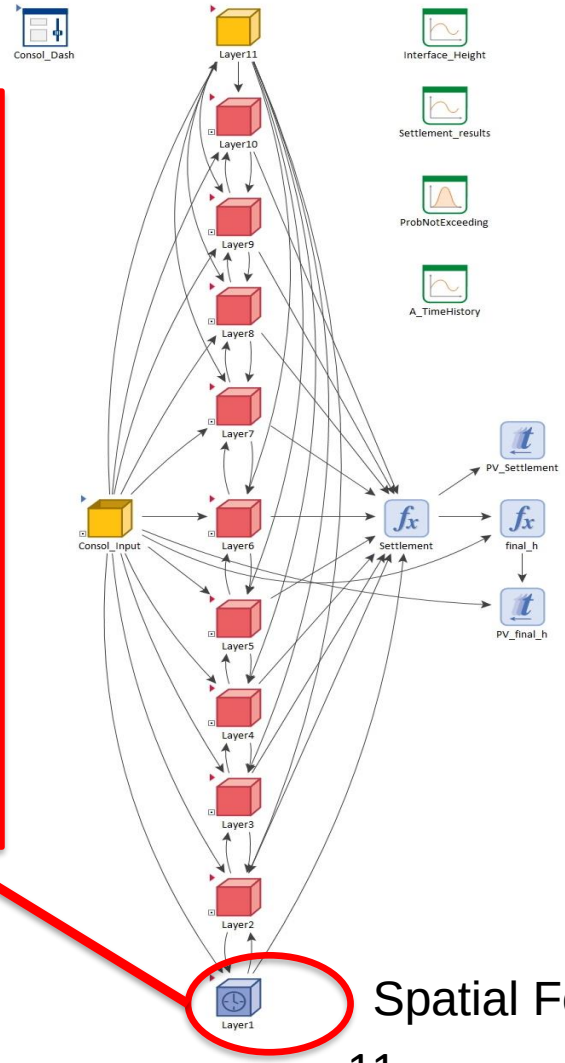


Case Study

Inside GoldSim ……



Temporal Feedback



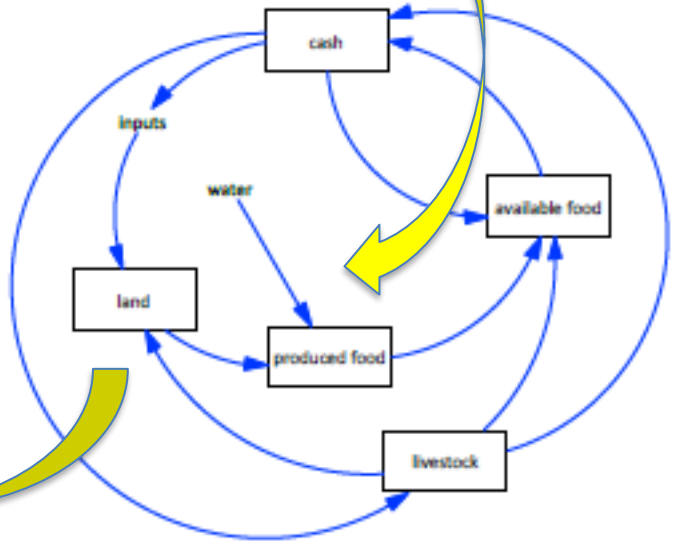
Spatial Feedback

See the GeoEdmonton 2018 conference paper for further details

Concluding Remarks

- Why System Dynamics?
  - **Feedback Structures**
  - Transparency
  - **Rigorous Qualitative Process**
  - Scalability
  - **Participatory Modelling**
  - Structural Sensitivity
  - **Ability to model soft variables**
  - And many more

Concluding Remarks – Participatory Modelling



Quantitative Model(s)

Modified from Hager et al, 2015

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