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Multi-Model Ranking and Inference :

Experimental Approach

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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Methods

- Develop a complex geological, hydrological, and groundwater flow model ("ground-truth" model) of a hypothetical site to provide synthetic data to the modeling team
- Synthetic data extracted from the hypothetical site model are provided to the modeling team in an incremental fashion similar to a site-characterization program
- Modeling team uses synthetic data to construct multiple alternative models of groundwater flow of varying degrees of complexity and parameterization
- As a second approach, the existing Horonobe groundwater flow model is used as the source of synthetic data and as a basis for constructing multiple models

Methods

- Multi-model ranking metrics, such as the Akaike Information Criterion (AIC), are applied to the multiple models and inferences are drawn regarding the reliability of alternative models (for both the approach using the hypothetical site model and using the Horonobe model)
- Interpretations of Kullback-Leibler Information are made for the multiple alternative models of groundwater flow that have been developed for the hypothetical site and the Horonobe site
- Comparison is made between the inferred reliability of alternative models and the original hypothetical, ground-truth model

Kullback-Leibler (K-L) Information

- **K-L information is the information, *I*, that is lost when a model, *g*, is used to simulate a true condition, *f*.**

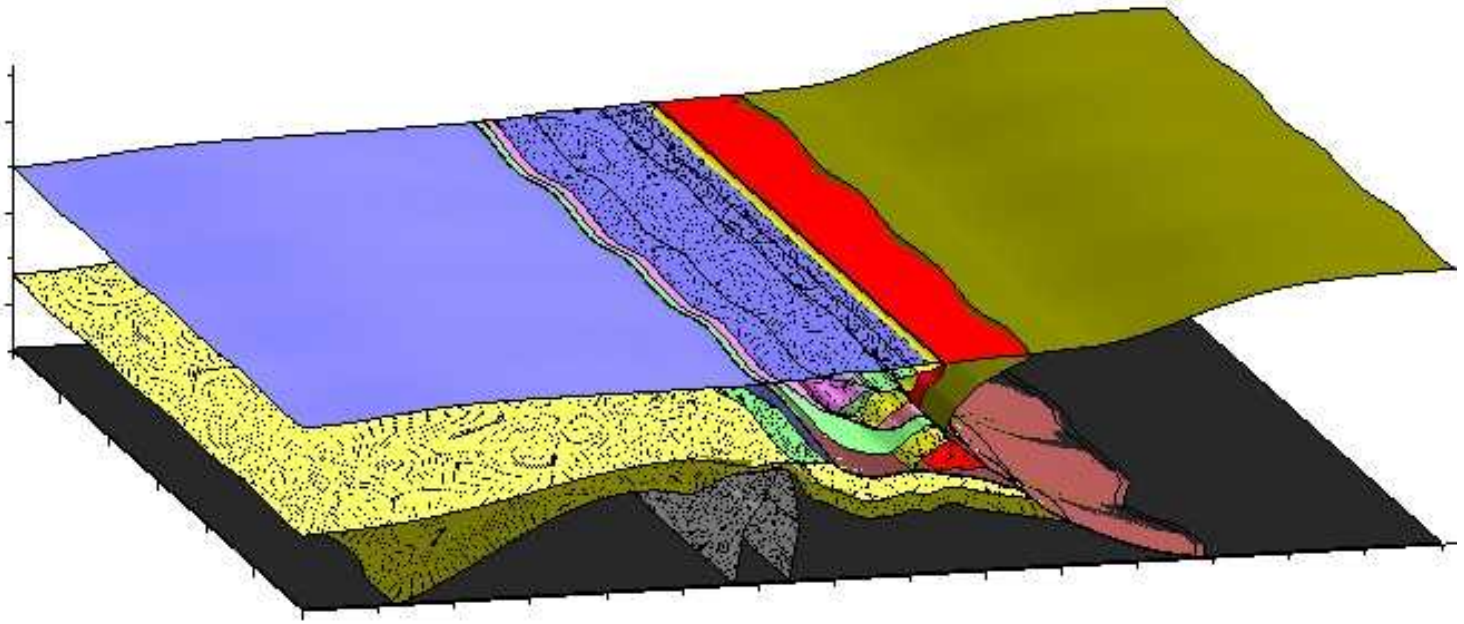
$$f = g + I$$

- **In the experimental approach used here the true condition is known, so the information lost for each of the multiple, alternative models can be evaluated**

Hypothetical Site Model

- Hypothetical site model is approximately 15 km by 15 km, with greatest complexity and resolution in the central 5 km by 5 km area
- Left boundary is constant head at sea level and right boundary is no flow at topographic elevation of 800 m
- Lateral and bottom boundaries are no flow
- Recharge increases with elevation; no net recharge occurs at lower elevations
- Relatively complex structural and geological geometry of hydrogeologic units is defined
- Spatial heterogeneity in permeability is applied to key hydrogeologic units

Develop Hypothetical Site Model



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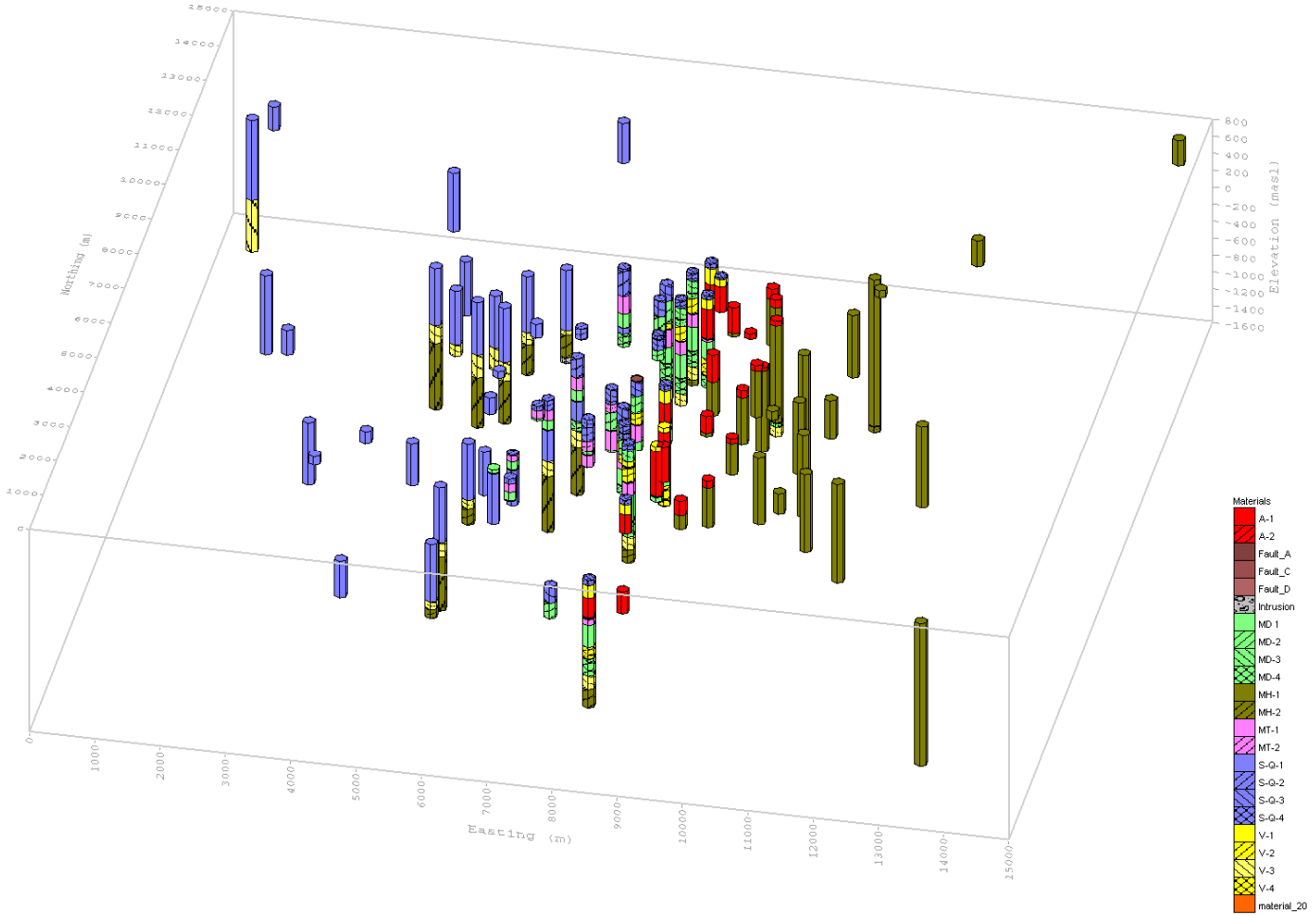
Extract Synthetic Data



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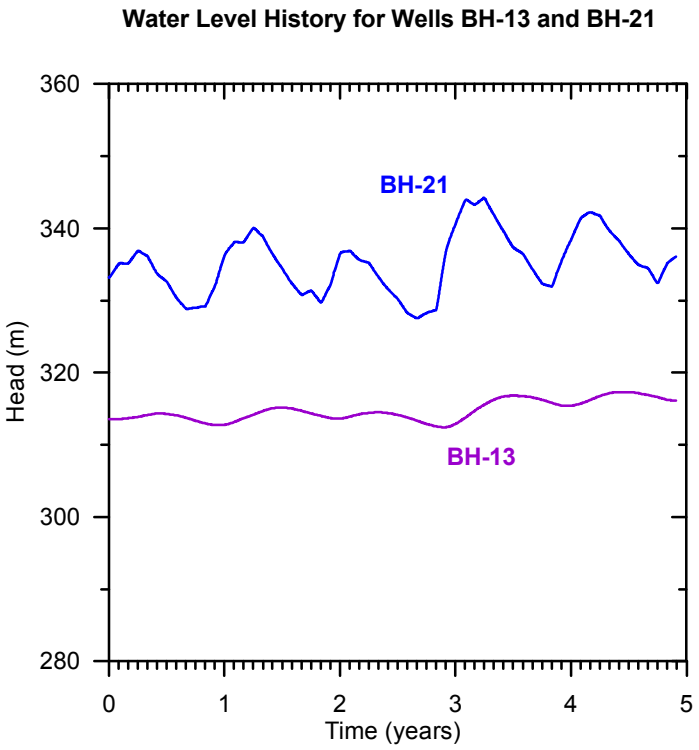

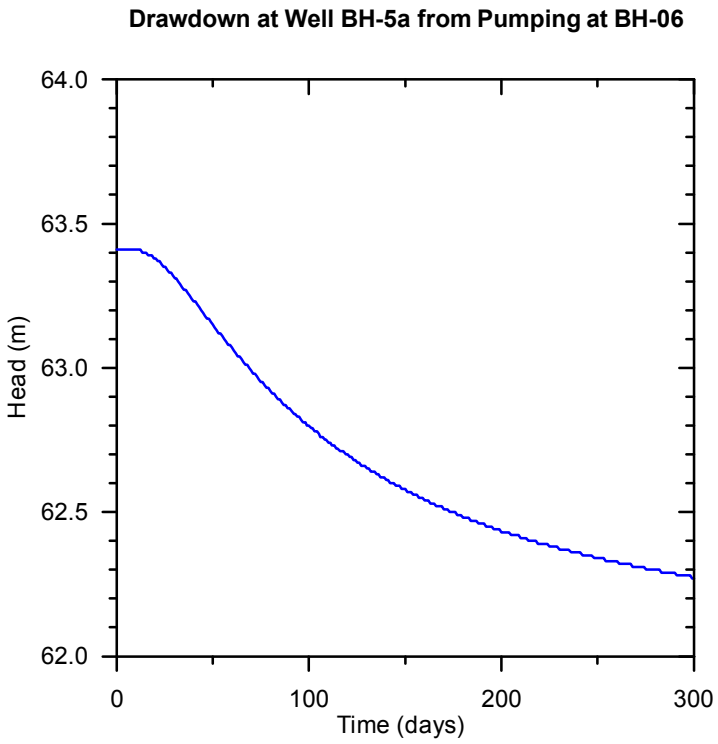

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Construct Multiple Alternative Models

- Simple Models
  - Reduced dimensionality (one-dimensional): vary the number of hydraulic conductivity zones and faults
  - Analytical solution with simplified boundary conditions
- Complex Models
  - Vary number of faults
  - Vary vertical and horizontal anisotropy
  - Vary recharge boundary conditions
  - Steady state and transient groundwater flow
- Use parameter estimation to optimize match to water level observations for each alternative model
- Iterate on alternative model development with each new set of synthetic site data

Horonobe Flow Model

- Graphic of Horonobe Model

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Multi-Model Ranking

- Calculate AIC, AICc, BIC, and HP ranking metrics for each alternative model or alternative model parameterization
- Evaluate alternative models based on various ranking metrics
- Evaluate models with different degrees of parameterization on the basis of ranking metrics
- The K-L information associated with alternative models is examined as a function of increasing number of observations (progression of site characterization)

Synthesis and Lessons Learned

- Patterns of multi-model ranking metrics for alternative models and parameterization schemes are analyzed
- Implications of applying multi-model ranking and inference to the site-characterization process for repository development are assessed
- Conclusions regarding the potential strengths and weaknesses of multi-model ranking and inference are summarized as lessons learned