Modeling and Planning Applications for Groundwater Management with Real Time and Distributed Web-based Resources

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Overview

- Introduction to Planning and Operations Applications for Groundwater Management

1. Model and Resource Requirements
2. Data Acquisition and Processing
3. Web and distributed services for model execution
4. Results presentation and exploration
5. Model Calibration and Uncertainty

Water Resources Management

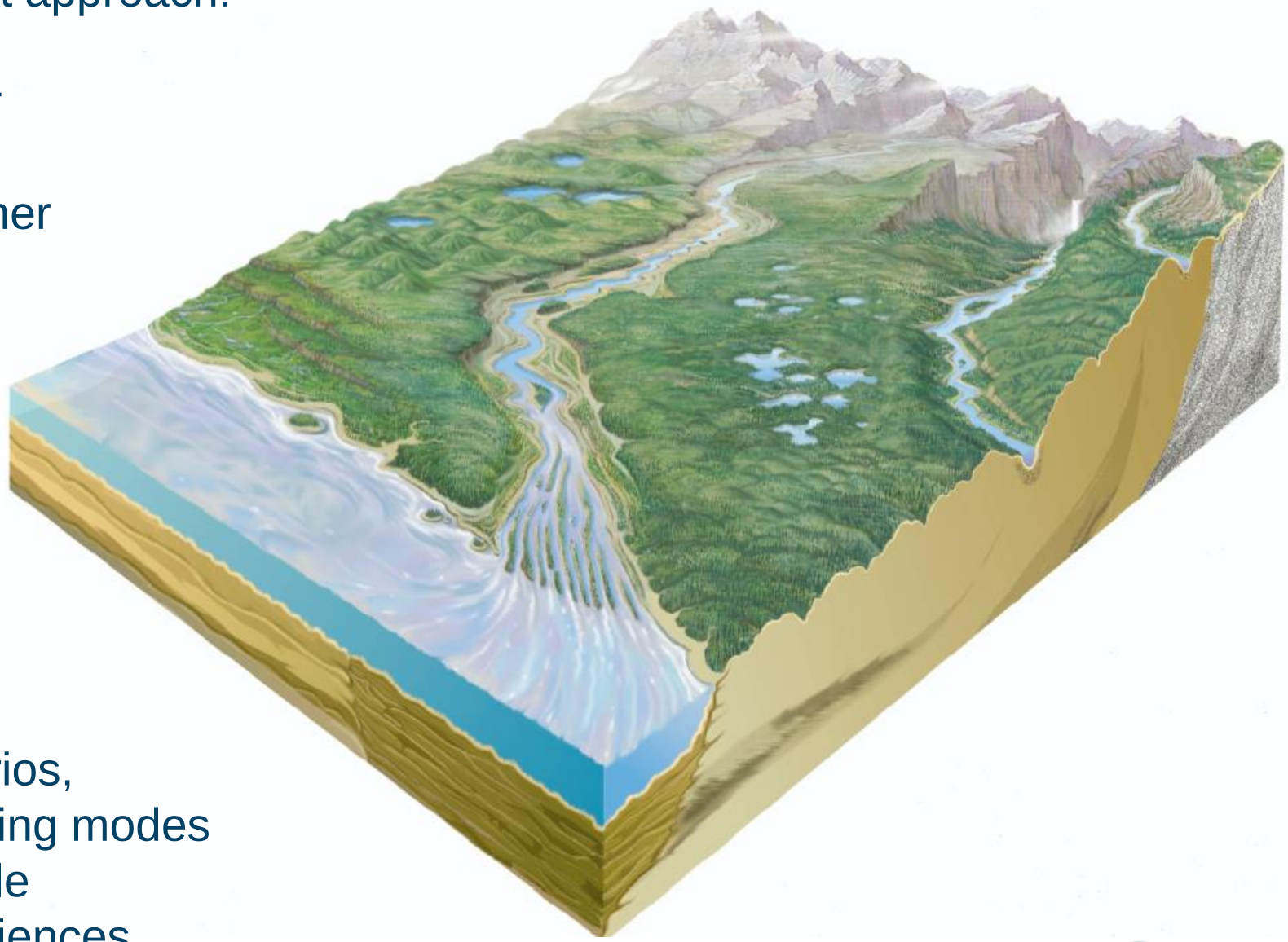
Danish and IWRM management approach:

Groundwater and surface water is one resource, and should be managed In an integrated manner

This requires integrated modeling tools and methods that explicitely handle the groundwater – surface water interaction

Applications required to

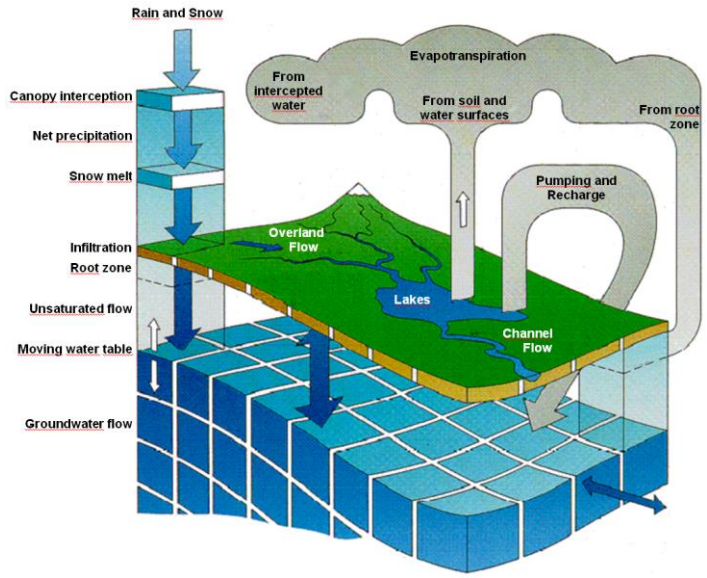
- process more data,
- run more models and scenarios,
- Utilize operational and planning modes
- and deliver results and enable decisionmaking to wider audiences



DHI model software – fields of application

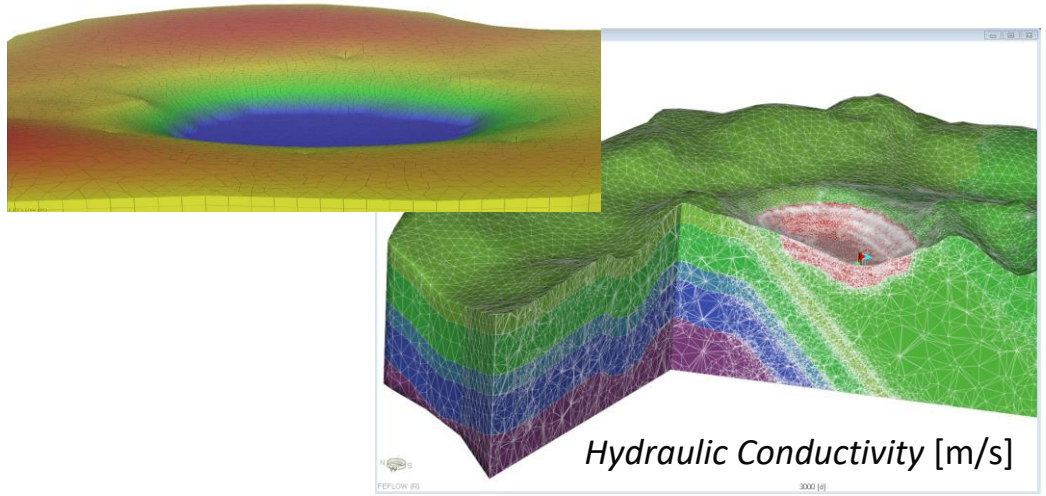
MIKE SHE – MIKE11

- Groundwater Recharge
- Catchment Water balance
- Hydrological climate change effects
- Land use changes and urbanisation
- Groundwater – surface water interaction



FEFLOW

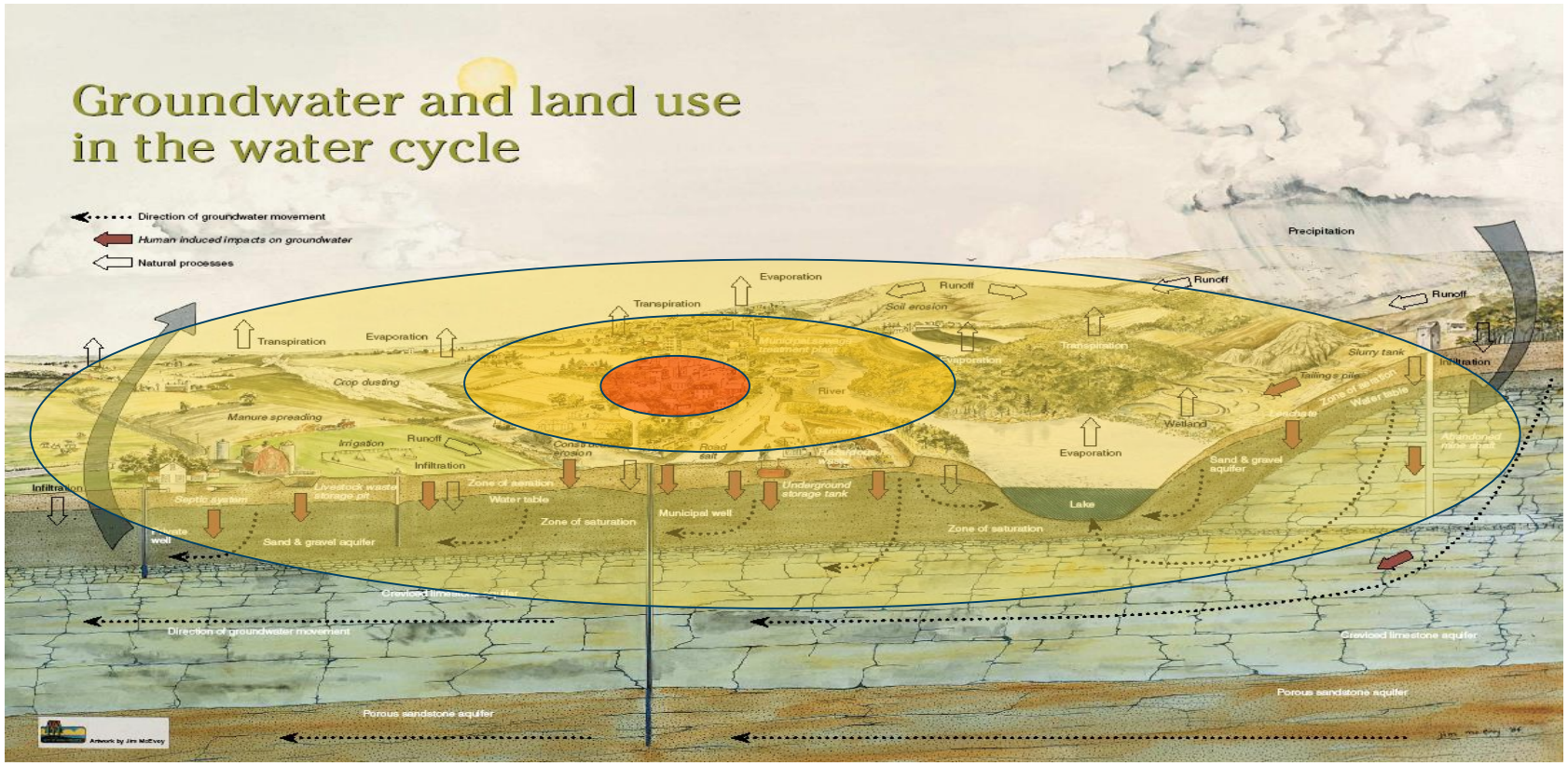
- Groundwater management
- Capture-zone delineation
- Contaminant transport
- Saltwater intrusion
- Mining and subsurface waste deposits
- Artificial recharge



Groundwater Resource Assessment Scale

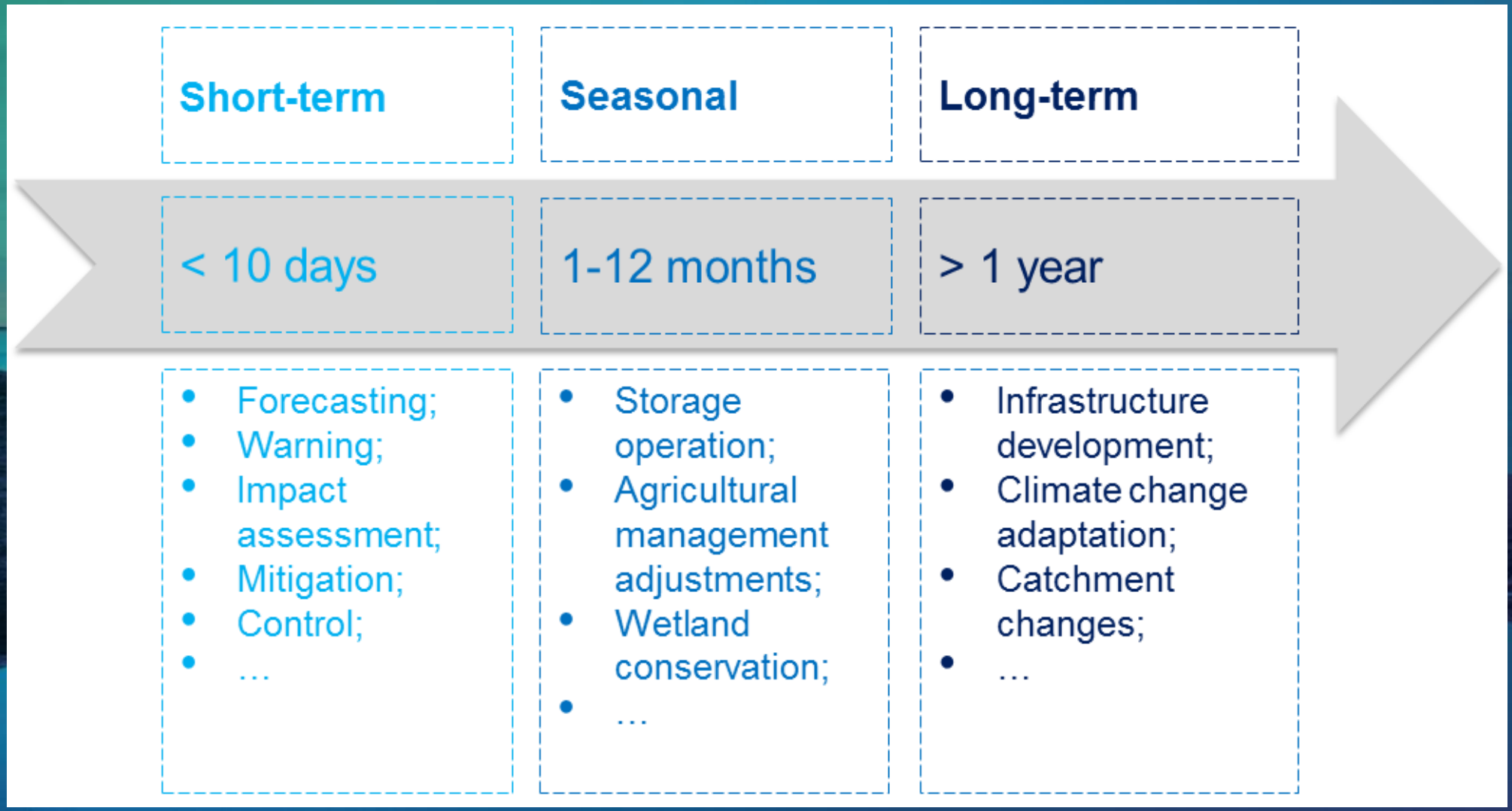
Solve the problems at the right scale

- Basin scale resources assessment, groundwater recharge
- Local feasibility considering aquifer and groundwater pumping conditions
- Well fields and waterworks operation



Scalable, flexible modeling tools well suited for resource assessment, impact assessment and scenario analysis.

What are the time scale of water management problems?



Computational Power and Capacity

Key techniques for applying advanced modeling capabilities include:

- Distributed resources: workstations and clusters
- Cloud based resources: AWS, Azure, Private Cloud
- Software as a Service (SAAS)

The availability, ease of use, and affordability present enormous untapped potential for improved capabilities in model execution.

The challenge comes in managing models, scenarios, results and presentation effectively.

Realtime and Web based Systems for Groundwater Management

IT systems (often internet or intranet) adapted to specific use, e.g. :

- Information system, displaying data, key numbers, indicators, updated status
- Planning system, resource versus water use, historical data, CC, scenarios
- Operational system, e.g. real time warning and structure control

Examples for groundwater planning and permitting

- Allerød, Denmark
- Helsingør, Denmark

Examples of Grounwater Data and Model Portal

- African Droughts and Floods Program

Example of Model Execution

- Groundwater parameter estimation and calibration

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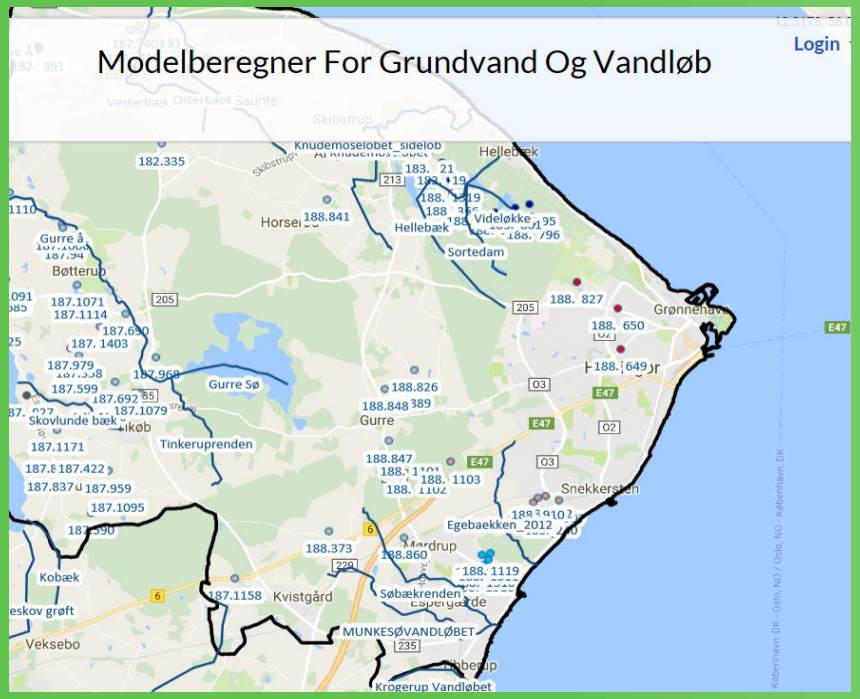


Groundwater Planning
Web Based Platform

Problems facing permitting authorities

Key tasks for local authorities

- Groundwater permit applications
- Environmental protection
- Regulations
- Develop climate adaptation plans
- Stream and river regulation
- A lot of administration and case handling

Limited in-house knowledge and budgets do not allow hiring consultants every time

Approach to groundwater permitting system

- Underlying water resources model to be used by non-model experts
- No software installation and license handling
- Results to be shared internally/externally
- To be used by authorities and stakeholders, transparency
- Results presentation adapted to specific use
- Tools integrated in permit application work flow to save time

User

municipality

water supply

authority

Show results in tables and maps

- GW drawdown
- Stream depletion impacts
- Wetland water level impacts
- Changes in well capture zones
- Water balances

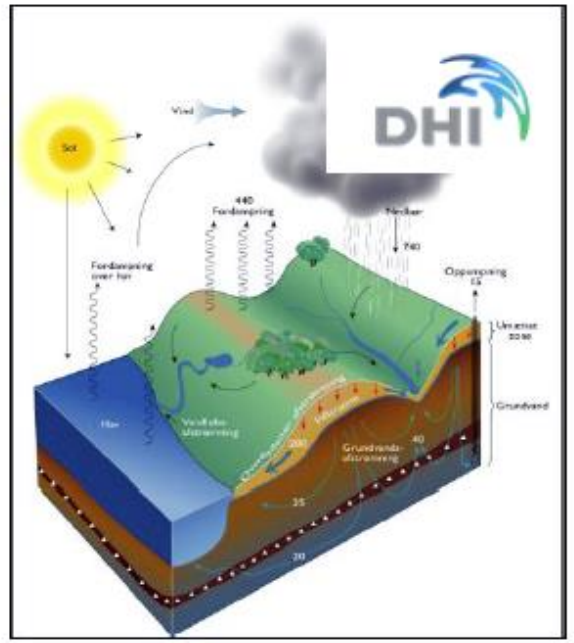
Export, Archive and Share

- Model setup and results
- Results viewing in GIS or Google Earth

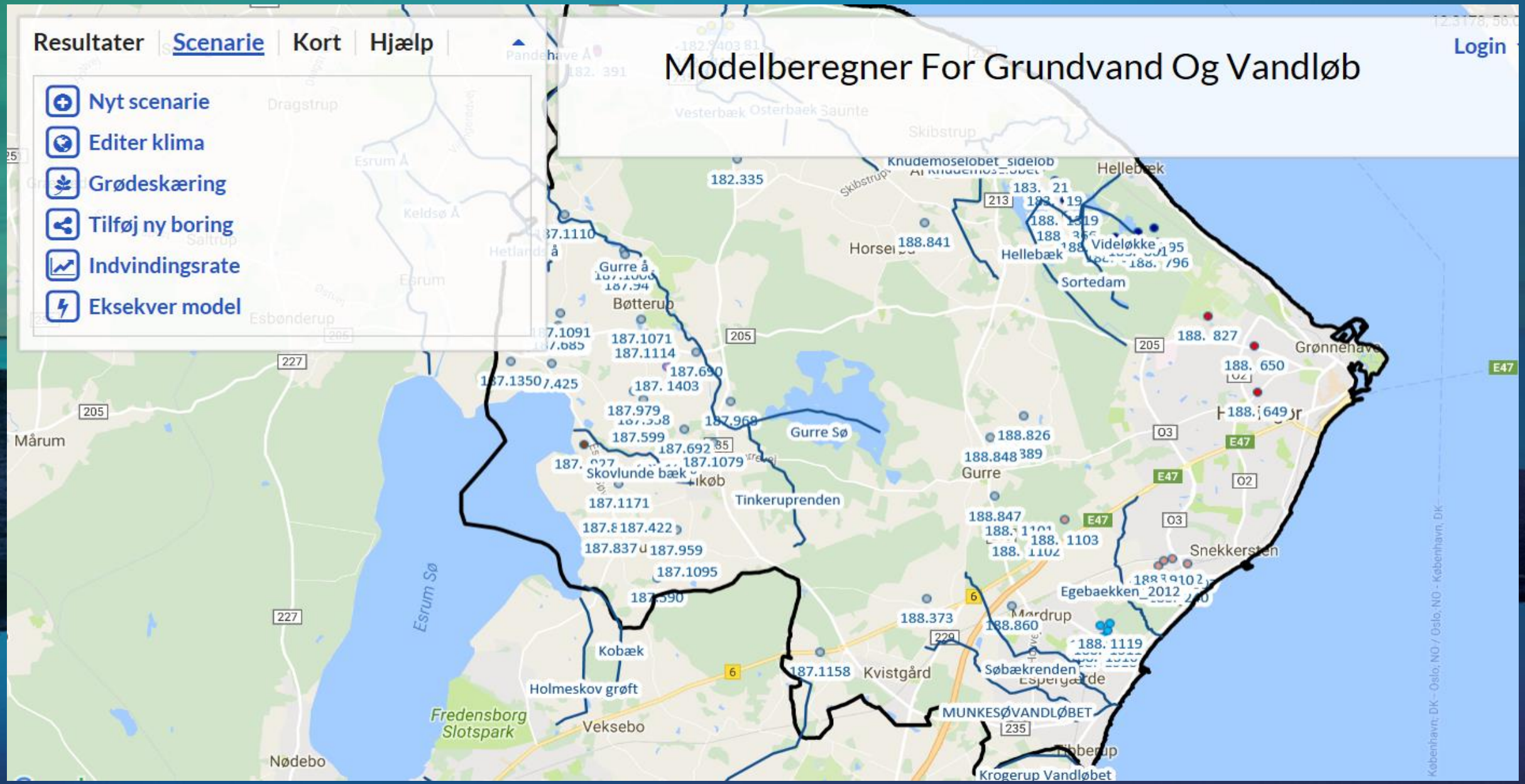
Report

- Write report, atttachment to permit application
- Summarize for periodic reporting

Server



Grounwater Management Web Interface



Results

- The system works and can be easily used (1/2 day training after installation)
- The system makes it easier to use models, adapted to limited specific applications
- The models must be maintained, software is updated on a server
- DHI continues to develop both MIKE software and system solutions to customer groups, including Danish authorities - both with and without models

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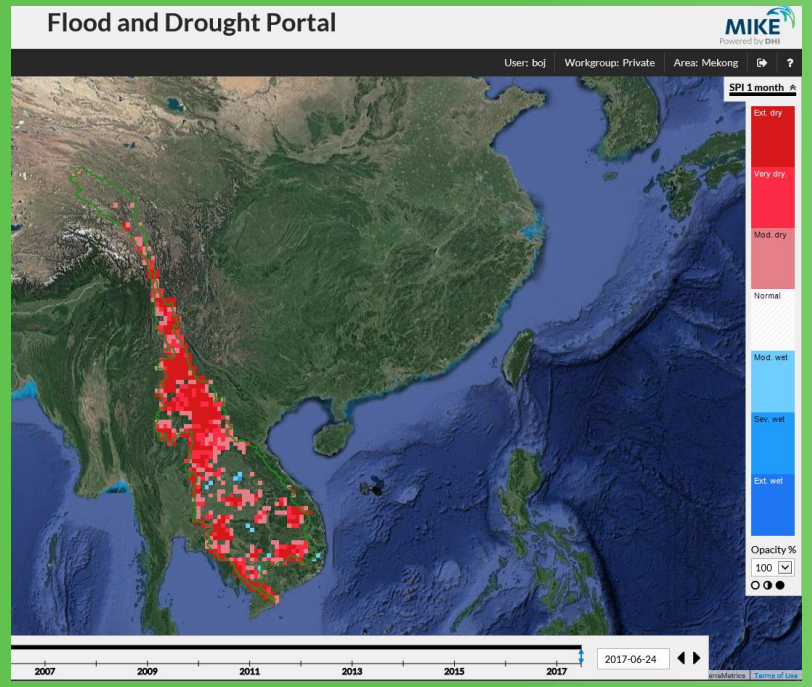
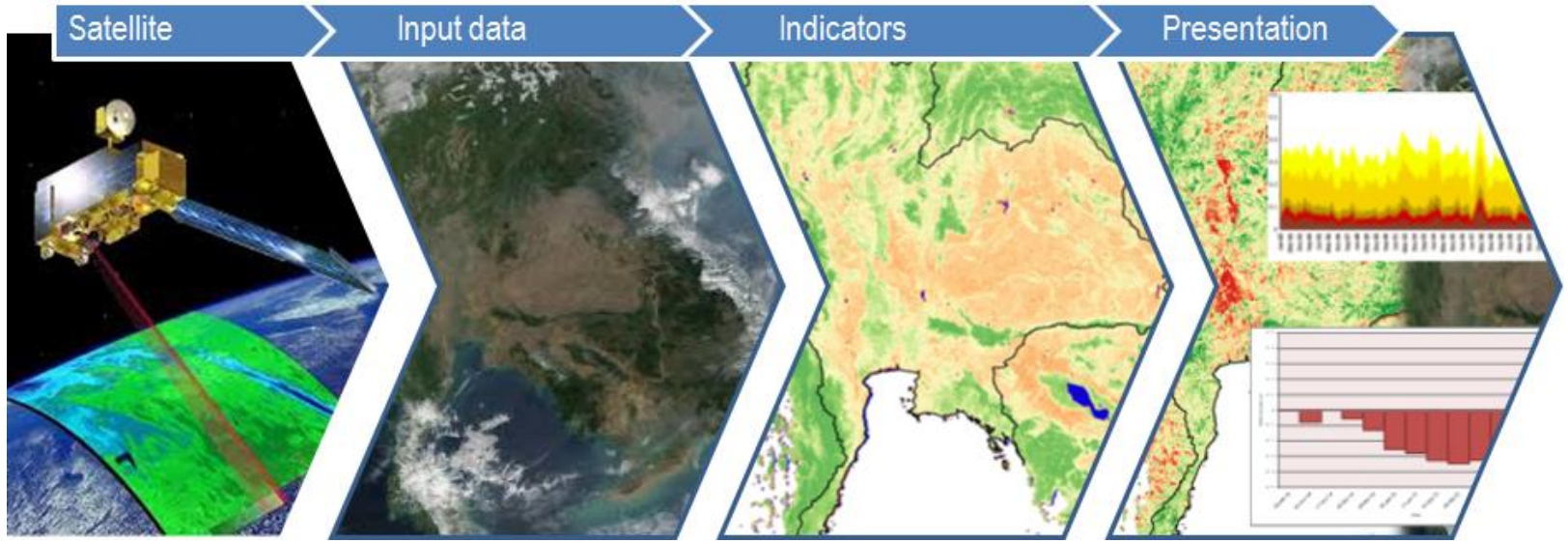


Web Portal Delivery of Models, Tools and Results

Tool example: Data portal

- Data availability is a key concern in many countries, regions and basins
- Availability of a “basic” set of data for planning is critical

Objective: data to be made assessable in near real time through a web based data portal

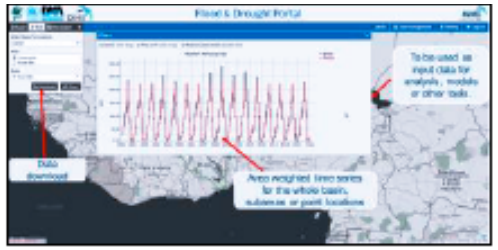


Platform Framework and Workflow

- Near real-time indicator monitoring
- Status reports

Implementation and monitoring

Baseline assessment

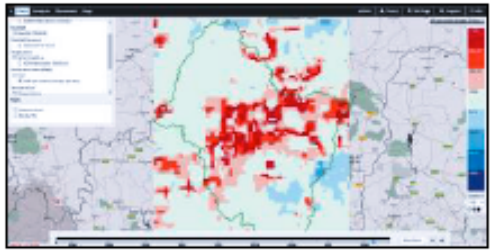


- Near real-time data
- Drought indices
- Status reports

- Automatic reports
- Operational early warning
- Dissemination

Dissemination and warnings

Impact assessment



- Drought forecast
- Drought early warning
- Link to crop and water resource models

Planning

- Investments
- Planning options
- Indicators and MCA
- Strategy

Flood and Drought Portal

Data | Analysis | Document

Select | Status | GIS layers

Rainfall
- ☐ Rainfall (TRMM)
  - ☐ Historical ensemble
  - ☐ Monthly mean
  - ☑ SPI 1 month
  - ☐ SPI 3 month
  - ☐ SPI 6 month
  - ☐ Rainfall deviation (30 days)

Vegetation
- ☐ NDVI (5600 m)
  - ☐ NDVI deviation rel. (5600 m)
  - ☐ NDVI deviation (5600 m)
  - ☐ Vegetation Condition Index (VCI)

Tool
- ☐ Time series
- ☐ Column chart
- ☐ Raster file

SPI 1 month

Ext. dry
Very dry.
Mod. dry
Normal
Mod. wet
Sev. wet
Ext. wet

Opacity %
100

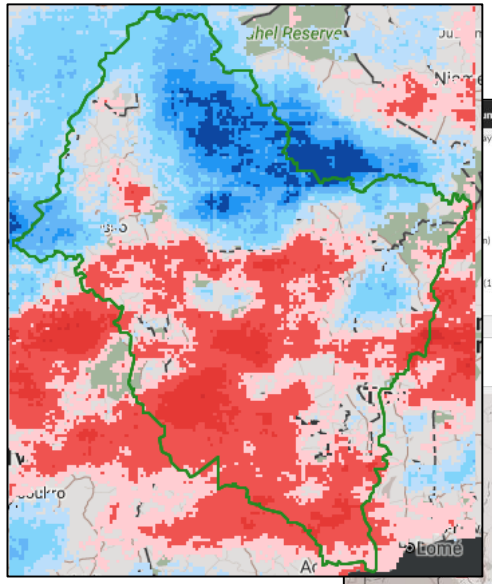
2001 2003 2005 2007 2009 2011 2013 2015 2017

2017-06-24

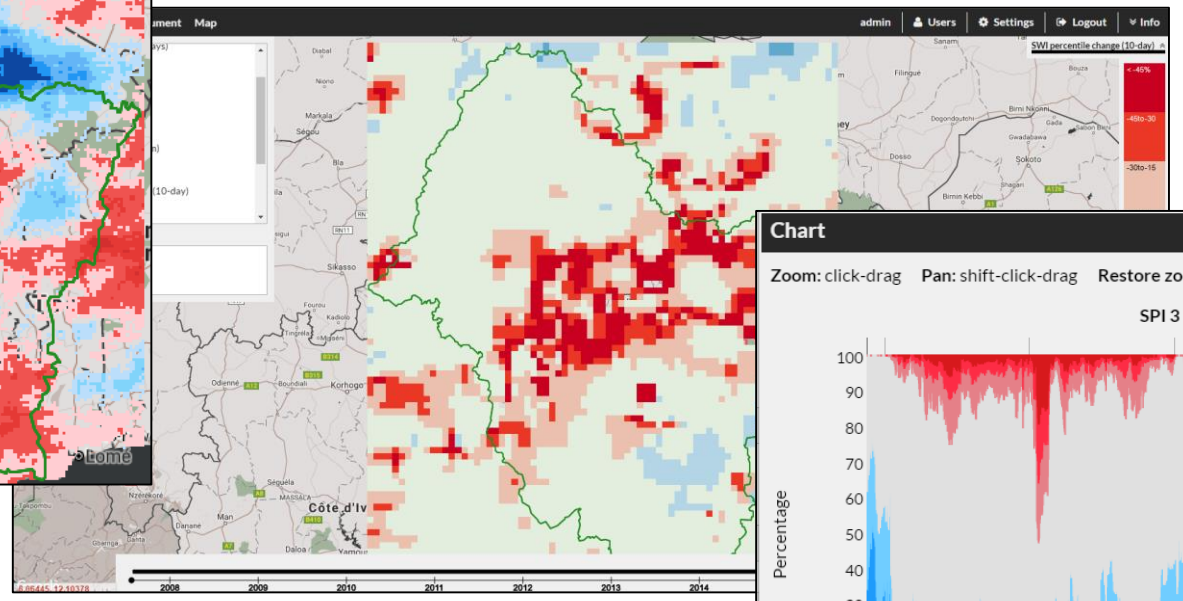
82.70508, 31.1282

Tool example: Impact assessment

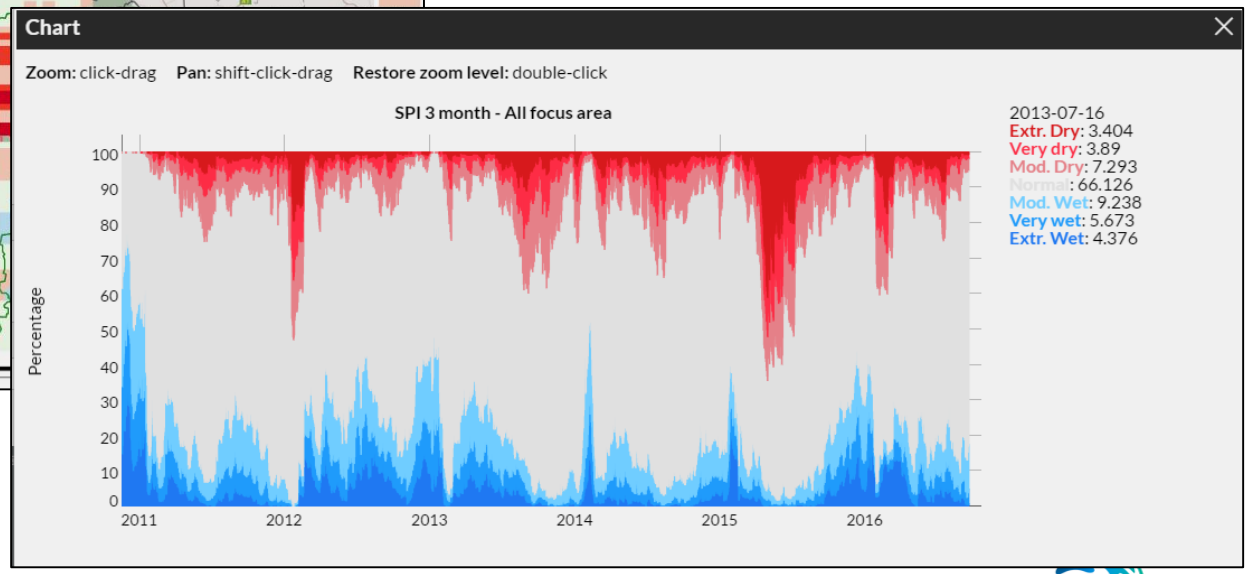
Impact assessment based on a number of climate, drought and flood related indices.



Rainfall deviation

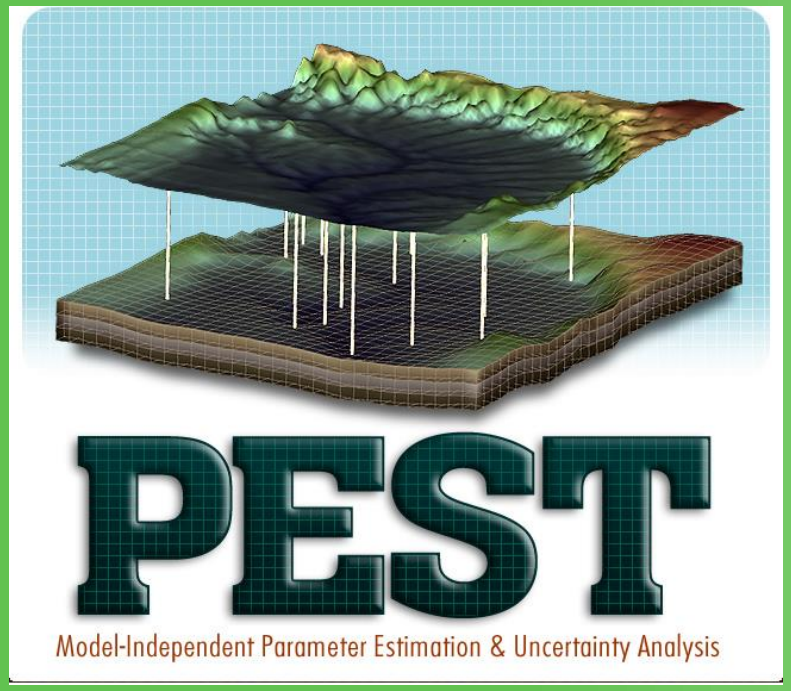


Soil moisture index



SPI

3



CALIBRATION with FE-PEST

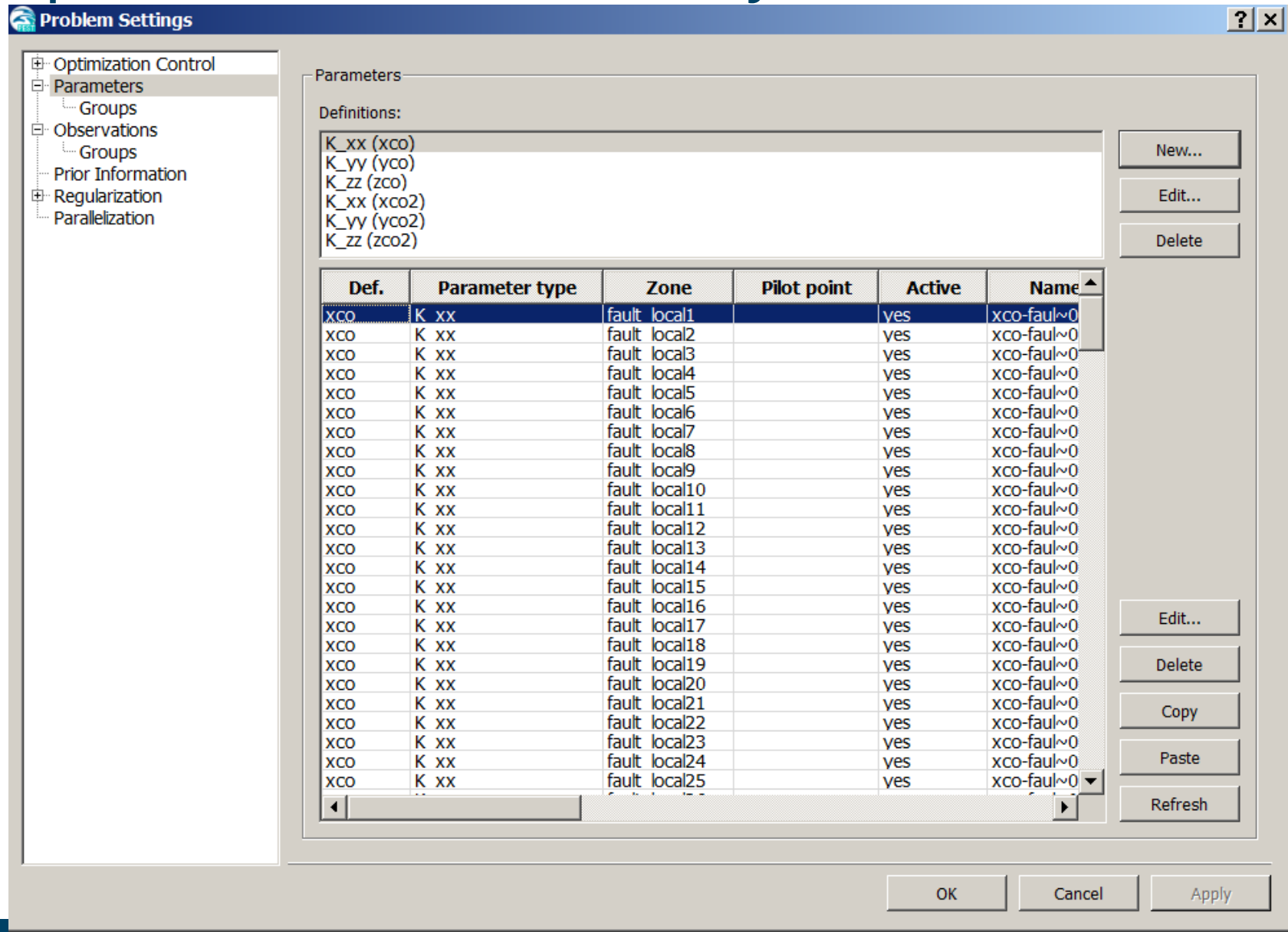
With Cloud Computing

FE-PEST allowed the calibration of model with more than 800 zones. This would be impossible if done manually

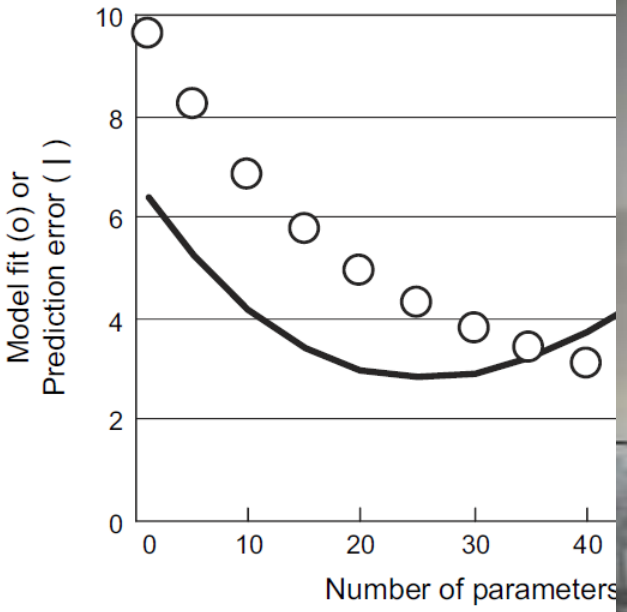
- ✓ 55 Faults
- ✓ 21 Geologic Zones
- ✓ 6 Depth Zones

- ✓ 804 parameters adjusted
- ✓ 1368 “tied” (dependent on other parameters)

The model was run through FE PEST for a total of more than 50,000 runs with the cloud



BUT: Complexity, Calibration and "Goodness" of the model



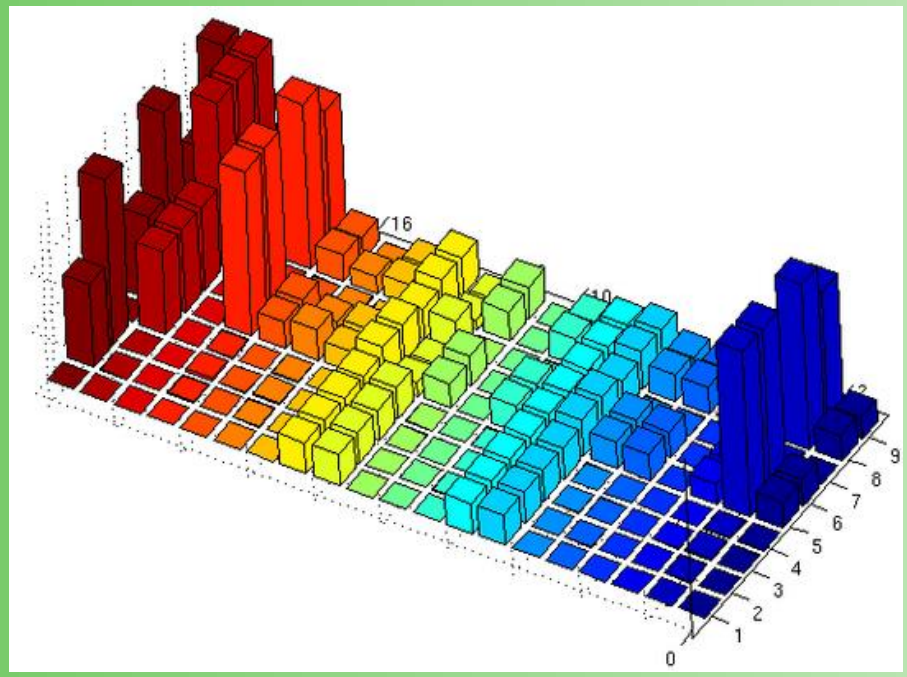
Complexity

Reliability of model

Error in Calibration

The Practical Use of Simplicity in De

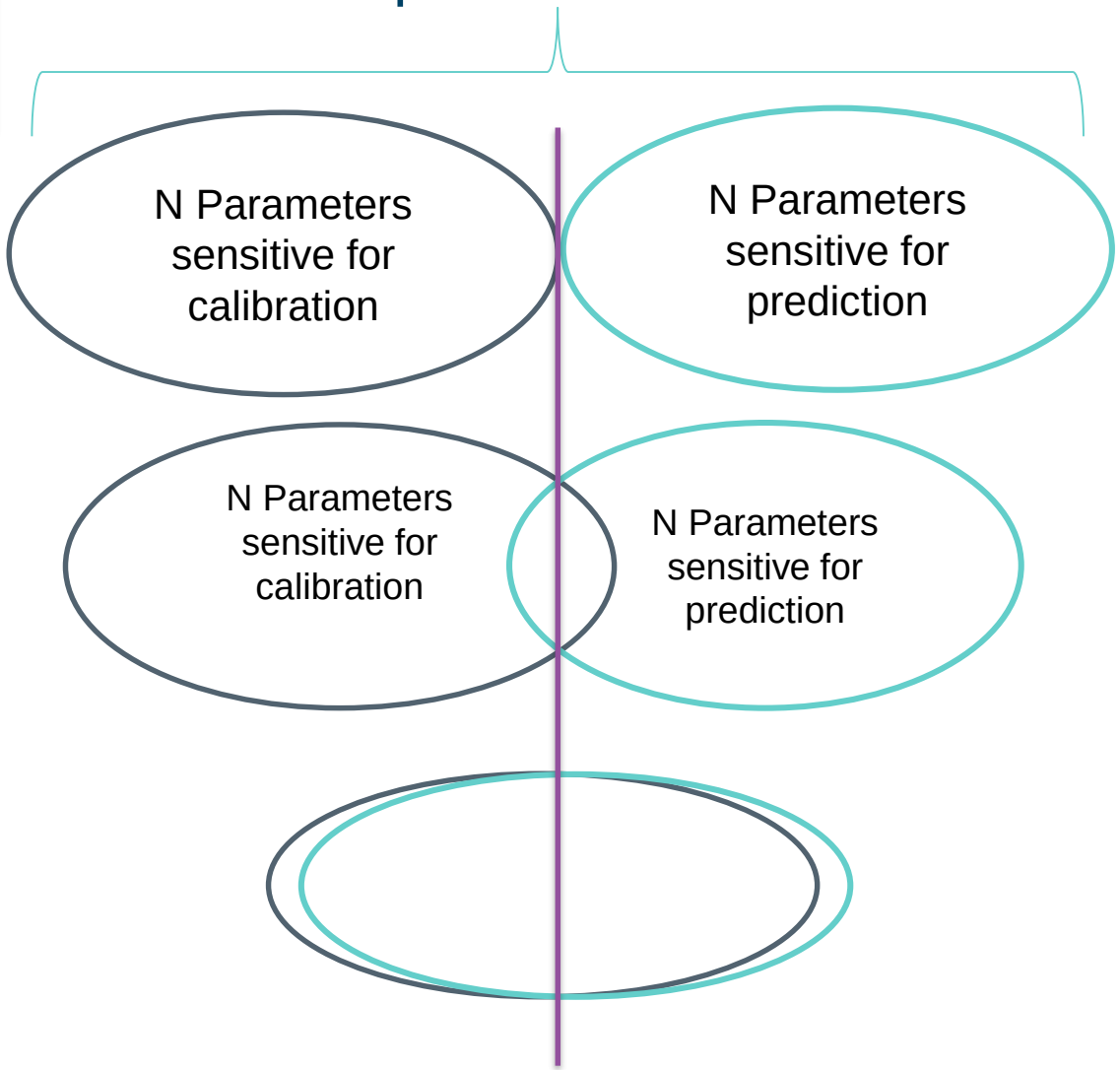
4



Sensitivity of parameters, uncertainty and optimization of the location of monitoring wells with FE-PEST

Calibration of levels

~800 zones of parameters



Predictions: Pore pressure Flows

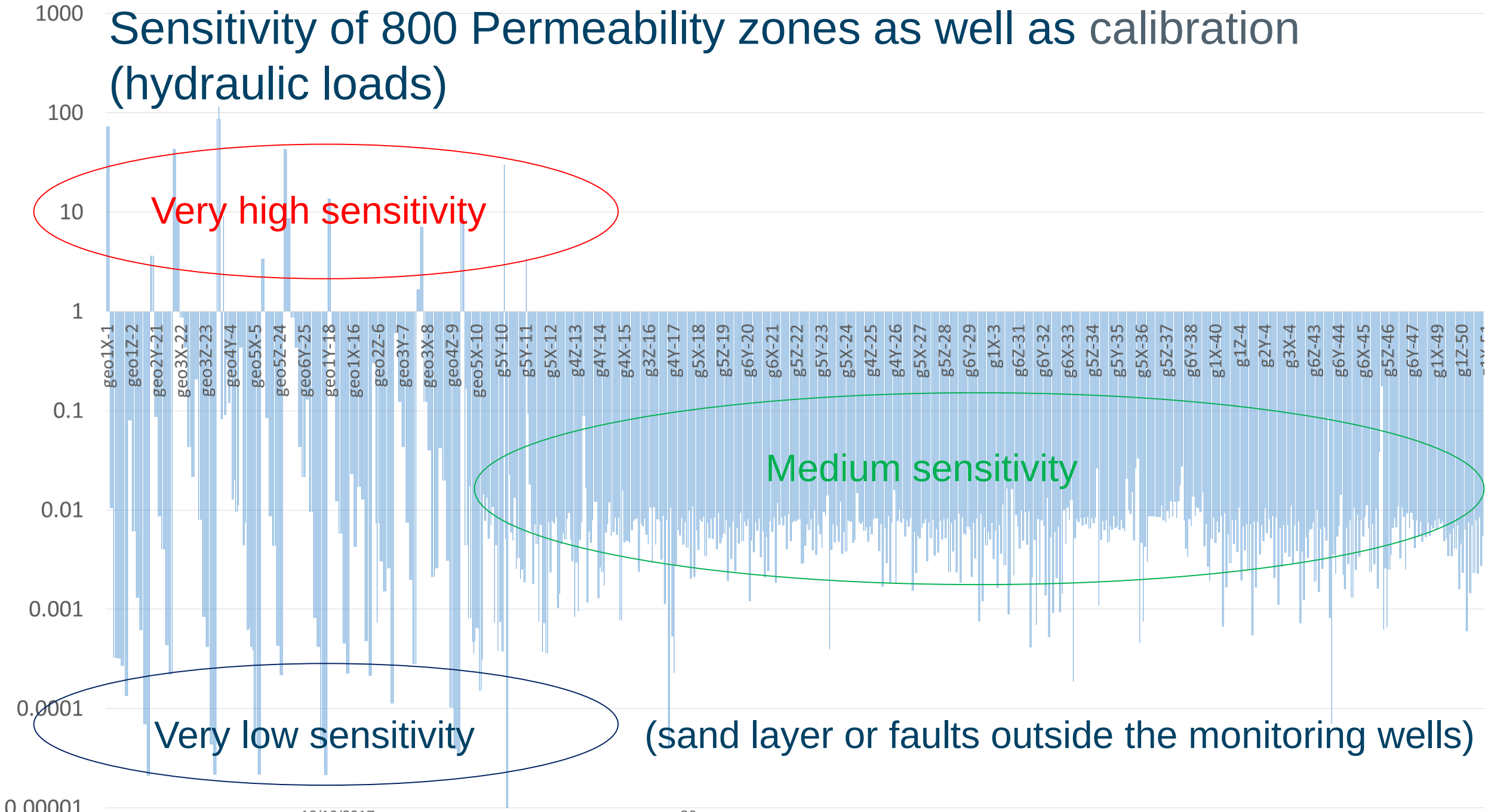
Worst case in validity of the model

Medium Case

With more data in the critical place

Best case

Sensitivity of 800 Permeability zones as well as calibration (hydraulic loads)



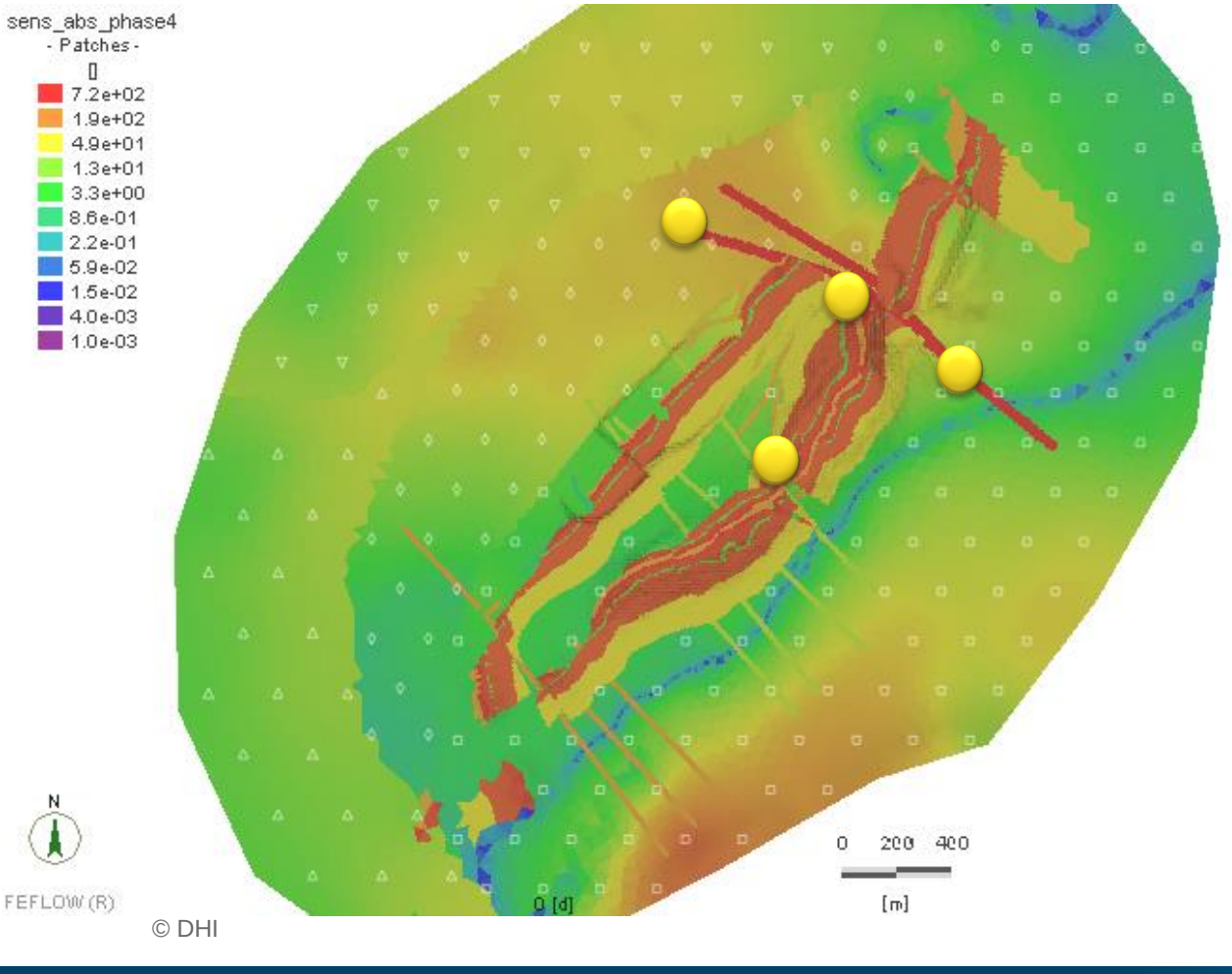
(sand layer or faults outside the monitoring wells)

Viewing the zones of high uncertainty

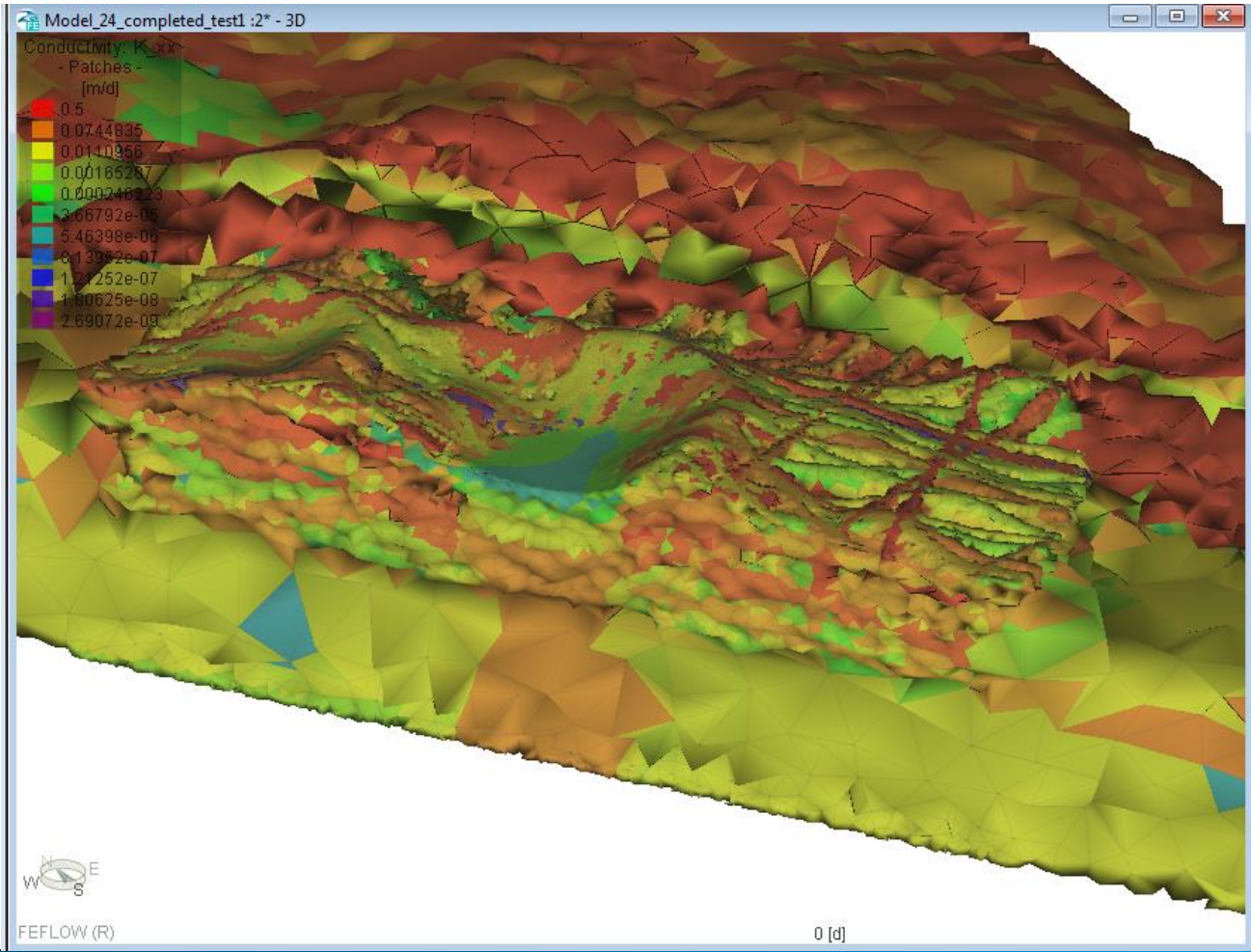
It can be seen if a zone of the model is very important for:

- Calibration
- Predictions

2D



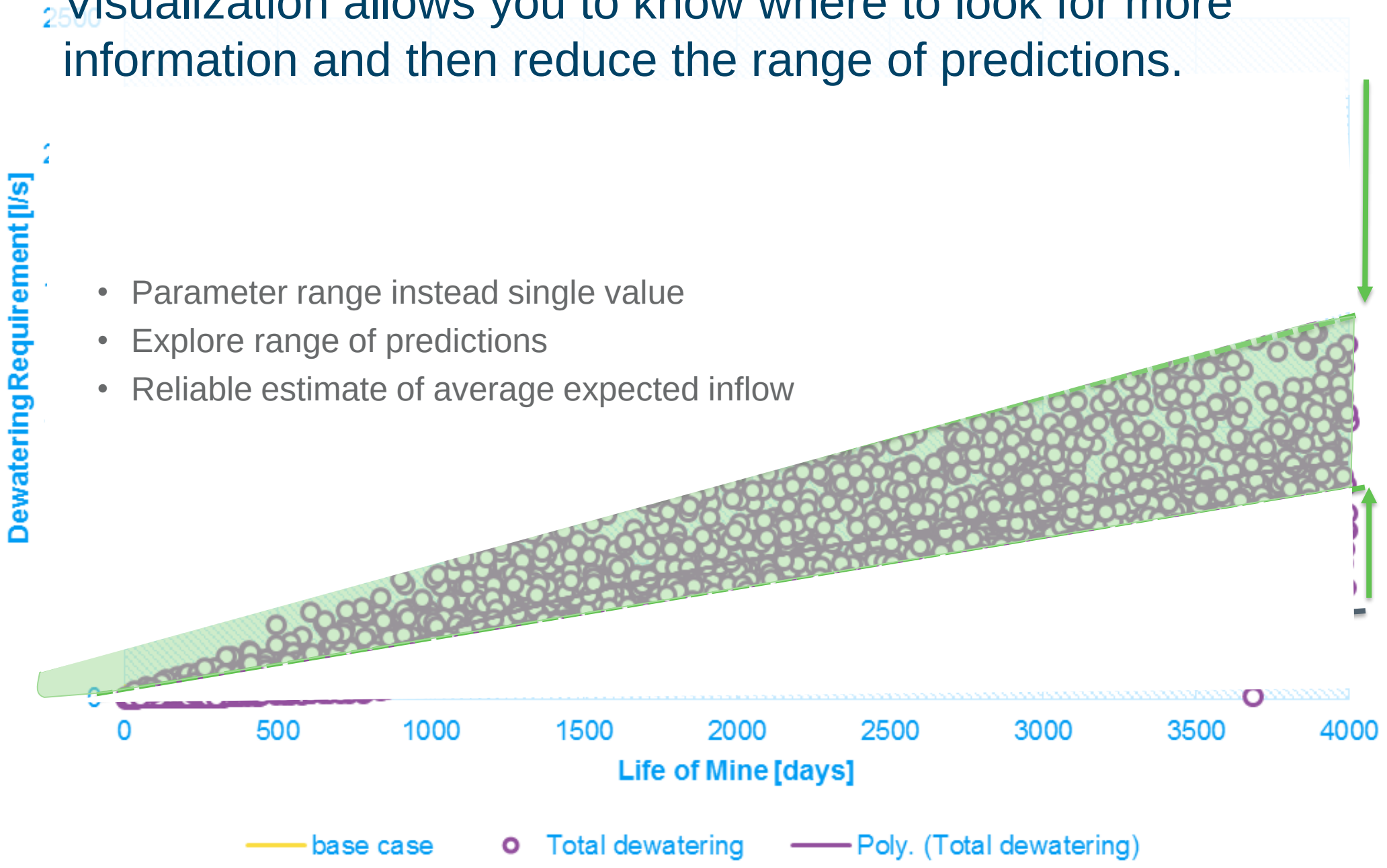
3D



Analysis of uncertainty…

Visualization allows you to know where to look for more information and then reduce the range of predictions.

- Parameter range instead single value
- Explore range of predictions
- Reliable estimate of average expected inflow



Conclusions

- Model, Data and Scenario Management tools are evolving quickly to meet current user needs
- Web based tools for expanding availability and accessibility of groundwater planning and operations
- Examples of Decision Support interfaces for sharing results and decision process
- Methods within software allow utilization of increasingly available computational resources with a variety of methods

Thank You

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Please contact us for further information