FREEWAT
Free and Open Source Software Tools for Water Resource Management
EU HORIZON 2020 Project

European Commission

ict4water.eu

Open Workshop
1st FREEWAT User and Developers International Workshop

September 21st 2017

IDAEA. CID - CSIC

16 Jordi Girona. 08034 Barcelona

Guidance on model-supported application of EU water-related Directives for water quantity and quality

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EIP Water Online Market Place
Matchmaking for water Innovation
MAR Solutions - Managed Aquifer Recharge Strategies and Actions (AG128)

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Taken from: http://travessa-pirineus.blogspot.com.es/2014/08/dia-15-de-lospitalet-al-refugi-de-juclar.html

Modelling & WFD

Do we need models? Which types of models?

- WFD (28) “Surface waters and groundwaters are in principle renewable resources; in particular, the task of ensuring good status of groundwater requires early action and stable long-term planning of protective measures…”. To develop long-term measures, models are necessary.

- Article 1 (a,b,c,d,e) framework for the protection of water, highlighting the components that need to be protected and how water quality and quantity can be improved.

Modelling & WFD

- Article 4 (b) “Member States shall implement the measures necessary to prevent or limit the input of pollutants into groundwater and to prevent the deterioration of the status of all bodies of groundwater…”, and “protect, enhance and restore all bodies of groundwater, ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status at the latest 15 years after the date of entry into force of the Directive…”

- Article 5: for each river basin “an analysis of its characteristics, a review of the impact of human activity on the status of surface waters and groundwaters; and an economic analysis of water use”

- Article 8: requirement for monitoring both the chemical and quantitative status of groundwaters

Existing guidelines

Many guidelines for the use and development of models already exist. From Refsgaard et al. (2005):

- The Dutch guidelines (Van Waveren et al., 2000; Scholten and Groot, 2002)
- Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra (Barnett et al, 2012)
- Danish groundwater modelling guidelines (Henriksen, 2002b)
- UK Standards (Packman, 2002)
- California Department of Water Resources, Modelling BMP, December 2016
- Anderson et al., 2015, Applied Groundwater Modelling

How can models help?

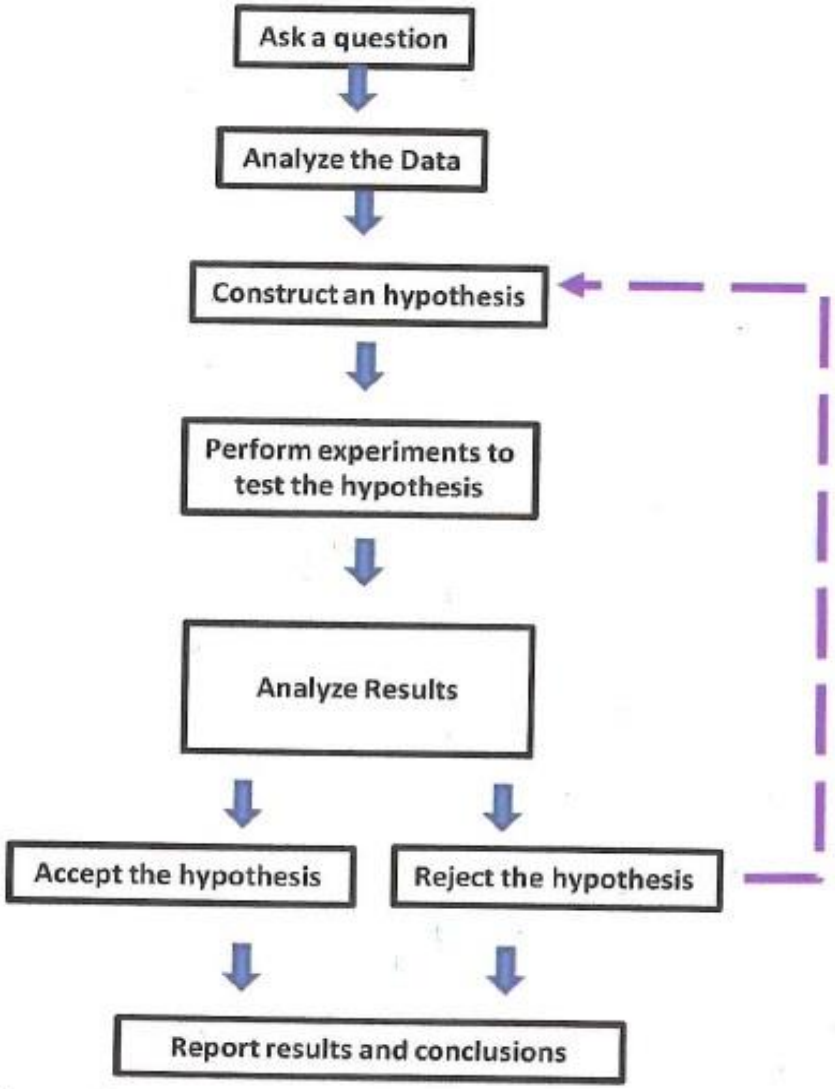
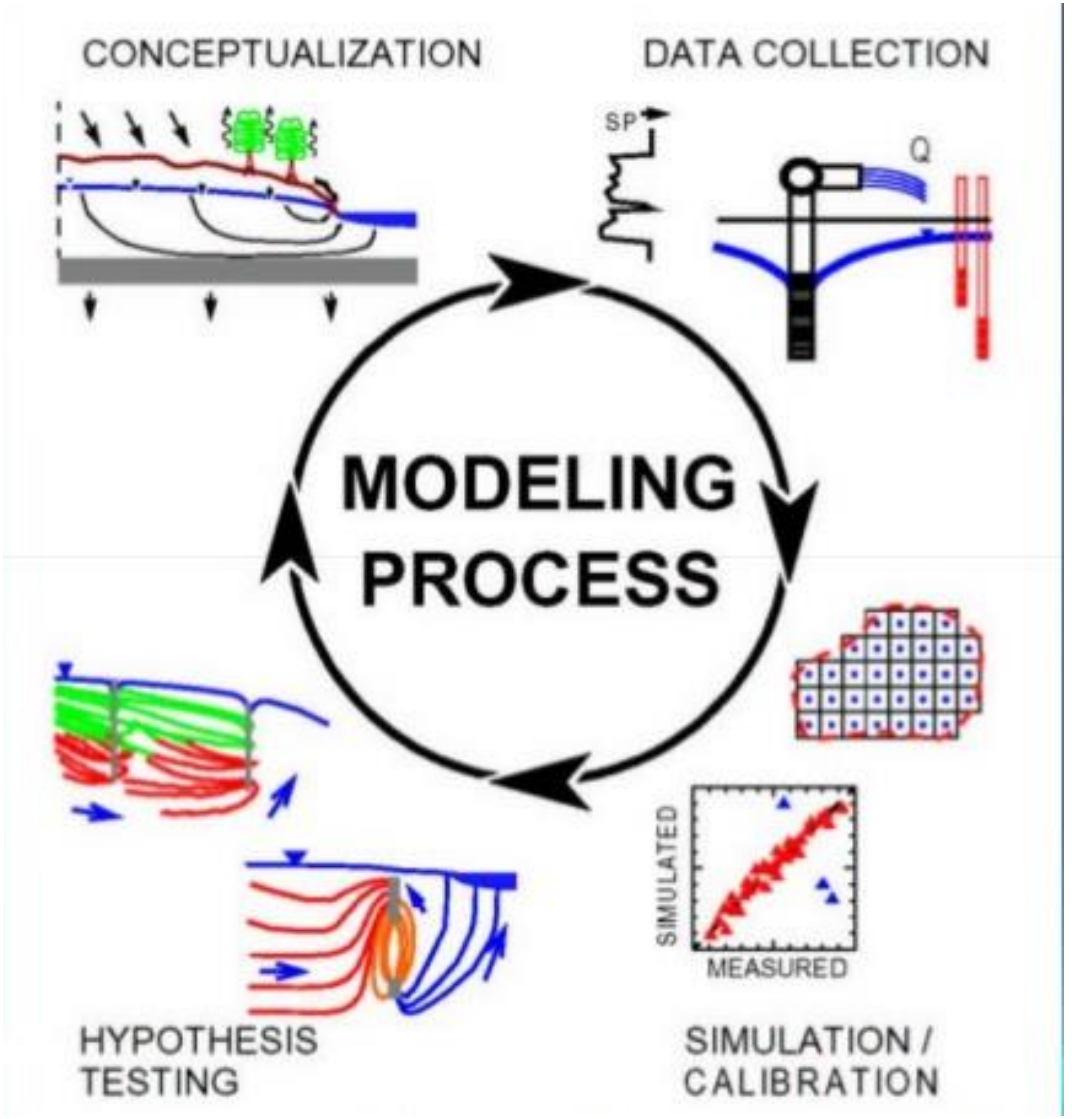


Figure 1.2 The scientific method *(modified from: http://www.sciencebuddies.org/science-fair-projects/project_scientific_method.shtml).*

Anderson et al., 2015

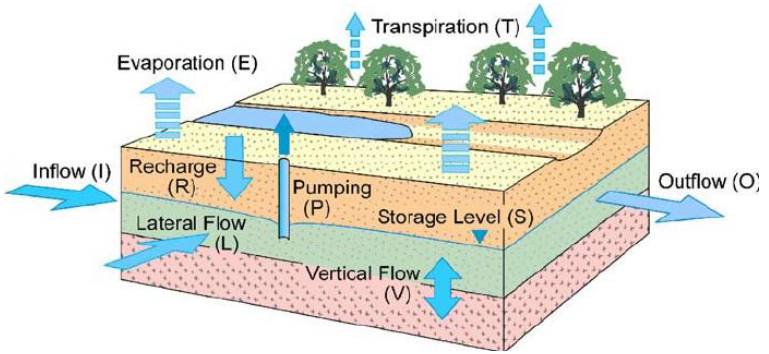
The modelling process

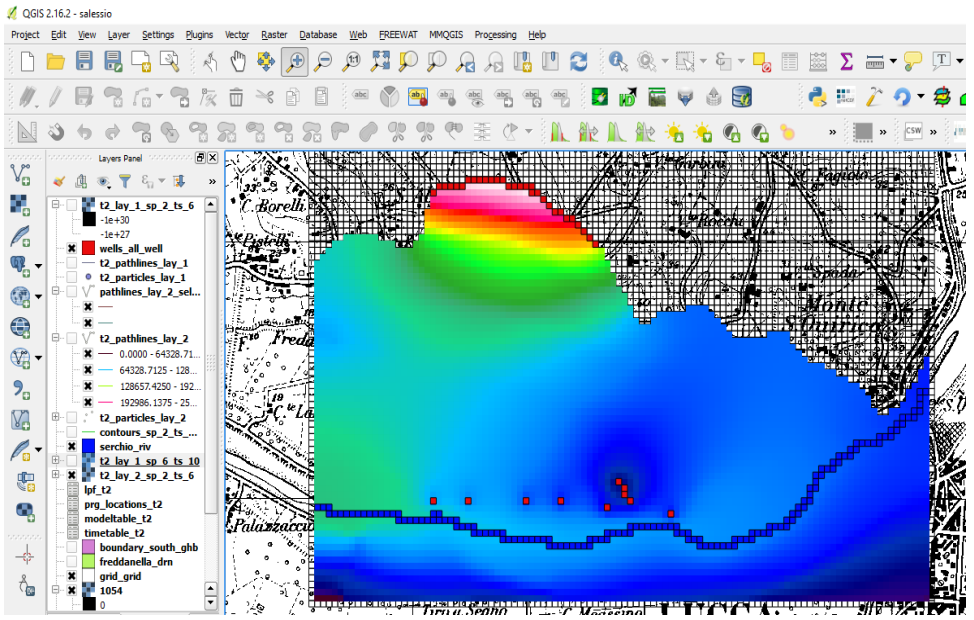


Types of models

1. Conceptual models

2. Mathematical models
   - Analytical models
   - Numerical models
     - ➢ Groundwater flow models
     - ➢ Integrated SW/GW models
     - ➢ Transport models
     - ➢ Inverse models
     - ➢ …





Types of modelling software

1. Model code solves the equations for groundwater flow and/or solute transport, sometimes called simulation software or the computational engine
2. A graphical user interface (GUI) that facilitates preparation of data files for the model code, runs the model code and allows visualization and analysis of results
3. Software for processing spatial data, such as a geographic information system (GIS), and software for representing hydrogeological conceptual models
4. Software for model calibration, sensitivity analysis and uncertainty analysis
5. Programming and scripting software that allows additional calculations to be performed outside of or in parallel with any of the above types of software
6. Model codes to solve problems related to gw flow and/or transport, (Farm, plant-water interactions, unsaturated zone flow and transport processes, stream flow processes, surface water - groundwater interactions, land subsidence, watershed processes, climate, geochemical reactions, economic water management optimization, or parameter calibration)

FREEWAT

1. Model cod d/or solute transport, omputational engine
2. A graphical n of data files for model cod l analysis of results
3. Software fo ware for representi
4. Software fo certainty analysis
5. Programmi tions
6. Model cod ort, (Farm, plant-water inter stream flow, sw/gw interaction te, geochemical reactions, parameter calibration

Common model uses

General uses (modified from Barnett and others, 2012)

- Improving hydrogeological understanding (synthesis of data).
- Aquifer simulation (evaluation of aquifer behavior).
- Calculating and verifying water budget components, such as recharge, discharge, change in storage and the interaction between surface water and groundwater systems (water resources assessment).
- Predicting impacts of alternative hydrological or development scenarios (to assist decision-making).
- Managing resources (assessment of alternative policies).
- Sensitivity and uncertainty analysis (to guide data collection and risk-based decision-making).
- Visualization (to communicate aquifer behavior).
- Providing a repository for information and data that influence groundwater conditions.

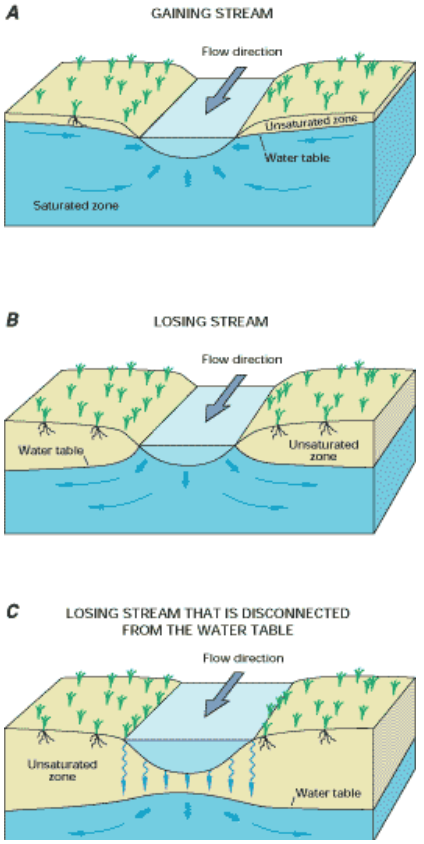
Regarding WFD, how do models help?

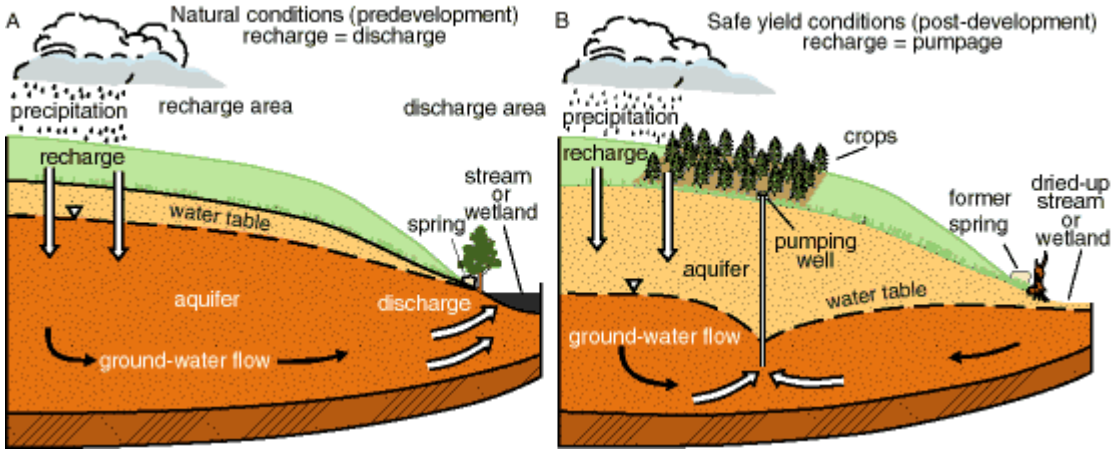
WFD Article 1, models should be used as tools by scientist and water managers to understand how to:

1. Prevent further deterioration and protect and enhance the status of the aquatic ecosystem.
2. Promote Sustainable water use based on a long-term protection of available resources
3. Aim at enhanced protection and improvement of the aquatic environment
4. Ensure the progressive reduction of pollution of groundwater and prevents its further pollution
5. Contribute to mitigate the effects of floods and droughts

Prevent further deterioration

1. Understanding actual status of existing water body
2. Use historical data for preliminary evaluation of the quality and quantity status
3. What is at risk?
   - Chronicle lowering of groundwater heads
   - Impacts on interconnected groundwater/surface waters
   - Impact on groundwater storage

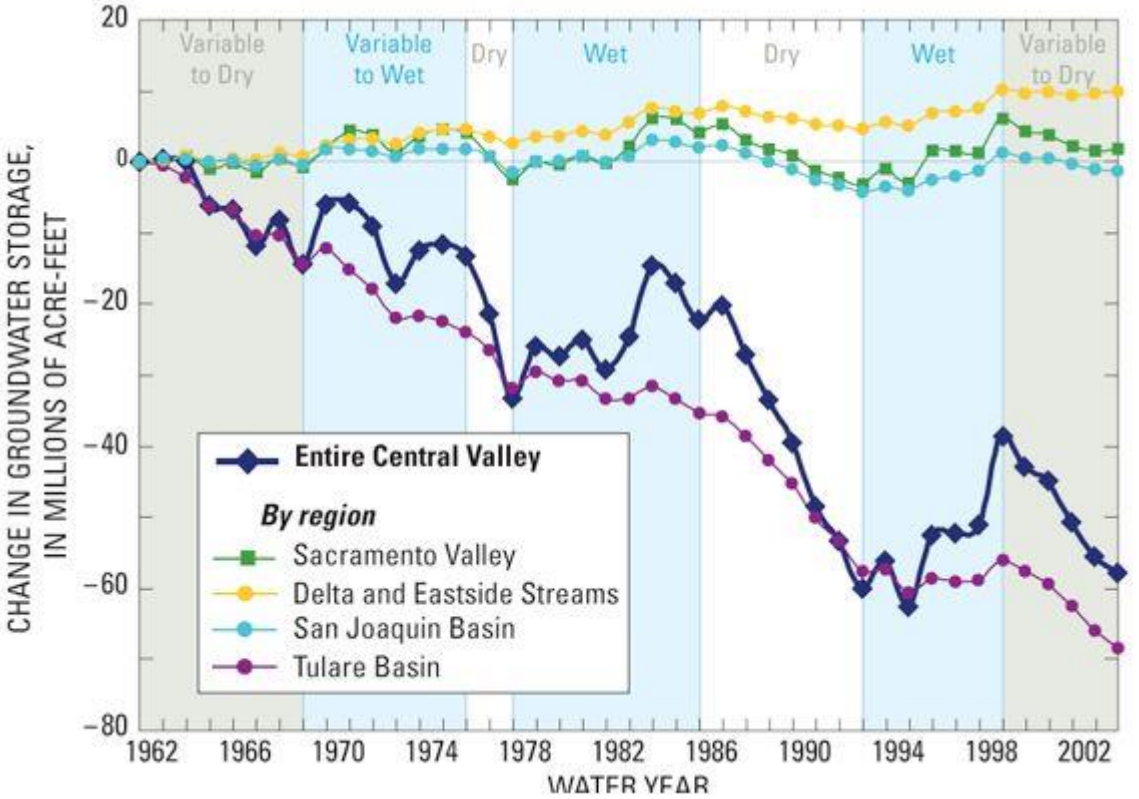




Long-term protection

1. Need models to simulate future scenarios
2. Use models to design new data collection
3. Inverse modelling can provide further insights

Groundwater concerns…



Modelling Procedure

Phase 1

Collect all existing data
Develop conceptual models
Estimate water budgets

Phase 2

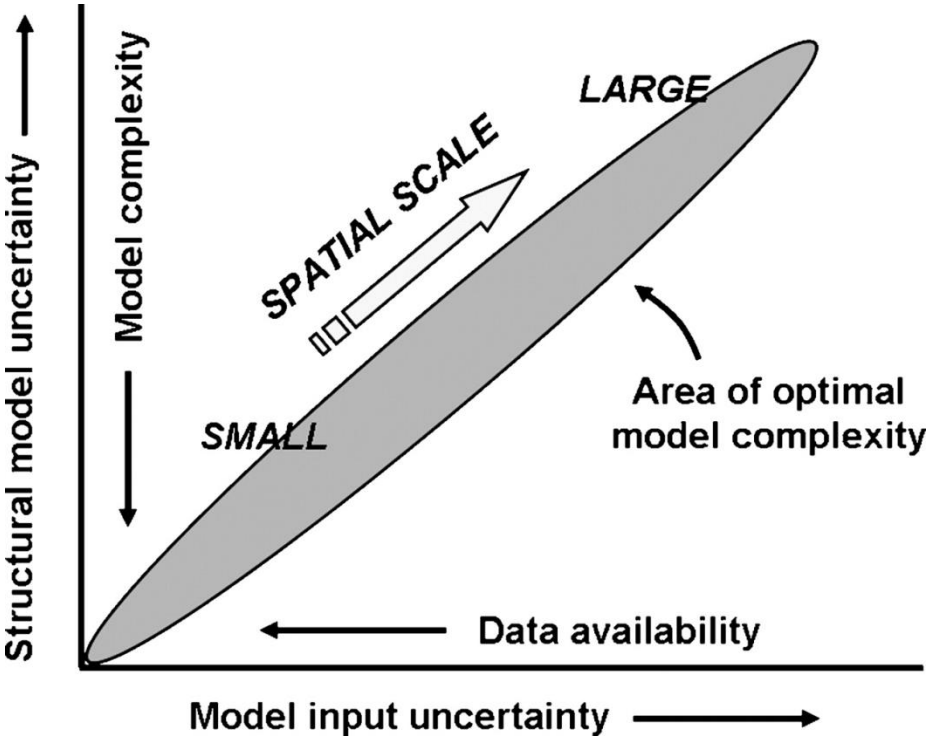
Develop numerical model
Use sensitivity analysis and calibration to evaluate the model and suggest new data to be collected
Develop future scenarios
Produce modelling reports!

The system should be in compliance with the WFD compliances require in Article 1

How complex should the model be?

Judgement of the modellers!
Some typical questions to start with…

1) What is the purpose of the model (fate transport models may require more details than models for groundwater/surface water interactions)?
2) Is steady state enough?
3) What complexity is supported by the data I have?



Schoups and Hopmans, 2006

Summary of the modelling project

1. Model documentation
2. Model working files: working copy of the complete modeling platform (for example native MODFLOW input files, output files, and executables) → any stakeholder can run the model, create and verify results, view input and output files, or perform any other evaluation and verification.
3. Model description: description of the model objective, of the available data, conceptual model, model development, assumptions, data inputs, boundary conditions, calibration, uncertainty analysis, and other applicable model application elements. Identify and explain uncertainties.

Model description

1. model objective
2. available data
3. conceptual model
4. model development& assumptions
5. data inputs& boundary conditions
6. calibration, sensitivity & uncertainty analysis

→ Need to demonstrate that model results are reasonable and within range of identified uncertainties.

Modelling procedure

1. Establish the model's purpose and objectives.
2. Collect and organize hydrogeologic data
3. Develop a conceptual model of the basin
4. Select the appropriate model code or existing model
5. Design and construct (or revise) the model
6. Develop sensitivity analysis and calibrate the numerical model to historical data
7. Develop and run predictive scenarios
8. Conduct uncertainty analysis of scenarios
9. Revise and refine model regularly during implementation
10. External review

Which data should be collected? Part 1

Strong stakeholders involvement!

1. Regional and local data from literature, technical reports, local authorities, etc.
2. Topographic data
3. Meteorological data (at least precipitation) in stations inside or nearby the basin
4. Land use definition and soil cover for ET and for estimates of infiltration coefficient
5. Areal extension and water depths of water bodies, preferably with seasonal variations
6. Estimates of river, stream and lake beds characteristics (materials, thickness, hydraulic conductivity).
7. Measures of streams discharge at basins and sub-basins closing sections (at least one measure for each season) if possible in different season (also dry season)
8. Well position, construction diagrams and stratigraphic logs
9. Geologic cross sections from borings and well logs
10. Definition of number of aquifers which play an important role according to the study objectives

Which data should be collected? Part 2

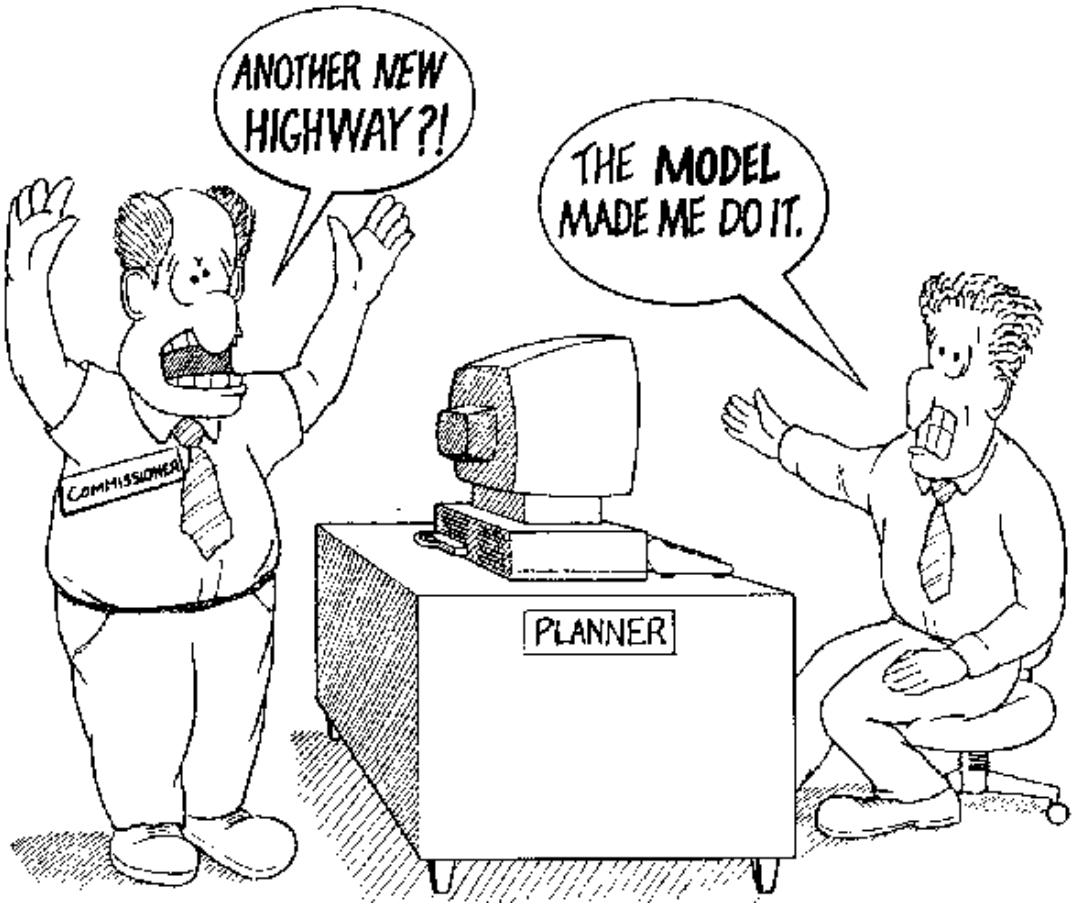
11. Measures of hydraulic heads taken at a frequency coherent with the scopes of the model (e.g. on a monthly basis for basin management)
12. Well temperature and EC logs
13. Aquifer tests with observation wells, Lugeon test, step-drawdown test and more
14. If more than one aquifer is present, definition of the overlapping aquifer interactions through specific aquifer tests for vertical hydraulic conductivity estimate
15. Location and estimate of flow rate of groundwater springs and/or sinks
16. Routine chemical analyses plus possible natural tracers that might be present
17. Isotopic analyses of stable isotopes for estimate of recharge elevation, especially if more than one aquifer is present.
18. More???

Model results presentation

- Description of the purpose and scope of the model application
- Hydrogeologic data used to characterize the project
- Documentation of source of data in the model (from published sources or measured or calculated from field or laboratory tests)
- Model conceptualization
- Model applicability and limitations
- Model approach
- Documentation of all calculations
- Summary of all calibration, history matching and sensitivity analysis results
- All model predictive simulation results as a range of probable results given the range of uncertainty in values of parameters.

Model results presentation

→ **Assumptions need to be very clear to stakeholders!!!**



Model results presentation

- Comments?
- Suggestions based on your application of FREEWAT?
- Lessons from the focus groups?

THANK YOU!!!

For the input on this and MOSTLY for this entire journey!

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And a special one!