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**TECHNISCHE  
UNIVERSITÄT  
DRESDEN**

# Numerical flow and transport modeling using the INOWAS platform

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## Tutorial 2: Transient groundwater flow model and scenario analysis



MAR Junior Research Group

# Introduction

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This tutorial gives an overview of the “Numerical groundwater modelling and optimization” tool of the INOWAS platform and guides users to create a simple **transient groundwater flow model**. Furthermore, a **scenario analysis** presenting tool “MODFLOW model scenario manager” will be conducted. More information about the tools can be found on the respective documentation pages:

<https://inowas.com/tools/t03-modflow-model-setup-and-editor/>

<https://inowas.com/tools/t07-application-specific-scenarios-analyzer/>

A prerequisite to start Tutorial 2 is that you have finished Tutorial 1 on the INOWAS platform. The tutorial takes about 45 min to complete.

# Background

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This spatial discretization is the same as for Tutorial 1. However, the model has 3 stress periods (one steady state and two transient periods). The aquifer is unconfined in this case. As boundaries two GHBs (General Head Boundaries) are defined on each side. In the center of the study area, there is a pumping well which only pumps water in the third stress period:

Period 1 (1 day):

- steady state with left and right GHB stage = 60 m

Period 2 (100 days):

- left GHB with stage = 60 m, right GHB with stage set to 50 m.

Period 3 (100 days):

- pumping well at model centre with rate =  $-100 \text{ m}^3/\text{d}$
- left GHB with stage = 60 m, right GHB with stage set to 50 m.

# Create new model /clone tutorial 1


As the model in Tutorial 2 has the same discretization as the model in Tutorial 1, the model can be cloned. For cloning, go to the dashboard, click on tool “T03: Numerical groundwater modeling and optimization” and search for your model from Tutorial 1. If you cannot find it, you can also clone “Tutorial 1” which was created by inowas.

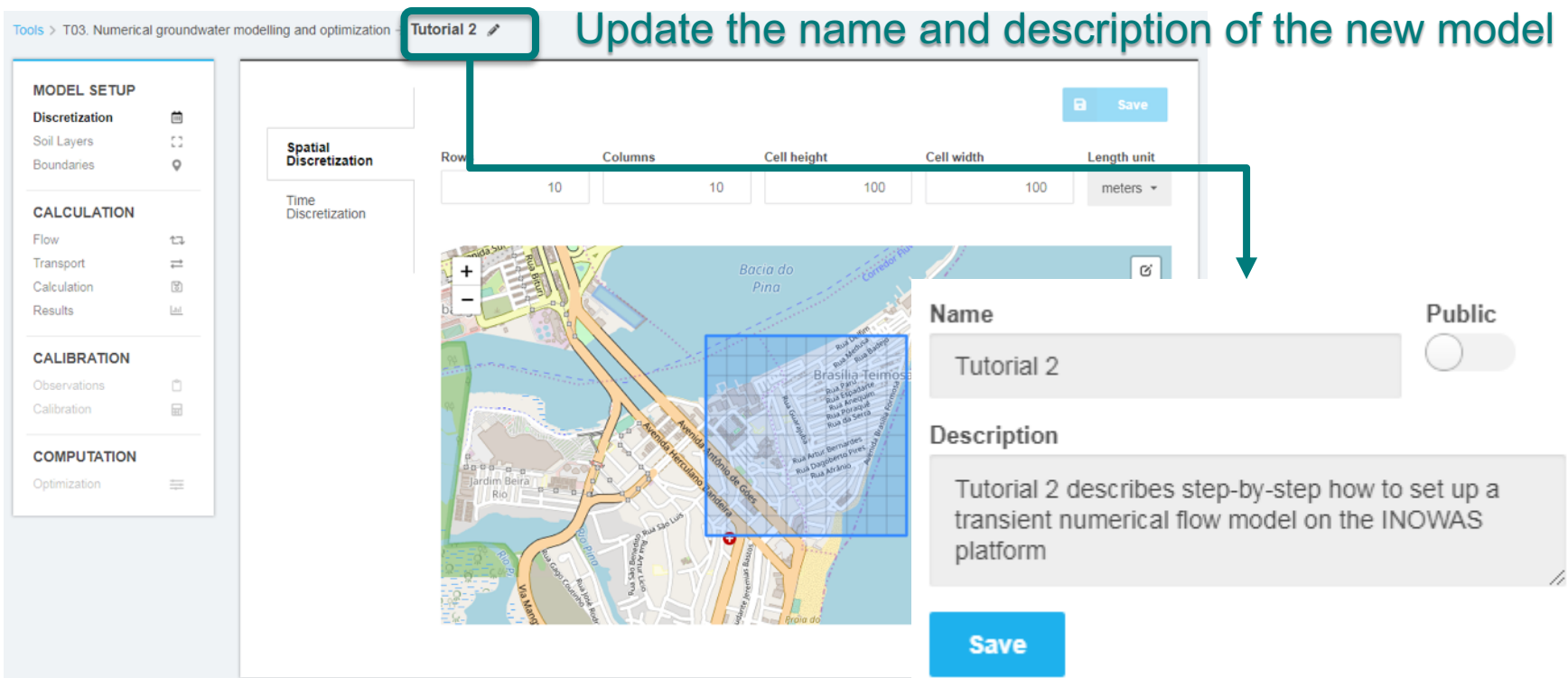
The screenshot displays the software interface. On the left, a sidebar lists various tools, with 'T03: Numerical groundwater modelling and optimization' selected. On the right, the 'Instances of T03: Numerical groundwater modelling and optimization' page is shown. It features a table with columns for 'No.', 'Name', 'Tool', 'Date created', and 'Created by'. Two instances are listed: 'Tutorial 1 Model Area' and 'Tutorial 1'. A red box highlights the 'Clone' button in the actions column for the 'Tutorial 1' instance.

No.	Name	Tool	Date created	Created by	Actions
1	Tutorial 1 Model Area	T03	04/10/2019 11:34	jana.glass	Clone
2	Tutorial 1	T03	04/10/2019 11:47	jana.glass	Clone

# Update name and description

You should now have two models with the same name in your **private dashboard**. Click on the model title to start editing. As a first step, update the general information of the new model. It is also possible to switch between private and public.

Tools > T03. Numerical groundwater modelling and optimization - Tutorial 2  Update the name and description of the new model



**MODEL SETUP**

- Discretization
- Soil Layers
- Boundaries

**CALCULATION**

- Flow
- Transport
- Calculation
- Results

**CALIBRATION**

- Observations
- Calibration

**COMPUTATION**

- Optimization

**Spatial Discretization**

Row	Columns	Cell height	Cell width	Length unit
10	10	100	100	meters

**Name**  Public

Tutorial 2

**Description**

Tutorial 2 describes step-by-step how to set up a transient numerical flow model on the INOWAS platform

Save

# Time discretization

The spatial discretization is kept the same as in Tutorial 1. The time discretization needs to be changed: create two new stress periods with starting date 02.01.2015 and 10.04.2015, respectively. The end date should be set to 20.07.2015, the total simulation time is 201 days.

Tools > T03. Numerical groundwater modelling and optimization → Tutorial 2

### MODEL SETUP

Discretization

Soil Layers

Boundaries

### CALCULATION

Flow

Transport

Calculation

Results

### CALIBRATION

Observations

Calibration

### COMPUTATION

Optimization

## Don't forget to save the changes!

Spatial Discretization

**Time Discretization**

Start Date: 01.01.2015

End Date: 20.07.2015

Time unit: days

Total time: 201 days

Start Date	nstp	tsmult	steady	
01.01.2015	1	1	<input checked="" type="checkbox"/>	
02.01.2015	1	1	<input type="checkbox"/>	
10.04.2015	1	1	<input type="checkbox"/>	

1 Day 1 Month 1 Year

Click on one of the buttons to add new stress period

3 stress periods:

1. Steady state (1 day)
2. Transient (100 days)
3. Transient (100 days)

# Update soil properties

The layer type needs to be changed to convertible. The following soil parameters also need to be changed:

- Top of model layer: **top: 60**
- Horizontal hydraulic conductivity **Hk: 1**
- Vertical hydraulic conductivity **Vka: 1**
- Specific storage **Ss: 0.0001**
- Specific yield **Sy: 0.1**

**Don't forget to save the changes!**

The screenshot shows a software interface for managing soil layers. On the left is a sidebar with navigation options: MODEL SETUP (Discretization, Soil Layers, Boundaries), CALCULATION (Flow, Transport, Calculation, Results), CALIBRATION (Observations, Calibration), and COMPUTATION (Optimization). The main panel is titled 'Add Layer' and shows a table of properties for '0: Top layer'. The 'Layer type' dropdown menu is highlighted with a red box and set to 'convertible'. Other dropdowns include 'Layer average calculation' (harmonic mean) and 'Rewetting capability' (No). A 'Save' button is visible in the top right corner.

Properties	top	botm	hk	hani	vka	ss	sy
Layer name	Top layer						
Layer description	-						
Layer type	convertible						
Layer average calculation	harmonic mean						
Rewetting capability	No						

# Update boundaries

Delete the two constant head (CHD) boundaries and create two general head (GHB) boundaries at the eastern and western boundary of the model domain.

Boundaries can be cloned or deleted here.

Start Date	Head (m)	Conductance (m/day)
01.01.2015	60	6066
02.01.2015	50	6066
10.04.2015	50	6066

GHB east:  
Conductance: 6066 m/d  
Head Stress Period 1: 60 m  
Head Stress Period 2: 50 m  
Head Stress Period 3: 50 m



# Update boundaries (2)

All (2) ▼
+ Add
Save

GHB east ⋮

**GHB west** ⋮

Type	Name	Selected layers
GHB	GHB west	Top layer <span style="font-size: 0.8em;">✕</span>

[Edit boundary on map](#)

Time dependent boundary values at observation point

Start Date	Head (m)	Conductance (m/day)
01.01.2015	60	6066
02.01.2015	60	6066
10.04.2015	60	6066

GHB west:  
 Conductance: 6066 m/d  
 Head Stress Period 1: 60 m  
 Head Stress Period 2: 60 m  
 Head Stress Period 3: 60 m


# Add pumping well

Add a pumping well boundary (WEL) in the central part of the model domain.

Edit boundary properties

Name  
Pumping well

Geometry Affected cells



Save Cancel

Cancel Apply

Pumping rate:  
Stress Period 1: 0 m<sup>3</sup>/d  
Stress Period 2: 0 m<sup>3</sup>/d  
Stress Period 3:  
-100 m<sup>3</sup>/d

# Run the model

In the calculation section, run the model and view the results. First have a look, if the simulation terminated normally. Then, you can have a look at the head results for the three stress periods.

## Normal termination of simulation?

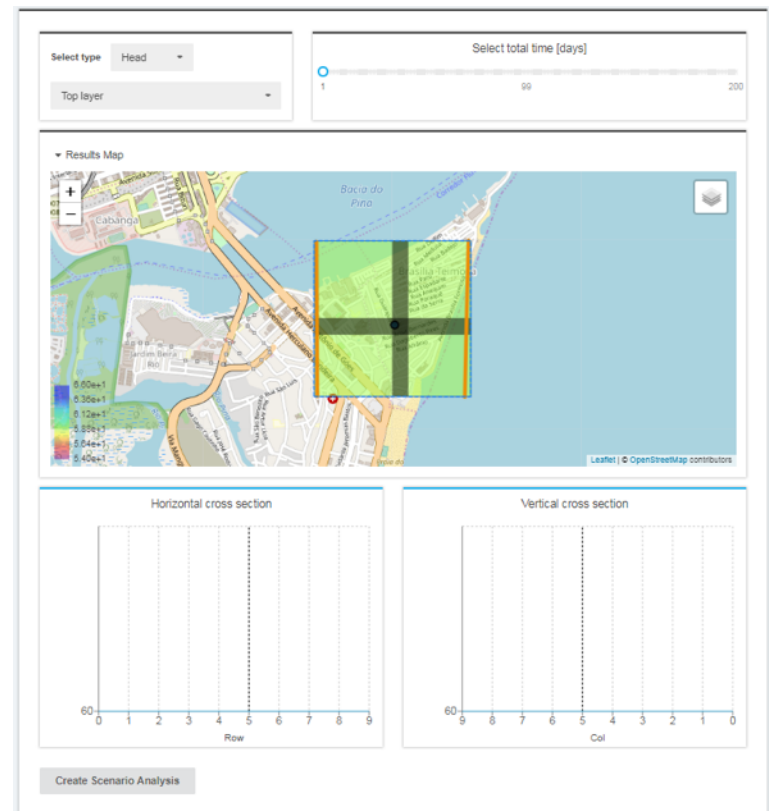
### Calculation logs

```
MODFLOW-2005
U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
Version 1.12.00 2/3/2017

Using NAME file: mf.nam
Run start date and time (yyyy/mm/dd hh:mm:ss): 2019/04/11 11:36:27

Solving: Stress period: 1 Time step: 1 Ground-Water Flow Eqn.
Solving: Stress period: 2 Time step: 1 Ground-Water Flow Eqn.
Solving: Stress period: 3 Time step: 1 Ground-Water Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2019/04/11 11:36:27
Elapsed run time: 0.003 seconds

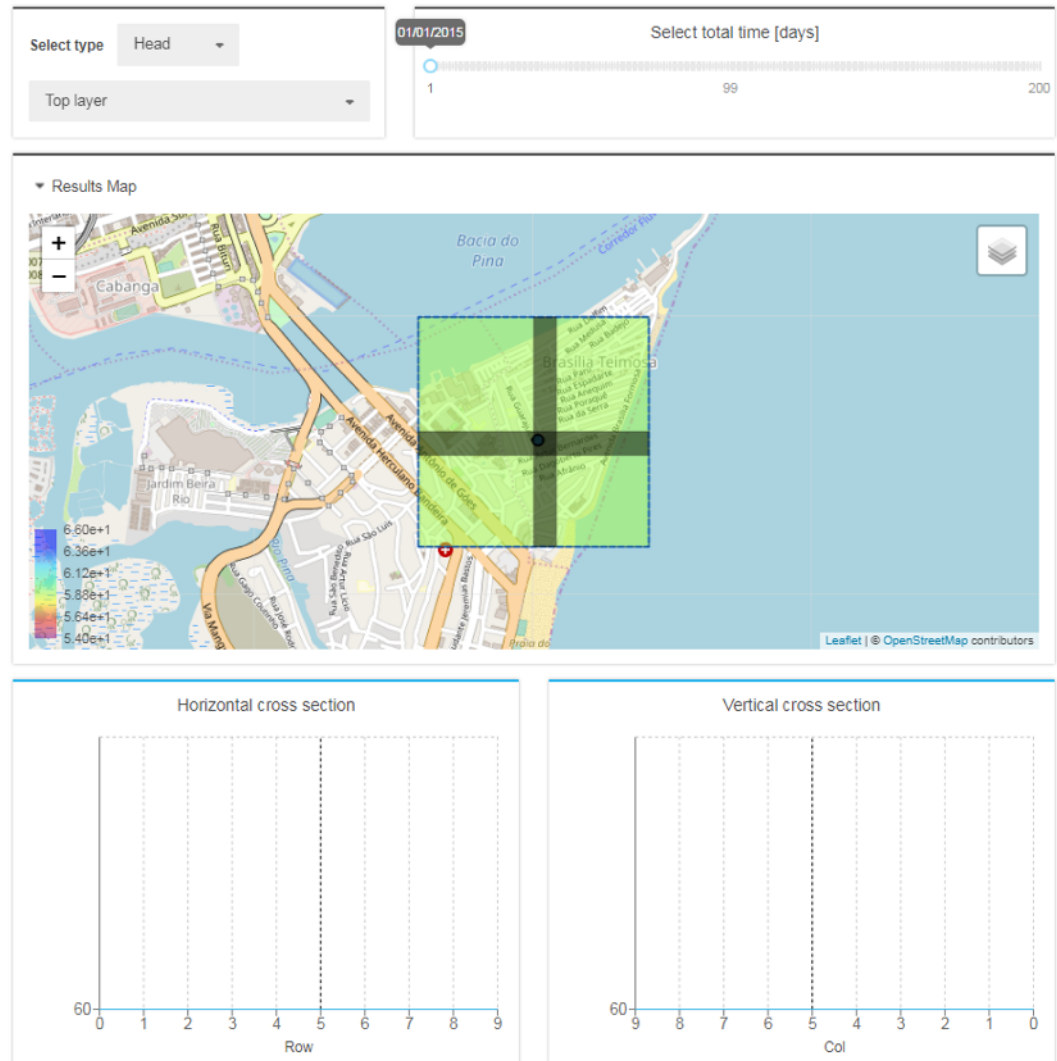
Normal termination of simulation
```



# Results

Stress period 1:

the head are constant throughout the model area.

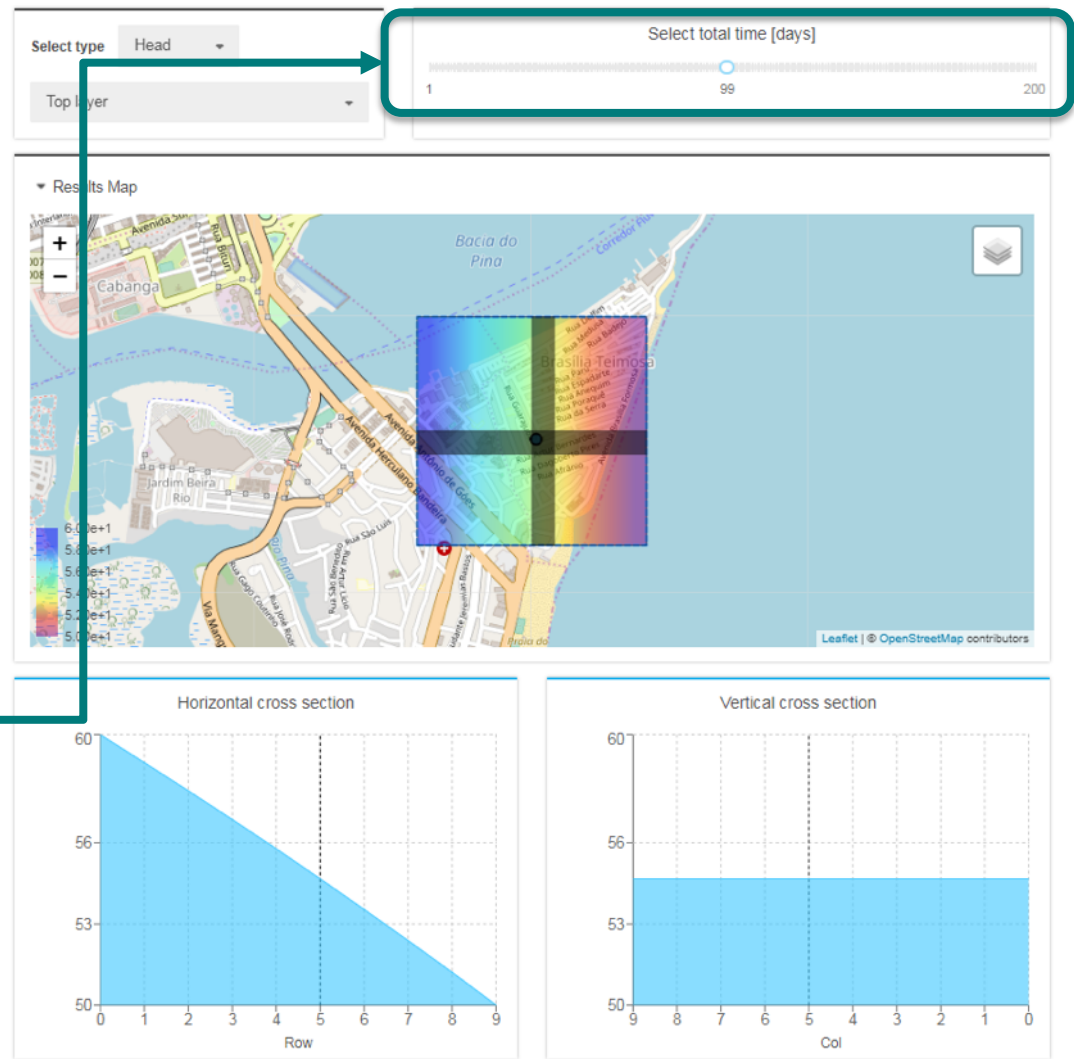


# Results

Stress period 2:

Water is flowing from left to right due to the GHB gradient.

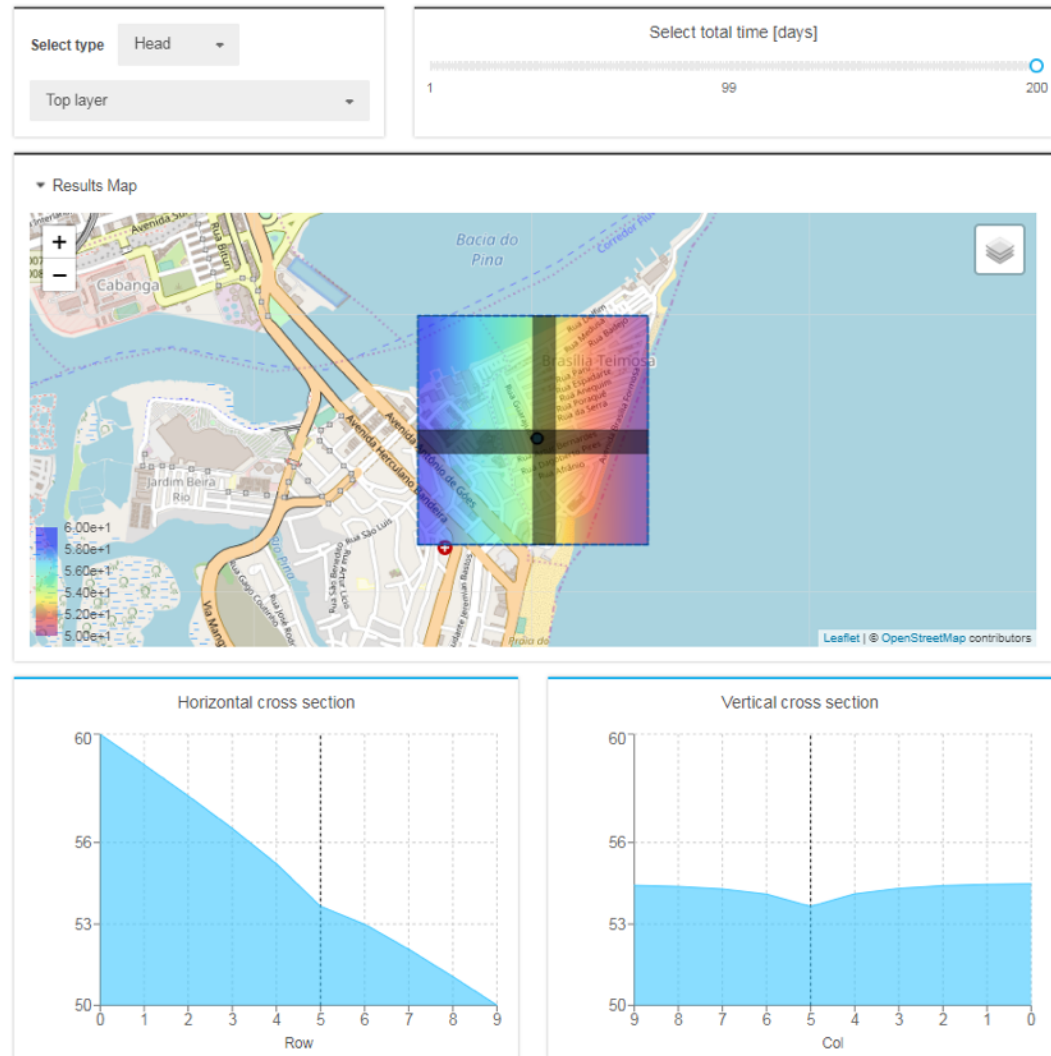
Change stress period, time steps



# Results

Stress period 3:

The pumping from the well causes a small depression cone.



# Scenario Analysis

In the scenario analysis, we want to examine what happens if the pumping rate is further increased.

For that create a scenario analysis in the results section.

The present model will be taken as the base model.

**MODEL SETUP**

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- Calibration

**COMPUTATION**

- Optimization

Calculation Progress ✕  
Finished successfully!

Select type: Head  
Top layer

Select total time [days]: 1 to 200 (99 selected)

**Results Map**

Horizontal cross section

Row	Value
0	60
1	58
2	56
3	54
4	52
5	50
6	50
7	50
8	50
9	50

Vertical cross section

Col	Value
9	54
8	54
7	54
6	54
5	53
4	54
3	54
2	54
1	54
0	54

Create Scenario Analysis



# Scenario Analysis

Be aware, that you are now in Tool „T07. MODFLOW model scenario manager“.

Change the name, description and public/private status.

Clone the base model to create a scenario.

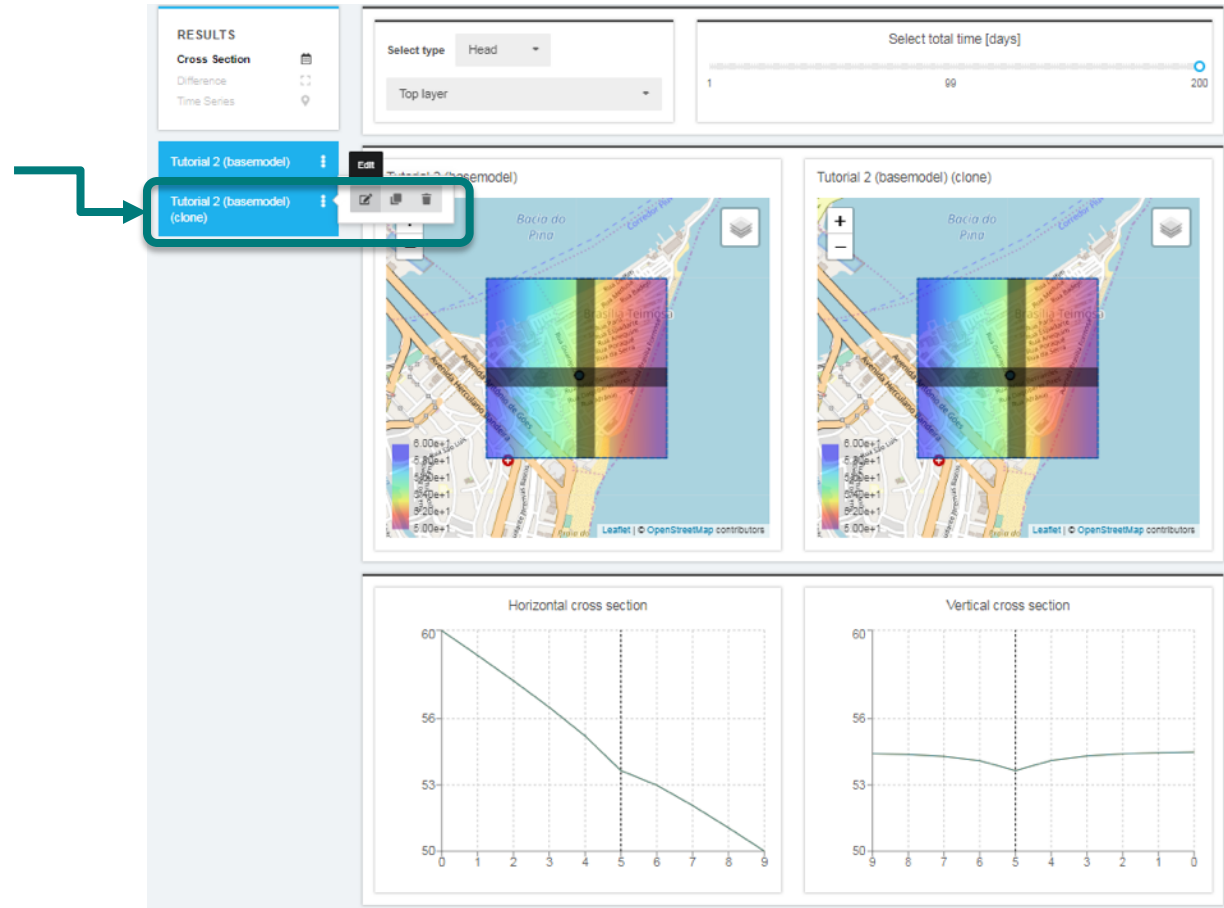
The screenshot displays the 'T07. MODFLOW model scenario manager' interface. At the top, the title bar reads 'Tools > T07. MODFLOW model scenario manager' and 'New scenario analysis Tutorial 2'. On the left, a 'RESULTS' panel includes 'Cross Section', 'Difference', and 'Time Series' options. The main workspace shows 'Tutorial 2 (basemodel)' with a 'Clone' button. A map of a coastal area is shown with a cross-section line. Below the map are two empty graphs: 'Horizontal cross section' and 'Vertical cross section'. A 'Select total time [days]' slider is at the top right, set to 99. A teal box highlights the 'New scenario analysis Tutorial 2' title, and another teal box highlights the 'Clone' button. A teal arrow points from the 'Clone' button to the 'New scenario analysis Tutorial 2' title.



# Scenario Analysis

There should be now two models in the slider: Tutorial 2 (basemodel) and Tutorial 2 (basemodel) clone.

Edit the clone to change the pumping rate.



# Scenario Analysis

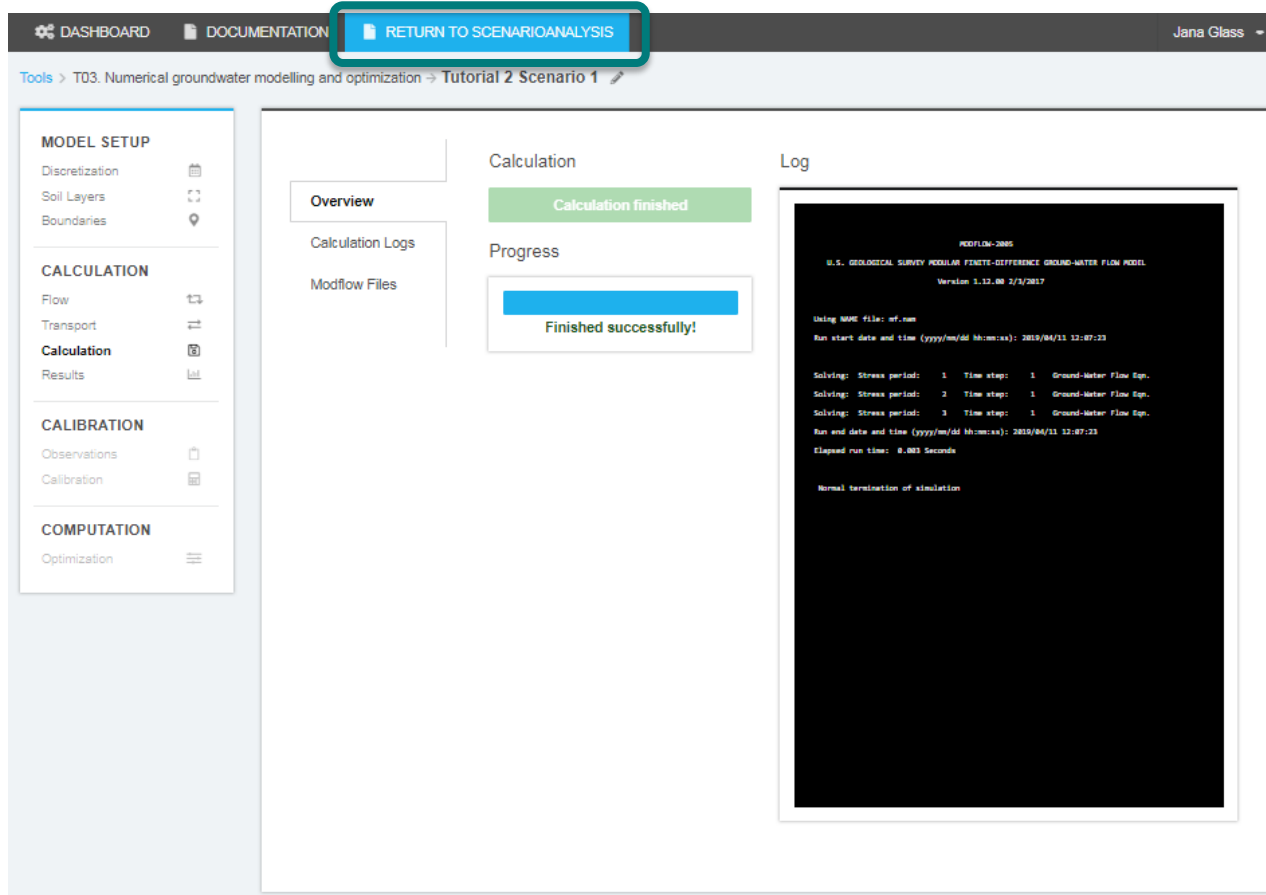
Be aware that you are now back in the Model Editor (Tool T03).  
Rename the Scenario to e.g. Tutorial 2 Scenario 1 and change the pumping rate to  $-1000 \text{ m}^3/\text{d}$ .

The screenshot shows the Model Editor (Tool T03) interface. The title bar indicates the current scenario is "Tutorial 2 Scenario 1". The left sidebar contains sections for MODEL SETUP, CALCULATION, CALIBRATION, and COMPUTATION. A "Calculation Progress" box at the bottom left shows "Finished successfully!". The main area displays a map of a coastal urban area with a blue dashed box highlighting a specific region. Below the map, a table titled "Time dependent boundary values at observation point" shows the pumping rate for different start dates.

Start Date	Pumping rate (m <sup>3</sup> /day)
01.01.2015	0
02.01.2015	0
10.04.2015	-1000

# Scenario Analysis

Run the model and make sure the simulation terminated normally.  
Then return to the scenario analysis.



The screenshot shows a software interface with a dark header bar containing 'DASHBOARD', 'DOCUMENTATION', and a highlighted 'RETURN TO SCENARIO ANALYSIS' button. Below the header, the breadcrumb path is 'Tools > T03. Numerical groundwater modelling and optimization > Tutorial 2 Scenario 1'. The left sidebar has sections for 'MODEL SETUP' (Discretization, Soil Layers, Boundaries), 'CALCULATION' (Flow, Transport, Calculation, Results), 'CALIBRATION' (Observations, Calibration), and 'COMPUTATION' (Optimization). The main content area is divided into 'Overview', 'Calculation', and 'Log'. Under 'Calculation', there is a green 'Calculation finished' button and a blue 'Finished successfully!' button. The 'Log' window shows the following text:

```
MODFLOW-2005
U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
Version 1.12.00 3/3/2017

Using NAME file: mf.nam
Run start date and time (yyyy/mm/dd hh:mm:ss): 2019/04/11 12:07:23

Solving: Stress period: 1 Time step: 1 Ground-water Flow Eqn.
Solving: Stress period: 2 Time step: 1 Ground-water Flow Eqn.
Solving: Stress period: 3 Time step: 1 Ground-water Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2019/04/11 12:07:23
Elapsed run time: 8.003 Seconds

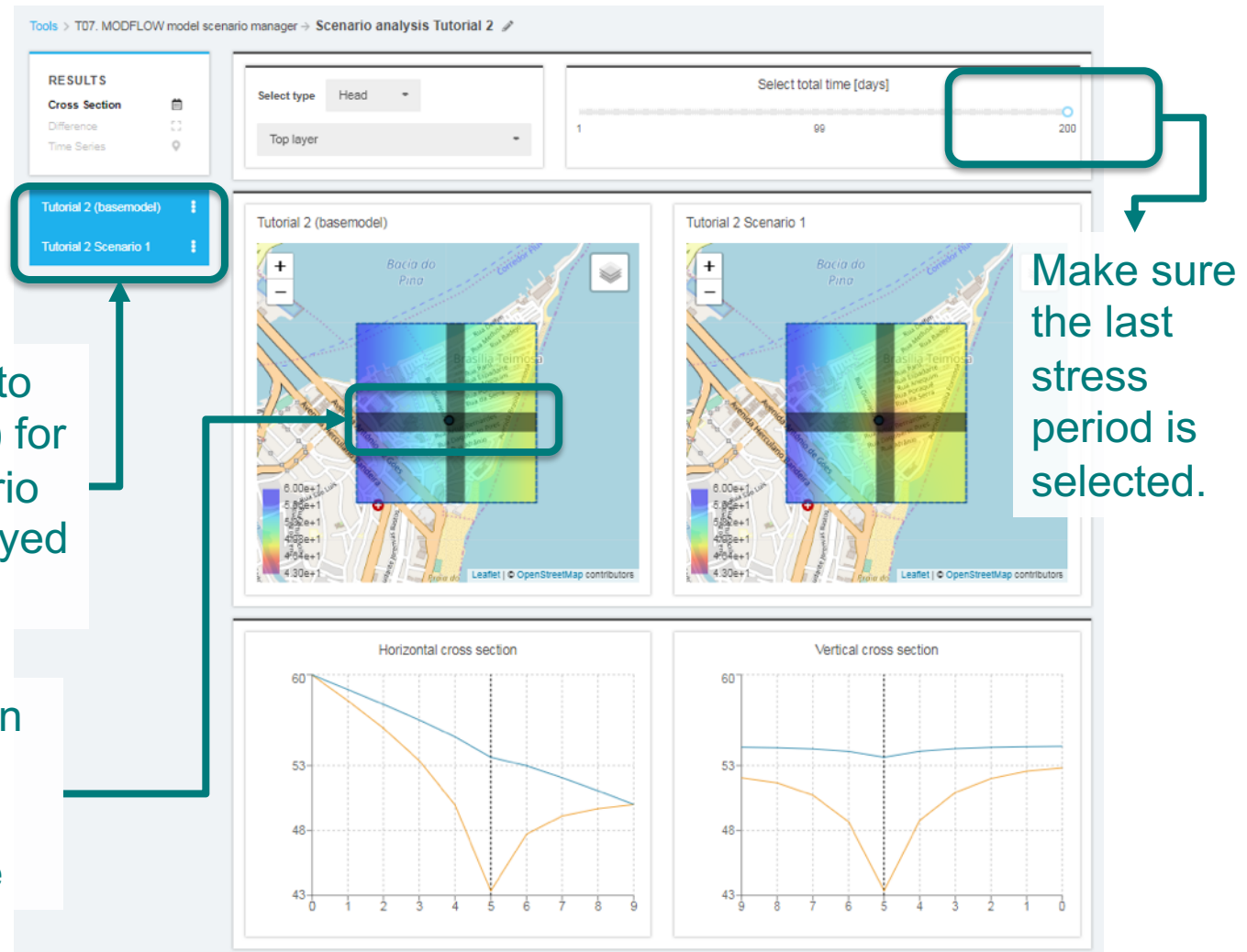
Normal termination of simulation
```

# Scenario Analysis

In the scenario manager, the head of the Base model and scenario 1 can be compared.

Both scenarios have to be switched on (blue) for comparison. A scenario is currently not displayed if the button is white.

Select the row/column where the pumping well is located to visualize its influence



# Additional Task

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The water authority decided that the groundwater head is not allowed to drop below 50 m in the whole model area due to land subsidence issues.

How much water can be pumped from the pumping well so that the water level stays above 50 m?

Create an additional scenario and try to find out.

# Contact

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Thank you for going through Tutorial 2. If you have any comments or questions, please contact us (also if you want to find out if your answer of the additional task is correct) !



Further Tutorials about the INOWAS platform:

Tutorial 1- Set up of steady state groundwater flow model

Tutorial 3- Set up of solute transport model