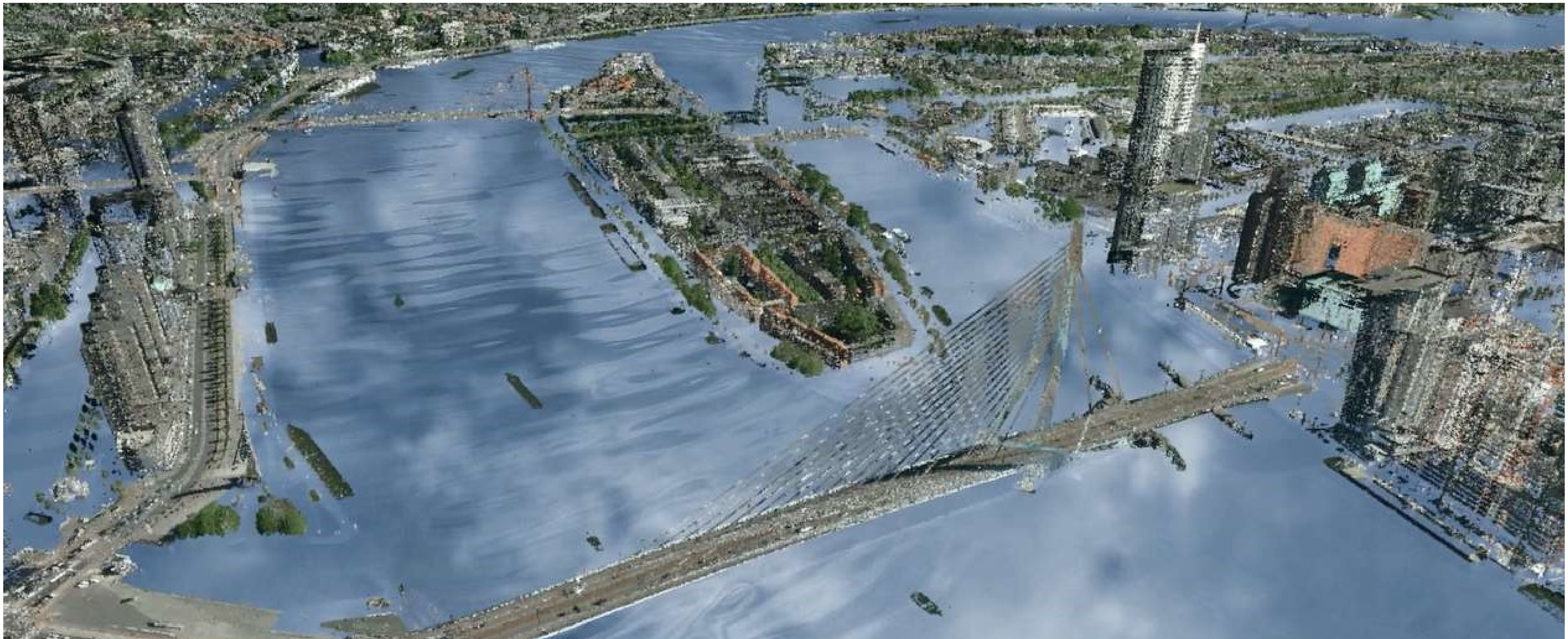


QGIS as a gui for hydrological modelling

Jonas van Schrojenstein Lantman

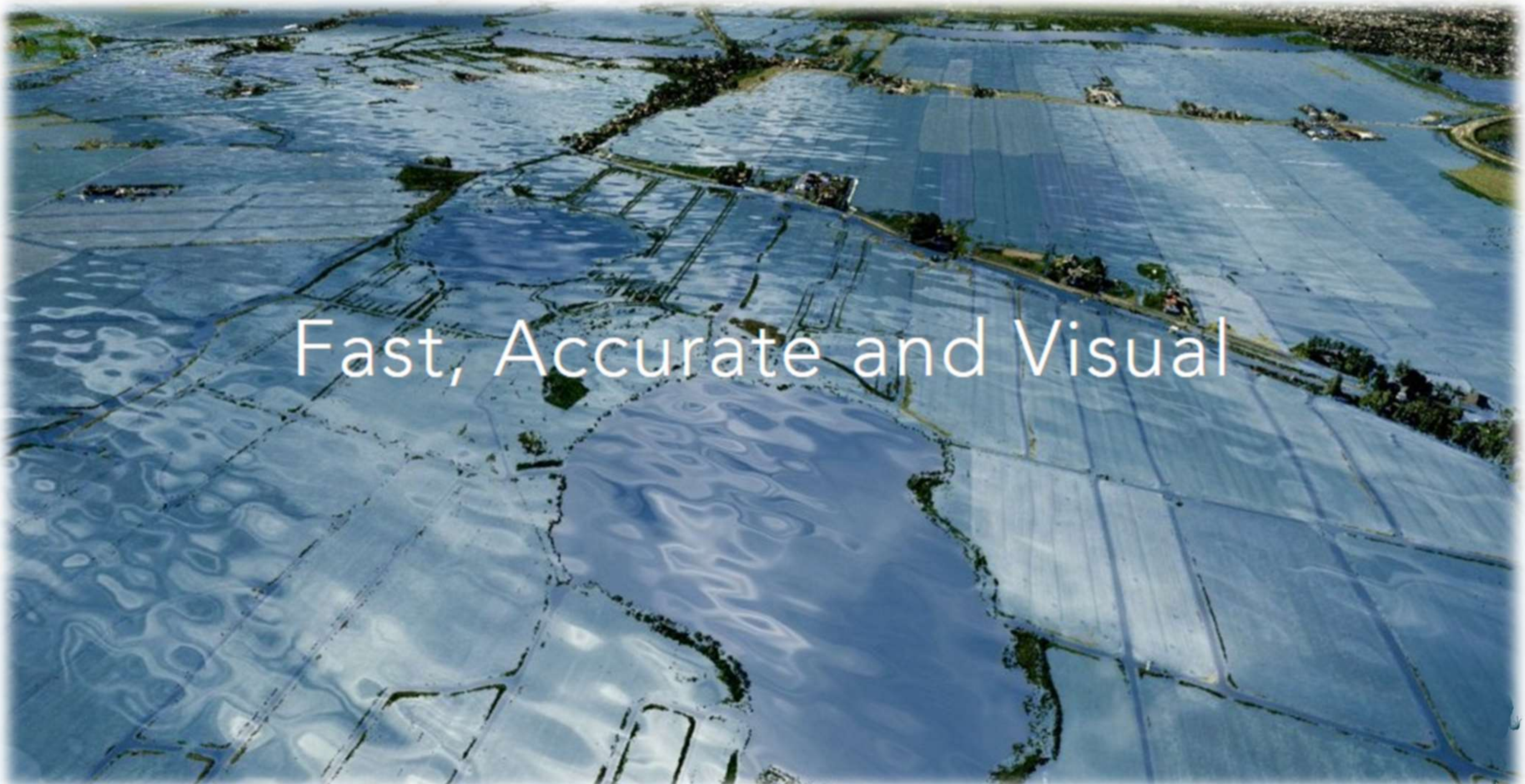
Nelen & Schuurmans

31-01-2018

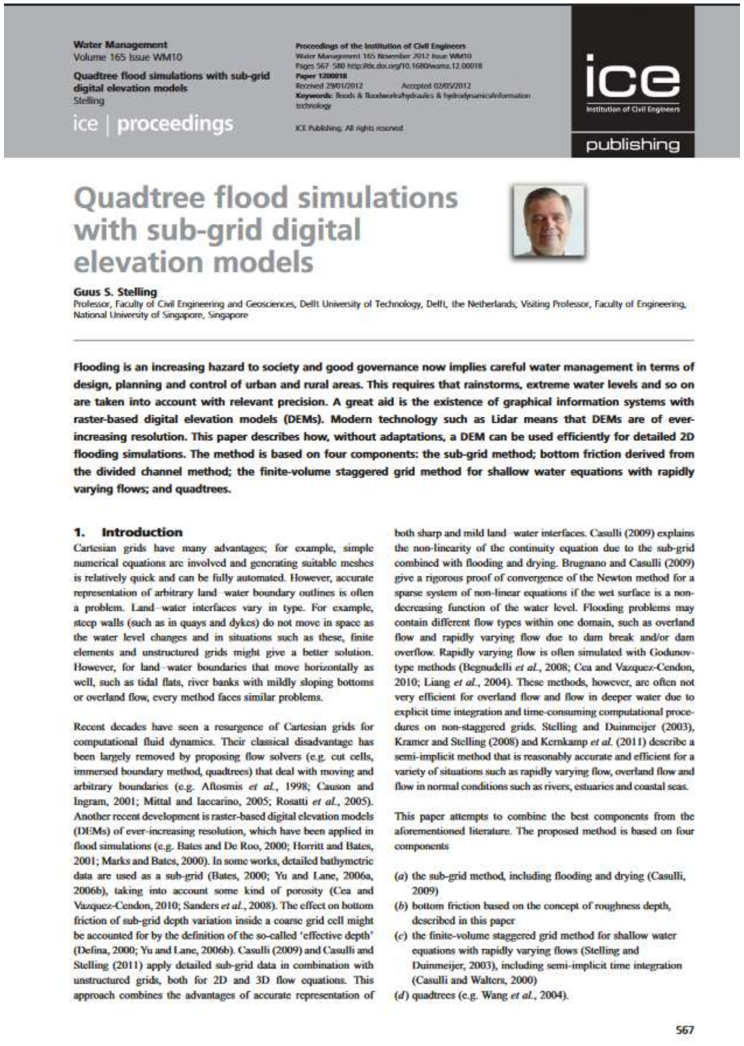
Nelen & Schuurmans

- Consultancy firm
- Water & IT
- 65 people MSc. & Postdoc
- Consultants & Developers

3Di Water Management



Improved mathematics



Water Management
Volume 165 Issue WM10
Quadtree flood simulations with sub-grid digital elevation models
Stelling

ice | proceedings

Proceedings of the Institution of Civil Engineers
Water Management 165 November 2012 Issue WM10
Pages 567–580 http://dx.doi.org/10.1680/wama.12.00018
Paper 1200018
Received 29/01/2012 Accepted 02/05/2012
Keywords: floods & floodworks/hydraulics & hydrodynamics/information technology

ice
Institution of Civil Engineers
publishing

Quadtree flood simulations with sub-grid digital elevation models

Guus S. Stelling
Professor, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, the Netherlands; Visiting Professor, Faculty of Engineering, National University of Singapore, Singapore

Flooding is an increasing hazard to society and good governance now implies careful water management in terms of design, planning and control of urban and rural areas. This requires that rainstorms, extreme water levels and so on are taken into account with relevant precision. A great aid is the existence of graphical information systems with raster-based digital elevation models (DEMs). Modern technology such as Lidar means that DEMs are of ever-increasing resolution. This paper describes how, without adaptations, a DEM can be used efficiently for detailed 2D flooding simulations. The method is based on four components: the sub-grid method; bottom friction derived from the divided channel method; the finite-volume staggered grid method for shallow water equations with rapidly varying flows; and quadtrees.

1. Introduction

Cartesian grids have many advantages; for example, simple numerical equations are involved and generating suitable meshes is relatively quick and can be fully automated. However, accurate representation of arbitrary land–water boundary outlines is often a problem. Land–water interfaces vary in type. For example, steep walls (such as in quays and dykes) do not move in space as the water level changes and in situations such as these, finite elements and unstructured grids might give a better solution. However, for land–water boundaries that move horizontally as well, such as tidal flats, river banks with mildly sloping bottoms or overland flow, every method faces similar problems.

Recent decades have seen a resurgence of Cartesian grids for computational fluid dynamics. Their classical disadvantage has been largely removed by proposing flow solvers (e.g. cut cells, immersed boundary method, quadtrees) that deal with moving and arbitrary boundaries (e.g. Aftosmis *et al.*, 1998; Causon and Ingram, 2001; Mittal and Iaccarino, 2005; Rosatti *et al.*, 2005). Another recent development is raster-based digital elevation models (DEMs) of ever-increasing resolution, which have been applied in flood simulations (e.g. Bates and De Roo, 2000; Horritt and Bates, 2001; Marks and Bates, 2000). In some works, detailed bathymetric data are used as a sub-grid (Bates, 2000; Yu and Lane, 2006a, 2006b), taking into account some kind of porosity (Cea and Vazquez-Cendon, 2010; Sanders *et al.*, 2008). The effect on bottom friction of sub-grid depth variation inside a coarse grid cell might be accounted for by the definition of the so-called 'effective depth' (Defina, 2000; Yu and Lane, 2006b). Casulli (2009) and Casulli and Stelling (2011) apply detailed sub-grid data in combination with unstructured grids, both for 2D and 3D flow equations. This approach combines the advantages of accurate representation of both sharp and mild land–water interfaces. Casulli (2009) explains the non-linearity of the continuity equation due to the sub-grid combined with flooding and drying. Brugnano and Casulli (2009) give a rigorous proof of convergence of the Newton method for a sparse system of non-linear equations if the wet surface is a non-decreasing function of the water level. Flooding problems may contain different flow types within one domain, such as overland flow and rapidly varying flow due to dam break and/or dam overflow. Rapidly varying flow is often simulated with Godunov-type methods (Begnudelli *et al.*, 2008; Cea and Vazquez-Cendon, 2010; Liang *et al.*, 2004). These methods, however, are often not very efficient for overland flow and flow in deeper water due to explicit time integration and time-consuming computational procedures on non-staggered grids. Stelling and Duinmeijer (2003), Kramer and Stelling (2008) and Kernkamp *et al.* (2011) describe a semi-implicit method that is reasonably accurate and efficient for a variety of situations such as rapidly varying flow, overland flow and flow in normal conditions such as rivers, estuaries and coastal seas.

This paper attempts to combine the best components from the aforementioned literature. The proposed method is based on four components

(*a*) the sub-grid method, including flooding and drying (Casulli, 2009)
(*b*) bottom friction based on the concept of roughness depth, described in this paper
(*c*) the finite-volume staggered grid method for shallow water equations with rapidly varying flows (Stelling and Duinmeijer, 2003), including semi-implicit time integration (Casulli and Walters, 2000)
(*d*) quadtrees (e.g. Wang *et al.*, 2004).

Faster calculations:

- Subgrid and quadtrees computation cells
- Mass conservative calculations
- Converging Newton iteration matrix solving

Use detail data for accurate results

- e.g. LiDAR based height data

Integration of:

- Rain radar
- Urban drainage system
- River flow and sea level

Where we operate

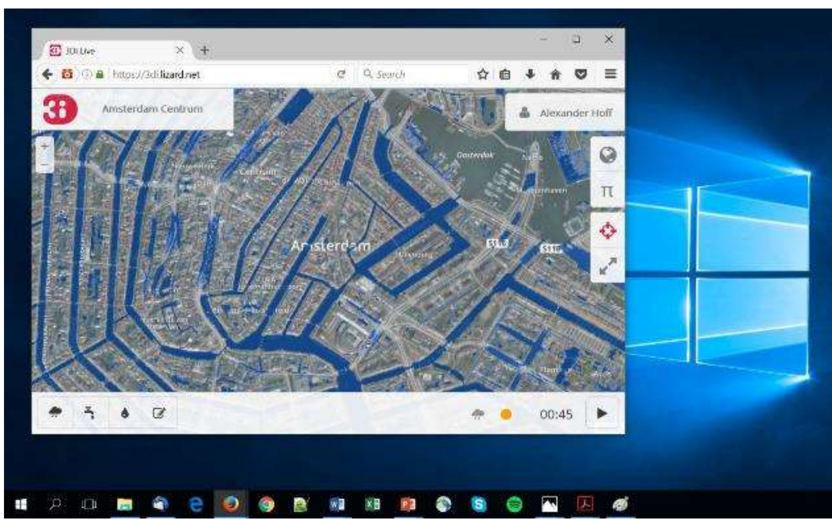
3Di studies

- Stress-tests
- Flooding
- Climate resilient design
- Water system analysis (integral)
- FEWS (Flood Early Warning Systems)

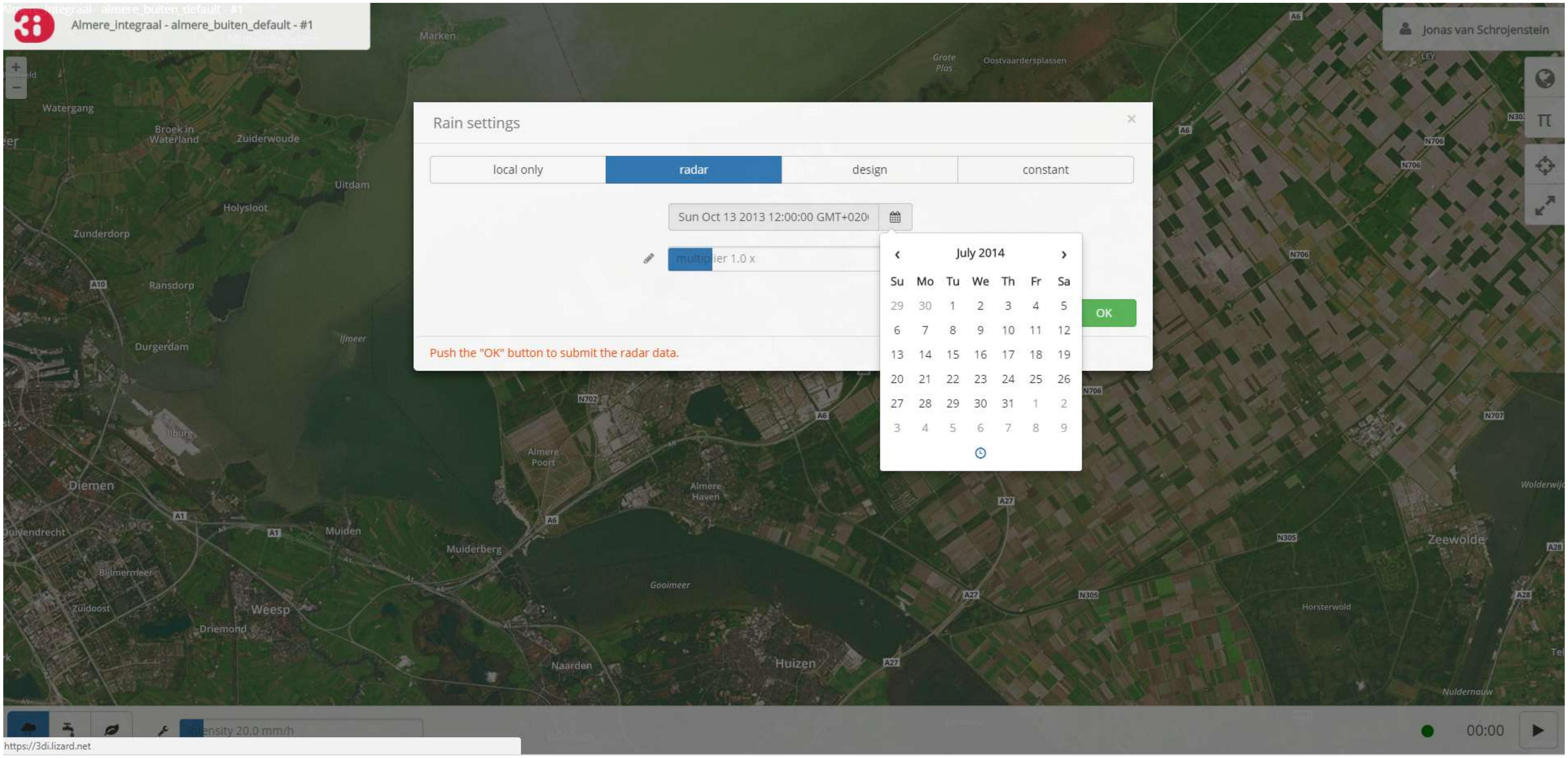
Alcatraz

Presentation & communication

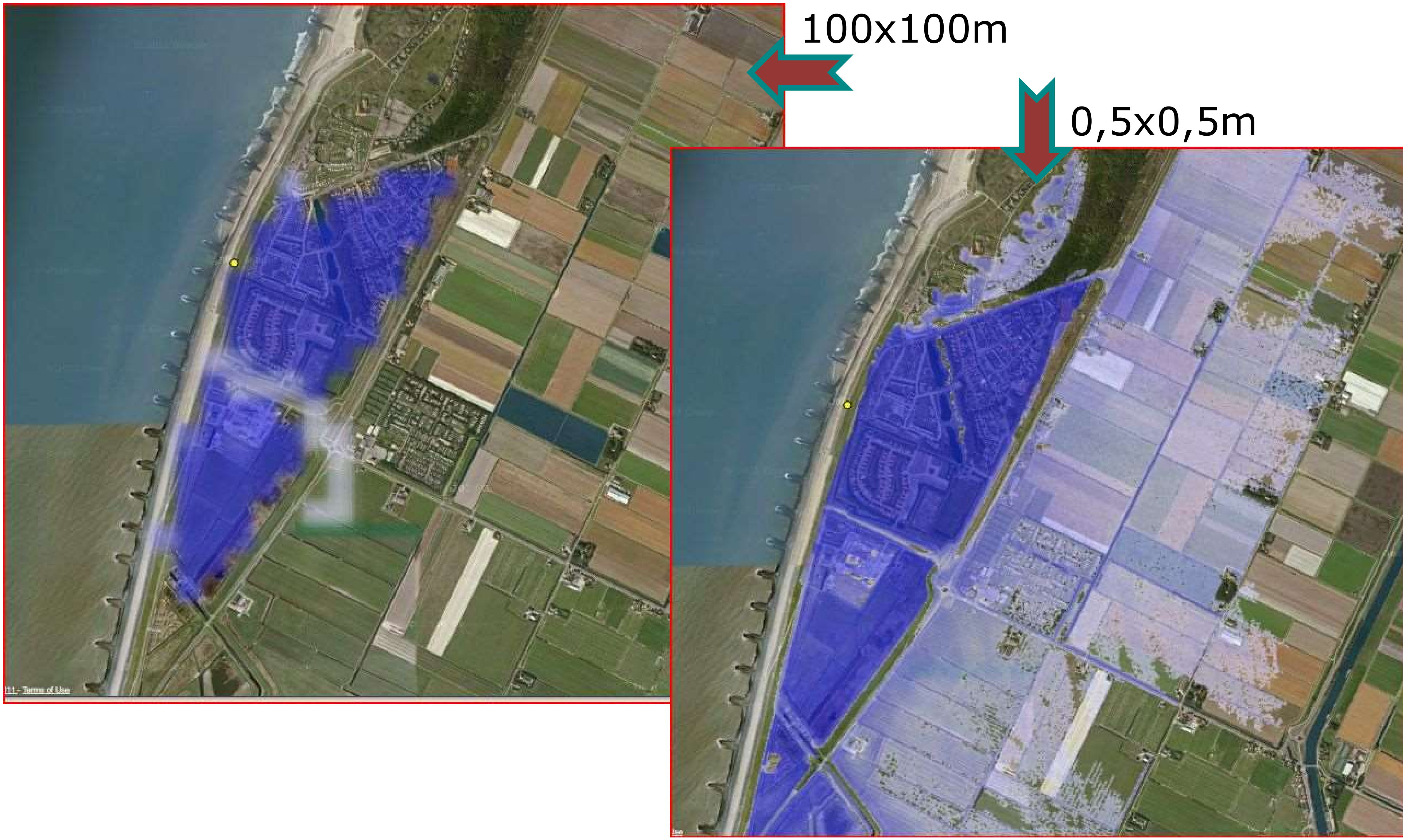
- Easy to understand maps
- Online presentation
- Touch Table
- Interactive



3Di Online interface



e.g. More detailed flood simulations



How to build these models?

- Create own custom interface?
- Use existing software?

How to build these models?

- Create own custom interface?
- Use existing software?

Why Qgis?

- Open Source

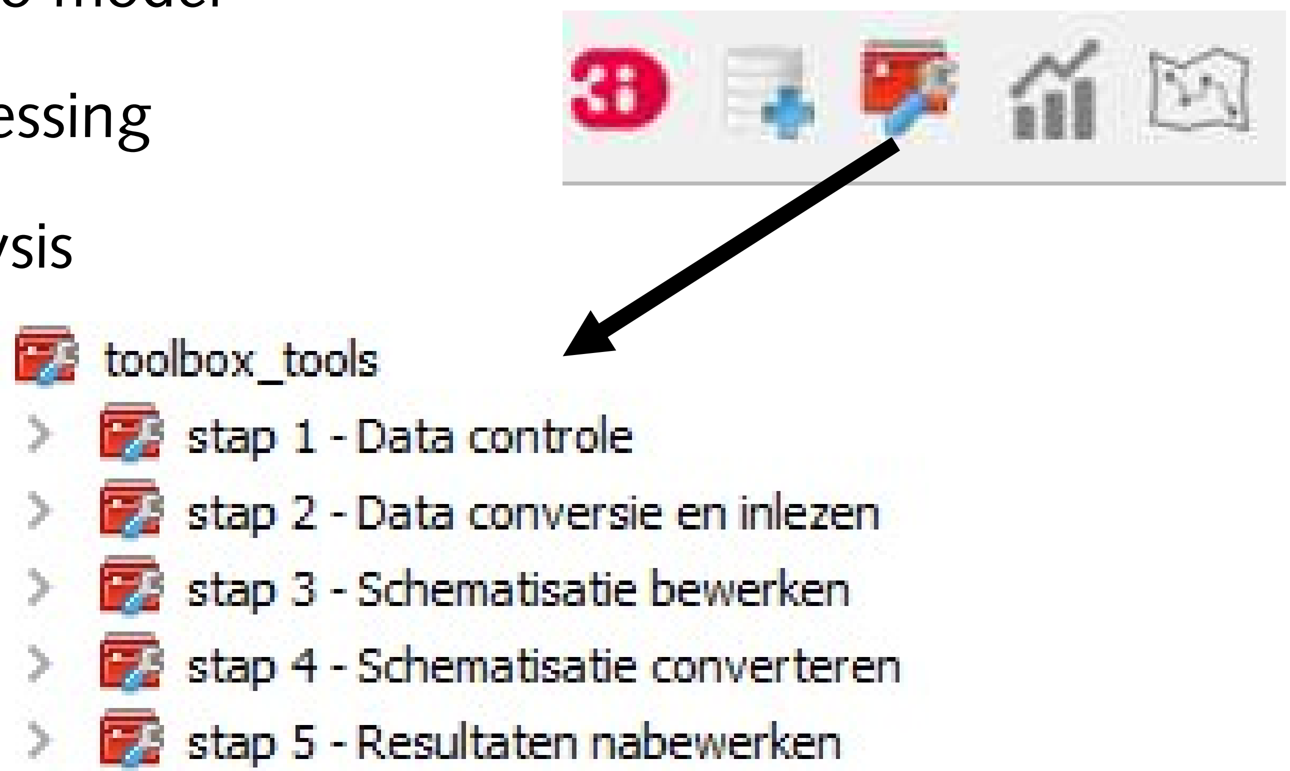
- No expensive licences required

- QGIS communicates very well with databases like spatialite

- Third party plugins can be easily used:
  - PDOK (Dutch plugin)
  - Value tool
  - Profile tool

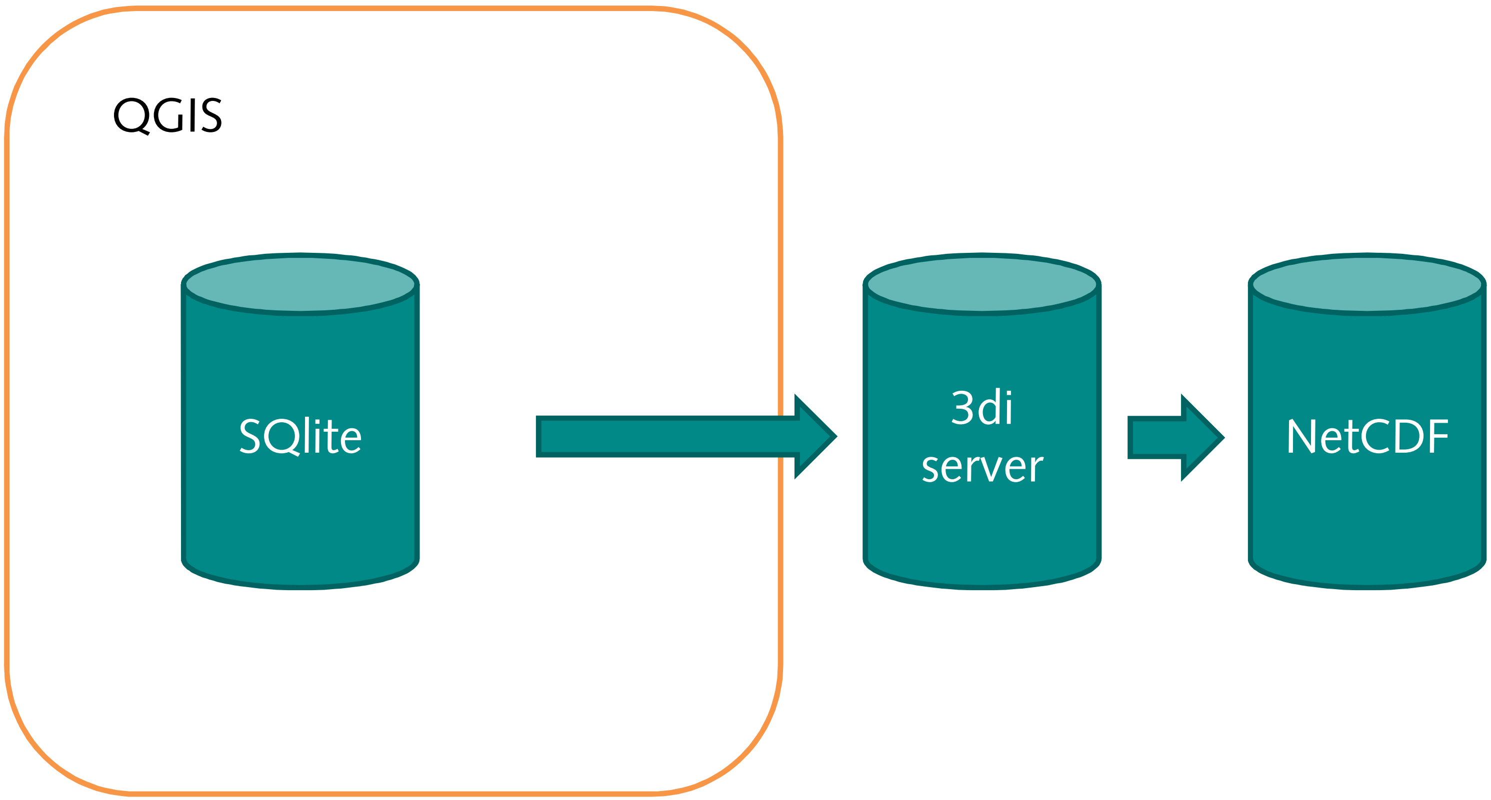
3di plugin

1. From data to model
2. Result processing
3. Result analysis

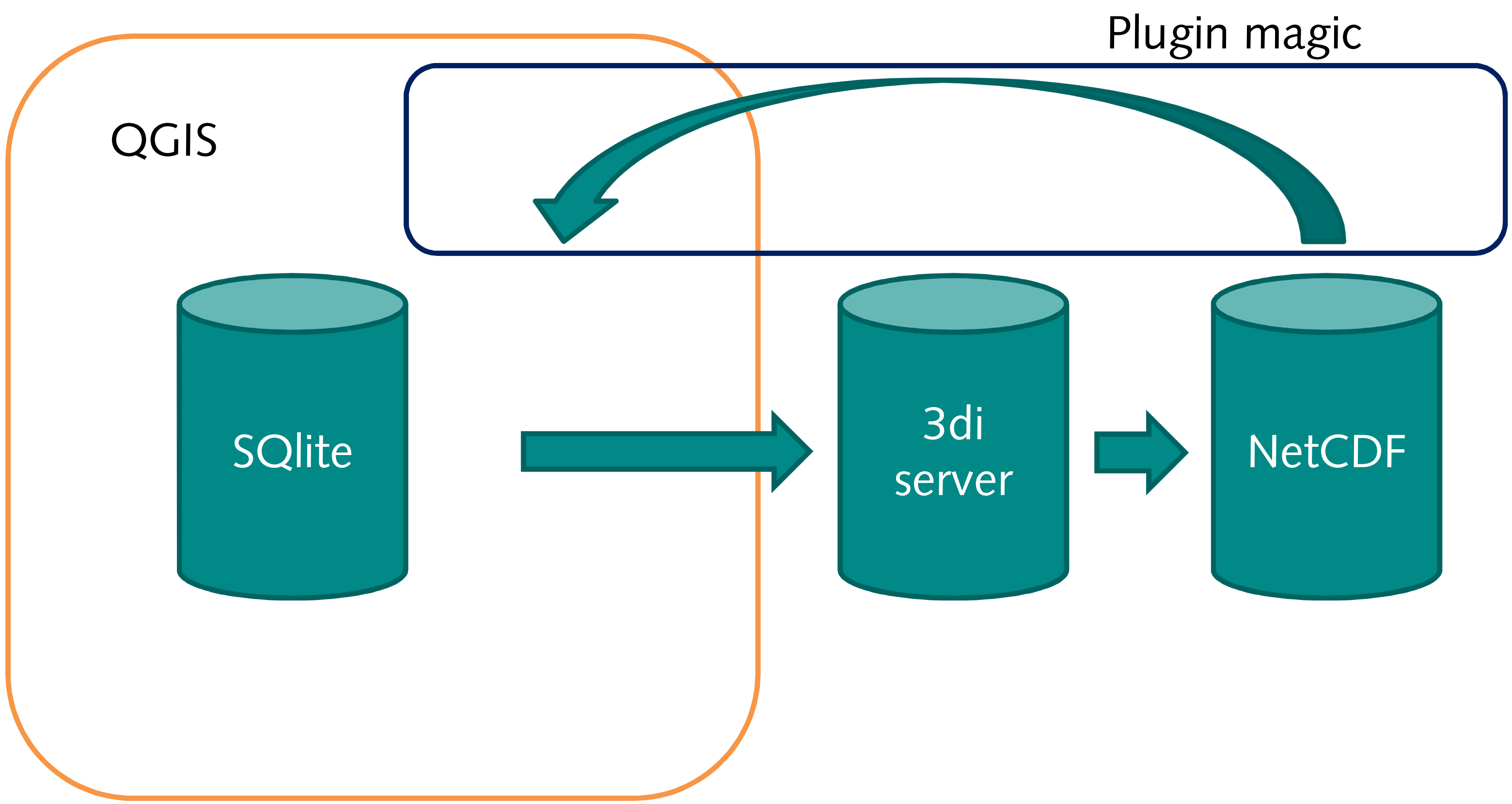


Why a new plugin?

From model to results



From model to results

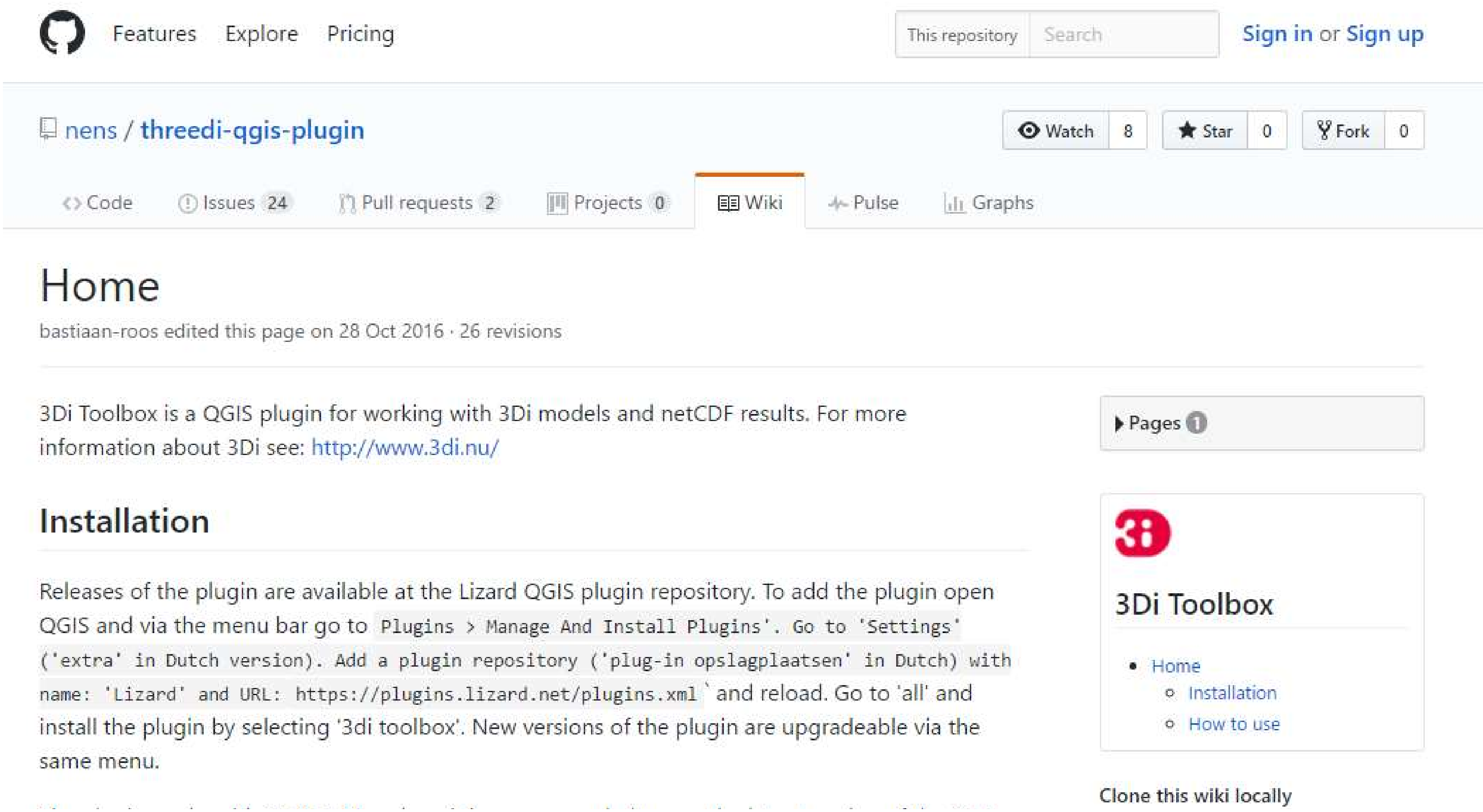


DEMO

Weir volume discharge

Plugin installation

- https://github.com/nens/threedi-qgis-plugin/wiki



Challenges

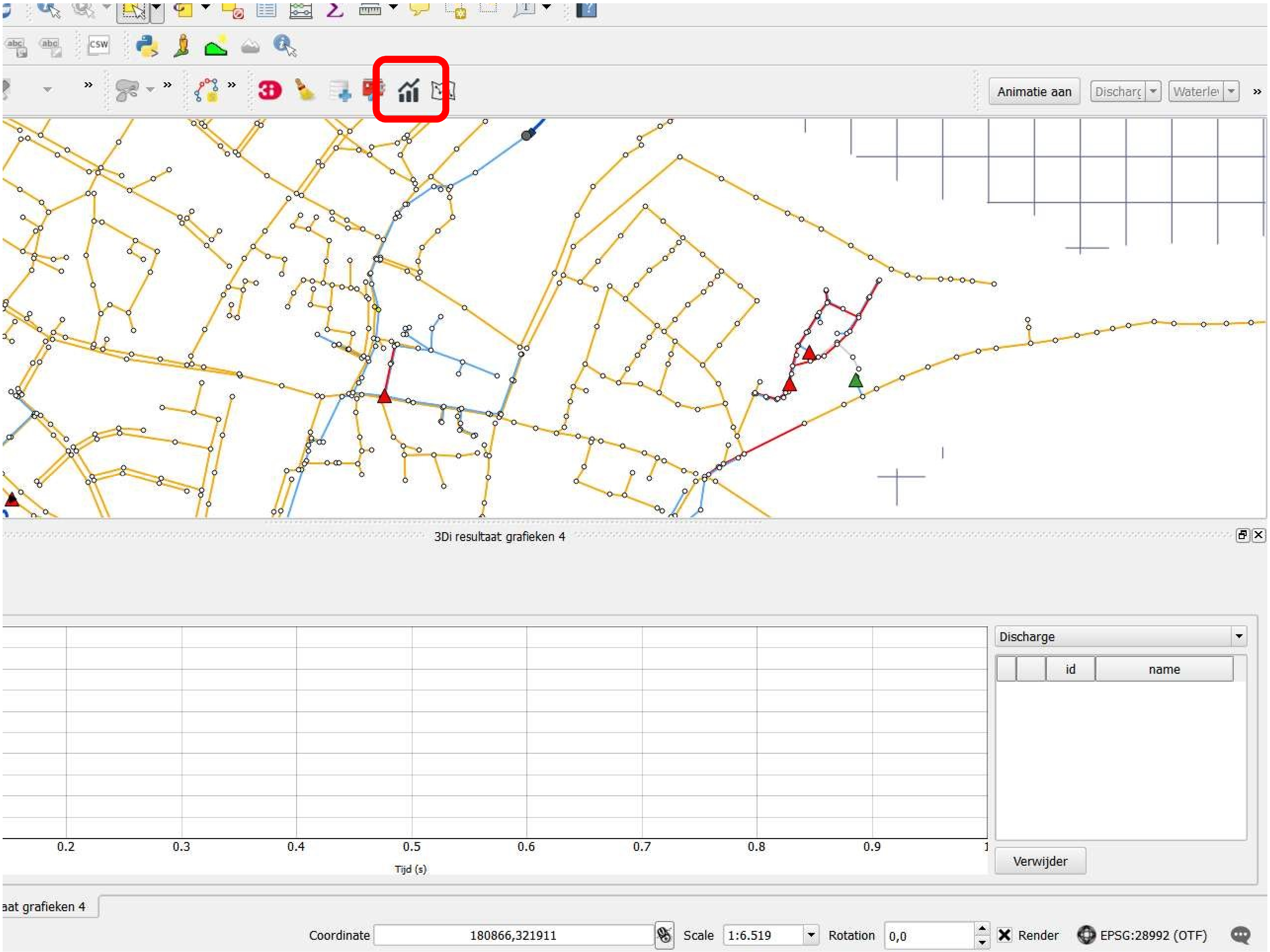
- Installation of QGIS including plugins at clients
- Professional support
- Competition with other GIS packages

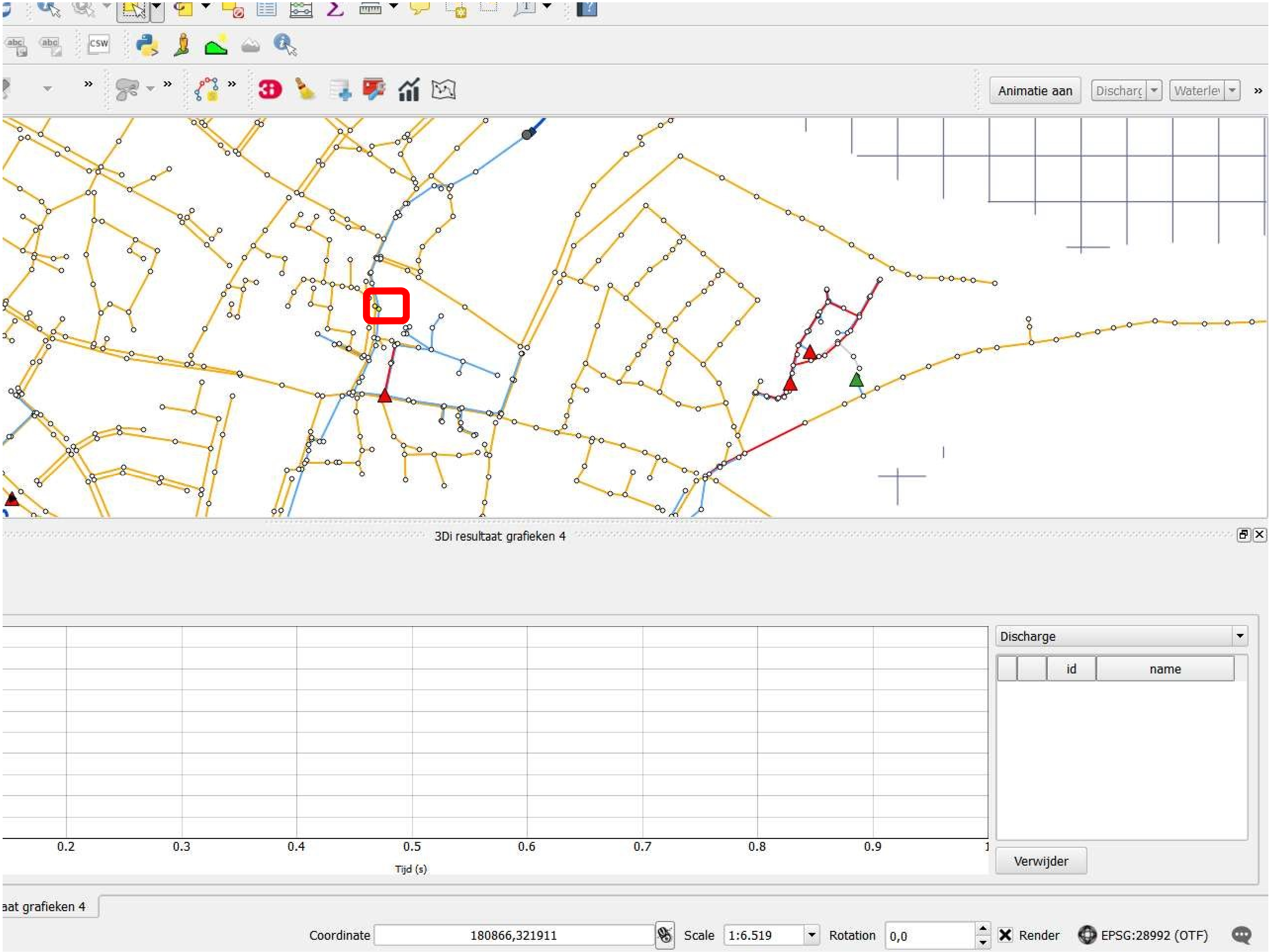
Questions?

- Jonas van Schrojenstein Lantman
- +31 6 82 07 32 84
- Jonas@nelen-schuurmans.nl
- @jonasvsl123

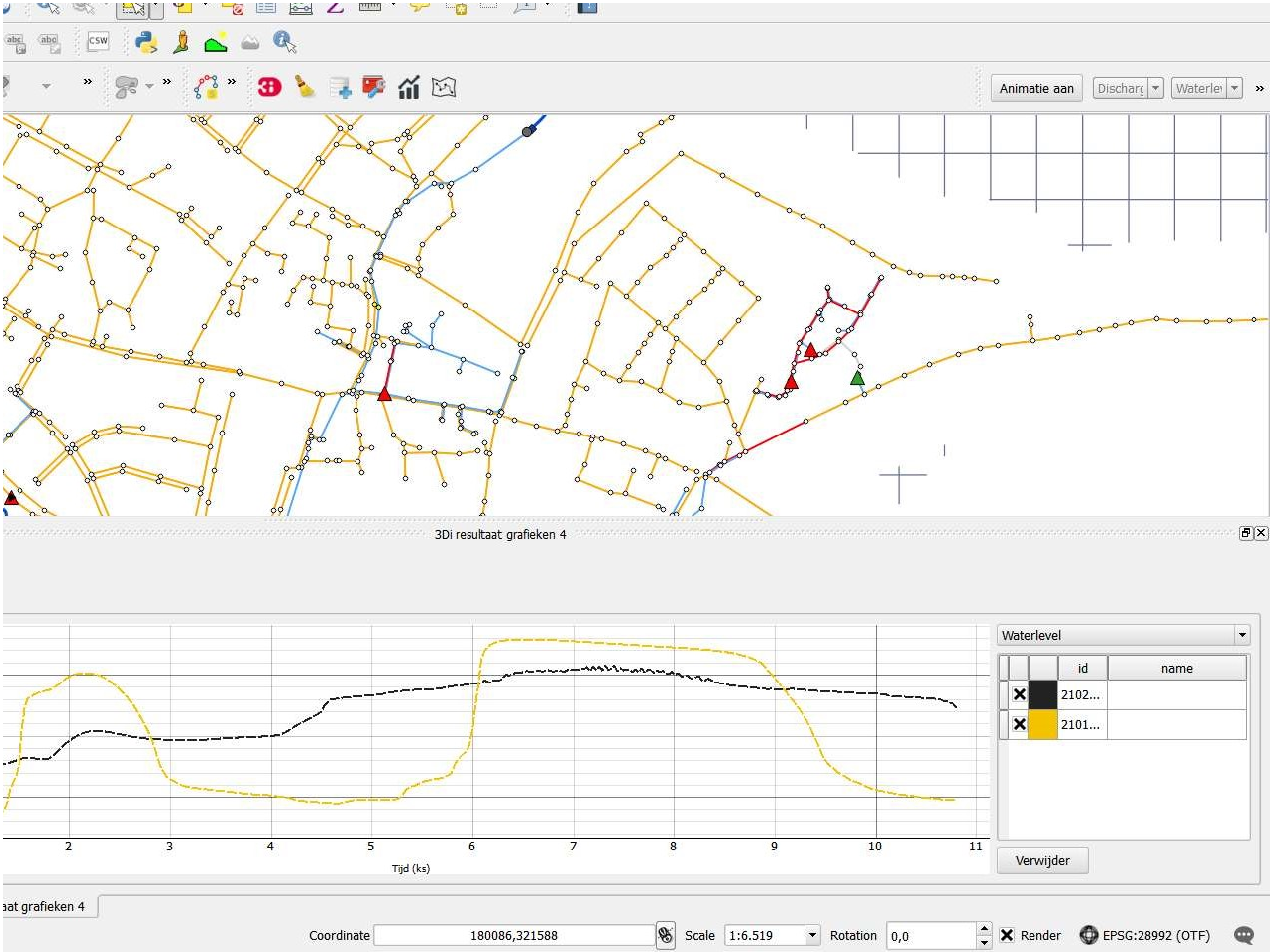
- More information:
- www.nelen-schuurmans.nl/en
- http://www.3di.nu/

Screenshots plugin


Animatie aan
Discharg
Waterle
3Di resultaat grafieken 4
Discharge
id
name
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Tijd (s)
Verwijder
aat grafieken 4
Coordinate
180866,321911
Scale
1:6.519
Rotation
0,0
Render
EPSG:28992 (OTF)

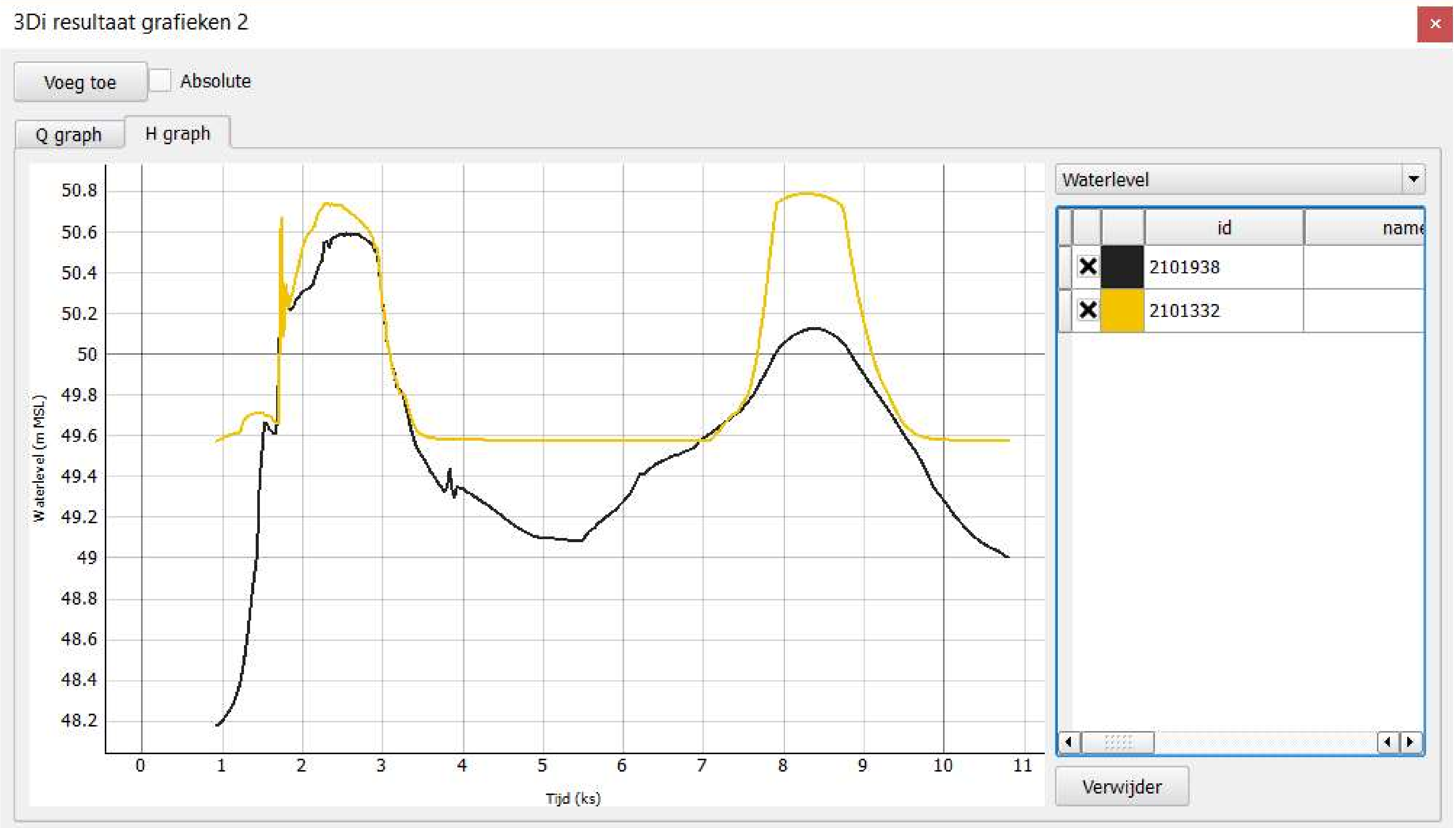


Animatie aan
Discharg
Waterle
3Di resultaat grafieken 4
Discharge
id
name
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Tijd (s)
Verwijder
aat grafieken 4
Coordinate
180866,321911
Scale
1:6.519
Rotation
0,0
Render
EPSG:28992 (OTF)

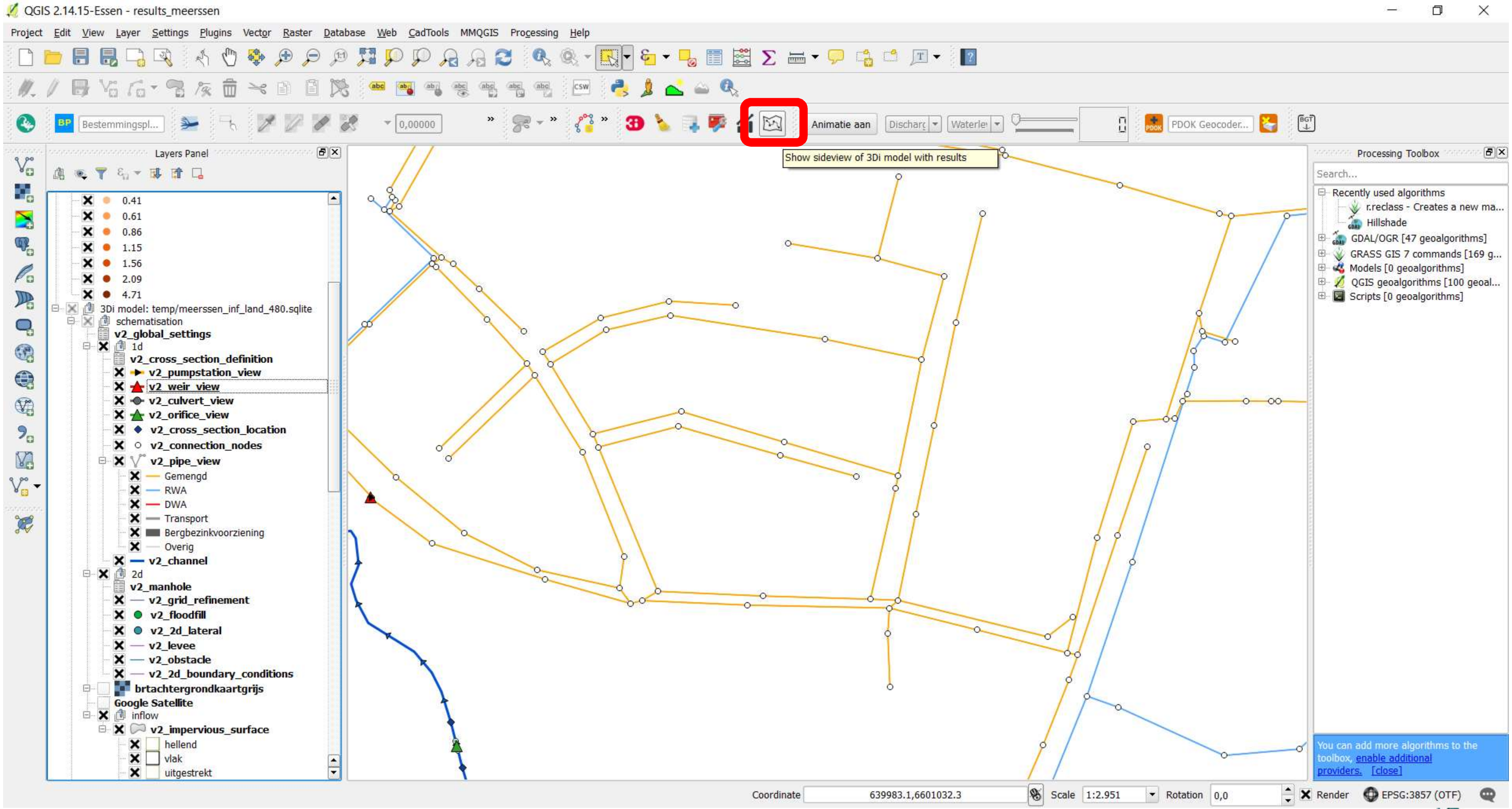


Animatie aan
Discharg
Waterle
3Di resultaat grafieken 4
Waterlevel
id
name
2102...
2101...
Verwijder
2
3
4
5
6
7
8
9
10
11
Tijd (ks)
aat grafieken 4
Coordinate
180086,321588
Scale
1:6.519
Rotation
0,0
Render
EPSG:28992 (OTF)

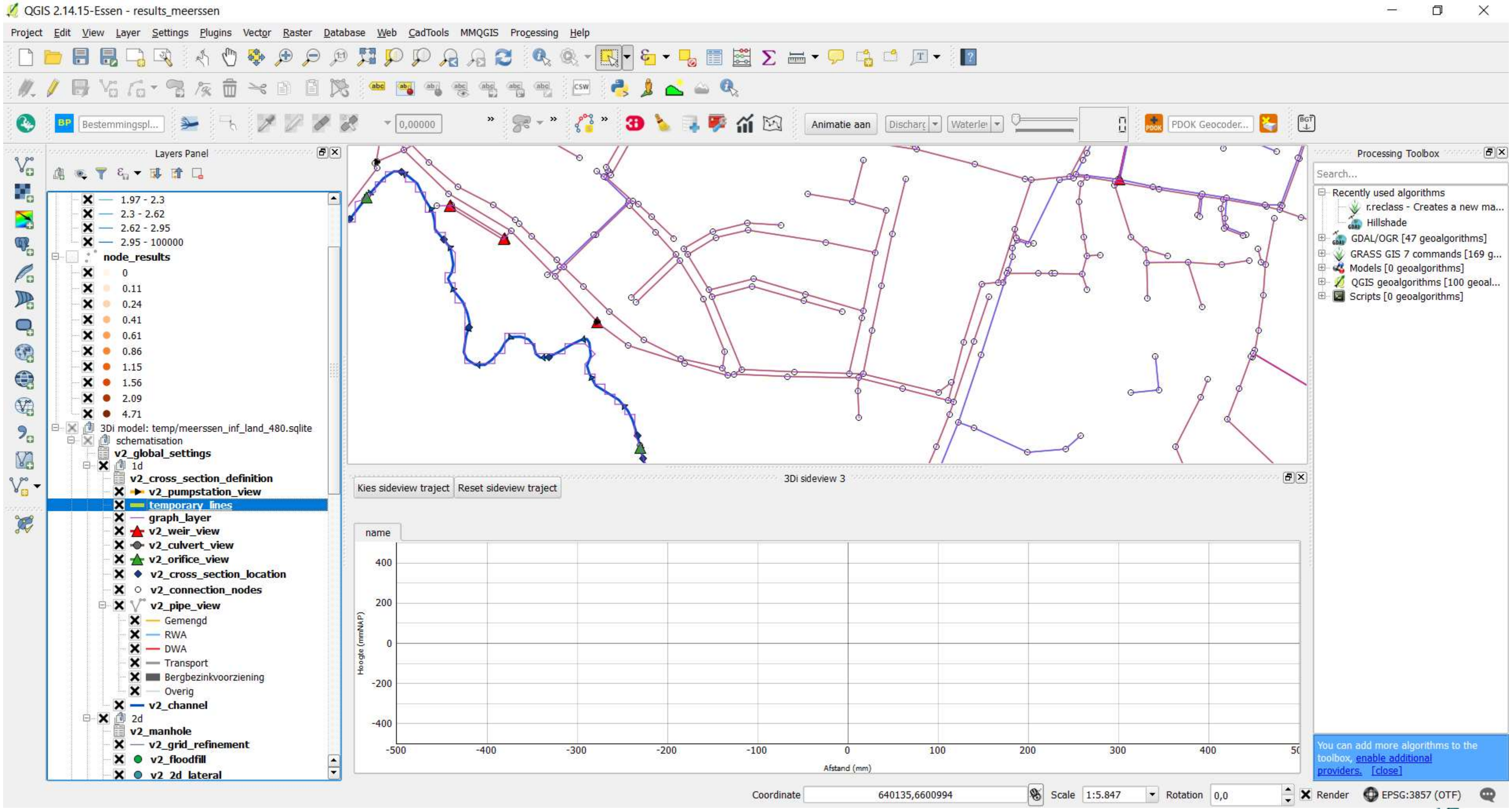
Water level per node



Sideview

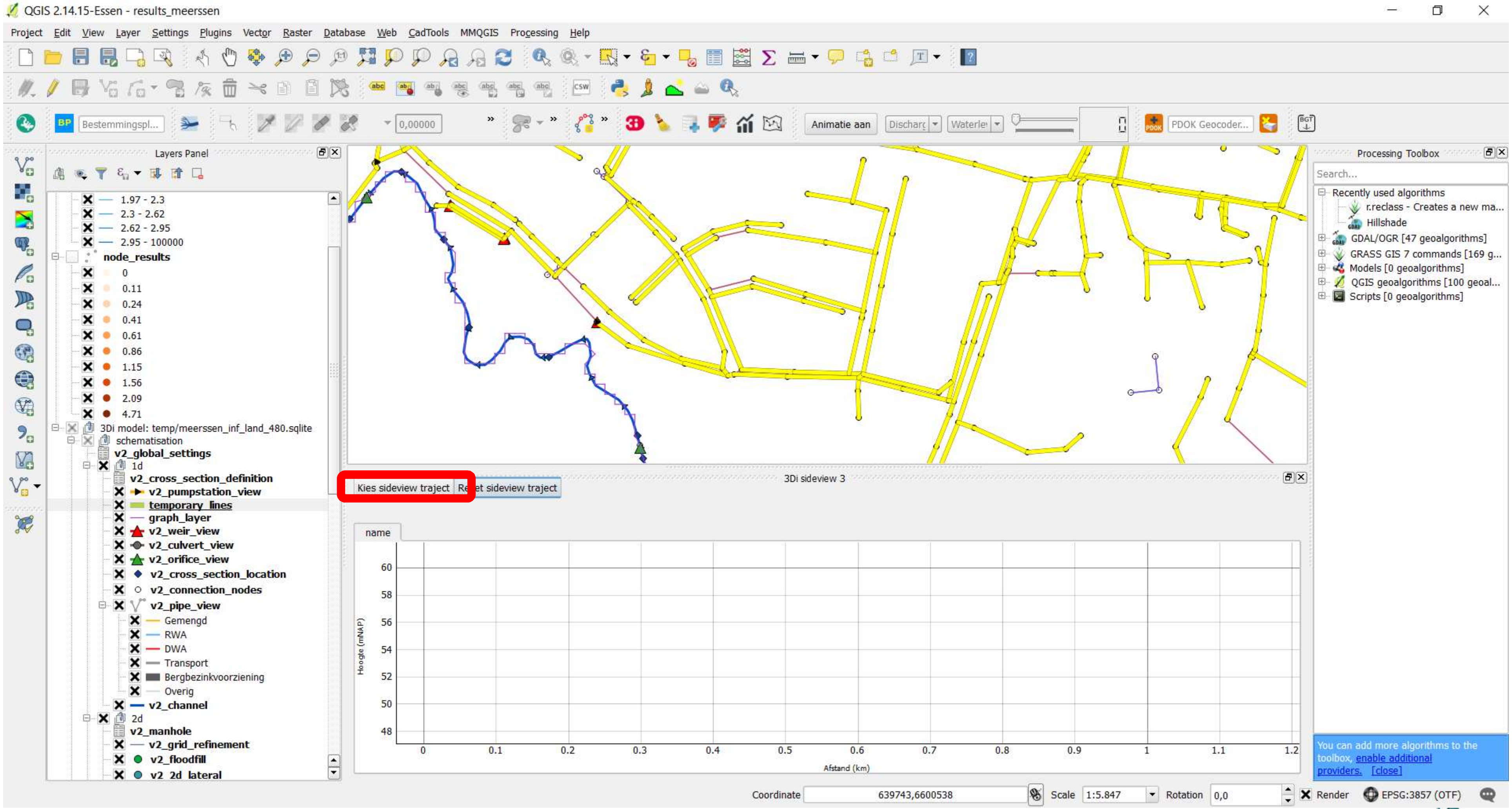

QGIS 2.14.15-Essen - results_meerssen
Project Edit View Layer Settings Plugins Vector Raster Database Web CadTools MMQGIS Processing Help
Animatie aan
PDOK Geocoder...
Show sideview of 3Di model with results
Layers Panel
3Di model: temp/meerssen_inf_land_480.sqlite
schematisation
v2_global_settings
1d
v2_cross_section_definition
v2_pumpstation_view
v2_weir_view
v2_culvert_view
v2_orifice_view
v2_cross_section_location
v2_connection_nodes
v2_pipe_view
Gemengd
RWA
DWA
Transport
Bergbezinkvoorziening
Overig
v2_channel
2d
v2_manhole
v2_grid_refinement
v2_floodfill
v2_2d_lateral
v2_levee
v2_obstacle
v2_2d_boundary_conditions
brtachtergrondkaartgrijs
Google Satellite
inflow
v2_impervious_surface
hellend
vlak
uitgestrekt
Processing Toolbox
Recently used algorithms
r.reclass - Creates a new ma...
Hillshade
GDAL/OGR [47 geoalgorithms]
GRASS GIS 7 commands [169 g...
Models [0 geoalgorithms]
QGIS geoalgorithms [100 geoal...
Scripts [0 geoalgorithms]
You can add more algorithms to the toolbox, enable additional providers. [close]
Coordinate 639983.1,6601032.3
Scale 1:2.951
Rotation 0,0
Render
EPSG:3857 (OTF)

Sideview

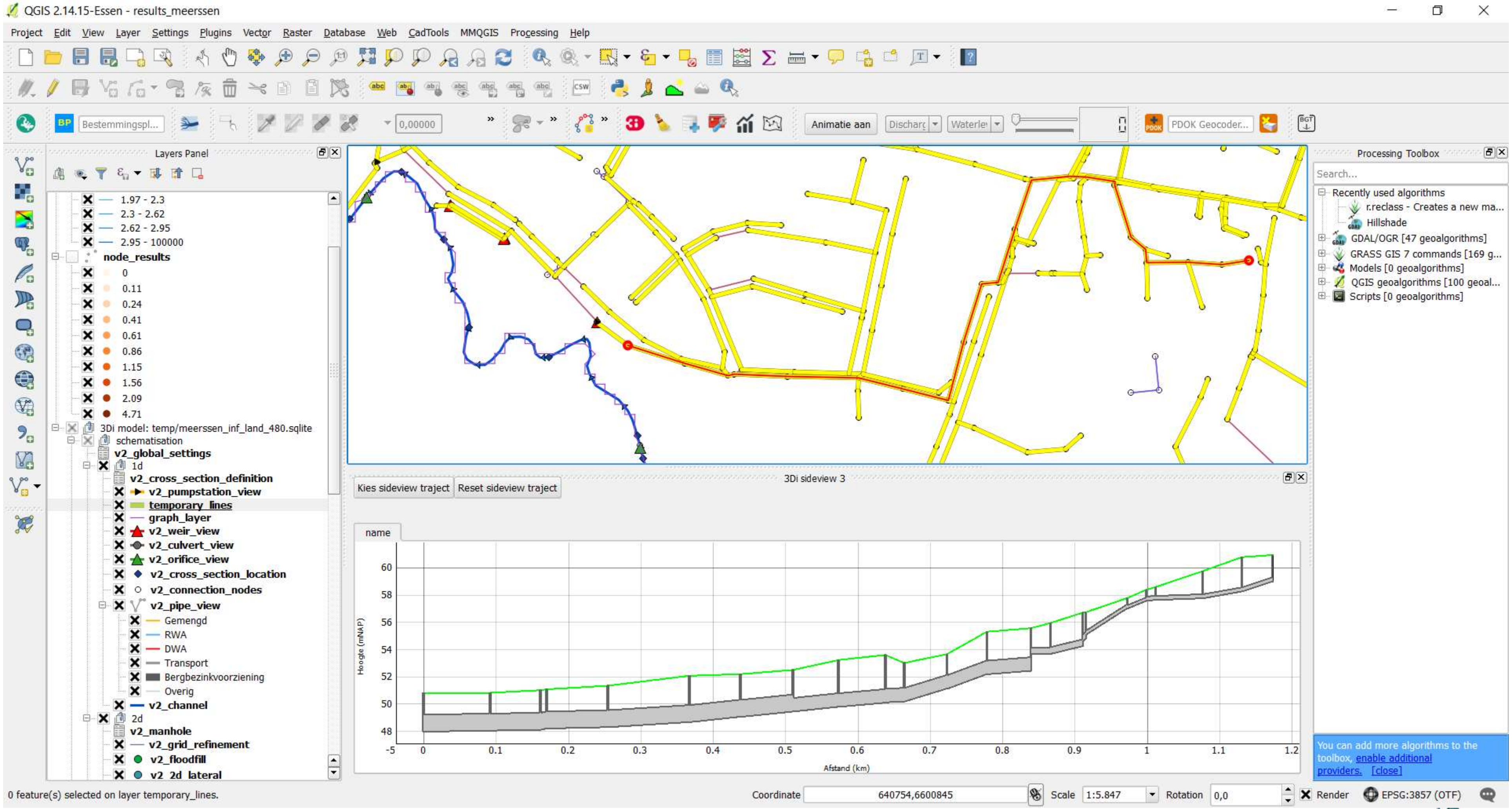


QGIS 2.14.15-Essen - results_meerssen
Project Edit View Layer Settings Plugins Vector Raster Database Web CadTools MMQGIS Processing Help
Layers Panel
node_results
3Di model: temp/meerssen_inf_land_480.sqlite
schematisation
v2_global_settings
v2_cross_section_definition
v2_pumpstation_view
temporary_lines
graph_layer
v2_weir_view
v2_culvert_view
v2_orifice_view
v2_cross_section_location
v2_connection_nodes
v2_pipe_view
Gemengd
RWA
DWA
Transport
Bergbezinkvoorziening
Overig
v2_channel
v2_manhole
v2_grid_refinement
v2_floodfill
v2_2d_lateral
3Di sideview 3
Kies sideview traject
Reset sideview traject
Hoogte (mmNAP)
Afstand (mm)
Processing Toolbox
Recently used algorithms
GDAL/OGR [47 geoalgorithms]
Models [0 geoalgorithms]
Scripts [0 geoalgorithms]
Coordinate 640135,6600994
Scale 1:5.847
Rotation 0,0
Render
EPSG:3857 (OTF)

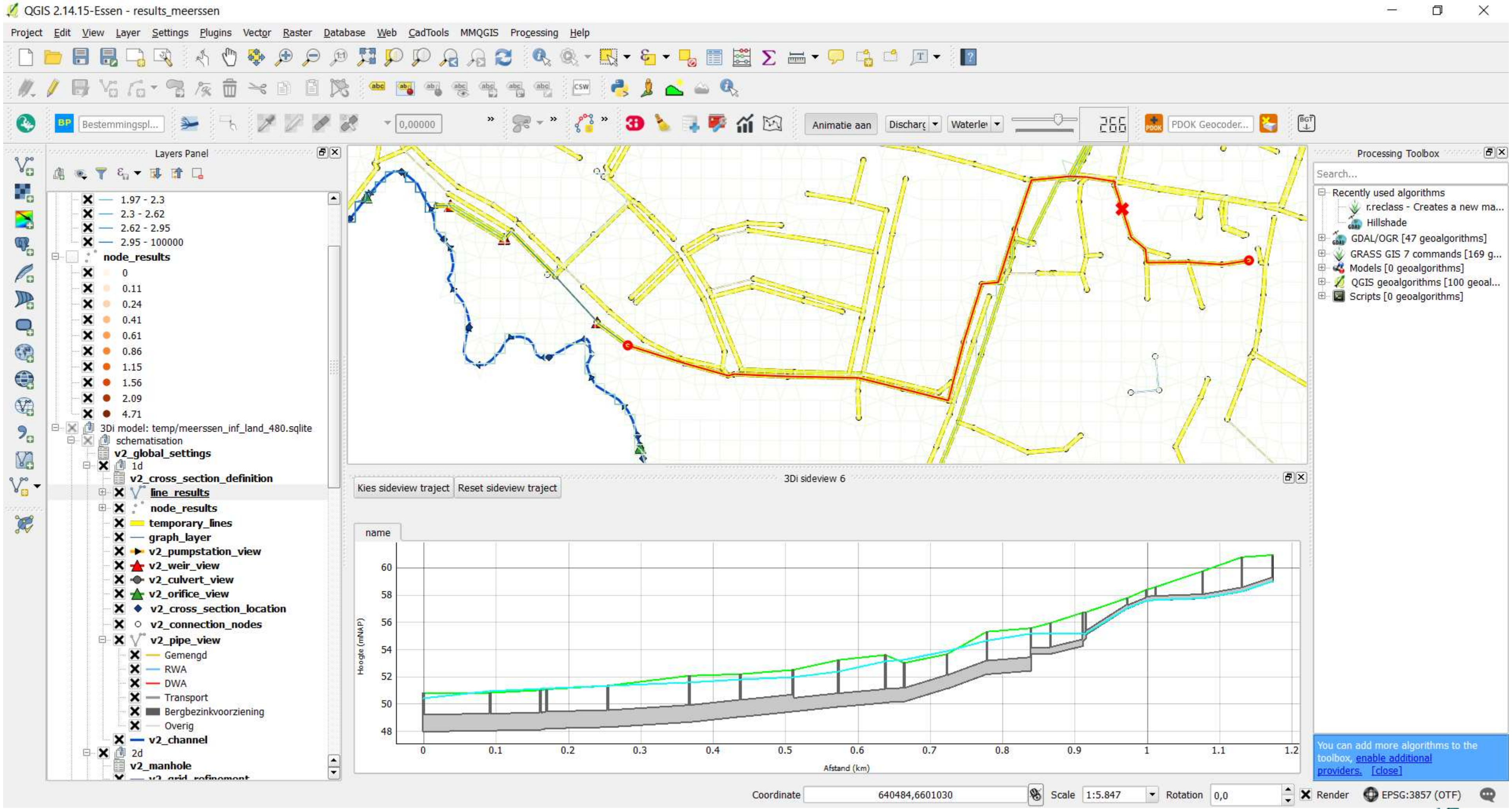
Sideview

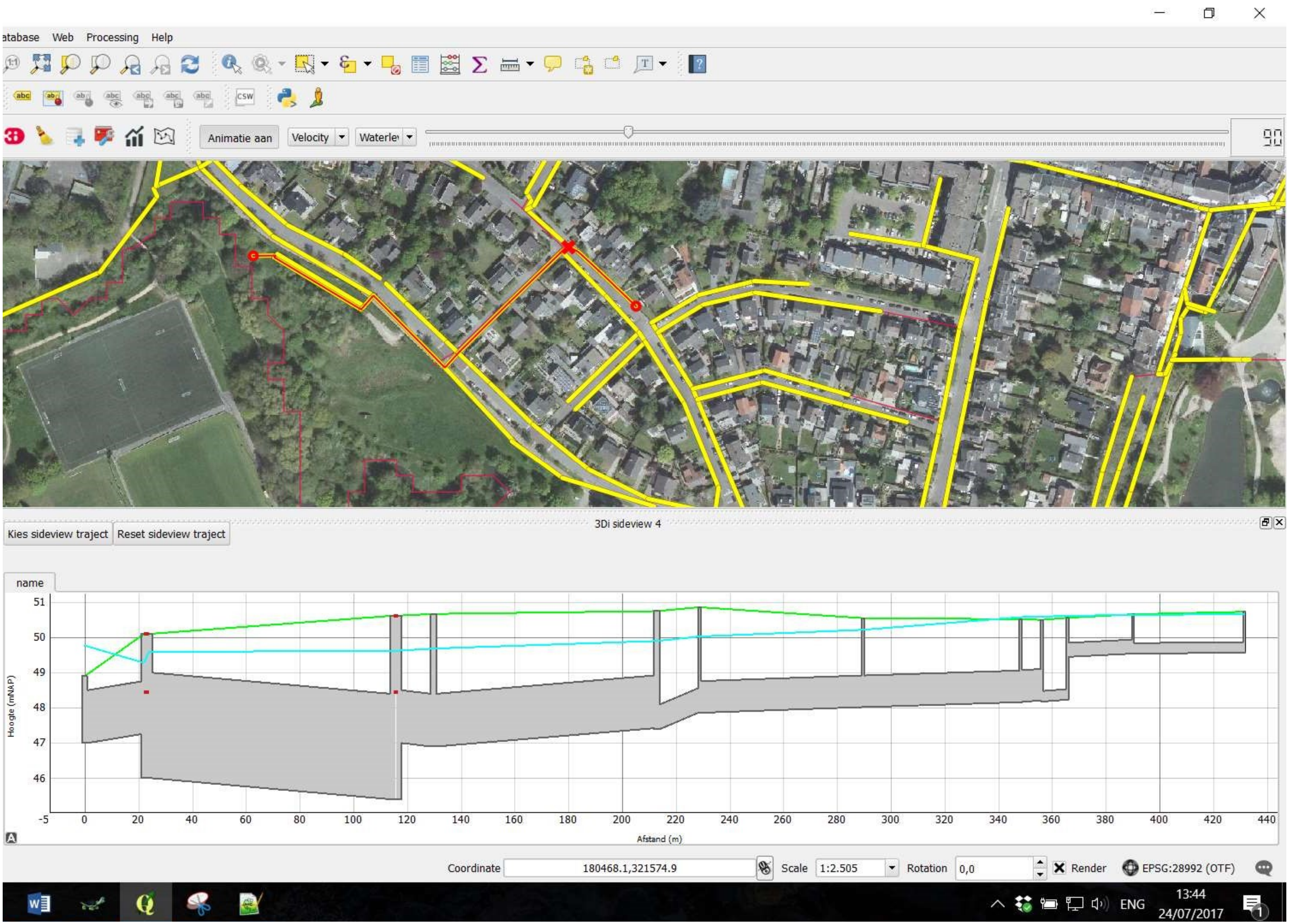

QGIS 2.14.15-Essen - results_meerssen
Project Edit View Layer Settings Plugins Vector Raster Database Web CadTools MMQGIS Processing Help
Layers Panel
node_results
3Di model: temp/meerssen_inf_land_480.sqlite
schematisation
v2_global_settings
v2_cross_section_definition
v2_pumpstation_view
temporary_lines
graph_layer
v2_weir_view
v2_culvert_view
v2_orifice_view
v2_cross_section_location
v2_connection_nodes
v2_pipe_view
Gemengd
RWA
DWA
Transport
Bergbezinkvoorziening
Overig
v2_channel
v2_manhole
v2_grid_refinement
v2_floodfill
v2_2d_lateral
Kies sideview traject
Reset sideview traject
3Di sideview 3
name
Hoogte (mNAP)
Afstand (km)
Processing Toolbox
Recently used algorithms
GDAL/OGR [47 geoalgorithms]
Models [0 geoalgorithms]
Scripts [0 geoalgorithms]
Animatie aan
PDOK Geocoder...
Coordinate 639743,6600538
Scale 1:5.847
Rotation 0,0
Render
EPSG:3857 (OTF)

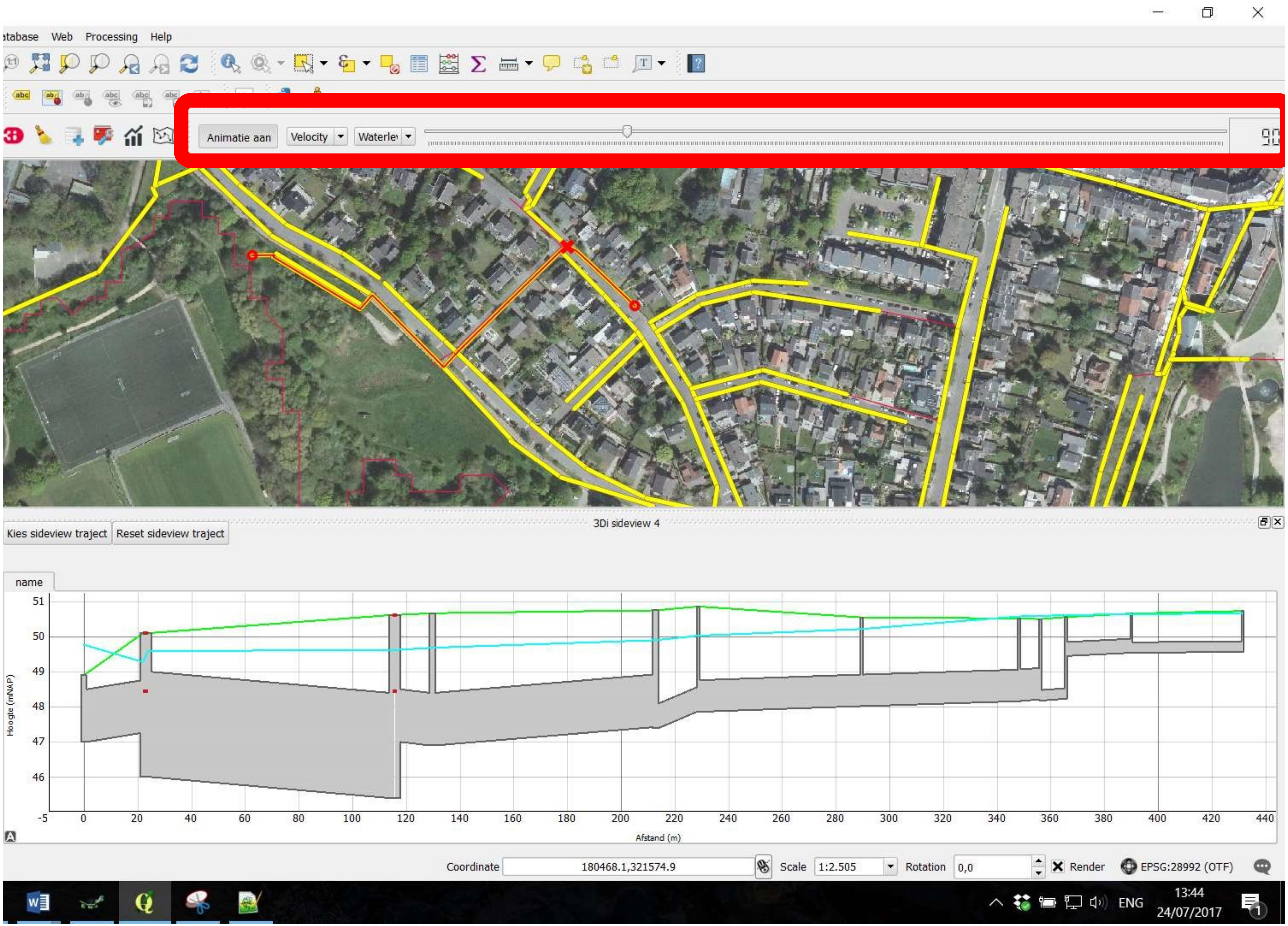
Sideview


QGIS 2.14.15-Essen - results_meerssen
Project Edit View Layer Settings Plugins Vector Raster Database Web CadTools MMQGIS Processing Help
Layers Panel
node_results
3Di model: temp/meerssen_inf_land_480.sqlite
schematisation
v2_global_settings
v2_cross_section_definition
v2_pumpstation_view
temporary_lines
graph_layer
v2_weir_view
v2_culvert_view
v2_orifice_view
v2_cross_section_location
v2_connection_nodes
v2_pipe_view
Gemengd
RWA
DWA
Transport
Bergbezinkvoorziening
Overig
v2_channel
v2_manhole
v2_grid_refinement
v2_floodfill
v2_2d_lateral
3Di sideview 3
Kies sideview traject
Reset sideview traject
Hoogte (mNAP)
Afstand (km)
Processing Toolbox
Recently used algorithms
GDAL/OGR [47 geoalgorithms]
Models [0 geoalgorithms]
Scripts [0 geoalgorithms]
0 feature(s) selected on layer temporary_lines.
Coordinate 640754,6600845
Scale 1:5.847
Rotation 0,0
Render
EPSG:3857 (OTF)

Sideview

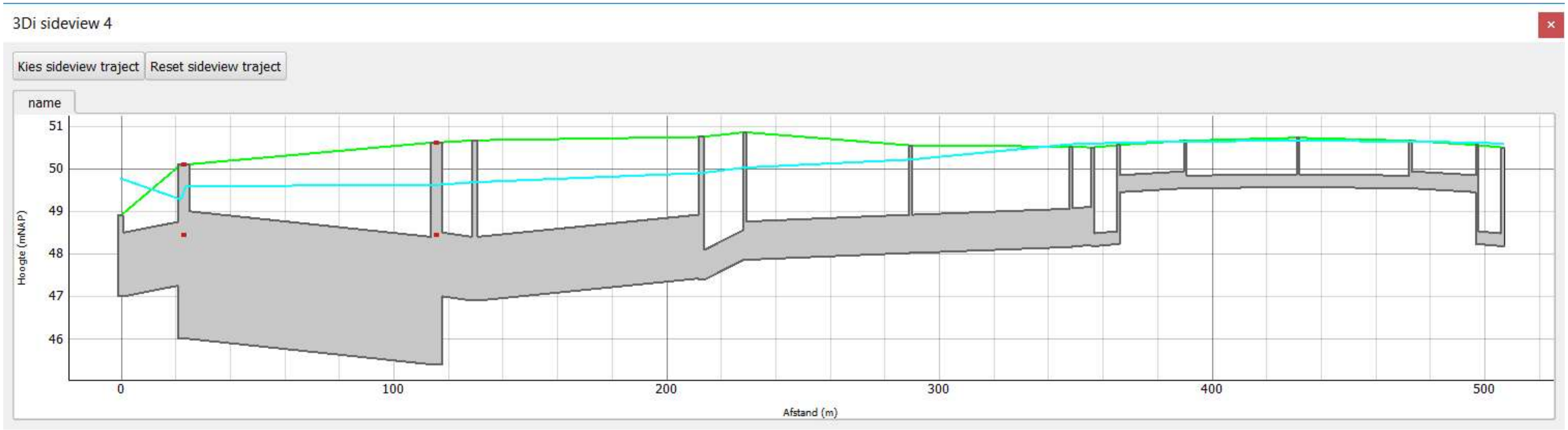

QGIS 2.14.15-Essen - results_meerssen
Project Edit View Layer Settings Plugins Vector Raster Database Web CadTools MMQGIS Processing Help
Layers Panel
1.97 - 2.3
2.3 - 2.62
2.62 - 2.95
2.95 - 100000
node_results
0
0.11
0.24
0.41
0.61
0.86
1.15
1.56
2.09
4.71
3Di model: temp/meerssen_inf_land_480.sqlite
schematisation
v2_global_settings
1d
v2_cross_section_definition
line_results
node_results
temporary_lines
graph_layer
v2_pumpstation_view
v2_weir_view
v2_culvert_view
v2_orifice_view
v2_cross_section_location
v2_connection_nodes
v2_pipe_view
Gemengd
RWA
DWA
Transport
Bergbezinkvoorziening
Overig
v2_channel
2d
v2_manhole
Animatie aan
PDOK Geocoder...
3Di sideview 6
Kies sideview traject
Reset sideview traject
name
Hoogte (mNAP)
Afstand (km)
Processing Toolbox
Search...
Recently used algorithms
r.reclass - Creates a new ma...
Hillshade
GDAL/OGR [47 geoalgorithms]
GRASS GIS 7 commands [169 g...
Models [0 geoalgorithms]
QGIS geoalgorithms [100 geoal...
Scripts [0 geoalgorithms]
You can add more algorithms to the toolbox, enable additional providers. [close]
Coordinate 640484,6601030
Scale 1:5.847
Rotation 0,0
Render
EPSG:3857 (OTF)


atabase Web Processing Help
Animatie aan
Velocity
Waterle
3Di sideview 4
Kies sideview traject
Reset sideview traject
name
Hoogte (mNAP)
Afstand (m)
51
50
49
48
47
46
-5 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440
Coordinate 180468.1,321574.9
Scale 1:2.505
Rotation 0,0
Render
EPSG:28992 (OTF)
ENG
13:44
24/07/2017



atabase Web Processing Help
Animatie aan
Velocity
Waterlev
Kies sideview traject
Reset sideview traject
3Di sideview 4
name
Hoogte (mNAP)
Afstand (m)
Coordinate 180468.1,321574.9
Scale 1:2.505
Rotation 0,0
Render
EPSG:28992 (OTF)
ENG
13:44
24/07/2017

Side view


3Di sideview 4
Kies sideview traject
Reset sideview traject
name
Hoogte (mNAP)
51
50
49
48
47
46
0
100
200
300
400
500
Afstand (m)

Questions?

- Jonas van Schrojenstein Lantman
- +31 6 82 07 32 84
- Jonas@nelen-schuurmans.nl
- @jonasvsl123

- More information:
- www.nelen-schuurmans.nl/en
- http://www.3di.nu/