# QGIS plugin Groundwater Vulnerability

This documentation describes the usage of the QGIS plugin *Groundwater Vulnerability*. Please refer to it at any times.

Groundwater vulnerability means the vulnerability of groundwater against contamination. Currently only the GLA method in included. The plugin will be extended with the methods DRASTIC, EPIK, GOD and PI.
The GLA method was introduced by HÖLTING et al. (1995) and considers the protective function of the cover above an aquifer. It distinguishes between the influence of the soil, unconsolidated and consolidated lithology as well as the annual percolation rate.
This plugin works with a scoring system, where a high score indicates a high protective function and vice versa. This means all input data are compared with predefined lookup values in order to set a certain score for each input data. After transferring the input data into scores, the protective function is calculated with the following equation:

$$P = \left( S + \left( \sum_{i=1}^{m} U_i \cdot T_i + \sum_{j=1}^{n} C_j \cdot T_j \right) \right) \cdot R + G_P + G_A$$

with

| | |
|---|---|
| P | protective function of the aquifer cover |
| S | available water capacity of the soil |
| U | lithology type of unconsolidated sediments beneath the soil |
| C | lithology type of consolidated rocks beneath the soil |
| T | thickness of each lithology layer beneath the soil $[m]$ |
| R | rate of percolating water |
| $G_P$ | perched groundwater |
| $G_A$ | artesian groundwater |
| i, j | continous numbering of geological layers. |

## Important notes

- Version 1.0 only supports TIFF-images.
- In order to avoid memory error, it is recommended to work with integer files. In most cases the spatial resolution is not high enough to display effects on a cm-scale.
- All input rasters *must* share the same geometry. This means, they have to cover the same area with the same spatial resolution, i. e. the number of rows and columns *must* be the same.
- The use of Nodata values is not fully supported. It is recommended to use a rectangular map extent, even if the shape of the study area is not rectangular. Then all values with no information are set to 0. This ensures, that the calculation does not fail.

## Input data

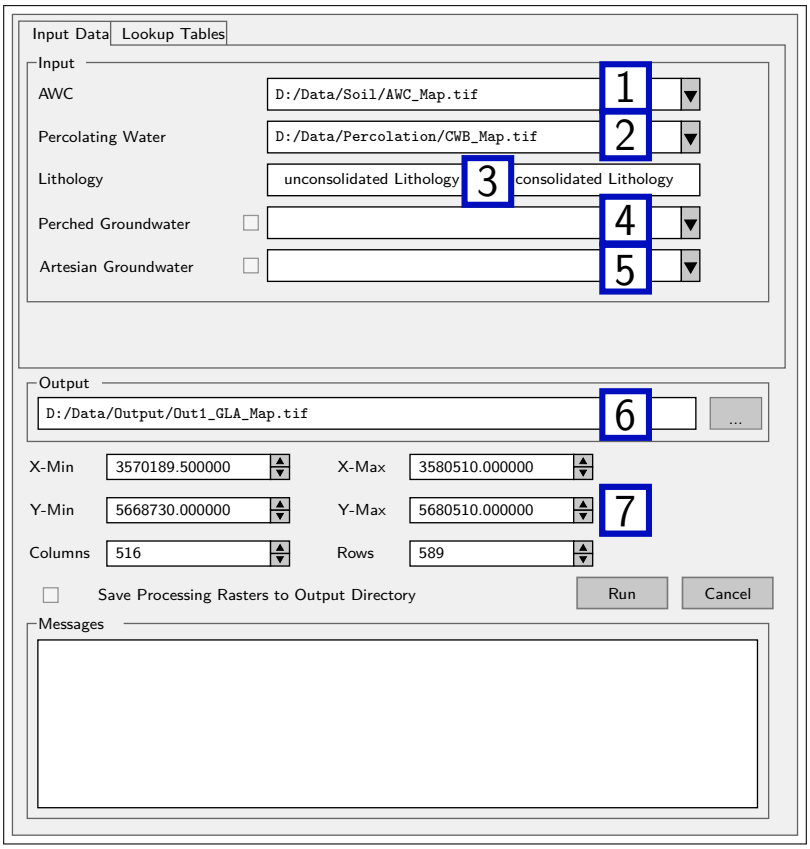


**Figure 1:** Interface to select input data.

### Field 1: Available water capacity

The available water capacity describes the amount of water in a soil that can be held against gravity and be available for growing crops. The GLA method includes the soil with a depth of 1 m. Thus the input data must have information about the AWC over a depth of 1 m. The plugin checks if the value of a pixel lies between a certain minimum and a certain maximum. *Example:* The total AWC at one location is given with 75 mm, therefore the score will be 50 points.

**Table 1:** Rating the soils according to their available water capacity (*AWC*) with a score for each interval.

| $\sum$ AWC [mm] to a depth of 1.0 m | | Score |
|---|---|---|
| Minimum | Maximum | |
| 0 | 50 | 10.0 |
| 50 | 90 | 50.0 |
| 90 | 140 | 125.0 |
| 140 | 200 | 250.0 |
| 200 | 250 | 500.0 |
| 250 | 99999 | 750.0 |

### Field 2: Percolation rate

The GLA method includes the percolation rate as either groundwater recharge or as climatic water balance. The input map shows the amount of water which is percolating from the surface to the top of the groundwater table.
The lookup table is set on the tab *Lookup Tables*. The user has to choose between *Groundwater Recharge* and *Climatic Water Balance*, the other table will be disabled by then. The GLA method recommends the use of GWR data. Therefore, this is selected by default.

### Field 3: Lithology

The lithology describes all geological layers from a depth of 1 m below the surface to the top of the water table or the potentiometric surface (in case of confined groundwater). It has to be

**Table 2:** Rating the amount of percolating water as groundwater recharge (*GWR*) with a score for each interval.

| GWR [mm/a] | | Score |
|---|---|---|
| Minimum | Maximum | |
| 0 | 100 | 1.75 |
| 100 | 200 | 1.50 |
| 200 | 300 | 1.25 |
| 300 | 400 | 1.00 |
| 400 | 99999 | 0.75 |

**Table 3:** Rating the amount of percolating water as climatic water balance (*CMB*) with a score for each interval.

| $N - ETP_{\text{pot.}}$ [mm/a] | | Score |
|---|---|---|
| Minimum | Maximum | |
| 0 | 100 | 1.50 |
| 100 | 200 | 1.25 |
| 200 | 300 | 1.00 |
| 300 | 400 | 0.75 |
| 400 | 99999 | 0.50 |

differed between *unconsolidated* and *consolidated* rocks. The lithology files are loaded as isopach maps for each petrography.

## Unconsolidated lithology

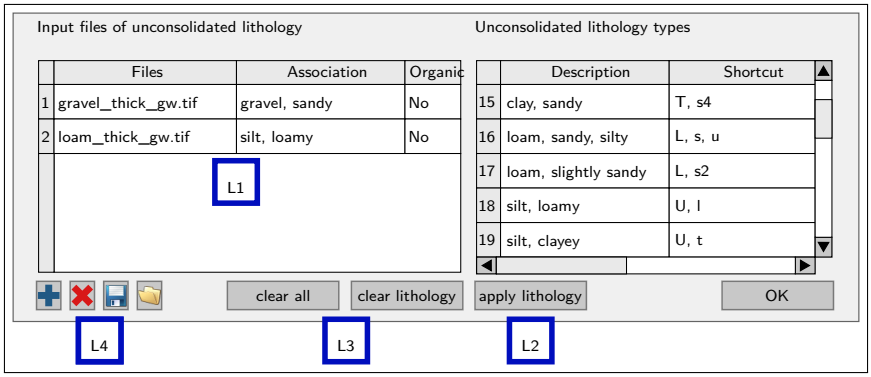


**Figure 2:** Interface to select input data.

The window to manage unconsolidated lithology features is divided in two parts. The left part handles all files to be loaded into the plugin (L1). The right part provides the lookup values.
Load lithology files by clicking the *Add* button (L4) .
Inside the browser search for the directory of interest and select all necessary input files. **Note:** Currently only TIFF-images are supported.
Each lithology file must be connected to a proper lithology description from the lookup table. The first click is on the lithology description, the second click is on the lithology file. The current selection is applied by clicking on the button *apply lithology* (L2).
If a single lithology association must be reset, the button *clear lithology* (L3)empties the selected line. The button *clear all* empties the whole list. A click on the OK button finishes the association.
By clicking on the save button the current lithology description can be saved to a text file. By clicking on the load button the current lithology description can be loaded from a text file.

### Consolidated lithology

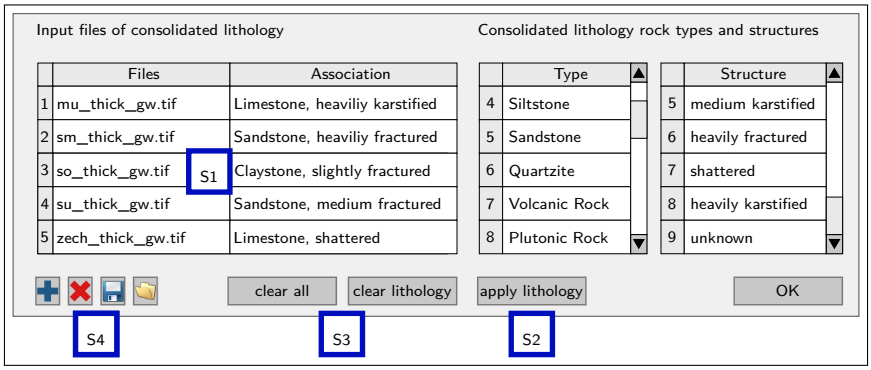


**Figure 3:** Interface to select input data.

The window to manage unconsolidated lithology features is divided in two parts. The left part handles all files to be loaded into the plugin (S1). The right part provides the lookup values.
Load lithology files by clicking the *Add* button (S4) .
Inside the browser search for the directory of interest and select all necessary input files. **Note:** Currently only tiff-images are supported.
Each lithology file with must be connected to a proper lithology description from the lookup table. The first two clicks are on the lithology descriptions (type & structure), the third click is on the lithology file. The current selection is applied by clicking on the button *apply lithology* (S2).
If a single lithology association must be reset, the button *clear lithology* (S3) empties the selected line. The button *clear all* empties the whole list. A click on the OK button finishes the association.
By clicking on the save button the current lithology description can be saved to a text file. By clicking on the load button the current lithology description can be loaded from a text file.

### Fields 4 & 5: Perched & artesian groundwater

The existence of *perched* and *artesian groundwater* is an effect of layers with extremely low hydraulic conductivities. Due to the fact that both do not occur frequently, their input is optional. The input field is unlocked, when activating the check box.
Working with perched or artesian groundwater does not require any look-up tables. The map only includes the information if the groundwater in an area is perched/artesian or not. Therefore a binary code of 1 (*perched*/*artesian*) or 0 (*not perched*/*not artesian*) is used.

### Field 6: Output

The output image is saved to the specified directory. **Note:** Currently only tiff-images are supported. The processing files can be saved separately. This includes scored AWC, percolation and lithology maps, which are saved to a subdirectory. The subdirectory is created automatically inside of the output directory. It must be deleted manually if saving to the same folder again.

### Field 7: Geometry

These fields allow to change the geometry of the output image. They will be filled with default values, taken from the AWC raster.

## Lookup tables

The plugin uses predefined lookup tables in form of CSV-files. It is not recommended to change any of them as they contain the default GLA values. However, local conditions may require a customization of the score function. For this case the user may change the default lookup directory to a target directory with customized lookup tables.
As for now, the plugin scans the lookup directory for files with predefined names. If the user creates customized lookup tables, they should be named in the same way like the default lookup tables. *Example:* the default lookup table *FC.csv* needs to be customized. Therefore, a new CSV-file with the name *FC.csv* is created in another directory, which is to select within the plugin.

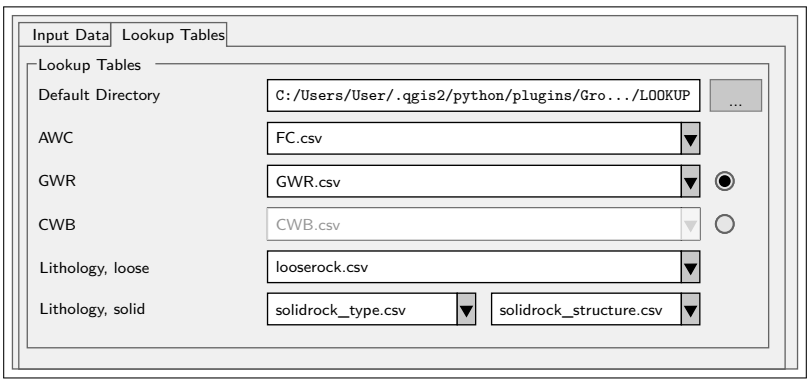


**Figure 4:** Interface to manage lookup tables.

## Future Development

The following points are planned for a future version of this plugin:

- Write and save a report file, containing statistics about the input and output data
- Provide automated creation of histograms
- Enable the input of float values
- Provide more flexibility with lookup tables
- Introduce a function to adjust the GLA formula
- Include Nodata values
- Read and write shape files.
- Also include the methods DRASTIC, GOD, EPIK and PI
- Support other raster formats
- Implement another calculation model to allow a different number of rows and columns of the input files

## References

HÖLTING, B.; HAERTLÉ, T.; HOHBERGER, K.-H.; NACHTIGALL, K. H.; VILLINGER, E.; WEINZIERL, W.; WROBEL, J.-P. (1995): Konzept zur Ermittlung der Schutzfunktion der Grundwasserüberdeckung. – Geol. Jb., C63: 5 – 24, 5 Tab.; Hannover.