

## D3.2 The SWS Toolkit





**Title:** The SWS Toolkit

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## Executive Summary

Task 3.2 attempts to develop a hydro-technical SWS decision support toolkit that will guide the choice and initial design of appropriate SWS solutions of practitioners, SMEs, policy makers and research organisations. Towards this direction, the SUBSOL Toolkit provides a series of online and open tools for developing, placing and modelling new SWS solutions.

Specifically, three levels of detail have been envisaged, depending on data availability of the end user: (i) high level assessment based on multicriteria analysis leading to initial design choices for SWS systems (ii) medium level assessment based on GIS/spatial analysis using risk based, spatial multicriteria techniques leading to locating SWS options and (iii) detailed assessment using advanced density dependent and geochemical groundwater modelling, using Open Source tools, models and algorithms coupled with GIS, leading to initial design as well as real-time evaluation and optimization of different operational modes of the SWS systems.

The SWS toolkit has been developed by the consortium and is up and running in the common landing page of all web applications, which is the Online SWS Platform under the URL: <http://subsol-data.euprojects.net/>.

The high level assessment of SWS systems, as described in section 2, is supported by the functionality integrated within the **SUBSOL Knowledge Environment (SUBSOL KE)**. The user is able to use simple and advanced search options to identify those SWS measures that fit best to the specified criteria.

The **Location Identification Tool**, introduced in section 3, has been developed to support the medium level assessment. It is a GIS-based screening tool that scans an area for locations suitable for applying subsurface water solutions, performing spatial operations on layers that describe the topographical and hydrogeological conditions of the study area.

With regard to the detailed assessment, an application has been developed in support of data managers responsible for small and large monitoring networks of the pilot areas, as described in section 4. The **SUBSOL Data Monitoring System** is a versatile and portable web application that is capable to collect in near real time environmental data from several stations, combine measurements into expressions, display historical time series using charts and other widgets and issue warnings and alerts if needed.

Finally, several other **tools, products** and **services** are described in the present report, supporting the stakeholders in performing detailed assessment of SWS systems, as described in section 5.

## 1 Introduction

Task 3.2 of the SUBSOL project results to the development of a hydro-technical SWS decision support Toolkit. According to the DoW, the Toolkit will:

*guide the choice and initial design of appropriate SWS solutions including monitoring and control systems for the specific problem at hand. This involves the application of hydrogeological investigations such as determination of hydraulic parameters, borehole logging, groundwater/geochemical modelling and location of monitoring wells. The user will be guided, using context-based filters, through the steps of selecting suitable SWS solution configurations that comply with the specific constraints of their case (hydraulic and geochemical characteristics), which often differ between single porosity (sand) and dual porosity systems (e.g. fractured carbonates and Karst). The technology choices will be associated with achieving specific criteria/objectives, defined by the user, depending on the geological and climatological setting and will be supported by advanced multi-criteria analysis. Depending on the data available to the user, the toolkit will support the provision of key subsurface and surface technical figures (e.g. initial design specifications, costs or locations if GIS data are available) at a prefeasibility level for the preferred options and provide an initial risk assessment.*

*Specifically, three levels of detail are envisaged, depending on data available to the end user: (i) high level assessment based on multicriteria analysis leading to initial design choices for SWS systems (ii) medium level assessment based on GIS/spatial analysis using risk based, spatial multicriteria techniques leading to locating SWS options and (iii) detailed assessment using advanced density dependent and geochemical groundwater modelling, using Open Source tools, models and algorithms coupled with GIS, leading to initial design as well as real-time evaluation and optimization of different operational modes of the SWS systems.*

The Toolkit in its initial version has been developed by the consortium and is up and running under the URL:

<http://subsol-data.euprojects.net/>

This is the common landing page of all web applications developed under the **SUBSOL Knowledge Environment (SUBSOL KE)**.

The high level assessment of SWS systems is supported by the functionality integrated within the SUBSOL KE. The user is able to use simple and advanced search options to identify those SWS measures that fit best to the specified criteria as described in section 2.



The **Location Identification Tool**, introduced in section 3, has been developed to support the medium level assessment. It is a GIS-based screening tool that scans an area for locations suitable for applying subsurface water solutions, performing spatial operations on layers that describe the topographical and hydrogeological conditions of the study area.

In section 4, an application is described which has been developed in support of data managers responsible for small and large monitoring networks of the pilot areas. The **SUBSOL Data Monitoring System** is a versatile and portable web application that is capable to collect in near real time environmental data from several stations, combine measurements into expressions, display historical time series using charts and other widgets and issue warnings and alerts if needed.

Finally, several other **tools, products** and **services** are available, supporting the stakeholders in performing detailed assessment of SWS systems, as described in section 5. The SUBSOL KE has collected information on these items and provides the means for the stakeholders to select the suitable ones. This repository will be constantly enhanced with additional tools, products and services in the next phase of the project.

## 2 Search for measures using the SUBSOL KE

As a first step of the high level assessment, leading to initial design choices for SWS systems, a new innovative approach has been developed which queries the Knowledge Base and filters out measures that fulfil certain user-defined criteria. At the same time this approach supports exploratory search combining querying and browsing activities.

### 2.1 Main concept

Search mechanisms are a common way to explore the content of a Knowledge Base. One possibility is full text search using approximate string matching algorithms (based on Levenshtein, 1965), capable to identifying certain keywords in the descriptive part on the KB. The SUBSOL KE uses approximate matching methods capable to track down specific measures, as described in the deliverable D3.1 (SUBSOL D3.1). Other advanced search possibilities take advantage of the database structure to narrow down the search based on a list of criteria or filters. This list, as well as the possible choices for each filter are usually limited to a few ones and are predefined by the developers of the system.

In this project, a new and innovative approach has been developed and tested in the SUBSOL KE, enabling the user to formulate complex queries involving any data category, including SWS Measures, Products and Services, Case studies and Projects. The complexity of the query is theoretically not limited by the number or the scope of data categories or attributes. The user is guided by a simple to use user interface that allows the formulation of complex queries without prior knowledge of a query language. The selections made by the user are automatically translated to the Django query language and submitted to the server. The server processes the requests and transmits back the results which are shown on the screen of the user without noticeable delay for the vast majority of queries and without the need to reload the page, achieved by the use of Ajax technique. Figure 1 shows the components and the main technologies involved in a query call between the front and the back-end of the system.

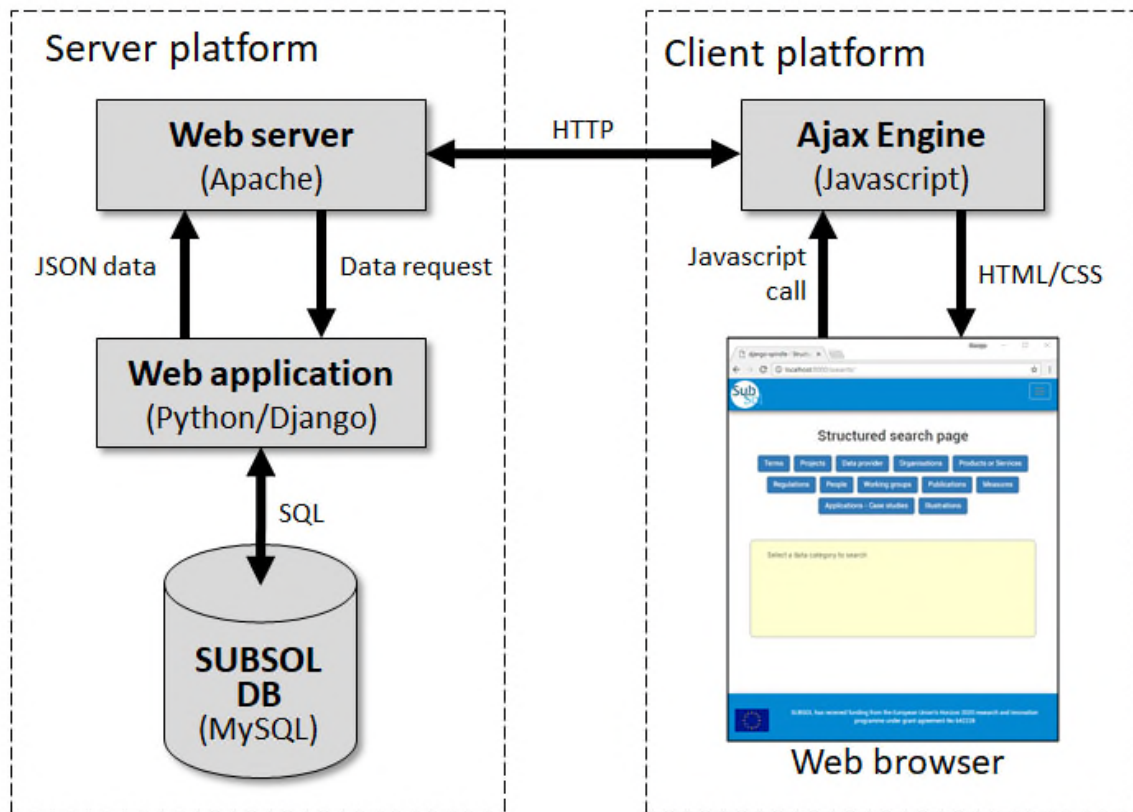


Figure 1: Main components and technologies involved in a query call

The new approach is based on introspection of the underlying database structure and therefore it can be applied to any given relational database, without the need to develop custom query forms. At the same time modifications of the database structure are automatically adopted. Elements of a database which are integrated in the user interface are the following:

- **Database tables**, represented by “*Models*” by the ORM<sup>1</sup> of the Django programming language
- **Table columns** (Object attributes)
- **Relationships** of any kind (one-to-many, many-to-many, one-to-one)

<sup>1</sup> ORM: Object Relational Mapper. Django: <https://www.djangoproject.com/>

Figure 2 depicts an excerpt of the ER-diagram representing part of the Conceptual Data Model.

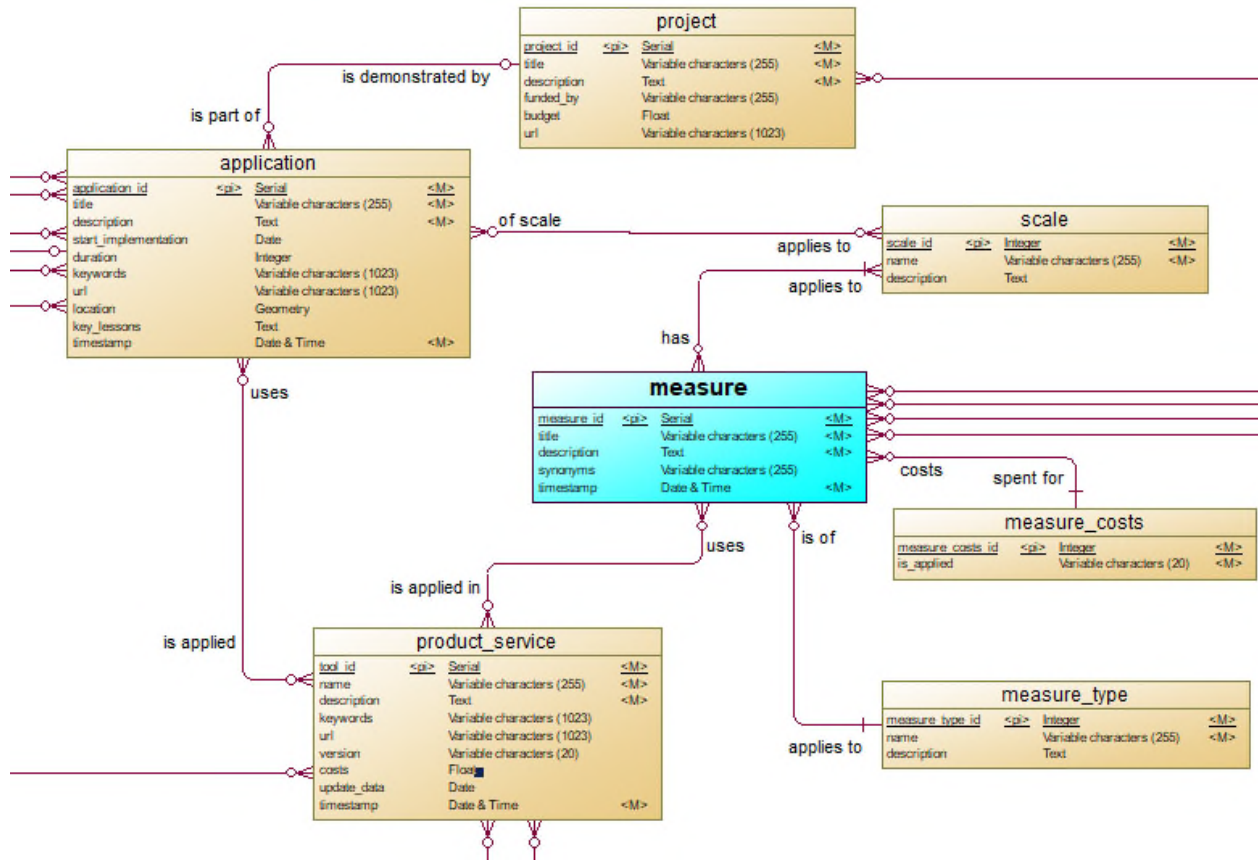


Figure 2: Part of the Conceptual Data Model of SUBSOL KB

## 2.2 User interface

The structured search page appears when the user selects *Search/Advanced search* from the main menu of the application. The initial page shows all data categories represented by a button on the upper part of the screen. The left pane displays useful information about the usage of the tool or a human readable formulation of the query and the corresponding number of retrieved records (Figure 3 and Figure 4).

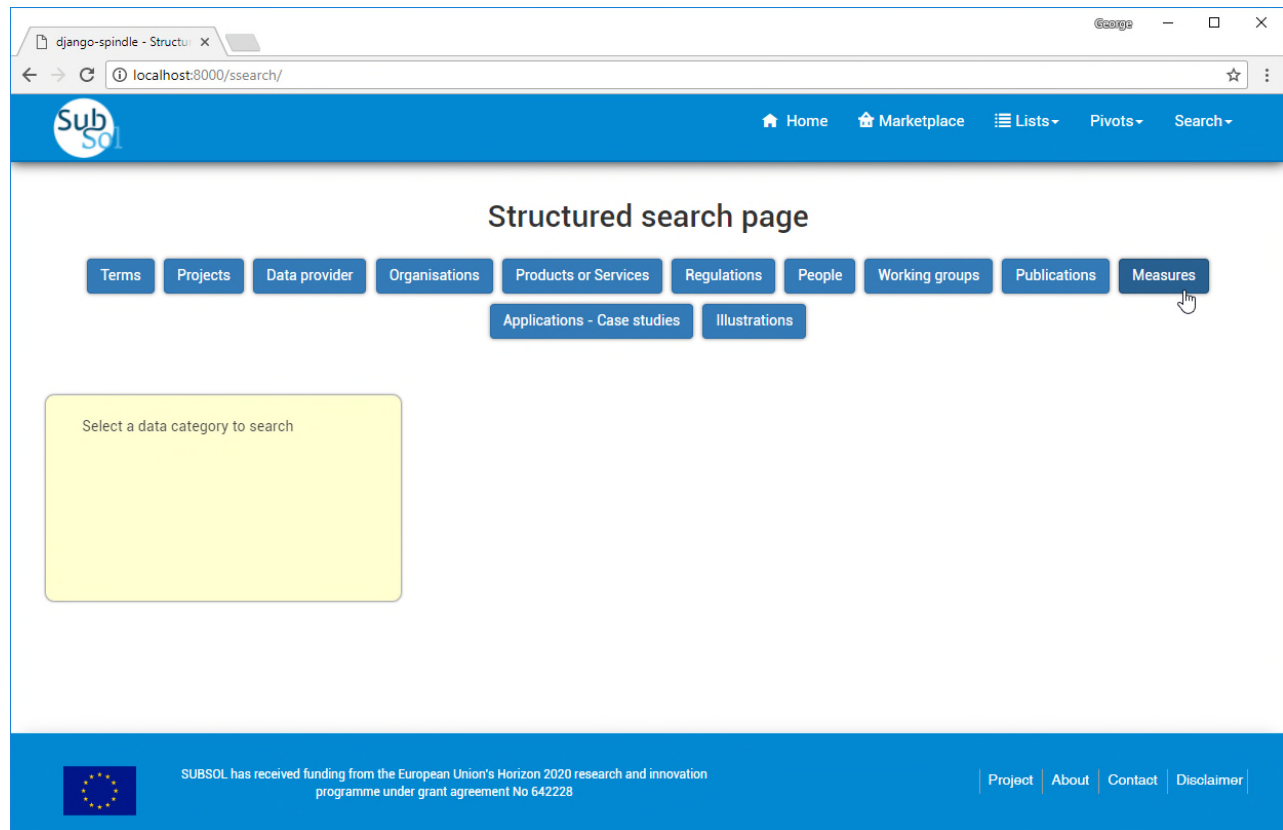


Figure 3: Structured search page – Initial view

Upon clicking with the mouse on a button, a pane appears below including input fields for all attributes of the related data category (class).

The user may specify criteria which are checked against the records stored in the database. The values to be given depend on the data type of the fields and have the following interpretation:

- **Integer** and **real** fields: A numerical upper and/or lower threshold is expected
- **String** fields: A sequence of characters may be given for which the system performs a case-insensitive containment test (similar to *LIKE* SQL statements)
- **Date** fields: A time period may be given
- **List** fields: A pull-down menu lists a number of possible values from which only one can be selected

When a value is specified or changed in any one of the fields, the system performs on-the-fly a check against the records stored in the database and displays on the left pane the number of records that match the actual criteria. At the same time, a human readable interpretation of the query is formulated and displayed (see Figure 4).

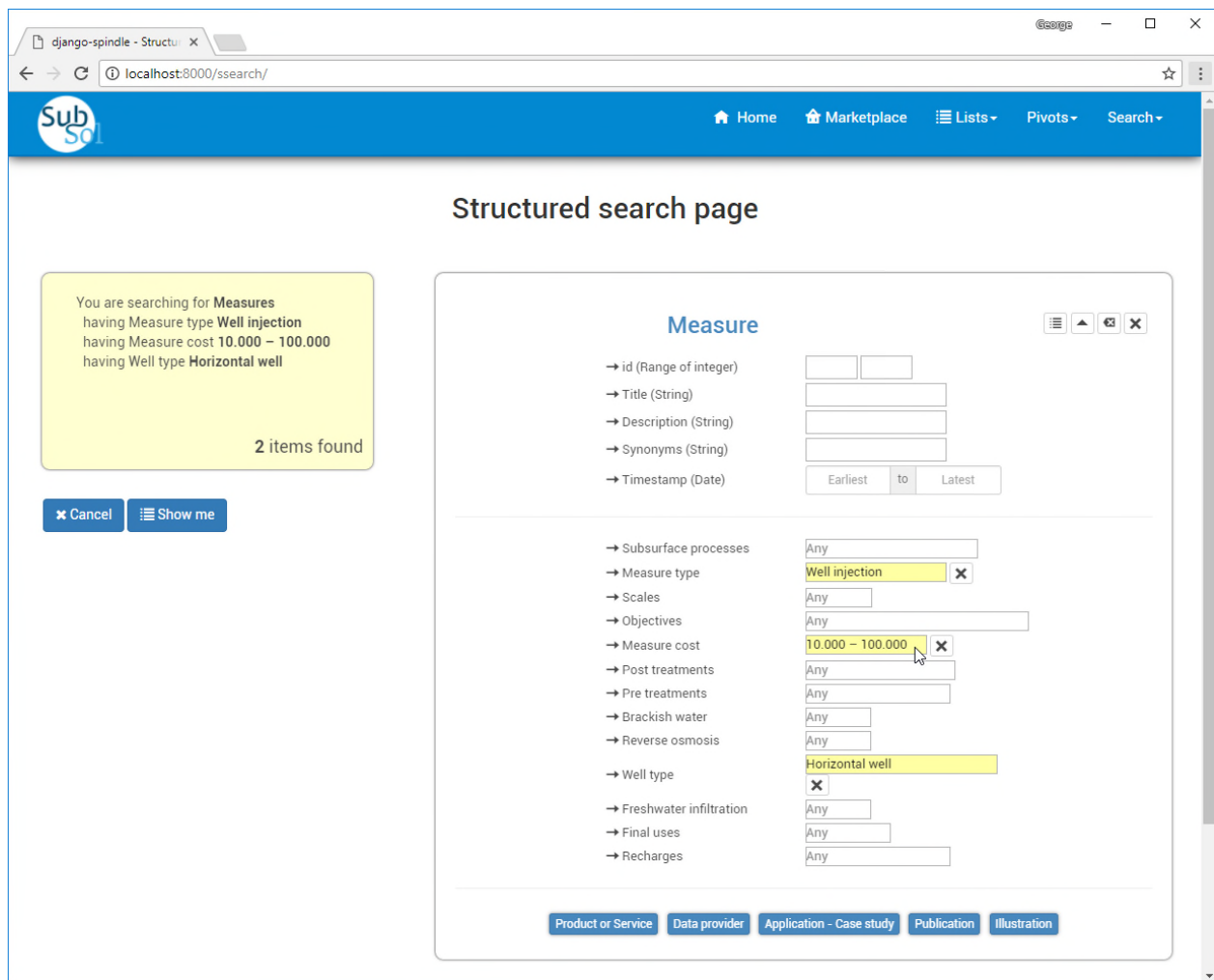







Figure 4: Structured search – Specification of criteria

At the top-right corner of the attributes pane a number of icons appear representing the following functionality:

-  List all records of this data category
-  Shrink this pane
-  Expand this pane
-  Clear all fields of this pane
-  Delete this pane (and all subordinate panes) removing all related criteria

At the bottom of the pane a number of buttons appear representing possible relationships of this class to other classes (data categories). By clicking on a button the attributes pane of the selected data category appears below the former one (i.e. the parent data category). At the same time the parent pane is shrunk to a single line, but can be expanded again at any time by clicking on the Expand icon. This way queries can be formulated which span across several related data categories in a way similar to which SQL statements JOIN database tables. Figure 5 illustrates the structured search page while formulating a query that spans across the data categories Measure and Application/Case study, i.e. a selection of measures which have been applied in case studies.

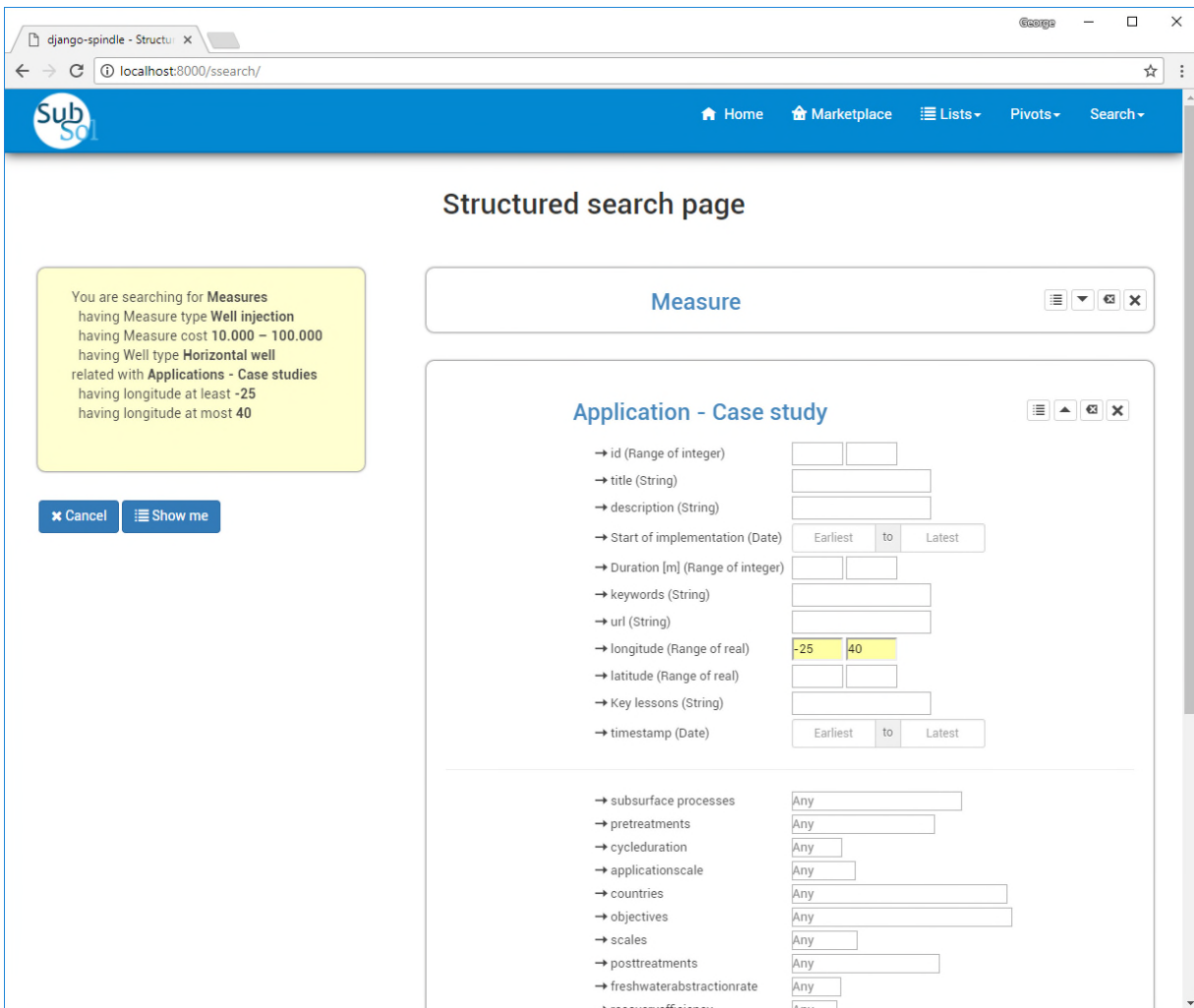


Figure 5: Structured search – Formulating queries that span across multiple data categories

At any time the user can press the button *Show me* to be navigated to the list of records that match the actual criteria as shown in the example of resulting Measures in Figure 6.



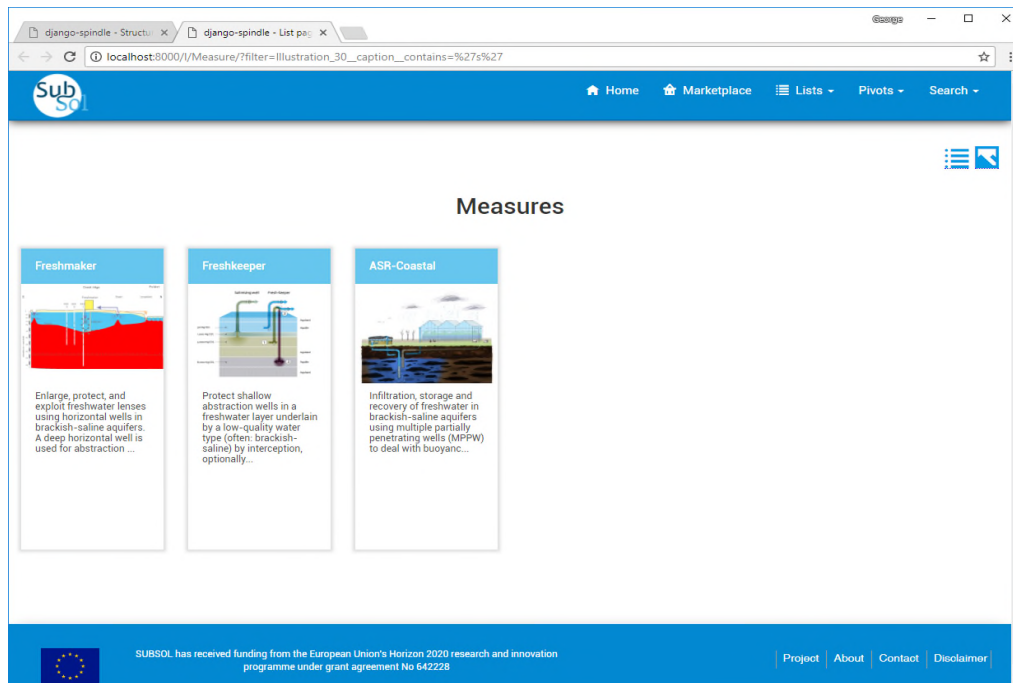


Figure 6: List of selected Measures (pictures view)

An alternative view of the resulting records is shown in Figure 7. Users can switch between views by clicking on the respective icons on the top-right corner.

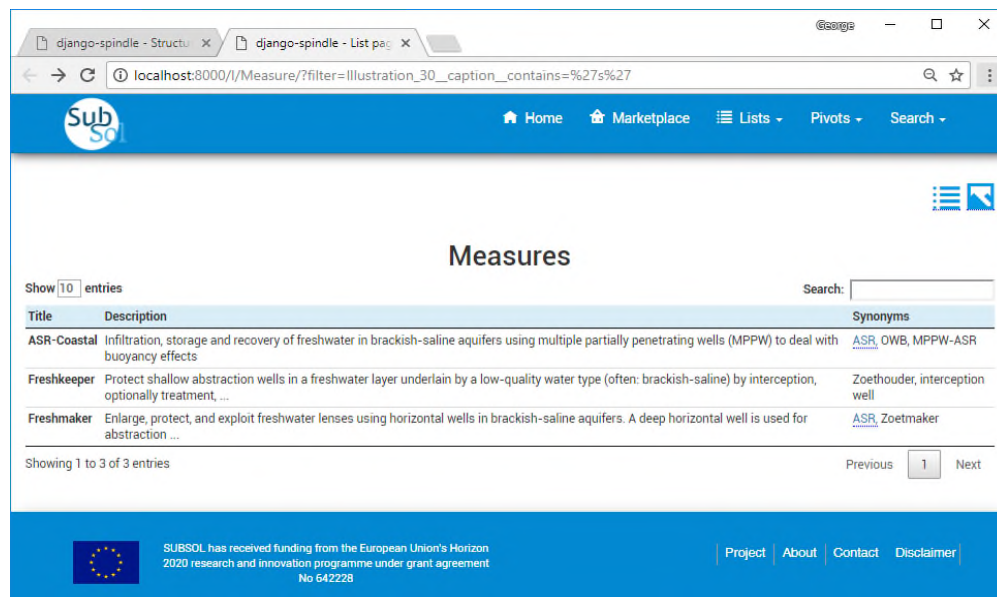


Figure 7: List of selected Measures (list view)

By clicking on a row (list view) or a picture (picture view) the user is navigated to the detail page of the specific item (see Figure 8).

The screenshot shows a web browser window with the URL `localhost:8000/d/Measure/4`. The page title is "Measure: Freshkeeper". The diagram illustrates a well system with a "Salinising well" and a "Fresh Keeper" well. The salinising well is shown with a green pipe and a yellow plume, while the Fresh Keeper well has a blue pipe and a blue plume. The diagram shows a cross-section of the ground with layers labeled "Aquifer" and "Aquitard". Concentration levels (C/L) are indicated: 30 mg C/L, 1,000 mg C/L, 3,000 mg C/L, and 8,000 mg C/L. The Fresh Keeper well is shown with three numbered points (1, 2, 3) indicating its depth and function. Below the diagram, the page contains the following sections:

- Description:** Protect shallow abstraction wells in a freshwater layer underlain by a low-quality water type (often: brackish-saline) by interception, optionally treatment, and re-injection of upconing low-quality water.
- Related Links:** Freshwater Infiltrations (always)
- Data Provider:** Koen Zuurbier
- Well Types:** Multiple partially penetrating well (MPPWs)
- Measure Types:** Other
- Title:** Freshkeeper
- Synonyms:** Zoethouder, interception well
- Timestamp:** 2017-08-22 08:03:05+00:00

Figure 8: Detail page

### 3 The Location Identification Tool

#### 3.1 Introduction

This tool implements the quick feasibility scheme given in the deliverables D1.1-1.3: *Technical and Economical guides*. Currently, only two feasibility schemes are implemented (regarding the freshmaker and freshkeeper aquifer management techniques), but the tool can be easily modified to implement other schemes too. The tool helps to scan an area to identify locations that can be suitable for applying a subsurface water solution (this can be any one of Freshmaker/keeper and ASR). To do so, spatial information regarding the topographical and hydrogeological conditions of the study area should be provided. This information is summarized in the following table.

Table 1: Required geographic layers

Name	Data model	Geometry	File type
DTM	raster	-	tiff
Water level	vector	point	csv
Coastline <sup>1</sup>	vector	polyline	kml
Lens width <sup>2</sup>	vector	polygon	kml
Lens thickness <sup>2</sup>	vector	polygon	kml
Aquifer bottom	vector	point	csv
Restricted	vector	polygon	kml
Secure	vector	polygon	kml
Power	vector	point	kml
Aerial	image	-	png

<sup>1</sup> only for Freshkeeper projects

<sup>2</sup> only for Freshmaker projects

The tool has two tabs. The first tab is for providing the spatial info presented in table 1 (Figure 9). Having provided all the required information the tool is ready to perform a spatial analysis.

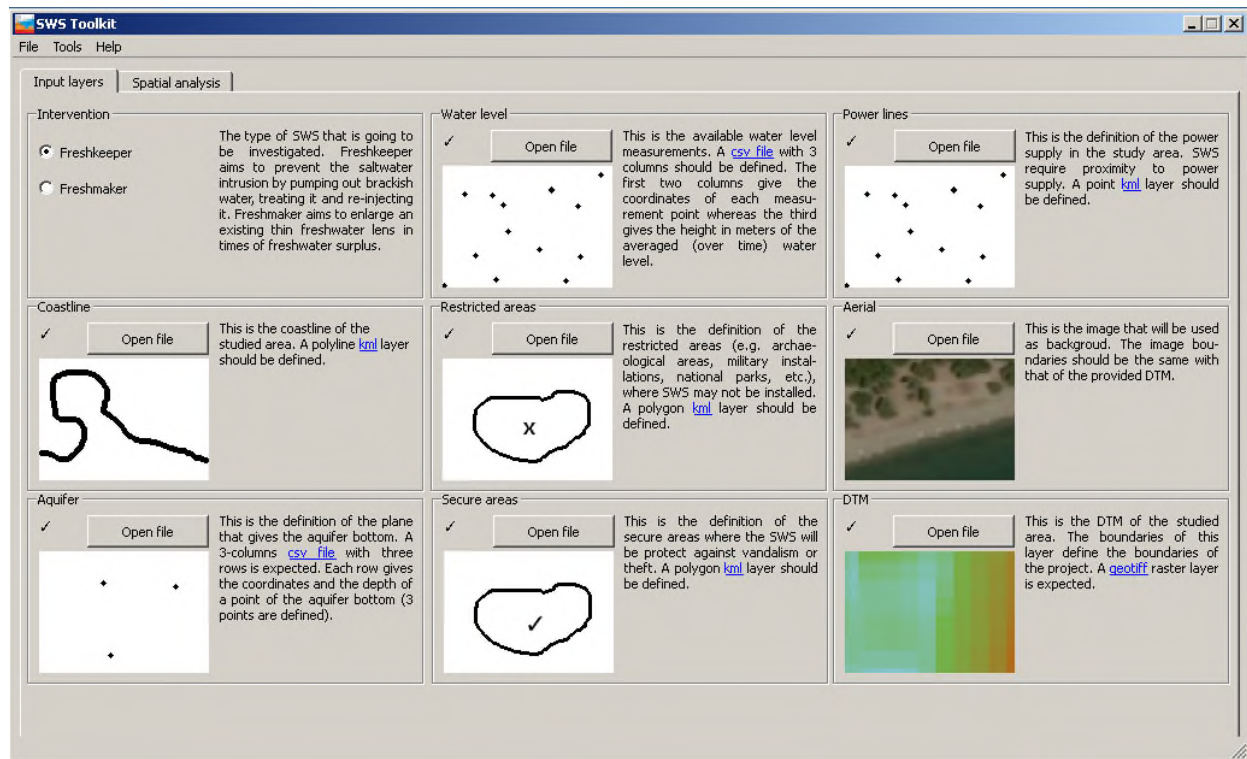


Figure 9: Definition of spatial info

The second tab of the tool is for inspecting the spatial information given in the first tab (DTM, water level, aquifer depth, distance from coast, distance from power supply, restricted areas and secure areas) and for displaying the results of the spatial analysis (Figure 10). For example, the user can examine which areas are more suitable for installing the pumping or injecting boreholes for different values of parameters (the map is updated with the selection of parameter values from a slide-bar). Finally, the user can export the results of the analysis to a kml format that can be opened in Google Earth for a further inspection.

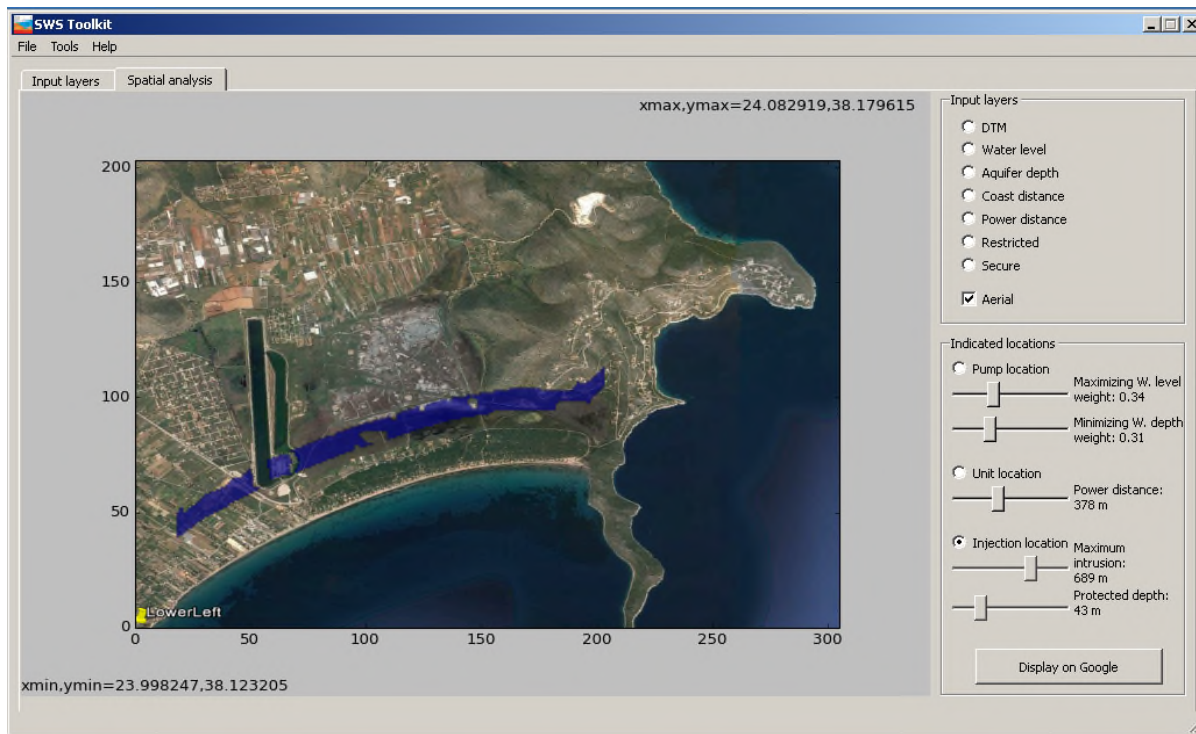


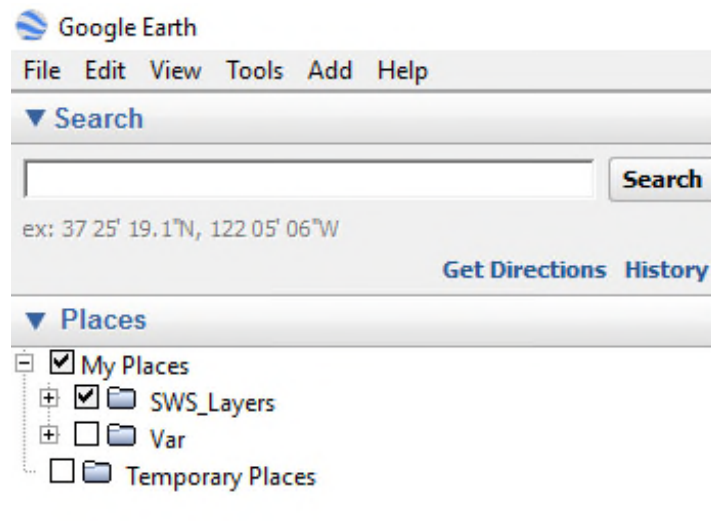
Figure 10: Spatial analysis

## 3.2 Required Spatial information

### 3.2.1 Definition of the study area

The definition of the study area requires the determination of two kml point layers that support the preparation of DTM and Aerial layers. Google Earth can be used to define these layers as follows:

1. Start Google Earth and add a folder (right click → select Add → select Folder) to “My Places” (in the “Places” of the left sidebar) that will keep all layers of the project (name it, for example, SWS\_Layers)



2. Right click on SWS\_Layers → Add → Placemark
3. Name it: “LowerLeft”
4. Move the placemark to the lower-left corner of the project or, if available, give the coordinates.
5. Right click on the mark of LowerLeft created in SWS\_Layers, select Save Place As..., select Save as type: kml, save the layer.
6. Repeat the steps 2 to 5 for the upper-right corner of the project (name it UpperRight).

### 3.2.2 DTM

DTMs can be obtained for EU study areas from the “Digital Elevation Model over Europe” of EEA<sup>2</sup>, available at: <http://www.eea.europa.eu/data-and-maps/data/eu-dem#tab-original-data>.

The EEA website offers the DTM of the whole EU in a single file (eudem\_dem\_4258\_europe.tif), which however is 19.1 GB. To facilitate the download, EEA has cut this large dataset into chunks of 5 degrees (558 MB), each one covering a different EU area.

The projection of the datasets provided by EEA is ETRS89 (EPSG:4258). However, all spatial data used in SWS Toolkit need to be in WGS84 (EPSG:4326). For this reason the downloaded raster from EEA needs to be re-projected and clipped to the study area. These operations can be performed with tools provided by a GIS program. Alternatively, the re-projection tool can be used, provided by the SWS Toolkit (see section 3.4).

<sup>2</sup> EEA: European Environment Agency

### 3.2.3 Water level

The information regarding the water level of the studied area should be provided with a three columns csv file that contains the coordinates in WGS84 (longitude, latitude) of the measurement points and the corresponding water level in MAMSL<sup>3</sup>. If the coordinates are available in a different coordinate system, they should be converted to WGS84.

An example of a water level csv file is given in the following lines.

```
24.027278,38.165587,0.0
24.025725,38.162973,0.6
24.014035,38.157568,1.4
24.014181,38.148555,1.2
24.015036,38.143147,0.9
24.012228,38.137920,0.7
24.023906,38.152429,0.9
24.005472,38.135397,0.7
24.004617,38.140535,1.2
24.004457,38.145221,1.4
24.004309,38.151981,1.6
```

The SWS Toolkit employs a linear interpolation method to produce from these measurements a raster layer with the water levels over the study area.

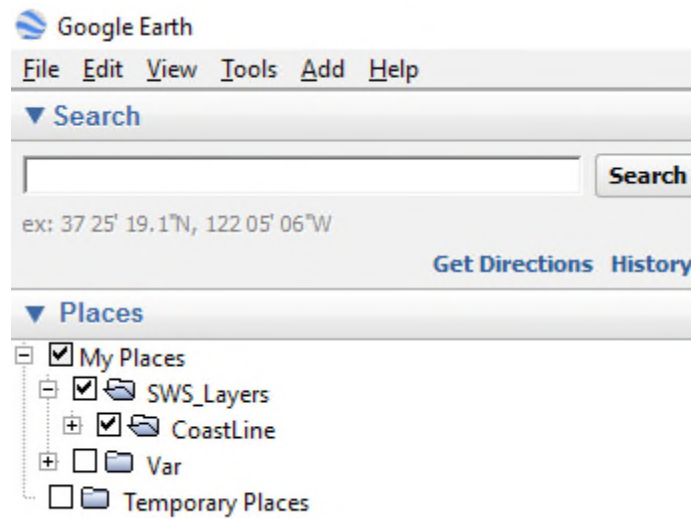
### 3.2.4 Coastline

This is a polyline kml layer with WGS84 coordinate system. Google Earth can be used to prepare this layer as follows.

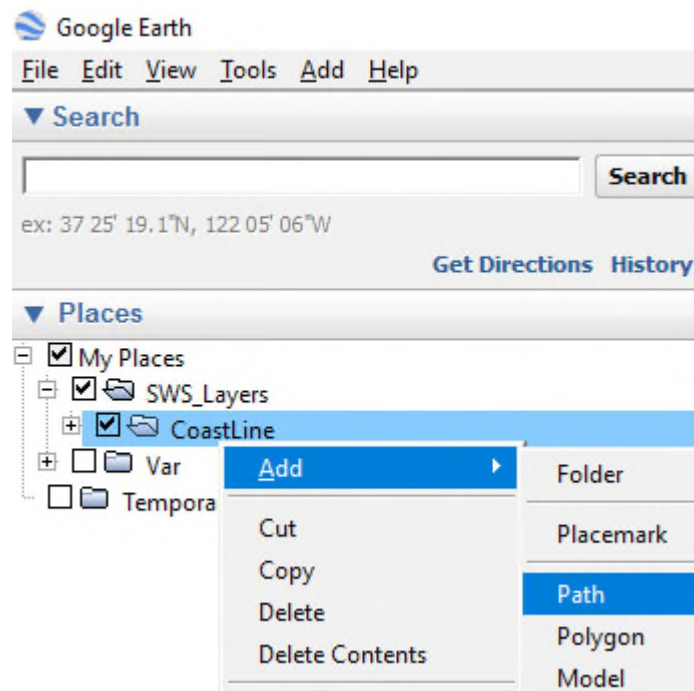
1. Add a folder inside SWS\_Layers (name it, for example, Coastline)

---

<sup>3</sup> Metres above mean sea level (MAMSL)



2. Right click on Coastline folder to add a Path



3. Digitize the path

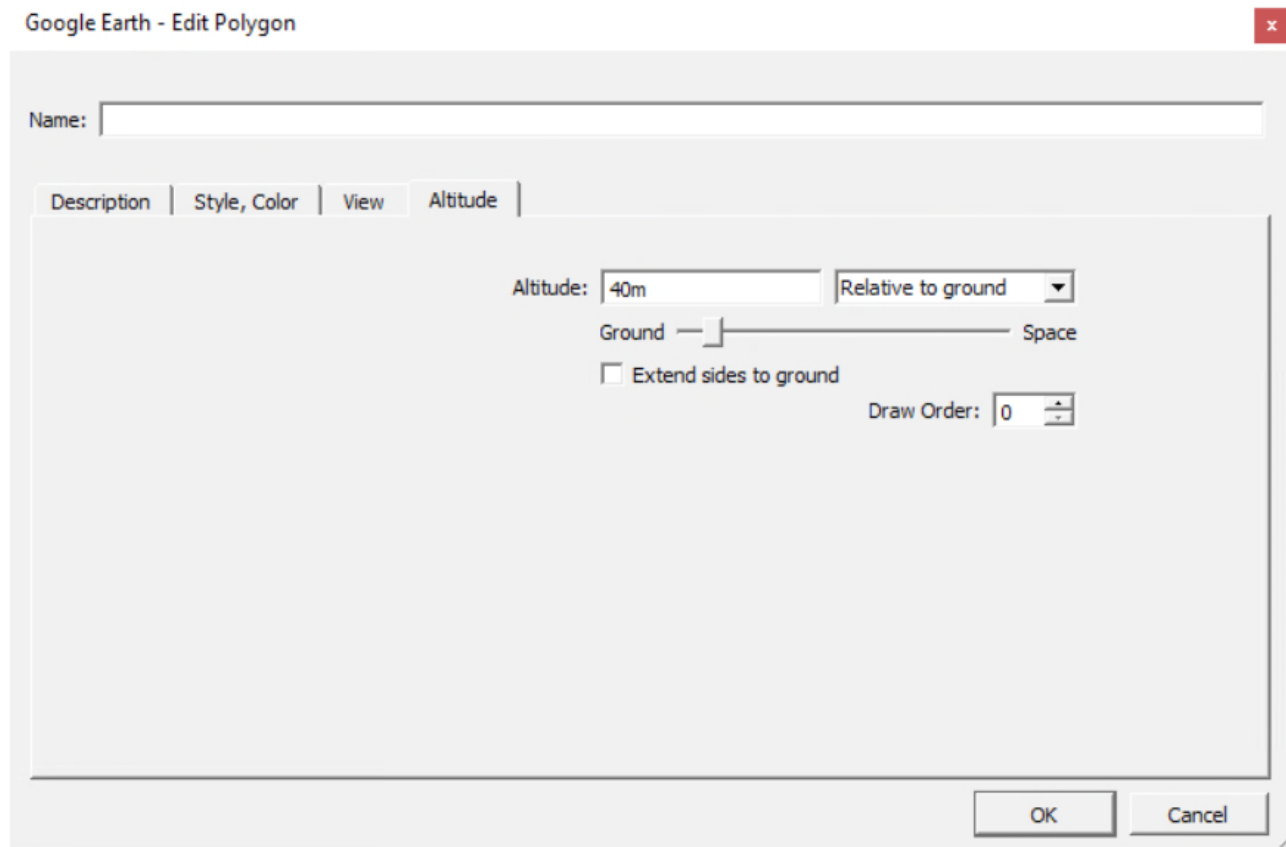
4. Right click on Coastline folder, select Save Place As..., select Save as type: kml, save the layer



### 3.2.5 Lens width

This is a polygon kml layer with WGS84 coordinate system that gives the width of the lenses under various areas. Google Earth can be used to prepare this layer.

1. Add a folder inside SWS\_Layers (name it, for example, LensesWidth)
2. Right click on LensesWidth folder to add a Polygon
3. Digitize the polygon (do not press OK when finish, see next step)
4. Go to the Altitude tab and give (in the Altitude field) the width of the lenses under the digitized polygon (select “Relative to ground” in the drop-down list)



5. Repeat steps 2 to 4 as many times as required
6. Right click on LensesWidth folder, select Save Place As..., select Save as type: kml, save the layer

Note: The use of altitude field to keep attributes of layer is a workaround. A side effect is the representation of the polygons as features elevated from the surface.

### 3.2.6 Lens thickness

See previous section.

### 3.2.7 Aquifer bottom

The aquifer bottom is defined by a plane, the definition of which requires three points. This information is provided by a three columns file that contains three records (each record corresponding to a plane point). The first two columns are the coordinates in WGS84 (longitude, latitude) and the third column is the depth of the aquifer bottom (positive number). An example of such a csv file is given in the following lines.

```
24.021120596,38.1544944718,49
24.031689336,38.1493389886,48
24.043546947,38.1461812551,47
```

### 3.2.8 Restricted areas

This is the definition of the restricted areas (e.g. archaeological areas, military installations, national parks, etc.), where SWS may not be installed. A polygon kml layer with WGS84 coordinate system is expected. Google Earth can be used to prepare this layer.

1. Add a folder inside SWS\_Layers (name it, for example, Restricted)
2. Right click on Restricted folder to add a Polygon
3. Digitize the polygon
4. Repeat steps 2 to 3 as many times as required
5. Right click on Restricted folder, select Save Place As..., select Save as type: kml, save the layer

### 3.2.9 Secure areas

This is the definition of the secure areas where SWS will be protected against vandalism or theft. A polygon kml layer with WGS84 coordinate system is expected. Google Earth can be used to prepare this layer.

1. Add a folder inside SWS\_Layers (name it, for example, Secure)
2. Right click on Secure folder to add a Polygon
3. Digitize the polygon

4. Repeat steps 2 to 3 as many times as required
5. Right click on Secure folder, select Save Place As..., select Save as type: kml, save the layer

### 3.2.10 Power

This is the definition of the power supply locations in the study area. A point kml layer with WGS84 coordinate system is expected. Google Earth can be used to prepare this layer.

1. Add a folder inside SWS\_Layers (name it, for example, Power)
2. Right click on Power folder to add a Placemark
3. Digitize the point
4. Repeat steps 2 to 3 as many times as required
5. Right click on Power folder, select Save Place As..., select Save as type: kml, save the layer

### 3.2.11 Aerial

This the png image that will be used as background in the SWS Toolkit. The image boundaries should be exactly the same with the DTM dataset of the study. This image can be obtained from Google Earth.

- Zoom-in to have the study area displayed in the screen
- Press the "n" key to reset the view to North Up
- Press the "r" key to get the straight down view of Earth
- Save in a png file the displayed area
- Make sure the png file boundaries are the lower-left and upper-right corners (see Definition of Study Area section) that define the study area (may need to crop the image with an image processing tool)

## 3.3 Spatial analysis of the studied area

### 3.3.1 Introduction

The siting of the SWS installations (pumping boreholes, the treatment unit, the injection area, etc.) is performed by employing boolean algebra over the spatial data (e.g. conjunction of two logical values and negation of a logical value). The symbols of the parameters employed in the formulation of the logical values are introduced in the following table.

Table 2: Nomenclature

Symbol	Meaning
$ij$	The row and column of the cell of a raster dataset
$Hg_{ij}$	The MAMSL elevation of the land surface of the cell $ij$
$Hf_{ij}$	The water level of the cell $ij$ (m)
$Hf$	The raster layer with water level of the study area
$w1$	The weight of groundwater resource potential [0,1]
$w2$	The weight of groundwater depth [0,1]
$A_{ij}$	The depth of the aquifer bottom of the cell $ij$ (m)
$a$	The maximum aquifer depth to protect from saltwater intrusion (m)
$Dp_{ij}$	The water level depth of the cell $ij$ (m)
$Dp$	The raster layer with the water level depth of the study area
$Rs_{ij}$	The restriction status of the cell $ij$ {False, True}
$\gamma$	The ratio of the fresh water density to the fresh/seawater densities difference (assumed 40)
$S_{ij}$	The secure status of the cell $ij$ {False, True}
$P_{ij}$	The distance of the cell $ij$ from the power supply (m)
$\rho$	The maximum acceptable distance from a power supply (m)
$C_{ij}$	The distance of the cell $ij$ from the coast (m)
$c$	The maximum distance from the coast that intrusion is allowed (m)
$Th_{ij}$	The thickness of the lenses of the cell $ij$ (m)
$R_{ij}$	The radius of the lenses of the cell $ij$ (m)
$dHf_{ij}$	The drawdown or the rise due to pumping at the cell $ij$ (m)
$Q_{ij}$	The pumping/injection rate at the cell $ij$ ( $m^3/d$ )
$K_{ij}$	Hydraulic conductivity at the cell $ij$ (m/d)
$Had_{ij}$	The water level rise required to prevent the saltwater intrusion at the cell $ij$ (m)

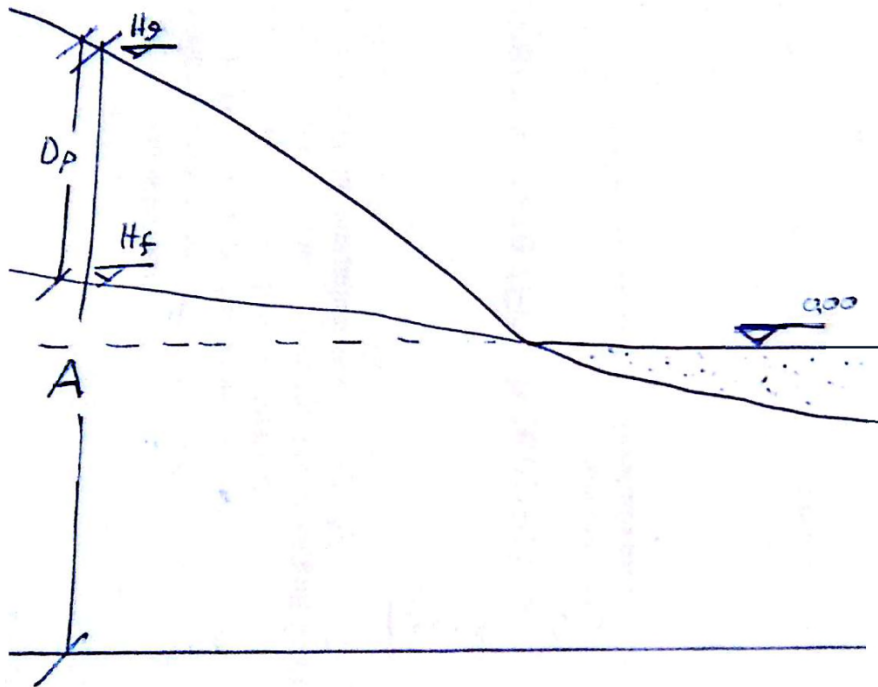


Figure 11: Characteristic depths and levels in coastal aquifers

Table 3: Operators used in logical values

Operator	Meaning
MIN()	the minimum value of the raster layer given as argument
MAX()	the maximum value of the raster layer given as argument
min(,)	the minimum value between the two values given as arguments
max(,)	the maximum value between the two values given as arguments
grad(X,i,j)	the gradient magnitude at the cell <i>ij</i> of the raster layer <i>X</i>
∧	logical AND
¬	logical NOT

### 3.3.2 Indicated areas for pumping boreholes (Freshkeeper)

The cell *ij* is suitable for injection if the following expression is true:

$$H_{f_{ij}} > \text{MIN}(H_f) + w_1(\text{MAX}(H_f) - \text{MIN}(H_f)) \wedge D_{p_{ij}} < \text{MIN}(D_p) + w_2(\text{MAX}(D_p) - \text{MIN}(D_p)) \wedge \neg R_{s_{ij}}$$

The previous spatial query has two parameters, the weight of water “abundance” *w1* (higher values indicate the desire to install the pumping boreholes in locations where the water level is higher), and the weight of the water depth *w2* (lower values indicate increased tolerance to

install the pumping boreholes in locations where the water is pumped from lower depths). This query identifies the locations where:

- the water level is higher than a specific level (defined by  $w_1$ , but between the minimum and maximum water level of the area) and
- the depth of the water level is lower than a specific level (defined by  $w_2$ , but between the minimum and maximum depth of the water level of the area) and
- it is permitted the installation of the boreholes.

### 3.3.3 Indicated areas for unit installation (Freshkeeper)

The cell  $ij$  is suitable for the unit installation if the following expression is true:

$$S_{ij} \wedge P_{ij} < p \wedge \neg R_{s_{ij}}$$

The previous spatial query has one parameter, the maximum acceptable distance  $p$  from a power supply point. This query identifies the locations where:

- it is secure and
- the power supply is acceptably close and
- it is permitted the installation of the unit.

### 3.3.4 Indicated areas for injection (Freshkeeper)

The cell  $ij$  is suitable for installation of injection boreholes if the following expression is true:

$$H_{g_{ij}} > \min(A_{ij} - H_{g_{ij}}, a - H_{g_{ij}}) / \gamma \wedge H_{f_{ij}} < \min(A_{ij} - H_{g_{ij}}, a - H_{g_{ij}}) / \gamma \wedge \neg R_{s_{ij}} \wedge C_{ij} > c$$

The previous spatial query has two parameters, the maximum distance  $c$  from coast that seawater intrusion is allowed (0 means to ensure no intrusion, hence to deploy injections, 0 meters from the seafront), and the maximum aquifer depth  $a$  to ensure freshwater quality.

This query identifies the locations where:

- the surface elevation allows the build-up of a water level sufficient to intercept the saltwater intrusion and
- there is the need (low water level) to do so and
- it is permitted the installation of the injections and
- it is at a reasonable distance from the seafront.

### 3.3.5 Indicated areas for Freshmaker SWS

The cell  $ij$  is suitable for Freshmaker SWS if the following expression is true:

$$S_{ij} \wedge P_{ij} < p \wedge \neg R_{s_{ij}} \wedge A_{ij} < 20 \wedge (A_{ij} - D_{p_{ij}}) > 9 \wedge Th_{ij} > 3 \wedge 5 \left| \text{grad}(H_f, i, j) \right| / 365 < 0.1 R_{ij}$$

This query identifies the locations where:

- it is secure area and
- the power supply is acceptably close and
- it is permitted the installation of the unit and
- the aquifer bottom is not deeper than 20 meters and
- the saturated aquifer thickness is greater than 9 meters and
- the thickness of lenses is greater than 3 meters and
- the hydraulic flow (estimated with Darcy formula assuming 5 m/d hydraulic conductivity) in m/year is less than the 10% of the lens radius.

## 3.4 Tools

### 3.4.1 Required injection rate (Freshkeeper)

Following the siting of a Freshkeeper SWS, the user can estimate the required injection rate at each indicated location. First, this tool estimates how much the water level should be increased to prevent the saltwater intrusion. This is calculated with the following formula:

$$Had_{ij} = \min(A_{ij} - H_{g_{ij}}, a - H_{g_{ij}}) / \gamma - H_{f_{ij}}$$

If  $Had_{ij}$  is greater than 0, the Thiem equation is used to estimate the required injection rate to accomplish this level increase:

$$Q_{ij} = Had_{ij} (2 \pi (A_{ij} - D_{p_{ij}}) K_{ij}) / \ln(2000/0.2)$$

In the above equation it is assumed that the radius of influence is 2000 m and that the borehole radius is 0.2 m.

### 3.4.2 Estimated drawdown

This tool can be used to estimate the drawdown or the rise due to pumping or injecting with a specific discharge at a specific location. The Thiem equation is used to accomplish this:

$$dH_{f_{ij}} = Q_{ij} / (2 \pi (H_{f_{ij}} + A_{ij}) K_{ij}) \ln(2000/0.2)$$

### 3.4.3 Reproject EEA DTM

From the menu “Tools” select “Reproject EEA DTM”. First, indicate the location of the downloaded DTM from EEA (click on “Browse” next to “Open EEA DTM for read”). Then, indicate the kml files that give the lower-left and upper-right corners of the study area. After that press “GdalWarp”. The DTM of the studied area (DTM\_Study.tif) is created in the same path with the layer of the lower-left corner.

### 3.4.4 Re-projecting and clipping geotiff files

The re-projection and clip of a geotiff file can be accomplished with GDAL tools. The following lines demonstrate how a DTM downloaded from EEA can be clipped to a window with bottom left corner coordinates (23.998247, 38.123205) and top right corner coordinates (24.082919, 38.179615), and re-projected to WGS84.

```
> set bounds=23.998247 38.123205 24.082919 38.179615  
> gdalwarp -s_srs EPSG:4258 -t_srs EPSG:4326 -te %bounds% -of GTiff EEA_DTM.tif Study_DTM.tif
```

### 3.4.5 Re-projecting csv files

In the following example, the coordinates given in Greek Grid (EPSG:2100) projection system are transformed to WGS84 (EPSG:4326) using the GDAL tool cs2cs.

```
> type WellObs_EGSA.txt|cs2cs +init=epsg:2100 +to +init=epsg:4326 -f "%f"
```

Where WellObs\_EGSA.txt contains the following lines.

```
502240 4.22390e+06 0  
502104 4.22361e+06 0.6  
501080 4.22301e+06 1.4  
501093 4.22201e+06 1.2  
501168 4.22141e+06 0.9  
500922 4.22083e+06 0.7  
501945 4.22244e+06 0.9  
500330 4.22055e+06 0.7  
500255 4.22112e+06 1.2  
500241 4.22164e+06 1.4  
500228 4.22239e+06 1.6
```



## 4 The SUBSOL Data Monitoring System

### 4.1 Description of the application

The SUBSOL Data Monitoring System (DMS) is a platform that lets the user visualize measurements from sensors installed in different measuring stations. The aim of this tool is to offer a variety of customization features and display methods in order to be reusable and extensible to fit the needs of any user.

For this purpose, the logic of the application was separated from the way stations store and process data. At the same time, the tool attempted to provide as many visualization features (widgets) as possible.

### 4.2 Overview

The DMS is comprised of the following modules (Figure 12).

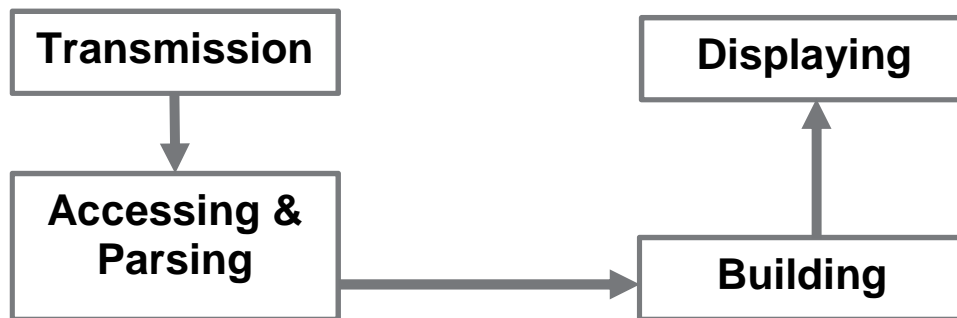


Figure 12: The basic modules of the DMS

In the following sections each one of these modules will be analysed.

#### 4.2.1 Data transmission

Measured data are usually transmitted in form of files from the observation stations to the server through the mobile phone network GSM. The exact way the data are transmitted depends on the local infrastructure and is examined on a case-by-case basis. The data files can be stored in an intermediate repository located either in the DMS server or in a remote server from where they are then accessed by the DMS.

#### 4.2.2 Accessing and Parsing Module

This module reads data transmitted by the stations and stores them into the main database. Data can be either single-valued or multi-valued (i.e. time-series). Storing multi-valued data into the database poses an interesting challenge, as these data tend to become really big with time. However, we tried to offer a solution that succeeds in managing big data while remaining uncomplicated and straightforward at the same time in order to be easily maintained by future developers.

The Parser is able to read and analyse data files having the following format:

- Comma Separated Values (CSV)
- JSON
- XML

The DMS can read these files in one of the following ways:

- (a) **Local storage** (files stored on the same computer that hosts the application). It requires that there must be a means for the data files to be transferred from the location of the station to the computer that hosts the application. An administrator can do this in various ways after consultations with the station owner and examination of the station equipment (see figure 2).
- (b) **Remote storage** (FTP). The DMS administrator may define a remote storage where data files are stored (see figure 3). In order to access the FTP storage, all FTP credentials are stored into the application database.

Reading from files can be scheduled to occur periodically with user-defined time intervals no less than one minute. Also, assuming that the data files include timestamped data, the sequence of the files themselves is not important, as the DMS looks and updates the database values in accordance with the timestamps inside the data files.

The screenshot displays the SubSol web interface for defining a local storage of data files. The main form is titled "Add new Data Sources" and has two tabs: "File Source" (selected) and "FTP Connection". The form contains the following fields and options:

- Name:** A text input field with the placeholder "Type any unique name for this resource...".
- Absolute Path:** A text input field with the placeholder "Type the absolute path needed to locate the meter files".
- Data start from row:** A numeric input field set to "1". Below it, a note states: "Some files have column names and the data start from the second row. In that case you should type '2'".
- Date Column:** A numeric input field set to "1".
- Time Column:** A numeric input field set to "2".
- Delimiter:** A dropdown menu set to "; (semicolon)".
- Quotation char:** A dropdown menu set to "None".
- Minutes between refresh:** A numeric input field set to "10". Below it, a note states: "New meter data will be added periodically. The default value between data readings is 10 minutes".
- Timezone:** A dropdown menu set to "Don't know (probably UTC)".
- Description (optional):** A large text area for an optional description.
- Submit:** A blue button at the bottom right of the form.

On the right side, a panel titled "Your Data Sources" shows a single data source named "dinteloord" with the path "/home/soulman/fusion/fusion/media/meter\_files/dinteloord" and "510 files".

At the bottom of the interface, there is a blue footer bar containing the European Union flag, the text "SUBSOL has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642228", and navigation links: "Project | About | Contact | Disclaimer".

Figure 13: Defining a local storage of data files

Other options include setting the time-zone of the source (usually this is set to UTC by default in most stations), the location of the timestamp inside the file, the delimiter which separates data (usually, a comma is used as delimiter but other characters may be specified as well).

It is important to note, that only staff members or system administrators are allowed to create data sources (either local or remote). We will describe the user types and their permissions in later sections of this document.

The screenshot displays the 'Add new Data Sources' dialog box in the SubSol application. The 'FTP Connection' tab is active, showing a form with the following fields:

- Name:** Type any unique name for this resource...
- FTP Server:** Type the IP of the server where the meter files are
- Working Directory:** Please, provide the working dir. Leave empty for root dir
- FTP User:** Please, provide the ftp user
- FTP User Password:** Please, give the password for the ftp user
- Data start from row:** - 1 +  
Some files have column names and the data start from the second row. In that case you should type "2".
- Date Column:** - 1 +
- Time Column:** - 2 +
- Delimiter:** ; (semicolon)
- Quotation char:** None
- Minutes between refresh:** - 10 +  
New meter data will be added periodically. The default value between data readings is 10 minutes
- Timezone:** Don't know (probably UTC)
- Description (optional):** [Empty text area]

On the right side, the 'Your Data Sources' panel shows a list of existing data sources:

- dinteloord**  
/home/soulman/fusion/fusion/media/meter\_files/dinteloord  
510 files

Figure 14: Defining a remote storage of data files

### 4.2.3 Building Module

Once data are stored in the database, users are able to define variables by combining measured data in order to visualize them on the screen. There are two types of variables:

- Atomic variables (single variables)
- Expressions (complex variables)

Figure 15 shows the basic steps for the definition of an atomic variable. Initially, users must provide a unique name for this variable (e.g. `Electrical_Conductivity_1`). After that, they must choose which column (in case of a CSV file) from the data file holds the values of this variable (column names follow Microsoft's Excel naming sequence for the user's convenience). Then, the users must specify how the data should be processed. The allowed types of functions currently are:

- Average of a column
- Maximum of a column

- Minimum of a column
- Sum of a column
- Most recent value of this column
- Latest value of this column
- Selection of all values (time-series)

Finally, the users specify the unit (units are user-defined) and a description for the atomic variable.

All user defined atomic variables are always visible on the right panel with their respective current value.

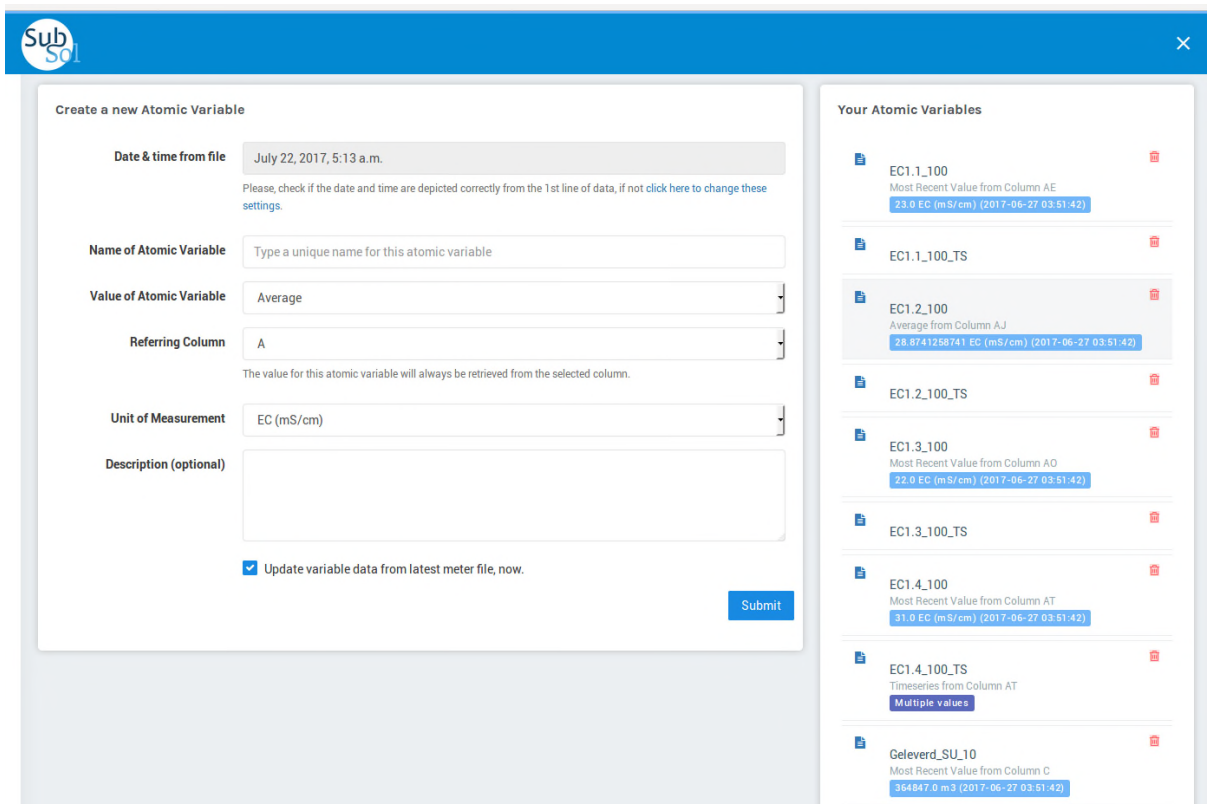


Figure 15: Creation of an atomic variable

In some cases users need to define complex variables, such as the average value of column C minus the average value of column E or the square root of the maximum value of column F

times 3. Figure 16, depicts this process. In the same way users may graphically display the values of the atomic variables, they are able to create and display complex expressions of any type.

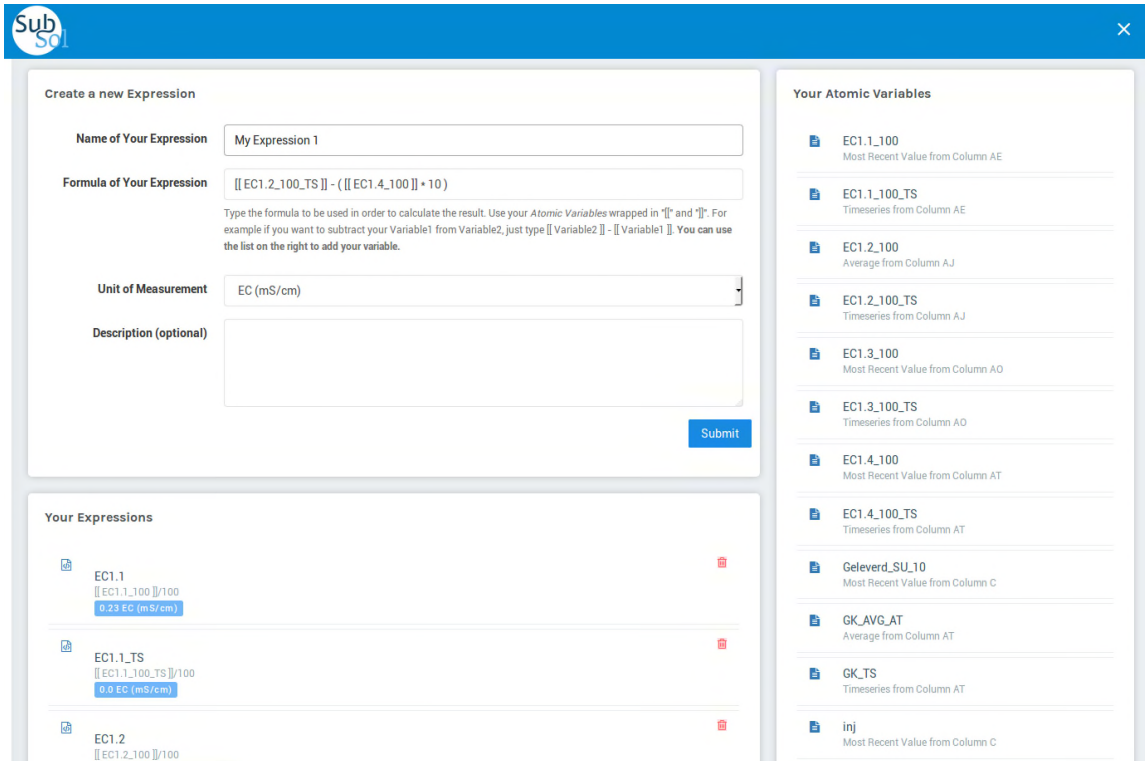


Figure 16: Building complex expressions from simple atomic variables

Many procedures of the DMS are aligned to Microsoft's Excel. This has many reasons, one of which is user convenience. Consistency with known methodologies is another. This can be illustrated by the following example.

Let's assume that we have created two atomic variables from a CSV file: *E\_Conductivity\_A* (which is the maximum value of column E) and *E\_Conductivity\_B* (which is the maximum value of column D).

We can then create a complex expression to represent the average of the sum of those values after they have been divided by 100. In this case the expression is defined by the user as follows:

$$\text{Average} ( [[ E\_Conductivity\_A ]] / 100 + [[ E\_Conductivity\_B ]] / 100)$$

Atomic variables should be placed inside double square brackets (“[[“ and “]]”) for the parser to locate them and substitute them with their respective latest values from the data files. The result of this expression is always updated to map the values from the most recent measurements.

It is important to note that values from the expressions are calculated “on-the-fly” and are *not* stored in the database (in contrast to the atomic variables). Although this adds a small temporal overhead when rendering the graphical widgets, there is a sound reason for this. Expressions tend to be modified more often by the user than a simple atomic variable. If we had pre-evaluated and stored the results of an expression beforehand, then after any user modification the expression would need to be re-evaluated and stored again. This would pose an even larger overhead every time the user updates the expression.

It is well understood that the purpose of the application is to give maximum autonomy to the users in order to build their own personal data dashboards. This has been successfully accomplished to a great extent. Because of the fact that the application is still under development, more customization options will be added in the future. Planned extensions of the existing functionality are described in later sections of this document.

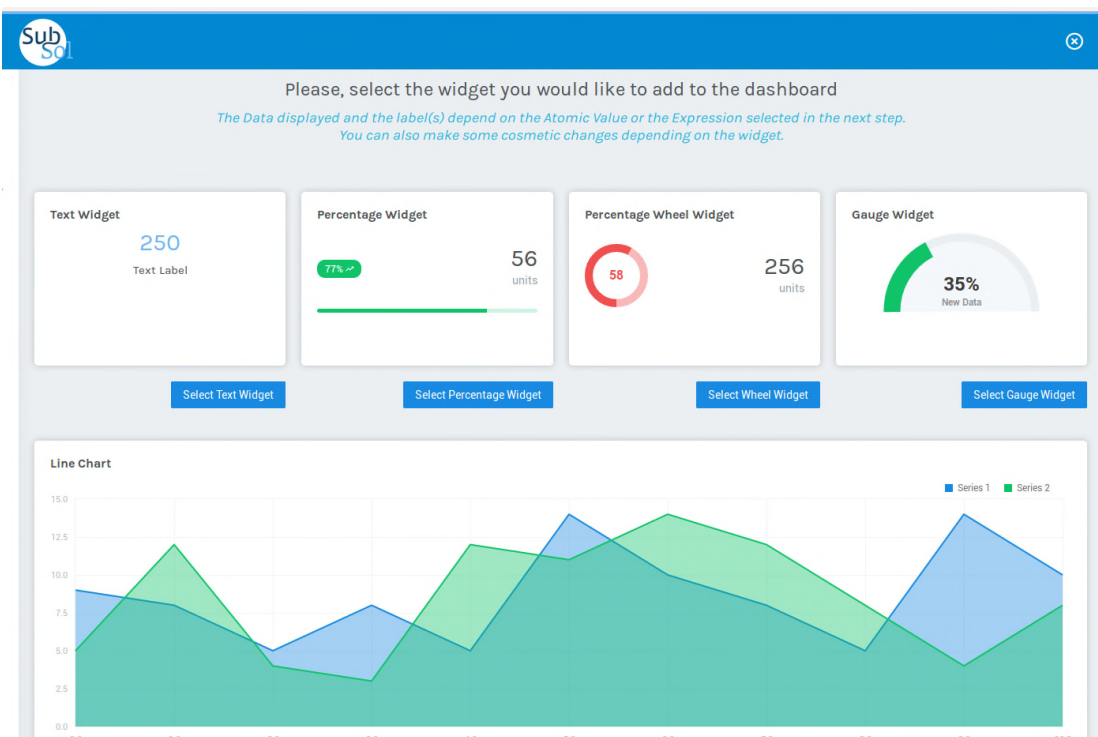


Figure 17: Options for representing single values or time-series data

#### 4.2.4 Display Module

Users after they have defined atomic variables and complex expressions, with this module they are able to configure their own dashboard pages consisting of the visual representations of their data.

The DMS application offers many options for the users to represent single or multi-valued data. Figures 18 show a selection of the ones currently implemented.

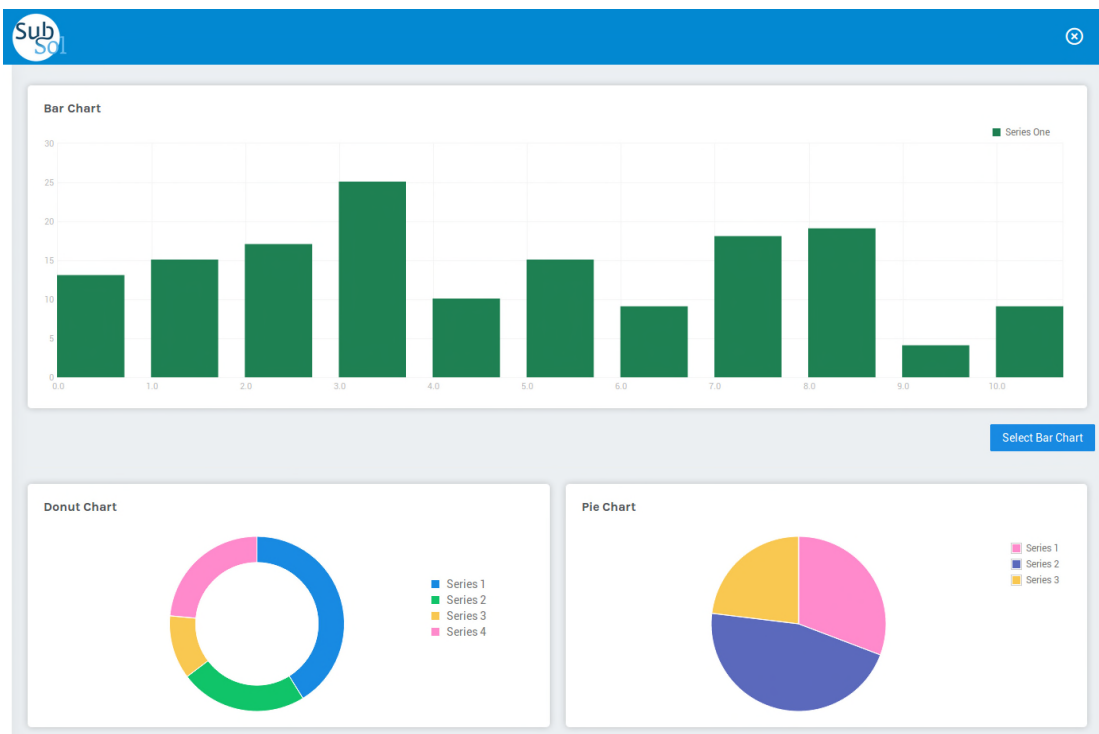


Figure 18: Options for representing time-series or multiple single-valued data

There are currently implemented graphical representations of five different data types:

- **Simple text.** This widget shows just the most recently evaluated atomic variable or expression and its unit of measurement.
- **Percentage data of one variable.** This widget shows a percentile representation of a variable or an expression. As an input users must provide the maximum value of this variable or expression in order for the percentile to be calculated correctly.



- **Time-series graphs (line or bar charts).** The user specifies which multi-valued variables should be shown. Multiple time-series variables can be displayed on the same graph for comparison.

Other options include labelling the x and y axis, specifying the colours for the data representation, displaying maximum number of values, and the selection of the type of aggregations. The users can zoom in and out to any period of the time series. Currently, the following types of aggregations are supported (more aggregation options may be provided if needed):

- o 1, 5 or 15 minutes
  - o Hourly
  - o Daily
  - o Weekly
  - o Monthly
  - o Yearly
  - o Raw data (“as is” in the files)
- **Percentage of multiple variables (pie or donut charts).** The users have the option to display combined single-valued variables into pie or donut charts. Users can customize the charts by providing the colour of each variable.
  - **Weather data.** This widget draws weather data from public weather sources (Open Weather Data) and can be placed in any of the user dashboards. Using this widget the user can have a quick overview of the weather in different locations. Weather forecasting is not supported.

All widgets are fully customizable and can be placed in various dashboard pages at the same time.

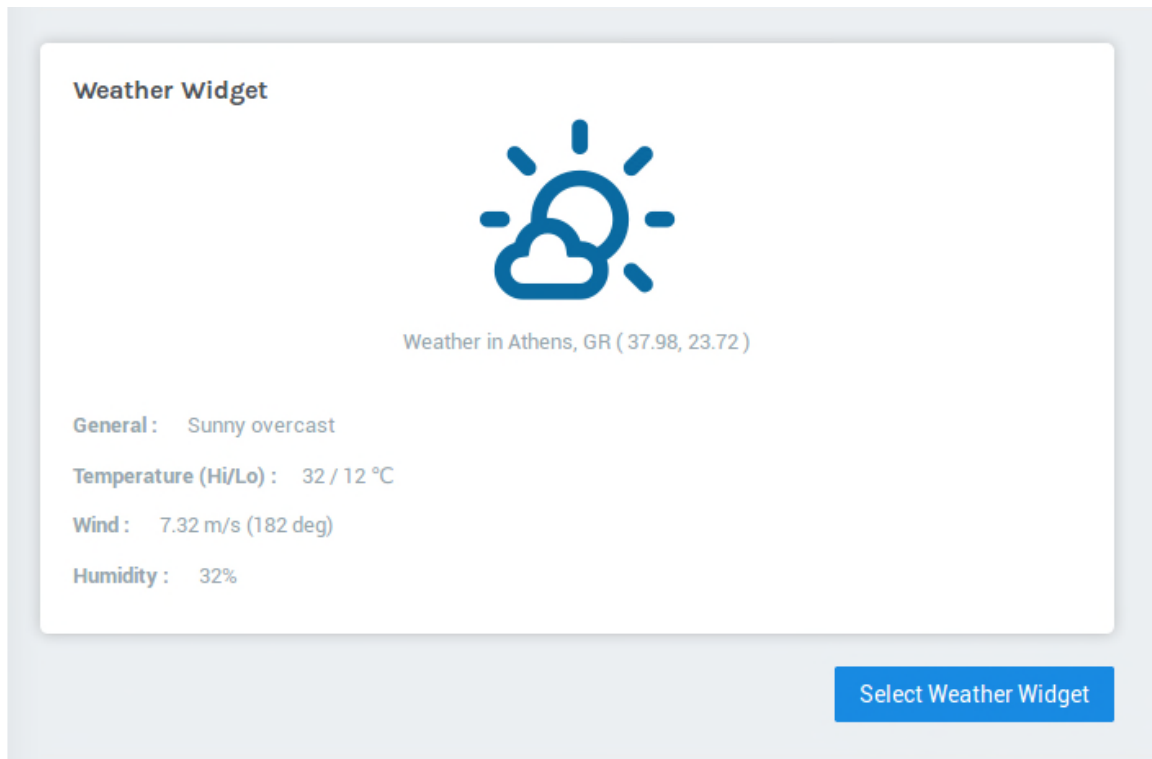


Figure 19: Current weather data widget

A combination of widgets will appear at the user's dashboard similar to figure 19. The users can create as many dashboard pages as they need. The Dashboard application offers complete autonomy to the users. Each user is registered separately and can only view the dashboard pages he/she has created. Only the application administrator can view all of the user dashboards. User permissions will be described in the next section of this document.

Users should not include more than three time-series related graphs on the same dashboard page, due to performance reasons related to the complexity of the rendering procedure. Instead, they should opt for the creation of more than one dashboard, each of them having a limited number of time series widgets..

All widgets are fully customizable. Figure 20 shows the available options on the example of a percentage-type widget.

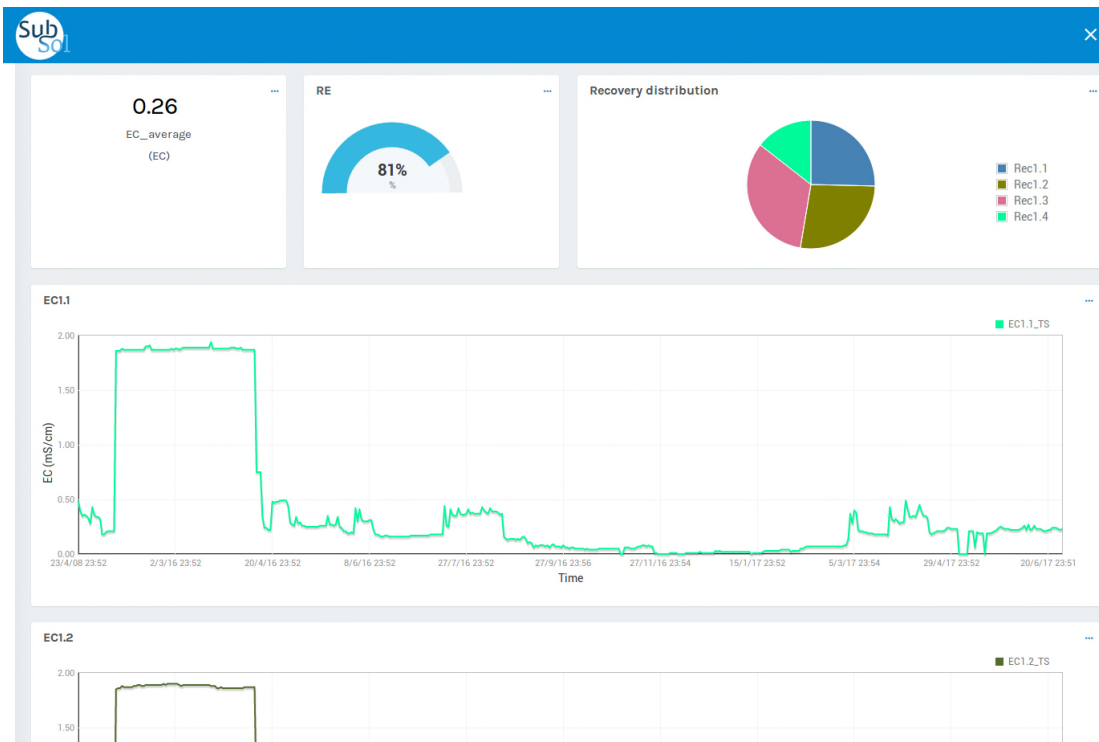


Figure 20: The dashboard page full of user defined widgets

Users may choose to add a widget to a previously created dashboard or create a new one for this and future widgets. Although, the final layout of the dashboard page is decided by the application itself (in order to have the best use of available space) users may define the position of this widget among similar widgets. For example, since time series graphs make use of the full page width (for obvious reasons) they are placed together (one after the other). However, users may specify the order of appearance for this type of widgets. Finally, the users may choose the number of decimals of real numbers to be shown and the colour of the graphs (figure 21).

### Widget removal

Any widget may be removed from any dashboard page. Removing a widget, does not necessary mean that it is deleted also from the database. This is the case only if the widget is removed from all dashboard pages. The user is notified before the DMS proceeds with such an action.

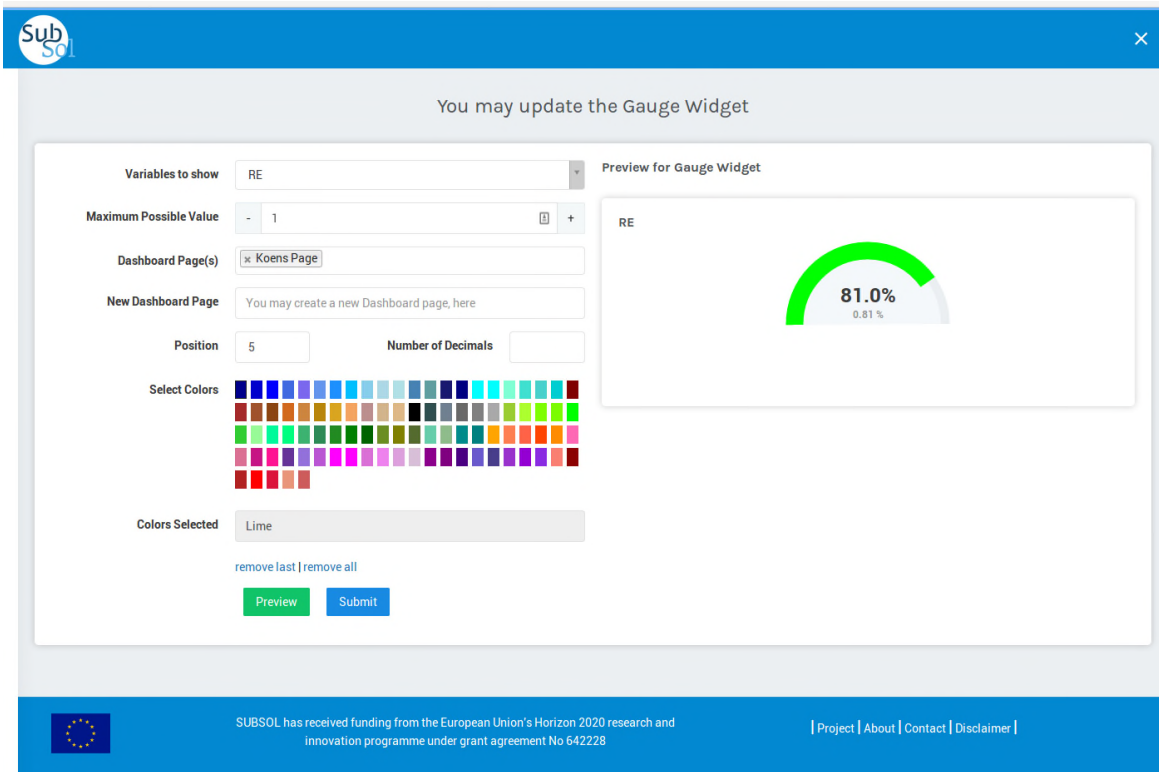


Figure 21: Customization of a widget

## Data history

Once a widget is created and added to a dashboard page, the DMS starts to record historical data for that variable. By “data history” all past variable values are meant that the system has stored. Data history is available to the user through the widget’s options on the dashboard page and is presented in form of a time series graph. This feature is not available for time series variables.

## 4.3 User Management

The DMS Web Application offers a simple but effective User Management.

With each installation, a system administrator is registered with it. The administrator has full access to the whole application including user management and the management of all dashboard pages.

The following three types of users are supported by the system.

- **Administrator.** In addition to all privileges that staff users have, administrators may create other user accounts, modify or remove existing accounts, access all dashboard pages and modify existing widgets and variables.
- **Staff.** Staff members can create their atomic variables or expressions and add them to the dashboard pages they create. They cannot access data created by other staff members.
- **Standard User.** Standard (or normal) users may only view the public dashboards. A dashboard page is set to public by its creator or a system administrator.

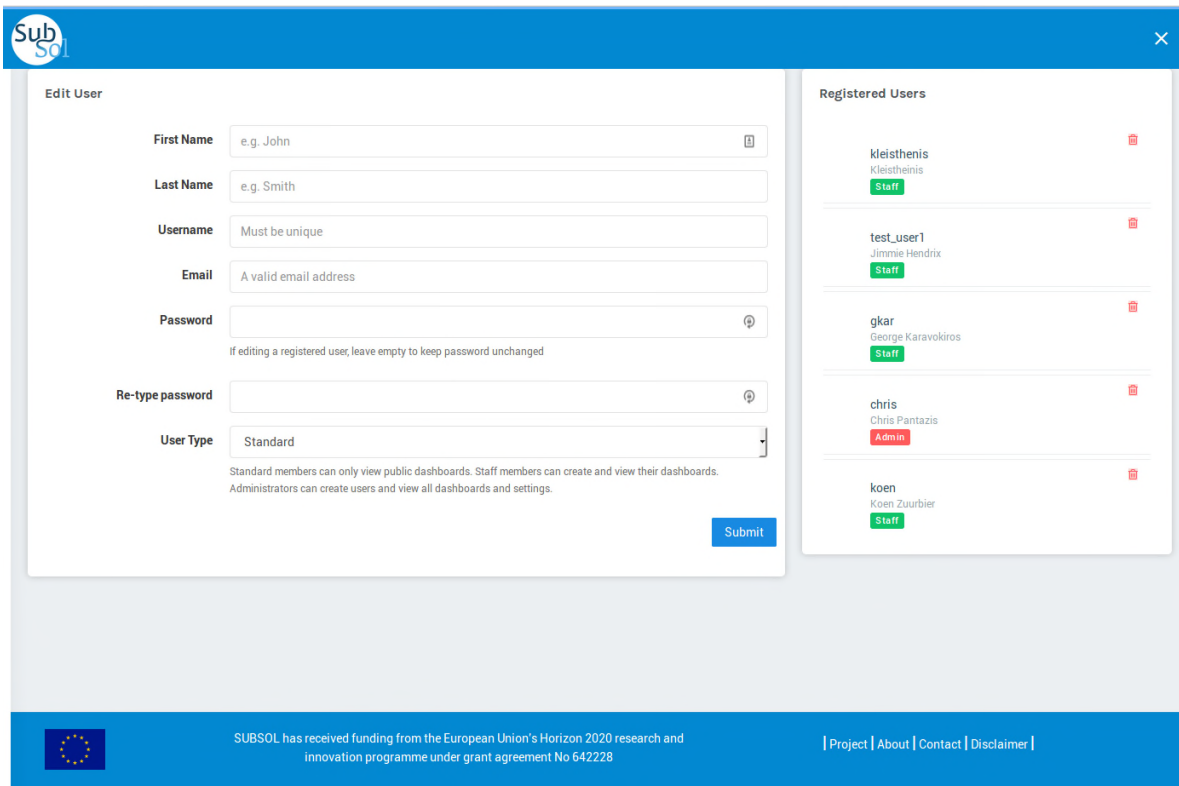


Figure 22: User Management - Creating new users

## 4.4 Future Additions

The DMS web application is a complex platform which supports reusability, is extensible and maintainable and can be easily installed on any server. While the first version is completed

and operational, there are additional features under development and may be included in the final version such as the following:

- **System alerts.** Users may choose for selected widgets to send email alerts or browser notifications whenever a variable exceeds certain user defined thresholds.
- **Exporting of historical data.** Users will have the option to download raw or aggregated timeseries to a CSV file.
- **Support for OGC standards** such as WaterML

## 5 Other tools, products and services

In this session, several other tools, products and services are described, supporting the stakeholders in performing detailed assessment of SWS systems. These tools are included in the SUBSOL Knowledge Environment and illustrated in Figure 23.

The screenshot displays the 'Products or Services' section of the SUBSOL Marketplace. The page features a navigation bar with 'Home', 'Marketplace', 'Lists', 'Pivots', and 'Search' options. Below the navigation, there is a search bar and a table listing various products and services. The table has columns for Name, Description, Keywords, Url, Version, and Costs. The entries include 'Falster Island products', 'FREEWAT', 'SAMPLE', 'Subsol Automated Control Unit', 'SWS Location Identification Tool', 'test prod', and 'Watershare: ASR Performance Assessor'. At the bottom of the page, there is a footer with the European Union logo, funding information, and navigation links for 'Project', 'About', 'Contact', and 'Disclaimer'.

Name	Description	Keywords	Url	Version	Costs
Falster Island products	Develop monitoring systems and real-time optimized SWS operation system based on automated SCADA/PLC solutions and on-line measurements of electrical conductivity, ...	None	None	None	None
FREEWAT	FREEWAT (FREE and open source tools for WATER resource management) is an HORIZON 2020 project financed by the EU Commission ...	None	http://www.freewat.eu	v 0.4	None
SAMPLE	asdfsadf	None	None	None	None
Subsol Automated Control Unit	Automated Control Unit to control efficient infiltration and recovery during ASR-Coastal	ASR, aquifer storage and recovery, ASR-Coastal	http://www.subsol.org/home/article/first-subsol-automated-control-unit-deployed	1.0	None
SWS Location Identification Tool	The SWS Location Identification Tool is a spatial assessment tool that helps to scan an area to identify locations that ...	SWS, Freshmaker, Freshkeeper, ASR	http://users.itia.ntua.gr/rozos/SWS_Toolkit/	1.0	None
test prod	it's a test product	None	None	None	None
Watershare: ASR Performance Assessor	Evaluation of potential recovery efficiency during ASR in brackish-saline aquifers. Evaluates potential impact of lateral drift and buoyancy effects	ASR, aquifer storage and recovery, recovery efficiency, buoyancy	https://www.watershare.eu/tool/asr-performance-assessor/	1.0.1	None

Figure 23: SUBSOL Marketplace: Products and Services

## 5.1 ASR Performance Assessor (Watershare)

### 5.1.1 Introduction

Aquifer Storage and Recovery (ASR) is defined as the injection of freshwater surpluses in aquifers using wells, followed by recovery in times of demand using the same well. It can be an efficient technique to store freshwater surpluses for times of demand. However, in brackish-saline aquifers the density-driven flow can result in limited recoverability of freshwater: injected freshwater is pushed up towards the top of the aquifer (buoyancy effect) and brackish/saline water eventually enters the lower well section.

The recovery efficiency (RE) – the part of the recovered injected water that is of satisfactory quality – will therefore be lower than 100% in brackish/saline aquifers. It is of utmost importance to have an indication of this RE prior to construction/planning of any ASR system, since it determines the water supply and business case of the system. The RE, however, depends on the aquifer properties (such as thickness, permeability, salinity) and operational parameter (pumping rates, duration of injection/storage/recovery periods).

### 5.1.2 Description of methodology

This tool is based on very valuable work in the field of ASR performance estimation by Ward et al. (2009) and Bakker (2010). Both publications demonstrated different approaches to estimate ASR feasibility:

- Ward et al. (2009): Use of the sum different dimensionless performance indicators. According to a large number of scenarios, a performance indication (qualitative) was given to this sum.
- Bakker (2010): Use of a Dupuit-based approach employing interfaces to calculate the moment that the interface between fresh and brackish/saltwater (the “toe”) reaches the lower well section.

This tool requires only common hydrogeological information (aquifer thickness, hydraulic conductivity, hydr. Gradient, salinity) and operational information (pumping rate during injection, duration of injection/storage/recovery periods).

Implementation of the tool involves the following steps:

1. Gather required hydrogeological and operational information
2. Page 1: select the ratio between injection/storage/recovery phases
3. Insert the exact duration of the injection or storage or recovery period
4. Page 2: insert the volume that is stored (i.e., injected)
5. Insert the aquifer properties derived from characterisation study are based on estimates
6. Calculate results



### 5.1.3 Pilot

Greenhouse horticulture in the Province of South Holland already makes use of subsurface water storage in areas with fresh/brackish groundwater in order to address its irrigation water shortages. By adapting the injection and abstraction system, subsurface storage also offers a high-yield (partial) solution in areas with brackish/saline groundwater. This is the conclusion of research carried out by KWR Watercycle Research Institute on behalf of the Province of South Holland, and in collaboration with the Water Buffer Foundation and LTO Glaskracht Nederland.

In its 'Spatial and Mobility Vision' the province establishes that in (greenhouse) horticulture areas priority should be given to the implementation of freshwater storage in the first aquifer as a (partial) solution in meeting the sector's water demand. This avoids competition for space in the subsurface, for example, with energy storage systems.

Among the study's outcomes are suitability maps for water storage in the first aquifer for the eight most important (greenhouse) horticulture areas in the Province of South Holland.

#### ***Mismatch***

Greenhouse horticulture has a continual need for sufficient, good-quality irrigation water. The quality of rainwater is so high that it can be used without extensive treatment, but it is not always available: there is in fact a mismatch between water demand and water supply. In the winter there is too much rain, while in the summer shortages occur. To address these shortages, horticulturalists today depend on other sources, for example, groundwater that has been desalinated using reverse osmosis.

The mismatch is also dealt with in practice by capturing and storing rainwater in above-ground reservoirs. The capacity of these reservoirs is not always sufficient to capture all of the precipitation, so that a possible source of quality water is lost for the horticulturalists. In areas with fresh groundwater, such as the Oostland horticulture area, surplus rainwater is also stored in the subsurface. It can then be recovered in periods of shortages. This subsurface storage offers the advantages of a large capacity, relatively low costs and limited use of surface space.

#### ***Fresh in saline***

Over the past few years the technique has been further developed to the point where rainwater can also be stored in groundwater that is brackish/saline. Several horticulturalists in the provinces of Zeeland and South Holland have gained experience in pilot studies in which rainwater is stored in brackish/saline groundwater using adapted injection and abstraction techniques. The yields achieved are very encouraging: it is certain that good-quality water can



This information was taken into account in the analysis. The results show that not all locations are suitable for small-scale (parcel level) water storage systems, but that larger, more robust systems – for example, collective installations – or smart adaptations to well design could offer possibilities to such locations.

## **Results**

The results of the research are available (in Dutch) on the Province of South Holland website in the form of suitability maps of freshwater storage in (greenhouse) horticulture areas. There is also a report which includes the possibilities and main features of the technique, as well as relevant background information. It also presents a closer examination of the potentials of the different (greenhouse) horticulture areas.

### **5.1.4 Conclusion**

The ASR Performance Assessor tool can quickly estimate the performance of ASR, based on commonly available hydrogeological and operational parameters a priori. It is therefore a vital decision-support tool in the field of ASR. Typically, unviable set-ups will be recognized efficiently and can be avoided, so that more focus can be given to promising cases.

## **5.2 ASR-Coastal Automated Control Unit**

### **5.2.1 Introduction**

Aquifer Storage and Recovery (ASR) can be an efficient technique to store freshwater surpluses for times of demand (figure 25). However, in brackish-saline aquifers the density-driven flow can result in limited recoverability of freshwater: injected freshwater is pushed up towards the top of the aquifer (buoyancy effect) and brackish/saline water eventually enters the lower well section. With ASR-Coastal Automated Control Unit, it is aimed to recover as much water as possible under these conditions by:

1. Focus infiltration of freshwater in deeper aquifer sections and recover at shallower section using multiple partially penetrating wells;
2. Optionally: intercept intruding brackish-saline groundwater at the base of the aquifer (deepest well has a *Freshkeeper* function then).

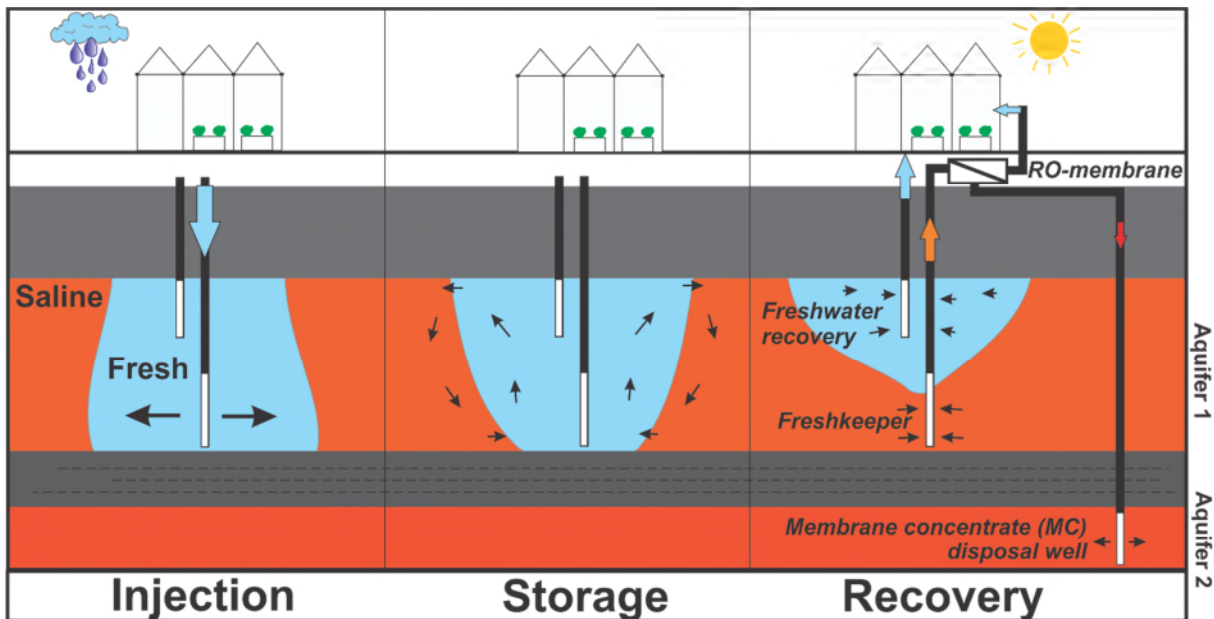


Figure 25: Use of ASR-Coastal with help of a Freshkeeper

### 5.2.2 Methodology of the Automated Control Unit

In order to efficiently recover freshwater and intercept brackish-saline groundwater, an automated control unit was developed in the framework of the SUBSOL project. Crucial aspect of the automation is the protection of the shallow freshwater recovery wells by exact interception of intruding saltwater with the deeper Freshkeeper well (figure 26).

The rate of this saltwater interception is optimized based on the EC measurements of the abstracted water by the different wells. This way, sufficient (but not excessive) saltwater is intercepted to safeguard recovery of freshwater. Regular adjustments of the system in the field by the end user are therefore not required. This increases the ease of use, while reducing the chance for mistakes. The automated control unit was built by Codema B-E de Lier.

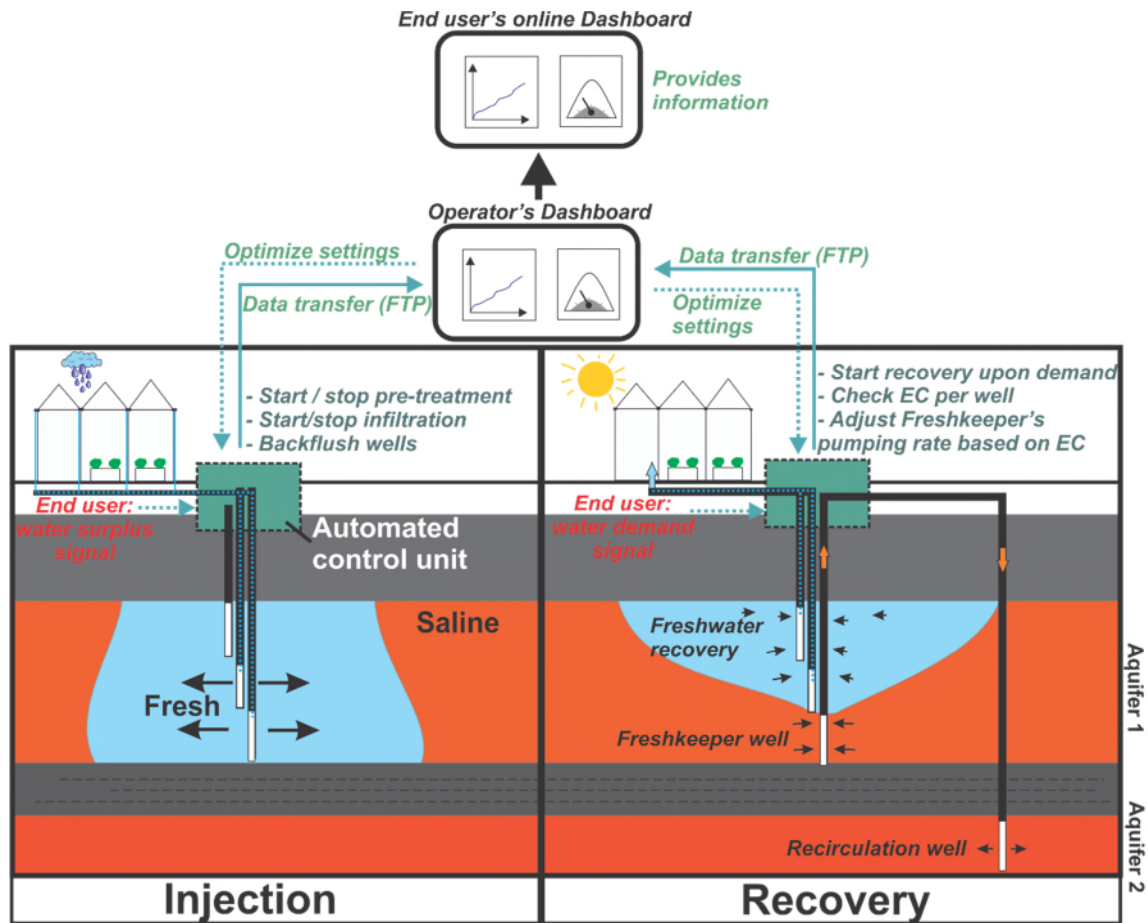


Figure 26: Outline of the automated control unit

The automated control unit can also be used to send the data to operational dashboards.

### 5.2.3 Requirements

The requirements for implementing the specific tool are described below.

- ✓ EC transmitters in every well layer of the multiple partially penetrating well
- ✓ Frequency controlled pumps, at least in the well(s) used for interception.
- ✓ Programmable logical controller (PLC)

## 6 Conclusions

The hydro-technical SWS decision support toolkit that has been developed will guide the choice and initial design of appropriate SWS solutions of practitioners, SMEs, policy makers and research organisations. It is currently up and running in the common landing page of all web applications, under the URL: <http://subsol-data.euprojects.net/>.

As a first step of the high level assessment, leading to initial design choices for SWS systems, a new innovative approach has been developed which queries the Knowledge Base and filters out measures that fulfil certain user-defined criteria. At the same time this approach supports exploratory search combining querying and browsing activities.

The Location Identification Tool represents the medium level assessment, as it aims at scanning an area to identify locations that can be suitable for applying a subsurface water solution, based on spatial information regarding the topographical and hydrogeological conditions of the study area.

As a final step of the detailed level of assessment, the SUBSOL Data Monitoring System is a versatile and portable web application that is capable to collect in near real time environmental data from several stations, combine measurements into expressions, display historical time series using charts and other widgets and issue warnings and alerts if needed. Additionally, there are several other tools, products and services described in the present report that support the stakeholders in performing detailed assessment of SWS systems.

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