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Report on the development of software for early warning
based on real-time data

Work Package 4.3 – Evaluation and development of reliable procedures
and technologies for early warning

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SUMMARY

This document is part of area 4 of the SafeLand project (EC-FP7). Area 4 addresses the technical and practical issues related to monitoring and early warning for landslides, and identifies the best technologies available in the context of both hazard assessment and design of early warning systems.

This deliverable describes new software specifically developed to support technical staff in data analysis and the decisional process. The project intends to realize a centralized interface for early warning centres to manage data from different monitoring stations.

The proposed software should be a separate and independent tool for real-time geo-scientific quantitative risk analysis, including threshold evaluation. The basic concept is to develop software that can integrate and automatically analyse the combination of sensors.

The integration and predefined analysis and correlation of different sensors will help the user in operative early warning centres to increase the quality of the geo-scientific evaluation. As a result, this report presents a brief description of the application structure and all necessary steps to start up a system. Finally, this report describes the data analysis in one of the test sites included in this part of the project.

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Acronyms used in document

Extensible Mark-up Language (**XML**)
SafeLand Mark-up Language (**SLML**)
Uniform Resource Identifier (**URI**)
Early warning system (**EWS**)

1 INTRODUCTION

Several kinds of monitoring instruments could be selected for a site-specific early warning system (EWS), and the choice is mainly related to the type of landslide and the budget. Today, sensors and monitoring sites use databases containing data in incompatible formats (Microsoft SQL Server, Firebird, Oracle, plain text, etc.). All monitoring test sites included in the SafeLand project use a language different from each other.

The integration, the predefined analysis, and the correlation of different sensors will help the user in the operative EW centre to increase the quality of the geo-scientific evaluation.

1.1 SAFELAND MARK-UP LANGUAGE (SLML)

The purpose of SLML is to provide the definitions for the data file structure to support an electronic exchange of information inside a site-specific EWS. SLML defines the structure and elements of measures, specifies how locations are referenced and provides a mechanism for linking observations with each other.

By building on existing Internet standards, SLML expresses information from site-specific monitoring instruments in a way that can easily be shared over the World Wide Web.

CSG designed this grammar on the XML (Extensible Mark-up Language) existing standard, which is promoted by the World Wide Web Consortium (W3C).

The XML is one of the most common tools for data transmission between all sorts of applications. XML data are stored in plain text format.

In order to define SLML, an XML-based standard configuration file, we created an XSD schema definition. According to a W3C Recommendation, the XSD scheme specifies how to formally describe elements in the XML document. In general, a schema is an abstract representation of an object's features and its relationship to other objects.

In order to create a schema for SLML, we analysed its data structure, defining each element as we encountered it.

1.2 MASS-MOVEMENT INDICATORS (GEOINDICATORS)

The indicators of impending mass-movement activation (mass-movement indicators) need to be defined with a deep knowledge of each site, also considering reliability, noise level and costs. For these reasons, only highly reliable and “stable” sensors should be included in this system.

In the first version of SLML, these monitoring instruments are included:

- Surface displacement: extensometers
- Subsurface displacement: DMS inclinometers
- Water level: piezometers
- Water runoff/input: precipitation, temperature sensors
- dGPS
- Geoelectrical monitoring system: GEOMON^{4D}

In this phase, we preferred real-time and automatic monitoring systems.

2 DETAILS ABOUT SLML

2.1 CURRENT DATA STRUCTURE

In order to share monitoring data, we need two files:

A file indicating the configuration of each site, called *Configfile*;

A file with the monitoring data, called *DataFile*.

2.2 WHAT IS AN XSD SCHEME

XSD provides the syntax and defines a way in which elements and attributes can be represented in an XML document. It also advocates that the given XML document should be of a specific format and specific data type.

XSD is fully recommended by the W3C consortium as a standard for defining an XML document.

What is the benefit of this XSD schema?

- XSD schema is an XML document so there is no real need to learn any new syntax.
- XSD schema supports Inheritance, where one schema can inherit from another schema. This is a great feature because it provides the opportunity for reusability.
- XSD schema provides the ability to define own data type from the existing data type.
- XSD schema provides the ability to specify data types for both elements and attributes.

After creating an SLML document, it is necessary to check its syntax with this XSD scheme. Checking against a schema is known as “validating against that schema”; the XSD Validation is an important component of quality assurance.

2.3 PROJECT XSD SCHEME

The ConfigFile header is *<SL:SafeLandSite>*.

The name space SL will be defined through the URI <http://www.cgsr1.eu/Safeland/SafelandCfg.html>.

This file must be in compliance with the XSD scheme that can be downloaded at <http://www.cgsr1.eu/Safeland/SafelandCfg11.xsd>.

The element *<SafeLandSite>* contains the following attributes:

- **Version:** The version of SafeLand protocol. This document describes the version 1.0.
- **DateLastCfgUpdate:** Date of the last modification to site configuration
- **Name:** Name of the reference site

At the second level, under the header *<Site>*, there are the following sub-elements:

- **<CoordinateX>**: coordinate X of the site location (WGS84 or UTM)
- **<CoordinateY>**: coordinate Y of the site location
- **<Altitude>**: altitude of the site [m a.s.l.]
- **<Owner>**: owner of the monitoring site, identified by the two sub-elements:
 - **<Name>**
 - **<Country>**
- **<Note>**: note
- **<GSMField>**: % GSM field

- **<Sensors>**: Under this node all the sensors must be listed. Each node must be named **<Sensor>** and at least one sensor is mandatory.

The **<Sensors>** node must contain the following elements:

- **<ID>**: unique identifier
- **<Depth>**: sensor depth [m]
- **<Azimuth>**: sensor azimuth [0.001deg]
- **<DateInstallation>**: installation date
- **<DateCalibration>**: calibration date
- **<Types>**: sensor types
 - Every child node must be named **<Type>** and one or more child nodes can be present.
 - Pluviometer
 - Thermometer
 - Anemometer
 - Piezometer
 - Inclinator
 - Extensometer
 - dGPS
 - Ohmmeter
 - Voltmeter
 - Moreover, there could be one **<GeoMonData>** with the following parameters:
 - **<LineName>**: can be an alphanumeric name
 - **<CoorXup>**: coordinate of this line
 - **<CoorYup>**: coordinate of this line
 - **<CoorXdown>**: coordinate of this line
 - **<CoorYdown>**: coordinate of this line
 - **<LineLength>** [m]
 - **<NElec>**: quantity of electrodes in this line
 - **<Apos>**: position of the sensor [m]
 - **<Bpos>**: position of the sensor [m]
 - **<Mpos>**: position of the sensor [m]
 - **<Npos>**: position of the sensor [m]

Figure 1 shows a tree diagram to represent the XSD file structure.

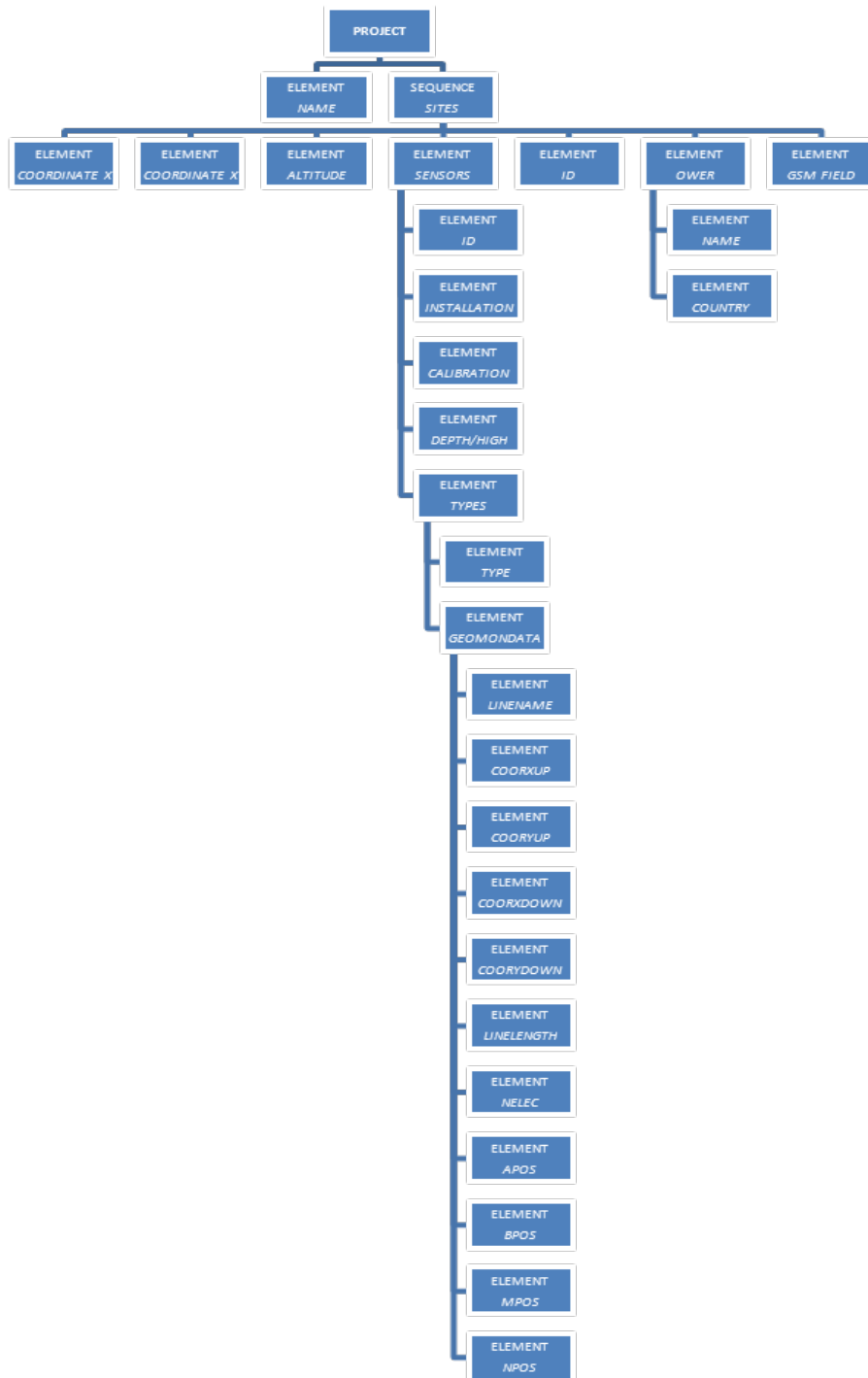


Figure 1 – XSD scheme for the configuration of a monitoring site

2.4 DATA STRUCTURE IN XSD SCHEME

The structure of this file is shown in the diagram in Figure 2.

The header is *<SL:SafeLandData>*.

The name space SL will be defined through the URI <http://www.csgsrl.eu/Safeland/SafelandData.html>.

This file must be in compliance with the XSD scheme that can be downloaded at <http://www.csgsrl.eu/Safeland/Safelanddata11.xsd>.

The element *Project* contains the following attributes:

- *Version*: The version of the SafeLand protocol. This document describes the version 1.0.
- *DateLastCfgUpdate*: Date of the last modification to data file.

Under the node *<SL:SafeLandData>* there are one or more *<DataAcquired>* elements.

There must be at least one record.

Each *<DataAcquired>* has the attribute:

- *Date*: date and time of the record

Under the node *<DataAcquired>* there are *<SingleData>* nodes, one per record of a sensor.

Each node *<SingleData>* contains only one of the following elements:

- *<Rain>*: rain [mm]
- *<Wind>*: <Direction> [0.01deg] and velocity [mm/s]
- *<Temperature>*: air temperature [0.001° C]
- *<Pressure>*: water pressure [mm H2O]
- *<Pitch>*: for monoaxial sensor, pitch axis [0.001deg]
- *<Roll>*: for monoaxial sensor, roll axis [0.001deg]
- *<Tilt>*: for biaxial sensor, *<Pitch>* and *<Roll>* [0.001deg]
- *<Deformation>*: extensometer output [0.001mm]
- *<PowerSupply>*: voltage [mV]
- *<GPSPosition>*: position
 - *<North>* [0.001deg]
 - *<East>* [0.001deg]
- *<Resistivity>*: ground resistivity [Ω OHMM]
- *<Voltage>*: potential [V]

And the following attribute:

- *IdSensor*: unique identifier

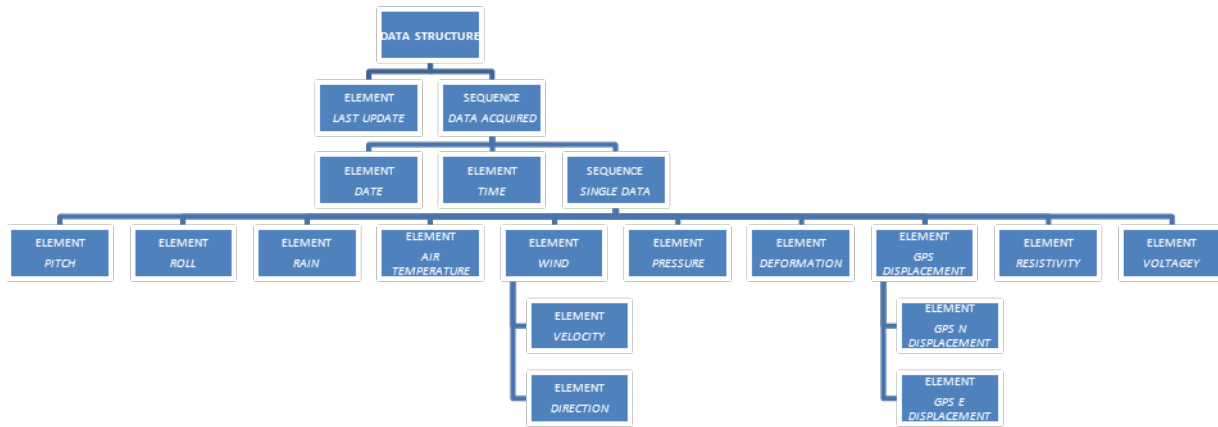


Figure 2 – The XSD scheme for multiple data harmonization

3 THE SAFELAND SOFTWARE SUITE DESCRIPTION

The SafeLand Early Warning System is a suite composed of different applications. Each of them performs a specific function:

- Data conversion from monitoring sites and SML language
- Data storage in a unique central database
- Data processing and graphical elaboration

As a consequence, in the SafeLand Suite there are three kinds of applications (see Figure 3):

- *SML Converters*: this software makes the data translation from the original language, syntax and database to SML format, following the two schemes described before. Obviously, it is necessary to create a single application dedicated to each monitoring site, because of the differences between the systems.
- *SL Engine*: this data collector acquires all the SML configuration and data files and stores all the information in a unique database.
- *SL Viewer*: the application that shows data plots and warnings, taking a look at only one window. Furthermore, it is possible to inquire into critical situations in more detail (time history, comparisons, etc.).

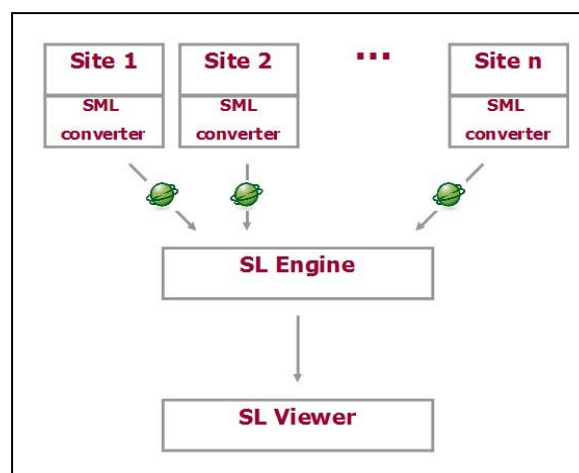


Figure 3 – SafeLand Suite structure

3.1 THE CORE DATABASE

The SafeLand central database uses an SQL open source database server: Firebird.

Firebird is a relational database offering many ANSI SQL standard features that runs on Linux, Windows, and a variety of UNIX platforms. Firebird offers excellent concurrency, high performance, and powerful language support for stored procedures and triggers. It has been used in production systems, under a variety of names, since 1981.

The Firebird Project is a commercially independent project of C and C++ programmers, technical advisors and supporters developing and enhancing a multi-platform relational database management system based on the source code released by Inprise Corp (now known as Borland Software Corp) on 25 July, 2000.

4 SAFELAND APPLICATIONS IN DETAIL

4.1 SLML DATA CONVERTERS

Acquisition data software is developed specifically for each information provider as indicated in Figure 4. This software copies the data from the owner database (plain text, Oracle, MS SQL, MySQL, etc.) in the respective SLM file, following the coding described in the section *2 Details about SLML*.

After the conversion, the data are uploaded in a reserved area on the web (through FTP, HTTP, mail or other defined protocols).

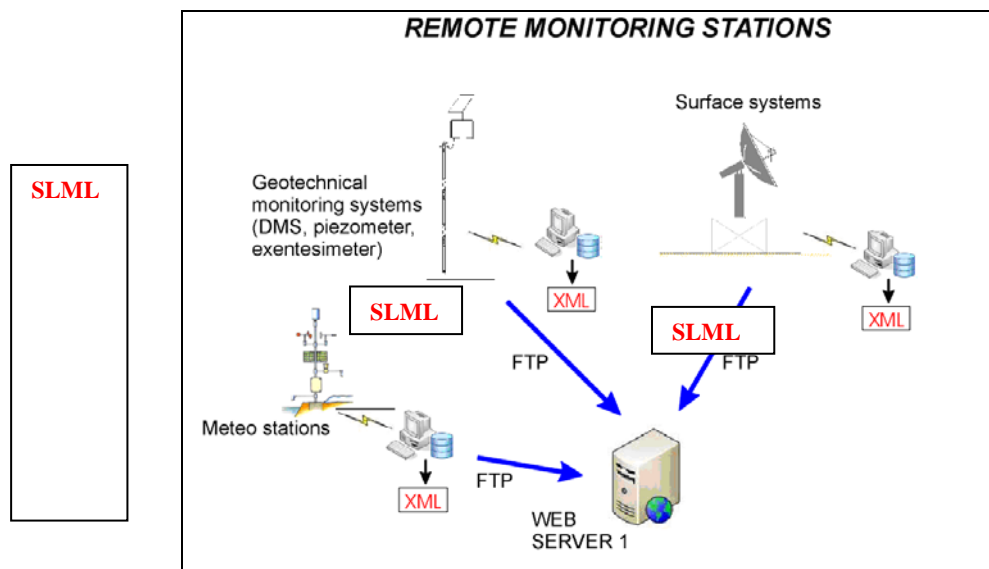


Figure 4 – Each of the SLML converters is specifically developed for individual monitoring systems

4.1.1 The SML converter for DMS data

This specific application was developed to convert DMS system output data:

- Inclinometers
- Piezometers
- Extensometers
- Thermometers
- Rain gauges
- Air thermometers
- Anemometers

The main window of DMS Data Converter is shown in Figure 5.

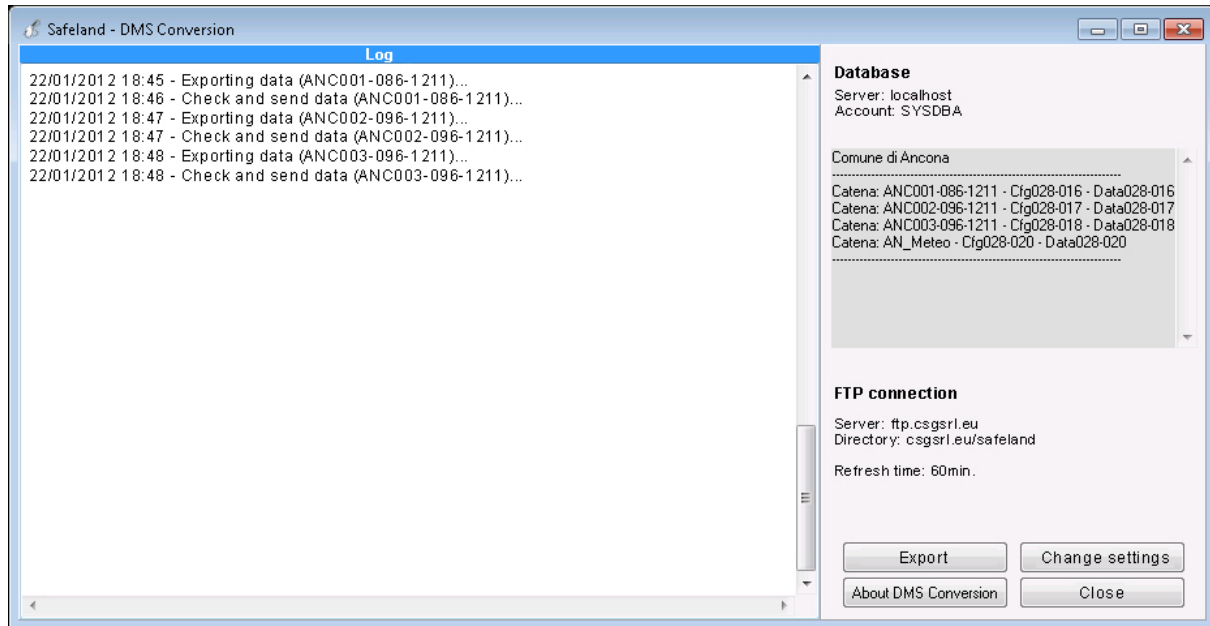


Figure 5 – SML Converter for SafeLand early warning software

4.2 THE DATA COLLECTOR: THE ENGINE

The *Engine* (see Figure 6) is the data collector that will manage the FTP data download from each organization.

When the final FTP location is defined, each organization will have an authenticated user to upload files to its destination folder.

This application is always running on the dedicated machine. It downloads data from the repository and stores them in the core database at scheduled time intervals.

The Engine will be the brain of the system; it will look for updated data, merge them, and it will make its results available for the client version.

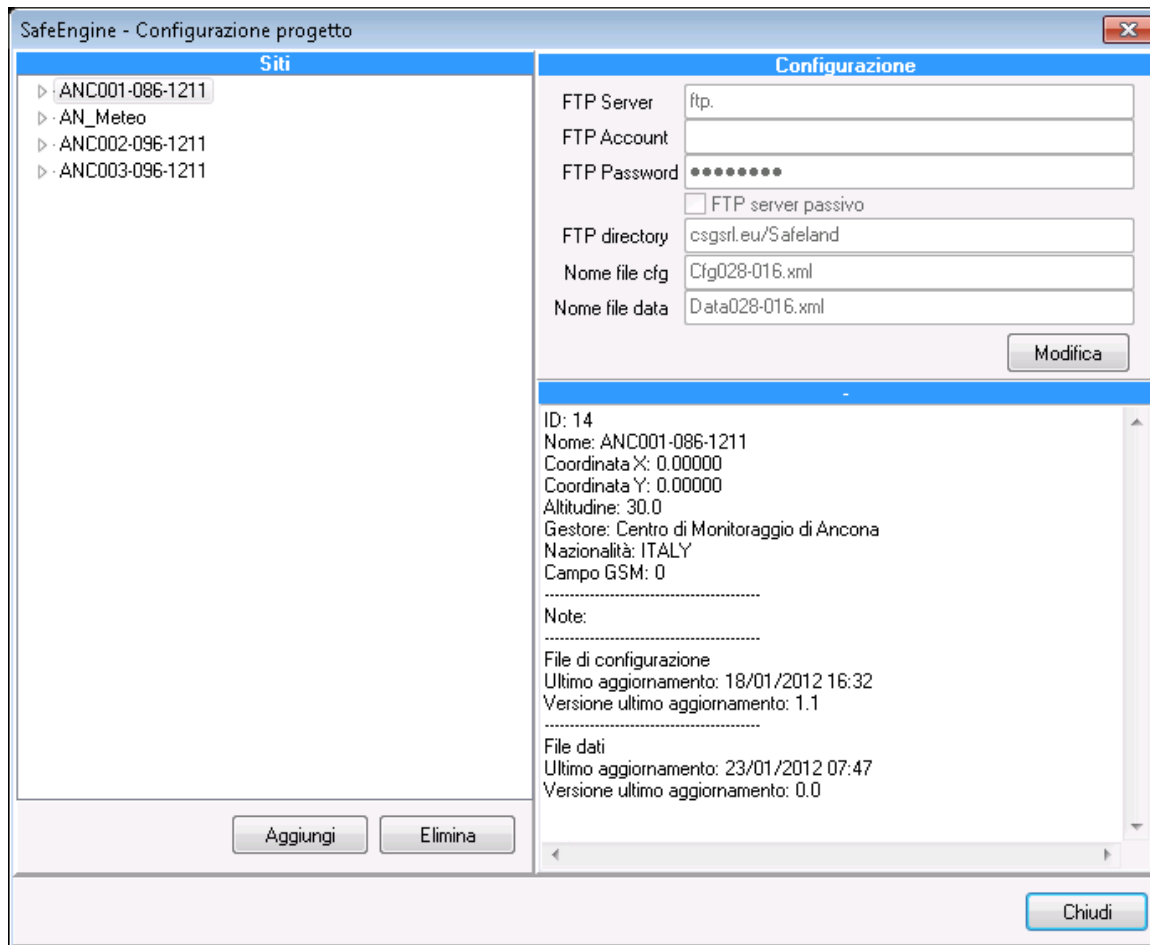


Figure 6 – The Engine control panel

It is possible to add in the system configuration an unlimited number of monitoring sites inside a project. At each site, the system administrator must join the right coordinates to find SML data and configuration files. Once the system is configured, it will continuously acquire the data from the internet and will store them in the core Firebird database.

In the visual control panel, it is possible to view the complete log of the software activity.

4.3 SAFELAND VIEWER

The last piece of software of this application suite is the graphical interface for all the collected data.

The end user can correlate all the monitoring sites inside a project, using intuitive control panels and time history plots.

When the software starts, its first window displays the status of all the sensors configured for the project. For each site, it is possible to read the main information (owner, nationality, kind of system, data installation, etc.). The last update date is also available.

Inside a site, you can have a detailed view of each sensor (e.g. ID, typology, updated data).

Figure 7 shows the first window of SafeLand Viewer. This window is specific for a particular project. As previously described, you can look at each site and its sensors in this window.

Each row displays a sensor; on the left you can read the last record, on the right warning icons are displayed.

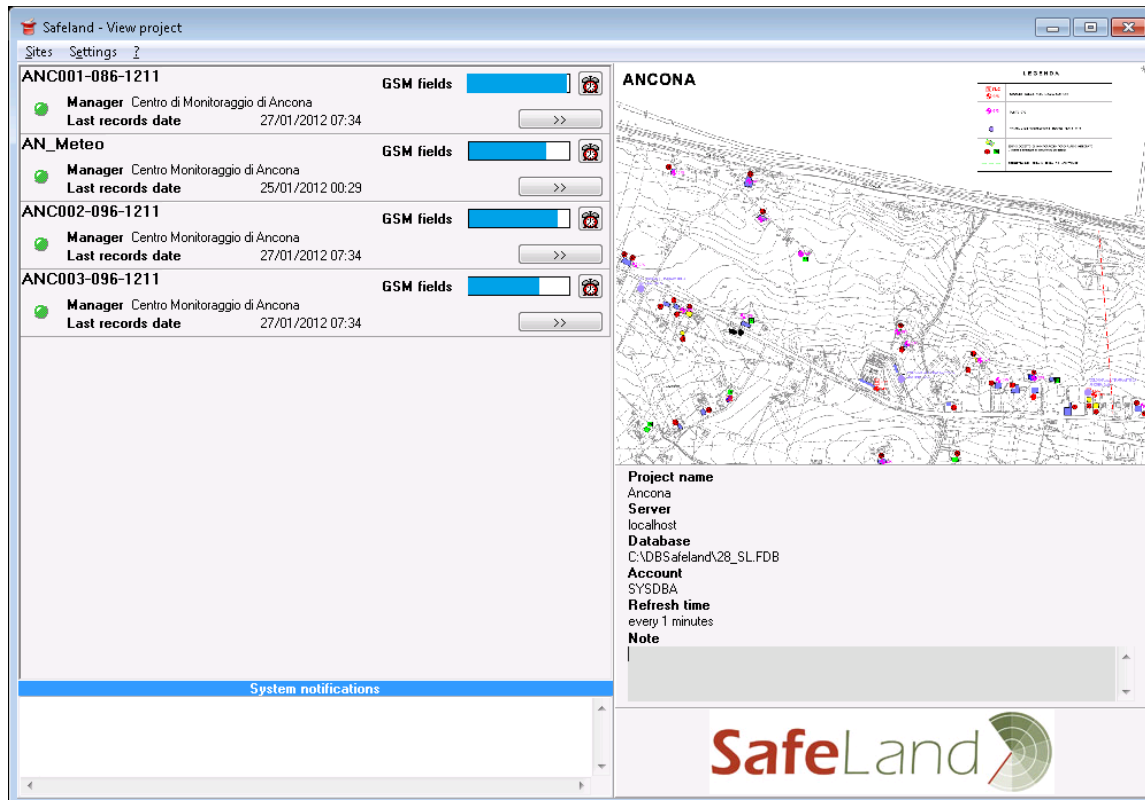


Figure 7 – Main window of SafeLand EW Viewer

For each sensor you can set warning thresholds (see Figure 8). If a reading exceeds one of these thresholds, a symbol specific to this kind of warning is displayed near the sensor. These thresholds are locally defined.

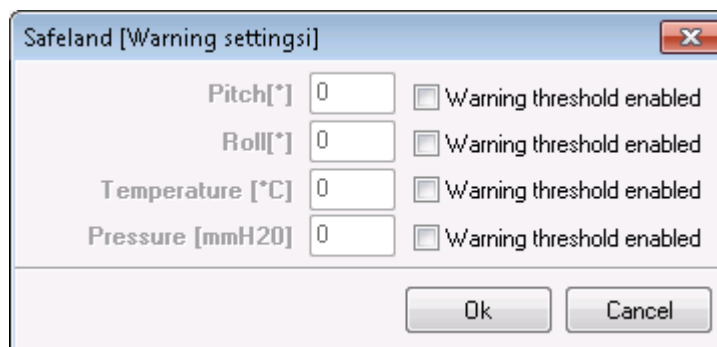


Figure 8 – Warning thresholds settings

By clicking on the menu item called *Site/Time history plots* it is possible to view all the sensors' time history. Here, by selecting different sensors inside the project and also between

different sites, many custom combinations of output plots can be obtained. It is also possible to display the plots in a list of separate diagrams.
The output can be a direct print report or a PDF file (without using a printer).

5 STARTING UP A NEW SAFELAND EW PROJECT

5.1 PLANNING

When starting a project, it is important to define which mass-movement indicators (or geoindicators) are necessary for the analysis and for defining a model of the considered site. Moreover, some geoindicators will be useful for risk evaluation. Once the geoindicators are defined, we must identify the related monitoring systems in order to get these fundamental parameters.

To decide which monitoring systems must be included in the project, the essential features are:

- Automatic data download and data acquisition procedures
- High reliability of the whole system
- Good communication infrastructure

5.2 CREATING THE DATA CONVERTERS

Different monitoring sites could belong to different organizations. Consequently, it is necessary for each system administrator to be able to develop the data converter, in order to create XML files (following XSD schemes) from monitoring system output files (see Figure 4). This site-specific application will be installed inside the LAN of the owner organization.

For each site, the converter will have to create the configuration file that will not change with time, and the data file.

This data file will be updated at scheduled time intervals and uploaded to a destination remote directory (the same one for all sites inside the project).

5.3 CONFIGURING THE ENGINE

All sites belong to a monitoring network composed of different systems that are physically separated and belong to different organizations. The lead organization will become the central node of this network, and it will take care to centralize and spread all the data coming from the monitoring systems. In this way, every organization will be allowed to elaborate and analyse data.

Therefore, the Engine must be installed in this central node. This application, which is completely automatic, will download updated data on the FTP server and will store them in the database. Finally, these data will be available for consulting and graphical elaboration with SafeLand Viewer software.

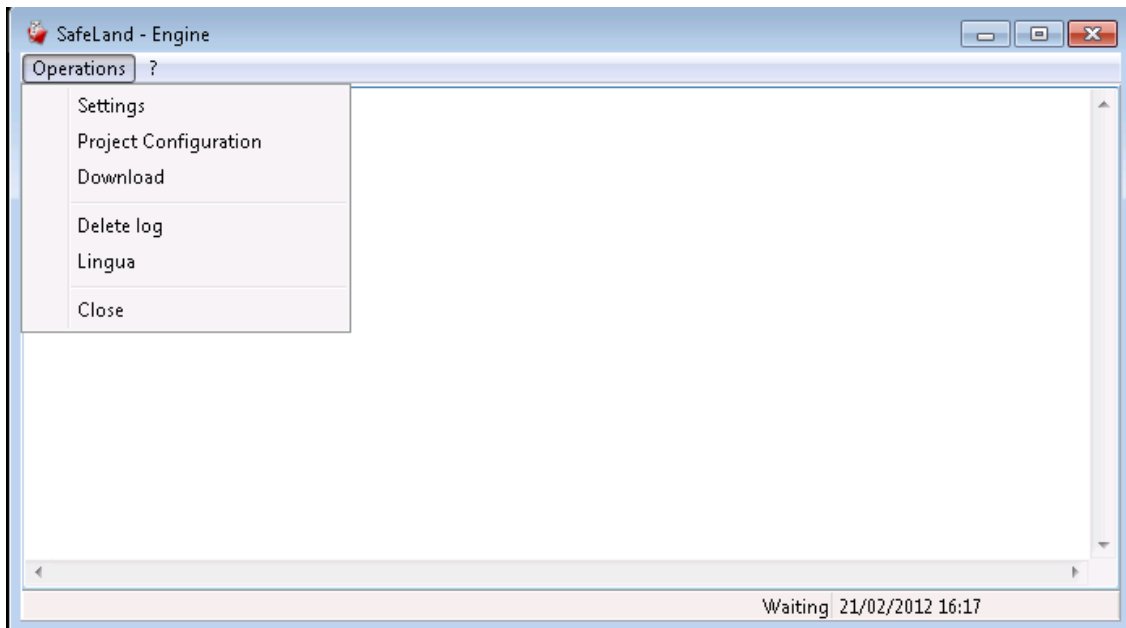


Figure 9 – Engine window

After clicking on the menu item called *Operations/Settings*, the window shown in Figure 10 will be displayed. It is necessary to set the destination path and the access parameters for the central database, which will store all the project's data.

The user must also set the refresh time for new data file searches on the remote directory.

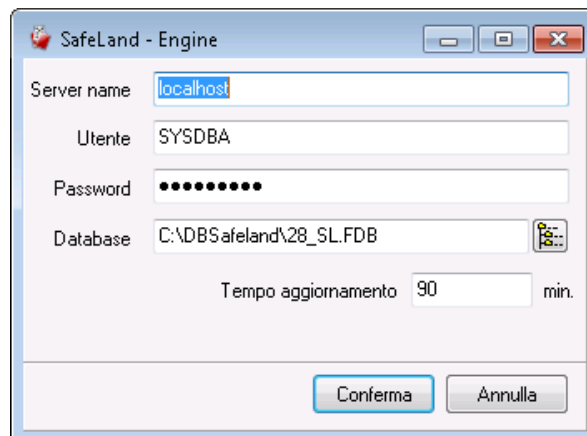


Figure 10 – Settings

Once the core database is configured, you must set the sites to be included in the project. By clicking on the *Operations/Project* configuration, the window shown in Figure 11 will open. To add a new site, click on Add button and insert the parameters for FTP server access to download data.

For each site, it is mandatory to set the following parameters:

- FTP host
- FTP account
- FTP password
- FTP directory path
- Configuration file name with the extension xml
- Data file name with the extension xml

It is crucial to set the correct parameters of xml files, because the files could easily be mixed. Once all the parameters are set, confirm the operation and the new site will be added to the list on the left.

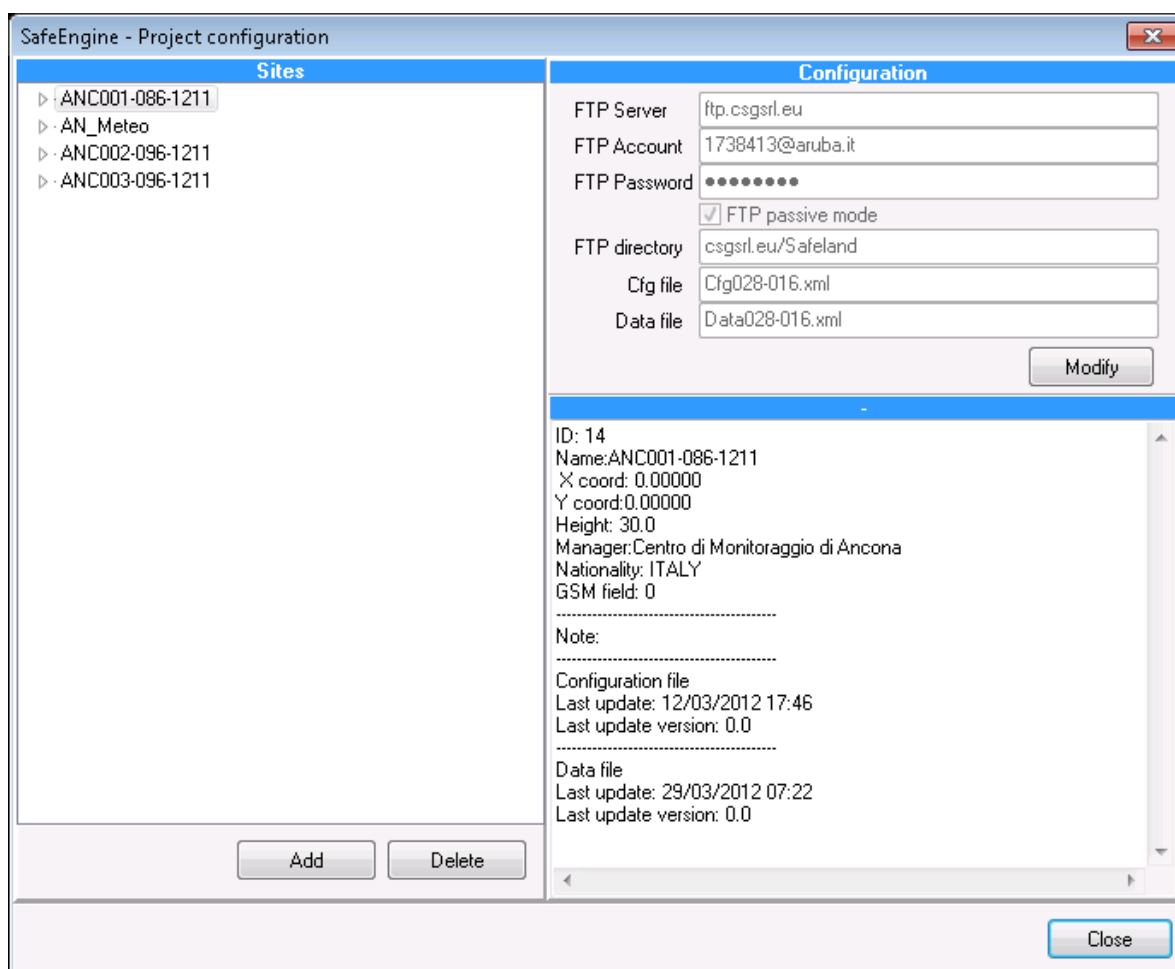


Figure 11 – Project configuration

Once all the sites in the project have been added, close the window and try to download data manually using the menu item *Operations/Download*.

In the main window (see Figure 9) you can see the operations log.

5.4 SAFELAND VIEWER

SafeLand Viewer allows all the sites within the project to be displayed. The first window of this application (see Figure 13) is the control panel of the whole project.

5.4.1 SafeLand Viewer configuration

At the first start-up of the system, it is necessary to configure the Viewer by clicking on the menu item called *Options/Project Configuration*. The window shown in Figure 12 will open.

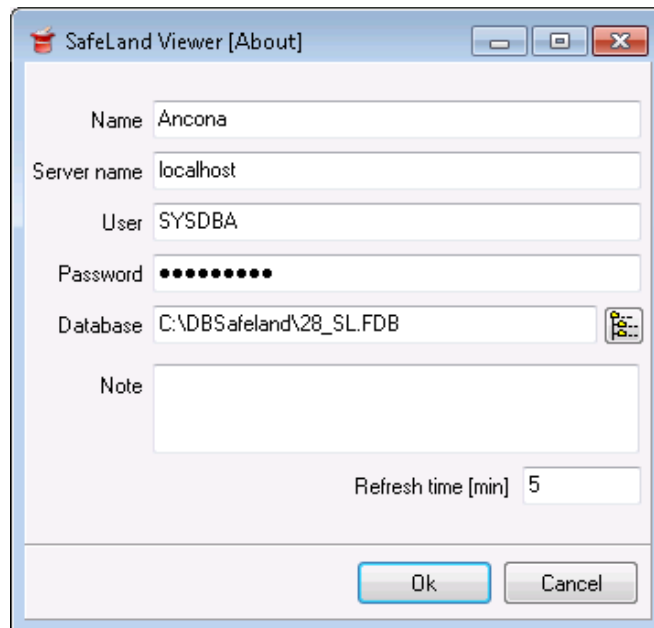


Figure 12 – Project configuration

5.4.2 Main window: the project control panel

Figure 13 shows the SafeLand main window. On the right-hand side, there is an image that represents the project (e.g. a map). Below this image are the main reference parameters, including refresh time.

On the left, there is the sites list (one per line), the date of the last update, and the status of the system. The LED near the site name indicates this status: the system is ok if it is green, and if there are active warnings the LED is red.

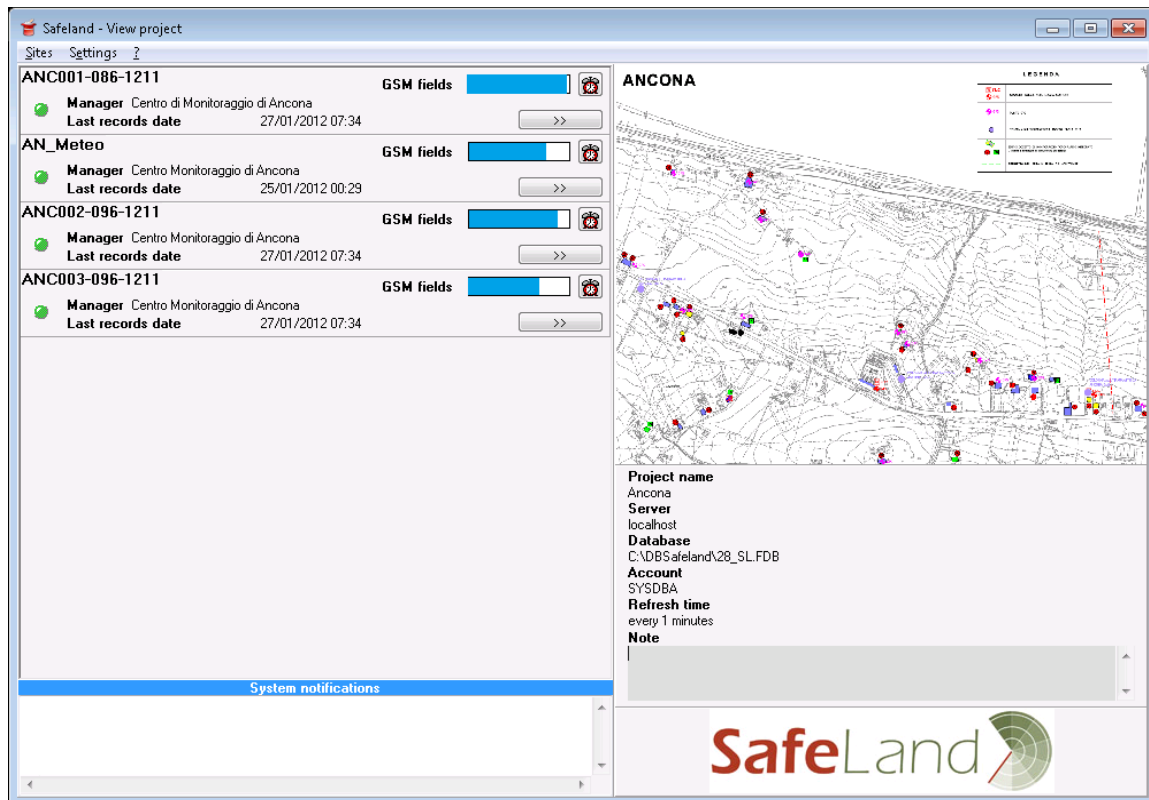



Figure 13 – SafeLand Viewer control panel

Near each site name, there is a blue bar indicating the signal level of the telecommunication system used on the site (e.g. GSM, WiFi). This indication is one of the operational notifications, and is useful for checking correct system functionality. It will be possible to add other parameters, for instance the supply voltage.

In order to expand the tree of a site, click on the >> button. Once extended, the user can read the list of all sensors inside the monitoring system, with the main indications about sensor type, last data, and warning status. For each sensor, warning thresholds are visible by clicking on , as shown in Figure 14.

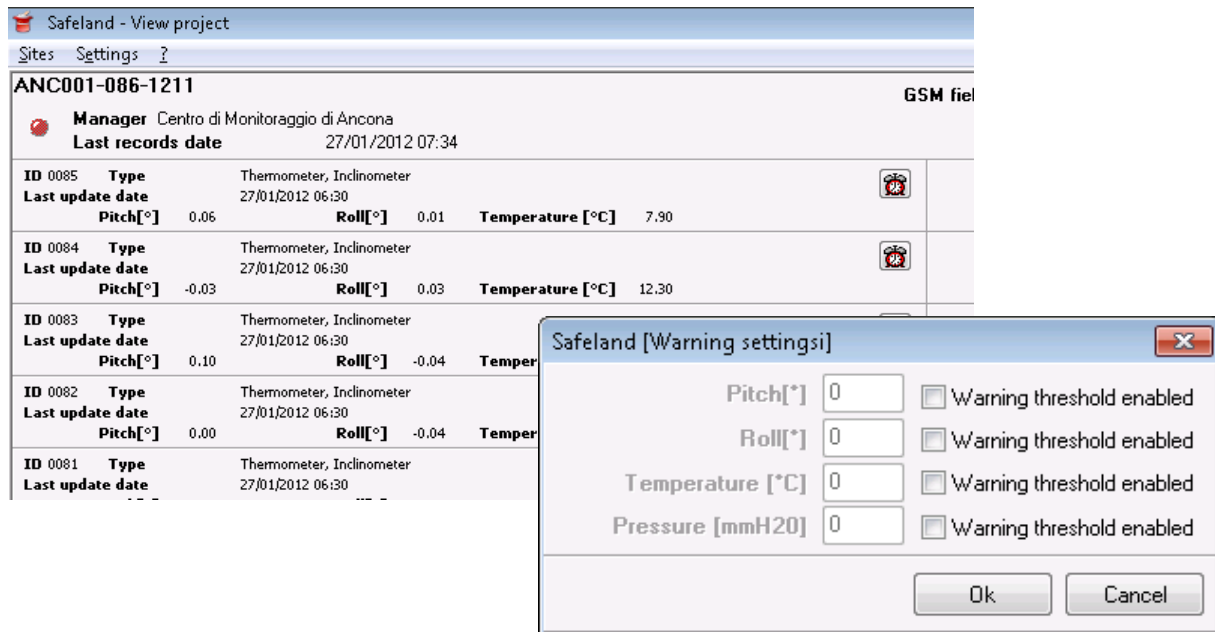


Figure 14 – Site detail and warning settings window

It is possible to set a unique threshold for all sensors in a site, or a threshold for each sensor (🔔 button near each sensor). In order to set only one threshold, click on 📍 button near the site name in the panel control window.

To delete one or more thresholds, it is necessary to set a 0 value and remove the check near the voice.

5.4.3 Polar diagram

For IPI, DMS, GPS and wall inclinometers it is possible to display a polar diagram of displacement. To open the windows in Figure 15, click on menu item *Sites/Polar diagram*. In this window, you must select the sites and the record you wish to display.

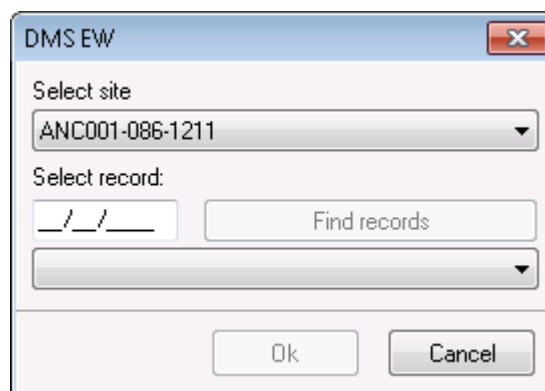


Figure 15 – Polar diagram settings

The polar diagram is displayed in Figure 16.

It is possible to display more than one plot on the same diagram. By clicking on the *Add* button, the window displayed in Figure 15 will open again and you can add other plots, also

belonging to different sites. To delete a plot, select it on the grid and click on the *Delete* button.

Moreover, the polar plot can be cumulative or differential. By default, at its creation, it is cumulative. To switch to differential check the *Differential plot* option.

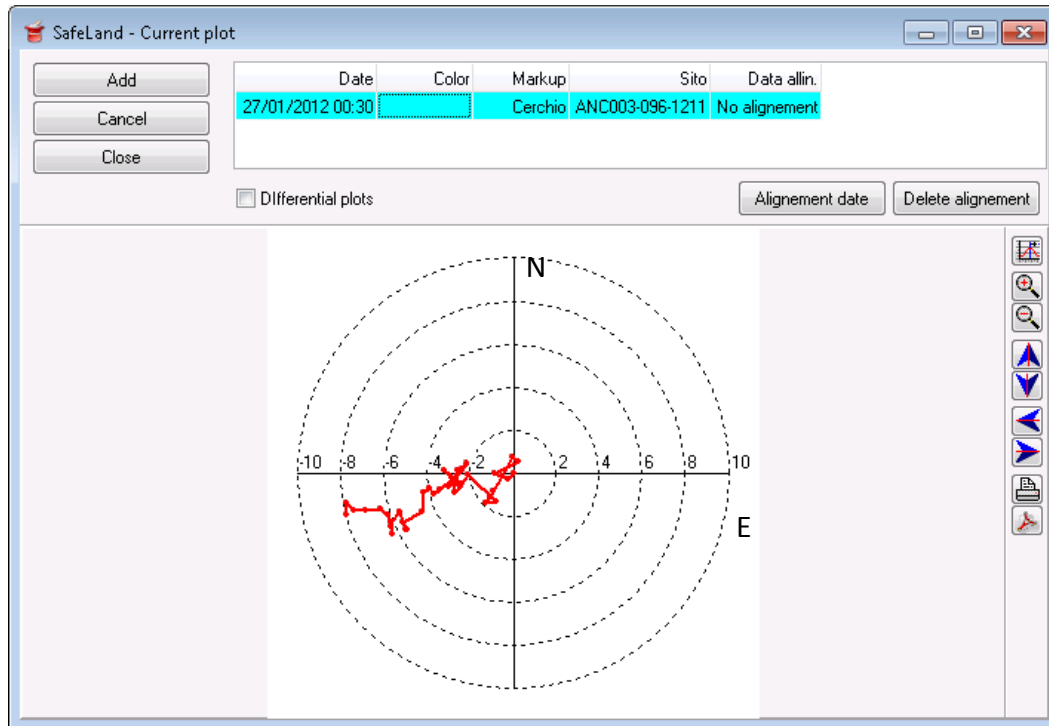


Figure 16 – Polar diagram

To set the alignment data in order to have relative displacement, click on the *Alignment date* button. Obviously, this reference point is unique for each site.

5.4.4 Time history plots

In order to display a time history plot, you can click on the menu item called *Sites/Time history*.

On the left of the time history window (see Figure 17), the list of all sensors for each site is displayed. By selecting different sensors inside the project and among sites, many custom combinations of output plots can be obtained.

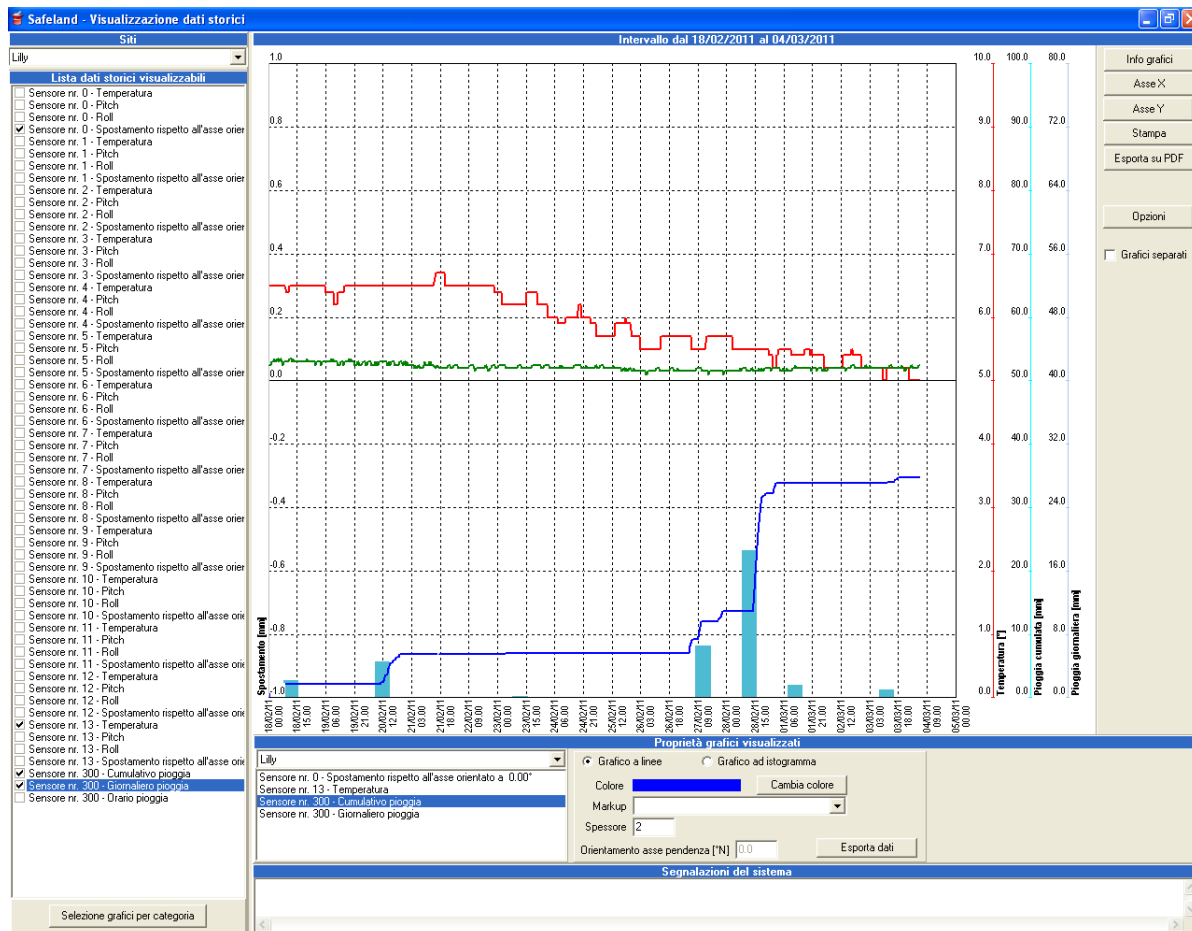


Figure 17 – Time history plot

The output can be a direct print report or a PDF file (without using a printer) by clicking on the *Print* or *Export on PDF* buttons (see Figure 18).

These plots are completely customizable. The user can change all the following features:

- Type of representation: single or multiple
- Type of diagram: line or bar
- Line colour and thickness (panel under diagram area)
- Axes scale (*X axis* or *Y axis* button)
- Main axis (Plots *detail* button)

In order to change the plot's default colours, click on the *Options* button. The window in Figure 18 will appear.

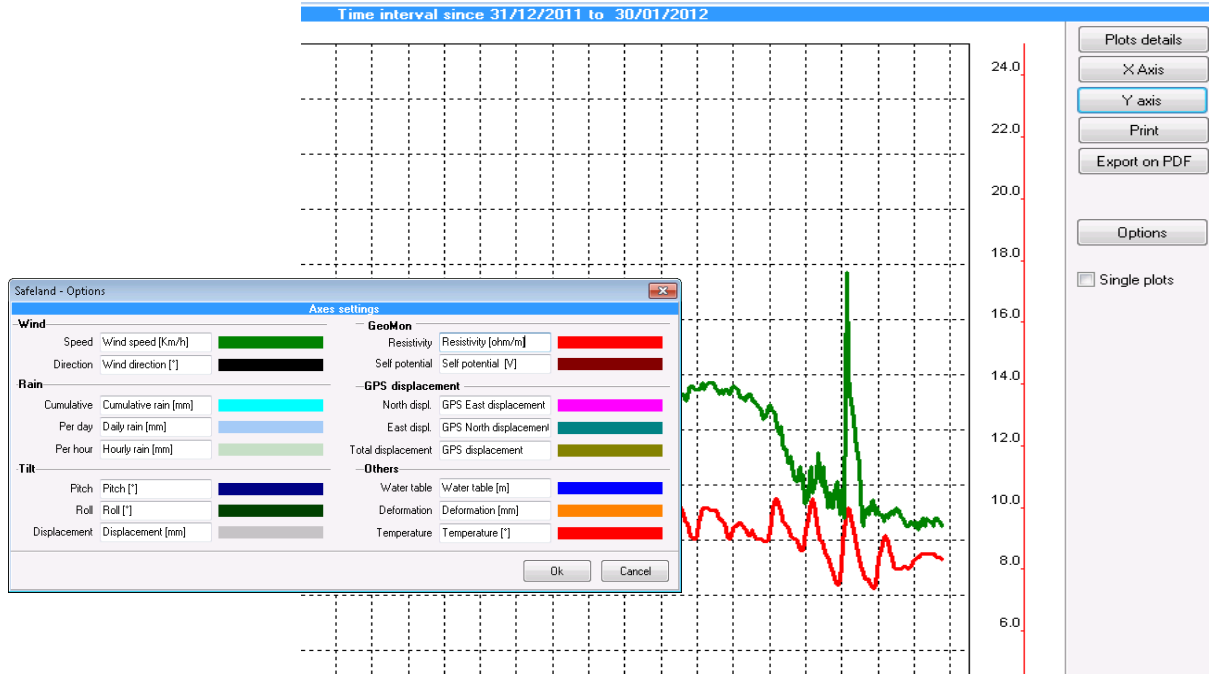


Figure 18 – Time history plot default colours

6 TESTS IN PROGRESS

At the moment, this new real-time EW software is being tested in the following test sites:

- Åknes rockslide (Norway) – EU: Åknes Beredskap IKS
- Ancona landslide (Italy, Regione Marche) – EU: Centro Monitoraggio di Ancona
- Bagnaschino landslide (Italy, Provincia di Cuneo) – EU: Geological Survey of Austria
- Gschliefgraben (Austria, Gmunden) – EU: Geological Survey of Austria
- La Saxe landslide (Italy, Regione Valle D’Aosta) – EU: Regione Valle D’Aosta

After a short testing period, the suggestions and improvements proposed by end users could be incorporated in the main application, *SL Viewer*.

7 FUTURE APPLICATIONS

The software is sparking an interest in real-time monitoring where single applications are difficult to integrate in a unique and easy interface. We hope this can be a starting point for future developments, not only in EW centres but also as a base to support scientific research for landside kinematic models.